



Fisheries Sector Contribution for Sustainable Food System: Past, Present, and Future

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Abstract

At global scale, the capture fisheries and aquaculture provide 3 billion people with almost 20% of their average per capita intake of animal protein, and a further 1.3 billion people with about 15% of their per capita intake. This share can exceed 50% in some countries. Fish are extremely important and fish farming has developed rapidly over the last 30 years: total dietary protein from fish is between 50% and 60% in Sri Lanka. Fish provides a similarly significant proportion of protein in the human diets in most small island nations in the world. The fisheries sector of Sri Lanka consists of three main subsectors, namely, coastal, offshore and deep sea, and inland and aquaculture. These three subsectors employ around 250,000 active fishers and another 100,000 in support services in Sri Lanka. Sri Lankan fisheries are managed by two core legislative instruments, namely, Fisheries and Aquatic Resources Act No. 2 of 1996 and Fisheries Act No. 59 of 1979, along with several regulations to assist in the implementation of these acts. The industry has seen a change of fortune in the recent past with a boost with the reinstatement of GSP Plus from the USA and lifting of export banning of fish to European Union (EU) in the recent past. Sri Lankan tuna, shrimps, and crabs have quality of unique taste and texture. Meanwhile, the Sri Lankan government agencies are also seeking to position the country's marine and inland fishing industries as major export earning sectors as well main source of economics and food security considering its nutritional impact on nations consuming plant-based diets. Thus, governance needs to ensure that fisheries and aquaculture adapt to the impacts of climate change and improve the resilience of

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food production systems where one of the solutions is integration. Availability of these natural aquatic resources provides immense opportunities to achieve high economic growth with guaranteed food and nutritional security for its population in near future by blue economic revolution.

Keywords

Fisheries · Aquaculture · Sustainable food system · Integration · Sri Lanka

14.1 Introduction

14.1.1 World Fisheries Resources and Captures: Current Context

Fisheries and aquaculture remain important sources of food, nutrition, income, and livelihoods for hundreds of millions of people around the world. Starting from 1950, global catches rose until 1988. With capture fishery production relatively static since the late 1980s, aquaculture has been responsible for the impressive growth in the supply of fish for human consumption. Whereas aquaculture provided only 7% of fish for human consumption in 1974, this share had increased to 26% in 1994 and 39% in 2004. Global total capture production in 2014 was 93.4 million mt, of which 81.5 million mt was from marine waters and 11.9 million mt from inland waters (SOFIA 2016). China is the main fish producer and the largest exporter of fish and fishery products. For marine fisheries production, China remained the major producer, followed by Indonesia, the United States of America, and the Russian Federation.

The Northwest Pacific remained the most productive area for marine capture fisheries, followed by the Western Central Pacific, the Northeast Atlantic, and the Eastern Indian Ocean. With the exception of the Northeast Atlantic, these areas have shown increases in catches compared with the average for the decade 2003–2012. The situation in the Mediterranean and Black Sea is alarming, as catches have dropped by one-third since 2007, mainly attributable to reduced landings of small pelagics such as anchovy and sardine, but with most species groups being affected. World catches in inland waters were about 11.9 million mt in 2014, continuing a positive trend that has resulted in a 37% increase in the last decade. Sixteen countries have an annual inland water catches exceeding 200,000 mt, and they represent 80% of the world total with China leading in both global marine and freshwater fish production (SOFIA 2018).

Production from aquaculture in 2014 amounted to 73.8 million mt, while China accounted for more than 60% of (45.5 million mt). Other major producers were India, Viet Nam, Bangladesh, and Egypt. In addition, 27.3 million mt of aquatic plants (US\$ 5.6 billion) were cultured. Aquatic plant farming, overwhelmingly of seaweeds, has been growing rapidly and is now practiced in about 50 countries. As indicated in Fig. 14.1 the world per capita apparent fish consumption increased from an average of 9.9 kg in the 1960s to 14.4 kg in the 1990s and 19.7 kg in 2013, with preliminary estimates for 2014 and 2015 pointing towards further growth beyond 20 kg (SOFIA 2016). In year 2016 it was reported as 20.3 kg (SOFIA 2018).

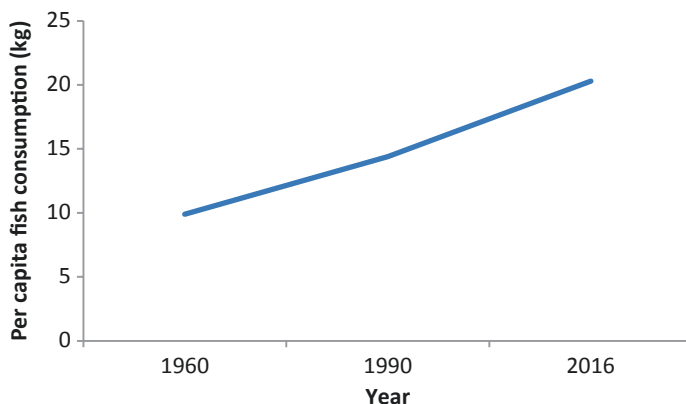


Fig. 14.1 Trend in global per capita fish consumption since 1960–2016 (Source: SOFIA 2016 and SOFIA 2018)

14.1.2 Historical Development of Fisheries Sector in Sri Lanka

The fisheries sector of Sri Lanka consists of three main subsectors, namely, (a) coastal, (b) offshore and deep sea, and (c) inland and aquaculture. These three subsectors employ around 250,000 active fishers and another 100,000 in support services in Sri Lanka. This workforce represents a population of some 1 million people. At present there are some organizations dedicated for the development of fisheries industry in Sri Lanka. The National Aquatic Resources Research and Development Agency (NARA) looks after research and development, and the National Aquaculture Development Authority (NAQDA) focuses its activities on the development and management of all freshwater aquatic resources in the country and also promotes development of aquaculture and sea farming. The Ceylon Fisheries Cooperation maintains cold storage facilities and carries out production and sale of fishery by-products, while the Ceylon Fisheries Harbors' Cooperation maintains fisheries infrastructure facilities such as proper landing facilities through construction, maintenance, and management of harbors and anchorages. The Department of Fisheries deals with management, regulation, conservation, and development of fisheries and aquatic resources and the Cey-Nor Foundation Limited carries out building, manufacturing, and selling of fishing crafts, engines, and gear, and the operation of workshops for repairing of fishing crafts.

Fishing is the largest extractive use of wildlife in the world, and aquaculture is the most rapidly growing food production sector globally with an annual growth rate of over 6% since 2002. The recent trends in marine fisheries worldwide are overcapacity of fleets both near shore and offshore resulting in dramatic and widespread declines in catches per unit efforts, the movement of the bulk of the world's fishing capacity from the developed to developing countries, declining catches, economic hardships for small artisanal fishers, and reduction in fish for poor consumers.

Sri Lanka has a well-established fishery industry. The Exclusive Economic Zone (EEZ) covers 517,000 km², of which some 27,800 km² form a continental shelf that is referred to as the coastal subsector. The balance beyond the continental shelf and out to the 200 nm EEZ boundary is considered the offshore and deep-sea subsector. The total fish production increased marginally over the years even though the offshore fish catch reported an increase while the coastal fish catch declined, due to high fishing pressures which lead to reduce the catch per unit effort (CPUE) and some unfavorable weather conditions prevail in coastal. The total fish production reported in Sri Lanka in 2016 was 530,920 mt, of which 17,593 mt was exported.

14.1.3 Current Situation of Fisheries Resources and Capture in Sri Lanka

Sri Lanka has exclusive economic rights for fishing in the ocean area of 517,000 km² and 21,500 km² of territorial water in marine water resources along the coastal line of 1770 km. This is in addition to the inland water bodies 262,000 ha of freshwater and 158,000 ha of brackish-water resources, which makes fishery to be one of the promising industries in the country. More importantly it contains a variety of coastal habitats that include estuaries and lagoons, mangroves, sea grass beds, salt marshes, coral reefs, and large extents of beaches and dunes that are vital for ecological functioning and maintenance of coastal biodiversity.

About 610 species of coastal fish have been reported from Sri Lankan waters, of which the more common species caught are *Sardinella* spp., *Amblygaster* spp., *Rastrelliger* spp., *Auxis thazard*, *Anchova commersoni*, and *Hirundichthys coromandelensis*. Most of these species live near the surface or high in the water column (pelagic species). These small pelagics account for about 40% of the coastal fish catch. Species such as *Lethrinus* spp., *Trichiurus* spp., *Caranx* spp., species of skates and rays, *Cynoglossus* spp., *Johnius* spp., and *Tolithus* spp. are bottom dwellers (demersal species). In addition, there are various mid-water species.

Katsuwonus pelamis and *Thunnus albacares* dominate the large pelagic catches from offshore and deep-sea fisheries. These are migratory fish species and therefore fall under stocks shared with other countries. Other important species are *Scomberomorus commerson*, *Platypterus* spp., *Tetrapturus angustirostris*, *T. audax*, *Makaira nigricans*, *M. indica*, *Xiphias gladius*, and *Coryphaena hippurus*. Moreover, about 60 species of sharks (De Silva 1984–1985) live in the oceanic waters of Sri Lanka. Some of the more common shark species are *Carcharhinus falciformis*, *C. longimanus*, *C. melanopterus*, *Alopias pelagicus*, *Sphyrna zygaena*, and *S. lewini*.

About 215 demersal species (Sivasubramaniam and Maldeniya 1985) have been reported from the oceanic waters around Sri Lanka. The commercially important, larger *Lutjanus* species are *L. lentjan*, *L. nebulous*, and *Pristipomoides* spp.; *Epinephelus* spp. are the demersal ones (Rajasuriya 2014). Although indigenous freshwater fish species like *Labeo dussumieri* and *Puntius sarana* are found in inland fish catches, their commercial importance is quite low. Introduced fish

species such as tilapias (*Oreochromis mossambicus* and *O. niloticus*) dominates the inland fish landings. Attempts have also been made to introduce Indian and Chinese carp species into reservoirs in the past and their stocking is continuing with culture-based fisheries practices conducted by NAQDA. There is close to 2.4 million direct and indirect employments being generated in fisheries sector. The key stakeholders are fishermen, breeders, processors, and logistics, cold chain, packing, and other service suppliers.

Sri Lankan fisheries are managed by two core legislative instruments, namely, Fisheries and Aquatic Resources Act. No. 2 of 1996 and the Fisheries (Regulations for Foreign Fishing Boats) Act No. 59 of 1979, along with several regulations to assist in the implementation of these acts. Yet many aspects including a three-decade long war, poaching and lack of coastal and ocean security, as well as poor understanding of sustainable fishing methods have seen the downfall of a promising industry abundant of resources. Over the years, the successive governments of Sri Lanka and international agencies have acknowledged that this enormous resource for fish farming or aquaculture has not been exploited in a sustainable way because, among other things, most of the marine fishing is focusing on coastal areas in which harvesting goes at near MSY (Maximum Sustainable Yield) level, but not the off-shore and deep sea where there are still underutilization of fisheries resources. As per inland fishing, changing policies by changing governments ensure politics play a bigger role than rational, sound, and pragmatic policies for the fisheries sector.

The year 2017, however, showed a series of changes in the local and global environment, which can make a positive impact on the Sri Lankan fishery industry in the long run. The industry, which has seen a change of fortune since the end of the civil war and the revival of the fishing industry in the Eastern and Northern regions of Sri Lanka, received a power boost with the reinstatement of GSP Plus from the USA and lifting of export banning of fish to European Union (EU) in the recent past, which can boost the exports of fish and fishery products. Meanwhile, the Sri Lankan government agencies are also seeking to position the country's marine and inland fishing industries as major export earning sectors by establishing aquaculture and marine industry parks in the Eastern and Southern coasts of the country. Two aquaculture industrial parks are to be established in the Mannar and Batticaloa districts while the establishment of another aquaculture park is being proposed in Hambanthota district.

In assistance of the Sri Lankan government's attempts to provide a quick boost to the local fishing industry, the South Korean government, too, has extended a soft loan facility to develop four multi-purpose harbors in Maadagal, Chalai, Udappuwa, and the island of Delft in North and North-Western provinces in Sri Lanka (EDB 2017a). Moreover, two technical training colleges on fishing and aquaculture were established to enhance the technical capacity of the Sri Lankan fishing community in developing sustainable and energy-efficient practices in fishing.

Sustainability in the local fishing industry is the main concern that has been addressed aggressively at various levels. While Sri Lanka's first Marine Finfish Hatchery was inaugurated in Tharmapuram in Batticaloa (Eastern province) to facilitate the development of marine finfish farming and produce sufficient amounts of marine fish to meet the demands of the national and international markets without

exhausting the natural supplies, the Sri Lankan parliament has unanimously amended the Fisheries and Aquatic Resources Act No.2 of 1996 recently in July 2017 to ban bottom-trawling, a practice which has threatened the future of the aquatic resources in Sri Lankan oceans (EDB 2017a). Under the fisheries sector development strategy (EDB 2017b), a modern and technically improved Vessel Monitoring System (VMS) will be established in order to curtail IUU fishing; this will be able to prevent national fishing vessels from drifting to other countries' territorial waters.

With the promising developments in technology training, infrastructure development, and sustainable harvesting practices, the fishing industry in Sri Lanka is in for a better future in the years to come.

14.1.4 Situation on Current Fish Utilization and Marketing

The share of world fish production utilized for direct human consumption has increased significantly in recent decades, up from 67% in the 1960s to 87% or more than 146 million mt in 2014 (SOFIA 2016). During the same year, The remaining 21 million mt was destined for nonfood products, of which 76% was reduced to fishmeal and fish oil, which are still considered as the most nutritious and digestible ingredients for farmed fish feeds.

Developing economies, whose exports represented just 37% of world trade in 1976, saw their share rise to 54% of total fishery export value and 60% of the quantity (live weight) by 2014 (SOFIA 2016). Fishery trade represents a significant source of foreign currency earnings for many developing countries, in addition to its important role in income generation, employment, food security, and nutrition.

Sri Lanka is ranked among the first 50 countries in the world exports with total share of 0.2% in the world export market (EDB 2017b). Sri Lanka has been exporting fish and fishery products to Europe, America, and Asia markets over the years. Based on the coastal areas surrounding the country, the fishing and fisheries processing industries in Sri Lanka attract many workers who have been unemployed and displaced by the war, tsunami, and other social and economic factors. After the 30 years' war is over, liberalizing the huge area of land and coast in the North and East are available for Aquaculture and sea farming of various varieties of fish and also to develop processing factories.

There are 52 government-approved fishing and processing facilities spread across the country, out of which 32 have been approved by the European Union as per their safety (EDB 2017a), sustainable fishing, and safe food processing practices; Sri Lankan fishing industry can expect a better future in exporting seafood and seafood-based products to the EU. Further, improvement of the country's long line fishing fleet used for tuna and billfish fishing, two types of fish, has a larger market in EU and Eastern-Asia.

Sri Lankan tuna, shrimps, and crabs have quality of unique taste and texture. Most of the seafood processing plants are situated in the Western Province in the Colombo and Gampaha districts due to its easy access to the airport. There are few

associations that support the seafood sector by addressing the sector-related issues through coordination with the government institutions. There are more than 75 medium- and large-scale companies engaged in exporting seafoods but only 32 companies have EU-Approved processing plants (EDB 2017b).

In addition to the exports, Sri Lanka has to import a substantial amount of dried fish, sprats, and canned fish annually in order to cater the excess domestic demand owing to a low level of domestic production of dry fish and sprats in the country.

14.1.5 Trends in Future Products and Markets

Potential for the future expansion of the fisheries sector rests with more concentration on value addition (especially focusing on exports) and convenient food production. Further, organic aquaculture production, especially organic shrimps, targeting high-end markets, also has the potential for expansion by using the available reservoirs for freshwater fish culture. Commercial culture of oysters, mussels, and seaweed farming are lucrative areas to look into.

14.2 Fish Production in Sri Lanka

14.2.1 Inland Capture Fishery

Sri Lanka has an extensive freshwater and brackish-water resource to sustain viable fishing activities. These include irrigation reservoirs, seasonal tanks, and brackish-water resources such as estuaries, lagoons, or marshes. The total inland and aquaculture fish production in 2016 was 73,930 mt and has contributed 14% to the total fish production of the country in the same year (Annual Performance Report 2016). Anuradhapura (18%), Puttalam (14%), and Ampara (13%) districts are dominant inland fish producing districts in the country. Capture fish production is mainly done with exotic fish species, which can breed naturally under Sri Lankan conditions, such as tilapia, common carp, and other indigenous fish species, i.e., Hiri kanaya (*Labeo* spp.), Lula (snakehead), and catfishes (butter catfish; stinging catfish, walking catfish). In addition to finfish being caught, freshwater prawn is also captured from aquatic resources where they are abundant. Capture fish production in inland fisheries by major species is presented in Table 14.1.

14.2.2 Inland Culture Fishery

Inland culture-based fishery has been performing since the introduction of exotic tilapia in the 1950s. At present Chinese major carps (bighead, silver, grass carp) and Indian major carps (catla, rohu, mrigal) are the major group of fish stocked in both perennial and seasonal inland aquatic resources. In addition, Genetically Improved Farm Tilapia (GIFT) has also been stocked in perennial reservoirs

Table 14.1 Inland capture fisheries by major species (MT)

Species	2012	2013	2014	2015	2016
Tilapia	39,950	39,070	46,610	40,504	43,836
Carp/Mrigal	3570	3450	3920	2847	3363
Catla/Rohu	12,460	8980	11,020	9117	7772
Hiri kanaya	670	590	580	358	230
Lula	1170	2040	2230	1582	1849
Freshwater prawn	290	540	460	374	705

Table 14.2 Annual fish production by sub sectors (mt)

Sector	2012	2013	2014	2015	2016
Marine	417,220	445,930	459,300	452,890	456,990
Coastal	257,540	267,980	278,850	369,020	274,160
Offshore/deep sea	159,680	177,950	180,450	183,870	182,830
Inland & Aquaculture	68,950	66,910	75,750	67,300	73,930

periodically to increase their population, while in seasonal tanks, it is done on annual basis as the culture-based fisheries is a cheaper source of animal protein for rural folk. Stocking of fingerlings continuously into inland water bodies has contributed significantly for the development of inland fisheries as well as the increase of fish production. Major, medium, and minor reservoirs as well as seasonal tanks were mainly targeted for stocking of fingerlings and of them medium reservoirs were major and about 32% of fingerlings have being released into them in 2016 (Annual Report NAQDA-2017).

14.2.3 Marine Capture Fishery

As stated earlier in this chapter, fish from the marine fisheries is the dominant sub-sector in terms of production, employment, and fishing fleet strength (Table 14.2). There are totally 15 fisheries administrative districts of the country. Of them, Tangalle and Galle districts are dominant and have contributed over 26% to the total marine fish production of the country in 2016, followed by Kalutara (10%), Puttlam (9%), Negombo (7%), Matara (7%), Chilaw (7%), and Jaffna (7%) districts that have also contributed a considerable proportion to the total marine fish production of the country. Skipjack tuna (Balaya) and yellow fin tuna (Kelawalla) are dominant species that have contributed 10.4% and 8.7%, respectively, to the total marine fish production in 2016. However, production of Skipjack tuna has decreased by 11.7%, compared to the previous year. Both tunas are classified under the world top 10 species been captured in marine fisheries.

14.2.4 Aquaculture

Global aquaculture production has increased steadily in the recent years as nearly 46% of the world's fish produced for human consumption comes from farmed sources (SOFIA 2016). It is the fastest growing food production sector and has become an important element of economic growth and poverty reduction plans in many countries. As Sri Lanka has vast water bodies and suitable environmental conditions, the country has an enormous potential to increase the production of finfish and shellfish through the sustainable development of aquaculture. The contribution from inland and aquaculture subsector is low. However, since 1980, fish culture in seasonal village tanks, marine shrimp culture in coastal earthen ponds, and live ornamental fish exports have reached commercial dimensions. Presently, tilapia and catla are dominant in inland and aquaculture fish production which contributed 59.3% to the total fish inland production in 2016 (Annual Report NAQDA 2017). Among others, the cultured shrimp contributes 8.2% to the total and was mainly focused on export market. In addition to aquatic fauna that has been cultured, culture of aquatic fauna in all three types of water resources (freshwater, brackish water, and marine water) is now being popularized in certain areas of the country owing to higher foreign exchange earnings by exporting them and their products for various commercial purposes. The future plans to develop country's aquaculture industry is mainly focused on the high-value aquatic resources by setting up a fishery mega zone to culture sea cucumber, sea bass, GIFT (tilapia), and seaweed on a commercial scale. Cage culture, mollusk, and seaweed culture are yet to be developed. Bivalve farming will be developed by which shellfish varieties such as oysters, mussels, clams, and cockles will be farmed for human consumption and exportation.

14.3 Fish as a Food

14.3.1 Protein Source

Fish provided more than 3.1 billion people with almost 20% of their average per capita intake of animal protein (Fish and human Nutrition, FAO). Further to being a rich source of easily digested, the high-quality fish proteins contain all essential amino acids. Even small quantities of fish can have a significant positive nutritional impact on nations consuming plant-based diets.

Fish provides a good source of high-quality protein and contains many vitamins and minerals all of which are vital for the healthy functioning of the body (Table 14.3). As an animal protein source, fish contributes to about 17% at the global level, but exceeding 50% of total animal protein intake in some small island developing states, as well as in Bangladesh, Cambodia, the Gambia, Ghana, Indonesia, Sierra Leone, and Sri Lanka (FAO 2014). Sri Lanka has a dietary concentration on one staple commodity (rice), which is deficient in essential amino acids such as lysine and methionine. Hence, fish are a vital food source that

Table 14.3 Nutritional aspects of fish compared to other animal origin food source per 100 g

Source	Calories	Protein (g)	Carbohydrates (g)	Fat (g)
Fish	110–140	20–25	0	1–5
Chicken (breast)	160	28	0	7
Beef (steak)	210	25	0	7
Lamb	250	30	0	7

Table 14.4 Nutritional composition of fish (100 g serving pack) (Source: Jag Pal et al. 2018)

Protein	Fat	Calories	Vitamin A	Vitamin B ₁₂	Iron	Zinc	Calcium
20–25 g	1–5 g	110–140	2503 µg	0.50–14 µg	0.34–19 mg	0.6–4.7 mg	8.6–1900 mg

contains all essential amino acids. Though Sri Lanka is surrounded by the Indian Ocean, the per capita fish consumption in Sri Lanka is yet below the world average of 20 kg (FAO 2017). For better nutrition and food security, the challenge is to increase fish harvest in an affordable manner by which fish consumption can be increased to improve nutritional status. The freshwater fishes have traditionally been obtained from the inland capture fisheries resources like rivers, reservoirs, and wetlands. Since last two decades, freshwater aquaculture sector has expanded significantly along with development of culture-based fisheries, producing large quantity of freshwater fishes as affordable animal protein source for rural communities.

14.3.2 Vitamin Supplier

Fish provides essential fats (e.g., long-chain omega-3 fatty acids), vitamins (A, D, and B), and minerals (including calcium, iodine, zinc, iron, and selenium), particularly if eaten whole (Table 14.4). Whitefish such as seer (*Thora*) contains little fat (usually less than 1%) whereas oily fish such as sardines contain between 10 and 25%. However, as a result of its high fat content, oily fishes contain a range of fat-soluble vitamins (A, D, E, and K) and essential fatty acids.

14.3.3 Micro and Macro Nutrient Supplier

The nutrient composition of fish varies widely across species, particularly for micronutrients. Iron content ranges from 0.34 to 19 mg/100 g raw edible parts, zinc from 0.6 to 4.7 mg/100 g, calcium from 8.6 to 1900 mg/100 g, vitamin A from 0 to 2503 µg RAE/100 g, and vitamin B₁₂ from 0.50 to 14 µg/100 g (Table 14.4).

14.3.4 Health Benefits of Fish

Fish is one of the best sources to provide essential fatty acids: omega-3, omega-6, EPA, and DHA. Fish is usually high in unsaturated fats and provides health benefits in protection against cardiovascular diseases. It also aids fetal and infant development of the human brain and nervous system. With its valuable nutritional properties, it can also play a major role in correcting unbalanced diets and, through substitution, in countering obesity in human beings.

Catfishes and snakehead have widely been caught naturally for food for hundreds of years in Asia, considering them excellent to eat due to its taste and high level of vitamin D, while some research has found that tilapia may be far less nutritious than generally believed as [omega-3 fatty acid](#) content is often far lower than that of other commonly eaten fish species. However, it contains high level of omega-6 fatty acid being a tropical fish species (Jag Pal et al. 2018).

14.4 Integrated Fish Farming Systems

Climate change is a fundamental threat to global food security, sustainable development, and poverty eradication. Thus, governance needs to ensure that fisheries and aquaculture adapt to the impacts of climate change and improve the resilience of food production systems where one of the solutions is integration. Integration amalgamates various food production systems in order to maximize resource utilization and minimize the waste and by-products.

There is a need to strengthen aquatic ecosystem governance to deal with the increasing use of water space and resources. Aquaponics is a symbiotic integration of two mature food production disciplines: (i) aquaculture, the practice of fish farming and (ii) hydroponics, the cultivation of plants in water without soil. Aquaponics combines the two within a closed recirculating system. In addition, available other farming systems can be incorporated with aquaculture practices as discussed below.

14.4.1 Integration with Livestock

The advantages of integration are obvious. Integrated fish farming is a process of farming where fish is produced in combination with other farm products and livestock. The system links each of the involved subsystems in it, such as fish, crops, and livestock, in such a way that the waste or by-products from one subsystem can be used as an input for the next system. An integrated agriculture system can ensure the maximum utilization of all resources, such as land, water, and feed, and also minimizes waste.

As far as fish production is concerned, livestock serves as the major purpose of providing organic manure for the fish ponds, thereby reducing the cost and need for providing compounded fish feeds and chemical fertilizers. By reducing the cost of fertilizers and feedstuffs, the overall cost of fish production is reduced and profits

increased. Aquatic resources (i.e., pond or tank) available in livestock farms are mainly used for irrigation and wallowing purposes. These ecosystems can thus be utilized as the place for stocking fish. The pond ecosystem transforms the inert nutrients of the manure to digestible, protein-rich, live food for the fish. Therefore, to make livestock-fish integration efficient, suitable fish species (plantivores, detritivores, and herbivores) are needed. They may not be available in the local fish fauna but in the exotic fish introduced to Sri Lanka.

14.4.2 Integration with Poultry

Some extent of poultry fish integration can be seen in Sri Lanka, mainly with duck (water fowl). In this system duck house is built on the pond to allow manures to fall directly into the pond or it is located on the dike and manure is washed in daily. As ducks are raised on the pond surface, they drop their nutrient-rich manure food in the pond; the fish gather protein-rich natural food from the pond ecosystem or may consume directly the feed spilled by the ducks. In order to prevent ducks from eating small fish, larger size of fingerlings are stocked in the pond. The recommended fish species are tilapia or tilapia cum carp at the stocking density of 2000 fish/ha.

14.4.3 Integration with Paddy (Rice)

Rice-fish farming system is site and socioculturally specific. It is important to note that fish is secondary to rice, which is still the main component of the system. However, in Sri Lanka, rice farming is carried out at an intensive level and the fertilizer subsidy program would enable farmers to make more money from rice than fish. Further, factors such as shorter growing season, intensive mechanization and greater use of pesticides and herbicides, and low productivity of the system also limits rice-fish integration to be popularized in Sri Lanka. Table fish production under rice-fish integration is not productive as paddy varieties cultivated in Sri Lanka have a short cultivation cycle. The period for fish grow-out cycles will be limited to 2 or 3 months and the fish that are produced will be small. The small-size freshwater fish are not preferred by Sri Lankans, and thus rice-fish integration should not be intended for table fish production. A system has to be developed to culture high-priced ornamental fish species (i.e., guppy, platy, goldfish), which have a good export market.

14.4.4 Integration with Plantation Crops

Most of the tea estate in Sri Lanka possess water source that is connected to the cooling system of the power-generated engine used before electricity supply received. These water bodies are now being used for stocking of food fish to be cultured as an animal protein source for estate people. In addition, available water

bodies in coconut plantations for irrigation purpose and for wallowing of grazing buffaloes have also been used to stock table fish in estates belonging to government and private sector. An aquaponic system can easily be set up at home where we can raise fish and grow plants at the same time. A recirculating water system from your fish tank would easily provide nutrients for your plants and also clean the water of your fish tank.

14.5 Economics and Social Contribution of Fishery

14.5.1 Economics Contribution

14.5.1.1 Fish and Fish Products Export

While coastal fisheries still dominate the overall fish output of the country, production from offshore and deep-sea fishing has been increasing rapidly since the early 1990s. This trend is largely in response to higher demand for tropical fish, particularly tuna species, from markets in industrial economies such as Japan, the EU, and the USA. The increase of offshore/deep-sea fish production by 2016 (Table 14.2) has gone hand in hand with a number of improvements throughout the entire chain such as more reliable and larger vessels with cold storage, modern navigation instruments and fishing gear, fish processing plants (for frozen fish), and laboratory and quality testing facilities. Tuna has rapidly become Sri Lanka's main fish export, overtaking cultured shrimp which dominated fish exports over the last two decades. Sri Lanka's fish products currently compete well in export market in terms of both price and quality, and most of the fish product categories (HS 06).

Export earnings have shown steady growth during recent years and now account for approximately 2% of the total GDP. Sri Lankan fish exports include fresh and frozen fish (tuna, swordfish, shark, seer, etc.). Tuna accounts for 51.5% of the total fish and fishery products exports of Sri Lanka. Export contribution of European market is 16.7%, Japanese market 3.7%, the USA 36.6%, and other states 43% (Annual Performance Report 2016). In order to expand the export market opportunities, discussions have been held with regard to exporting yellow fin tuna head to the Korean market. Crustaceans (i.e., prawns, lobsters, and crabs), sea cucumber and shark fins. The European Union is the main international buyer for Sri Lankan fisheries exports—36%, followed by the USA and Japan, accounting for 27% each of total fish exports by Sri Lanka (Annual Report CBSL 2017). Further, the rapidly growing opportunities for fish exports have yet to be fully exploited in light with lifting of banning of exportation of fish and fishery products to EU countries and GSP tax relief offered by the USA to Sri Lanka recently.

Meanwhile, fish exports increased by 41.8% in volume terms and 48.5% in rupee terms, in 2017 compared to 2016, following the removal of the ban on fish exports to the EU in 2016. Further, fish imports to Sri Lanka declined by 8.4% in volume terms and 3.4% in rupee terms in 2017 compared to that of 2016.

14.5.1.2 Fish Supply and Availability

A critical element of the supply chain is the broad base of numerous small-scale fishers who operate in small motorized, traditional craft and relatively large, multi-day boats that are able to exploit offshore and deep-sea fisheries and carry out fish production. Of the two marine fishing categories, the major share of production, about 60%, in 2016 (Table 14.2) comes from coastal fishing along the entire coastline where fishing operations are at near MSY level. Fishers harvest a variety of species that reflect the spatial variations of the fishing grounds. The output of coastal fishing is marketed through diverse channels to different, mainly domestic end, markets that include urban and rural retail fish outlets, small mobile vendors, supermarket chains, and the state-owned Ceylon Fisheries Cooperation (CFC) outlets. Urban wholesale markets, such as St. Johns Fish Market in Colombo and Kandy wholesale fish market, play an important role in distributing coastal fishery outputs. While coastal fisheries still dominate the overall fish output of the country, production from offshore and deep-sea fishing has been increasing rapidly since the early 1990s (Table 14.2). The per capita availability of fish is 15.3 kg. Currently there are 12 harbors on the coastline with the main fishery harbor situated in Colombo, and 37 anchorages and 710 fish landing sites (*thotupola*), which are also inadequate, poorly managed, and often lack even basic facilities and are to be improved in order to minimize postharvest losses and for better distribution of fish being harvested.

In progressive markets, some actors who are successfully performing multiple roles at different levels of the supply chain are contributing to the momentum of the system. For instance, coastal operators venturing into deep-sea fishing have moved from being local market suppliers to suppliers for the export market, along with the government subsidiary program introduced recently on purchasing of trawlers. In spite of these important signs of progress, Sri Lanka's fisheries sector has performed less than satisfactorily with domestic supply unable to provide the quantities of fish products required at affordable prices to meet the nutritional needs of the country's population.

14.5.1.3 Annual Fish Consumption per Capita

The Sri Lankan fishery sector serves both the domestic and export markets, with the domestic component attracting 75% of the marine fish production. Recently, the Ceylon Fisheries Corporation (CFC), which has established 130 retail fish outlets located island-wide, has extended its support to small fishermen by assisting them in marketing and providing price support under a guaranteed price scheme. The per capita consumption as at present is 17.3 kg, which is expected to increase up to 22 kg in near future. Daily basis per capita fish consumption has increased by 47.2 per day from January to September 2016 (Annual Performance Report 2016). Canned fish and dry fish also contribute immensely to the per capita fish consumption in the country.

14.5.1.4 Contribution to GDP

Fisheries sector contribution to national GDP was 1.3% for the last two consecutive years (CBSL 2017). There was a marginal increase in fish production in 2017 (0.1%) compared to 2016. However, marine fish production, which accounted for 84.6% of

the total fish production in 2017, declined by 1.7% to 449,440 mt, while inland fish production increased by 10.7% to 81,870 mt. Prolonged dry weather in the deep sea and substantial postharvest losses had an adverse impact on marine fishing last year.

14.5.1.5 Other Indirect Contributions of the Fisheries Sector

Fifty-two government-approved fish processing facilities spread across the country have also provided employment opportunities for the people. The number of functioning ice factories in 2013 was 90 and has been increased up to 123 by 2016 (Annual Performance Report 2016). Ice production has remained at 3949 mt at the end of September 2016. Further, feed manufacturing, marketing, and transportation will also enhance with the development of aquaculture industry in the country.

14.5.2 Social Contribution

14.5.2.1 Contribution to Livelihood Development

Many projects have been launched by the Ministry of Fisheries during 2016 aiming the expansion of new employment opportunities for enhancing the life standards of fishers. Community-based sea cucumber farming as an alternative livelihood method in Northern and North-Western provinces, identification of suitable locations considering the environmental factors in chank shell farming, breeding edible fish with community participation in the abandoned clay pits, development of sea moss and seed cultivation have also been commenced.

14.5.2.2 Financial Strength

Total export value of food fish and fishery products accounts for Sri Lanka Rs. (SLR) 26,802 million in 2016 while ornamental fish exportation alone contributed another SLR. 2382 million to the country's economy.

14.5.2.3 Social Strength

Fishing fleet of Sri Lanka marine fishery comprises 15,022 small traditional craft (48% motorized) used in the lagoons and coastal areas, 8334 fiber glass speed boats with kerosene out board motors (18–24 ft. and 25–40 hp. motors), 1550 (21–24 ft.) day boats, and 1700 larger multi-day boats (32–52 ft.). The number of total fishers directly involved in marine fishery is over 2,70,000 and its created over 6,50,000 employments to the sector (Annual Performance Report 2016). Further, job opportunities have been created in freshwater fish fingerling production by the mini hatcheries, private ponds, and cages, which have accounted for 44.85% share of the total fish seed production in the country (Annual Report NAQDA 2017). Fish as a commodity has also created more employment in marketing, processing, packing, transportation, and input provision to the industry. Hence, the whole fishery sector created over 2 million jobs to the nation.

14.6 Conclusion

Recent actions taken by global community for the sustainable use of fisheries resources are commendable. The use of GIS and remote sensing has expanded the suite of modeling approaches to include higher-resolution and more reliable predictors of yield, including direct measures of primary production and hydrologic regime. For example, researchers have established relationships between chlorophyll concentrations as a measure of freshwater primary production and fishery yields worldwide. Further, progress has been made worldwide in managing by-catch and reducing discards. The FAO–GEF project Sustainable Management of By-catch in Latin America and Caribbean Trawl Fisheries (REBYC-II LAC) (2015–2019) have aimed to reduce food loss and support sustainable livelihoods by improving by-catch management and minimizing discards and sea-bed damage, thereby turning bottom trawl fisheries into responsible fisheries.

Measures that have been taken to control fishing operations within the exclusive economic zones are now considered much stronger. Steps being taken to combat illegal, unreported and unregulated IUU fishing prevent further build-up of fishing overcapacity and/or reduce it, and implement plans for the protection and conservation of marine fauna and flora.

In tropical and subtropical fisheries, gillnets and trammel nets are among the main gear types used in fisheries. A food loss and waste reduction project initiated by the FAO and focusing on the harvesting stage of the fish supply chain has been started with gillnet and trammel net fishing operations, the results of which should be of wider interest (FAO 2015a, b).

Among the varied research projects implemented in the recent past by NARA for encouraging fish export industry are, informing fishers by providing prediction on tuna fishing grounds, introduction of fishing gear for octopus harvesting, and controlling white spot syndrome of brackish-water prawn. Fish aggregation devices have been located in sea by NARA. Further, diverse strategies are being adopted by NAQDA to promote ornamental fisheries exports such as the introduction of new species of ornamental fish, fish breeding, prevention of fish diseases, provision of training to the farmers on high-quality fish feeds, technology development, diagnosing fish diseases, and assisting fishers to obtain loan facilities and organization of international exhibitions on ornamental fisheries.

Research recently conducted were on the Sri Lankan skates and lobsters fisheries, scientific studies on tuna, conservation of spiny lobsters carrying eggs, assessment of algae constitution of Maduru-oya reservoir, water quality assessments, disease management, and implementation of information sharing projects are among the research projects launched by NAQDA. Research on marine mammals and studies on fish habitats such as coral reefs, sea grasses, and mangroves were conducted by NARA with relevant conservation recommendations. Government has taken actions in 2016 to promote high-seas fishing through the introduction of state-of-the-art fishing vessels and to encourage marine fish farming. Further, fundamental measures have been taken in promoting shrimp, crab, and other freshwater fish species cultivation and thereby developing the freshwater fishes to commercial levels with private sector contribution.

Sri Lanka, being an island nation and having eight times higher marine water resources compared to its land area, possess enormous natural resources including fish. Sri Lanka also gets benefits from those global actions taken by the UN by being a signatory to practicing the code of conduct for sustainable fisheries and many more agreements. At present, 86% of the country's total fish production is received from the marine sector. The marine water area that belongs to Sri Lanka will further expand by another 1 million square km in the near future according to the new maritime mapping system, thus resulting in an increase in both marine fish production and available fishing area of the country. Further, Sri Lanka is one of the countries having the world's highest freshwater resources with 4% of freshwater bodies compared to its land area. At present, only 10% of it is used for fish production. Availability of these natural aquatic resources provides immense opportunities to achieve high economic growth with guaranteed food and nutritional security for its population in near future by blue economic revolution.

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