Diversification in Aquaculture
Towards Achieving Sustainability

Edited by

Shiba Shankar Giri
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SAARC Agriculture Centre
South Asian Association for Regional Cooperation (SAARC)

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This book 'Diversification in Aquaculture: Towards Achieving Sustainability' contains the papers and proceedings of the regional Expert Consultation on Fish Culture in Cages and Pens in Reservoirs, Lakes, Rivers and Marine Waters for Aquaculture Diversification in South Asia organized at Water Front Hotel, Pokhara, Nepal, from 17-19 April 2019, jointly by the SAARC Agriculture Centre, Ministry of Agriculture and Livestock Development, DLS/CFPCC, Nepal, and Directorate of Livestock and Fisheries Development, MLMAC, Gandaki Pradesh, Nepal. The experts for country papers presentation were the representative of their respective governments. Other experts selected for technical paper presentation were spoken in their personal capacity. The opinions expressed in this publication are those of the authors and do not imply any opinion whatsoever on the part of SAC, especially concerning the legal status of any country, territory, city or area or its authorities, or concerning the delimitation of its frontiers or boundaries.

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FOREWORD

In 2016, the global total fisheries production was 171 million tons. Asia shared 89% of World fish production and South Asia shared 27.3% that of global production and 30% of Asian fish production. An additional 27 million tons of fish production would be needed to maintain the present level of per capita fish consumption of 20 kg per year in 2030. In South Asia the bulk of the aquaculture production takes place in semi-intensive farming systems and a considerable segment of the total fish production comes from these farms, in which major aquaculture technologies are not used. There are enormous number of lakes, reservoirs, rivers, canals, open water bodies and marine waters in the SAARC region. With the rapid decline of capture fisheries in these water bodies hundred thousands of fishermen and marginalized poor people have been suffering from their livelihood displacement and poverty. In order to increase the fish production as well as engage these people in traditional income generating activities, diversification of aquaculture can be the solution for them. The cage culture of mono-sex tilapia in the rivers of Bangladesh and reservoirs of Sri Lanka and grass carp and silver carps in cages in the Pokhara lake, Nepal have been found successful in improving the livelihood of poor fishermen and marginally poor people as well as in enhancing the fish supply in the local and urban markets. Therefore, it is necessary to diversify aquaculture along the entire value chain of production in the South Asian region.

This book '**Diversification in Aquaculture: Towards Achieving Sustainability**' is published to share information on crucial aspects of aquaculture diversifications and the related opportunities, challenges, available policies and future needs, for the SAARC region. The available policies on aquaculture diversification through Cage and Pen culture and further policy interventions are required to realize the importance of aquaculture diversification for small-scale aquaculture in South Asia are also included in the publication.

Dr. S.M. Bokhtiar
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TECHNICAL PAPERS

Chapter 1

Aquaculture Diversification in South Asia

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Introduction

With increasing global population the demand on fisheries has been increased. As the capture fisheries are overexploited, aquaculture is the only alternative to meet the demand of fish and fisheries products. The global total fisheries production is 171 million tons (mt) (FAO, 2018). Asia shares 89% of World fish production, and South Asia shares 27.3% of global and 30% of Asian fish production. An additional 27 mt of fish production would be needed to maintain a per capita fisheries consumption of 20 kg per year in 2030 (FAO, 2016). In 2016, aquaculture accounted for 47% of the global fisheries production with a fish sale value of 232 billion USD. The South Asian countries, India produces 6.62%, Bangladesh 6.65% and rest of the South Asian countries produce 0.74% of the total global fish production. The majority of the total 80 mt of aquaculture production in the World, 58.80 mt was supplied by China with a worth of 138 billion USD (FAO, 2016). The highly diversified Chinese aquaculture industry comprises over 150 different species with a wide-range of products for the multiple markets. This includes fishes, mollusks, crustaceans, seaweeds, and invertebrates (China Agriculture Yearbook Editorial Board, 2011). The methods of aquafarming in China have well embraced polyculture systems, integrated farming systems, extensive and intensive culture systems (Cao et al., 2015; Li et al., 2011a). The sustainability of aquaculture depends on its ecological consideration, economic consideration and social consideration. The UN Food and Agriculture Organisation (FAO, 1997) has established the following definition of sustainability in relation to agriculture and fisheries: "Sustainable development is the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development (in the agricultural, forestry and fishing sectors) conserves land, water, plant genetic resources, is environmentally non-degrading, technologically appropriate, economically viable and socially acceptable".

Aquaculture is the fastest growing food sector as well as the world's most diverse farming system in terms of number of species farmed, the methods used and the environments where the farms are located. Diversification for sustainable aquaculture sector includes greater attention to environmental responsibility and sustainability, quality improvement and product diversity, improved economic efficiency and benefits to fish farmers, and strengthened business integration along the value chain and economies of scale (FAO, 2018). Primary drivers of the diversification of aquaculture include market demand, funding opportunities, competition for resources, landscape opportunities and shortages, and other environmental and social factors. Extreme climatic events are likely to play increasingly important roles in determining the success or aquaculture industries. Diversification of aquaculture could provide resilience in the face of external drivers. At the farm and local community scale diversification can add economic, social and ecological insurance to aquaculture systems, particularly for small-scale and family-based enterprises.

There are enormous number of lakes, reservoirs, rivers, canals, open water bodies and marine waters in the South Asian region. With the rapid decline of capture fisheries in these water bodies hundred thousands of fishermen and marginalized poor are suffering from their livelihood displacement and poverty. In order to increase the fish production as well as engage these people in and traditional income generating activities technologies like aquaculture in cages, pens and race ways have been found suitable partly in some selected areas of SAARC countries and in countries of South-east Asia such as in Vietnam. The cage culture of mono-sex tilapia in the rivers of Bangladesh and reservoirs of Sri Lanka, and grass carp and silver carps in cages in the Pokhara lake, Nepal are the examples of successful strategies in improving the livelihood of fishermen and marginally poor people as well as in enhancing the fish supply in the local and urban markets. Therefore, it is necessary to diversify aquaculture along the entire value chain of production. Schmidt et al. (2011) suggested that for facilitating the diversification processes undertaken by different players in the aquaculture sector, they may analyse different aspects of diversification: diversification of sites, diversification of the cultivated species, diversification of cultivation density, diversification of production systems, diversification of the production cycle, diversification and sustainability of aquaculture nutrition, diversification of products, and diversification of markets.

Drivers of diversification

The main drivers of aquaculture diversification are, market demand, less availability of a species in natural water bodies, resource availability, diseases, government policies, social pressure and climate change.

Table 1. Main drivers of diversification

Driver	Mechanism
Market demand	As the world becomes more populated, urbanized and rich, more people will want and be able to afford more fish and fish products
Climate change	Changing environment will necessitate new species/strains, or the movement of established species into new areas
Desire for increased resilience	Aquaculture will need to supply consistent product in spite of external impact
Consumer demand	Consumers will want to continue to eat fish that they are accustomed to eating and at affordable prices, tastes may change in response to new trends or the introduction of new species
Environmental concerns	Governments and consumers will want to promote and eat fish that are efficiently grown in an environmentally friendly manner
Profit	Aquaculturists will strive for species, breeds and systems that are efficient and meet market/consumer demands
Competitive advantage	Developing new species, breeds or farming systems often gives the innovator an initial competitive advantage

Source: FAO (2016)

Diversification of aquaculture sites

Aquaculture is practiced in all types of aquatic environments ranging from river, lakes, reservoirs, paddy field, flood plain, reservoirs, ponds, ox-bow lake, cage culture in rivers, pen culture in seasonal water bodies, cold waters, freshwater, brakishwater and marine waters. Aquaculture is also practiced both mid- and high-land areas. The key to developing sustainable aquaculture lies in selecting the most appropriate site. Aquatic environment and the location of the production facilities are also determined by the biological characteristics of the species to be farmed, the climatic and geographical factors and the sociological and economic factors of the activity. The quality of the water is an essential parameter in determining the suitability of a site and is defined by factors which have the greatest influence on the development of the aquatic species. A series of physical, chemical and biological parameters exists for determining whether an environment is suitable or not for installing an aquaculture facility. Geographic Information Systems (GIS) offer a magnificent opportunity to model the environment. The models allow the environmental conditions and factors that can influence it to be analysed, and enable explanations to be found for the potential consequences of decisions or planning projects that have an impact on the use and organisation of resources. It is more appropriate to go zoning plan for aquaculture. There must be a balance between the environment and aquaculture production activity. The ideal aquaculture production zones should be characterised of (1) zones in which the growth of the farmed species can be developed as much as possible, (2) zones with the lowest operating costs, (3) ones where impact is minimal, and (4) zones where conflicts between the different uses of the water bodies are avoided to reduce to a minimum (Schmidt et al., 2011). Also they opined that the most important parameters to be considered in analysing a specific region with GIS are, territorial ordinance plans, ownership of the occupied area, zones of tourist and archaeological interest, zones where underground cables/underwater pipes emerge, coastal waste tipping points, bathymetry, port and industrial infrastructures, zones where dry components are extracted, protected spaces and habitats, and zones owned by and used by ports. Based on all the studies conducted and after analysing the information obtained, the zoning is carried out for determining the most suitable zones, zones with limitations and excluded zones. This classification is made in keeping with the degree of compatibility and suitability of the zones for housing the cultivated species.

Diversification of aquaculture species

Over the past three decades, Asian aquaculture and in particular the South Asian aquaculture has undergone tremendous growth as an alternative to wild fisheries for fish supply. A wide range of strategies are made for diversification of farmed species. These strategies are,

- The development of species that are optimum in terms of rearing technology for producing a large biomass of fish in short span of time. They must be species with rapid growth that individually reach large sizes, and their body structure must allow for their commercial production and processing.

- The development of popular species with high consumers demand but scarce due to excessive exploitation and have demanding production systems in terms of rearing technology, such that they do not allow for large-scale production in pond system, floating cages and pens.

In South Asian region, in Bangladesh a total of 260 fish species have been recorded in the freshwaters (Rahman, 1989) of these it is estimated that about 200 species are truly freshwater while the rest are examples of estuarine and marine species. At present, Indian major carps, along with exotic carps are cultured in polyculture system in ponds in Bangladesh. There are also not less than 40-50 small indigenous fish species which grow to a maximum length of 25 cm (Felts et al., 1996). The coastal aquaculture has been developed significantly in the last decade particularly the shrimps (*monodon* and *indicus* sp.) culture in medium to high saline water and prawn (*machrobrachium* sp.) culture in less saline areas. In addition, a small production of mangrove crabs, and varied quantities of brackish and marine water fish species like sea bass and mullet, most of which are produced as by-crops or fallow crops in the shrimp ponds. This constitutes the major export oriented sub-sector, and is increasingly shaped by the international trade regulatories. It has been reported that a total of 230 fish species are found in various water bodies in Nepal (Rajbanshi, 2012). They inhabit at a altitudes ranging from a few hundred meters above sea level to as high as 4,000 meters. Recently, Nile tilapia (*Oreochromis niloticus*), Java barb (*Barbonymus gonionotus*) and giant river prawn (*Machrobrachium rosenbergii*), Pangas (*Pangassius hypophthalmus*), Rupchanda (*Piaractus brachypomus*) have been introduced to study the viability of their commercial production. Assessment of species composition and distribution of fish in Bhutan's three major river basins (Amochhu, Wangchhu and Punatsangchhu) by National Research Centre for Riverine and Lake Fisheries (NRCR&LF) reported 104 species of which 11 species were non-native introduced into various parts of the country for commercial purpose (NRCRLF, 2017). India has rich and diverse fish genetic resources and has high level of endemism too. Close to a total of 34,000 finfish species of 5131 genera are known globally. India possesses nearly 9-10% of the global biodiversity in terms of fish and shellfish species. Interesting scenario, which often pose challenge in defining the fish diversity for any country is the validation and revision of systematics. The new discoveries of the species which are not recognised are another challenge. A total of 7668 new species have been added between 1998 till 2017, average 380 species per year (Eschmeyer and Fong, 2017). Approximately 200 finfish species are reported from India, as new species during this period. This number is likely to be expanded with more and more exploration. Recently, over 25 species are brought in to the ambit of aquaculture diversification in India.

FAO (2016) suggested that for considering a new species for aquaculture diversification should: (1) have reliable seed supply and survival to harvest, (2) be euryhaline and/or eurythermal, (3) tolerate low oxygen and pollution, (4) come from lower trophic levels, (5) have cost-effective feed conversion, (6) have short production cycles, (7) comply with biosafety requirements, and (8) be culturally acceptable and reflect evolving consumer preferences. Under the present fast changing climatic condition it may be safer to continue with a species with an established market, technology, management etc. than to domesticate or introduce new species. Increasing the number of species being farmed and or spreading their production may not be the answer under all conditions.

Diversification of cultivation density

Safeguarding the welfare of the farmed fish has become important for the aquaculture industry from the prospective of consumers, the marketing strategy and acceptance of the products, and its effect on efficiency, quality and production size (FSBI, 2002; Ashley, 2007). Density is one of the most important factors in intensive production facilities like cage culture and pen culture. The Asian aquaculture produces a wide range of species in facilities designed for operating them with different densities and production cycle. Cultivation density can be the number or gram of eggs, or spawn per liter of water, or number or kg of fish per cu.m or sq.m culture system. The cultivation density varies depending upon the growth of fish, mortality, classifications etc. In commercial facilities, density is usually expressed as the initial or final density or the density obtained after they have reached a size that enables them to pass on to the next production phase (Schmidt et al., 2011). Hence, density must be taken into account as a key factor when considering the production of a species, as it effects growth, survival and behaviour of of a species (Van de Nieuwegiessen et al., 2006). The effects associated with high production densities viz., reduced growth, deficient nutritional status, increase in the feed conversion rate, fin erosion, mortality, alterations in swimming patterns, etc., have their origin in alterations in the behaviour of the fish (increase in competition, aggression, cannibalism, etc.) and the deterioration in water quality (Ellis et al., 2001). In order to maximise productivity, the density must be considered on the basis of production systems, ability to maintain the water quality, environmental conditions, production cycle, restrictions imposed by legislation, insurance policies, certifications, etc.

In the South Asian region fish are stocked at different densities during their growth phases. In India, for nursery rearing 3-4, 4-8 million spawn/ha are reared in extensive and semi-intensive culture, respectively for fry production. In grow-out culture, fingerlings are stocked at 5,000-10,000, 12,000-15,000 and 15,000-25,000 fingerlings/ha, respectively for extensive, semi-intensive and intensive culture practices. Generally, in poly-culture system, a density of 5,000-10,000 fingerlings/ha-m is maintained as standard stocking density in carp culture with a target of moderate production at 3-5 t/ha-m. Normally, under intensive culture a size group of 50-100g of advanced fingerlings are stocked for higher production target. The stocking ratios depend upon the candidate species to grow, befitting to culture environment. A combination of 30-40% surface feeder (Catla, Silver carp), 30-35% column feeder (Rohu, Grass carp) and 30-40% bottom feeder (Mrigal, Common carp) is the most commonly adopted for pond polyculture. In Nepal, generally 15,000 fingerlings are stocked for grow-out carp production system. In Bangladesh, in 5000 and 10,000-15,000 fingerlings are stocked, respectively for extensive and semi-intensive types of carp polyculture. In Bhutan the stocking density is determined in relation to water surface area of a pond. A pond having an average water depth of 2.5 m may be stocked at the rate of 700–900 fingerlings/1350m^2. The stocking density advised to the farmers may be increased up to 5 fish/m^2 (10 cm length approx) if high quality feed and sufficient aeration are maintained. However, in poorly managed ponds (undrainable ponds especially) the recommendation is 700-900 fish/1350 m^2 of water surface area.

Diversification of production systems

Aquaculture production systems can be classified on the basis of water salinity, organism farmed, farming phases, degree of human intervention required, culture density and the location of the facilities. Diversification of aquaculture systems i.e. recirculating aquaculture systems (RAS), integrated multitrophic aquaculture (IMTA), cage culture, pen culture, raceway culture and offshore aquaculture provide opportunities for using new species in aquaculture.

South Asia is very rapidly adapting the diversification of aquaculture production system. In India, at present, 18,000 cages are operated in reservoirs, wetlands and open coaliary pits (OCPs) for freshwater aquaculture, and producing 0.1 mt of fish. In marine sector, 300 cages are engaged for the production of sea bass, cobia, pompano and groupers. Cage culture was introduced in Bangladesh in late 1970s on an experimental basis. Cage culture is now expanding in flowing water of rivers and canals in various parts of the country, raising hopes for an increased production of fish. At present, mostly tilapia are farmed in 6,000 cages in rivers, where such farming was not existed even a decade ago. In Nepal, fish farming are practice in lakes and reservoirs. In Pokhara and Kulekhani lakes cage fish farming as well as open water stocking and harvesting practices are followed since last several years. Sri Lanka has recently used cage culture of tilapia in lakes, and Maldives is doing sea cucumber culture in cages, and recently has established cages for grouper aquaculture, with the assistance from the World Bank.

Introducing a RAS to an area with low input extensive aquaculture could help ensure biosafety in the culture of exotic species, eliminate seasonality, be located close to markets, reduce water use and allow effluent treatment. There is scope for further diversification in culture systems particularly in urban and offshore areas, and in irrigation systems. Multicomponent systems, i.e. IMTA can be difficult to manage as has been seen even in seemingly simple integrated systems such as rice-fish systems (Brummett, 2011).

Diversification of cropping pattern and production cycle

Recently, lots have been done in Asian aquaculture for rotating cropping pattern. Polyculture is a farming technique, contributed immensely for the success of aquaculture in South Asian region. It works on the principle that different species feed at different trophic levels, leading to greater food utilization in pond ecosystem with greater food production efficiency. Polyculture was adapted to improve the water quality over that of monoculture. Recently, several changes are made in the management of polyculture ponds in order to reduce environmental damage. For example, the rotation of cultivable species is being used to reduce the environmental impact. In China, by rotating carp polyculture with mitten crabs reduced the amount of nitrogen and phosphorus loading, reducing the risk of eutrophication in the Honze Lake (Wang et al., 2016). Cropping patter is also modified as per the stocking and harvesting schedules under different cultural regimen as, (a) single stocking–single harvesting, (b) single stocking–multi harvesting, and (c) multi stocking–multi harvesting.

Diversification and sustainability of aquaculture feeds and nutrition

Feed is the major contributor in aquaculture and shares about 50-80 % of the total production cost (FAO, 2017). Also, feed has got a significant impact on the quality, safety and nutritional value of farmed fish. The feed requirements of fish vary in quantity and quality according to the feeding habits, physiological stages of the species, environmental variations viz., temperature and the amount, and type of natural food availability in the culture system. Globally the total use of industrially compounded feed in the production of major species is estimated at 47.7 million mt during 2015, excluding the commercial feeds used by Indian major carps (FAO, 2017). The use of farm-made aquafeeds is estimated to be 15-30 million tons (Schlekamp et al. 2015), and direct use of raw organisms, mostly trash fish, is estimated to be 3-6 million tons (FAO, 2012 and 2014). In South Asia the bulk of the finfish and crustacean aquaculture production takes place in semi-intensive earthen pond farming systems. The great majority of these farming systems and in particular freshwater non-carnivorous finfish production (which accounts for over 80% of the total finfish production in Asia) depends on farm-made feeds as supplementary feeding. The natural pond productivity contributes significantly to the nutrient requirement of these species, reducing the feed costs. In South Asia three categories of feedings are practiced are followed in aquaculture, (i) use of industrially produced pelleted feed (intensive), (ii) use of industrial and farm-made feed mixes (semi-intensive), and (iii) use of on-farm farm-made feeds consisting of a mixture of locally available feed ingredients (traditional/ extensive). As a common practice carps and omnivores are fed with bran-cake mixture with a FCR of 3.0-4.0 in semi-intensive system of aquaculture. The FCR for industrially compounded feed for fish and shell fish ranges between 1.5-2.0. There are three factors to consider in the choice of feed ingredients for aquafeeds, (a) quality - nutrient composition and presence of any anti-nutrients (substances that interfere directly with the absorption of nutrients or contaminants); (b) quantity – quantum of availability and is in regular supply; and (c) price of ingredients. Also, the other challenges of fish feed management are feed formulation, feed processing, storage, handling and transport. The diversification of aquaculture must be considered as the achieving of a balance between the main factors, viz. breeding, new species, environment, pathologies, genetics, management and, nutrition.

Diversification of products

The majority of the production of South Asian aquaculture targets the domestic markets. Fisheries products are mostly dominated by fresh fish/live fish marketing and well established domestic industries. Shellfish have been traditionally associated with the processing industry, and a large range of different processed products have been present in the market for many years. India and Bangladesh are the major fisheries exporting countries in SAARC region. India is exporting 50 different fish and shellfish products to 75 countries around the globe. The products may range from live and frozen fishes and shellfishes to *ready to serve* convenience products. Processing methods used are chilling, modified atmospheric packaging, active packing, freezing, drying, thermal processing, and dry and wet smoking. Accordingly, the Bureau of Indian Standards (BIS) and FSSAI have set up control and compliance systems for aquaculture products in India. Importance must be given to market survey, advertisement and packaging in order to formulate a successful value added product.

Diversification of markets

Asia is often characterized as a market-driven high fish demand region. The diversification of markets offers important sustainability elements in aquaculture. The competitiveness of an aquaculture product depends on consumers' preferences in terms of species, freshness, presentation, captured or farmed, and price. Product differentiations are essential in opening up new markets. Any type of market diversification must be aimed at placing the correct product in the correct format in the correct market segment at the correct time and at the correct price. The consumption of aquatic products in certain countries depends on the culture, history and religious beliefs of the people. It is a complex task to launch a new type of fish in a market, whether or not a high quantity of fish is consumed in that market or whether the consumption of aquatic products is low.

In India, in 2017-18, the volume of fish and fish products exported was 1.38 mt and Rs. 45,107 crore in value. The export of marine fish products registered an annual growth of 21.35% in volume and 19.11% growth in value. The government had drawn up plans to increase marine exports to Rs. 1,00,000 crore over the next five years (The Hindu News Paper, 2019). The volume of fish and fishery products are exported from Bangladesh to around 60 countries of the world. Major export destination of Bangladeshi fish and fishery products are the EU member countries, USA, Russia, China, Japan, Canada, Australia, India, Saudi Arabia, Malaysia, Thailand and Vietnam. Recent export volume of fisheries product of Bangladesh is 68,935.72 t, with a value of 4,309.94 core Bangladeshi Taka (BDT). Similarly Sri Lanka has dominance in ornamental fish export and Maldives is the leader in tuna export.

Conclusion

Diversification has advantages and can help in increase resilience in aquaculture. There are also challenges that can constrain diversification. The cost of developing new species for culture and the time required to bring a species to market are all challenges of aquaculture diversification. Resources and research may need to be spent on biodiversity, aquaculture design, marketing, regulations and processing. Restrictions on exotic species introduction in to the water bodies, escapes of these species from aquaculture facilities, and exports of genetic materials also limit diversification. Wild genetic resources are impacted when seed or early life history stages are collected from the wild for grow-out or for culture-based fisheries.

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Chapter 2

Fish Culture in Cages and Pens for Aquaculture Diversification in Bangladesh

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Introduction

Bangladesh is one of the world's leading fish producing countries with a total production of 4.277 million MT in the Fiscal Year 2017-18, and aquaculture contributed 56.24% of the total fish production. The annual average growth of aquaculture sector was almost 5.43 % (DoF, 2018) during last 10 years. Through this remarkable achievement, Bangladesh for the first time in the history, became a self-sufficient country in fish production. According to the FAO (2018), Bangladesh ranks 3rd in inland capture fisheries production and 5th in aquaculture in the world. The fisheries sector contributes 3.57% to the national GDP and 25.30% to the agricultural GDP. However, fisheries resources play a significant role in the economy of Bangladesh as an important dietary source of animal protein (60%), export earnings (2.46%) and 11% of Bangladesh population depends on fisheries directly or indirectly for their livelihood (DoF, 2018). The aquaculture sector has potential to achieve the Sustainable Development Goals (SDGs) of UN in respect to its increasing contribution to nutrition, employment and national economy.

The rich and diversified fisheries resources of the country are divided into two major groups, inland fisheries and marine fisheries. Inland fisheries sector has two sub sectors, inland capture and inland culture (aquaculture) fisheries. Inland capture fisheries include rivers and estuaries, Sundarbans, beels, Kaptai lake, flood plain etc. covering an area of 3,927,142 ha. The inland culture fisheries includes ponds, Baors, shrimp/prawn farms, seasonal cultured water body, pen and cage culture etc. covering an area of 797,851 ha. Inland capture contributes 28.45%, inland culture (aquaculture) contributes 56.24% and marine fisheries contributes 15.31% of the total fish production (DoF, 2018). Bangladesh is blessed with huge open water resources with a wide range of aquatic diversity. But due to mainly decline and degradation of wetland resources, the share of inland capture fisheries has been reduced remarkably during recent past decades.

For sustainability of the sector, aquaculture diversification is utmost important now in Bangladesh. The diminishing capture fisheries stocks, ever increasing population and demand for more food provides an impetus for more aquaculture diversification, and that is possible through diversification of aquaculture. Major drivers of aquaculture diversification are: a) market demand, b) funding opportunities, c) availability of fish seeds, d) competition for resources, e) climate change, f) advancement of technology, g) landscape opportunities and shortages, and h) the other environmental and social factors.

Diversification of aquaculture species

A total of 260 fish species have been recorded in the freshwaters of Bangladesh (Rahman, 1989) of these it is estimated that about 200 species are truly freshwater while the rest are examples of estuarine and marine species. Of these 200 species, 59 belong to 20 families that are commercially important, the majority of which are carps and catfish. At present, major carp species such as *Catla catla* , *Labeo rohita* , *Cirrhinus mrigala* and *Labeo calbasu* along with exotic carps such as silver carp (*Hypophthalmichthys molitrix*); grass carp (*Ctenopharyngodon idellus*) and common carp (*Cyprinus carpio*) are cultured in polyculture system in ponds. There are also not less than 40-50 small indigenous fish species which grow to a maximum length of 25 cm (Felts et al., 1996), some of the more commonly found species include *Puntius ticto*, *Amblypharyngodon mola*, *Colisa lalius*, *Anabas testudineus* and *Glossogobius giuris*. Indian major carps and exotic carps are the most commonly stocked species in Kaptai Lake and in oxbow lakes. Major cultured fish species are used in the aquaculture practices in Bangladesh are shown in Figure 1 and 2.

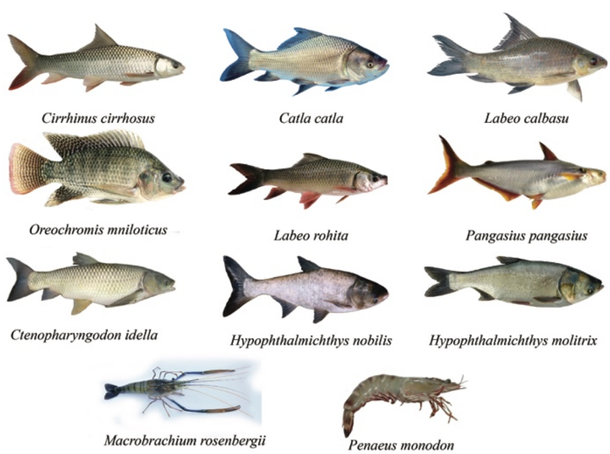

Figure 1. Common aquaculture species in Bangladesh

Figure 2. Recently introduced aquaculture species in Bangladesh

The coastal aquaculture has been developed significantly in the last decade particularly the shrimps (*monodon* and *indicus* sp.) culture in medium to high saline water and prawn (*Machrobrachium* sp.) culture in less saline areas. In addition, a small production of mangrove crabs, and varied quantities of brackish and marine water fish species like sea bass and mullet, most of which are produced as by-crops or fallow crops in the shrimp ponds. This constitutes the major export oriented sub-sector, and is increasingly shaped by international trade conditions and by national responses to these.

Diversification of aquaculture sites

In Bangladesh aquaculture sites are very diverse and can be grouped into different types. The major activities through fresh water aquaculture sites are fish culture in ponds, fish culture in paddy field/flood plain, fish culture in barrow-pit and khal/ditch, fish culture in baor (ox-bow lake), cage culture in river, pen culture in seasonal water body, freshwater mud eel culture. Coastal aquaculture site in brackish water through shrimp culture (Black Tiger) in paddy field/Gher/pond, prawn culture (Giant prawn) in paddy field/Gher/pond, SPF black tiger shrimp culture in paddy field/Gher/pond and crab culture and crab fattening in pens and cages are also playing a very important role in aquaculture sector. However, Marine aquaculture through small scale seaweed culture, pilot project on 'Introduction of Oyster (*Crassostrea* spp.) Culture' and Marine cage farming (Seabass, Snappers, Groupers) by a development project.

Table 1. Site-wise annual fish production in inland water bodies, 2017-18 (DoF, 2018)

Sl.	Origin	Total (t)	%
1	River	320598	8.85
2	Sundarbans	18225	0.5
3	Beel	99197	2.74
4	Kaptai Lake	10152	0.28
5	Flood Plain	768367	21.21
6	Pond	1900298	52.47
7	Seasonal cultured water body	216353	5.97
8	Baor	8072	0.22
9	Shrimp/ Prawn Farm	266154	7.35
10	Pen Culture	11015	0.28
11	Cage Culture	3523	0.12
	Total	3621954	100

Diversification of stocking density

On the basis of intensity of input and stocking density aquaculture is categorised as follows.

1. Extensive fish farming system
2. Semi-intensive fish farming system
3. Intensive fish farming system and
4. Integrated aquaculture system

Extensive fish farming system

The extensive fish farming system is the least managed form of fish farming, in which little care is taken. This system involves large ponds measuring 1 to 5 ha in area with stocking density limited to only less than 5000 fishes/ha. No supplemental feeding or fertiliser is provided. Fish production depends only on natural foods. Yield is poor (500 to 2 ton/ha), and survival is low. The labour and investment costs are also low. In this system of aquaculture in the income is minimum.

Semi-intensive fish farming system

Semi-intensive fish culture system is more prevalent in Bangladesh, which is practiced in small ponds (0.5 to 1 hectare) with higher stocking density (10000 to 15000 fish/ha). In this system, care is taken to develop natural foods by using fertilisers and t supplemental feeding is provided. In this system of aquaculture the yield is moderate (3 to 10 ton/ha), and fish survival is high.

Intensive fish farming system

An intensive fish farming system is the well-managed form of fish farming, in which all attempts are made to achieve maximum production of fish from a minimum quantity of water. This system involves small ponds/tanks/raceways with very high stocking density (10-50 fish/m^3 of water). Fish are reared solely on balanced formulated feeds, and contribution of natural food is almost zero. Proper management is undertaken to control water quality by use of aerators and nutrition by use of highly nutritious feed. The yield ranges from 15 to 100 ton/ha or more. Although the cost of investment is high, the return from the yield of fish exceeds to ensure the profit.

Integrated aquaculture system

Fish farming with agriculture

In the fish-agriculture integrated system, fish culture is integrated with agricultural crops such as rice, banana and coconut, thereby producing fish and agricultural crops. Agriculture based integrated systems include rice-fish integration, horticulture-fish system, mushroom-fish system, seri-fish system.

Livestock integrated fish farming

Livestock integrated fish farming system includes the cattle-fish system, poultry-fish system, duck-fish system, goat-fish system, pig-fish system, rabbit-fish system. In this integrated farming the excreta of ducks, chicks, pigs and cattle are used directly in ponds to increase plankton production which is consumed by fish or serve as direct food for fish. Hence, the expenditure towards chemical fertilisers and supplementary feeds for fish ponds are totally avoided reducing the production cost.

Diversification of production systems

Pond aquaculture

In general the size of fish ponds in Bangladesh varies between 0.020 and 20 ha with an average of 0.30 ha. In Bangladesh, the highest number of ponds exists in the Barisal district (12.11 %%), followed by Cumilla (9.36 %), Sylhet (9.10 %), Chittagong (8.02 %) and Noakhali (7.75 %) (BBS, 2002).

Historically, people depended mainly on natural waters for supplies of fish; but as a result of declining catches of wild fish due to an increased fishing effort by the growing population as well as environmental degradation, people began to culture fish in enclosed waters. The polyculture of major and exotic carps and monoculture of striped catfish (*Pangasius hypophthalmus*), Nile tilapia and Java barb (*Barbonymus gonionotus*) and to some extent catfish (*Clarias batrachus*) are the most widely practiced culture system in Bangladesh. Three Indian major carps namely, *Labeo rohita* , *Catla catla* and *Cirrhinus mrigala* and one exotic carp, *Hypophthalmichthys molitrix* now account for about 39.61 % of total pond production (DoF, 2018). However, carp polyculture at the individual small holder level has the greatest potential for expansion since it can, through the implementation of more intensive culture systems including the application of fertilisers, use of supplemental feeding and improved management practices (Gupta et al., 1999), provide a significant potential increase in income. At present annual average fish production using pond culture is 4,850 kg/ha (DoF, 2018).

Table 2. Species composition and annual fish production from ponds in 2017-18 (DoF, 2018)

Species	**Production (t)**	**%**
Catla *(Catla catla)*	157571	8.29
Mrigal *(Cirrhinus cirrhosus)*	171261	9.01
Kalibaus *(Labeo calbasu)*	31065	1.63
Bata *(Labeo Bata)*	37277	1.96
Ghonia *(Labeo gonius)*	14110	0.74
Silver Carp *(Hypophthalmichthys molitrix)*	184909	9.73
Grass Carp *(Ctenopharyngodon idella)*	44783	2.36
Common Carp *(Cyprinus carpio)*	70106	3.69
Other Exotic Carp	26426	1.39
Pangas *(Pangasius pangasius)*	441643	23.24
Boal/Air *(Wallago attu/ Sperata aor / Sperata seenghala)*	754	0.04
Shol/Gazar/Taki *(Channa striatus/C. marulius/C. punctatus)*	1982	0.10
Koi *(Anabas testudineus)*	46457	2.44
Singi/Magur *(Heteropneustes fossilis/Clarias batrachus)*	27331	1.44
Tilapia/Nilotica *(Oreochromis mossambicus/ O. niloticus)*	316286	16.64
Sarpunti *(Puntius sarana)*	43799	2.30
Big shrimp/prawn	1871	0.10
Small shrimp/ prawn	4351	0.23
Other Inland fish	39170	2.06
Total	1900298	100.00

Table 3. Culture method-wise annual fish production in Ponds, 2017-18 (t) (DoF, 2018)

Culture Method	Production range (t/ha)	Number of ponds	Area (ha)	Area %	Production (t)	Production %	t/ha	Growth Rate %
Extensive	<1.5	553994	36779	9.39	46463	2.45	1.26	-19.47
Semi-intensive	1.5-4	1400313	240091	61.29	842268	44.32	3.51	0.43
Intensive	>4	449571	97741	24.95	626103	32.95	6.41	10.66
Highly Intensive	>10	74005	17143	4.38	385464	20.28	22.48	3.91
Total		2477883	391753	100	1900298	100	4.85	3.66

Shrimp farming

Shrimp farming in the south and south-eastern coastal belt of Bangladesh began in the early 1970s. From less than 20,000 ha of brackish water ponds in 1980, the area under cultivation expanded to 184,821 ha by 2017-18 (Wahab, 2003; DoF, 2018). The major shrimp producing districts in Bangladesh are Bagerhat, Satkhira, Pirojpur, Khulan, Cox's Bazar and Chittagong. Recently farmers in Bagerhat and Pirojpur districts have began shrimp farming in their paddy fields. Traditionally shrimp farming began by trapping tidal waters in nearby coastal enclosures known as 'gher' where no feed, fertilisers or other inputs were applied, with an increasing demand from both national and international markets farmers started to switch over into improved extensive and semi-intensive systems.

Semi-intensive farming began in 1993 in the Cox's Bazar region. In this system ponds were stocked with 10-35 post-larvae (PL)/m^2 using supplemental pellet feed. The first outbreak of a viral epidemic in shrimp farms occurred in 1994 in semi-intensive farms in the Cox's Bazar region (Larkins, 1995; Karim and Stellwagen, 1998). In 1996 it was spotted in other coastal districts, affecting extensive shrimp farms (Karim and Stellwagen, 1998). In 2001, the disease once again caused the collapse of shrimp production in both the Cox's Bazar and Khulna regions. The disease has not yet been completely eradicated and can still cause havoc for shrimp producers.

Shrimp farming is a capital intensive business with total production costs of US$ 735 per ha/crop for extensive system, US$ 1 837 per ha/crop for improved traditional systems and US$ 9 184 per ha/crop for semi-intensive systems, the corresponding net income however is US$ 1,275, US$ 2,204 and US$ 153,061 per ha/crop, respectively (ICLARM, 2002).

Table 3. Species-wise Production of Shrimp/Prawn Farms, 2017-18 (DoF, 2018)

Species	Total Production (t)	%
Bagda *(Penaeus monodon)*	61709	23.19
Galda *(Macrobrachium rosenbergii)*	51571	19.38
Harina *(Metapenaeus monoceros)*	3882	1.46
Chaka *(Fenneropenaeus indicus)*	2029	0.76
Other Shrimp/Prawn	3359	1.26
Total Shrimp/Prawn	122550	46.04
Rui	28244	10.61
Catla	21076	7.92
Mrigal	3663	1.38
Bata	2538	0.95
Ghonia	187	0.07
Silver Carp	14185	5.33
Grass Carp s	616	0.23
Mirror/Common Carp	580	0.22
Tilapia/Nilotica	38465	14.45
Thai Sharpunti	15190	5.71
Other Fish	7073	2.66
Total Fish	131817	49.53
Crab	11787	4.43
Grand Total	266154	100

Integrated fish farming

The integration of aquaculture with duck and chicken production was begun experimentally at the BFRI, Mymensingh showing some promising results. The project demonstrated that 500 Khaki Campbell ducks can be profitably raised on a 1 ha carp pond while also producing 4.5 t/ha of fish without any additional supplementary feed or fertilizer. The most promising integrated farming in Bangladesh however, is rice fish culture, Ameen (1987) reported on the technique from many parts of Bangladesh. Traditionally one or more sump pond(s) are constructed at the lowest corner of the paddy field where fish accumulate as the water level reduces. The fish are harvested from the sump without any additional stocking or management practices. In a study, Islam and Ahmed (1982) obtained 346 kg fish in 4 months by stocking minor carp, catfish, climbing perch and common carp in a rice field. Similarly, Ameen (1987) reported a production of approximately 457 kg fish and 6 kg prawn/ha paddy field in 131–175 days.

Fish culture in ox-bow lakes

The most successful example of culture based fisheries has been accomplished in oxbow lakes located in South-west Bangladesh (Hasan and Middendrop, 1998; Hasan, 2001a). There are approximately 600 oxbow lakes in Bangladesh with an estimated water area of 5,488 ha (DoF, 2018). Most of these oxbow lakes are located in five districts of south-west Bangladesh (Khulna division: Jessore, Jhinaidah, Chuadanga and Kushtia districts and Dhaka division: Faridpur district). Twenty-three of these lakes were brought under a culture based fisheries management through the Oxbow Lakes Project (OLP II, 1997). The average production reported for oxbow lakes fishery during 2016-17 is 1,458 kg/ha (DoF, 2018).

Fish farming in Kaptai Lake

The Kaptai Lake (latitude 22°22'-23°18' N; longitude 92°00'-92°26'E) was created in 1961 by damming the river Karnaphuli at Kaptai in the Chittagong hill tracts. It covers an area of approximately 68,800 ha. Initially the lake was used only for capture fishery. However, at present about 35 t of carp juveniles are stocked in the lake every year as a part of a fisheries management program. The species used for stocking are the three major carps and exotic carps (silver, grass and common carps) (ARG, 1986; Rahman and Hasan, 1992). The lake also contains 76 other freshwater fish species, of which 68 are indigenous and the rest are exotic. In addition, there are also a few species of freshwater prawn. During initial days in 1965/66 the indigenous major carps was dominating the catch (with about 81 %). At present, this percentage has been declined to about 5 %, while the production of small forage fish has increased to 90 % of the total catch (Alamgir, 2004). Annual revenue from earnings from fishing in the lake currently is approximately US$ 0.42 million (Alamgir, 2004).

Figure 1. Fish harvesting in Kaptai lake

Fish culture in cages

Cage culture was introduced in Bangladesh in late 1970s on an experimental basis. A series of experiments were conducted at the Bangladesh Agricultural University (BAU) (Hasan et al., 1982 and Ahmed et al., 1997) which demonstrated the potential of cage aquaculture. The Department of Fisheries conducted a cage culture project in Kaptai lake during 1985-86 and achieved a production of 6,900 t of fish (Hasan, 1990). CARE, an international NGO, initiated a project 'Cage Aquaculture for Greater Economic Security (CAGES)' with the financial support from the Department for International Development (DFID), at the end of 1995, and continued till 2000. Cage culture is now expanding in flowing water of rivers and canals in various parts of the country, raising hopes for an increased production of fish. Fishes, mostly tilapia, are now farmed in nearly 6,000 cages in rivers where such farming did not exist even a decade ago.

Figure 2. Cage culture practice in Bangladesh

Pen culture

In typical pen culture, the sides of the enclosure are constructed by mesh or nettings, fitted to the wooden poles, and the bottom being the natural beds (soil bed). Pen culture originated in the inland sea areas of Japan in the early 1920s. China adopted it in the 1950s for rearing carps in freshwater lakes and later it was introduced in the Philippines between 1968 and 1970 in order to rear milk fish (*Chanos chanos*). The commercial culture of fish in pens is a relatively new practice.

Figure 3. Pen culture practice in Bangladesh

In Bangladesh the concept of pen aquaculture for commercial fish production was included in the national development programme in 1977. During 1981-1984, experimental pen culture activities were undertaken in a few places, viz Bahadurpur baor, Nabaganga River and Saganna baor in Jhenidah, and Dhanmondi and Gulshan lake in Dhaka city. In Saganna baor, 1,890 kg of fish was harvested from a 0.5 ha pen after 8 months of polyculture of carps with supplemental diet. Silver carp grew to 350 g; catla, rohu, and mrigal grew even less. In 1981, a 0.25 ha pen of 100' 25m size was installed in Dhamnondi lake and stocked with five species of carps viz silver carp, grass carp, catla, rohu and mrigal of 4.0-5.6g size at a density of 38,600 individuals/ha. The fish reached an average weight of 186g in 6 months time, and a total of 15,195 kg fish was harvested.

Polyethylene knotless net, bamboo fence (bana), bamboo poles, tire cord, and nylon cord are considered suitable materials for pen construction. Polyculture of Indian major carps and Chinese carps at a stocking density of 20,000/ha was found suitable for culture in a profitable manner. *Macrobrachium rosenbergii*, *Oreochromis* spp., *Pangasius sutchi* and *P. pangasius* were also found suitable for culture with carps in pens. Fingerlings of 10 cm size and 3 months old are found optimum for stocking. Economic analysis reveals that a net profit of about Tk 70,000 (about US $855) is possible from an irrigation pen of 0.50 ha within one cycle.

Table 4. Species-wise Fish Production of Cage and Pen Culture, 2017-18 (DoF, 2018)

Species	**Cage Culture**		**Pen Culture**	
	Production (t)	**%**	**Production (t)**	**%**
Rui	0	0	1517	13.77
Catla	0	0	1059	9.61
Mrigal	0	0	967	8.78
Kalibaus	0	0	120	1.09
Bata	0	0	262	2.38
Gonia	0	0	146	1.33
Silver carp	0	0	826	7.50
Grass carp	0	0	270	2.45
Mirror/Common carp	0	0	238	2.16
Other Exotic carp	0	0	174	1.58
Pangas	0	0	284	2.58
Boal/Air	0	0	42	0.38
Shol/Gazar/Taki	0	0	39	0.35
Koi	0	0	14	0.13
Shingi/Magur	0	0	7	0.06
Tilapia/Nilotica	3523	100	2680	24.33
Sarpunti/Thai punti	0	0	71	0.64
Big Shrimp/Prawn	0	0	0	0.00
Small Shrimp/Prawn	0	0	1184	10.75
Other Inland Fish	0	0	1115	10.12
Total	3523	100	11015	100

Case study: Doudkandi Model - a community based approach in Bangladesh aquaculture

In 1996 SHISUK, a local NGO, initiated a pilot project to develop a viable management system of community-governed aquaculture in six villages of the North Elliotgonj union. The people of these villages, surrounding the floodplain, were not the professional fish farmers. Before the initiation of FPA project, the local people were fishing in floodplain during the rainy season when the floodplain was inundated. With the main objective of utilizing a local underutilized resource through active community participation the project started with around 115 ha (285 acres) of floodplain that turns into a water-body in the monsoon (June-September). The pilot project adopted an innovative mechanism to solve the primary problem of capital. It distributed shares to landowners and other villagers and started the FPA operation. Although initially the shares – each valued Tk. 1000 – had only been issued to landowners holding lands in the floodplain, the project soon found that issuing of shares in this way was ineffective to raise required capital. So other households, who didn't own the land in the floodplain were also allowed to buy the shares, with a condition that the shareholders must be an inhabitant of any of these surrounding six villages. Also, it was specified that a shareholder can by a maximum of 20 shares.

Eighty percent of the shares were distributed to landowners and villagers, and 20% were kept with the initiator NGO, SHISUK. The NGO, SHISUK distributed 5% of the shares, out of its 20% shares, exclusively for less advantaged and impoverished villagers. After its initial two years of success, using the issued shares, the FPA was registered in 1997 as a joint stock company under the Company Act 1994 and named Pankowri Fisheries Ltd.

Since, then all activities of the FPA have been running like a conventional company. Shareholders select a Board of Directors, comprising one Chairman, one Managing Director and nine Directors, for a period of two years. This board oversees the day-to-day operations run by a group of employed personnel and sometimes form committees for specific management operations.

The FPA doesn't own the lands in the floodplain. It simply in the status of a private limited company, takes lease of lands from land owners for use during the monsoon through a contract that grants the legal right to use the land in exchange for the lease money. After deducting all costs the lease money is paid as 27% of the profit. After that, 70% of the net profit is distributed as dividends to shareholders regardless whether landowners or not, and 3% is kept for development of local areas. However, the amount of lease money is directly dependent on the profit the FPA makes every season, and this rate of 27% of earnings before paying dividends remains unchanged as long as the amount of leased asset remains fixed.

Figure 4. Women empowerment in the community based fisheries management of Daudkandi model.

Diversification of aquaculture production cycle

The principal aim of fish farm management is to achieve the maximum feed conversion ratio (FCR) and income with minimum investment of feed and care from a limited water area within the shortest possible time through proper management skill. The other management procedures include maintaining most favourable physico-chemical and environmental conditions of water, a well-lighted and aerated atmosphere, free from diseases, and a good soil bed, safe from inundation due to natural causes.

Fish farms in Bangladesh consist mostly of different sized ponds that can be categorized into nursery, rearing, and stocking ponds. Nursery ponds are usually less than 0.1 acre in size, rectangular, with depth 0.75 to 1 m. The sizes of rearing ponds vary from 0.1 to 0.66 acre, rectangular, and 1 to 1.5 m deep. The stocking ponds are of 0.66 to 1.50 acres, rectangular, having depth 1.5 to 2 m.

Hatchling stocking

Transported hatchlings after 15-20 minutes acclimatization are usually released at 6-8 g/decimal for single stage management, while for dual stage management 15-20 g/decimal is suggested. As management practices demand, netting is done fortnightly for recording growth, fry exercise, feed assessment, bottom racking, and for other changes.

To maintain a constant growth of plankton as natural feed for the fish, regular water flashing with a small amount of fertilizer (urea 15g, TSP 25 g/decimal) is recommended as a daily manuring practice. Equal amounts of soaked oil cake and wheat or rice bran are suggested for broadcasting over the shore areas for morning and noon feeding. Such a daily feeding schedule is continued, except on cloudy and rainy days, until harvesting.

The early crops (March-June) harvesting is done within 4-5 weeks in case of single stage, and for the dual stage, the fry get ready for thin-out within two weeks of hatchlings.

Rearing pond

Like nursery ponds similar management practices are done in rearing ponds. However, depending on the species 70-100 fry and reduced feed intensity (5% of body weight) once daily are suggested in rearing ponds.

Table 5. Fish production cycle

Culture Stage	Duration (months)
Hatchery	1-2
Nursery	2-3
Grow-out	6-7

Diversification of aquaculture products and market

Preserving, transporting and marketing are three important links in the chain of fish production and consumption connecting the producer, broker, wholesaler, retailer and consumer. Fish production is profitable only when the fishery products are marketed in a wholesome condition with an acceptable price.

Fish marketing is almost entirely a function of the private sector and operates through a complex system of village markets (hat), township markets (bazar), assembly centres, major urban wholesale and retail markets. There is a corresponding network of personnel, from buyers who may be hat traders or agents of bigger bazaar fish merchants (Bepari/Mahajan) to wholesale market commission agents (Adotdar/Paikar) who effectively control the whole system. The fishermen hand over their catches to the trader/middleman (Adotdar/Paikar) at a price fixed by the trader/middleman later. The middleman is often an owner of capital, like boat, net, etc, which he leases out to the fishermen. Also, he may be a fisherman himself owning and operating boat, gear, employing fishermen on a fixed wage as hired labourers and enjoy unearned income by depriving the actual beneficiary fishermen. The exploitation of the fishermen is mainly due to the monopolistic set up in the fish trade.

Despite many problems the fish marketing system in Bangladesh is quite efficient and enables fish to be moved as and when needed between market centres without excessive loss of quality. Boats are used to collect fish from the fishermen. The fishes are packed in baskets with ice. Trucks and buses are used to transport the fish to larger towns. The main problems, however are unavailability of ice, or inadequate supplies at most landing centres and the unsatisfactory state of fish market structures. Almost all markets are ill managed and unhygienic.

The Bangladesh Fisheries Development Corporation has constructed a modern fish harbour at Chittagong and fish landing centres at Cox's Bazar, Barisal, Khepupara, Patharghata and Khulna for marine catches, and at Rangamati, Kaptai, Rajshahi and Dabor for freshwater catches. The harbour and all the centres are equipped with modern and hygienic facilities like berthing, auctioning, ice-plants, cold storage, freezer storage, fish vans, etc. But the traders are often less interested in using these facilities due to ignorance and self-interest.

Fish and fishery products are exported from Bangladesh to around 60 countries of the world. Major export destination of Bangladeshi fish and fishery products remain the member countries of the European Union (EU), USA, Russia, China, Japan, Canada, Australia, India, Saudi Arabia, Malaysia, Thailand, Vietnam etc. Recent export volume of fisheries product of the country is 68,935.72 t, with a value of 4,309.94 Core Bangladeshi taka (BDT).

Table 6. Annual export of fish and fish Product (2017-18)

Fish and Fishery Products	Quantity (t)	Value (Core BDT)
Frozen Shrimp/ Prawn	36167.77	3527.07
Frozen Fish	8265.26	276.29
Chilled Fish	8889.85	214.80
Dry fish	3143.93	42.59
Salted/dehydrated fish	11435.33	217.53
Shark fin/ Fish Maws	0.50	0.12
Others	819.46	4.96
Total	68935.72	4309.94

Policies, laws and regulatory

After the partition of British India in 1947, the headquarters of the Directorate of Fisheries was shifted from Kolkata to Dhaka, and the Directorate had to look after only the fish marketing and fishermen's welfare. Since then the Directorate started considering other aspects of fisheries and aquaculture, like conservation of fish, control of the fishing period, mesh size of the gears, etc. and framed a set of laws which directly and positively influenced the development of the fisheries sector. amazing

The East Bengal Protection and Conservation of Fish Act: *The Act* was passed in 1950 by the provincial legislative with an objective conserving young and brood stocks of specific species of fish and restricting certain fishing activities. The Act, with subsequent amendments in 1963, 1970, 1982 and 1985-is still in force, empowers the government to promulgate laws and regulations to ensure conservation of fishery resources. The salient features of the Act are as follows: capture of fish by fixed net, cage, traps, etc put across the river, canal and outlet khal or beel is prohibited; such fixed structures may be removed or seized; construction of temporary or permanent weir, dam, bund, embankment except for flood control, drainage and irrigation is prohibited; capture of fish by use of explosives, gun, bow and arrow in inland and coastal waters is prohibited; destruction of fish by poisoning water or by polluting water by industrial wastes or other means is prohibited; capture of shoals of fry of Shol, Gazar and Taki (snakeheads) or their broods in the river, canal, khal and beel from 1st April to 31st August, except for the purpose of culture, is prohibited; except for the purpose of culture, nobody is permitted to catch (i) Rui, Catla, Mrigal, Kalibaus and Ghonia below the size of 23 cm from July-December, Jatka (young Hilsa) and Pangas from November to April every year; and (ii) Shillong and Air below the size of 30 cm from February to June every year; fishing with the help of current net/mosquito net having mesh-size below 4.5 cm is prohibited; first-time violators are to be jailed for 6 months or fined Taka 500 or both; second-time violators are liable to be jailed for one year or fined Taka 1000 or both.

The Marine Fisheries Ordinance, 1983: The ordinance is generally known as the Marine Fisheries Rules, 1983, which were amended in 1992. The salient features of the rules are as follows: The Director, posted at Chittagong, shall be responsible for the survey, conservation, development and management of marine fisheries resources, enforcement of laws and licensing, etc; an annual fishing license (January-December) is compulsory for every fishing trawler and mechanised boat and is obtainable after the payment of prescribed fees (Taka 200-1,800). Non-mechanised boats were brought under licensing in 1995. Every licence-holder must furnish data on every catch and the sale of the fish to the Director at Chittagong. Entry of foreign trawlers in Bangladesh waters is banned. The government reserves the right of permitting to any trawler or person for scientific investigation in Bangladesh waters; an illegal trawler will be seized along with its crew.

The Tank Improvement Act, 1939: Generally, the act is known as the Pond Development Act, 1939, which was amended in 1986. Under the Act, any unused pond may be brought under fish culture by the Upazila Nirbahi Officer (UNO) after issuing proper notice and time to the owner of the pond.

The Fish and Fish Products (Inspection and Quality Control) Ordinance, 1983: Generally, the ordinance is known as the Fish Quality Control Act, 1983, which was amended in 1989. The salient features of the ordinance are as follows: freshly caught fishes and shrimps may be processed in processing plants which fulfill the necessary terms and conditions and after payment of prescribed fees. During processing use of any element affecting the quality is prohibited. Export is allowed only after receiving a good condition certificate from the government.

Shrimp Culture Tax Act, 1992: According to this Act, the government can impose tax on a shrimp culture area if anybody is benefited by the construction of an embankment and water control structures and the excavation of khals.

Besides these, other policies, laws and regulatories related to the fisheries sector of Bangladesh are as follows:

- National Fisheries Policy (NFP), 1998

- National Fisheries Strategy (NFS), 2006
- National Shrimp Policy, 2014
- Government Vision 2021
- 7th Five Year Plan (2016-2020)
- Bangladesh Country Investment Plan 2017-2021
- UN SDGs and Targets (2016-2030)
- The Fish and Fish Products (FIQC) Rules, 1997 (amendment in 2008)
- Fish Feed and Animal Feed Act, 2010
- Fish Feed Rules, 2011
- Fish Hatchery Act, 2010 & Fish Hatchery Rules, 2011
- Marine Fisheries Act 2018 is being drafted
- The National Marine Fisheries Policy also being drafted

Human resources and institutional setup

Fisheries and aquaculture play a major role in nutrition, employment and foreign exchange earnings. About 12 million people are associated with the fisheries sector of which 1.4 million rely exclusively on fisheries related activities (Shah, 2003). An estimated 9.5 million people (73 %) are involved in subsistence fisheries on the country's flood plains (Azim et al., 2002) and the number increases dramatically to 11 million between June to October (during monsoon) each year with the availability of small indigenous species (SIS). There are 3.08 million fish farmers, 1.28 million inland fishermen and 0.45 million fry collectors (fish and shrimp) in Bangladesh (DOF, 2003) and it is estimated that fisheries and related activities support 11% of the country's population. Currently, more than 600,000 people are engaged in shrimp farming activities (Karim, 2003). It is also estimated that around 14,000 fishermen (2.5 fishers per ha water body) are directly involved and 70,000 rural people are the direct beneficiaries of oxbow lake fisheries (Hasan, 2001a; Hasan and Talukdar, 2004). The male members of a family carry out most of the activities in aquaculture and fisheries in Bangladesh. Recently women are encouraged to participate through the motivations by the NGOs and some private entrepreneurs. Thengamara Mahila Sabuj Sangha is a woman's NGO which is actively engaged in aquaculture development activities in the country.

Institutions involved in aquaculture and fisheries in Bangladesh:

- Department of Fisheries (DoF) under the Ministry of Fisheries and Livestock (MoFL) is the sole authority with administrative control over aquaculture in Bangladesh. The DoF is managed by a Director General and has two main sub-departments namely, inland and marine. The main responsibilities held by the DoF include planning, development, extension and training.

- Bangladesh Fisheries Research Institute (BFRI) conducts and coordinates research and to some extent training.
- Bangladesh Rural Development Board is responsible for the fisheries component of integrated rural development.
- Land Administration and Land Reform Division is responsible for the leasing of public water bodies.
- Export Promotion Bureau is responsible for export of fisheries products, along with the Bangladesh Frozen Foods Exporters Association which is also involved in the export of frozen shrimp, fish and fish products.
- The country's universities are responsible for higher level fisheries education.
- External Resource Division under the Ministry of Finance is responsible for external aid for aquaculture development.
- Bangladesh Krishi (Agriculture) Bank, Bangladesh Samabay (Co-operative) Bank and some other commercial banks are responsible for issuing credit to the aquaculture sector.
- Many of the national and international NGO's provides credits to the fish farmers and as well as takes up projects for aquaculture extension and development.
- International organizations (DFID, Danida, NORAD, JICA, World Bank, IMF, ADB etc.) provide grants and credits for aquaculture development.
- Youth Development Training Centers, under the Ministry of Youth, deals with extension and the training of unemployed young people and fish farmers.

Conclusion

Aquaculture is the fastest growing food producing sector in the world, also the world's most diverse farming system in terms of number of species farmed, the methods used and the environments where the farms are located. Climate change and extreme climatic events are likely to play increasingly important roles in determining the success or failure of aquaculture enterprises. Diversification of species and culture systems could provide resilience in the face of this and other external drivers. At the farm and local community scale, diversification can add economic, social and ecological insurance to aquaculture systems, particularly for small-scale and family-based enterprises. However, there are costs, challenges and risks associated with diversification. Bangladesh fisheries have ample scope to strengthen the national economy. Concerned government departments, development partners, researchers and non-government organisations can play important role in the wide-ranging advancement of the fisheries sector. DoF formulates and implements development projects under the revenue and development budget toward the sustainable utilization of fisheries resources to ensure food security.

The following issues require to be addressed in future for sustainable development of aquaculture and fisheries in SAARC regional countries:

- Establishment of an SAARC Fisheries Management guidelines for sustainable use of fisheries resources
- Establishment of an SAARC Sustainable Aquaculture Development Cooperation
- Capacity building in fisheries management and aquaculture
- Joint research in aquaculture sciences, among the SAARC countries and in collaboration with other fisheries organizations, academic and research institutions;
- Institutional development
- Technology sharing
- Exchange visit
- Brood stock development and sharing
- Quality seed production
- Aquaculture farm mechanization

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Chapter 3

Fish Culture in Cages and Pens for Aquaculture Diversification in Nepal

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Introduction

Nepal is one of the least developed countries in the Human Development Index. Hunger and mal nutrition is the major areas of concern. Around 25% of the population spends their life below poverty line and food poverty is nearly 24%. The scenario of malnutrition is more critical as 31% of the children below 5 years are under weight, 42% are stunted and 24% of all women are undernourished (ADS, 2013). Lack of animal protein in the diet is one of the major reasons for malnutrition as availability of animal protein is only 40% of the requirement in the country (ADS, 2013). Agriculture is the principal source of food, income, and employment for the majority, particularly the rural mass. Higher growth rate in agriculture is thus crucial for reducing poverty. However, in contrast to the country's needs, the share of agriculture in national GDP is declining, mainly due to expansion of tertiary sector of the economy (ADS, 2013). But on the other hand, there is considerable scope for increasing productivity through diversification of agricultural sector and utilizing their full potential. Improved governance, commercialization of farm produces, value addition of farm products, optimization of productivity of land and water through improved technologies can address issues related to food and nutritional insecurity and rural livelihoods (ADS, 2013).

For the economic development of the country, agriculture needs to be commercialized and commodities having competitive advantages need to be promoted. Small land holding (average 0.8 ha) is one of the major problems in mechanization and commercialization of agricultural sector. A large number of people are migrating from rural to urban areas for better livelihood opportunities. Nepali youth, the most productive labour force, have looked for job elsewhere. Agriculture Development Strategy clearly mentioned that low productivity of labour and agriculture land is the main reason of migration. Aquaculture offers excellent opportunity for better land and labour productivity. The potential of aquaculture in terms of fish production, supplementing family income, betterment of environment, and overall rural development has been demonstrated repeatedly with increased investment. Aquaculture is fastest growing food growing sector in Nepal with an annual average growth rate of 10.8% in last 5 years (CFPCC, 2018).

Aquaculture is fairly a new activity in Nepal. It began in the 1940s with pond culture of Indian major carps. Over the years, carp polyculture in ponds has developed as the most viable and popular aquaculture production system, it accounted for over 89 % of total aquaculture production. The major part of the pond fish production takes place in the southern part of the country – the Terai plain – where 94 % of fish ponds are available. Cage fish culture and fish culture in lakes and reservoirs as well as monoculture of pangas and rainbow trout farming in race-ways are popular diversified production systems. Moreover, fish culture in gholes/marginal irrigated agriculture land, swamps and ditches – is a recent intervention in Nepal and has supported for livelihood improvement to the rural targeted community. The various factors responsible for aquaculture commercialization and diversifications in Nepal are; execution of aquaculture friendly program through fish mission, Prime Minister Modernization Agriculture Project (PMAMP), availability of diversified fish species and sites along with diversified technical package of practices (cage culture, trout fish culture, polyculture of carp fish farming), increasing consumer awareness towards fish consumption, changing of food habit of people, improvement in supply chain, and higher profit margin of the sector. Furthermore, the pro-active role played by media house, farmers group, Fisheries Association of Nepal, Nepal Fisheries Society, universalities, private organization, cooperatives, financial institution, input suppliers further supported fast growth of aquaculture in the country.

Water resources of Nepal

In Nepal, rivers, lakes and reservoirs in the form of natural water bodies are the dominant water resources in the country and cover 48.9% of the total and the rest is covered by low land irrigated payday field, ponds and marginal swamp as shown in Table 1.

Table 1. Water resource available in the country

Resource Details	Estimated Area (ha)	Coverage (%)
Natural Waters	401500	48.9
Rivers	395000	48
Lakes	5000	0.6
Reserviors	1500	0.2
Ponds	11396	1.1
Marginal Swamps	12500	1.5
Irrigated paddy Fields and low lands	398000	48.4
Total	823396	100

Source: CFPCC (2018)

Fish production based on water bodies

Aquaculture and capture fisheries are the two main sources of fish production in the country. Table 2 shows types of water bodies, area coverage and fish production in the country during 2017/18. Based on table total, total fish production in the nation was 86544 t (CFPCC, 2018) out of which the share of aquaculture and natural catch was 65544 t (75.7 %) and 21000 t (24.3%), respectively. Table 2 further shows the various diversified aquaculture practices of which pond based farming seems most dominant and it contributes 89 % (58433 t) followed by marginal swamps 10% (6390 t).

Table 2. Types of water bodies, area coverage and fish production

Types of water bodies	Area coverage (ha)	Fish production (t)
Cultured		65544
Ponds	11895	58433
Paddy fields/enclose/government	100	98.8
Marginal swamps	3550	6390
Cage fish farming (m^3)	71800	302
Raceway	3.2	320
Captured		21000
River /lakes/reservoir/swamps	410500	13835
Low land irrigated paddy fields	398000	7165
Total fish production		86544

Source: CFPCC (2018)

Availability, requirement, contribution to GDP from fisheries sector

Table 3 shows the proposed demand of fresh fish, its availability as well as contribution of the sector to AGDP and GDP over a period of 5 years. Based on table, during 2016/17 fish consumption in Nepal was 97301t (including import) with per capita availability 3.39 kg. The contribution of fisheries sector to AGDP and GNP was 4.18% and 1.13%, respectively (CFPCC, 2018).

Table 3. Annual availability, requirement and contribution to GDP from fisheries sector

Details	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**
Population	27,214,684	27,582,082	27,954,441	28,317,849	28,62,1803
Fish Requirement (t) proposed*	161,113	165,556	167,791	170,056	172,352
Fish availability (t) including import	74863	82369	88177	91780	97301
Per Capita Fish Production (Kg)	2.14	2.38	2.52	2.75	2.93
Per Capita Fish Availability (Kg)	2.86	2.92	3.01	3.36	3.39
Agriculture GDP Contribution (%)	3.7	3.96	4.44	4.52	4.18
National GDP Contribution (%)	1.21	1.24	1.29	1.31	1.13

Source: CFPCC, 2018

*Assumption: Calculation, 60 g protein/person/day requirement out of which ¼ from animal protein. From ¼ animal protein fish supplies 20 % (Protein content in fish 18% assumption)

Diversification of aquaculture species

It has been reported that a total of 230 fish species are found in various water bodies in Nepal (Rajbanshi, 2012). They inhabit altitudes ranging from a few hundred meters above sea level to as high as 4,000 meters. Three indigenous major carps (rohu - *Labeo rohita* , catla - *Catla catla* and mrigal - *Cirrhinus mrigala*) are already included in the country's aquaculture production systems. Studies are also currently being carried out into the commercial production of three high-value indigenous cold water fish species: asala (*Schizothorax* spp.), katle (*Acrossochielus* spp.) and mahseer (*Tor* spp.). In addition to these indigenous fish species, exotic species such as rainbow trout (*Oncorhynchus mykiss*), common carp (*Cyprinus carpio*) and three species of Chinese carps (grass carp - *Ctenopharyngodon idella*, silver carp - *Hypophthalmicthys molitrix* and bighead carp - *Aristichthys nobilis*) of commercial value have played significant role to enhance fish production in the country. Recently, Nile tilapia (*Oreochromis niloticus*), Java barb (*Barbonymus gonionotus*) and giant river prawn (*Machrobrachium rosenbergii*), Pangas (*Pangassius hypophthalmus*), Rupchanda (*Piaractus brachypomus*) have been introduced to study the viability of their commercial production.

Diversification of Aquaculture sites

Nepal possess various water bodies namely river, lakes, paddy field, reservoirs, ponds and swamps which are situated at various part of the country. Furthermore, based on their geographical location, water bodies are divided into cold water and warm water region. Both mid- and high-land areas are cooler where trout fish farming has adopted. The sites like reservoir and lakes which are mostly located at mid-hill where cage fish farming and open water stocking and harvesting practices are performed. The reservoir was selected for displaced communities due to damming effect of Kulekhani hydropower in 1982. In recent years inland waters have been increasingly impounded for hydropower generation, irrigation and other purposes (De Silva 1998). Impounding submerges the plains suitable for human settlement, agriculture, and several other uses, affecting the traditional livelihoods of these communities dependent on those lands (Gurung, 2009). At the beginning there were 500 families and now 685 families are involved in both cage fish farming as well as open water stocking and harvesting practices to meet their livelihood. Likewise, the marginalized community namely Bote (fishers) around lake Phewa, Rupa and Beganas in Pokhara valley were given opportunity to performed cage fish farming as well as open water stocking and harvesting opportunity through co-management approach. Moreover, in far western part of the country, out of 12500 ha swamps 3500 ha has been utilized for fish farming by poor communities. In mid-high land area where cold water is available throughout the year in the form of river and spring is being used for trout fish farming where the local communities are engaged in the business. The production potential of different water bodies located at various geographical regions varied based on water temperature, farming system.

Diversification of stocking density

In Nepal, carps contribute more than 95% in aquaculture production where farmers mostly stock Chinese/Indian major carp along with common carp.

Table 4 shows ideal stocking density (15000/ha fingerlings) commonly practices in carp polyculture system in Nepal where silver carp is stocked as a major species (35%) followed by rest of species. The stocking density is determined based on the feeding habit of fish species and available resources in the farms where plankton feeder and artificial feeder are stocked at 45 and 55 %, respectively.

Table 4. Species-wise stocking density/ha of carp fingerlings their composition on carp polyculture system commonly practices in Nepal

Species	Composition %	Stocking size (g)	Stocking numbers
Common carp	25	5-10	5250
Silver carp	35	5-10	1500
Bighead carp/Bhakura	10	10	3750
Grass carp	5	10	750
Rohu	15	5	2250
Naini	10	5	1500
Total	100		15000

Source: CFPCC, 2018

Table 5 shows cost of construction and depreciation of new fish pond having 1 ha water surface area with 1.5 meter water depth including machineries equipment required for semi-intensive carp fish culture.

Table 5. Fixed cost and depreciation of fish pond

S.N	Activities	Unit	Quantity	Rate (%)	Amount (NPR)
A)	**Fixed cost**				
1	Depreciation of ponds	NPR	800000	10	80000
2	Depreciation of Aerator (2 number)	NPR	150000	10	15000
3	Electric motor (1)	NPR	40000	10	4000
4	Shallow tube well (1)	NPR	150000	10	15000
	Total fixed cost		1140000		114000

Source: CFPCC, 2017-18

Table 6 describes operational cost required to produce 7 t/ha food fish (Plankton feeder 55%) annually through partial stocking and harvesting practices along with net return from the business. Based on Table 6, the farm generates NPR 562150/- (US$ 5110.0) as a net profit with 2.3 FCR.

Table 6. Operational cost, production and profitability of semi-intensive carp polyculture farming

	Activities	Unit	Rate (NPR)	Amount	Total (NRP)
B)	**Operational Cost**				
1	Pond preparation	LS			10000
2	Lime	kg	500	25	12500
3	Compost	kg	6000	3	18000
4	Fingerlings	No	15000	1	15000
5	Urea	kg	1000	25	25000
6	DAP	kg	700	50	35000
7	Paleted feed	kg	7000	60	420000
8	Electricity/chemicals/	LS			34000
9	Bank Interest	NPR	2093500	10%	209350
10	Labor/security	Months	12	10000	120000
11	Harvesting cost	NPR	1750000	10%	175000
	Total operational cost (B)				1073850
	Total Cost (A+B)				1187850
C)	**Income (fish sale)**	kg	7000	250	1750000
1	Net profit	NPR			562150
2	Production cost/kg	NPR			170
3	Net profit/kg	NPR			80
4	FCR				2.3

Source: CFPCC (2018)

FCR is calculated based on 45 % biomass of total fish production

Case study I

A case study was conducted during May 2018 in Sarlahi district to access viability of Pangas fish farming. The Pidari fish farm covers 4.6 ha water surface area which is being operated by innovative farmer since last couple of years. The farm purchases Pangas seed having 1-1.5 g two times in a year (August and March) and stocked in nursery ponds where they are fed with 32 % protein based paleted feed of 1 and 1.5-2 mm size. The fries purchased in August are reared in nursery ponds in high density up to January when they reached at 100 g. The survival of fingerlings has achieved 60%. The 100 g advanced stunted fingerlings are stocked in production pond @ 60000/ha at the beginning of February. They are fed with 28 % protein based floating feeds and harvested during April to Jun when reached at 700 g size. Similarly, the March fingerlings are stocked in July and harvested from October till November. The productivity of two production cycle has reported 47.8 t/ha with FCR 1.6. As shown in Table 7, the farm earns annual net profit NPR 7059000/- (US$ 64172.00) through investment of NPR 31661000/- (US$ 287827/- @ 1 US$ = NPR110).

Table 7. Production and profitability of Pangas fish culture in Pidari fish farm, Sarlahi

SN	Activities	Unit	Quantity	Rate	Amount (NPR)
A)	**Operational Cost**				
1	Fingerlings	Nos	277000	9	2493000
2	Fish feed (28 % cp) floating pellet	t	365	56000	20440000
3	Farm labor cost	Person	20		2500000
4	Fish harvesting cost (10% of harvest)				1000000
5	Annual Bank interest				2860000
6	Depreciation of ponds (4.6 ha)	NPR	3680000	10	368000
6	Other expenses				2000000
	Total operational cost				31661000
B)	**Gross profit**	NPR	220000	176	38720000
	Net profit (B-A)	NPR			7059000
	Production cost/kg	NPR			144
	Net profit per kg	NPR			32
	FCR : 1: 1.6		1 US$ = 110 Nepalese rupees		

Source: Giri et al. (2018)

Case study II: Chhadi fish farming

Chhadi (having average 50 g marketable size Naini (*Crrihina mrigala*) is popular in Nepal which is mostly cultured in Bara district (80%) followed by Rautahat, Parsa, Chitwan and Nawalpur. To find out economic viability of this farming system, a case study was conducted in BK Fish farm, Benauli, Bara district during March 22-24, 2019. The farm covers 5 ha water surface area with average 1.5 meter water depth where fries of Naini fish *Crrihina mrigala* (90%) and 10% silver and big head carp having 1-1.5g are stocked @ 150000/ha during Jun to July. The fish are fed with mustard oil cake (85%) and rice bran on daily basis, at 1-2 % body weight. Fish harvesting started 3 months after stocking (October). As and when they reached a marketable size of 40- 50 g are sold, and the process continue till the end of March. Table 8 shows the production and profitability of Chhadi fish in BK fish farm, Bara, in 5 ha water surface area. The farm has produced 50 t Chhadi fish during 2016/17 by operating 5 ha water surface area with the productivity of 10 t/ha/year. The farm has generated net profit NPR

2435000with an investment of NPR 6565000. The table further shows that per kilogram production cost as well as profit was NPR 131.3 and 67.7 kg, respectively.

Table 8. Production and profitability of Chhadi fish in BK fish farm, Bara

SN	Activities	Unit	Quantity	Rate	Amount (NPR)
	Operational Cost				
1	Fries (5 ha)	Nos	800000	0.2	160000
2	Lime	t	2.5	300000	75000
3	Farm labor cost	Person	2	15000	360000
4	Fish harvesting cost (10%)	t	5	200000	1000000
5	Annual Bank interest (10%)	NPR	5200000	10	520000
6	Fish feed (Oil cake 85%+15% rice bran)	t	90	35000	3150000
7	Depreciation of old ponds	ha	5	100000	500000
10	Water management/electricity/chemical	ha	5	100000	500000
11	Miscellaneous				300000
A)	Total operational cost				6565000
B)	Fish production (50 t -5 harvesting cost) = 45 t	t	45	200000	9000000
	Net profit (B-A) = NPR 2435000/-		1 US$ = 110 Nepalese rupees		
	Fish production cost/kg	NPR		131.3	
	Profit/kg fish production	NPR		67.7	

Source: Giri et al (2018)

Diversification production system

Various aquaculture systems are in practice in the country to enhance fish production. These systems broadly divided into land-based and water based. The land based production system includes pond fish farming of polyculture of carp, monoculture of Pangas, integrated fish farming with pig/ducks/livestock, mono culture of trout fish farming in raceway as well as fish farming in marginal swamps and paddy fields. Likewise, water based fish farming system are practice in lakes and reservoirs as in Pokhara and Kulekhani where cage fish farming as well as open water stocking and harvesting practices have been followed since last several years. Out of them, based on profitability, 2 case studies; namely fish farming in cage and open water as well as trout fish culture in mid-hill will be discussed in details.

Cage fish farming and open water stocking/harvesting in Kulekhani reservoir

Modern cage culture in Nepal has a history of over 4 decades starting from the early 1970s (Swar and Pradhan, 1992). Cage culture of carp is considered a major step towards the utilization of natural water fisheries management for increased production. This sector plays important role in poverty alleviation of dependent and displaced community as part of the mitigation efforts following reservoir construction and loss of farmland. This technique was started in Kulekhani reservoir in 1984 for the local people. The Kulekhani reservoir is situated 1430-1530 meter height above sea level with an area of 216 ha during rainy season and 92 ha in dry season. It has maximum depth 80 meters and average depth is 48 meters and water temperature of the reservoir ranges from 10 to 26 degree Celsius. Currently, there are 685 families involved in group and cooperatives whose livelihood is fully depends on 4 types of activities carried on reservoir, namely fish farming in cages, open stocking in reservoir and harvesting, aqua-tourism as well as fish marketing through value addition.

Extensive method of cage culture with planktivorous carps is dominant culture practices in Nepal. Management of an extensive cage culture is considered easy because feeding is not required. Stocking densities in cages depends on the natural productivity of the water body. They first stock the fry into nursery cages (5-15 mm mesh) at 20-100 fish/m^3. When fingerlings attained 20-30 g body weight, they are transferred to production cages of 50 mm mesh. The mesh size of production cages has reduced sharply (20 mm) in Kulekhani in recent years in order to protect growing fish from weed fish (Chanda). Recommended stocking density in production cages during the late 1980s was 6-10 fingerlings/m^3 in lakes/reservoir (Swar and Pradhan, 1992). Recently, stocking density has been adjusted to 6-8 fish/m^3 due to enormous increase in the number and volume of cages both in lakes and reservoir. Cage culture usually starts in April-May with stocking silver and bighead carp fingerlings at a ratio of 50:50, respectively. It takes about 12 months to reach a marketable size of 700 g in Kulekhsani. Currently, there are 150 production cages in Kulekhani reservoir which produces 7000 kg fish annually (RFDC, 2017). Likewise, open water stocking of fish seed and harvesting through gill nets is common practices used in the reservoir where the entire fisher community (685 members) are operating their business through co-management approach. The major inputs required for cages and open water fisheries management are cage materials, gill nets, fish seeds and labor cost. The cages can sustained more than 5 years, so the production cost can be reduced substantially from second year of operation. On other hand the gill nets need to chang in every 6 months of operation.

Table 9/10 show the production and profitability of cage fish farming and open water fisheries management in Kulekhani reservoir over a period of five years (2012/13 -2016/17). These tables clearly shows that the communities were able to earn net profit NPR 14620000 from cage fish production (30 t) as well as open water fish catch (144 t) over a period of five years. Both table further shows that the major operational cost required for cage operation as well as open water fish catch is labor cost which accounts 41.5%, is being managed by the communities themselves. Recently, slow growth and low production of fish in cage culture is being noticed due to various factors (introduction of alien fish species, change in water quality etc) the cage numbers have been reduced in Phewa lake, Begnas lake and Kulekhani reservoir by 83%, 88%, and 62%, respectively in year 2017 as compared to 2011(Husen et al., 2019). In recent years harvesting from open water has increased substantially. Likewise, the communities are being involved in diversified business like aqua-tourism as well as value addition of the produce as a result, generating cash income which has increased their living standard to a large extent as seen during case studies.

Table 9. Production and profitability of cage fish farming in Kulekhani reservoir over period of five years

SN	Activities	Unit	Quantity	Rate	Amount (NPR)
A)	**Operational cost (cage)**				
1	Production cage cost (50) m^3	No	150	10000	1500000
2	Fingerlings (10/m^3)	No	100000	1	100000
3	Labor cost	No	4	12000	576000
4	A) Total cost (Ist year)	NPR			2176000
	B) Total cost (Ind year) labor+ seed)	NPR	676000	4	2704000
	C) Total cost (5 years) (A+B)	NPR			4480000
5	D) Fish production (5 years)	T	30	220000	6600000
6	a) Net profit (C-D)	NPR			2120000

Source: Giri et al. (2018)

Table 10. Open water fish catch and its profitability over a period of five years in Kulekhani resorvoir

S.N.	Activities	Unit	Quantity	Rate (NPR)	Amount (NPR)
B)	**Open water stocking and harvesting**				
	Operational cost (last five years)				
1	Fingerlings (1000000 nox5 years)	NPR	5000000	1	5000000
2	Gill net required (72x5 years)	kg	72	1500	540000
3	Labor (18 person@ 2000/month)x 5 yrs	NPR	18	36000	2160000
4	Labor get Rs 25/kg as bonus fish catch(5 years fish catch 144 t)	t	144	25000	3600000
	A) Total operational cost (5 years)				16300000
	B) Fish catch (5 years)	t	144	200000	28800000
	b) Net profit captured (B-A)	NPR			12500000
	Total net profit from cage fish farming and open water catch (a+b)	NPR			14620000 US$ 132909 1 US$= NPR110

Source: RFDC (2017)

- Cage can sustain more than 5 years, so from 2nd year the cost of cages has not added in the operational cost

Trout fish farming in mid-hills

Rainbow trout (*Onchorhynchus mykiss*) farming technology was developed in 1998 in Nepal and successful up scaling led to its expansion in the Himalayan region (NARC, 2016). Currently, 125 fish farmers from 25 districts are engaged in trout fish farming in 3.2 ha raceways and produces 320 t trout fish annually with average productivity of 100 t/ha. Table 12,13 and 14 shows the fixed and variable cost required to operate 200 m^2 trout farms along with production and profitability of the business.

Table 11. Capital cost required to operate 200 m² trout farm

A) Part 1: Capital cost			
Activities	**Cost (NPR)**	**Life expectancy (year)**	**Depreciation (NPR)**
Raceway contraction (200)	652000	20	32600
Water management	224000	20	11200
Feed store house	181000	20	9050
Harvesting nets	6000	5	1200
Hapa, Hemok, etc	12000	5	2400
Digital balance/ small pumps etc.	12000	5	2400
Buckets, mug, clothes etc.	7000	2	3500
Total	1094000		62350

Source: CEPCC (2018)

Table 12. Operational cost required for trout fish production in 200 m² area

B) Part 2: Operational cost				
Activities	**Unit**	**Amount**	**Rate**	**Total (NPR)**
Fry (2 g)	No	15000	8	120000
Feed (advance fingerlings)	kg	375	150	56250
Feed (food fish)	kg	6000	110	660000
Small equipment, chemicals,				12000
Communication				12000
Fuel and transportation				30000
Oil, vitamin etc.				12000
Electricity				12000
Total				914250

Source: CEPCC (2018)

Table 13. Capital cost required and production and profitability of trout in 200 m^2

C)Part 2: Running capital cost				
Activities	Unit	Amount	Rate	Total (NPR)
Salary for manager	Months	12	12000	144000
Labor cost	Man days	240	600	144000
Land on lease				10000
Bank interest (14% of the capital cost				153160
Depreciation cost				62350
Repair/maintenance (5% of capital cost)				54700
Miscellaneous				12000
Sub-total				580210
Total annual operational cost (A+B+C)= E				1556810
Fish production	kg	2000	1000	2000000
Net profit (F-D)				443000
Production cost/kg				778.40
Profit/kg				444
FCR				2.26

Source: CEPCC, 2018)

Diversification of production cycle

Fish seed required for carp fish farming in the country was 295 million of which private sector contributed 75% (CEPCC, 2018).There are more than 60 fish hatcheries currently in operation both in private and public sector who supply hatchling/larvae, fry and fingerlings to the farmers. Most of hatcheries operated by private sector usually supply hatchlings (80%) rather than fry and fingerlings due to their limited nursing and rearing facilities; where as public sector hatcheries supply all types of seeds as per farmers demand throughout the year. Since last couple of years farmers have developed both nursery and rearing units along with production ponds and adopted a three tier culture system, comprising nursery, rearing and grow-out.

Hatchlings nursing

Hatchlings nursing commonly practices in earthen ponds, 0.05 to 0.1 ha with 1 m water depths. As a pre-stocking management practices, the nursery ponds are dried for a week, limed @ 500 kg/ha and applied organic manure as a basal dose @ 300 kg/ha, then after fresh water is filled about ½ meter and left it for about 2-3 days (CPCC,2018). When water became fully green, fresh water is added to about 1 meter and treated with Malathion (organophosphate, 50% EC) @ 0.75 to 1 ppm to kill larger zooplankton. After completion of pre-stocking management practices, carp hatchling (one species at a time) are stocked @ 4000000 to 6000000/ha and fed with chicken eggs and small size zooplankton (rotifer etc), for the first week. From second week onwards, they are fed locally made fried soybean powder (80%) along with wheat flour (20%) for about 2-3 weeks. In the mean time, the pond is treated with diesel (75 liter/ha along with 2-3 kg detergent powder) to kill water insect like back swimmer. Normally, 3-4 weeks later, the fries of 0.5 to 1 g size are harvested and distributed to farmers as per their demand or restocked for fingerling production. The survival rate from hatchling to fry of major carp, Chinese carp and common carp have achieved <50%, 30-50% and 25-35%, respectively (CFPCC, 2018).

Fry rearing

Growing 0.5 to 1 g fry to fingerlings (5-10 g) over a period of 45 to 90 days in monoculture system is commonly practices in Nepal. The ponds used for culture fish fries range from 0.1 to 0.2 ha with water depths 1.25 to 1.5 m. The ponds are treated with lime and fertilized with manure as described earlier in nursing ponds preparation. Besides, 200 kg Nitrogen and 300 kg Phosphorus/ha/crop are applied by dividing the amount in 10 equal parts. Table 15 shows the stocking density of carp fries for fingerling production in different feeding conditions. The fries are fed with 25% protein based feed @ 15% body weight daily at the beginning and feeding rate gradually reduced with increase in growth rate and finally maintained 8% feeding rate at the time of harvesting. Moreover, feeding rate is determined by the water quality and growth rate of fingerlings. In the course of management, over sized fingerlings from the mass are separated out every 30 days interval. The fingerling of 5-10 g are harvested and supplied to table fish growers. Table 14 shows the stocking density of fish fries for fingerlings production.

Table 14. Stocking density of fish fries for fingerling production

Size of fish fries (g)	Stocking density/ha	
	Partial artificial feeding	Complete feeding
0.5- 1	400000	1000000
1-2	300000	700000

Source: CFPCC (2018)

Fish seed stunting

Since last couple of year, progressive farmers especially from fisheries pocket areas practicing multiple stocking and multiple harvesting techniques, as a result the pond productivity has increased sharply in these areas (Sarlahi, Bhaktipur, Rupendehi). To achieve this progress advanced size stunted fingerlings has played important role because it has faster growth rate, high survival, and short production period along with low FCR. The stunted juveniles grow fast and compensate the growth in grow-out culture environment.

In Nepal, some progressive fish farmers in Terai region, usually prepared their ponds during March-April of each year. As a pre-stocking management ponds are dried, limed, fertilized and water filled to about 1 m and left for a week to gain pond fertility. Based on availability of fish seeds, farmers start stocking fries/hatchlings of various carp species (60% IMC) in the same pond until end of July. Commonly, stocking density of fry is maintained 800000-1000000/ha. Fish are fed with mustard oil cake (90%) and rice bran on regular basis. During monsoon, most of the ponds filled up with water to about 1.5 m (new ponds) and old ponds (2 m). Fish harvesting starts from October where most of the bigger sized fish are harvested along with some smaller size based on market demand. The multiple stocking and multiple harvesting practices frequently done accordingly market demand of fish and it is continuous up to February. The remaining stock of each species mostly having 100 g size are restocked during March in production ponds with the densities of 10000- 15000/ha. They are fed with oil cake and water quality is maintained throughout production period. The stocking of stunted fingerlings over 100 g size has increased pond productivity 6 t /ha from 2-3 crop cycle.

Diversification of aquaculture product and market

Nepal has produced 86544 t food fish in 2016/17, of which major contributor of the produce was (75.8 %) aquaculture followed by captured fisheries (24.2

%). Based on the consumption pattern, over 90% of captured fish is consumed locally and rest is supplied to major cities of the country. Besides domestic production, in 2016/17 Nepal imported 10757 t fresh and 529.3 t boneless frozen fish, respectively (CFPCC, 2018). The share of imported fresh fish in national fish consumption accounts 11.5% only. Out of imported amount of fish, 61% is supplied to major cities and the rest to Kathmandu valley. A survey shows that 3% of domestic aquaculture production (58433 t) was exported to India during 2016/17 (Giri et al., 2018). The Fig. 1 shows of the quantity of fresh fish imported over a period of five years (2013-2017). . The graph further shows that there was sharp decline in fish import during 2015/16, which was 7882 t.

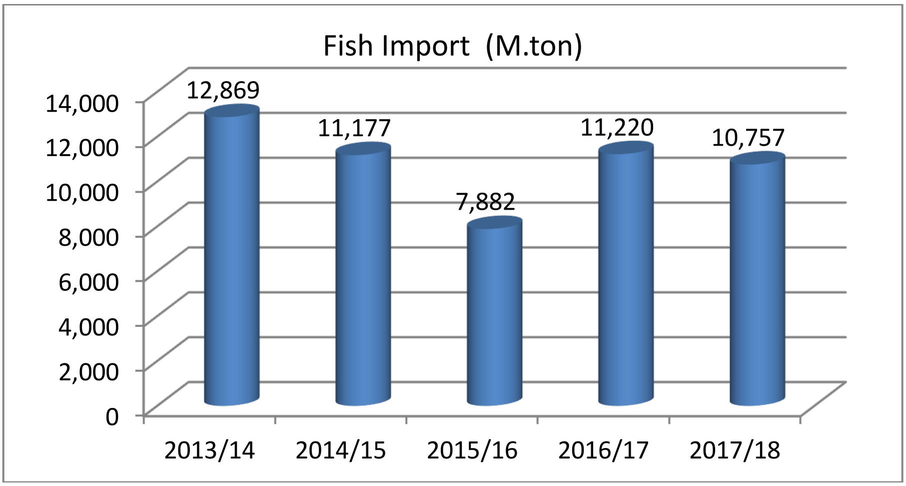

Figure 1. Importation of fresh fish during last five years

Source: CFPCC (2018)

Analysis of consumption pattern of domestic aquaculture produce shows that 70% aquaculture produce is consumed locally and 20% of is supplied to major cities at different parts of the country. Furthermore, 7% domestic aquaculture produce is supplied to Kathmandu valley of which major portion (30%) is contributed by Chhadi fish.

There is no well organized fish processing unit in the country. Mixing ice with fish before transportation as well as holding fish in chilling room/deep freezer are the practice followed since last couple of years. On the other hand, there are sufficient numbers of restaurants located in major cities as well as along the high ways where trout and Chhadi fish are marketed through value addition. For example, out of total annual production of trout fish (315 t), 90% are marketed on the production sites through value addition (CFPCC, 2018).

Policies, law and regulation

The policies, laws and regulation required for aquaculture diversification are not available in the country. Till now, aquaculture based program are conducted with the help of national agriculture policies and act. To address this, fisheries act is drafted recently but not approved yet.

Table 15. Polices, laws and regulation in aquaculture

Policies, laws/regulations	Issues	Responsible orgnization
Aquaculture	Registration of fish farm/hatcheries/ Nurseries	District local office (PAN), Company Registrar office (VAT)
	Fish farm design/estimates/construction	Directorate of Fisheries Development Engineer
	Regulation on electricity/water supply/conversion of agriculture land to fish farm	No authorized body till now
	Recommendation of culture species	National Agriculture Research Council
	Band on alien species	Department of livestock Service(DLS)
	Restriction of stocking density/composition/feed quality inspection/health monitoring	CEPCC , DLS
	Pure line brood quality maintained	CEPCC, NARC
Seed quality regulation	Seed verifications/monitoring/seed testing/standardized size/quality/ inspection of hatcheries/nurseries	Drafted fish seed Act/ not approval
Fresh fish quality control	Monitoring/ quality inspection	Department Food and Quality Control Animal Health and service Act
Live fish transportation regulation	Specification and procedures required for live fish transportation (fish species /size/density/transportation van/ water quality health monitoring)	Animal health and service Act, Meat inspection Act, Animal transportation Act
Feed and quality control	Leveling, quality monitoring / inspection	CEPCC, DLS
Regulation on use of drug and chemicals	Breeding hormone, pond treatment chemical, disease control antibiotics/feed additives/growth promoters etc.	CEPCC, DLS

Source: CFPCC (2018)

Government support program for aquaculture diversification

As Nepal is an agricultural based country and fisheries being economically viable, the most important income generating commodity program, since last couple of year government has a implemented policy to promote commercial fish farming throughout the country via Priminister Modernization of Agriculture Project (PMAMP). Based on these policies several fish culture district in the country are categorized for fisheries super zone, zone, block and pocket where respectively, 1000, 500, 100 and 10 ha water area are planned to cover under this provision. This program will help over 20,000 families of medium and small-scale fish growers, over 50 hatchery operators and 500 nursery keepers, and also thousands of laborers and traders/ marketer involved in fish feed / seed/ other input suppliers (PMAMP, 2015). Moreover, the PMAMP has several program to develop good infrastructure such as, roads, electricity, cold storage, strengthen/ establishment of fish ponds, fish hatchery, laboratory, training center which are consider critically important initial facilities to these areas in order commercialization of the sector.

In spite of PMAMP, there are several regular programs for technical support and services to boost up fish production both from central government (Department of Livestock Service) as well as provincial government (Directorate of Livestock and Fisheries Development under 7 provinces). Moreover, policies are focused on insurance of the commodity as well as provision of soft loans with minimal interest rate to fish growers.

Human resource and institutional set-up

Aquaculture is an important commodity program of Government of Nepal, Ministry of Agriculture and Livestock Development under the Department of Livestock Services. The Central Fisheries Promotion and Conservation Center (CFPCC) is the commodity specific national focal body currently it falls under the Department of Livestock Services. It is responsible for central level policy issues, planning, monitoring, supervision, as well as performs database and regulatory activities. It is an authorized unit to coordinate with national and international fisheries and aquaculture related institutions. Currently, there are three centers under the CFPCC;

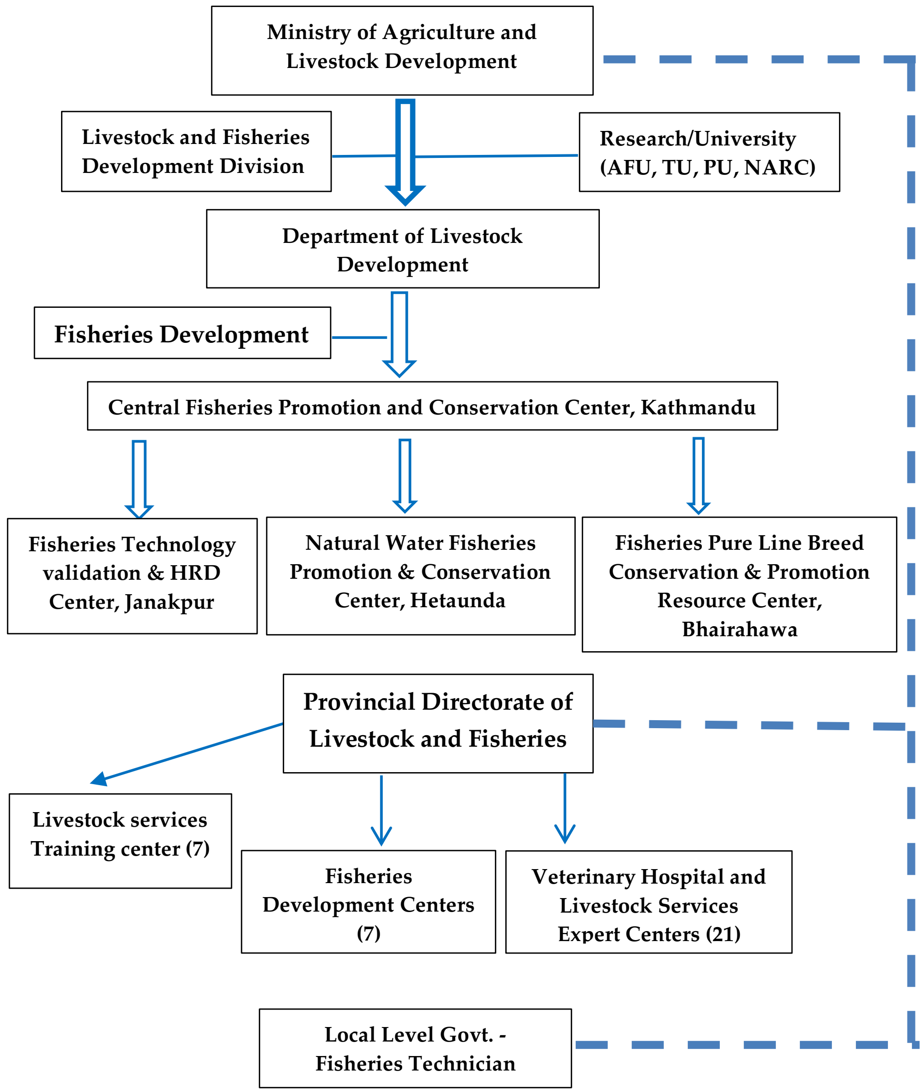

Figure 2. Institutional Frameworks for Fisheries and Aquaculture in Nepal

Source: (CFPCC,2018)

1. Fisheries Technology validation and Human Resources Development Center, Province 2, Dhanusha, Janakpur
2. Natural Water Fisheries Promotion and Conservation Center, Province 3, Makawanpur, Hetauda
3. Fisheries Pure Line Breed Conservation and Promotion Resource Center, Province 5, Rupandehi, Bhairahawa

Based on federal system, 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) (Fig. 2). 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 center, mandated for the technical support and capacity development of livestock services as well as fisheries technicians.

Table 16. Fisheries scientists and technicians available in the country

Nepal Agriculture Research Council		**Department of Agriculture**	
Principal Scientist	1	Chief Fisheries Development Officer	3
Senior Scientist (S4) 2, (S3) 3	5	Senior Fisheries Development Officer	21
Scientist (S2) 3, (S1) 2	5	Fisheries Development Officer	69
Senior Technical Officer (T8) 1, (T7) 3	4	Junior Technician (JT)	95
Technical Officer (T6)	20	Junior Technical Assistant (JTA)	25
Total	37	Total	213
College and university	7	All together: 37+13+213 = 263	
University professor	13	B.Sc. fisheries pass out student: 13	

Source: (CFPCC.2018)

Scientific research is carried out by Nepal Academy for Science and Technology (NAST). Agriculture and Forestry University (AFU), under AFU there are two departments namely, Department of Aquaculture and Department of Aquatic Resources. There are 15 B. Sc. Fisheries graduates completed every year. Tribhuvan University (TU), Kathmandu University (KU), Purbanchal University, Pokhara University and associated institutions also provide basic fisheries and aquaculture education to produce skilled and semi-skilled manpower for the promotion of this sub-sector 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 field of fisheries and aquaculture.

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

Conclusion

Nepal has diversified water bodies coverings 5.5% of the total land area where 232 indigenous along with 15 exotic fish species are available and growing. Out of total water resources, 1.0% is utilized in aquaculture production. Aquaculture has diversified of forms; carp polyculture in pond, Pangas monoculture in ponds, cage fish farming, trout farming in raceway, integrated aquaculture with agriculture and livestock. There are 7 carp species commonly cultured in ponds along with trout, tilapia and Pangasious. Nepal is self-reliant in carp fish seed, where private sector contributes over 80%. Since last couple of years, stocking stunted advance size fingerlings of diversified fish species in high density is in practice. Availability of sufficient number of technical manpower as well as aquaculture friendly programs has supported for vertical & horizontal expansion of the sector, as a result pond productivity is increased 6 times i.e. 4.64 t/ha in 2017/18 as compared to 0.8 t/ha in 1980 with 9.6% annual growth rate. Currently national fish production is 86544 t. of which aquaculture contributes 65544 t. Fisheries sector contributes 1.33% in GDP and 4.18% in AGDP whereas per capita average fish availability in the country is 3.39 kg including imports (10657 t). The existing production and productivity is not enough to make country self-reliant and prosperous Nepal. So, higher level production and productivity is utmost essential through sustainable approach. To achieve maximum sustainable benefit from aquaculture sector, more diversification and specialization is necessary in context with human resource, production sites/system, fish species, and production cycle as well as aquaculture products. For that congenial policies, laws and act are necessary along with supportive program.

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Chapter 4

Fish Culture in Cages and Pens in India for Aquaculture Diversification

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Introduction

The most vibrant sector under the umbrella of 'Agriculture' in India is the aquaculture and fisheries sector, with a contribution of 5.23% to the country's Agriculture GDP and 1.01% of NGDP. With annual 7.14% growth in last four years, this sector contributing all time high production of 12.61 million ton (mt) of fish in 2017-18, with major share from inland resources (68%) (GOI, 2019). Imbibing with the spectacular rise in this sector that are providing nutritional security (9.5 kg fish consumption per capita per year) to around 60% of 1.3 billion Indian populace with direct involvement of 15 million fishers and fish farming communities (DADF, 2018). Government of India has opened a new Department of Fisheries in February 2019 under the Ministry of Agriculture & Farmers' Welfare with a budget layout of more than Rs. 10,000 crores – Rs. 3,000 crores for 'Blue Revolution Schemes' and Rs. 7,532 crores as Fisheries Infrastructure Development Fund (IFDF). It aims at human resource development of rural unemployed youths and creating 27,000 fishery professionals to achieve 2nd Blue Revolution for doubling farmers income by 2022 (Aquaculture Spectrum, 2019). The program aims to implement in 6,41,000 villages across 725 districts of India to eradication of malnutrition. A recent review has highlighted importance and potentials of aquaculture sector in India (Jayasankar, 2018).

Drivers of aquaculture diversification in India

The aquaculture and fisheries sector is striding fast with inclusion of more species and enhancing fisheries from inland open waters. These have been possible through aquaculture diversifications, viz., Re-circulatory Aquaculture System (RAS), Integrated Pond Re-circulatory System (IPRS), Flow-through system, Integrated Multi-Trophic Aquaculture (IMTA), introduction of catfishes in aquaculture, wastewater aquaculture, biofloc system, aquaponics, organic aquaculture, application of genetically modified species in aquaculture, adoption of Better Management Practices (BMP) and fish culture in enclosures (in cages and Pens) during the last two decades. Culture of small-indigenous fish species (SIFS) is gaining momentum as valued species for providing nutrient supplements. About 100 indigenous freshwater ornamental species are brought in to aquaculture for up-lifting the socio-economic status of rural and peri-urban population. The substantial growth of the Indian aquaculture is because of availability of quality broodstock and seeds, improved fish nutrition, management and diseases control, intensive aquaculture practices, diversification in cultured species and systems, development of integrated farming systems, elimination of middlemen, and facilitation of improved quality products for the national and international markets. One of the most important drivers of aquaculture development in India is market and demand for aquatic food within the country and abroad.

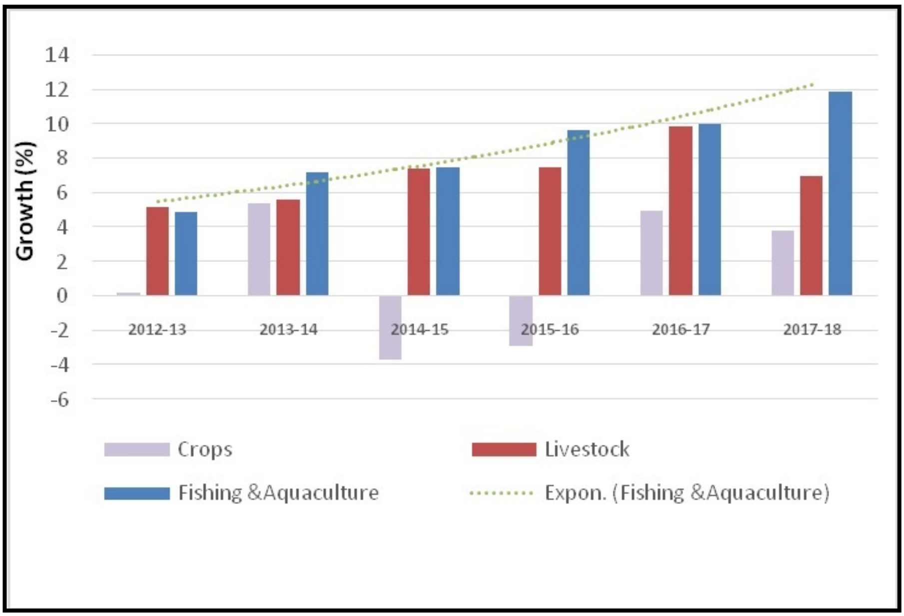

Figure 1. Sector-wise growth rate of agricultural commodities in India

The estimates on last five years growth performance of inland fisheries clearly showed that a growth rate between 6.15 and 10.8 (Figure 2) has been attained. Inland fish production in the country contributed to 7.77 mt (68.1%) during 2016-17 with aquaculture sector contributing to nearly 90% of total inland fish production (Figure 3).

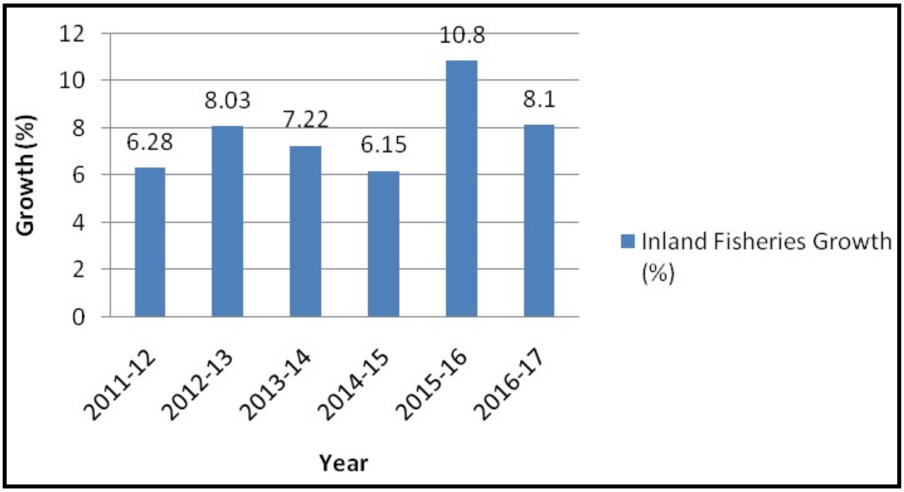

Figure 2. Average annual growth rate of Inland fisheries

Some of the factors which offer hindrance to aquaculture growth in the country are, non-availability of quality seeds, quality feeds and its' escalating price, health management issues and lack of timely market support mechanism. These factors could be tackled through diversification of many inherent processes at different levels.

Diversification of aquaculture species

The current increased aquaculture production in India due to various factors viz., technology interventions, species diversification, bringing derelict water bodies under aquaculture, aquaculture in enclosures, government policy interventions and institutional settings. In India, the six species used under composite fish culture, contribute around 90% of total freshwater aquaculture production. These species are Catla: *Catla catla*, Rohu: *Labeo rohita* and Mrigal: *Cirrhinus mrigala,* and three Chinese carps – Grass carp: *Ctenopharyngodon idella*, Silver carp: *Hypophthalmichthys molitrix* and Common carp: *Cyprinus carpio.* Improved variety of rohu "Jayanti Rohu' which has18% growth increment per generation is one step forward for improving farm productivity (Das Mahapatra et al, 2016). Other economically viable species play great role in Indian aquaculture are *Labeo calbasu, L. bata, L. gonius, L. fimbriatus, Puntius sarana, P. pulchellus, P. kolus, Cirrhinus cirrohosa,* Murrels-Channa spp., Catfishes-*Sperata seenghala, M. gulio, M. vittatus, M. tengara, Wallago attu, Ompok bimaculatus, O. pabda, Pangasius panngasius,* Air-breathing fishes – *Anabus testudineus, Anabus cobogius* (exotics), *Clarius magur, Heteropneustes fossilis,* Featherback – *Notopterus notopterus, Chitala chitala,* Spiny eel – *Mastacembelus armatus,* *Monopterus cuchia*, Coldwater- trout spp., *Tor putitora*, and other Tor spp., Freshwater SIFS like *Amblypharyngodon mola, Ailia coilia, Gadusia chapra, Osteobrama belangiri*, *Macrognathus pancalus*, *M. aral*, *Salmostoma bacaila, Paluciosoma daniconius, Eutropiichthys vacha, Tricogastor faciata, T. lalia, Chagunius* chagunio, *Pethia ticto, Puntius sophore, P. tittetiya, P. binotatus, P. conchonius*, *P. chola*, most of which are high valued fish species specially eastern and North-eastern parts of India and ornamental fishes.

The exotics – Tilapia (monosex & Red tilapia), *Barbonimus gonionotus, Pangasianodon hypophthalmus,* Paku *(Pioractus brachipomus),* Asian seabass - *Lates calcarifer*, Grey mullet – *Mugil cephalus*, Pearlspot – *Etroplus suratensis* and Brackish water ornamental fishes are the candidate species introduced in Indian aquaculture but some of them are not yet cleared by the Central Exotic Committee.

The shellfishes, *Macrobrachium. rosenbergii, M. malcolmsonii,* Tiger shrimp- *Penaeus monodon,* Indian white shrimp- *P. indicus,* Banana shrimp- *P. merguinsis*, Pacific white shrimp - *P. vannamei,* Kuruma shrimp – *P. japonicas*, Mud crab *Scylla serrate* are in Indian aquaculture.

Figure 3. Pangas in a fish pond of Andhra Pradesh

Figure 4. Black carp for eradicating molluscs in floodplain wetlands

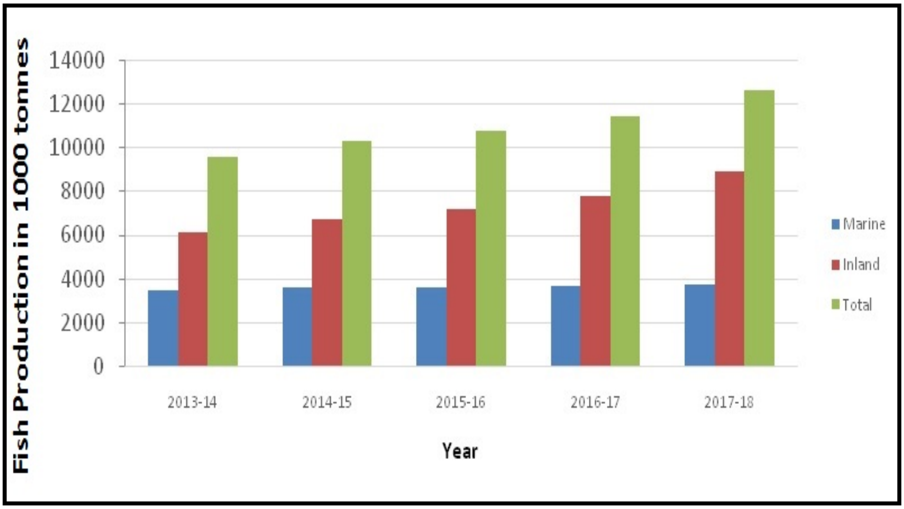

Figure 5. Sector-wise annual fish production in India

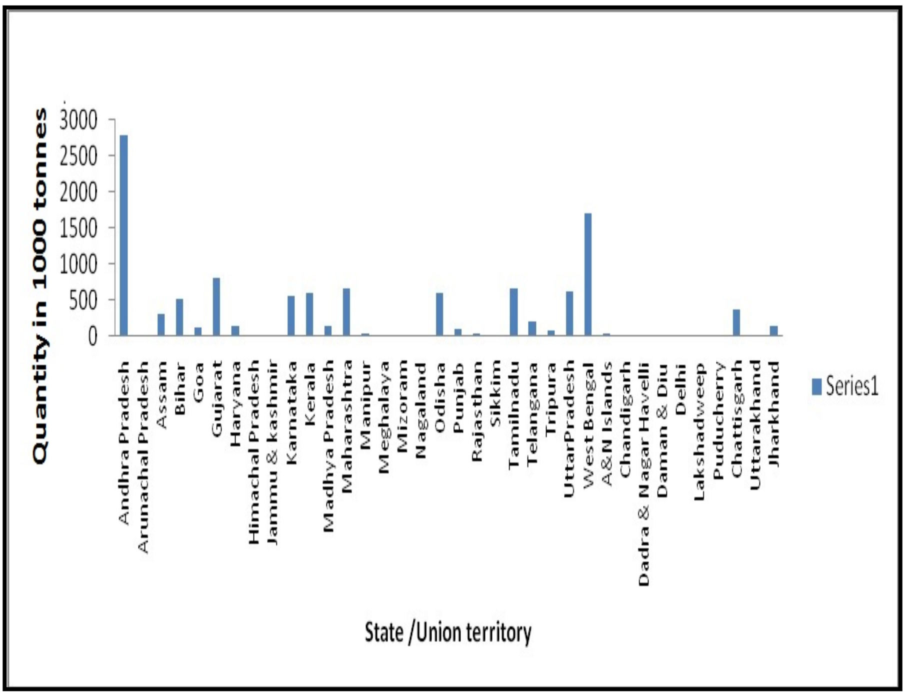

Figure 6. State-wise fish production in India (2016-17)

Diversification of aquaculture sites

India is bestowed with diverse inland fisheries resources viz., 2.36 millon ha (m ha) ponds and tanks, 3.51 m ha reservoirs, 0.584 floodplain wetlands, 0.72 m ha upland lakes, 0.19 m km rivers and canals, 1.24 m ha brackish water with immense potentials (DADF, 2018). During the last decade, aquaculture has been expanded from mere land based nurseries to water based enclosure culture systems for intensive exploitation of existing, especially large, fresh or brackish water and marine resources. New nurseries are created with financial support from Central Blue Revolution Scheme. Also, for the production of stocking materials a number of nurseries has been developed/rejuvenated by the 'Matsya Mitra'. The DoFs in Jharkhand, Chhattishgarh, Madhya Pradesh, Kerala, Karnataka and other States are also buying the seeds from the nurseries and stocking in the reservoirs. The production of stocking materials in cages has been proved economically worthy (Das et al, 2009). ICAR-CIFRI has disseminated the knowledge of this technology across India through capacity building workshops and hands on trainings. A good number of NGOs including Tata Trust, Enterpreneurs like Indipesca, Simran Fisheries, Women Self-Help Group (WSHG), SHGs, College of Fisheries (CoF) are involved at grass root level besides numbers of line Departments of 16 States of India for promoting this eco-friendly and cost-effective technology (Philips and Silva, 2006; Das and Das, 2018).

The pen culture technology got thrust under the NATP project during 2000-2005 in the floodplain wetlands of North-East states (Gorai et al, 2006). At present pen culture in floodplain wetlands for production of fingerlings and table fish are being practiced in Karnataka, Madhya Pradesh (Tuli, R.P., 2004) West Bengal, Bihar, Uttar Pradesh, and recently farmers of Odisha and Telangana showing interests. In Tungabhadra reservoir, raising fish seeds (fingerlings) through pen culture is an age old practice (Swaminathan and Singit, 1982, Gireesha et al, 2003). In Tamil Nadu, successfully pen culture was done in Odathurai reservoir (Murugeshan et al, 2005). Economics of pen culture in four wetlands of Assam viz., Haribhanga, Raumari, Damal and, Puthimari revealed B:C ratio at 2.15, 1.93, 2.23 and 1.89, respectively (Chandra et al, 2013). In Bihar, 5 wetlands in Motihari district are chosen for pen and cage culture with a financial layout of Rs. 2.84 crores during 2018-20. In Odisha, 100 pens of 0.1ha dimension and their installations have been in progress to produce fingerlings in reservoirs.

Diversification of stocking density

Progressive farmers are the drivers of deciding stocking in pond eco-system with right size fingerlings for boosting aquaculture. The stocking density prescription is gaining more footage due to adoption of the same by the small- farmers. The demand of fish seeds for supporting the aquaculture is increasing (Fig. 5). Aquaculture production is mainly predominated by 3 IMCs and 3 Chinese carps, sharing >90%. All the fish production system in aquaculture through three distinct culture systems, i) Extensive, ii) Semi-intensive, and iii) Intensive culture practices. The basic difference among these are the stocking densities, targeted production, pond productivity and carrying capacity. Other associated factors are, species to be cultured, feed conversion efficiencies, size at stocking, growing period and inputs.

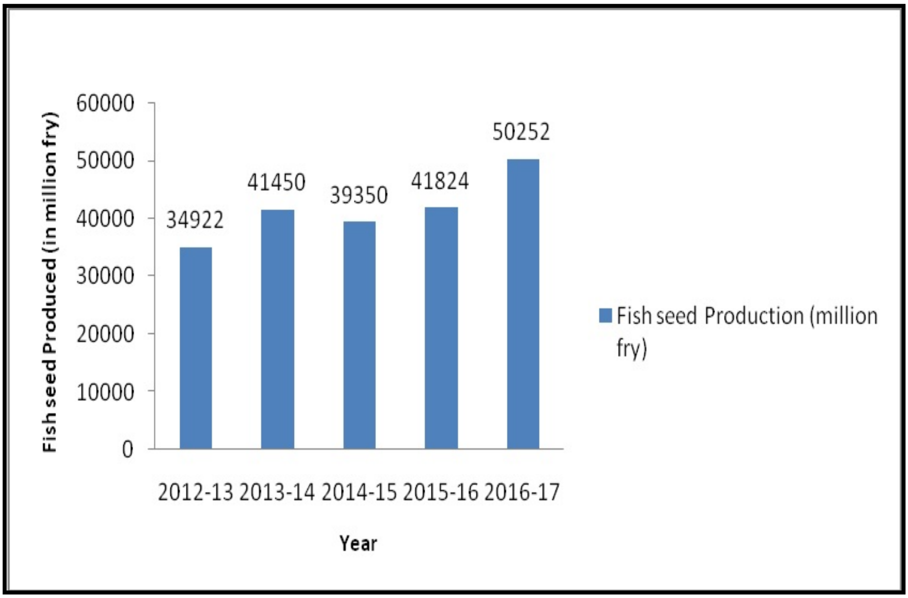

Figure 7. Fish seed production in India

In nursery rearing of spawn (7- 8mm) to fries (15-20 mm), which requires 15 days, stocking density is maintained at 3-4 million spawn /ha-m, under extensive culture practices. A stocking density of 4-6 or even 6-8 millions spawn are followed in semi - and intensive culture methods. For grow-out culture fingerlings of 100-125 mm sizes are stocked at 5,000-10,000, 12,000-15,000 and 15,000-25,000 fish/ha-m in extensive, semi-intensive and intensive culture practices, respectively, targeting a harvest of 3-4 t, 4-6 t and 10-15 t, respectively. Generally in poly-culture system, a density of 5,000-10,000 fingerlings/ha-m is maintained as standard stocking density for a moderate production target of 3-5 t/ha-m. Fingerlings of >100 mm size are the best suited for grow-out culture. Normally, under intensive culture, 50-100g sized over wintered advanced fingerlings (yearlings) are stocked for a higher production target.

For nursery rearing of larvae the stocking ratio maintained as catla : rohu : mrigal = 3:4:3 or six species combinations catla : rohu : mrigal : grass carp :

silver carp : common carp = 1:1:1:1:1:1. In grow-out production ponds the stocking ratios of fishes depend upon the candidate species to grow. In polyculture more than one species is cultured to utilise available food niches and to reduce competition among the species for foods at different trophic levels. A combination of 30-40% surface feeder (catla, silver carp), 30-35% column feeder (rohu, grass carp) and 30-40% bottom feeder (mrigal, common carp) is the most commonly adopted carp polyculture practice in India. The ponds with more macrophyte coverage a 5-10% more grass carp are added, while with more pond bottom organic load more bottom feeder are stocked. Similarly, more rohu are stocked if the water depth in the pond is very high. In sprawled and deeper ponds with good bloom of zooplankton more catla are stocked for better growth. Now-a-days stunted growth concept for the fingerlings is in practice. In this practice, huge number of fingerlings are stocked in a small pond with less feeds and reared them over wintered, before release in larger water bodies in March-April, resulting in higher compensatory growth in a short culture period.

Diversification of production systems

The confined aquaculture systems in the form of cages, pens or enclosures are used for growing fingerling and table fishes. At present, 18,000 cages are operating in reservoirs, wetlands and open coaliary pits (OCPs) for freshwater aquaculture, and producing 0.1mt of fish. In marine sector, 300 cages are engaged for the production of sea bass, cobia, pompano and groupers. Rearing of finfishes and shellfishes in cages and pens is the advanced aquaculture technique, gaining importance during the last two decades in India. Pen is a confined bay, where shoreline is typically closed-off by a net or a screen barrier on all but one side. The sides of the pens are covered by bamboo-matting, netting or screening. The bottom of pen is bound by lake bed. All sides of a cage are covered, leaving a small space at the top for operations and monitoring. Cages are of four types: fixed, floating, submersible and submerged. The most functional one is 'floating cage'. Race-ways are used for the aquaculture of coldwater fishes, especially rain-bow trout at the foot hills of Himalayan states of India. Now a days numbers of progressive farmers in India are opting for Re-circulatory Aquaculture System (RAS). Fish production in polythene tank with circulating the waste water for horticultural crops, also being adopted in rural India. Cemented/FRP tanks are being used for air-breathing fish culture – a new initiative in aquaculture sector. Pen culture in NE states, Bihar, West Bengal and some southern states of India is being opted for production of fingerlings.

Figure 8. Climate-resilient pen without bamboo mat

Figure 9. Cage feeding with floating feeds

Future scope of cage culture and Govt initiatives

The cage culture in India has already passed its nascent stage, starting its journey in seventies. It gets momentum immediately after 2008 with the development of full proof technology for *in situ* production of stocking materials through bamboo-made low cost cage under an FAO project (Challenge Program on Water & Food, CPPF-34) executed by ICAR-CIFRI (Das et al, 2009). With the establishment of National Fisheries Development Board (NFDB) in 2006, the cage culture technology got financial support for table fish production. ICAR-CIFRI took lead role in developing cage culture technology for table fish production of Pangas and other fish and shell-fish species at Maithon reservoir, Jharkhand, and backstopping to the State Deptt of Fisheries (DoF) in Jharkhand, Chhattishgarh, Madhya Pradesh, Andhra Pradseh, Telangana, Maharashtra, North-Eastern states, Odisha, and Southern States of India. Govt. of India (DADF, 2012) has launched the "National Mission for Protein Supplement (NMPS)", a project of Rs. 100 crores in the reservoirs in 17 Indian states. With the development of such promising technology there has been an upsurge of other related industries viz., feed industries (extruded, >30 nos), net making industries (Garware wall rope etc.), cage collar/framing industries (Neelkamal, Indipesca, Das & Kumars etc.) including other service providers. Fish seed requirement for cage culture also open up new vistas creating more job opportunities in rural sector.

Diversification of production cycle

In India, about 90% carps spawns are produced around March-April to November-Dececember. The stocking and harvesting schedules under different cultural regimen also vary: a) Single stocking – Single harvesting, requiring 10-12 months, b) Single stocking – Multiple harvesting, where 3-4 crops of lower size being harvested and sold live due to local food preferences and c) Multi stocking – Multi harvesting, where on regular intervals fingerlings growing in rearing ponds are being stocked in stocking ponds maintaining harvesting schedules on regular basis with a modest harvest of 4-5 crops annually.

In most part of India, since time immemorial, one time harvesting is practiced in aquaculture. In multi-stocking and multi-harvesting practice in eastern India, the IMCs are harvested at 200-300 g rohu, 150-200 mrigal and 450-550 g catla, and are sold live. The single stocking and single harvesting system is practiced all over India. In this system the harvesting size of fish is around 1.0 kg. In multi-stocking and multi-harvesting practice, farmers are maintaining rearing ponds for production of fingerlings of around 50 mm and above raising from fry of 20 to 25 mm size year round. In sewage-fed 'Bheri' (> 4000 ha), known as East Kolkata Wetland (EKW), a 'Ramsar Site', fish are stocked at monthly intervals and selective harvesting is done daily. In this wet land the total stocking of fish is around 1.0 lakh fingerlings/ha-m annually at size group of 50-60 mm with a total harvest of 10-12 t /ha/year. In '*Moyna Model'* prevailing in East Midnapore district of West Bengal, where low lying paddy field >10,000 ha were being converted to flooded land of lower depth following intensive aquaculture practices of single stocking and single harvesting (1.5-2.5 kg size). Of late, some of the closed *beels* (Floodplain wetlands) under Ganga and Brahmaputra basins in West Bengal, Bihar and Assam are producing 3-4 t carps/ha-m/year following single stocking - multiple harvesting or multi stocking – multi harvesting schedule applying external feeds into the system, which is a new initiative in India. In Jharkhand, the single stocking and multi harvesting method is being practiced in derelict water bodies like homestead 'Wel' and very small homestead ponds or 'Duba' for extensive culture of carps/monosex tilapia year round, satisfying the local needs for protein supplement at individual family level.

The culture of air-breathing fishes *viz., Anabus cobogius, Heteropneuestes fossilis, Clarius batrachus* is done in cemented/HDPE tanks. The hapa culture of Small Indigenous Fish Species (SIFS) like *Mystus tengra, Amblypharyngodon mola* is being practiced in eastern India. This sort of practice is of low cost due to utilization of natural foods available in the system and cost-effective with application of minimal dose of artificial feed formulations, inviting more price during selling and increasing per unit water productivity from the same system without disturbing the stocked fish. Ultimately, this diversification will lead to attain more efficient and wise-use of existing water bodies of India deriving more benefits to rural sector with additional income generations.

Diversification of aquaculture products and market

The acceptability and expansion of consumer base within and abroad markets may be an area which needs more focused interventions. Particularly, the value addition of farm products may greatly help in doubling the fish farmers' income, a program envisioned by the Govt. of India. At present, India is exporting 50 different fish and shellfish products to 75 countries in the world. Fish and fish products emerged as the largest export commodities in India, with 1.377 mt in terms of quantity. This accounts for around 10% of the total exports and nearly 20% of the agricultural exports, and contribute to about 0.91% of the national GDP. The products may range from live and frozen fishes and shellfishes to 'ready to serve' convenience products.

The marketing of the value added products is entirely different than sea food products. It is dynamic, sensitive, complex and very expensive. A lot of importance must be given to market survey, advertisement and packaging in order to formulate a successful value added product. Processing methods used in this area includes chilling, modified atmospheric packaging, active packing, freezing, drying, thermal processing, dry and wet smoking. The main fishes which can be used for or already in the market are Trout, Milk fish, Rohu, Catla, Mrigal, Nile Tilapia, Common carp, Scampi, Pangas. The Indian fish market was worth INR 1,110 Billion in 2018; the market is further projected to reach INR 1,998 Billion by 2024. The marketing efficiencies for Indian major carps (IMC), sardine and seer fish have been found to vary from 34% to 74%, depending on the length of market channel. The marketing efficiency has been found more in the case of marine species (80%) than freshwater species. Some of the products popular in the market require appropriate storage temperature with longer shelf-life period. In India, the production of pangas (*Pangasianodon hypophthalmus*) in 2018-19 was 0.8555 mt, from >43,000 ha area (Rao et al, 2019), from which the share of cage cultured pangas was around 40,000 t. The local market selling is only 25%, are rest are made fillets for consumption in Hotels/Restaurants. In brackish water aquaculture, with predominant species *Penaeus vannamei*, India produces 0.69 m t shrimp, of which 0.622327 mt from *P. vannamei* earns a total of Rs. 45,106 crores through exports during 2017-18 (MPEDA, 2019).

The ornamental fish culture sector in India also has a great potential both in domestic as well as international markets. India's share is only 1% of international ornamental fish trade with some 30-35 species of freshwater fish are in the market, out of 374 available species in the country. North eastern states dominate in ornamental fish production from natural waters, where West Bengal, Tamil Nadu and Maharashtra are culturing these species at a larger dimension as a home industry. About 90% of ornamental fish is traded from Kolkata port, followed by 8% from Mumbai and 2% from Chennai. The UK is the largest importer of ornamental fish followed by USA. In India, though fish aquarium hobby is only about 70 years old and in-spite of having immense potential, India's contribution to the international ornamental fish trade is negligible.

In India, the traditional form of value addition/preservation using smoked fish especially in North-eastern states and other states like Madhya Pradesh, Maharashtra, Chattisgarh, Odisha, where it's a delicacy among native tribal populations. Though marine dry fish is more preferred, the freshwater species carps, catfishes and barbs are also used for dry fish production in peninsular states. The Indian Standard are developed (2019) by the Bureau of Indian Standards (BIS) for Good Aquaculture Practices –India GAqP for Carps, Striped Cat Fish - Pangas, Cage Culture in Fresh Water, Fresh water Prawn Culture, Shrimp Culture besides Cage Culture of Sea Bass and other marine Fish species. Accordingly, the BIS has set up control and compliance system for various kinds of aquaculture produce in India paying attention to the quality of production practices, attention at different aspects of production, storage, handling, distribution so as to make the products acceptable to the world markets.

Policies, laws and regulations

Integrated development and management of fisheries

The Ministry of Agriculture and Farmers' Welfare, DADF has restructured the scheme by merging all the ongoing schemes under an umbrella of 'Blue Revolution'. The restructured scheme provides focused development and management of fisheries, covering inland fisheries, aquaculture, marine fisheries including deep sea fishing, mariculture and all activities undertaken by the NFDB, Hyderabad.

The restructured Centrally Sponsored Scheme on Blue Revolution: Integrated Development and Management of Fisheries formulated at a total Central outlay of Rs. 3,000 crores for five years have the following components:

- National Fisheries Development Board (NFDB) and its activities
- Development of Inland Fisheries and Aquaculture
- Development of Marine Fisheries, Infrastructure and Post-Harvest Operations,
- Strengthening of Database & Geographical Information System of the Fisheries Sector
- Institutional Arrangement for Fisheries Sector and (f)Monitoring, Control and Surveillance (MCS) and other need-based Interventions
- National Scheme of Welfare of Fishers

Guidelines and policies

- Draft National Inland Fisheries & Aquaculture Policy (NIFAP)-
- Guidelines for regulating establishment and operation of Specific Pathogen Free (SPF) Shrimp Broodstock Multiplication Centres (BMC) and Proforma for submitting Proposal for Establishment of Shrimp BMC.
- Guidelines on Fish Seed Data
- Details of Subsidy Pattern
- RKVY-Additional Proposal 2017-18 (12.6.17)
- List of Beneficiaries_BR (6.6.17)
- RKVY Proposal 2017-18 (24.4.17)
- RKVY Proposal 2017-18 (20.3.17)
- Revalidation of unspent balance under BR Scheme (15.05.2017)
- Tentative allocation under BR Scheme for FY 2017-18 (9.5.17)
- National Inland Fisheries & Aquaculture Policy
- Guidelines for import of Asian Seabass/Barramundi (*Lates calcarifer*) seeds and fingerlings
- Guidelines for the States for framing a bill on Inland Fisheries & Aquaculture
- Guidelines for Developing Fish Seed Certification & Accreditation System in India
- Notification regarding Guidelines for regulating hatcheries and farms for introduction of *Penaeus vannamei* under the coastal Guidelines Culture of SPF
- Guidelines *P. vannamei* in FW, 29-9-2011

- Amendment to the Guidelines for regulating hatcheries and farms for introduction of *Penaeus vannamei*
- Notification Amending the Costal Aquaculture Authority (CAA) Rules, 2005
- Notification regarding guidelines for farms for *P. monodon* culture to take *P. vannamei*
- Proforma for submitting proposals for introduction of live Aquatic Organism
- Uploading of the Notification regarding Guidelines for seed Production and Culture of specific Pathogen Free (SPF) *P. monodon*
- Guideline of NMPS 2012-13-Fisheries
- Tilapia policy guidelines

Laws for Indian fisheries sector

Indian fisheries legislations

The need for fisheries legislation was emphasized long back in 1873 when the attention of the then Government of India was drawn towards widespread slaughter of fish, fry and fingerlings and the urgency to adopt legislative measures to conserve the fisheries resources. At the time, the Govt. of India enacted the Indian Fisheries Act, which came into being in 1897.

The Act highlighted the followings

- Use of destructive methods of fishing such as dynamiting or other substances in inland and coastal waters (up to one marine league) was prohibited. Similarly, poisoning of water with noxious materials was also prohibited.

- Provincial Governments were empowered to frame rules in selected waters for protection of fish with previous notification, restricting the creation and use of fixed engines (dams, weirs, bar pattas etc.) for catching fish; to put a limit on mesh size, size of fish and catch, and to ban the fishing in certain seasons and certain places for a period of 2 years (declaration of closed season and sanctuaries).

Human resources and institutional setup

HRD comprises a series of activities such as, i) training to improve performance on the job ii) education to develop competence and iii) development to prepare the worker/employee to keep pace along with the organization or tools, techniques as it develop. Training at primary level as well as developing trainers trainee by 'Manage', and NFDB, Hyderabad under operational both at inland as well as marine sector. National Council of Education, Research and Training (NCERT), a Govt. of India organization, have identified 150 vocational courses in all branches of agriculture, engineering and commerce of which one is operational in Inland Fisheries and another in Post-Harvest Technology in over half-a dozen states (Tripathy S. D., 2017). Krishi Vigyan Kendras (KVKs) are very vibrant with fishery Subject- Matter Scientists in most of the 706 numbers KVKs across India. Four hundred Fish Farmers' Development Agencies (FFDA) and 31 for Brackish water (BFDA) in coastal districts are established with financial support from Govt. of India, which trained more than 1.0 million farmers. Besides, ICAR's Transfer of Technology Programme under the 'Lab to Land' programme through its Institutes, SAUs, CoFs engaged in awakening the farmers with application of modern tools and techniques across India. Besides, ICAR-CIFRI/IDRC Project on Rural Aquaculture with financial assistance from Govt. of Canada was operated in West Bengal and Odisha engaged in developing entire gamut of seed production and Composite Fish Culture. Training at secondary level through Certificate Course initiated at ICAR-CIFRI, Barrackpore in 1947 and similar type for marine fisheries at Mandapam – 10 to 12 months certificate course, now in operational by ICAR-CIFE. ICAR Fisheries Research Institutes are functional in disseminating knowledge support to the farmers, entrepreneurs and other stake holders including DoF officials through their Extension & Training Cell on regular basis.

Way forward for aquaculture

- There is an urgent need for species diversification in aquaculture and enclosure culture, as at present only Pangas has 90% share of commercial cage production in India. The industries involved with cage aquaculture also should extend all possible support for mutual benefit in species diversification which is the need of the hour.
- Pen culture in *beels* in commercial scale is a for raising fingerlings and grow-out table fish production.
- Cage culture in deeper water bodies with more exchange of water circulation for cleaning the fish wastes inside the cages would be recommended.
- Guidelines have been framed by NFDB with consultation with ICAR-CIFRI that in all medium and large reservoirs up to 0.1% of their area could be f covered under cage culture. Also cage culture be practiced in

small reservoirs up to 500 ha very selectively with restrictions, as all reservoirs are multi-stake holders water body.

- Value addition and proper marketing of Pangas through filleting, targeting chain of hotels would be ensured, where DoF of different States should take the lead role for negotiating with hoteliers/restaurants so as to deriving more benefits to ultimate producer.
- Locally available low cost feed should be ensured to make the cage culture viable.
- Designing of low cost cage, larger round cage for IMC grow-out, utilization of netlon cage spaces in between outer predatory net and netlon cage wall by introducing periphytic feeder species, introducing 1-2% of fish.
- Local artisans may be made to involve in designing simplest form of low cost cages for reservoir and wetlands
- Researcher, policy makers, planners, DoF of states to derive suitable site specific policy for governance and setting up of Institutional arrangements to make the system viable and sustainable targeting towards 2nd Blue Revolution
- New culture systems *viz.*, RAS, Biofloc or Aquaponics should be suitably improvised so as to produce more economical species

Conclusion

The aquaculture and fisheries has immense potential to meeting the challenges of agriculture and rural development encompassing food, nutrition and livelihood security. Mainstreaming aquaculture and fisheries in the overall framework of agriculture and rural development will have multiplier effect including reduction in input cost, environmental well-being, availability of diversified food basket, diversification of risk and preventing farmers for committing suicide. The Indian aquaculture sector has been transformed from traditional fish production unit to enterpreneural sector during the last two decades with encompassing modern technological tools and production systems and introduction of high value species. Enclosure cultures have added up extra mileage as to wise-use of open waters for increasing productivity. The single brackish water Pacific white shrimp *Penaeus vannamei* has triggered the Indian economy to all time high of Rs. 45,106 crores as export value during 2017-18. More than 30 numbers of feed industries with extruded pelleted feeds have come into operation involving huge job opportunities, imbibing the farmers to use floating feeds in conjunction with sinking one to avoid feed loss.

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Chapter 5

Fish Culture in Cages and Pens for Aquaculture Diversification in Sri Lanka

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Introduction

Sri Lanka is a continental Island of around 65,000 km^2 in monsoonal Asia with rich water resources. Sri Lanka's fisheries and aquatic resource base includes an Exclusive Economic Zone (EEZ) of 517,000 km^2. Length of coast shore-line is 1585 km. Sri Lanka has extensive freshwater and brackishwater resources like lagoons/estuaries, mangrove zones, mud flats, salt marshes and irrigation reservoirs and flood plains to sustain viable fisheries and aquaculture activities (MFAR statistics, 2016). There are 116 lagoons spread all over Sri Lanka, with a lagoon shoreline of 2791 km and the lagoon shoreline skirts 1580 km^2 of brackishwater mass (Silva et al, 2013). There are 103 perennial rivers in Sri Lanka, most of which run radially from the central highland area and drain into the western, southern and eastern coasts. These river basins drain over 90% of land area (NSF, 2000). There are no natural lakes in Sri Lanka, but the country has a multitude of reservoirs, over 13,000 in numbers covering and water area of around 300,000 ha. On average, size of these reservoirs ranges from few ha to 8000 ha. Depending on their hydrological regimes these reservoirs are broadly categorized into seasonal and perennial.

Three main subsectors of the fisheries sector are coastal fisheries, off-shore/high seas fisheries and inland fisheries/aquaculture. Coastal fisheries include both fisheries in shallow seas or in the continental shelf area and in brackishwaters. In 2017, fish production from coastal fisheries were 259,720 t with a contribution of around 49.0% to the national fish production. Offshore/high seas fisheries take place in an area outside the continental shelf and up to EEZ limit and fish production from this sub-sector in 2017 was 189,720t contributing around 36.0% to the national fish production. At present inland fisheries/ aquaculture production comes mainly from culture-based fisheries in reservoirs and shrimp farming. In 2017, production from this sub sector was 81,870 t contributing around 15.0% to the national fish production.

Sri Lanka's fishery sector contributes around 1.8 % to GDP with marine fisheries and inland fisheries/aquaculture contributing 1.6 and 0.2 % respectively. Sri Lanka exported around 25,000 t of fish and fishery products valued at SLRs. Million 39230 in 2017. Main contributors for export income are finfish (63.0%), crabs (8.5%), shrimps (8.2%), molluscs (6.7%) and ornamental fish (5.7%). Sri Lanka import considerable amount of fish and fishery products (including dried fish, canned fish and Maldive fish) annually and value of these imports in 2017 was SLRs. Million 33,969. Sri Lankans are considered as fish eaters and around 55% of animal protein consumed by them from fish. Export of fish and fish products contributes 2-3% to nationalexport earnings. Per capita fish consumption in Sri Lanka is around 15.3 kg per annum, consisting of 10.8 kg of fish, 3.8 kg of dried fish and 0.7 kg of canned fish. Recent trends in fish production in two main contributory sub sectors the national fish production, namely coastal fisheries and offshore fisheries is shown in Figure 01. It is apparent that despite the facilitation and support provided by the government (eg. Provision of new fishery harbors, provision of loans/ subsidies to purchase large fishing vessels), fish production from marine waters has not shown a significant improvement during last five years. Further it is alarming to note that results of the stock assessment study conducted in collaboration with Norwegian scientists indicates depletion of some fish stocks in marine waters in Sri Lanka.

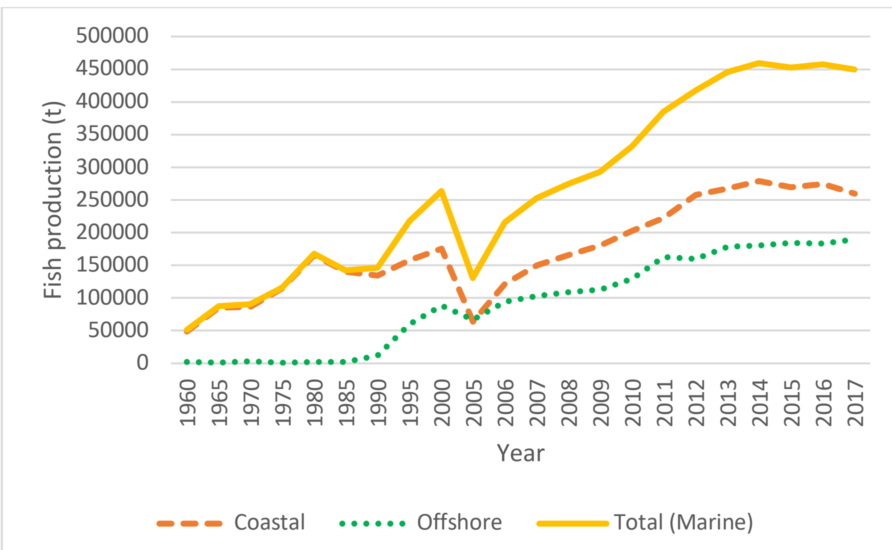

Figure 1. Fish production coastal fisheries and offshore/ high seas fisheries

This situation points to importance in paying more emphasis for development of aquaculture by optimum utilization of vast resources available. Aquaculture is Age old practice in many countries of the world in particularly in the Asian region. A milestone in the development of aquaculture was reached in 2014, when aquaculture sector's contribution to the supply of fish for human consumption in the world overlook that of wild caught fish for the first time (SOFIA, 2016). This significant increase in aquaculture production has been brought through introduction of new technologies, diversification of aquaculture species, habitats and aquaculture systems, genetical improvements, improvements in feed technology and intensification of culture practices. Although Asian region contribute more than 80% of the world aquaculture production, Sri Lanka is lagging far behind from other Asian countries in the utilization of the resources available for aquaculture development.

Sri Lanka has no tradition of fish farming. Among aquaculture activities undertaken at present culture-based fisheries (CBF) is practiced in reservoirs and it has contributed significantly for enhancing freshwater fish production and for the provision of livelihoods for rural communities (Chandrasoma et al., 2015, Chandrasoma and Pushpalatha, 2018). Tilapia farming in ponds, in particularly in backyard ponds in both freshwater and brackish water environments is a recent development (Pushpalatha et al., 2016). Shrimp farming in ponds is the main coastal aquaculture activity, which is practiced at present in Sri Lanka.In 2018, 1800 ha were under shrimp farming and produced around 7700 t of shrimps (NAQDA statistics, 2018, Figure 02). Ministry of fisheries and aquatic resources of Sri Lanka made efforts in recent years to promote other coastal aquaculture activities involving seabass, sea weed, crabs, sea cucumber etc. with the objective of promoting exports and also to provide livelihoods for coastal communities. Although not falling under food fish category, ornamental fish farming for exports (Figure 03) as well as for domestic markets has became a popular small- scale business, especially among rural communities.

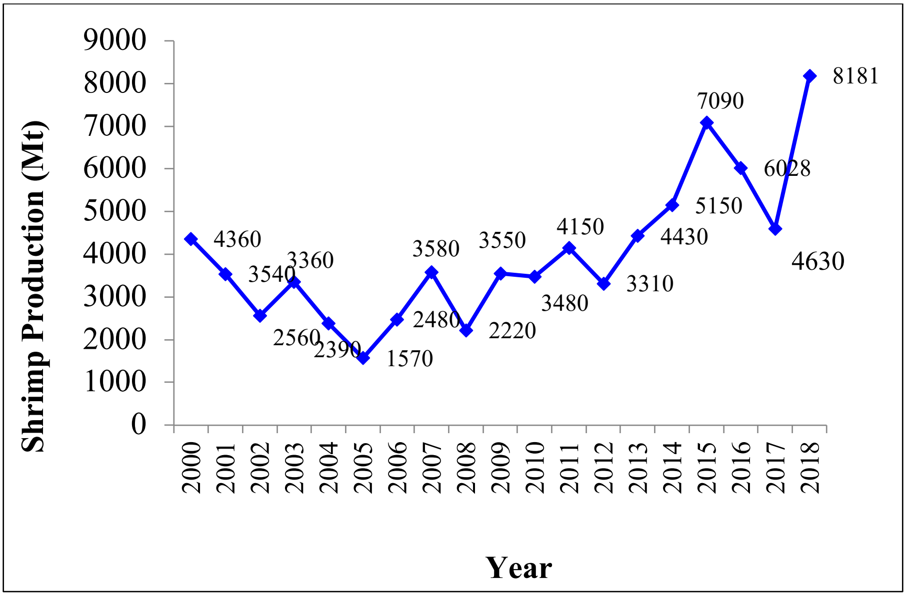

Figure 2. Shrimp production in Sri Lanka

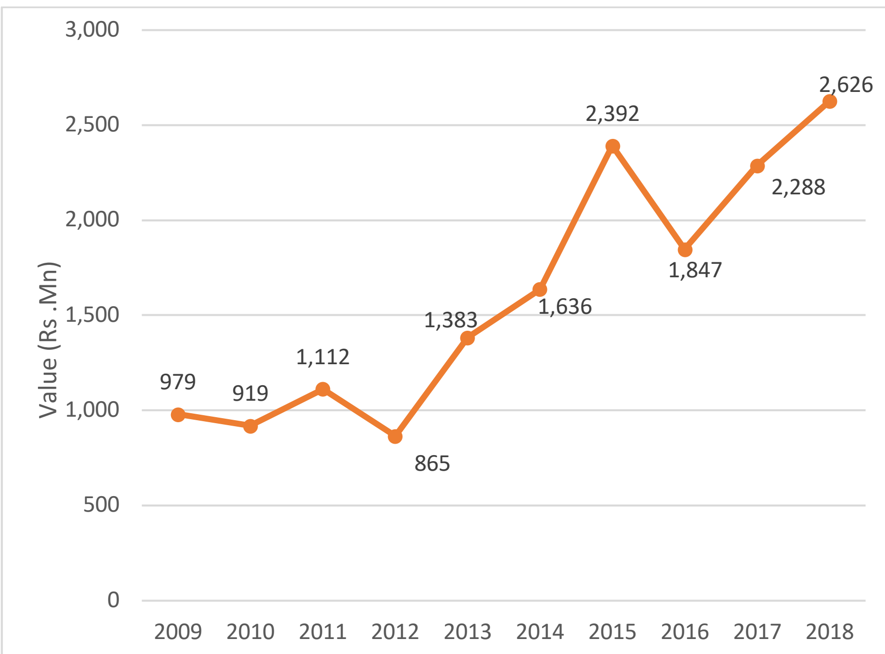

Figure 3. Export values of Ornamental fish in Sri Lanka

Primary drivers of aquaculture diversification are, need to supply of fish to meet the increasing local demand in view of limitation anticipated in marine capture fisheries, export opportunities and social factors such as provision of livelihoods and strengthening rural economy.

Diversification of aquaculture species

Table 01 gives details of aquaculture species used and species considered as potential for farming in near future.

Table 1. Aquaculture species used, and species considered as potential and production systems

Species	Production system	Present status	Potential/ potential to expand
Freshwater species	CBF in perennial reservoirs	Nile Tilapia contribute to around 50% of fish production	Very high
Nile Tilapia (*Oreochromis niloticus*)	Grow out in ponds	55 farmers involved	Moderately high
	Fry to fingerling rearing in ponds	24 individual farmers involved and 6.26 million fingerlings produced in 2018. 25 community based mini nurseries 15.38 million fingerlings produced	Moderately high
	Fry to fingerling rearing in cages installed in reservoirs	Cages in operation in 85 reservoirs. in 2018 34.58 million fingerlings produced.	High
	Fry to fingerling rearing in pens installed in reservoirs	Around pens operational in 2018, and 4.2 million fingerlings produced	High
	Grow out in cages installed in reservoirs	Carried out only in experimental basis	Low
Cala – *Catla catla* Rohu – *Labeo rohita* Mrigal–*Cirrhinus mrigala*	CBF in perennial reservoirs	Contribute to around 40% of fish production	Very high
Catla, Rohu, Mrigal bighead carp *Aristichthys nobilis*, Silver carp *Hypophthalimis molitrix*, Grass carp *Ctenoparyngodon idellus*, Common carp *Cyprinus carpio*	CBF in seasonal reservoirs	All these species are used in polyculture systems adapted in CBF. Fish production potential 750-1000 kg/ha/yr.	Very high

Species	Production system	Present status	Potential/ potential to expand
Fresh water prawn – *Machrobachum rosenbergii*	CBF in perennial reservoirs	Important species used in perennial reservoirs	Moderately high
	Grow out in ponds	Only few backyard ponds in operation	low
Ornamental fish	ponds	Small scale and large scale entrepreneurs involved	high
<u>Brackish water Species</u> Tiger prawn – *Peneus monodon*	Pond culture	In 2017, 42 hatcheries in operation. Produced 411 million PL's. around 2000 ha under culture producing 5000 – 7000t annually	High
White leg shrimp – *Leptopeneus vannamei*	Pond culture	In 2018 introduced. One hatchery commenced operation	high
Mud crab – *Scylla serrata*	Pond culture	One hatchery in operation. 57 t produced from ponds	high
	Fattening in cages	Small scale fattening of crabs as a value addition is carried out in lagoon areas	low
Sea cucumber – *Seabras cabra*	Pens installed in shallow seas and in coastal ponds	Around 40 pens in operation in Northern seas and only few ponds. Around 30 t produced in 2017, one hatchery in operation	Moderate
Milk fish – *Chanos chanos*	Pond culture	Farming in few ponds using seeds collected from the wild. Establishment of a hatchery in progress	Potential is high to produce juveniles as a bait for long line fishing.
Sea weed – *Kappa phycasalverrezii*	Culture in calm shallow seas, using raft or line method	Coastal communities specially women in Northern areas involved. In 2017, 692 t (wet weight) produced	Moderate
Oysters- Mussels -	Raft culture	Few small-scale entrepreneurs involved.	Moderate
Marine ornamental fish	Recirculation tank systems	Used in breeding and storage facilities	low
Seabass – *Lates calcarifer*	Pond culture	Few small-scale entrepreneurs involved.	high
	Cage culture	About 80 small scale farmers involved. One company operating on commercial scale.	high

Diversification of aquaculture sites

Varieties of sites with diverse characteristics, which are suitable for aquaculture are available throughout the country. Details of sites available and relevant aquaculture production systems at present are shown in table 02 and Figure 04.

Table 2. Details of sites available and relevant aquaculture production systems

Site	Utilization/ potential for utilization
Perennial reservoirs	CBF;grow out farming in cages; fingerling rearing in cages and pens; water-based hatcheries for Tilapia.
Seasonal reservoirs	Culture-based fisheries
Lagoons /estuaries	Small scale cage farming of grow-out of sea bass; fattening of crabs in cages
Lands adjacent to brackish water resources (lagoons/estuaries and connected canals etc)	Shrimp farming in ponds; seabass farming in ponds; grow- out farming of mud crabs in ponds; milk fish farming in ponds
Inland land areas with access to adequate volume of fresh water	Tilapia farming in ponds; fresh water prawn farming in ponds; ornamental fish farming in cement tanks/ ponds
Shallow coastal seas	Sea cucumber arming in pens; sea weed farming; large scale sea bass farming; oyster/ mussel farming
Open seas	Large scale cage farming of seabass

Figure 4. Suitable sites of aquaculture systems in Sri Lanka

Diversification of stocking density

Very diverse stocking densities are used in aqua farming industry.stocking densities varies with species, growing stage (fry/fingerling/juveniles/ grow-out etc) production system, level of intensification, characteristics of holding facilities, input provided etc., Details of stocking densities adopted in aquaculture production systems are given in Table 03.

Table 3. Stocking densities adopted in aquaculture production systems in Sri Lanka.

Production system	Stocking density
Shrimp farming in ponds	
Without aeration – extensive	5-15 PL's/m^2
With aeration - intensive	20-30 PL's/m^2
CBF in perennial reservoirs	500 – 1000 / ha
CBF in seasonal reservoirs	2000-2500 / ha
Small scale seabass cage farming	30 fingerlings / m^3
Tilapia farming in backyard ponds	2-5 fingerlings / m^3
Tilapia farming in commercial farms	100 fingerlings / m^3
Sea cucumber farming in pens	4000 juveniles / ha
Fry to fingerlings rearing in cages	500-1000 fry/m^3
Fry to fingerlings rearing in ponds	100-200 fry/m^2
Fry to fingerlings rearing in pens	100 fry/m^2

Diversification of production systems

Table 01 gives details of aquaculture production systems. Shrimps, crabs, sea cucumber, sea weeds used as monoculture and poly culture systems used in perennial (Chandrasoma et al., 2015) and seasonal reservoirs (Chandrsoma and Kumarasiri, 1986) and freshwater fish culture in ponds.

Diversification of production cycle

Shrimp farming industry in Sri Lanka including seed production is entirely private sector driven. Capacity of 42 hatcheries (around 500 post larvae per annum) in operation is capable of fulfillingcountries requirement of post larvae for farming.

Country is not producing adequate number of carp fish fingerlings to meet the demand for culture-based fisheries in reservoirs. Unlike in other South Asian Countries, Brood-stock management, breeding and post larvae rearing to fry stage in respect of Tilapia and carps is entirely carried out in government breeding centers/ Aquaculture Development Centers. In order to diversify Nile tilapia breeding, government recently established water-based hatchery in a reservoir (Urusitawewa). This hatchery is managed by the fishers of community -based organization of the reservoir. This programme of establishing water-based hatcheries to be expanded to the other reservoirs in future.

Rearing of fry upto fingerling stage has been diversified in recent years. Upto 1990's entire fingerling production of the country came from government fish breeding centers. At present fish fingerling production of the country come from different production systems, due to diversification of fry to fingerling rearing as follows

- Government fish breeding centers/Aquaculture Development Centers
- Community-based fish nurseries consisting of mud ponds
- Backyard ponds
- Cages installed in reservoirs managed by fisher CBO's
- Pens installed in reservoirs managed by fisher CBO's.

In 2017, 46% of Sri Lankas total production of carp/ tilapia fish fingerlings were produced in government hatcheries and the rest came from other production systems.

At present, hatcheries for freshwater prawn (government as well as private sector managed), seabass (government and private managed) sea cucumber (private sector) and crab (private sector) are in operation. Construction is in progress to establish a hatchery for milk fish. Action is being taken to establish a tissue culture laboratory to produce propagules of *Kappaphycusalverezii.*

Diversification of aquaculture products and market

Around 80% the production from inland fisheries and aquaculture sub sector comes from reservoirs and mainly consist of tilapia and carp verities. Major portion of the tilapia and carp verities (Mainly Catla, Rohu, Mrigal and Common carp) are mainly reaching consumers specially in rural areas in fresh form. Small part of production reach urban markets and super markets, again in fresh form. In addition, a small %age of tilapia and carp production is used to produce dry fish and smoked fish in certain areas and these also consumed in rural areas. Recently attempts have been made to introduce some value added products targeting urban consumers using carp verities in the form of canned products including sandwich spread.

Of the aquacultured products Sri Lanka export around 2000 t of shrimps annually in recent years. As there is a good demand for shrimps for domestic consumption and for hotels and restaurants targeting tourists, around 2/3 of aquacultured shrimps reached the local market in fresh form. Sri Lanka has around 30 processing plants with majority of them meeting EU standards. Value added shrimps such as nobashi and butterfly cut are popular in Japanese markets while head-on, headless, shell -on, peeled and cooked shrimps are popular in the USA, Japan and Asian markets such as Singapore. Sri Lanka exports all these value-added shrimp products (EDB, 2019).

Three exporters are involved in exporting freshwater prawn, mainly Thailand in chilled form. It was reported that of the 896 t of freshwater prawns produced, 115 t have been exported (NAQDA, 2017). Seabass produced is exported in frozen form and the large-scale cage farming enterprise has introduced fillets to urban consumers, hotels and restaurants. Value addition of seaweed/*Kappaphycas* sp. is not feasible in Sri Lanka due to low quantities produced at present. Seaweed is washed, cleaned, dried and exported. In 2018, 62 t of dried cultured sea weeds had been exported. As per sea cucumber, only preliminary processing of sea cucumber is carried out and exported to China, Honkong and Taiwan. As the demand is very high for this commodity, any increase of sea cucumber production through aquaculture will not create any marketingdifficulties. Governments programme planned for breeding and culture of milk fish juveniles will be for use as a bait for long line fishing in the deep sea, as an alternative to imported baits.

Policies, laws and regulatory

Fisheries and Aquaculture Policy

One of the objective of the new policy on Fisheries and Aquaculture sector is increased aquaculture and inland fisheries production. Under the policies on Aquaculture attention has been given to the sustainable management of resources. Under this following policy applicable to aquaculture have been spelled out.

- Apply temporal and spatial planning in development of aquaculture
- Allocate land and water resources for aquaculture projects only after environmental, socio-economics and cultural impact assessment.
- Ensure that aquaculture projects are implemented in strict compliance with conditions of approved

- Strengthening the aquaculture – animal health care activities
- Promote the use of best management practices (BMP) in aquaculture.

Policies given under the strengthening of governance are

- 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 waterbody for sustainable management of fisheries in the respective waterbody.

Policies listed under the broad policy of increasing fish production are as follows

- Develop fisheries and aquaculture as appropriate 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.

Above policies will facilitate diversification of aquaculture.

Legislation

The principal legislation related to fisheries & aquaculture, aquatic resources and coastal resources are;

- The fisheries and Aquatic Resources Act No.2 of 1996 (as amended by Act No. 4 of 2000, No. 4 of 2004, No. 35 of 2013, No.2 of 2015 and No.2 of 2016): This Act is to provide for the management, regulation, conservation and development of aquatic resources in Sri Lanka; give effect to Sri Lanka's obligation under certain international and regional fisheries agreements; and provide for matters connected therewith or incidental there to. A summary of provisions available under this Act are given in Annex1.
- National Aquaculture Authority of Sri Lanka Act no. 53 of 1998 (as amended by Act No. 23 of 2006): This Act is to provide for the establishment of the National Aquaculture Development Authority of Sri Lanka, to develop aquatic resources and make provisions for

matters connected therewith or incidental thereto. Under this Act minister is vested with the powers to make regulations in respect of the management of aquaculture; the management of aquatic resources; and all matters in respect of which regulations are authorized or required to be made by this Act. Relevant regulations under this Act and the FAR Act is given in Annex2.

- Coast Conservation Act No. 57 of 1981 (as amended by Act No. 64 of 1988): prohibits any person to engage in a "Development activity", within the coastal zone, unless such person is authorized by a permit issued by the Director General of Coast conservation. No permit will be issued unless it is consistent with the coastal zone management plan and unless it has no adverse effect on the stability, productivity and environment quality of the coastal zone. The Director General may require the applicant to submit an Environment Impact Assessment. The coast conservation regulations (1982) define criteria to be used in determining issuing of permits.
- The National Environment Act No. 47 of 1980 (as amended by Act no.56 of 1988): makes provisions for the protection, management and enhancement of the environment, for regulation, maintenance and control of pollution. THE Act establishes the Central Environment Authority (CEA) for its administration. Part IV of the Act requires the approval of "Project Approving Agencies" for "Prescribed Projects" following an Initial Environment Examination (IEE) or Environment Impact Assessment (EIA). According to the National Environment (Impact Assessment) Regulation (1992), the MFAR is considered a project approving agency for fisheries matters. The "prescribed Projects" that require an IEE or EIA are further defined by an order issued in 1993 under section 23z of the National Environmental Act. The procedures to be followed by the 'Project approving agencies" is regulated in the National Environmental (procedure for approval of project) regulations (1993). The discharge or disposal of waste into the environment is prohibited by the National Environment Act (Part IV A) and the National Environmental (protection and quality) Regulations (1990), unless such person is authorized by an Environment Protection License in accordance with the standards and the criteria prescribed in the Act. Standards for emission (discharge of effluents) into inland surface, brackish and marine coastal waters have been set by Central Environmental Authority.
- Marine Pollution Prevention Act No.59 of 1981: provides for the prevention, reduction and control of pollution in Sri Lankan waters.

The Act establishes the Marine Pollution Prevention Authority to administer the Act. In case of pollution, the owner or the operator of a ship, pipeline or any off-shore installation is liable for any damage caused by the discharge, escape or dumping of any oil or any other pollutant into Sri Lanka waters.

- Animal Diseases Act (1992).
- Animal Feed Act (1986).
- Control of Pesticides Act (1980, as amended in 1994).
- Cosmetics, Devices and Drugs Act (1980).
- Food Act (1980, as amended in 1991).
- Land Development Ordinance (1935, as amended).
- Land Grants (Special Provisions) Act (1979).
- Water Resources Board Act (1964, as amended in 1999).
- State Lands Ordinance (1949).

Human resources and institutional setup

Diversification of aquaculture involves introduction of new aquaculture technologies. Further aquaculture technologies improve /change day by day. So far inputs provided by relevant institutions are minimal and whatever achieved towards diversification of aquaculture has been through technology transfers, from other countriesin particularly from other Asian countries. These technology transfers have been carried out by training technical personnel in leading aquaculture institutes in foreign countries or bringing foreign experts to work with local technical personnel in Sri Lanka. It was observed that trainingprogrammes which allows, trainees to aim more hands-on experience by working in a aquaculture production facilities are more beneficial in transferring new technologies.

Institutional setup

Ocean University of Sri Lanka and University of Ruhuna conduct degree level course in fisheries and aquaculture. Almost all other state universities have included course units related to aquaculture in their Biology, Agriculture or veterinary Science streams. National Aquaculture Development Authority (NAQDA) provide short courses for fish farmers in freshwater aquaculture, with more experience on practical aspects at the National Inland Fisheries and Aquaculture Training Institute at Kalawewa. Plans are underway to establish a similar training institute in Mannar, to transfer technologies in respect of coastal aquaculture. National Aquatic

ResourcesResearch and Development Agency (NARA) is vested with the responsibility of carrying out research on all living and non-living aquatic resources in order to develop and manage fisheries and aquatic resources.

International linkages for improvement of Aquaculture

International linkages are important for diversification of aquaculture for transfer of technologies and for technology exchanges. Sri Lanka has developed linkages with various countries in the Asian region as well as with intergovernmental or international agencies. They are,

- Freshwater fisheries research Center, (FFRC), Wuxi, China
- Research Institute of Aquaculture (RIA3), Natrang, Vietnam
- Department of Fisheries, Thailand
- Asian Institute of Technology, Thailand
- South East Asian Fisheries Development Center, Philippine
- Central Institute of Fisheries and Aquaculture, India
- Network of Aquaculture Centers in Asia and the Pacific Region (NACA)
- Food and Agriculture Organization (FAO)
- SAARC Agriculture Center, Dhaka, Bangladesh
- Australian Center for International Agriculture Research (ACIAR)
- USAID

Conclusion

Fish production trends during last few years, together with result of stock assessment studies indicates the limitations in the marine fish production in Sri Lanka. Similar to global trends, Sri Lanka need to accelerate their efforts to utilize available resources optimally to expand aquaculture and to meet the increasing demand for fish. Utilization of available resources will require diversification of aquaculture, including diversification of sites, species, production systems, stocking densities, and seed production activities.

As at present, technology development in respect of aquaculture through research is minimal in Sri Lanka, country need to rely heavily on technology transfers from other countries, in particularly from Asian region, where around 90% of the aquaculture production is generated. Affiliation and links with institutes and organizations related to aquaculture and the support and coordination from international and inter-governmental organizations such as FAO, NACA, and SAARC are vital for facilitation of efforts in technology transfer and knowledge sharing.

Intensification of farming systems are part of diversification. Any efforts at intensification will accompanied by use of good quality feeds and increased threats from diseases. Hence it is vital to pay more attention on feed development and disease diagnosis and prevention.

Use of genetically improved fish varieties too will facilitate higher production. Hence knowledge sharing and sharing of brood stock of improved varieties need to be supported. As intensification of aquaculture is associates with risks, a suitable insurance schemes for fish farming will be important. One of the constraints for the development of cage culture and pen culture on commercial basis is the non-availability of suitable net materials in Sri Lanka and at present importation from neibouring countries through a third party has resulted in high prices, thus discouraging people from farming of fish in cages and pens.

Recommendations

- More opportunities should be provided for technology transfers and sharing of knowledge
- Barriers preventing exchange of fish species including genetically improved species should be removed and facilitated.
- Training programmes conducted to transfer knowledge need to be re-constituted to include more time for trainees to acquire hands on experience by working in production facilities.
- Introduction of insurance schemes for aqua farming.
- SAARC to take lead in coordination of supply of netting materials at reasonable prices from producing countries.

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Annexure 1

Summary of provisions available under Fisheries and Aquatic Resource Act (FAR Act) and National Aquaculture Development Authority Act (NAQDA Act) and related regulations

Provisions	Reference
DG/DFAR is responsible for the administration and giving effect to the provisions of this Act	Part I - Clause 2
Establishment of fisheries and aquatic resources advisory council	Part I - Clause 3,4,5
No person shall engage in any fishing operation without a license	Part II - Clause 6-14
Provide for prohibition of fishing in foreign waters	Part II - Clause 14F
No person shall engage in any prescribed fishery in High seas; except under the authority of a license granted by DG	Part II A
License to comply with conservation and management measures adopted under international agreements	Part II
Provide for registration of local fishing boats used for the purpose of taking fish in Sri Lanka water or the high seas	Part III - Clause 15-26
Provisions for protection of fish and other aquatic organizations are available under part(iv)	Part IV
Prohibition of use and possession of poisonous and explosive substances for catching fish	
Minister has powers to prohibit export and import of any species of fish, by order published in the gazette	
Provisions for declaring fisheries management areas.	
Establishment of co-management committees and its composition	
Preparation of fisheries development and fisheries management plans for declared management area	
Minister may by notice published in the gazette declare a closed season or an open season specifying times and areas	
Provision for conservation available under Part IV.Minister vested with the power to declare any area of Sri Lanka's water or/and land adjacent there to as a fisheries reserve. Prohibits any acts in the fisheries reserve	Part V

Provisions	Reference
Provisions related to aquaculture are available under part VI. Provisions are available for (i) for leasing of state land or srilankan waters for the purpose of aquaculture. (ii) Licensing of aquaculture operations	Part VI
Provisions for settlement of fisheries and aquaculture desputes	Part VII
Powers of authorized officers	Part VIII
Deals with offences and penalties for contravening or failing to comply with the provisions of the Act	Part IX
Minister has powers to make regulations related to fisheries and aquaculture	Part X

Annexure 2

Aquaculture Related Regulations

Regulation	Relevant Act
Aquaculture management regulations,1966	FAR Act
Brackish water and marine Prawn culture regulation,2007	NAQDA Act
Shrimp Aquaculture management (operation of crop cycle) regulations,2009	NAQDA Act
Brackish water shrimp hatcheries(issue of post larvae) regulations,2010	NAQDA Act
Live rock culture for export regulations no.1 of 2011	NAQDA Act
Aquaculture management regulations,2011	NAQDA Act
Aquaculture management (disease control) regulations,2000	FAR Act
Aquaculture (monitoring of residues) regulations,2002	FAR Act

Chapter 6

Aquaculture Diversification in Bhutan

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Introduction

The Kingdom of Bhutan is a landlocked country with an area of 38,364 km^2 and population of 750000, situated on the southern slope of the Eastern Himalaya, bordering China to its North and India to its south, east and west. Today, Bhutan is known for its proactive approach to modern development characterized by its emphasis on environmental preservation in development process and more recently the pursuit and promotion of Gross National Happiness (GNH) as an alternative approach to modern development. The northern region of Bhutan consists of an arc of Eastern Himalayan alpine shrub and meadows reaching up to glaciated mountain peaks with an extremely cold climate at the highest elevations. Most peaks in the north are over 7,000 m (23,000 ft) above sea level; the highest point in Bhutan is Gangkhar Puensum at 7,570 m (24,840 ft), which has the distinction of being the highest unclimbed mountain in the world. The lowest point, at 98 m (322 ft), is in the valley of Drangme Chhu, where the river crosses the border with India. Watered by snow-fed rivers, alpine valleys in this region provide pasture for livestock, tended by a sparse population of migratory shepherds.

The country is almost entirely mountainous with altitudes ranging from 150 - 7,500 m above sea level within a short north-south distance of 170 km. The climate varies hot subtropical in south to cold alpine slopes in the north. Human settlement is confined mostly to interior river valleys and a swath of southern plains; nomads and other tribes live in the north, raising sheep, cattle and yaks. Bhutan straddle two major bio-geographic realms, the Indo-Malayan realm consisting of the lowland rain forests of South and Southeast Asia and the Pale-arctic realm consisting of conifer forests and alpine meadows of northern Asia and Europe (RSPN). Due to the presence of large number of glaciers and glacial lakes, high level of precipitation and the relatively well-preserved forests and watersheds, Bhutan is endowed with tremendous inland water resources in the form of rivers, rivulets, springs and streams. Bhutan with the rich biodiversity of natural freshwater river system fish species whereby preliminary studies have reported a total of 91 freshwater fish species from Bhutan (Gurung, et al., 2013).

Fisheries in Bhutan can be divided into two parts, aquaculture and wild fisheries. There has been growing pressure on the Bhutan's water bodies. Numbers of mega hydropower projects are currently being implemented; many are in the construction phase. Its impact on the aquatic and avian life has already been felt. Bhutan has five major and two minor river basins. The total length of rivers and their tributaries is estimated to be about 7200 km. there are over 590 natural lakes of various sizes; most of them located above an altitude of 2,200 m. the Kingdom's rich resources have been used for different purpose, starting from fishing to hydropower development (NRCRLF, 2017). As per the statistic record in of Livestock department, fisheries farm have produced 222 MT of fish in the year of 2017 and imported 558.7 MT of fresh fish and 150.2 MT of dry fish in the year of 2017 from India (Livestock Statistic, 2017).

Diversification of aquaculture species

Assessment of species composition and distribution of fish in Bhutan's three major river basin (Amochhu, Wangchhu and Punatsangchhu) by National Research Centre For Riverine and Lake Fisheries (NRCR&LF) reported 104 species of which 11 species were non-native introduced into various parts of the country for commercial purpose (NRCRLF 2017).

The main objective of Trout Breeding Centre in National Research Centre For Riverine and Lake Fisheries, Haa is to promote and develop cold water fish culture in the country; the facility currently rears Rainbow trout (*Onchorhynchus mykiss*) which are bred for seed production to be supplied to private entrepreneurs and restock within the facility. However, fresh fish are also supplied into the market through Bhutan Livestock Development Corporation Limited (BLDCL).

The NRCR&LF is also studying the feasibility of Siberian sturgeon which is mainly for caviar production deemed of high nutritional value and prolific venture. The fishes are reared in the raceways (flow-through system) and rearing tanks depending upon the age of the fish and its space requirement.

Figure 1. Trout breeding centre, Haa

National Research and Development Centre for Aquaculture (NR&DCA) in southern Bhutan which is mandated to coordinate the production and distribution of aquaculture live inputs (fingerlings). The Centre currently deals with Indian major carps (Rohu, Mrigal and Catla) and Chinese major carps (Common carp, Grass carp and Silver carp). Carp farming are usually earthen pond based, which are being cultured mostly in the southern foothills while gradual increase is observed in the central Bhutan. The culture techniques adopted in Bhutanese rural farming are polyculture consisting of Indian and Chinese Major carps among which common carp and grass carps are relatively preferred higher attributed to their faster growth and low mortality.

Figure 2. Earthen fishery pond at Gelephu

Community fishery program in Bhutan

In order to address the issue of illegal fishing and to promote the sustainable use of aquatic resources in an effort to enhance the social and economic life of rural people, the Department of Livestock under the Ministry of Agriculture and Forests held the charge to NRCR&LF, Haa and NR&DCA, Gelephu to develop and promote Community-based wild fisheries (NRCR&LF, 2017).

It makes the particular community realize their ownership and custodianship of allocated stretch of river and its resources. Community Based Fisheries Management (CBFM) centers around the premise that community collaboration, and local participation can be an extremely productive and accurate means of managing, monitoring, and maintaining fishery resources. As of now the country has seven capture-based fishery management group consisting 267 households as shown in the Figure 3.

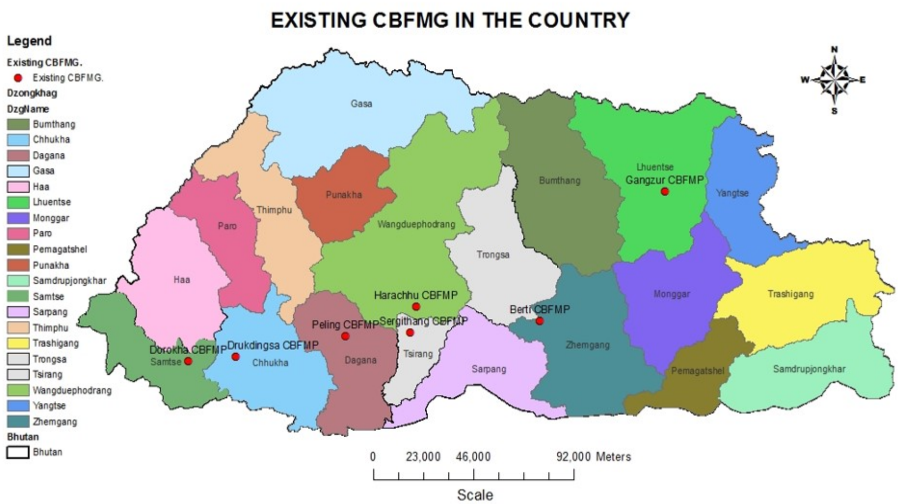

Figure 3. Capture based fishery management group in Bhutan

The community management plan is felt more effective as the group exhibits characteristics such as; full commitment and pride over the allocated stretch, the illegal and destructive fishing practices are seen declining, more protective over the resources and utilization are not made too burdening and abides by the rules and regulations. The community activities as a result provide enhances their livelihood. Having observed the efficiency of such program the government has planned for additional 12 such communities in 12th Five Year Plan.

Diversification of aquaculture sites

The size of the fish ponds are mostly small considering the topography as well as small land holding of the farmers which impedes the establishment of large-scale ponds. The lack of scientific advances in carp culture and management is one main cause apart from land topography; however, the fish farming has seen increasing trend over a period of time.

In Bhutan the aqua farming particularly the warm water carp farming enterprise can be classified in to following four categories:

- Backyard undertaking category "A": An enterprise whose total pond area pond is less than 500 m^2.
- Backyard undertaking category "B": An enterprise whose total pond area pond is between 501 m^2 - 750m^2.
- Semi-commercial enterprise: An enterprise whose total pond area is in between 751 to 1000m^2.
- Commercial enterprise: An enterprise whose total pond area exceeds 1000m^2.

The facilitators/ agency carries out detail feasibility studies for both trout and carp culture with objectives to check suitability of the farm which includes; topography, accessibility, water source and land holdings.

Diversification of stocking density

For warm water aquaculture, a combination of six species, viz. Catla (*Catla catla*), Silver carp (*Hypophthalmichthys molitrix*), Rohu (*Labeo rohita*), Grass carp (*Ctenopharyngodon idella*), Mrigal (*Cirrhinus mrigala*), and Common carp (*Cyprinus carpio*) fulfills the species selection requirement and has proven to be ideal combination for freshwater carp culture in Bhutan. Among these carps, Catla and Silver carp are surface feeders, Rohu is a column feeder, Grass carp is a macrovegetation feeder and Mrigal and Common carp are bottom feeders. The six species combinations have been found to yield maximum production. Therefore, these species are the "back bone" of Bhutan's carp polyculture.

The rate of stocking generally depends on the biological productivity of a pond and the amount of supplementary feeding. In general, stocking rate is determined in relation to water surface area of a pond. A pond having an average water depth of 2.5 m may be stocked at the rate of 700–900 fingerlings/1350m^2. The stocking density advised to the farmers may be increased up to 5 fish/ m^2 (10 cm length approx) if high quality feed and sufficient aeration are maintained; however, in poorly managed ponds (undrainable ponds especially), the recommendation is 700-900 fish/ 1350 m^2 of water surface area.

Species ratio

Selection of species ratio generally depends on seed availability, market demand, nutrient status of a pond etc.; however, as a general rule:

- For six species combination, surface feeders are maintained about 40–50% (catla 10–15%, silver carp 30–35%); column feeder (rohu) 20–25% in moderately deep ponds (above 2 m average water depth), and 10% in shallow ponds (below 2 m average water depth); bottom feeders 30–40% (mrigal 15–20% and common carp 15–20%) and macrovegetation feeder (grass carp) 5–10% depending upon the availability of a dependable source of weed supply;
- For Five species culture system, for example in the absence of dependable source of feed for grass carp, Silver carp, Catla, Rohu, Mrigal, Common and Mirror carp may form 20–30%, 10–15%, 15–20%, 10–15% and 15–20%, respectively.
- Although silver carp grows faster and contribute significantly to the total production, due to lower price and market demand in some areas it is not a preferred species. Under such condition four species combination are followed consisting of Catla 30–40%, Rohu 20–30% in deeper ponds and 10–15% in shallower ponds, Mrigal 15–20% and common carp 15–20%.

Depending upon the market demand, price and availability of quality seed, even a three species combination system consisting of 3 indigenous carp species may be followed (Catla 40%, Rohu 30%, and Mrigal or Common carp 30%). Generally, all the fish species are stocked at a time. However, it has been observed that due to some degree of inter-specific competition for food between catla and silver carp the growth of catla is affected. As such, it is recommended that silver carp should be stocked one or two months later than catla stocking, by the time catla generally picks up good growth rate. Silver carp with its faster growth rate is able to attain over 1 kg size in 9–10 months.

It is advisable to stock the ponds with larger fingerlings of 10–15 cm size for better survival. Recent experiments have indicated the possibility of high survival and production rates when stocked with early fingerlings (5–8 cm) in predator free ponds. The other advantage of using smaller size (5–8 cm) is the cheaper price.

The fresh water species which is being carried out in National Research Centre for Riverine and Lake Fisheries at Haa rears Rainbow trout (*Onchorhynchus mykiss*) in an area of 4611.1 m^2 which are in designed in different structures as illustrated in Table 1. The production capacity of the facility is 15 MT but it is not met attributed to improper structure, lack of quality feeds and other technical reasons.

Table 1. Facility of trout breeding centre, Haa

Structure	No	Dimension (L/B/H)	Capacity (kg)	Total
Hatchery	2			2
American type raceway	6	10/1.2/1.2	200	1200 kg
European type raceway	4	18/1/1.8	300	1200 kg
Natural raceway	3	25/0.4/1.2	200	600 kg
Rearing tank	2	1/1/0.5	2500 Fry	5000 Fry
Advance rearing tank	2	1.5/1.5/0.5	3500 Fry	7000 Fry
Hatching Trays	84	0.3/0.3/0.1	3500 Egg	294000 Egg
Fish Cage	11		9800 Fry	107800 Fry

Artificial breeding of Rainbow trout is carried out for fish seed production, which is distributed to the fish farmers. The breeding is done according to the fish spawning season with standard procedures and dry stripping method recommended by Raina (1992). The standard stocking rate followed in the facility is 80 fingerlings, each weighing 25 g in a m cube. The Centre recorded an average of 315 days for an eyed ova to grow up to 25 g with 12 cm of total length which is comparatively longer which could be attributed to various factors of the facility.

Table 2. Hatchery rearing days in NRCR&LF

Stages	Stage From	Stage To	Duration (days)
1	Eyed ova	Yolk sac fry (Alevin)	15
2	Yolk sac fry (Alevin)	Swim -up fry	20
3	Swim -up fry	Fry (2 g/ 5 cm)	100
4	Fry (2 g/ 5 cm)	Fingerling (25 g/ 12 cm)	180
Total duration			315

Diversification of production system

Carp farming is done in earthen pond based and Trout farming uses raceways (American, European and Natural Raceways). Although cage culture has gained lot of popularity in developing countries, it has never been introduced as of now in Bhutan. The benefits from the several hydro-power generating infrastructure that have been built/ are being built in the country can be reaped making the optimal utilization by establishing a cage system of aquaculture. The dams could be capitalized by installing such system with fast growing species provided considering a minimal impact to the environment

Hydropower sector in Bhutan is one main economic jewel for revenue generation which led to construction of several hydroelectric dams. Consequently, the fishery Centre is making an effort to study the feasibility of cage aquaculture system in native breed Snow trout (*Schizothorax richarsonii*).

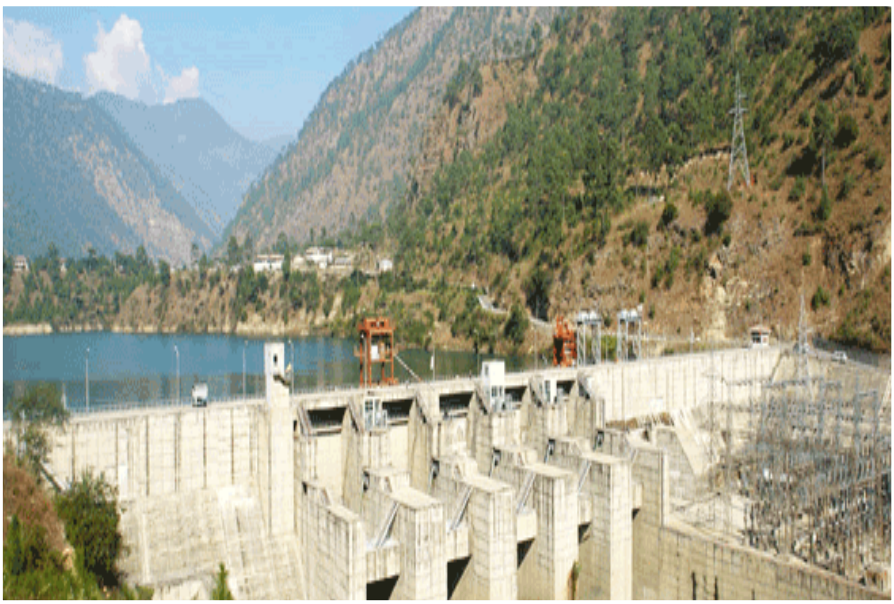

Figure 4. Hydroelectric dam, Kurichhu

Diversification of production cycle

Trout Breeding Centre reported an average of 315 days for eyed ova Rainbow trout to attain fingerling size with 25 g of weight and 10-12 cm of length. Life cycle of Rainbow trout in TBC is explained as follows,

Egg Stage: Trout eggs have black spot at the centre which is an indication of healthy development. The hatching rate is determined the temperature of the water.

Alevin Stage: Once hatched, the trout have a large yolk sac attached to abdomen which is used a food source. Each alevin gradually develops and exhibit trout characteristics and they usually live in the bottom of the tank until they are able to swim.

***Fry* Stage:** By this stage they can freely swim and yolk sac are completely absorbed therefore, it starts depending on artificial feed.

Fingerling Stage: They attain 2-5 inches of total length with 20-25 g weight with prominent dark marking on their body.

Juvenile Stage: Though the juvenile resembles like that of an adult characteristic yet, they are not fully grown enough for breeding.

Adult Stage: The fish gonads are fully developed and are ready for breeding as per their spawning seasons. The species usually spawn in autumn season (Sep-Nov).

Diversification of aquaculture products and market

Fresh fish: Though Trout Breeding Centre, Haa is not mandated to supply the fresh fishes into the market; however, to meet the domestic demand the centre supplies vacuum packed fish to reduce atmospheric oxygen which limits the growth of aerobic bacteria or fungi. The supply does not reach directly to the consumer but it goes through Bhutan Livestock Development Corporation Limited outlet located in capital, Thimphu. The fish attains table size while being supplied.

Figure 5. Fresh Trout, TBC

Smoked fish: It is one of the oldest forms of preserving technique which still is popular in Bhutan; moreover, the value addition upon the traditional technique has further attracted the consumers. Cured fish with smoking has earned the taste and preferences which is making it a high potential product in the market. The government is supporting the farmers as well as the members of capture fisheries in establishing a smoke house with mechanized smoking chamber in order to meet the demand from individuals and hoteliers.

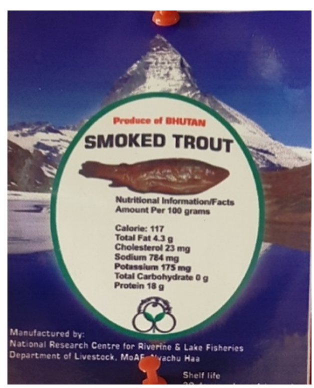

Figure 6. Smoked Trout, TBC

***Red Caviar*:** Basically, made from eggs of Rainbow trout (*Onchorhynchus mykiss*) or Brown trout (*Salmo trutta*). National Research Centre for Riverine and Lake Fisheries, Haa under the guidance of Department of livestock, Ministry of Agriculture and Forests with support from the Royal Project Coordination Office (RPCO), Thimphu was successful in processing red caviar for the first time in 15th December 2017. It is one of the most expensive delicacies in the world and with the modern taste and preferences trends, it can be produced in various scale depending upon the demand in Bhutanese market. Among few types Black caviar is more expensive compare to red caviar because red caviar is made from rare species of Sturgeon which takes many years to develop roe while, red caviar is made from more abundant species which takes less time.

Policies, laws and regulations

Aquaculture development support: a stimulus to enhance the national output offish

Realizing the importance and impacts from huge import; the government initiated "Aquaculture Development Support: A stimulus to enhance the national output of fish". It is a holistic approach whereby both sides; supporter and beneficiary (aquaculture firm) would strive with optimum capacity to achieve common goal in enhancing domestic production. The support has been broadly covered with short run objective of encouraging on to aquaculture and long run objective of sufficing domestic demand.

In order to smoothen the implementation of the package, fish farms were categorized into Backyard Undertaking Category "A" (BUCA), Backyard Undertaking Category "B" (BUCB), Semi-commercial farms and Commercial farm. The subsidy package received by the beneficiaries depends upon the category the particular firm fall in aforementioned category (Table 3) and the new proposal submitted for approval (Table 4).

The beneficiary of the support should meet the standard requirements articulated in the policy. The policy also includes stringent procedures involving closely related stakes to avoid any kind of conflict in the future. The sanction of the package is followed by timely monitoring and evaluation of the venture. The package policy also upholds clear and strong obligations to concerned stake holders involved and the beneficiaries.

Table 3. Existing aquaculture subsidy

Commodity	Subsidy level		Modalities (Governance-approving authority, proportion)	Issues/gaps/concerns	Interventions and changes required
	List of inputs	Type of support			
Fish (aquaculture)	Construction of fish ponds and dyke with minimum of 500 sq m and maximum of 3 acres per farmer	Maximum Nu. 48/Sq m (1 acre=4047 Sq m), (30% of the total cost of 455,000/acre, which is Nu. 195,000)	-do-	Aquaculture below 500 sq m not supported	Provide subsidy to all categories of aquaculture farms
	Water supply connection and inlet-outlet water ways establishment	In kind-Maximum Nu. 22/Sq m (30% of the calculated cost of Nu. 209,132/ acre, which is Nu. 89,628/acre)	-do-	Nil	Continue as usual
	Supply of fingerlings (ordinary and stunted carp) with free transportation	In kind-90% subsidy for ordinary carp fingerling (Nu. 0.5/ fingerling with total cost of production of Nu. 5/fingerling). In kind-83% subsidy for stunted carp fingerling (Nu. 1/fingerling with total cost of Nu. 6/fingerling)	-do-	Nil	Continue as usual
Fish (riverine and lake)	Trout farm establishment	In kind-construction of pond, including supply of fingerlings free of cost	Interim approval from MoAF/DoL/dzongkhag	New initiatives and less takers	Develop subsidy package for trout farming
	Community managed capture fisheries	In kind-100% for basic equipment for harvesting, processing and marketing	Interim approval from MoAF	New initiatives with limited resources	Develop complete subsidy package for riverine and lake fisheries

Table 4. Proposed aquaculture subsidy

Type of subsidy -(Input)		Justification	Beneficiaries (subsidy %)			Frequency of subsidy
			Subsistence (<500 m^2)	Semi-commercial (501 m^2 - 3 acres)	Commercial (>3 acres)	
1.	**Aquaculture**					
1.1	Fish farm establishment (Example, Construction of fish ponds and dyke, feed store, etc)	For household food/ nutrition security, enhancement of rural livelihood, beneficial engagement of youth and disadvantaged women and enhance national output of farmed fish toward reducing import.	100% subsidy for establishing a fish farm with effective production water surface area of up to 500 m^2.	Subsidy of Nu. 48/m^2 of total farm size subject to a minimum size of 501 m^2 and a maximum size of 3 acres.	Subsidy of Nu. 48/m^2 of total farm size subject to a minimum size of 12000 m^2 (approximately 3 acres) and a maximum size of 40000 m^2 (approximately 10 acres)	one-time support
1.2	Fish farm water supply/ irrigation system	Ensure adequate supply of water to operate fish farm	100 % free	Subsidy of Nu. 22/m^2 of total farm size subject to a minimum size of 501 m^2 and a maximum size of 3 acres.	Subsidy of Nu. 22/m^2 of total farm size subject to a minimum size of 12000 m^2 (approximately 3 acres) and a maximum size of 40000 m^2 (approximately 10 acres)	One time
1.3	Fingerlings (ordinary & stunted)	Encourage farmers to take up fish farming and enhance production	100 % (3 times only)	50 % of total cost of fingerlings	25 % of total cost of fingerlings	As and when required

Type of subsidy -(Input)		Justification	Beneficiaries (subsidy %)			Frequency of subsidy
			Subsistence (<500 m²)	**Semi-commercial (501 m² - 3 acres)**	**Commercial (>3 acres)**	
1.4	Equipment (Drag net, cast net, deep freezer, weighing scales, transportation box, fish packagaing materials, demand feeders, ice making machines and other such production and post-production equipment)	Enable efficient production of fish, marketing and value addition/ product development	Free supply of 1 drag net (30 m length and 3 m breadth) and 1 cast net (7 kg capacity)	50 % of actual cost of equipment	70 % of actual cost of equipment	One time calculated for total/ entire equipment requirement
1.5	Construction of raceways including water supply,	Encourage fish farming among the youths/ Ensure year-round water supply for maximizing fish production	1 raceway; (20m* 2m * 1m) 100% free	2-4 raceways; (20m * 2m * 1m) 100% free up to 3 raceways	5-8 raceways; (20m * 2m * 1m) 100% free up to 6 raceways	One-time support
1.6	Supply of fingerlings	Encourage farmers to take up fish farming and enhance production	100%	100%	100% (up to 22,000 fingerlings)	One-time support
1.7	Supply of trout feed	Encourage farmers to take up fish farming an enhance production	100 % (up to 1 MT)	100 % (up to 4 MT)	100% (up to 8 MT)	One-time support
1.8	Post-harvest equipment	Produce quality fish products	100 %	50 % of actual cost	50 % of actual cost	One-time support
2.	**Riverine and Lak Fisheries (Capture Fisheries)**					
2.1	Post-harvest facilities and fisheries equipment for capture fisheries.	To supplement fish production.	100%	100%	100%	One-time support

Conclusion

Today, Bhutan is known for its proactive approach to modern development characterized by its emphasis on environmental preservation in development process and more recently the pursuit and promotion of Gross National Happiness (GNH) as an alternative approach to modern development.Indeed Bhutan is very fortunate to be a member of SAARC country members whereby we can share about the potential of cage and pen culture in Bhutan and even we can get some of the ideas and information regarding the cage and pen culture from different SAARC country.

The topic that was chosen for this meeting is very relevant topic to our country. While going through the imported status of fish in Bhutan, it was found that fish farming in Bhutan needs to produce lots of fish to meet the demand of people. Therefore, after looking at the different climate that Bhutan has can help to raise different varieties of fish according to fish adaptation in their different climate, and even finding the lots of reservoir in the country and lakes the potential of cage and pen culture of fish can is very high in Bhutan which can help Bhutan to produce more fish production with less investment and with more profit.

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Chapter 7

Fish Culture in Cages and Pens in Pakistan for Aquaculture Diversification

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Introduction

Pakistan's economy is essentially based on agriculture. For aquatic products (fish particularly), Pakistan is blessed with plenty of marine as well as inland aquatic resources. It is located in the northern part of the Arabian Sea and has a coastline of about 1,120 km with a broad continental shelf and its Exclusive Economic Zone extends upto 200 n miles from the coast. These fishery resources have immense potential for economic development (Mohsin et al., 2017). Freshwater and marine water are the major resource for aquaculture. There are about 8,563,820 km^2 area is in the form of rivers, lakes, ponds and water lodging areas (Jarwar, 2008). Considered as suitable for aquaculture, there is a great potential of coastal fisheries with about 1120 km coast line. In Pakistan, only freshwater extensive and semi-intensive aquaculture system have been adopted (MINFAL, 2012). Coastal sources and deep water marine sources are still not utilized for aquaculture purposes. Then, from the marine aspects, we are dependent totally on the natural availability.

Aquaculture farming system production is estimated about 179,900 metric tons (t) and 600,000 t from the natural catch (MINFAL, 2012). Aquaculture contributes 1% to Gross Domestic Product (GDP) (Nazir et al., 2016). Due to limited culture, majority of contribution is from capture fisheries. Currently, fish stocking in reservoirs, lakes, earthen ponds, tanks, and a little cemented or fiber glass tanks are practiced for aquaculture production. Thanks to government support, fish and fishery products are processed and exported to over 50 countries. About 30–35% of the fish and fishery products are exported to European Union countries. However, due to the limited output and the increasing of fish price, the government import the fishes from China, Myanmar, Viet Nam, Singapore, Thailand and Burma (PBS, 2017).

Diversification are required for aquaculture sustainability (1): to increase the fish production per unit in short space, (2): for the best use of some available food in aquaculture, (3): for the decomposition of some compounds and make available some nutrients for other species, (4): to face climate change impacts, (5): to face increase demand of fish by the population (Harvey et al., 2017). Hence, the diversification of species, more precisely the polyculture consists in introducing into the same space new species of fish species already exist. Some drivers of aquaculture diversification are market demand (including export opportunities), consumption preferences, funding opportunities, competition and climate change, as well as other environmental and social factors cited aboved.

Diversification of aquaculture species

In Pakistan, The fish farming based on mostly *Labeo rohita*, *Cirrhinus mrigala*, *Catla catla*, *Cyprinus carpio*, *Hypophthalmichthys molitrix*, *Ctenopharyngodon idella*, and *Hypophthalmichthys nobilis* species. However, diversification of species is due to consumer preferences. Mostly, species such as Catla catla, Labeo rohita and Cirrhinus mrigala are very appreciated by the population. However, to satisfy the demand, the farming of catfishes, snakeheads and tilapia are still in progress. More recently, 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. In addition, cold water fish is in progress and include species like rainbow trout (*Salmo trutta* and *Oncorhynchus mykiss*) (Muhammad, 2018).

Diversification of aquaculture sites

The selection of a site for aquaculture takes into account several factors i.e the species of fish to raise. The site should be also located in an area that is not subject to frequent flooding and should have enough elevation, so that farm can be drained out in case of any emergency, should have suitable texture, enough water supply, availability of required inputs, have market road access even during the rainy season. The temperature and soil conditions can also influence the practice of aquaculture. Hence, to determine suitability of the site for fish culture, soil samples should be taken from the proposed site, placed in a plastic bag and taken to the departmental laboratory for analysis. The bag should be labeled with the farm name, the location and the depth at which the soil sample was taken. The water quality water should be analyzed. For this purpose a sample should be taken preferably in a sealed bottle and sent to the Department of

Fisheries Laboratory for the testing of total alkalinity, hardness, pH, nitrogen, total dissolved solids along with other required parameters.

Diversification of stocking density

The stocking density of fish is a crucial parameter for production during rearing. In fact, a high storage density can lead to:

- Decrease the water quality (decreased feed avaibility, dissolved oxygen and aeration, increased ammonia and risk of diseases);
- Increase stress (Håstein, 2004);
- Increase incidence of physical injuries (North et al., 2004);
- Poor body condition (Ellis et al., 2002);
- Reduce growth, feed intake and feed conversion efficiency (Ellis et al., 2002).

Several previous studies showed that low density improve growth performance and productivity (Arul and Kwei, 1992; Sirakov and Ivancheva, 2008; Rahmatullah et al., 2010). For example, the effect of different stocking densities on growth, production and survival rate of Pangas (*Pangasius hypophthalmus*) fish in cemented tanks at fish hatchery Chilya Thatta, Sindh-Pakistan was studied (Abdul et al., 2014). Fry of Pangas (1.52 ± 0.03 cm in length and 1.08 ± 0.02 g in weight) respectively were stocked into cemented tanks measuring 15 x 6 x 3 ft. Three treatments with two replicates were used: T1-100; T2-150 and T3-200 fry/tank. Pangas fry were fed twice daily with formulated feed 35 % protein at 10%, 5%, and 3% body weight for the first, second, and third month, respectively. After 90 days, the highest growth performances (determined in terms of average weight) were recorded in T1 (27.5±2.5 g) and T2 (22.4±2.8 g) while T3 (18.2±3.5g) recorded the smallest growth. Survival was significantly different among treatments ($P<0.01$). Highest survival (100%) was attained in T1 with lower stocking density, followed by T2 (96%) and T3 (90%).

Intensification and development of new techniques in aquaculture have shown that polyculture improves growth performance and production compared to monoculture. In monoculture, studies have shown that a stocking density of 5-10 fish m^{-2} or 30,000 fish ha^{-1} allowed good production in Nile tilapia *Oreochromis niloticus* (Suresh, 2003). In polyculture, a culture of Nile tilapia and Clarias gariepinus in the proportions 3: 1 allows a good production (Suresh, 2003). Similarly, polyculture of Nile tilapia with shrimp in proportions of 2:9 or 2:12 per m^2 provided good yield (Ambrosio et al., 2012). In addition, 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 percent).

Diversification of production systems

The different fish farming production systems are generally distinguished according to their degree of intensification which is itself usually difined according to the feeding practises. In Pakistan, monoculture and polyculture are practised. However, polyculture when properly applied has many advantages: improving water quality, increasing the use of food, reducing the overpopulation of a rapidly proliferating species, reduced risk of disease, compared to the monoculture. These fish are also reared according to different production systems: extensive, intensive and semi-intensive.

Extensive fish farming production system has low production because there is no supplemental feeding is done, the stocking density is too low (less than one ton per hectare per year), 20 to 40 cubic meter is used per kg fish, the amount of harvested fish is variable and based on the climate conditions (water temperature, dissolved oxygen, salinity, pH), animal health and welfare is not under control, food safety is low.

Intensive fish farming production system is the latest and improved technology of fish farming. There are many advantages: maximum fish production is possible in intensive polyculture. more profit from fish farming is possible, creates many employment opportunities, intensive polyculture of fish is fully controlled by the farmer, more fish can be cultivated and produced from short place. However, this system has also more disadvantages : intensive polyculture of fish is very expensive and risky, in this system the probability of diseases is most, this farming system get obstructed due to lack of better facilitated artificial farm, it is not possible to make the fish big sized in this system, intensive polyculture needs highly experienced employee.

Semi-intensive fish farming systems rely on the use of fertilization (organic and/or mineral) to produce natural feed and/or supplementary feed, but with a significant amount of the fish diet supplied by natural feed. Integrated croplivestock- fish farming systems are typically belonging to this type of fish culture as well as all fish farming systems recycling various types of wastes including direct excreta reuse systems and indirect sewerage systems (crop-livestock/poultry-fish). Both systems provide high fish yields. In this system like intensive system, the main facilities used for this type of fish farming are pens, cages or raceways with a very high water renewal rate (natural through water currents of artificial through pumping).

In Pakistan, cage and pen culture are also praticed. They are a system that confines the fish in a mesh enclosure. However, these types of crop have its advantages and disadvantages.

Cage culture: Cage culture can be established in a variety of waterbodies, including lakes, ponds, mining pits, streams or rivers with proper water quality, provided the potential operator has access and legal authority. This makes cage culture one of the most flexible form of aquaculture. Compared to the cost of construction for other large-scale aquaculture methodology cage culture in can be relatively inexpensive. The observation of fish behavior, especially feeding behavior, is essential for good husbandry. One of the advantages of cage culture is that it is possible to partially harvest fish from cages as needed. The husbandry of fish in cages should not hinder other users of the water resource, including those pursuing fishing, boating, and swimming. Hoever, feed must be nutritionally complete and kept fresh. Caged fish will get no natural food and so depend on the manufactured diet for all essential nutrition. Feed must provide all necessary proteins (down to specific amino acids), carbohydrates, fats (including essential fatty acids), vitamins and minerals for maximum growth, water quality problems, particularly low dissolved oxygen, are a possible outcome ofcage culture,if cage systems are not properly sited. Caged fish can be the easytarget people bent on theft or vandalism. Predation can be a problem if cages are not constructed or managed properly. Turtles, snakes, otters, raccoons and fish-eating birds will take fish or damage cages unless precautions are taken.

Pen culture : Pen culture is a continuous process due to continuous supply of water. Gretar production is assured in a limited space with rich food and oxygen supply. Greater growth is possible as energy is saved towards locomotion and feeding, the harvesting is easy. Pen culture produce about 4–5 t/ha/year and cage culture about 10 – 15 tons/ha/year.

Figure 1. Pen and cage culture of fish in Pakistan

Diversification of production cycle

A fish hatchery is a place for artificial breeding, hatching, and rearing through the early life stages of fish. Hatcheries produce larval and juvenile fish, shellfish, and crustaceans, primarily to support the aquaculture industry, where they are transferred to on-growing systems, such as fish farms, to reach harvest size. Several hatcheries and nurseries are located in the main provinces where aquaculture is practiced. For examples: 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 farm cum hatcheries are operating in the NWFP.

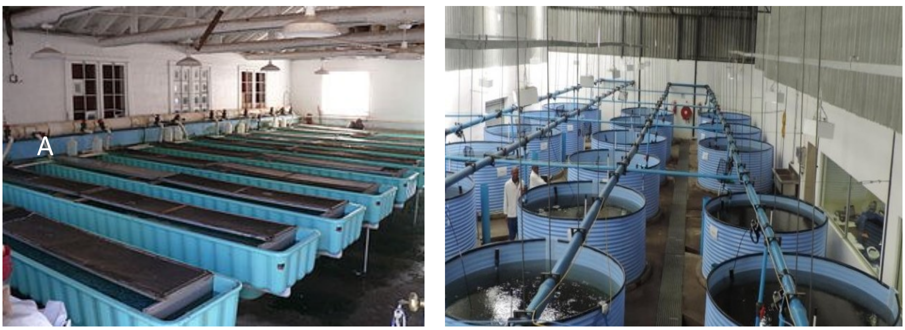

Figure 2. (A) Fish hatchery, (B) Crab hatchery

Diversification of aquaculture products and market

After harvest, aquaculture products in general and fish in particular, can be sold fresh directly or be transformed into derived products (smoked, salted, sausage, fillet etc.). However, Local consumers generally prefer freshwater fish over marine fish because of their familiarity with river and inland farmed fish as well as the fresh condition of the product. This difference is reflected in both wholesale and retail prices where freshwater fish sell at a higher price than marine fish. Hence, Products are sold into the market to wholesalers and then onto retailers and end consumers through agents working on commission basis. Farmed fish tend to be marketed either at the farm gate, through middle men or during open auction where ice-packed fish sent to fish markets after harvest were sold. Buyers can be members of the public, retailers, wholesalers, agents for processing plants or exporters.

In addition to the domestic market, Pakistan has a market of fish and fish products at international level. Pakistan exports reasonable quantity of shrimp, fish and its products and earns a substantial amount of foreign exchange. Fish and fish products are processed and exported to many countries, European countries being at the top. Major markets for export are: Canada, USA Denmark, Japan, Holland, Norway, Iceland, Korea, Hong Kong, Taiwan, Singapore Malaysia, Gulf.

Policies, laws and regulatories

In aquaculture, the government of Pakistan has many policies measures in fisheries :

- Value chain development for high value fish farming in warm-water areas
- Coordination for Trout Farming development in GB and mountainous areas of KP
- Promotion of private sector led establishment of service centers for production of inputs, cold chain and auction etc.
- Promotion of Shrimp Farming in saline inland and barren coastal areas of Sindh and
- Development of high value intensive aquaculture for different ecologies
- Establishment of cold chain across supply line for meeting international trade requirements
- Establishment of fish feed production units and fish hatcheries and
- Availability of low markup loans for aquaculture sector
- Regulatory framework to support exports from aquaculture production

The government supports the aquaculture sector through the transfer of technologies and funds in the different provinces of production for the construction of infrastructures. Concerning the laws and regulatories, the Pakistan fisheries ordinances and supporting legislation and regulation promulgated by the provincial DOFs provide rules and regulations for the marketing, handling, transportation, processing and storage of fish and shrimp for commercial purposes and the sale of fish used for domestic and inter-provincial trade. Contravention of this ordinance is punishable by imprisonment of up to six months or fines of up to 10, 000 rupees (PKR) or both. A provision has also been made for a total ban on the use of destructive fishing gears as well as a closed season for the catching of shrimp during June and July.

Human resource and institutional setup

According to a best estimates, about 50,000 people are either directly or indirectly employed in the fish farming sector. More departments of fisheries (DOF) in the different provinces of Pakistan have a training and research programs for aquaculture development. For this purpose, The Punjab DOF has a Fisheries Research and Training Institute located at Manawan in Lahore, which offers training programmes in warmwater fish farming for private sector fish farmers, in-service personnel of DOF and staff from other provinces. The NWFP DOF also has a training institute at Sherabad in Peshawar, while the Sindh DOF has a training institute at Thatta. The NWFP DOF also has a pilot commercial trout farming and training center located in Madyan in Swat. This facility is the largest commercial trout production unit in the country and is also used as a demonstration and training facility.

The various departments provide training to the participants both from within Pakistan and from neighbouring Afghanistan. The PARC has established the Aquaculture and Fisheries Research Institute (AFRI) which conducts production technology-oriented research in aquaculture and reservoir fisheries. The center has also established a trout breeding and production unit near Gilgit in the NA of Pakistan. In addition, several other institutions in the country play important roles in the development of aquaculture :

- The Fisheries Development Commissioner (FDC) is responsible for policy making, planning and coordination with the provincial fisheries departments as well as other national and international agencies
- The Marine Fisheries Department (MFD) Karachi is the central level of coordination of fisheries, working under the Ministry of Food, Agriculture and Livestock (MINFAL),
- The Water and Power Development Authority (WAPDA) also has a fisheries department responsible for the regulation and auction of fisheries rights in the large reservoirs found in Pakistan
- The fisheries research unit at the National Agricultural Research Center (NARC) of PARC, the country's biggest research organisations established under the MINFAL

In addition to these institutions, Pakistan also collaborates with international organization such as Food and Agriculture Organization (FAO) – Fisheries Department for different projects or research and development for industry, fisheries and aquaculture.

Conclusion

Pakistan is one of the countries with a large population in the world. Its economy is based essentially agriculture. Thanks to its hydrolic potential, its human workforce and in support of the government, aquaculture has undergone considerable growth in recent decades and has contributed greatly to the country's economy. Despite these potentials, several factors are holding back good production in the aquaculture sector: lack of market intelligence and knowledge, lack of access to cold storage, inadequate road infrastructure which leads to high post-harvest losses, poor packaging techniques, lack of smal-lholder access to high end markets and lack of value addition in agro based products. In this regard, information and education are critical for the farmers and consumers to make appropriate policy and adopt improved farming practices. The research system is continuously generating new technologies for increasing fish production for domestic consumption and exports.

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Chapter 8

Aquaculture Diversification in Afghanistan

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Introduction

Afghanistan is located in the hearth of Asia. Afghanistan is one of the 48 Least Developed countries in the world. About 85% population are engaged in agriculture and livestock.

Figure 1. Afghanistan located in the heart of Asia

Afghanistan is a net food importing nation. The area of the country is 650,000 km^2, and 75 % of its territory is mountainous. Its population is about 35 million with a literacy rate of 80 %. Afghanistan has a young population, with 45 % falling below 15 years of age. Nearly 75% of the population lives in rural areas and agriculture is their main source of income and employment.

Table 1. General geographic and economic indicators of Afghanistan

Attributes	Value
Area	652,000 km^2
Shelf area	None (country is landlocked)
Population (2019)	35 million
Urban population as % of total population (2018)	24 %
Literacy rate (2018)	80 %
GDP at current prices (2018)	US$ 20.4 billion
GDP per head 2018	US$ 680
Fisheries as percent of agricultural GDP (2012)	< 1 %
Unemployment (2018)	40 % (estimated)
Percent of population below poverty line (2018)	30 %
Exports of fish	0
Fish products /year	12,000 t
Share of agricultural products in total imports	13.8 %
Imports of fish /year	130,000 t

Table 2. Afghanistan livestock population limit

Livestock	Number	Meat production (%)
Cattle	6 million	25
Sheep	15 million	14
Goat	8 million	08
Chicken	8345 farm	20
Fish	3855 farm	10
Camel	45000	03

Diversification of aquaculture species

Afghanistan is land-locked country with seasonal water flows and diversion of water for irrigation purposes, fisheries are not a large contribution to the economy, although from a biodiversity perspective, fisheries is considered in the context of water use and water withdrawals. Afghanistan have minimal aquaculture feasibility but with changing economic conditions there are some aquaculture operations slowly developing as niche markets around large towns and among the northern border where water supplies are more regular, noting that cold water environments may offer reasonable potential for cold water, high value species" FAO initiative for fisheries in Afghanistan. However, Afghanistan has adequate water reserves and suitable climate for fish farming (both cold and warm species). The construction of medium size and small dams on a number of rivers also provides opportunities for fish stocking.

Figure 2. Afghanistan Balkh province cold water fisheries

Areas that have reasonable potential for fish production (including aquaculture) are:

- Perennial rivers in northeast Afghanistan (Amu Draya, Kokcha, Balkh, Kunduz and Murghab Rivers) for cold water species.
- Perennial rivers in eastern Afghanistan (Laghman, Kunar, Pech and Panjshir Rivers) for cold and warm species.
- Perennial rivers in southern Afghanistan (Helmand and Arghandab Rivers) for warm species.
- The Hamoun wetland for warm species. Hamoun is an inland water delta created by spring floods from the Helmand River. The Hamoun is shared by Afghanistan and Iran. Its waters is said to house nearly 140 species of fish and receives a variety of migrating birds. Once a fertile land, the productivity of this wetland of approximately 2,000 km^2 has deteriorated severely due to mismanagement. Investment for fish production in these areas can only be undertaken on the basis appropriate feasibility studies for each potential river basin.

Figure 3. Fish production for local consumption

Table 3. Fish production in Afghanistan

Fish species	Production (t/year)
Carps	7300
Trout	354
Royal	2000
Others	1500

Diversification of Aquaculture sites

In Afghanistan sites for aquaculture are selected on the basis of close the market or market availability. Near of the place which have more smooth water and density of water and processing site is very important in Afghanistan to have relation with market and farmers for making communication with the market and farmers also the site must be or reserve the fisheries cooperative and fisheries association demand and counterpart each other's always.

Figure 4. Carp fingerling production farm in soil pond and raceway

Diversification of stocking density

Fish remains a very minor part of the Afghan diet. Commercial fishing in the country does not produce enough fish on a sustainable basis' to meet local demand. In rural areas fishing is done for family subsistence. Electricity and explosives are used to kill fish from rivers. Although these methods of fish catching are illegal, it's monitored by the public authorities.

Very little fish is marketed, except in the spring months when the rivers contain enough fish. As rivers recede in the summer months the availability of fish declines. Urban populations mostly depend on imported fresh and frozen fish, shrimps and smoked fish. These products are imported from Pakistan, Iran, UAE, Norway, UK and other European countries. Afghanistan imports about 4,0000 t of fish and fish products annually

Figure 5. Seed stocking for aquaculture

Diversification of production systems

In Afghanistan fish production from aquaculture are done by marina, small farms or laver. Afghanistan is a model dry country, there are only few rivers viz., Band Salma Harirod and Amo River and Band Qargha in Kabul. Others are a lot of small laver, raceway. Hatcheries and nurseries belong to the government of Afghanistan and produce fingerlings for distribution to farmers.

Figure 7. Warm species fingerling production farm raceway system in Kabul

Diversification of Aquaculture products and market

All the fish produced in the country are consumed locally. For transportation to different parts of the country fish are preserved in ice for short period and sold. As fish is a very high demand commodity, is sold instantly, hence long time preservation is not required. We import fish in all season from neighbors countries about more than 500 t /day .

Policies, laws and regulatory

Afghanistan does not currently have a significant fishery sector and lacks a coherent policy for the development of fisheries and aquaculture. Farmers are being identified and trained through different workshops and training programs and upgrading livestock methods also encourage farmers.

Figure 9. Artificial mixing of milt with stripped eggs at Kabul Qargha reproduction farm

Human resources and institutional setup

Human resources and institutional setup and availability in the country to address the issues related to diversification of aquaculture. Also, describe the training, research, extension, linkages between state and federal system, and international linkages for the improvement of aquaculture.

Aquaculture human resources in Afghanistan

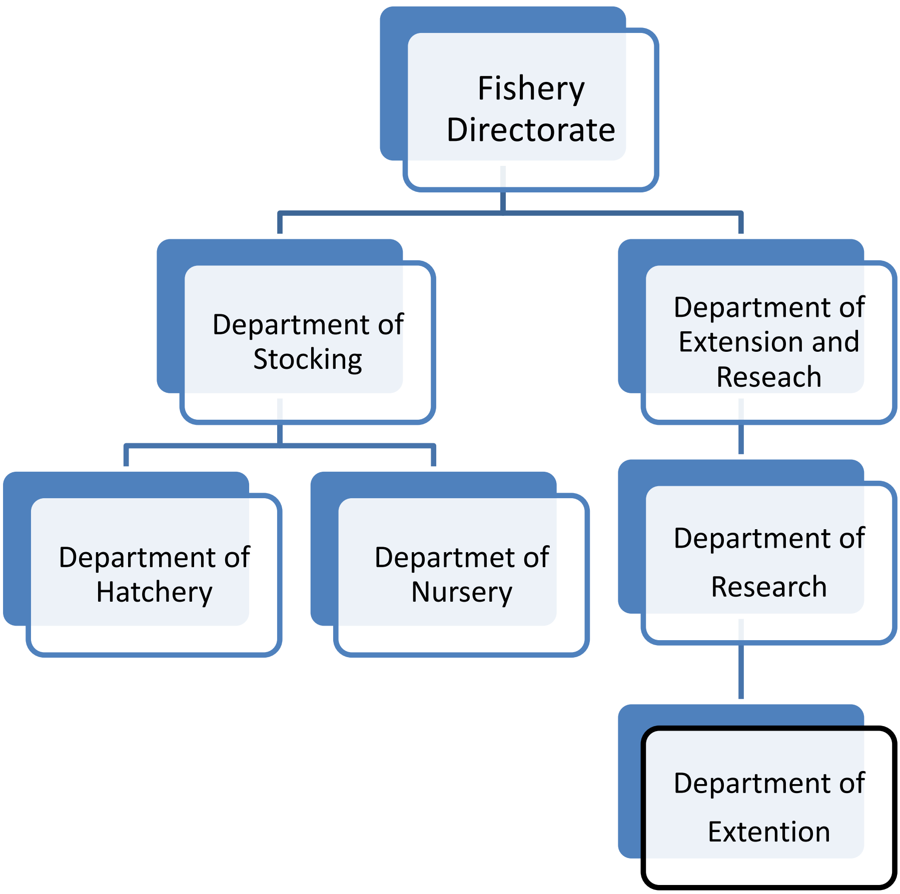

Figure 10. Afghanistan fishery establishment chart

Conclusion

- Serious study is needed to assess the potential of inland fish production (both capture and culture fish) in Afghanistan and to explore the means by which the potential can be exploited.
- After 4 decade of war Afghanistan agriculture and livestock are reviving. At present Afghanistan livestock especially fishery production is in promotion phase.
- Increasing fish production and decreasing import is one of the goal of the government.

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Chapter 9

Women's Involvement in Aquaculture in Nepal

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Introduction

In South Asia work of rural women is mostly confined to the homestead because of cultural, religious, social regions (De and Pandey, 2014). Traditionally, social and family structures of Nepal are dominated by the male and most of the women members in a family depend on the income of men. Until late 1990s in rural Nepal almost all economic decision in a family was taken by the male members. The role of women always graded as supplementary though the women contribute significantly to the livelihoods of a family.

In Nepalese agricultural activities women are engaged in aspects of value chain in all the sectors i.e. crops, horticulture, animal husbandry, aquaculture and fisheries etc. The contribution of women in these sectors remains imperceptible because the works they perform are considered as their normal duty. In South Asian region including India women's average contribution in overall farm production is estimated to be 55-66% of the total labour with percentages much higher in certain regions (Krishna, 2012). In Nepal also the situation is similar like India. Women empowerment for improved and modern agriculture production is a highly essential, which is comprehensive and multi-dimensional concept. It is a process through which women gain greater access to resources and also manage over decision-making. Empowerment indicates a transformation from the position of enforced powerlessness to greater self-reliance (De et al., 2012). Besides agriculture activities, women's contributions in aquaculture sector have become the subject of global consideration.

Women status in Nepal

Although women represent more than half of the total population in the country discrimination against women continues in different forms. However, there have been many positive changes over time Nepalese patriarchal society and many socio-cultural norms are discriminatory for women. Though the government has envisaged the programs for gender equality by policies and law, discrimination toward women and girls is still rampant. Son preference is high and employment opportunities for females are still lower (UNFPA, 2017).

Aquaculture development in Nepal

Aquaculture and fisheries are the one of the fastest growing food production sector in the world. The sector is immensely contributing to the nutrition and food security and poverty reduction in the developing countries (ADB, 2005). Nepal is rich in inland freshwater resources, lakes, rivers and reservoirs. Diversity of wildlife, birds and aquatic animals with high value fish are great assets of the country. Man-made ponds and diversified aquatic habitats of natural water bodies such as rivers, lakes, reservoirs, swamps/ghols, rice fields, are the major sources of fish production in the country. These water resources and rice fields are considered as the important sources of capture fishery, that contributes approximately 25% of the total fish production in the country (CFPCC, 2018). About 230 indigenous fish species are listed in the inland habitats with different abundance status (Rajbanshi, 2012), majority are tied up with capture fishery.

Aquaculture was started in late1950s with introduction of Common carp (*Cyprinus carpio*) and its successful breeding was done in mid1960s. Three cultivable Chinese carps (*Ctenopharyngodon idella, Hypophthalmicthys molitrix, Aristichthys nobilis*) were introduced in the early 1970s followed by their successful induced breeding in mid 1970s. In the late 1970s breeding techniques of indigenous major carps (*Labeo rohita,Cirrhina mrigala and Catla catla*) were established (Singh and Yadav, 1996) which was the significant achievement in Nepalese aquaculture history that provided momentum to polyculture system in the country. At present, around 33% of women are working in aquaculture sector in Nepal (Kunwar and Adhikari 2016/17).

Gender equity in aquaculture

Gender issues are of severe concern in the middle class Nepalese society (Yadav, 2000). Women development program started in the country only after UN's declaration for a ten years period plan (1975-1985) "Decade of Women" (Shrestha and Yadav, 2003). Although the main policies and strategies include mainstreaming gender balances and empowerment of women in aquaculture and aquatic resources management, the planning and priorities focusing these target groups has not been implemented objectively and sufficiently so far. In reality, women's access to opportunities of using technology, aquaculture inputs and credits and/or subsidies for their capacity building has been very limited. Still the women's chores continued for traditional responsibilities to their family and society.

Women in aquaculture

Both public as well as private sector have been actively involved in promoting small-scale aquaculture among women through training and demonstration with a view to empower them socially as well as economically. Women play an important role in small-scale aquaculture in India as well as in south-east Asian countries (Himanshu and Pandey 2014). Increasingly important actors in aquaculture processes are women (Weerantunge and Snyder 2015). Women participation is at least half of the inland fisheries' workforce (FAO 2012). This role encompasses social and economic activities and duties, both within and outside the family.

Jaliri women are traditionally working in cage fish farming in lakes of Pokahra valley. Women are involved in weaving net, feed the fish, cage cleaning, fish harvest and marketing. Women's empowerment through developing and strengthening farmers' organization was formed as savings groups involving women members of the households initially, which later developed into a full-fledged cooperative and it has strengthen through fish farming (Gurung et al, 2005; Pant et al. 2012).

"Women in Aquaculture in Nepal", an adaptive research project involving women members of fishing communities among the Tharu, Darai and Bote ethnic minority groups were carried out in Chitwan and Nawalparasi districts to diversify the livelihood options. The project encompassing social, economic, agro-ecological and institutional aspects successfully developed a model for homestead pond aquaculture development (Shrestha et al., 2012). Women's education level and involvement in decision making in Jalari community has been improving, gradually since 2000s (Nepal, 2011). Wetlands dependent communities are becoming more concern and involving to conserve the resources for their sustainable use. In these communities women are being more inclusive and active in recent years with activities of conservation and sustainable utilization of the resources. Jalari women from a deprived fisher community formed two separate groups as associations in 2000 by the name of Machhapuchhre Women Group in Phewa Lake and Piple Women Group in Begnas Lake in Pokhara valley. Likewise, many other women groups across the country are active in small-scale aquaculture and fisheries with resource conservation activities

(Table 1). Now, women are participating almost equally with man in aquaculture and aquatic resources management activities. However, they need opportunities for capacity building on educational as well as financial strength to contribute in aquaculture successfully and effectively.

Table 1. List of some women's group working in aquaculture sector in Nepal

Women's group	**District**	**Number of members**	**Fish farming**	**Role**
Macchapichre Jalari women group, Phewa Lake	Kaski	36	Cage fish farming and indigenous fish conservation	Cage weaving, fish feeding, marketing
Piple Jalari women group, Begnas Lake	Kaski	12	Cage fish farming and indigenous fish conservation	Cage weaving, fish feeding, marketing
Bikash Mahila Machapalan Krishak Samuha	Chitwan	15-18	Pond fish farming	Fish feeding, marketing
Mahila Machapalan Krishak Samuha	Chitwan	15-18	Pond fish farming	Fish feeding, marketing
Rai Mahila Machapalan Krishak Samuha	Chitwan	15-18	Pond fish farming	Fish feeding, marketing

Involvement of women in aquatic biodiversity conservation and culture-based fisheries

Jalari community is concerned on present condition of the lake resources and women are actively participating on management of Phewa Lake, an important asset for the sustainability of biodiversity and their livelihoods. Main focus has been given in conservation of indigenous fishes including Sahar (*Tor putitora*), Katle (*Neolissochilus hexagonolepis*) and other high value species and improvement of the degraded condition of the lake. The women group in Fewa is participated to release fingerling/fry of indigenous fish every year in collaboration with Phewa Fish Entrepreneurs Committee, Fisheries Research Station, Pokhara, District Agriculture Development Office and other respective stakeholders. As the result of ex-situ conservation activities performed by women group with support of other concern stakeholders, 77231 (8%) hatchery produced Sahar were restocked in the Phewa Lake out of total 962061 fingerling, where 90% was the indigenous species such as Rohu (*Labeo rohita*), Naini (*Cirrhinus mrigala*) and Bhakur (*Catla catla*) including Sahar in past five years period (2005/06 – 2010/11). Since 2004, Machhapuchhre Women Group are involved in stocking of indigenous fish fingerlings including few exotic species into the lake and the contribution of women group was about 9.2% in the past five-years period (Nepal et al., 2011).

Due to the effective In-situ and Ex-situ conservation activities performed by Jalari women the catch of Sahar (*Tor putitora*), a high-value species of the Phewa Lake, was increased by 64% within the last five-year period, 2005/06–2010/11 (2062/63-2066/67 BS) with average 783 kg of annual catch (Fig. 1). However, the volume of total annual catch of the lake is decreasing and Katle (*Neolissochilus hexagonolepis*) are in fluctuating trend.

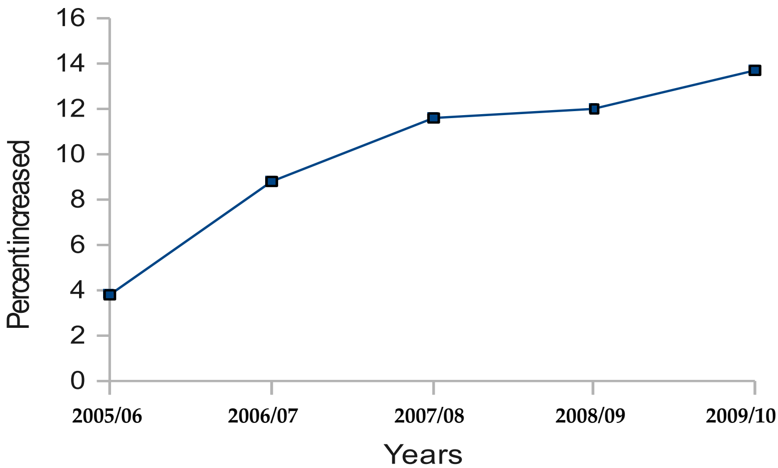

Figure 1. Increased percentage of Sahar out of total catch of indigenous fish from Phewa Lake in last five-years (2005/06 – 2010/11) (Nepal et al., 2011)

Besides the stock enhancement activities women are performing some in-situ activities for conservation of indigenous fish and biodiversity as well. Jalari women have a strong will power and are playing a significant role in conservation and lake resources management activities, in a participatory approach with strong backing by Fisheries Research Station, Pokhara and District Agriculture Development Office, Kaski. They are using the indigenous knowledge and skills to conserve the native fish species and cleaning the lake by removing water hyacinth. They patrol the major sensitive and upstream areas for protecting spawning grounds and achieving to control illegal fishing. Every fifth day of the Nepali month they have a meeting to decide the works to be done for one month period of upcoming month or most important works to be done immediately. They organize the rally, campaigns and set the hoarding boards and distribute pamphlets and leaflets with necessary information for public awareness.

Women's role in food security and livelihoods

Involvement in aquaculture has improved the household food and nutrition security as well as livelihood of ethnic women due to availability of fish in their diet (Bhujel et.al. 2008, Pant et al. 2012). It is found that the per capita fish consumption in the communities has increased from 3 kg (Bhujel et al., 2008) to 11 kg in 2009 (Pant et al. 2012), which is over 7 times higher than the national average of 3 kg (DOFD, 2016/17). Aquaculture played a vital role in augmenting household income and the income from fish farming was used to purchasing food and household merchandises and also for children's education where the women group was launched a small-scale aquaculture project (Bhujel et al., 2008; Pant et al., 2012). In another small-scale aquaculture project income generation and pond ownership was the outcome of the project which helped the women to be empowered financially (Rai et al., 2012). Women are performing fulltime job of different nature in aquaculture. Generally they work on;

- Collecting fish from landing and harvesting areas
- Net weaving and mending
- Making fish collecting, harvesting and marketing baskets (especially from bamboo)
- Making small tools and fishing gears
- Fish feed preparation and feeding the fish
- Grass cultivation and feed to fish
- Fish processing and preservation
- Small-scale fish marketing
- Group formation and organization

Issues and challenges

Although, there is no discrimination to women by national legislation and opportunities are offered for equity they are overloaded with farming, marketing etc. on the top of chores. Traditionally, it is misunderstood that taking care of children and senior members of the family are the responsibilities of the women. Still there is a lack of access to productive resources for them, such as resource ownership, economic or monitory management etc. Even the government policies are made for equity and mainstreaming them, still seems lack of support services for production sector and proper opportunities to the capacity building activities from the nation.

Women have only traditional knowledge of aquaculture. Adequate training, support and infrastructure can strengthen their role in the aquaculture and fisheries sector for increasing aquaculture production and productivity. Women fish farmers' improved access to resources and their increased role in household decision-making were noted (Pant et al. 2012; Nepalet al., 2011). Projects with specific mission seems more effective to develop level of livelihoods through improving their occupation. However, there is a lack of proper institutional back up and setup for its management. Many groups are formed for initial works, but cooperative approach is necessary for community development through aquatic resources conservation and sustainable utilization. There is no proper and adequate institutional framework for the promotion of these target women group in the country. Recently, under new constitutional framework, Ministry of Women, Children and Senior Citizen at Federal/Central Government level, and Ministry of Social Development at Provincial Government level are instituted.

Conclusion and Recommendations

The Jalari women at the Phewa Lake they are confident that they highly capable to perform the effective aquaculture works if they would be given opportunities. Similar situation can be developed in other areas of the country, where women are involved in aquaculture and fisheries management activities. It is essential to strengthened their capacity, specifically the level of education and financial resources to make work more effective. As the consequence of conservation approach, lesson learned from the Phewa Lake could be an example to the other groups and areas. Implication of these models with necessary improvements would be effective approach for aquaculture development in the country.

There is no doubt women are critical mass for aquaculture and aquatic resources management. Their direct involvement in the development process will be of great support to achieve the overall progress of the nation especially towards poverty alleviation and community development. For successful planning, there should be gender aware and modification in local level planning to achieve the goal through more integrated approach. Some measures recommended to bring the women in mainstream are:

- Women need priorities in suitable development activities and constraints should be addressed in aquaculture and aquatic management plans and programs.
- Revenue generated by women from aquaculture should be analyzed.
- Wide range of women oriented training and extension services of different disciplines for their capacity building.
- Research should be focused to strengthen the weak part of the society related with women development.
- Women participation in planning, programming and implementation of aquaculture development and aquatic resources management activities at local level.

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Chapter 10

Cage and Pen Fish Farming in the Lakes to Obtain Income and Employment for Landless Fisher Community

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Introduction

Cage culture of fish consists of raising fish from the juvenile stage to commercial size in a volume of water enclosed on all sides, including the bottom, while permitting the free circulation of water through the 'cage' (Coche, 1979; Schmitton, 1969). It is a method of farming aquatic organisms in the enclosure placed in a body of water (Beveridge and Stewart, 1998). Floating cage fish culture was probably originated from lower Mekong basin in Kampuchia, as a convenient holding facility for marketable fish (Pantulu, 1979). In freshwater cage fish farming, China dominates with a production exceeding 68.4 percent of total reported freshwater cage aquaculture, followed by Vietnam 12.2 % and Indonesia 6.6 % (Tacon and Halwart, 2007). Cage fish culture is considered to be an old tradition that has developed into a major sector in aquaculture only in the recent past (De Silva and Phillips, 2007; Tacon and Halwart, 2007).

A pen or enclosure a fixed enclosure in which the bottom is the bed of the water body (Beveridge, 1984). Pen culture was originated in the Inland Sea area of Japan in early 1920s (Alferez, 1977). It has been practiced on a commercial basis in the Philippines, Indonesia and China (Lam, 1982). An annual potential yield of milk fish was about 4,000 kg/ha from pen culture in Lake Laguna Philippines (Anon 1979). Pen culture of carps has been carried out in Bangladesh and Egypt (Ishak, 1979; Karim and Haroud-al-Rashid Khan, 1982).

From 5000 ha area of the lakes of Nepal, fish production is only 1000 t (DOFD 2016/17). Cage fish culture was introduced in Nepal in 1972 at Lake Phewa, Pokhara Valley as a means of holding brood of common carp (Swar and Pradhan, 1992). There are eight lakes in the Pokhara valley occupying around 1000 ha area. The farming of cage culture has been carried out in three lakes of Pokhara valley and in Kulekhani reservoir only. The total volume of cages for fish culture in Nepal is 71,000 $m^{3,}$ production and productivity is 299 metric and 4.21 kg/m^3 of cage volume respectively (DOFD, 2016/17).Traditionally, subsistence cage farming by use of planktivorous fish species (silver carp *Hypophthalmichthys molitrix* /bighead carp *Aristichthys nobilis*) in nylon cage of 50 m^3 cage volume with bamboo frame have been practiced by farmers (Gurung and Bista, 2003; Wagle et al., 2007). This technique has extended to Kulekhani reservoir in 1984 for the local people as part of the mitigation efforts following reservoir construction and loss of farmland. Introduction of cage fish farming in the reservoir became successful strategies for an alternative livelihood option (Gurung et al., 2009). Enclosure fish culture was started in 1984 in Nepal in the lakes of Pokhara Valley. At present the enclosure culture is practiced in Begnas and Rupa lakes. From 75 ha area of enclosure area, fish production and productivity have been reached to 98t and 1.3t/ha, respectively in the Nepal (DOFD 2016/17).

Fisher community involved in cage and pen fish farming

Three are two hundreds Jalari family living around the Pokhara valley, and their livelihood is dependent on the income from aquaculture and fisheries from the lakes. Mostly Jalari fishers are involved in Phewa and Begnas Lake for cage and pen fish farming. Other ethnic communities that were involved in cage fish culture are Brahman and Chhetri (10%), Gurung (20%) and Magar (3%) (Bista et al. 2012). There are 172 family members are engaged in about 35750 m^3 of cage volume in three lakes of Pokhara valley in the year 2011(Prarsad et al. 2013). In the present survey, number of families still continuing cage fish farming is 70 and involvement for pen fish farming is 20 families.

Cage and pen area in the lakes of Pokhara valley

In 2011, 35,750 m^3 of cages were used for cage culture in the Pokhara valley lakes (Prasad et al., 2013). At present, the number of cages were only 309 with volume 14,160 m^3 in which fish farming in cages is still continuing in the lakes of Pokhara Valley. The cage numbers have been reduced in Phewa Lake by 83%, Begnas Lake by 88%, in year 2017 as compared to 2011 while it has been increased in Rupa Lake (Fig.1A-C). The major reasons for cage number and volume reduction in these lakes due to change of Lake Environment, change of flow direction of feeding streams. The total numbers of enclosure are 14 with estimated total area 21.1 ha in Pokhara valley Lakes. 10 enclosures (6.6 ha) in Begnas Lake and 4 enclosures (14.5 ha) in Rupa Lake.

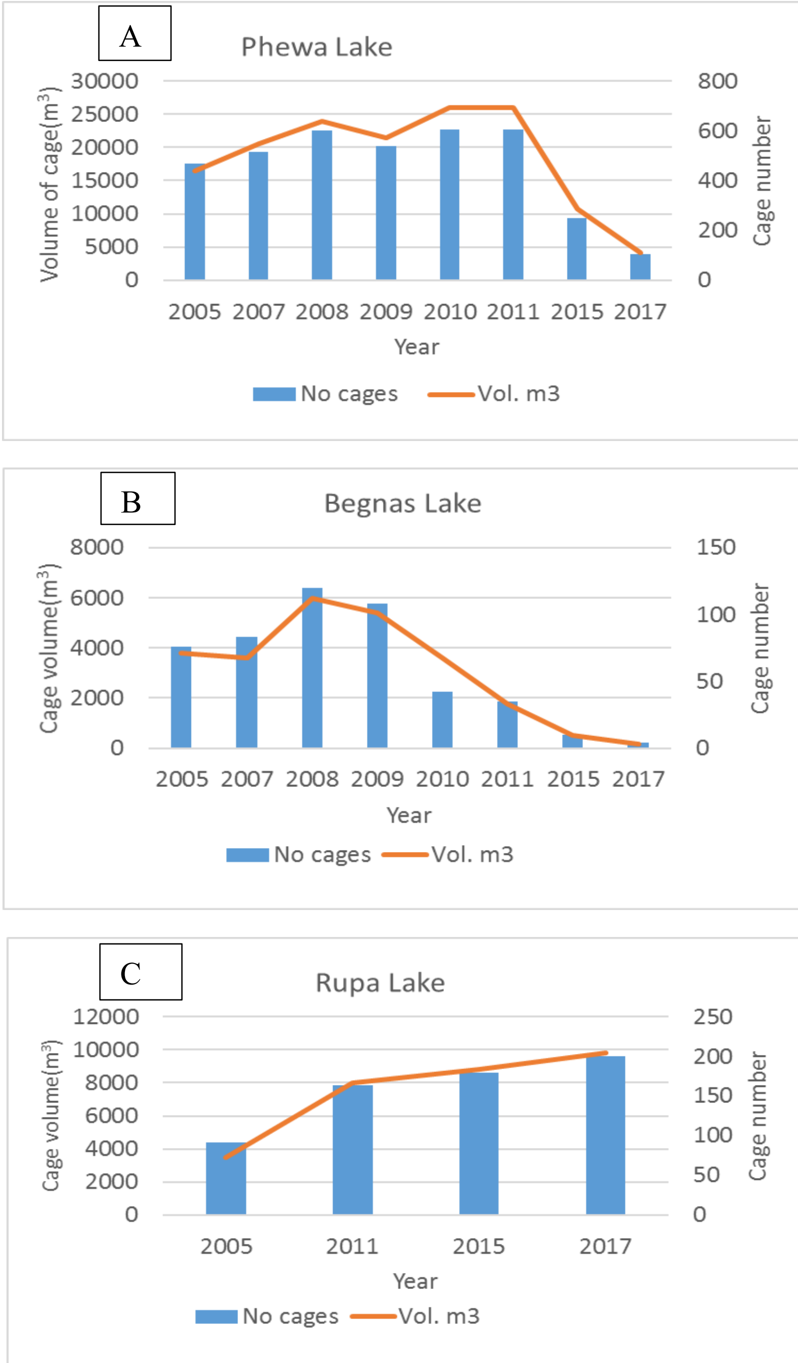

Figure 1. Cage number and volume (m^3) in lakes: Phewa Lake (A), Begnas Lake (B), and Rupa Lake (C).

Cage and pen construction

Nylon or polyethylene net cage have been most popular among cage fish farmers of lakes of Pokhara valley. Generally, farmers are using nylon or polyethylene knot-less floating type cages of 50 m^3 (5m x 5m x 2m) size and cage frame of bamboo structure (Fig.2) act as frame and float (Wagle et al., 2007; Gurung et al., 2009; Bista et al., 2012). However, some farmers are using large sizes cages of 62.5-150 m^3. Local fisherman could weave their own netting of mesh size more than 25 mm locally. Almost 90% of nursery cage is made by netlon cage (Kalo jal) and production cages by nylon or polyethylene threads (Husen, 2010a).

Figure 2. Fish culture in bamboo floating nylon cages in Phewa Lake

Pens are built in shallow waters area of 2-3 m deep in Begnas Lake and 1-2 m deep area in Rupa Lake. The pens in both lakes are located near the shore of lakes. Pens are constructed with nylon or polyethylene with mesh (25mm) nets. The nets are attached to post set in every few meters, and the bottom of the net is pinned to the substrate with long wooden pegs or stones. Most of enclosures were made up by the use of bamboo poles, wooden flakes and net, anchoring with stones in Begnas Lake and wooden poles in Rupa Lake (Fig. 3). Some enclosure made by use of concrete masonry works with netlon nylon screen in Begnas Lake. In Rupa Lake, the durability of bamboo and wooden flakes enclosure is over 15-20 years. In Begnas Lake, where most of enclosure is made by use of netlon net and bamboo stripes and less use of wooden poles and anchoring by stones has durability of 3-8 years (Husen et al. 2010).

Figure 3. Pen fish farming in Rupa Lake

Fish species for cage and pen farming

Fish species used for culture in cages are silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*) and grass carp (*Ctenopharyngodon idella*) in the lakes of Pokhara valley. Monosex Nile tilapia *(Oreochromis niloticus*), Common carp (Cyprinus *carpio*) could be used for the cage culture. Studies have shown that trout farming in lakes and reservoirs of the mid-hills in winter could be one of the alternative opportunities for cage farmers to increase their income (Bista et al., 2004; Gurung, 2008). For pen fish farming, mainly Indian major carps: Rohu (*Labeo rohita*), Naini (*Cirrhina mrigala*), Bhakur (*Catla catla*) and Chinese carp: Bighead carp (*Aristichthys nobilis*), Silver carp (*Hypophthalmichthys molitrix*), and Grass carp (*Ctenopharyngodon idella*) are used in the enclosures of Pokhara valley lakes.

Raising of fry in cages and pen

In the Pokhara valley, farmers use to grow the 1-2 g of silver carp and bighead carp in the nursery cages (Fig. 4) and in around 9 months they reach to sizes of 50-100 g, and there after they are stocked in table size fish production cages (Wagle et al., 2007; Husen, 2010a). Fingerlings are now raised in open cages in Rupa Lake (Fig.6). Pen have been used in Begnas Lake for raising of fry to advanced size fingerlings to release in the lakes (Fig.5). Fish fry is usually fed with oil cake and rice bran. In Assam, fingerlings raised in pens have shown higher rate of survival, better growth and increasing the fish production (Chandra, 2010).

Figure 4. Raising of fry in cages in Rupa Lake

Figure 5. Raising of fingerlings in pen in Begnas Lake

Figure 6. Raising of fry in open cages in Rupa Lake

Culture practices in cage and pen fish farming

The fishes of 50-100 g size are stocked in cages at stocking density 10 fingerlings/m^3. Depending on the type of plankton dominance and the market demands, stocking of fish usually constitutes 60% bighead carp and 40% silver carp and vice versa (Wagle et al., 2007). The best stocking density in Phewa Lake found was 70% bighead and 30% silver carp at 10 fingerlings/m^3 of cage volume (Husen et al., 2012b). In pen culture, 15-20 g sized fish are stocked at about10000fish/ha in the lakes (Husen et al. 2010). No feeding is done for the farming of planktivoruos fish species for cage fish farming. For monoculture of grass carp in cages, submerged macrophytes are fed that are collected from the lake bottom. In the pen culture farm made feed are fed occasionally.

Production and productivity of cage and pen fish farming

According to Wagle et al. (2007), fish production ranged from 1.3-5.0 kg/m^3/yr in a 12-18 months cage culture in the Pokhara Valley Lake. Nepal (2008) reported that the average yield in cage fish culture of Phewa Lake was 1.41 kg/m^3/yr. In an experiment, the cage productivity was found 1.55

kg/m^3/yr at 3:7 stocking ratio of silver carp to bighead carp at a stocking density of 10 fingerlings/ m^3 in Phewa Lake at Khapuadi in the year 2010 (Husen et al., 2012). Total production from cage fish farming was 34.4 mt. in 2017. The production of planktivorous fish in extensive cage fish farming was found decreasing from lakes and reservoirs (Prasad et. al. 2013). Cage fish farming of grass carp in monoculture feeding with aquatic macrophytes was found profitable (8.4kg/m^3) in comparison to planktivorous fish species (3-5kg/m^3) as it approximately doubles the fish production (Prasad et al., 2012). From pen fish farming, generally fish are harvested after one year of stocking. The culture period is usually 10 months. Total fish production from enclosure is 34.44 t in lakes of Pokhara valley with 10.4 t in Lake Begnas and 24.04 t in Rupa Lake. Productivity is 1.58 t and 1.67 t/ha area of enclosure in Begnas and Rupa Lake respectively (Husen et al. 2010)

Fish harvesting and marketing practices

The fish harvested from cages after reaching the marketable size > 500 g. It is based on the consumers demand. The fish harvested from production cage by the use of bamboo pole of length slightly longer than the frame of the cage. The bamboo is inserted beneath the cage at the opposite side of the opening. Then, it is slowly moved toward the opening of the cage. Fishes removed with the help of small scoop net. In the enclosure, either use drag or gill net for harvest of fish. Some farmers used to multiple harvesting four to five times in a year.

The fish marketing is done by both male and female member's .They sale their fish as a partial harvest directly to consumer at their home. Only 2% of cage fish farmer's sale their fish to middleman. There is huge demand of fish in hotels around the Lake (Husen, 2010a). The harvested fish from pen culture are also sold directly to the consumers in the nearest markets and are also sold to the middleman.

Technical advancement in cage fish farming

At present, low productivity of fish from lakes and reservoirs in extensive cage culture (productivity≈1.0kg/m^3/2year) experienced by farmers of lakes and reservoirs. It is due to slow growth of fish in cages because of change of lake environment and low stocking of fish. To solve the problem of low productivity, recently cage aquaculture has been started in Begnas Lake. The results showed that feeding with 20% CP containing floating feed in Begnas Lake, fish yield was higher (0.75±0.1 to0.92±0.1 kg /m^3/year) in comparison to that without feeding (0.33±0.1 kg /m^3/year) (FRS, 2017).

Economics of cage and Pen fish farming

Cage fish culture with planktivorous carps in the lakes of Pokhara Valley is lucrative and profitable and support livelihood of landless fisher community (Sharma, 1979; Swar and Pradhan 1992; Gurung and Bista, 2003; Wagle et al., 2007; Husen, 2010c). Economics analysis of extensive form of cage culture showed that the net return to total investment was 125.2% and average net profit generated was US$ 467.3 (27.3% of income) and US$ 252.4 (18.8% of income) for a fisher family with an average cage holding of 250 m^3 in Phewa lake and 135 m^3 in Begnas lake, respectively (Wagle et al., 2007). The net profit estimated from cage fish culture in polyculture of bighead carp and silver carp without feeding is total NRs is 30593.17(US$ 424.9) is 1.5 times lower than monoculture of Grass carp is NRS 51708.17 (US$718.16) from one nursery and two production cage (Husen, 2010a). The net profit was found NRS 11750/50 m^3 of cage at 3:7 stocking ratio of silver carp to bighead carp at stocking density of 10 fingerlings/ m^3 (Husen, 2010b). Benefit cost ratio of one cage (50 m^3) using silver carp and bighead carp was found 4.1 in Phewa lake (Husen, 2010b).The net profit estimated from enclosure fish farming at present is NRs 152895 (US$ 1528) and NRs 138704 (US$ 1387) per hectare area of enclosure in Rupa Lake and Begnas Lake, respectively (Husen et al. 2010). The net profit from cage and pen fish farming indicated that it is economical to landless fisher community for sustaining their life as they have no other lands and occupations.

Problems in cage and pen fish farming

The unavailability of large size fingerlings (20-25g) to stock cages and quality cage knitting materials hindered the cage fish farming in the lakes of Pokhara valley. Besides, over siltation, landslides, periodic heavy storm in lakes are the some constraints faced by cage fish growing farmers. Sudden fish mortality in cages due to lake over turn also having bad experience for the cage and pen fish farmers. Low quality of cage threads and materials causes fish scale damage at the time of handlings and cage cleaning then fish mortality. Lake environments water is becoming polluted. Invasions of water hyacinth in rainy seasons in the Lakes having negative impact on the cage and pen fish farming.

Way forward

For fish species diversification, suitable species for cage culture should be tested and recommended for different water quality of lakes. Testing of new cage types, materials such HDPE type circular or rectangular cages and new floating materials to support the cages will advanced the cage fish farming in Nepal. Supplementary feeding with quality floating pellet feed in oligotrophic lakes will enhanced the fish production and productivity from cage fish farming. Testing and scaling up of cage and pen fish culture into other potential lakes, reservoirs, rivers, and irrigation canal of Nepal for the expansion of area will address the problems of fish import in Nepal.

Conclusion

Cage and pen fish farming in Phewa, Begnas and Rupa Lakes have been found profitable for small and landless fisher community. Cage and pen fish farming profit contributed major portion to their livelihood. Cage and pen fish culture is an ecologically sound method of fish farming with low cost technology for the fishermen living around the natural water bodies for improving their livelihood. The productivity and return from cage fish farming could be improved if they follow recommended practices with timely supply of adequate number of appropriate size of fingerlings. Fish fry nursing in the community fish nursery of fisher group will be an option for the timely stocking of cages with large size fingerlings (20-25g) in the lakes. The potential of cage fish culture in the upcoming reservoirs of hydropower and in irrigation canal is tremendous in Nepal. It is estimated that 92,400 ha of reservoir will be available for the cage fish farming in near future (Pradhan, 2009).

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Chapter 11

A Case Study on Restoration Using Biomanipulation by Cooperative for Fish Production in Lake Rupa, Nepal

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Introduction

In general, natural small lakes are vulnerable and their overall condition is deteriorating (ILEC, 2007; IUCN, 2004). Once such lakes are degraded, the restoration i.e. to bring them in original state (Bradshaw, 1996) would be difficult, especially by local innovation. Nevertheless, as Leigh (2005) has pointed out that community based restoration could be an instrument to cure ecological crisis, degraded lake ecosystem might be brought back to original stages to great extent by involving cooperatives (Gurung et al. 2019).

In developing countries most lakes are generally government entities, and falls in the category of neglected natural resource (Béné, 2003) because the management consume state resources. In general, absence of adequate management, ownership or multi-ownership is known to be main reasons of degradation of smaller lakes in Nepal. There are numerous small lakes lesser than 500 hectare in area in Nepal (Bhandari, 1998; Gurung, 2007; Gurung et al. 2019) and worldwide. In Asia, many subtropical and tropical lakes are heavily eutrophicated and degraded due several reasons including, the global warming, thus gaining knowledge on nutrient, energy, trophic web interactions and possible lake restoration is desirable for sustainable development.

In biomanipulation, generally obtaining high transparency by allowing the growth of aquatic plants by adding predatory fish or removal of benthic fish species in lakes were prioritized (Moss, 1998; Richter, 1986; Rowe and Champion, 1994; Baldry, 2000; Bio et al. 2008). Most of biomanipulation studies were focused on water quality for obtaining high transparency with clear water by supporting aquatic weeds growth (Jeppesen et al. 1997; Shapiro, 1990; Søndergaard et al. 2017). The role that could play by herbivore carp such as (*Ctenopharyngodon idella*), phytoplankton feeder silver carp (*Hypophthalmichthys molitrix*) and zooplankton feeder (*Aristichthys nobilis*) and common carp (*Cyprinus carpio*) on water quality regulation were well known since early times (Mitchell, 1980; Rowe, 2007).

Dissolved Oxygen (DO) is one of the most important 'life giving' parameters (Wetzel, 2001; Tang et al., 2013) to determine the state of water quality. However, biomanipulation and restoration experiments rarely prioritized DO, removal of disadvantageous aquatic plants, fish production, livelihood and cooperative management approaches. Therefore, the present case study elucidates a long term biomanipulation tool for balancing phytoplankton abundance, consistent transparency and higher DO concentration in water column as a part of degraded lake restoration by addition of herbivore, bottom and plankton feeder carp and theirs removal or harvest by a local cooperative in Nepal.

Fig 1. Aerial photograph of Rupa Lake taken around 1980 (B), Cooperative members (B).Rupa Lake around 1998, a degraded phase (C), Rupa Lake in 2010, a restored lake by carp biomanipulation (D)

Methodology

The Lake Rupa is a small water body of approximately 100 ha with maximum depth of about 4.7 m, which has been reduced down from 135 ha of total area and maximum depth of 6.5 m in 1972. Rupa Lake Restoration Fishery Cooperative is located along the west-southern bank of Lake Rupain Rupakot Village Development Committee, Kaski District, and Central Himalaya in Nepal at an altitude of 600 m from the sea level (Fig. 1 A, 1B). The cooperative was established formally in year 2001 (Gurung, 2007; Chaudhary et al. 2015). For whole lake fish addition and removal experimentation, carp fry (mean body weight ~2 g each) were obtained from Fisheries Research Center located in Lake Begnas about 3-4 km away from Lake Rupa. The added number of carp fry was kept low ranging from 6894 in 2002 (Gurung, 2007) but only 772 in 2011/12.

Detail on stocked number of fry from year 2002/03 to 2006/07 is illustrated in Gurung (2007), while from 2007/08 to 2015/16 has been shown in Table 1. A combination of carp species having bottom browsing (*Cyprinus carpio*); detritus and plankton feeding during fingerling stage, but filamentous algae, decomposed vegetation feeder such as *Labeo rohita* (Chondar, 1999); *Cirrhinus mrigala* an illiophagous (feeding on decayed vegetation) and zooplankton feeder (bighead and *Catla catla*) were added in different years.

After one year of carp addition, the larger ones mostly above 2 kg were strategically removed using 250 mm mesh size gill nets. The gill nets were set up every evening except few festival holidays. Captured fish were weighted before marketing. Basic water quality parameters such as water temperature, transparency, pH, Chlorophyll *a*, Phosphate, Total Phosphorus (TP), Ammonium Nitrogen (NH4+N), Nitrite+Nitrate (NO_2+NO_3) were measured once in every month, from 2007 to 2010. The detail methods of water sampling, collection and analysis has been given in Gurung (2007).

Findings

Effects of carp biomanipulation on aquatic weed control: After the carp fry addition they grew well and gradually showed their impacts as predicted. Major aquatic plants started to disappear. Many merged, submerged and floating plants were consumed by grass carp; on addition uprooted by browsing activities of bottom feeder common carp. There was high turbidity caused by upwelling of bottom sediments due to the common carp activities that reduced abundance of floating, merged and submerged plants.

For 2-3 years there were patchy floating vegetation blocks up to 750 m^2 or bigger in most parts of the lake. Probably those floating masses were comprised of decaying plant materials, sediments and green vegetation. Those blocks were probably uprooted by common carp, thus appeared as floating masses. Some of those floating chunks were manually pushed out of the outlet streams by cooperative members. The excess weeds are reduced down gradually and by 2007-08 there were only about 10% coverage area remained. Later the lake become more dominant by phytoplankton as predicted (Fig. 1 C and D).

Table 1. Carp species (Common = *Cyprinus carpio*, Grass = *Ctenopharyngodon idella*, big head = *Aristichthys nobilis*, silver carp = *Hypophthalmichthys molitrix*, rohu = *Labeo rohita*, bhakur = *Catla catla*, Naini = *Cirrhinus mrigala*) stocking number in Rupa Lake from 2007/08 to 2015/16

Carp species	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Common carp	12,700	64,970	26,215	-	-	3,085	41,273	46,500	21,000
Grass carp	26,000	41,185	28,146	-	-	6,820	2,190	20,500	4,000
Bighead	12,116	6,400	22,032	27,541	6,661	40,009	-	15,260	-
Silver carp	18,000	9,390	14,123	17,638	20,495	-	41,221	-	14,859
Rohu	36,000	105,944	61,124	293,062	13,115	64,805	32,850	21,100	3,400
Bhakur	13,222	5,190	36,166	39,424	8,992	3,085	-	11,000	100
Naini	9,180	10,000	22,075	12,640	18,235	6,820	23,818	48,100	29,302
Total	127,218	243,079	209,881	390,305	67,235	114,719	141,352	162,460	72,661
Stocking rate (No. ha^{-1})	1272	2430	2098	3903	672	1147	1413	1624	726

Fish removal by recapture practices: The fish removed from the lake or captured by the cooperative reached up to 60 t in year 2008-09 (Figure 2) with a value of 70,000 US$. The market value of removed fish sale reached upto 150,000 US$ per year. However, after 2009 the total fish removed has been declined reaching about 23.6 t

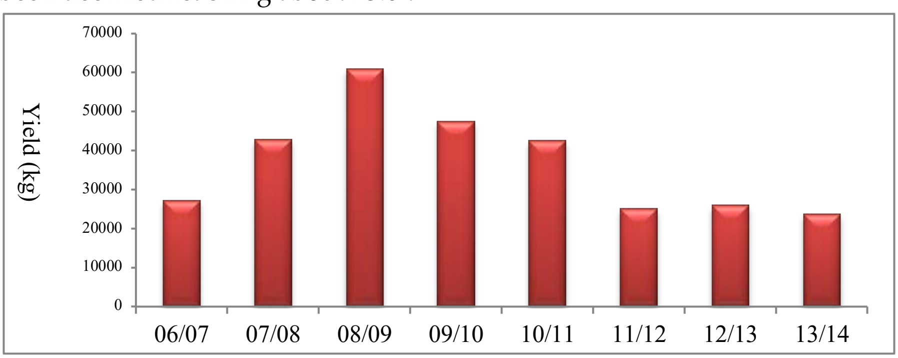

Figure 2. Annual fish removed or captured from Rupa Lake Cooperative from year 2006/07 to 2013/14

Dissolved Oxygen: From 2007 to 2010, the minimum DO has been improved and reached to 3.4 mg l^{-1} onwards in later years in same depths and months of April 2007 while, highest was 12.7 mg l^{-1} in the month of December 2010 (Fig. 3 A). The DO in general was lowest in the months April or May. The DO tended to be equal in water column at 0, 1 and 2 m from January to May, while differentiated in the months June-August.

Chlorophyll a: The chlorophyll *a* concentration from the year 2007 to 2010 was in a range of 0 to 58.74 mg l^{-1} at surface (Fig. 3 B) tended to be higher during the months of June-September (Fig. 3 B).

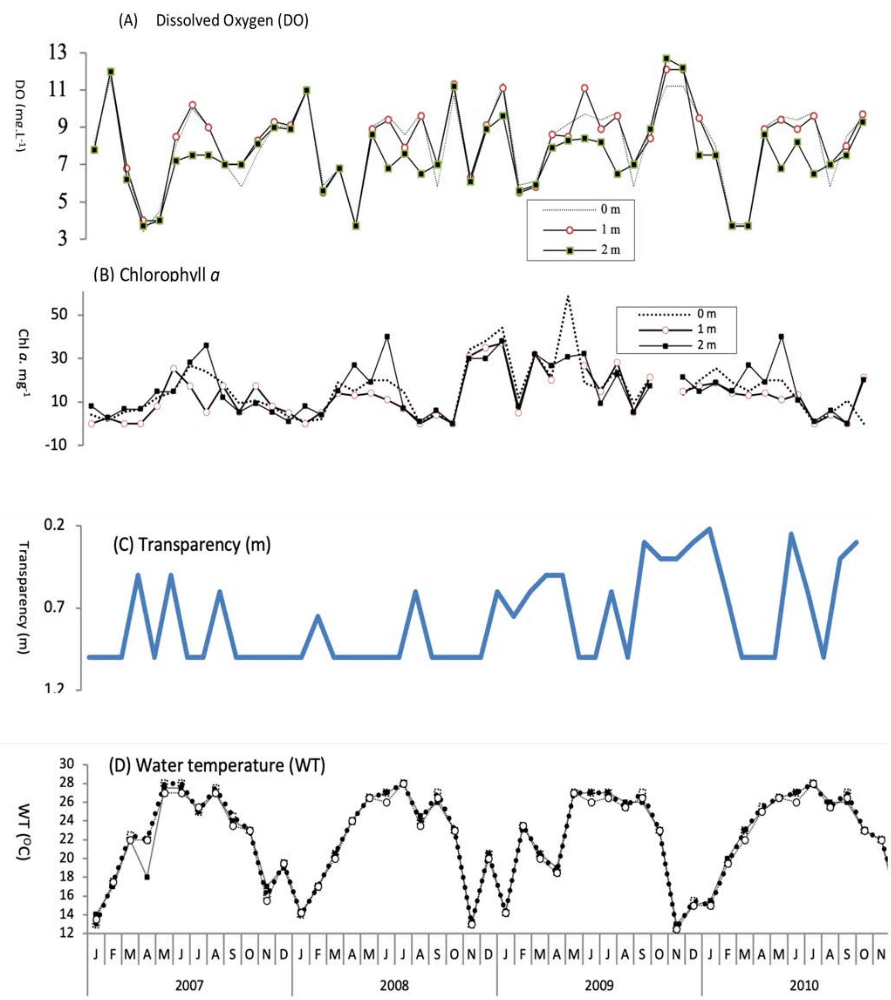

Figure 3.Some water quality parameters (A) DO, (B) Chlorophyll *a* (C) Transparency and (D) water temperature in Lake Rupa during biomanipulation phase (2007-2010).

In general, the chlorophyll a was higher during the months of June-Sept, except in 2008 when higher value occurred in May.

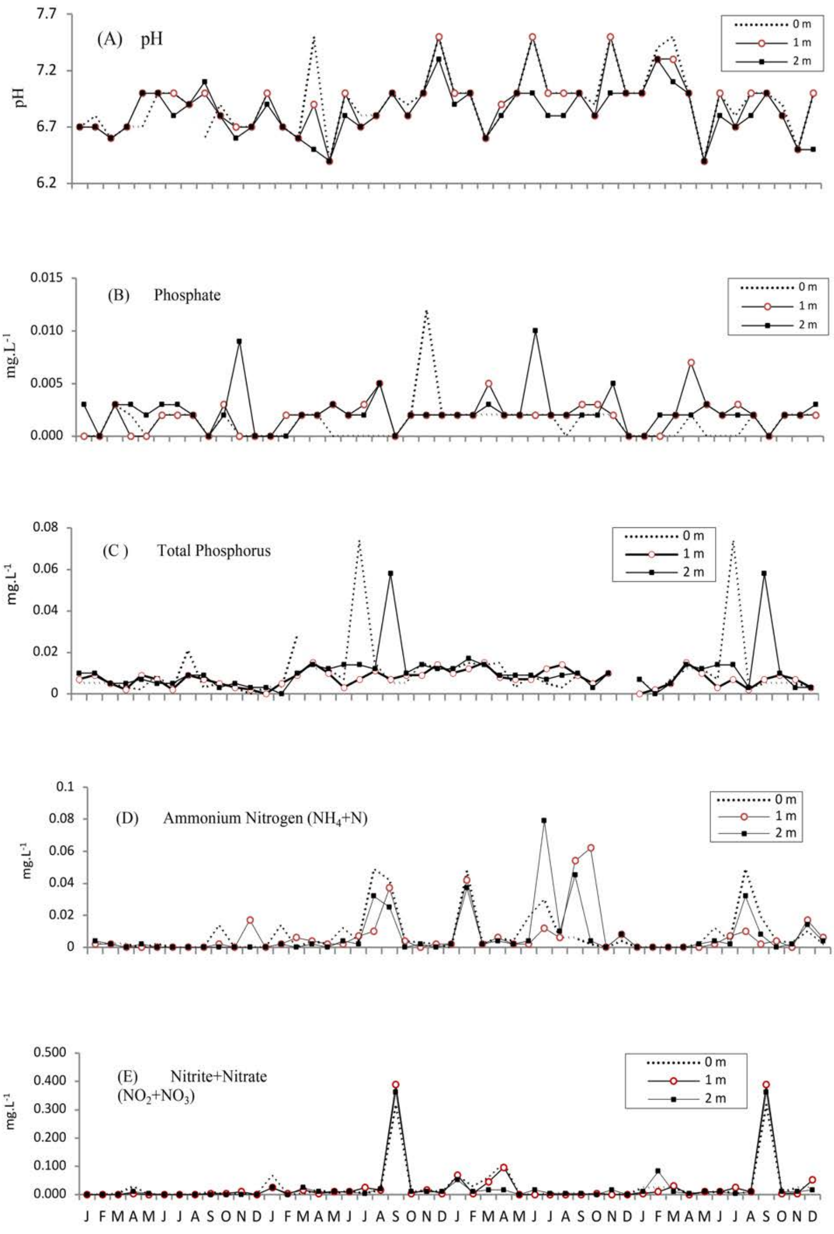

Figure 4. Seasonal changes in pH, phosphate, TP, NH_4+N, and NO_2+NO_3 in Lake Rupa at different depths (from 2007-2010)

Transparency: The water transparency, in general, still not consistent varied from 0.22 m in the month of March 2010 to the maximum of 1 m in most sampling months (Fig 3C). The transparency tend to be clear and high in the months of January, February, October, November when the lake water is calm and not expected to be disturbed by strong wind, rain and rainwater discharges (Fig 3C).

Water Temperature: In general, the water temperature showed clear seasonal trends. The water temperature ranged 12.5 ^{0}C in November 2009, while highest was 28 ^{0}C in the months of May, June and July of 2008 and 2009 (Fig. 3D).

pH: The pH in lake water ranged from 6.4 to 7.5 (Fig. 4A). The lowest value in the month of May in 2008, and 2010, the higher values undulated in various months (Nov, March, April, and December).

Phosphate, Total Phosphorus, Ammonium Nitrogen, Nitrite+Nitrate: Phosphate ranged from 0 to 0.012 mg $l^{-1}$with higher value at 2 m depth (Fig. 4B) in November 2007; a peak was noticeable in November again, at surface layer (0m) in 2008. In other sampling periods the phosphate was less than 0.011 mg l^{-1} (Fig. 4 B).The undetected values appeared frequently, however the maximum value was in November 2008. Total phosphorus value ranged from 0 to highest value of 0.074 mg l^{-1} at surface in July 2008 and 2010 (Fig. 4C). The Ammonium Nitrogen maximum value was 0.079 mg l^{-1} in June at bottom in 2009. In the month of July 2008 other peak was remarkable (Fig 4D). Nitrite +Nitrate value appeared were0.318 mg l^{-1} in the month of September 2008 and 2010 at surface layer (Fig. 4E). The Nitrate+ Nitrite concentration tend to show higher values in the months of June to September (Fig. 4 E).

Some characteristic features of lake Rupa before and after the restoration by cooperative approach has been shown in Table 2. The inconsistency in surface are of the lake was probably due to some over and under estimations. The lake maximum depth, mean depth, total volume, length, breadth have been reduced down than before in 1978. The DO has substantially improved after the restoration. The fish production has also gone higher reaching up to 60t in a year.

Table 2. Some characteristic features of lake Rupa before and after the restoration by cooperative approach (Based on Gurung, 2007)

Description	After Ferro & Swar (1978)	After Rai et al. (1995)	After Rai (2000)	After Gurung (2007)	Present study
Surface area (ha)	117	135	-	~100	~99
Maximum depth (m)	6.5	6		4 .7	nd
Mean depth (m)	2.3	3		2.7	nd
Vegetation coverage %	~5	~65		~35	~ 5
Volume (x10^5 m^3)	–	32.5	-	31	nd
Length (m)	–	2800	-	2700	nd
Breadth (m)	–	400	-	–	nd
Surface Temp (^{0}C)	–	14–30		15–28	13-28
pH	–	5.6–7.8		6.9–8.5	6.4-7.5
No. of fisher family	5	6	-	6	3
DO (mg/l)	–	5.0–8.9	-	1.6–11.3	3.4-12.7
Fish catch (ton/year)	3.0	–	-	18.0	27-60
Cooperative members	-	-	-	38	760

Conclusion

The present case study showed that combination of carp stocking in appropriate density (common carp, grass carp, silver carp, bighead carp) can controlled the spread of aquatic vegetation, enhance the growth of phytoplankton, increase DO in water column, in general. Application of this model of stocking and management might be applicable to restore millions of such a shallow and smaller lake facing degradation throughout the world.

DO is the most important parameter (Wetzel, 2001) which require to restore in lake water column necessary to fish, invertebrates, bacteria and plants (Fowler and Miller 2007). The oxygen deficiency that reported in earlier studies (Rai, 2000; Gurung, 2007) was probably because DO was consumed to decay demised aquatic plants; organic matter that might have entered into in the lake with pre monsoon rain along with onset of increasing temperature. The DO is one of the main indicators of water quality, thus without interpreting the DO concentrations in water column the complete story of lake restoration may not be revealed. Gurung (2007) showed that the DO increased in the water column after intervening by carp addition, which favored phytoplankton abundance over macrophytes. In present study the lowest DO was 3.4 mg.L^{-1} in the month of April showing improvement (Fig 3 A) in same month than earlier years when DO was recorded almost none (Rai, 2000) causing mass fish kill.

It is known that by reducing the submerged aquatic vegetation, more phytoplankton abundance might occur because phytoplankton might have advantage on submerged plants for nutrient use in water column (Moss, 1998; Gurung et al. 1999; Sabin 2010). The dense phytoplankton might control sunlight to penetrate deep into the bottom preventing photosynthesis by merged and submerged plants. The phytoplankton, in turn release oxygen into the water column as a byproduct of photosynthesis. With restoration of DO in water column, the lake became suitable for fish growth and production. Gurung (2007) demonstrated that cooperative based restoration actually works well. With the help of bio-manipulation the weeds in the lake has been cleaned. Cage fish culture and captured fisheries resumed with an increased annual catch for income generation and livelihood to fishers. The present study demonstrated that addition and removal of carp balance abundance of phytoplankton, DO and aquatic vegetation.

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Chapter 12

Aquaculture Products Quality Assessment for Marketing and Trade: A Study of Nepal

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Introduction

Preference of fish consumption has been increased recently in Nepal to supplement the other source of animal protein. Fish protein is compared favorably with eggs, meat and milk in its amino acid content, and has a higher level of essential lysine and methionine both of which are lacking in a cereal-based diet (Eyo, 2001; Amusan and Okorie, 2002). Most of the fresh fish markets of Nepal are in southern Terai area where 90% of country's fish are produced, and in the major cities where fresh fish are supplied. Transportation of fresh fish for marketing in far remote areas of Nepal is very limited because of its heaviness and perishable nature. High nutrient content, neutral pH and high-water activity makes fresh fish perishable within short period of time and starts to deteriorate immediately after catch (Huss, 1995).

The dried fish could be one of the alternatives sources of animal protein for many people living in remote and poor physiographic areas because of enhanced self-life and lightness of the dried fish. Traditionally fish collected in Nepal from rivers, wetlands and ponds is locally preserved in the form of dry fish in order to retain quality for longer (Shrestha, 1999). This product has been marketed where there are poor road access areas and mountainous regions, where often severe malnutrition persists, and transportation of bulky commodities is difficult. As a result, the demand for dry fish has increased in recent years and the dried fish coming from wild capture is not enough to meet the ever-increasing demand for fish.

Small sized whole fish, mostly mrigal (*Cirrhinus mrigala*), is commonly called as chhari fish. Dried fish is a popular fish product and has good market in Nepal. Considering the demand for small sized dry fish, fish farmers started farming of chhari fish. Farming of chhari mrigal fish is more compatible for multiple stocking and harvesting which results in high yield.

The appropriate size of fish for production and drying preferred is ranged between 20 to 100 g. Dried fish of this size is believed to be stored for long period of time and consumed when desired. Market of dried chhari fish has expanded rapidly and has established network centers. Central Terai of Nepal (Bara, Parsa and Rautahat districts) is the main site for chhari size fish production. Chhari produced in central Terai are processed in different locations, far from production sites, require considerable time for fresh fish transportation. Fresh fish should be preserved as soon as possible because chemical breakdown of protein, fat and water contribute to quick spoilage (Daramola et al., 2007). Poor quality dried fish consumption as well as export has been declined (Sugumar et al., 1995). The spoilage of dried fish is mainly due to bacterial, fungal or yeast action, rancidity, autolysis, browning and other reactions, all of which are temperature and moisture dependent (Doe, 1982). The quality of the dried fish never receives much attention at any stage of processing, storage and marketing (Gupta and Samuel, 1985). Little efforts were made to study the cause, nature and extent of deterioration of dried fish even though the poor quality of dried fish product is a well-known fact. Since few years, commercially dried chhari mrigal is available in the markets, which has high consumer's demand in different parts of Nepal. But the quality and food safety status of locally processed chhari mrigal is not yet known. In dried fish products the oil and moisture content are considerably low and protein content is more on weight for weight basis (FAO, 1989). Nevertheless, cooking and preservation techniques could cause modifications in proximate composition, fatty acids and amino acids as well as changes in solubility and nutritional quality of fish (Castrillon et al., 1997; Yamamoto and Imose, 1989; Selmi et al., 2010). Improperly or inadequately dried fish could reabsorb moisture and develop favorable condition for bacterial and mold growth. The present study was undertaken to assess the quality (proximate, biochemical and microbial) of dried mrigal chhari fish available at different market outlets and processing sites of Nepal.

Materials and methods used for the study

A survey based on semi structured questionnaires followed by interview was carried out at commercially fish processing center, wholesale and retail markets during 2014 to 2015. A sum of 36 respondents was asked about the fish curing and drying methods, storage condition, post-harvest loss and marketing, they follow. The general conditions of the curing yards and the methods preparations were noted at each center.

A total of 36 samples of cured (partially gutted and washed) and uncured (ungutted and unwashed) dried fish were collected from the fish processing centers and their respective wholesale and retail markets. The samples were subjected to proximate, chemical and microbial analysis at Public Laboratory, Lalitpur. The proximate composition of the samples was determined following standard methods of AOAC (1995) (Table 2). Peroxide value (PV) was determined by titration method as described by Onwuka (2005). Total plate count (TPC), cfu/g was determined by Most Probable Number (MPN) technique and pour plate method for enumeration of mold (APHA, 1992). The differences in moisture content, protein content, fat content, PV, TPC and mold between cured and uncured dried fish were tested by standard statistical models.

Results

Processing system and physical loss

Survey revealed that smoking is the only method of fish drying for both cured and uncured chhari size fish practiced in commercially fish processing centers. At the uncured fish processing centers fish are transported from the landing centers to the drying place in jeep or rickshaw and heaped on the floor directly. Fish are smoked whole, without washing, gutting and removal of gills in uncured fish processing centers. For smoking a locally made mud oven about 1.0 to 1.5 cubic meter size is prepared under the ground with brick and mud. The fish which are heaped on the ground without ice are arranged on the iron mesh frame one by one laying the belly downward. Then the iron mesh frame with fish is kept over the mud oven one above another up to four to five layers and covered with thick paper. Smoke is produced from the burning of wood.

At the cured fish drying centers fish from landing sites are transported by preserving in ice in styrofoam box. Before drying, fishes are washed with water, split opened the ventral part, and guts are removed partially. Small sized fish are dried whole, big sized fish are made in to pieces before drying. For smoking the fish a temporary mud oven is constructed above the ground with bricks. Smoke is produced from burning of wood.

According to the respondents the duration of chhari fish drying period was depended on the size of fish, usually larger the size longer the duration of drying. The days required to dry 25-50g, 51-75g and 76-100g sized fish are one, two and three respectively. The dried fish were stored differently at cured and uncured fish processing centers. In uncured fish processing centers dried fish were kept on iron wire mesh cage. The iron wire mesh frame with dried fish were piled one above another and kept inside the cage made from iron wire mesh. The dried fish were also stored inside the underground mud oven by keeping on iron wire mesh frame and covered with aluminum sheet. In cured fish processing centers, most of the dried fish are kept hanging in rope inside the room. Dried fish are also kept in tokari (made of bamboo). At both cured and uncured fish processing centers dried fish are stored open, without packing. At cured fish processing centres the dried fish are sold within 4-5 days, whereas in uncured fish processing centers the dried fish are transported to Kathmandu after one week of drying. In wholesale and retail shops of all market places dried fish are stored as open in big sized plastic bags for sale.

The post-harvest losses of dried fish are due to insect infestation, mold, fragmentation, bird and animal predation (Table 1). Mold causes 40-50% of spoilage of dried fish in uncured fish processing centers. The loss of dried fish in cured fish processing centers due to insect infestation and mold are 30-40% and 35-40%, respectively. Post-harvest loss due to birds and animal predation is also high (30-35%) in uncured fish processing centers.

Table 1. Estimated physical loss of cured and uncured dried fish in the processing sites during storage

Cause of post-harvest loss	Uncured dried fish (%)	Cured dried fish (%)
Insect infestation	20-30	30-40
Mold	40-50	35-40
Fragmentation	10-15	20-22
Bird and animal predation	30-35	15-20

Nutrient quality and microbial loads

The proximate compositions of cured and uncured dried fish in different market channels are presented in Table 2. The Moisture content of cured dried fish at the processor level is low (6.9 ± 0.2 %) and subsequently increases at retail (9.6 ± 0.1%) level. The protein content of both cured and uncured dried fish was decreased from processor to retail. The fat content of cured dried fish also decreased from processor to retail.

Table 2. Proximate composition of cured and uncured dried fish at different marketing channels (mean ± SD) (n = 3)

Market channel	**Moisture (%)**		**Protein (%)**		**Fat (%)**	
	Cured	**Uncured**	**Cured**	**Uncured**	**Cured**	**Uncured**
Processor	6.9 ±0.2^{a}	10.6±1.8^{a*}	73.4 ±0.7^{c}	67.2± 2.4^{b*}	12.4±0.1^{c}	9.6±1.0*
Wholesale	8.9±0.2^{b}	13.0±1.7^{a*}	68.5±1.1^{b}	62.8±2.6^{a*}	9.7±0.2^{b}	8.6±3.2
Retail	9.6±0.1^{c}	18.1±2.8^{b*}	64.3±0.7^{a}	60.4±3.6^{a*}	6.7±0.2^{a}	7.0±1.6

Different superscripted letters within column are significantly different at ($p < 0.05$).

*Denotes significant different ($p < 0.05$) within row.

Table 3. The peroxide value (mEq O_2/kg of fat) and pH of cured and uncured dried in different market channels (mean ± SD) (n = 3)

Market channel	**Peroxide (mEq O_2/kg of fat)**		**pH**	
	Cured	**Uncured**	**Cured** **Mean (H+) and range**	**Uncured** **Mean (H+) and range**
Processor	6.3±1.1^{a}	8.3±3.8	6.02 (5.9 - 6.2)	6.01 (5.8 - 6.2)
Wholesale	8.3±0.2^{b}	10.3±5.2	6.27 (6.2 - 6.4)	6.34* (6.2 - 6.5)
Retail	9.4±0.5^{c}	16.6±11.1	6.39 (6.4 - 6.6)	6.75* (6.6 - 7.0)
Over all mean	8	11.7		

Different superscripted letters within column are significantly different ($p < 0.05$).

*Denotes significant different ($p < 0.05$) within row.

The total plate count (TPC) increases from processor to retail in both cured and uncured dried fish marketing channels (Fig. 1). Also, TPC content of uncured dried fish is significantly higher ($p < 0.05$) than cured dried fish at processor center. Same was the case in wholesale and retail market.

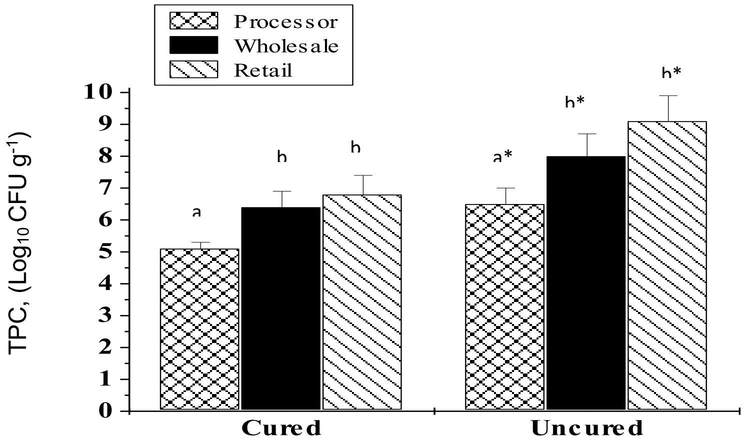

Figure 1. Total Plate Count, (Log_{10} CFU g^{-1}) of cured and uncured dried fish at different market channels. Different superscripted letters denote significant different at ($p < 0.05$) within processing method. An asterisk denotes significant difference ($p < 0.05$) within market outlets between processing methods.

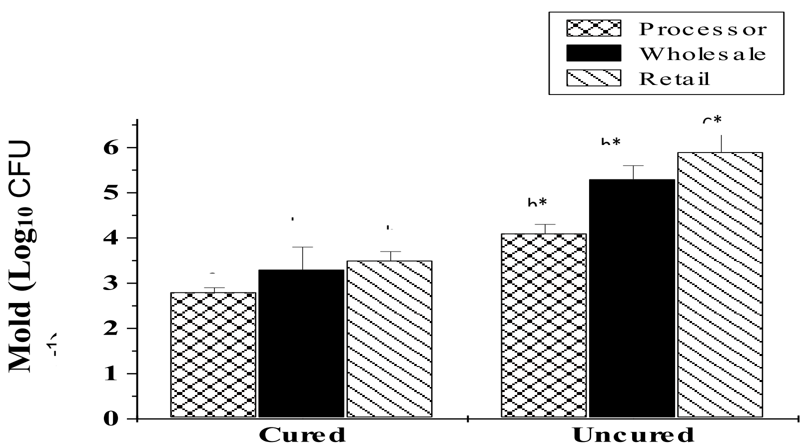

Figure 2. Mold (Log_{10} CFU g^{-1}) of cured and uncured dried fish at different market channels. Different superscripted letters denote significant different at ($p < 0.05$)within processing method. An asterisk denotes significant difference ($p < 0.05$) within market outlets between processing methods.

Conclusion

The study showed that the inherent health risks associated with delayed consumption of smoke-dried fish purchased from open markets. Since most of the microbial species isolated during this study are probably contaminants rather than originating in the fish, better methods of preservation (curing, processing, drying and storage) and handling will reduce their incidence or eliminate them. The fish absorbs moisture during storage. Therefore, storing smoked fish at low initial moisture content (< 20%) under ambient conditions (25^{o}C) would not be advisable or considered as proper storage. The proximate analysis is a useful tool to determine the nutritive quality of smoke-dried fish as the nutritional contents of the fish. Purchased smoke-dried fish should also be properly cooked prior to consumption in order to reduce or kill hazardous spore-forming microorganisms. It is recommended that more research be carried out to determine the time lapse between processing and sale of smoke-dried fish in open markets in order to give a better idea of the length of storage of these products.

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REPORT OF THE SAC/ MINISTRY OF AGRICULTURE AND LIVESTOCK DEVELOPMENT, DLS/CFPCC, NEPAL /DIRECTORATE OF LIVESTOCK AND FISHERIES DEVELOPMENT, MLMAC, GANDAKI PRADESH, NEPAL ON "FISH CULTURE IN CAGES AND PENS IN RESERVOIRS, LAKES, RIVERS AND MARINE WATERS FOR AQUACULTURE DIVERSIFICATION IN SOUTH ASIA"

(17-19 April 2019, Waterfront Resort Hotel, Lakeside, Pokhara, Nepal)

Opening of the session

The SAARC Agriculture Centre (SAC), Dhaka, Ministry of Agriculture and Livestock Development, DLS/CFPCC, Nepal, and the Directorate of Livestock and Fisheries Development, MLMAC, Gandaki Pradesh, Nepal jointly organized the Regional Expert Consultation on "Fish Culture in Cages and Pens in Reservoirs, Lakes, Rivers and Marine Waters for Aquaculture Diversification in South Asia", at Waterfront Resort, Lakeside, Pokhara, Nepal during 17-19 April, 2019. The meeting was attended by the National Focal Point Experts of 7 SAARC member countries, experts from Nepal Agricultural Research Council, SAARC Agriculture Centre, Ministry of Agriculture and Livestock Development, DLS/CFPCC, Nepal, Directorate of Livestock and Fisheries Development, MLMAC, Gandaki Pradesh, and Agriculture and Forestry University, Nepal. Welcome addresses were delivered by Hon'ble Lekh Bahadur Thapa Magar, Minister for Land Management, Agriculture and Cooperatives, Gandaki Pradesh, Nepal; His Excellency Mr. Amjad Hussain B. Sial, Secretary General, SAARC; Mr. Prakash Mathema, Secretary, Ministry of Agriculture and Livestock Development; Dr. Tek Bahadur Gurung Executive Director, Nepal Agricultural Research Council; Mr. Sharad Chandra Shrestha, Secretary, Ministry of Land Management, Agriculture and Cooperatives, Gandaki Pradesh; Chief Fisheries Development Officer, Central Fisheries Promotion and Conservation Center, Balaju, Nepal and Dr. S. S. Giri, Senior Program Specialist (Fisheries), SAARC Agriculture Centre, Dhaka, Bangladesh.

The regional expert consultation was organized with the objectives:

- Identification of drivers of diversified aquaculture.
- Review the research and development needs for sustainable aquaculture development in the SAARC region.
- Coordination of the regional research, extension and training activities to assist the development of sustainable diversified aquaculture in South Asia.

Papers presented

A total of 7 country papers on "Fish Culture in Cages and Pens in Reservoirs, Lakes, Rivers and Marine Waters for Aquaculture Diversification in South Asia" were present at the expert consultation, covering Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. Another four technical papers covering crucial aspects of aquaculture diversifications and their opportunities, challenges, available policies and future needs were also presented by the acknowledged experts from the SAARC nations in these special fields.

Recommendations

Technological Issues

- Greater success of diversification lies with species choice that directs towards those with very limited and seasonal availability
- The new candidates species should have high fecundity and seed survival, tolerate a wide range of culture conditions and climate change; come from lower trophic levels; have cost-effective feed conversion; short production cycles; and high consumer preferences
- Evaluation is required for potential new technologies, markets, socio-economic and environmental sustainability of diversification
- Collaborative research and development are necessary to develop location and species specific cost-effective balanced feeds, since in cage and pen culture the contribution of natural feed is negligible
- Culture density may be decided on the basis of the species behaviour, prevailing environmental conditions and production system to be used

Policy Issues

- While considering the use of non-native species, the guidelines of the International Council for the Exploration of the Sea and FAO Technical Guidelines for Responsible Fisheries should be followed
- Diversification of culture systems, e.g. recirculating aquaculture systems (RAS), integrated multi-trophic aquaculture (IMTA) and offshore aquaculture should ensure bio-security in the culture of exotic species, eliminate seasonality, preferably located close to markets, reduce water use and with effluent treatment
- While choosing the sites, the foreseeable environmental stresses should be considered
- Grant supports required at National and SAARC regional level to initiate and diversify cage and pen culture

- Development and implementation of aquaculture insurance program that provides coverage the losses due to natural perils
- Networking and collaboration on capacity building between institutions among regional, international and donor countries
- Exchange of potential germ plasm among member states to augment aquaculture diversification
- Encouraging entrepreneurial participation in the value chain of cage and pen culture to ensure sustainability
- Advocacy at various levels is felt necessary for the due recognition of aquaculture and fisheries sector-Policy

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

Social issues

- Research and development, appropriate to the diversification of aquaculture in the region, to address food and nutrition security, sustainability, livelihood and social issues; public and private investments
- Strengthening community participation through knowledge and capacity building in culture based fisheries and natural water aquaculture management

Following this Expert Consultation, which has recorded for the first time, the importance of aquaculture diversification 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 aquaculture and its diversifications, institutional frame work and capacity available in SAARC member countries; and
- organize further meetings and finally drafting the policy to be followed for aquaculture diversification in south Asian region. Also, framing policy for technological and financial support to farmers of the region for aquaculture diversification for sustainable aquaculture development as livelihood support and revenue earning through export and trade.

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