Importance of fisheries for food security across three climate change vulnerable deltas

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Abstract

Deltas are home to a large and growing proportion of the world's population, often living in conditions of extreme poverty. Deltaic ecosystems are ecologically significant as they support high biodiversity and a variety of fisheries, however these coastal environments are extremely vulnerable to climate change. The Ganges-Brahmaputra-Meghna (Bangladesh/India), the Mahanadi (India), and the Volta (Ghana) are among the most important and populous delta regions in the world and they are all considered at risk of food insecurity and climate change. The fisheries sector is vital for populations that live in the three deltas, as a source of animal protein (in Bangladesh and Ghana around 50-60% of animal protein is supplied by fish while in India this is about 12%) through subsistence fishing, as a source of employment and for the wider economy. The aquaculture sector shows a rapid growth in Bangladesh and India while in Ghana this is just starting to expand. The main exported species differ across countries with Ghana and India dominated by marine fish species, whereas Bangladesh exports shrimps and prawns.

Fisheries play a more important part in the economy of Bangladesh and Ghana than for India, both men and women work in fisheries, with a higher proportion of women in the Volta then in the Asian deltas. Economic and integrated modelling using future scenarios suggest that changes in temperature and primary production could reduce fish productivity and fisheries income especially in the Volta and Bangladesh deltas, however these losses could be mitigated by reducing overfishing and improving management. The analysis provided in this paper highlights the importance of applying plans for fisheries management at regional level. Minimizing the impacts of climate change while increasing marine ecosystems resilience must be a priority for scientists and governments before these have dramatic impacts on millions of people's lives.

1. Introduction

According to the United Nations, the world population is likely to grow from the present 7.6 billion people to about 9.8 billion by 2050 and half of this growth is expected to be concentrated in developing countries (e.g. India, Nigeria, the Democratic Republic of the Congo, Pakistan, Ethiopia, the United Republic of Tanzania;

United Nations, 2017). This unbalanced population growth will exacerbate the current problems of hunger and malnutrition already plaguing many poor communities of South Asia and Sub-Saharan Africa. To feed this growing world population it will be necessary to increase the global food production by 50% by 2050 (FAO, 2017a). Food insecurity is one of the major societal and international concerns and how to feed the increasing world population is a long-debated challenge amongst politicians, economists and scientists.

Fishery resources are an important source of proteins, vitamins and micronutrients that are not available in such quantity and diversity either in crops or in other animal products. They represent circa 17% of animal protein consumed by many low-income populations in rural areas (FAO, 2016). In recent years, the world per capita fish consumption has doubled from an average of 9.9 kg in the 1960s to above 20kg in 2016 (FAO, 2017b) as a result of a combination of factors such as: population growth, increasing incomes and urbanization, strong expansion of fish production and more efficient distribution channels (FAO, 2014a). However, fish consumption varies substantially from country to country depending on local traditions and supplies. For example, fish is a key component of people's diet in many developing countries because it is often the only affordable and easily available source of animal protein. In fact, in Bangladesh, Cambodia and Ghana around 50% of animal protein comes from fish, while in India it provides only 12.4% of the total animal protein supply (Dey et al., 2010). In addition, because of their geographical and social characteristics these countries are highly vulnerable to the potential impacts of global and regional climate change, and future projections suggest a negative impact on their fisheries production (Barange et al., 2014; Fernandes et al., 2016).

Deltas are home to a large and growing proportion of the world's population and in developing countries the average population density in coastal areas is about 80 persons per km^2, twice the world's average figure (United Nations System-Wide Earthwatch, 2003). In most cases people that live in delta areas experience extremes of poverty. Deltas are important for biodiversity (e.g. they contribute to sustaining mangrove forests, support wetland animals and plant communities, provide shelter for young fish), nevertheless these coastal environments are extremely vulnerable to climate change. This is due to the coincidence of physical characteristics (e.g. low elevation and high flood probability, significant land erosion and accretion, dependence on fluvial inputs of water and sediment) and socio-economic characteristics (e.g. high population density, high prevalence of poverty and low levels of socio-economic development). Here we present a review of the fisheries and aquaculture sectors and associated socio-economic structure of three important populous deltas of the world at risk of food security and climate change: the Ganges-Brahmaputra-Meghna (GBM) delta (Bangladesh/India), the Mahanadi delta (India), and the Volta delta (Ghana). These deltas are different geo-physically, economically, and in their social, governance and cultural characteristics. Comparing their human, economic and environmental aspects in relation to fisheries will provide greater insights than studying them individually.

The Ganges-Brahmaputra-Meghna (GBM) delta is the largest delta in the world and supports the fisheries of Bangladesh and parts of India. Both countries are among the countries most affected by climate change and weather events during the last two decades (Sönke et al., 2015). Bangladesh is sixth and India ranks 14th, however in 2014 and 2015, India ranked fourth and tenth respectively since the country faced several types of extreme weather events in 2015. After floods in February and March due to unseasonal rainfall, India suffered from one of the deadliest heatwaves in world history killing more than 2,300 people in May, followed by a much weaker monsoon than normal. These results emphasise the vulnerability of poor and developing countries to climatic risks. This GBM delta is located in the flood plains of Bangladesh and southern part of West Bengal (India) and is formed by waters from a vast complex river basin and their tributaries (Mouths of the Ganges, FAO, 2006). The Sunderbans, a world heritage site and the world's largest block of mangrove ecosystem, is a part of this delta and shared by these two countries.

The Bangladesh delta region is one of the poorest region worldwide (FAO, 2006). The coastal population of Bangladesh has doubled since the 1980s, now reaching more than 16 million (circa 10% of the total country population) and a great proportion experience poverty as well as environmental vulnerability (Allison et al., 2009; Newton et al., 2007). The Indian part of the GBM delta (Indian Sundarbans Delta, West Bengal) comprises 102 islands of which 54 are inhabited. The population is almost 4.6 million and growing by 2% per annum (Hazra et al., 2002). Changes in coastal morphology due to erosion and accretion (Thomas et al., 2014) along with anthropogenic activities are influencing the coastal ecosystems and its functioning. These changes are affecting the socio-economic well-being of the inhabitants (Malone et al., 2010).

The Mahanadi delta in India is formed by the discharge of three major rivers: Mahanadi, Brahmani and Baitarini. It has a coastline of 200 km and covers approximately 3% of the area of Odisha state. The delta is the ecological and socio-economic centre of Odisha (formerly Orissa), supporting a large population, of which most are farmers with incomes on or close to the poverty line (FAO, 2015a). The luxuriant mangrove forests of Bhitarkanika, the nesting grounds for the Olive Ridley Turtle on the spits and sandy barrier islands and the rich aquatic life of the Chilika lagoon make it an important biodiversity hotspot (Madhusmita, 2012).

The Volta delta, in the south-east of Ghana, is the smallest of the three deltas considered here. It covers an area of 4553 km^2 and supports a population of 856,000 (DECCMA Brief, 2017a). The main sources of livelihood are agriculture, fishing and salt production. Drought, flooding, coastal erosion and salinization are key issues for people working in these sectors, with loss of landing sites due to erosion being a key issue for fishers.

The Ganges-Brahmaputra-Meghna delta, the Mahanadi and Voltas delta support millions of people’s lives by providing food, home and resources, therefore a deep knowledge of their status is necessary in the context of resources management and regional developing planning. In the following sections we provide an overview of the fisheries sector in Bangladesh, India and Ghana with detailed information for each country.

2. Overview of fisheries in Bangladesh, India and Ghana

The fishery sector plays a central role in the national economy, employment and food security of the countries where the GBM, Mahanadi and Volta deltas are located, representing the main earning activity for the poorest people and contributing between 4-5% of the Gross Domestic Product (GDP) (Asiedu and Nunoo, 2013; Mruthyunjaya et al., 2004) (Table 1). In Bangladesh and Ghana around 50-60% of animal protein is supplied by fish in contrast to India where this accounts only for the 12% (DoF, 2013; FAO, 2015a; Speedy, 2003). This difference is probably due the fact that India exports higher volumes of fish products than the other countries (Table 1), but it could also be related to social aspects. In India there are a high number of vegetarians while in Bangladesh fish is one of the main staples in the national diet as a complement to rice, giving rise to the saying “Machhe Bhate Bangali”, literally meaning “fish and rice make a Bengali”. This is also confirmed by the average consumption of fish products which in Bangladesh is 14kg/year per person (DANIDA-DFID, 2003) almost double the amount that is consumed in India (8.2kg; Table 1; Mruthyunjaya et al., 2004).

The fisheries sector provides employment to about 10% of the total population in Bangladesh and 73% of rural households are involved in aquaculture (Dey et al., 2010). Bangladesh is the fourth highest producer of inland fisheries and the sixth highest aquaculture producer in the world (FAO, 2016); since independence in 1971 the fisheries industry has seen steady growth, with production tripling in the last two decades (Dey et al., 2010; Golub and Varma, 2014).

In India over 14.5 million people depend on fisheries activities, making this sector a pillar for the country's economy and livelihood security (FAO, 2015a). The total fish and fisheries-derived goods production reached 9.6 million tonnes during 2013-14; the country is the third largest inland capture and aquaculture producer in the world (FAO, 2016; Government of India, 2014). The overall growth in this sector in 2013-14 was 5.9%, which has been mainly due to 7.3% growth in inland fish production while the growth in marine fish production has been 3.7%. The export of fish and fish products has risen generating an economic turnover of Rs. 30213.26 crores (US$46.5 million) during 2013-14 (a crore is a unit in the Indian numbering system equal to 10,000,000; Government of India, 2014). In spite of the importance of fisheries for the country, Indian fishing communities are ranked among the poorest. This is due to multiple reasons such as the decline in availability of fish from the coastal waters (which is accompanied by a declining access of the poor to fish resources because of changes in fishing technology from subsistence-based artisanal activities to sophisticated modern technologies) and in market supply chains (De Young, 2006). The two Indian deltas (Mahanadi & GBM-India) comprise 0.4 % and 0.43 % of the land area of India respectively, but provide 4.4 % and 6.07 % of fish production.

In Ghana the fisheries sector produces 420,000 tons of fish per year (Ministry of Food and Agriculture, 2010), playing a major role in the national economy, employment and food security for the country. Fish is consumed daily and is one of the main staples in Ghanaians' diet (fish consumption exceeds 50% of animal consumption). This is because fish is a relatively low-price source of protein compared to other high-quality protein sources (i.e. milk, meat and eggs) and has a long shelf life through low-cost sustainable technologies such as smoking, drying and salting. About 2 million people are dependent on the fisheries subsector for their livelihood (Ministry of Food and Agriculture, 2010), which includes 110,000 small-scale fishers in the marine sector and 71,000 small-scale fishers for Lake Volta (Ministry of Food and Agriculture, 2010). The fisheries sector supports about 10% of the population (Seini et al., 2004) and is also important from a gender perspective. Men are involved in fish harvesting, undertaking the main fishing activities in the artisanal, semi-industrial and the industrial sectors, while women are the key players in on-shore post-harvest activities, undertaking fish processing and storage and trade activities (Cobbina, 2010). Currently Ghana is estimated to require 880,000 tons of fish per year which is almost double the country's total production (Ministry of Food and Agriculture, 2010). To account for this deficit Ghana imports a large volume of fish (DoF, 2007) however this is still not enough for the country to meet its fish demand. Statistics indicate that about 18.2% of Ghanaians who fall below the extreme poverty line are chronically food insecure while about 10.3% are classified as poor and vulnerable to food insecurity (Ministry of Food and Agriculture, 2010).

	Bangladesh/India GBM delta	India Mahanadi delta	Ghana Volta delta	Reference
Contribution of fisheries to GDP %	4.4	4.7	4.2	(Asiedu and Nunoo, 2013; Jose A Fernandes et al., 2016; Mruthyunjaya et al., 2004)
Consumption (fish protein intake %)	60	12	60	(DoF, 2013; Sarpong et al., 2005; Speedy, 2003)
Per capita consumption/year (kg)	14	8.2	25	(DANIDA-DFID, 2003; Mruthyunjaya et al., 2004)
Contribution of export to country economy (%)	4.8	23.7	19.6	(FAO, 2006; Maung, 2004; Sarpong et al., 2005)

Table 1. Summary table showing the importance of fisheries in the 3 deltas.

3. Structure of the fisheries sector in Bangladesh, India and Ghana

In the three delta regions catches come from marine, inland and aquaculture sectors, which have different importance depending on the countries that exploit them (Table 2). In general, the three countries show a continuous increase in fish production driven mainly by aquaculture and to a lower degree by marine catches (Figure 1). The country where aquaculture and inland fisheries is most developed is India followed by Bangladesh, while Ghana is the country that shows the highest proportion of marine catches. However, Ghana also shows a high increase in aquaculture during last decade (Figure 1).

Country	Marine %	Inland %	Aquaculture %
Bangladesh	20	37	43
India	17	23	60
Ghana	70	27	3

Table 2. Percentage of the contribution per sector to the total catches in the three deltas regions. Data are from http://www.fao.org/fishery/statistics FAO Global database data relative to 2010.

In Bangladesh marine catches come from the Bay of Bengal ecosystem, which includes 86,392 km^2 of Bangladesh Exclusive Economic Zone (EEZ). In this area about 225 trawlers and 52,514 mechanized and non-mechanized boats are engaged in fishing (DoF, 2013). Inland fisheries include both open waters (i.e. rivers, estuaries, lake and flood plains) as well as semi-enclosed water bodies (i.e. lake and shrimp/prawn farms). Here aquaculture provides most of fish production, although this strongly depends on the provision of larvae and juveniles from wild river and marine ecosystems (Kathun, 2004).

In India freshwater and marine fisheries provide about 40% of total fish production but the main contribution to the country' economy comes from fish farming (Table 2; Figure 1b). In terms of numbers of fishers and distribution of assets major differences occur between the east and west coasts of the country. For example, while the eastern coast, including the GBM and Mahandi deltas, accounts for 55% of total number of fishing vessels, the number of active fishers is higher in the west coast (about 65% of total population; (De Young, 2006). According to the Handbook of Fisheries Statistics of India (2014), the west coast of India is more dominated by motorised crafts and mechanised boats, compared to the east coast. The Mahanadi (Odisha) and GBM-India (West Bengal) deltaic regions contribute about 10.47% of the total marine fish catch of India. These two states cover a coastline of 638 km and 43,000 km^2 of continental shelf. The number of boats operated in the Mahanadi delta region during 2013-14 (including the brackish water and the open sea) was 17,925 of which 7,208 were motorised, 8,962 non-motorised (country crafts) and 1,755 mechanized (or industrial). In West Bengal, the total number of boats operated in the ocean during 2013-14 was 7066 (3888 mechanized boats and 3178 non-mechanized boats; (Government of India, 2014).

In Ghana the marine sub-sector is the most significant source of local fish production and supplies about 70% of the total fish amount (Table 2; Figure 1). Marine fish production in Ghana has generally been assessed as among the highest in the Western Gulf of Guinea and this is mainly due to the occurrence of the seasonal upwelling events which tend to promote the general biological productivity in the region (Kwei and Ofori-Adu, 2005). The average annual domestic production between 1993 and 2000 was about 358,000 tonnes and was approximately 80% of overall fish supply (FAO, 2004). The inland freshwater captures come from Lake Volta, which has a rich biodiversity of fish (140 species; Braimah, 2003) and provides livelihood for about 300,000 people who live around the lake. Lake Volta was estimated to have produced over 70,000 tonnes of fish in 2002 which is about 16% of total domestic production and 85% of inland fisheries output. Stock assessment studies suggest that there is over-exploitation of major commercially important stocks in the lake (Ofori-Danson, 1999). This serious situation is aggravated by the progressive reduction in water level, brought about by poor rains in the Volta basin. The aquaculture sector is dominated by small scale operators (Cobbina, 2010), although the country has a great potential for aquaculture development, this sub-sector is still largely underexploited (Hiheglo, 2008). Aquaculture production could be important to Ghana as it can potentially bridge the gap between fish demand and supply, as well as support the country's export of fish products. The industry is growing rapidly, with hatcheries developed in less than one decade now producing 80 million fish seeds in a small area. However, only 2.5 % of the fish seed is produced in the coastal delta area. Currently export of fish and fishery products are very important for the country' economy accounting for over 50% of earnings (Sarpong et al., 2005).

4. Fleet structures in Bangladesh, India and Ghana

In delta areas marine capture fisheries can be further subdivided into subsistence, artisanal and industrial fisheries, though the distinction between the first two sub-sectors is not very clear (Table 3; FAO, 2006). In Bangladesh the artisanal sector is the most productive (99% of volume of landings; Table 4; Figure 2a). Marine fishing activities occur at shallow depths (within 100m) while deep-water resources remain unexplored by Bangladesh fishers; although there are reports of significant illegal foreign fishing offshore this is still not addressed due to a lack of surveillance activity (De Young, 2006). Subsistence fisheries are of great importance in Bangladesh (catches in Bangladesh were over 13.5 million tonnes from 1950-2010; Ullah et al., 2014) as many people feed their families in this manner, however species of greater commercial value are not fished for subsistence purposes (e.g. the low commercial value Bombay duck is the most popular subsistence species, representing over 12% of the catch). The only industrial fishing developed in Bangladesh operates out of Chittagong on the east coast and comprises two distinct industrial fisheries: longline tuna and bottom trawl (Table 4; FAO, 2006). The most important artisanal fisheries are reported by the Department of Fisheries (DoF) as mechanized gillnet, pots and traps, as well as estuarine set bag net fishery (Table 4). Model projections in Bangladesh show that catch increases are not due to an increase of marine productivity, but to an increase of fishing pressure from an increase in coastal population (Fernandes et al., 2016), for example Hilsa shad has been estimated to be fished at 2-3 times the Maximum Sustainable Yield (MSY).

Type of fisheries	**Description**
Industrial	Capital-intensive fisheries using relatively large vessels with a high degree of mechanization and that normally have advanced fish finding and navigational equipment. Such fisheries have a high production capacity and the catch per unit effort is normally relatively high.
Artisanal	Traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amount of capital, relatively small fishing vessels, making short fishing trips, close to shore, mainly for local consumption.
Subsistence	All fish caught are shared and consumed directly by the families and kin of the fishers rather than being bought by intermediaries and sold at the next larger market. Pure subsistence fisheries are rare as part of the products are often sold or exchanged for other goods or services.

Table 3. Description of the types of fisheries occurring in the three deltas.

In India industrial (or mechanized) and artisanal fisheries are equally important (Vivekanandan, 2002; Table 4; Figure 2b). Artisanal fisheries represent a significant portion of India's fisheries and the major fishing activities are concentrated in the areas shallower than 100m deep (Planning Commission, 2011). In the GBM delta region about 68% of all vessels are non-mechanized with most of them less than 20m in length overall. Artisanal vessels consist of catamarans and plank-built boats and the main gear types are usually gillnets, boat seines and driftnets (Table 4). Differently mechanized vessels are mainly used for trawling but also purse-seining, long lining and gillnetting (Table 4; FAO, 2006). Approximately 67% of the total fish produced in the country is consumed in fresh forms and nearly 6% is used for fish meal production, the rest (about 27%) is exported (Planning Commission, 2011).

Country	**Artisanal landings**	**Industrial landings**
Bangladesh	•**99%** •Gillnets •Pots & Traps	•**1%** •Bottom trawl •Longline tuna
India	•**49%** •Gillnets •Boat seines •Driftnets	•**51%** •Shrimp trawl •Mid-water trawls •Bottom trawls
Ghana	•**49%** •Gillnets •Seine nets •Hooks or gorges	•**51%** •Purse seines •Mid-water trawls

Table 4. Landings by gear type in the three deltas regions. The percentages of artisanal and industrial landings are calculated from the EEZ database (available at http://www.seaaroundus.org/).

In Ghana the marine sector includes small scale (artisanal or canoe), semi-industrial (or inshore) and industrial fisheries (Figure 2c). Artisanal fishery is the most important in terms of output producing about 70% of the total marine supply (FAO, 2007). The industrial sector in Ghana's Volta delta includes many locally built semi-industrial trawler/purse seiners with wooden hulls, the tuna fleets and the formerly the distant water fleet of Ghana. Small scale fisheries include both artisanal and subsistence fisheries (Figure 2c). This fishery accounts for 12,000 artisanal canoes (Bannerman, 2015) and it has about 200,000 fishers operating from 334 landing centres in 195 fishing villages located along the coast (Amador et al., 2006). Several gears are used (Table 4), in particular beach seine, set net, hook and line, drift gill net (Asiedu and Nunoo, 2013). Canoe fishers also use a variety of gears, including gill and entangling nets, seine nets (purse and seine nets) to exploit both pelagic and demersal fish species. This fleet is responsible for over 70% of the total annual landings of both pelagic (e.g. sardines, mackerels and anchovies) and demersal fish species (e.g. croakers, breams, snappers) (Asiedu and Nunoo, 2013). Lagoon subsistence catches contribute to the national fisheries and various types of gears are used in lagoon fishing, including cast nets and set nets. The most productive of these lagoons is the Keta lagoon which is estimated to have a potential total annual fish landing of 4,000 tonnes. In the Ghanaian artisanal fisheries, discards are negligible as almost all catch is sold and consumed, in contrast in the industrial sector, and especially the shrimping sector, up to 80% of the catch is by-catch, and much of it is discarded (Asiedu and Nunoo, 2013).

5. Main fished species in the three delta regions

Fisheries in delta zones are dominated by species such as sardines and Hilsa Shad (Figure 3) whose life cycle are entirely or partially marine. However, in both Bangladesh and India higher captures are made of freshwater species, mostly carp and catfish species (Figures 3a-b). Hilsa shad is the national fish of Bangladesh (locally known as ilish or ilisha), and it is found in marine, coastal and freshwater environments. A significant part of the catch is exported to India, where it is especially consumed on religious holidays, and it is also eaten by non-resident Bangladeshis living in many countries. In 2012-13, it contributed to 10% of the total fish production of Bangladesh (0.35 million tonnes with a market value of $2250 million) and contributed about 1% of Bangladesh's GDP (Fernandes et al., 2016). During the last two decades hilsa production from inland waters declined by about 20%, whereas marine water yield increased by about 3 times (Kathun, 2004). Bombay duck provides the second largest fish catches in the Bangladesh coastal region (Figure 3a; Table A1) and is usually consumed fresh or dried. It represents a lucrative fishery in the Bay of Bengal despite its price being approximately six times lower than Hilsa, because it is more affordable for the poorest people (Fernandes et al., 2016). Indian major carps, exotic carps and catfish are the most commonly cultured species in the lakes of the delta (Figure 3a; Table A1). Some carps such as *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala* and *Labeo calbasu* along with exotic carps (see Table A1) are cultured in polyculture system in ponds, while coastal areas are dominated by cultured giant tiger prawn (*Penaeus monodon*) and giant river prawn (*Macrobrachium rosenbergii*) (Azim et al., 2002).

On the eastern coast of India, the fish species that contribute to most of the catches are Hilsa shad and Indian oil sardine, followed by the farmed Catla and Rohu (Figue 3b; Table A2). However, some differences occur at state level; Scombridae are quite an important part of the marine landings in the Odisha state while production of major carps, minor carps and catfishes is much higher in West Bengal (Lauria et al., 2017). In general, an increase in landings has been recorded in both states during the period 1976-2005 (Central Marine Fisheries Research Institute). Three species of Indian carps (Rothu *Labeo rohita*, Catla *Catla catla* and Mrigal *Cirrhinus mrigala*) account for over 70-75% of total Indian fresh water fish production as well as freshwater prawns (i.e. *Macrobrachium rosenbergii* and *Pangasius pangasius*) that are farmed almost exclusively for export (Ayyappan, 2016). In contrast, almost the totality of fish produced by aquaculture is consumed by the domestic market (FAO, 2015a). Along with the carps, culture of catfishes (air-breathing and non-air breathing), tilapia (*Oreochromis niloticus*) are also very popular. In brackish water sector, the aquaculture includes culture of shrimp varieties like native giant tiger prawn (*Penaeus monodon*) and exotic white-leg shrimp (*Penaeus vannamei*) (Ayyappan, 2016). In the early 1970s, Fish Farmers Development Agency (FFDA) was set up with World Bank assistance to promote the adoption of modern aquaculture techniques and thereby increase fish production. Along with the production of native species (i.e. Catla, Rothu and Mrigal) three exotic species (Silver carp *Hypophthalmichthys molitrix*, Grass carp *Ctenopharyngodon idella* and Common carp *Cyprinus carpio*) are also intensively farmed (Katiha, 2000). The national average productivity from FFDA has rapidly increased making aquaculture a fast-growing enterprise and a viable alternative to the declining capture fisheries in India (Katiha, 2000). Fish consumption per species varies, on average freshwater carps (i.e. Catla, Rohu labeo and Mrigall) and low value marine pelagic fishes (Sardines and Bombay duck *Harpadon nehereus*) constitute the major share of total fish consumption even if the amount consumed differs among social classes (the richest consuming on average more than poor people; Maung, 2004). Some data on the economic value of freshwater carps and main fished species for West Bengal are available from the Handbook of Fisheries Statistics (2012-13). Carps are generally sold between 90-185 Rs/kg (US$1.4-2.8), while Hilsa is one of the most expensive species with a general price varying between 250-365 Rs/kg (US$3.8-5.6) however because of its limited availability (this species is mainly available during the monsoon season, while a small batch is also recruited during winter) its price can reach 1500-1600 Rs/kg (US$23-25) in some years (as per discussion with local fishermen). In the Indian Bengal Delta, similar to Bangladesh, Hilsa shad is being overfished nearly two times of its sustainable limit (Das et al., 2018).

Among Ghana's marine coastal fisheries pelagic fish account for about 65% of total landings (Nunoo et al., 2014b)(Figure 3c; Table A3). Round sardinella (*Sardinella aurita*), Madeiran sardinella (*Sardinella maderensis*) and Atlantic chub mackerel (*Scomber colias*) are very important in the entire Gulf of Guinea (Ansa-Emmim, 1973) followed by Scombridae, Carangidae and Thunninae (i.e. yellowfin tuna *Thunnus albacares*, skipjack *Katsuwonus pelamis* and big-eye *Thunnus obesus*; Nunoo et al., 2014). Between 2001 and 2010, skipjack tuna dominated in terms of total catches followed by yellowfin and bigeye (Adinortey, 2014). Among the farmed fish there are several species of tilapia (e.g. Redbelly tilapia *Tilapia zillii* and Mango tilapia *Sarotherodon galilaeus*, Nile tilapia *Oreochromis niloticus*) with the latter being one of the most important in terms of catches (Figure 3c). Of relevance are also the banded jewelfish (*Hemichromis fasciatus*), and the catfishes

(African sharptooth catfish *Clarias gariepinus* and African catfish *Heterobranchus bidorsalis*) (Table A3). Information on their relative importance is scarce but tilapias are the most dominant species in aquaculture with a production of about 80% of the total (760 tonnes) (FAO, 2015b). Both tilapia and North African catfish sell at ¢15 000 (US$ 1.63)/kg in Kumasi, Ghana's second largest city. In Accra, the largest city and the capital of Ghana, the cage culture farm sells tilapia at ¢35 000 (US$ 3.80)/kg at its sales outlets, while Clarias spp. sells for ¢50 000 (US$ 5.44)/kg (FAO, 2015b).

6. Economic importance of the fisheries sector

6.1 Present state of the fisheries sector in the deltas

The fishing sector, especially the artisanal and semi-industrial fisheries, has long been the prime source of employment for unskilled young men (Pauly, 1976), this is particularly true in delta areas where aside from professional fishermen there are also many people that fish occasionally to procure food for their families (subsistence fishermen). In Bangladesh the fisheries sector provides employment to 12 million people, of which 1.4 million rely exclusively on fisheries (DoF, 2002). Of these there are 900 000 in the marine fisheries sub-sector (including up to 450 000 seasonal fry fishers, mainly women and children). An estimated 9.5 million people (73 percent) are involved in subsistence fisheries on the country's flood plains. There are 3.08 million fish farmers, 1.28 million inland fishermen and it is estimated that fisheries and related activities support more than 7 percent of the country's population (FAO, 2014b). In Bangladesh most of the poor people work in the fisheries sectors; they are employed as labour under rich fish/shrimp farmers, boat/net owners and fish traders and receive daily wages about 200-250 taka ($US2.5-3.1) (Kathun, 2004).

Fisheries products are exported from Bangladesh to Europe, USA and Japan, of these 90% are frozen shrimp and prawns (Kathun, 2004). In 2003 shrimp exports amounted to US$ 297.04 million which was approximately 5% of total exports. More than 2 million people are engaged in upstream and downstream activities related to the shrimp industry in the country, such as harvesting, culture, processing, exporting and other ancillary activities (Aftabuzzaman, 2004). Bangladesh fish exporters have faced many problems meeting international food safety and quality standards over the years (BBS, 2001). These situations pushed the government, local industry and external donors to invest a conspicuous amount of money to upgrade plant infrastructure, train employees and audit sanitary facilities (Dey et al., 2010; Golub and Varma, 2014). The country also imports several commodities, most notably fish meal and dried salted or unsalted fish (FAO, 2015a).

The fishery sector is also quite important in India as it provides jobs to 14.5 million of people (of whom 32% are men, 28% are women and as many as 40% are children; data from a census in 2003 conducted by the Indian government; Planning Commission, 2011). Women play an important role in fisheries and aquaculture in India, both in pre-harvest and post-harvest processing (ICSF). They work as paid/ unpaid workers in fisheries industries or within the community respectively. According to the CMFRI (Central Marine Fisheries Research Institute) census 2005 (Government of India, 2005), 48% of the marine fisher folk community of India are women. The major fishing related activities are marketing (41.8%), labour (i.e. intended as not active fishing) (18.4%) and curing/processing (18%). A large part of fishermen operate on the east coast (37% of the total fishermen in India; Planning Commission, 2011). Fishery products hold a prime status among the various commodities exported from India and represent about 13% of the total exports (Shinoj et al., 2009). Until 1960 export of Indian marine products mainly consisted of dried items (i.e. dried fish and dried shrimp), but since 1961 the export of dried marine products was overtaken by that of frozen items, leading to a steady growth in export earnings to new countries such as Japan, USA, Europe and Australia (Kaza and Venkataiah, 2012). The main commodities exported are frozen shrimps and prawns, as well as fish (including ribbon fish, oil sardine and mackerel) but the main contribution to exports comes from Indian shrimp aquaculture (Shinoj et al., 2009). Although the selling price of these crustaceans is less lucrative than fish, prawns and shrimps still bring high economic returns to India. Marked differences occur between the east and west coast of India, with the east coast traditionally exporting more low volume-high value products (mainly shrimp) than the west coast (Shinoj et al., 2009). In comparison, Indian imports of fish and seafood products are very low, this is probably because of past import bans that led to high tariffs and complicated licensing schemes (FAO, 2015a).

Data from the populations and housing census in 2010 suggest that in the Volta delta region, the fishing sector employs about 6-7% of the population in Ghana (Ghana Statistical Service, 2012) despite it is likely that an higher number of people are involved in fisheries (i.e. occasional fishers). A canoe census conducted for the marine fisheries in 2001 estimated 120,000 artisanal fishermen suggesting that the artisanal fishing sector is a growing source of employment (Bannerman et al., 2001). However, the combination of an increased number of fishers per boat between 1992 and 2001 and overall reduced catches/boat (from 35 tonnes in 1992 to 23 tonnes in 2001) indicates the decline of this sector as a source of gainful employment (Atta-Mills et al., 2004). Because of the increased number of boats, the earnings of fishermen have decreased. Ghana exports about 12% of the total national fish products (by weight); one of most significant non-traditional fish export is canned tuna but also canned and fresh tilapia, and shark meat and fins are exported to the European Union, Japan, United States of America, Canada, Hong Kong and Singapore (Food and Agriculture Organization of the United Nations, 2015b). It is estimated that the total value of fish exports from Ghana increased from US$ 68.5 million to 84 million between 1997 and 2000 (FAO, 2015b). Despite the export of fish products, the country is not able to meet its fish demand. Currently fish is imported to fill the seasonal and annual deficits, among the species imported are frozen horse mackerel (*Trachurus trachurus*), chub mackerel (*Scomber japonicus*) as well as sardinella, mainly during the lean season November to May (FAO, 2015b).

6.2 The fisheries sector within the wider socioeconomic context in the three deltas

Data from the Census of the years 2010 and 2011 of Bangladesh, India and Ghana complemented by statistics from the states for those years (i.e. the elaboration of multi-regional input-output tables for the delta and non-delta regions for each of these countries based on Cazcarro et al., 2018) are presented in Table 5 (data were collated from several sources; BBS, 2014; Cazcarro et al., 2018; GSS, 2013; PCA, 2011). These show the importance of the fisheries in comparison with other sectors, but also in relation (through the supply chains) to them. In addition, the main economic magnitudes (production and value added) and employment in fisheries in the deltas (also by gender) are discussed in the following sections. To compare the deltas with socioeconomic magnitudes in the rest of the country, we split the Ganges-Brahmaputra-Meghna into the Bangladeshi Bengal Delta and the Indian Sundarbans Delta sides.

	Total Value Added (Mio $)	Share	Value Added Fisheries (Mio $)	Share	Value Added Fisheries/ Total Value Added
Bangladesh	107,015	100.0%	1,990	100.0%	1.9%
Bangladeshi Bengal Delta	30,343	28.4%	1,275	64.1%	4.2%
Rest of Bangladesh	76,672	71.6%	715	35.9%	0.9%
India	1,753,854	100.0%	14,175	100.0%	0.8%
Indian Sundarbans Delta	17,443	1.0%	710	5.0%	4.1%
Mahanadi Delta	6,407	0.4%	198	1.4%	3.1%
Rest of India	1,730,004	98.6%	13,267	93.6%	0.8%
Ghana	35,972	100.0%	662	100.0%	1.8%
Volta Delta	1,099	3.1%	81	12.2%	7.4%
Rest of Ghana	34,873	96.9%	581	87.8%	1.7%

Table 5. Value Added in the deltas and non-delta areas.

Table 5 shows the distribution of the Value Added (VA) of the countries analysed (distinguishing delta and non-delta regions) and the contribution of the fisheries sector to the VA in reach region. The delta regions are relatively small in terms of contribution to the total VA of the country (below 1.1% in both the Indian deltas and 3.1% for the Volta), except for the Bangladeshi Bengal Delta which represents about 28.4% of the economy of Bangladesh. The deltas show a higher specialization (i.e. share of fisheries sector in the total VA of the region) in fisheries than the areas outside the deltas of each of the countries. For example, when we consider all the agricultural, industrial and services activities we have seen that the delta represents about 28.4% of the economy of Bangladesh, but in the case of the activities of fisheries, the delta comprises a notable 64%. Still, the fisheries sector represents less than 8% of the total VA of the deltas: 4.2% in the Bangladeshi Bengal, 4.1% in the Indian Sundarbans, 3.1% in the Mahanadi and 7.4% in the Volta.

The economic importance of fishing activity was quantified with the Hypothetical Extraction Method (HEM) (Heimler, 1991; Schultz, 1977), this modelling approach is used to *extract* a sector hypothetically from an economic system and examine the influence (both direct and indirect macroeconomic effects) of this *extraction* on other sectors in the economy. For example, in the case of the Volta it is necessary to add to the direct losses of 7.4% in the whole economy (81 million dollars), additional 2.3% of indirect losses (25 million dollars), notably from activities of trade, transport and “Business services nec”. For the Bangladeshi Bengal delta additional 1.3% indirect losses (384 million dollars), add up to the direct losses of 4.2% (1,275 million dollars), while for the Indian deltas the indirect (backward) effects are quite small, adding a few decimal points to the 4.1% of direct losses (710 million dollars) in the Indian Sundarbans Delta and 3% (198 million dollars) in the Mahanadi delta. These results suggest that, in relation to other activities in the economy, fisheries have much greater importance in the Volta delta (between 5.7 to 7.4% share in production, and value added) than in other deltas. Similar findings (shares) are found for the analogous analysis of employment. It is important to notice that this type of information is useful when considering the figures with respect to the macroeconomics, but these variables do not tend to reflect the importance for livelihoods as much as other info on population sustained by subsistence fishing, food security challenges and share of animal protein obtained from fish.

The destination of share of production for each delta is shown in Figure 4, this suggests that the Volta delta has the highest share (close to 60%) of production for the final demand, which contrasts with the small share for exports to the rest of the world (smaller than that of the rest of Ghana).

6.3 Employment and gender issues

The gender breakdown of employment differs among the deltas (Figure 5). In the Volta delta employment in fisheries is slightly higher for male than female (but not too far from the 50%), as for the whole Ghana, while in Bangladesh it is a dominantly male activity (around 95% of the employment). The shares in India lie around 70% of male employment. It appears that despite being mostly done by males, the fisheries sector represents a quite important share of the total employment for females, close to 50% in the Volta delta, and 16.6% in the Indian Sundarbans delta, by comparison to the usual share around 25% of female employment in agriculture. In this regard the structure of household sources of income notably differs across deltas, agriculture being a dominant source for females in the Bangladeshi Bengal delta, while mainly services-based in the Volta and Mahanadi.

In some coastal areas of south Asia women live in considerably difficult conditions (especially where the seasonal rural-urban migration is marked). For example, they are left to run the households with increasing work burdens and decreased roles in the community (Prati et al., 2018). This is the case of women in the Mahanadi Delta region, here most of women’s work is unpaid (so it does not appear in the employment statistics). They work hard at home and often in the fields, while having less autonomy than their male counterparts over income and assets. In India women also play an important role in marine and freshwater aquaculture. In the Indian provinces of West Bengal and Odisha, the specific activities of fisherwomen in marine aquaculture involve collection of prawn seeds and crabs from estuaries and backwaters, labour in pond construction and management of small ponds (Alagarswami, 1992). This type of work is responsible for discomfort in many different body parts, especially in the lower back (98%), knees (88%), shoulders (75%) and feet (67%) due to prolonged working hour and excessive work load which affect their health and work performance (Das et al., 2012). In coastal villages of Bangladesh women generally do the same laborious and long working hours as men with the difference that men receive about 50% higher wages (DANIDA-DFID, 2003).

In the Volta delta women are indispensable to the survival of the artisanal fisheries sector as they are principally involved in the processing and distribution of the catch post harvesting. They are considered indirect participants to production due to the support they offer to the fishermen especially during the peak fish season in Ghana (Odotei, 1991). In fact, the perishable nature of fish requires that the landed catch be given prompt attention by way of processing and sale. The men being very tired on return from fishing trips and inexperienced in this area require the help of women to take charge of the post-harvest activities. Failure to process and sell the catch will mean disaster for both the fishers and the populace who depend on fish for protein (Tetteh, 2007).

6.4 Economic resilience

One of the main driving factors of the economics modelling has to do with the levels of capital, since it strongly affects the possibilities of higher expansion of the economy from investment. In this regard, it is key to consider general infrastructure loss, and in the case of fishing, ports and damage to boats. While India and Ghana can barely reach half of the landings in Bangladesh, artisanal catches represent all the fish provisioning there (Table 4) and capital intensity in fishing is lower. Challenges though may be higher in this area due to high exposure, frequency of extreme events, and given that the lower industrialization of the “fleet” may also indicate higher vulnerability of the boats. Factors which drive the socioeconomic evolution, and condition the challenges as well, are the projected population and general GDP growth, notably in Bangladesh, processes of structural change (from primary sectors to industrial and services sectors), which are also highly linked to urbanization, and other economic factors (e.g. openness to trade), and biophysical ones (e.g. land use change). Additionally, climate change impacts will likely not occur for fisheries alone, but also for agriculture and other sectors, which may further accelerate the challenges, notably given the combined losses of food supply.

6.7 The potential impact of climate change on fisheries in the deltas

Global climate models show sea surface temperatures near all three deltas rising by 1-3°C this century, depending on the level of carbon emissions (Bopp et al., 2013). However, projections of change in primary production differ greatly between the deltas, with the same study showing production stable or slightly increasing in the northern Bay of Bengal but falling by 60-100 g C m^{-2} y^{-1} in the region of the Volta delta. Studies of seas near the Volta delta are already showing a decrease in surface chlorophyll detected by satellite and in observed zooplankton biomass, both associated with rising temperatures (Nieto and Mélin, 2017; Wiafe et al., 2008). Regional projections for the Bay of Bengal, using the medium-carbon A1B scenario, gave a 21st century sea surface temperature rise of 2.3-2.9°C in the region of the GBM and Mahanadi deltas (Fernandes et al., 2016). The same study showed a small rise (0-5%) in net primary production over the 21st century, but a fall of 3-9% in fish production. The consistent picture from all these studies is that climate change is likely to lead to a reduction in available fish biomass.

The socioeconomic impact of climate change was investigated using an integrated modelling approach, i.e. using climate models coupled with fisheries size spectra models and socioeconomic models (see for more details on the modelling Cazcarro et al., 2018; Fernandes et al., 2017; Fernandes et al., 2016). This was applied to quantify the expected impacts of climate change on fisheries and consequently on socioeconomic aspects, up to the year 2050. In this integrated model, the fisheries productivity losses (based on likeliness of fisheries changes, which may involve growth of stock of some species, and higher losses in others) for each deltaic region are introduced as input. Under Business as Usual (BAU) Management these values were about 7.8% for Ghana, and of about 4.3% for the Bay of Bengal (to avoid the yearly variability given by climatic models, the productivity values for the initial and final years are estimated with 10 year averages). The results of the socioeconomic model reveal that up to 2050 the impacts of climate change would imply losses in the whole GDP for the three deltas of about 0.2% for the Mahanadi delta, 0.25% for the Bangladeshi and Indian Sundarbans deltas, and 0.7% for the Volta delta. Consumption levels would be affected by similar percentages to GDP but with different levels of dependency. Under a scenario of sustainable management, the estimated losses under the same scenarios would be strongly reduced (approximately cut to a third) and to fully counteract the effects a solid sustainable management plan should be applied. Future climate change and socioeconomic predictions (based upon IPCC emission scenarios) have similarly shown that these countries will face a decline in the potential fish production but that this could be mitigated under sustainable management practices (Barange et al., 2014; Fernandes et al., 2016).

The high share of production for the Volta delta (Figure 4) means that the impacts evaluated would have the largest direct effect on livelihoods there, in terms of self-sufficiency and food security. In addition, a larger share of the income of households, especially low-income ones, comes from fisheries in the Volta delta than elsewhere. In the other deltas larger impacts would come via reduction of income from exports. More refined simulations on climate change impacts show much further reflection in metrics such as value of exports and GDP, which are also the ones more likely to suffer reductions according to the fisheries modelling (Fernandes et al., 2016). Consequently, the impacts from the loss of fisheries would be disastrous, for example in the case of Bangladesh where more than half of animal protein obtained in households comes from fish.

7. Conclusions

Here we compared three deltas (the Ganges-Brahmaputra-Meghna, Mahanadi and Volta) that are found in some of the countries more dependent and vulnerable to changes in fish resources (i.e. Bangladesh, India and Ghana). The fisheries sector is vital for populations that live in the three deltas, as a source of animal protein through subsistence fishing, as a source of employment and for the wider economy. The aquaculture sector shows a rapid growth in Bangladesh and India, while in Ghana this is just starting to expand with a substantial increase of fish seed from hatcheries to reduce their higher dependence on marine catches. Inland fisheries are particularly important in Bangladesh, while Ghana has the highest proportion of marine catches. The fleet structure is quite similar in the three deltas with gillnets, pots, and seines being predominant in the artisanal fisheries, while the industrial sector mainly utilises trawls.

Fisheries play a more important part in the economy of Bangladesh and Ghana than for India, as evidenced by modelling the effect of the disappearance of this sector. On macroeconomic measures, fisheries play a larger part in the Volta delta than the others. Both men and women work in fisheries, with a higher proportion of women in the Volta then in the Asian deltas. Gender inequality is an issue, particularly in the Mahandi and GBM deltas, where women engage mostly in laborious tasks, often unpaid or with lower income than men. Their direct involvement in fishing is minor (except for support tasks at land) with a higher involvement in aquaculture.

Economic and integrated modelling using future climate scenarios suggest that changes in temperature and primary production could reduce fish productivity and fisheries income, however these losses could be mitigated by reducing overfishing and improving management. Our results from the economic analysis suggest that the dependency and impacts of changes in fisheries production are higher in the Volta and Bangladeshi delta compared with India. This could be due to the country's economic development and the size of the delta in relation to the country size. As a strategy of adaptation to climate change people migrate from the coastal areas to metropolitan areas with a gender bias towards men (DECCMA Brief, 2017a, 2017b, 2017c). This study provides a great insight on the human, economic and environmental aspects linked to three deltas vulnerable to climate change, despite many differences exist, still fisheries appear as key component of livelihoods in all three deltas as interrelates with many significant socio-economics aspects (e.g. food security, welfare, migration, gender, etc.). Active management, in the context of economic and environmental change, is needed to prevent overfishing and ensure sustainable production.

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Figures Legends

Figure 1. Fisheries production (expressed in tonnes) in Bangladesh (a), India (b) and Ghana (c) between 1950 and 2012.

Figure 2. Fleet structure in Bangladesh (a), India (b) and Ghana (c) between 1950 and 2010.

Figure 3. Main fished species (expressed in tonnes) in the three deltas in Bangladesh (a), India (b) and Ghana (c) between 1950 and 2012.

Figure 4. Destination shares of production for the three deltas.

Figure 5. Shares of employment by gender and sectors in the deltas.

Figure 1

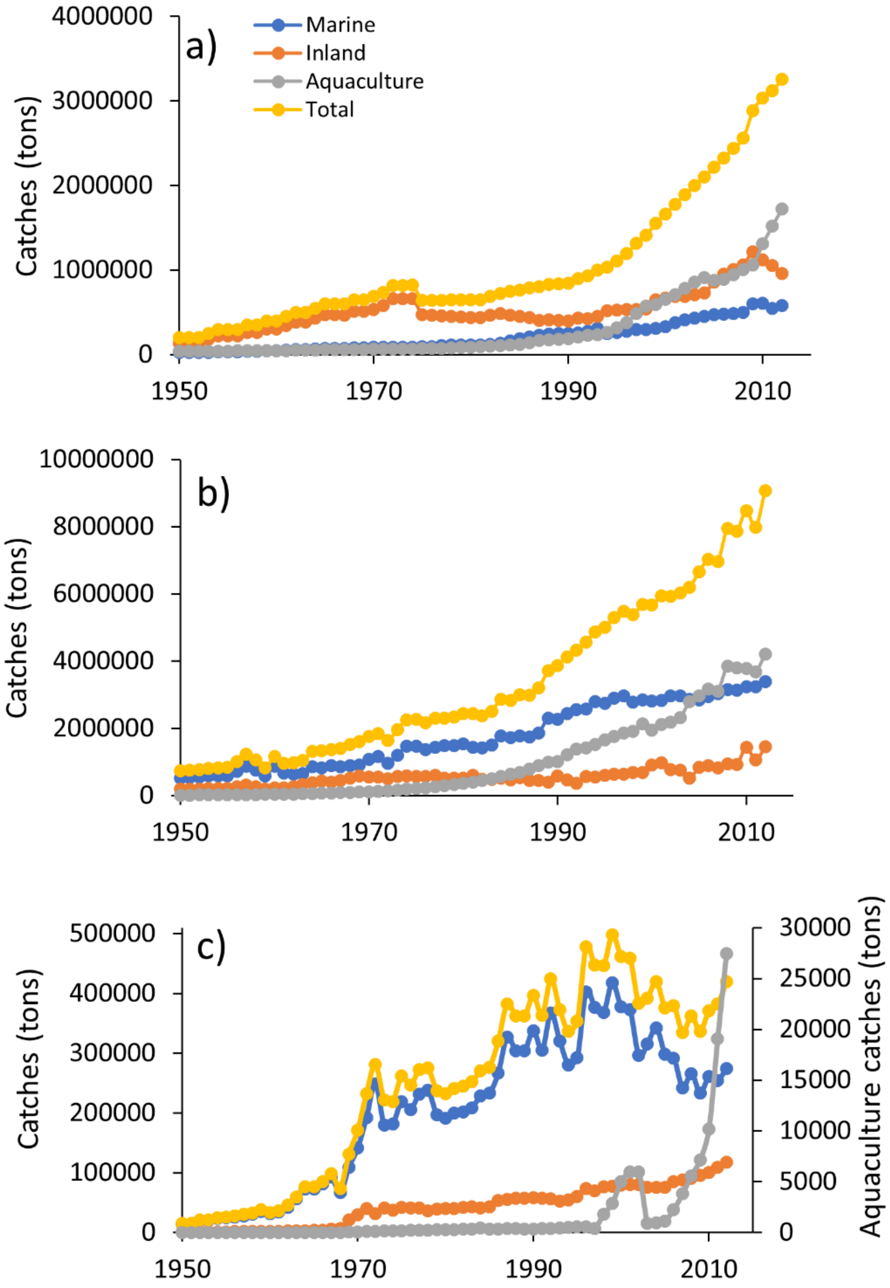
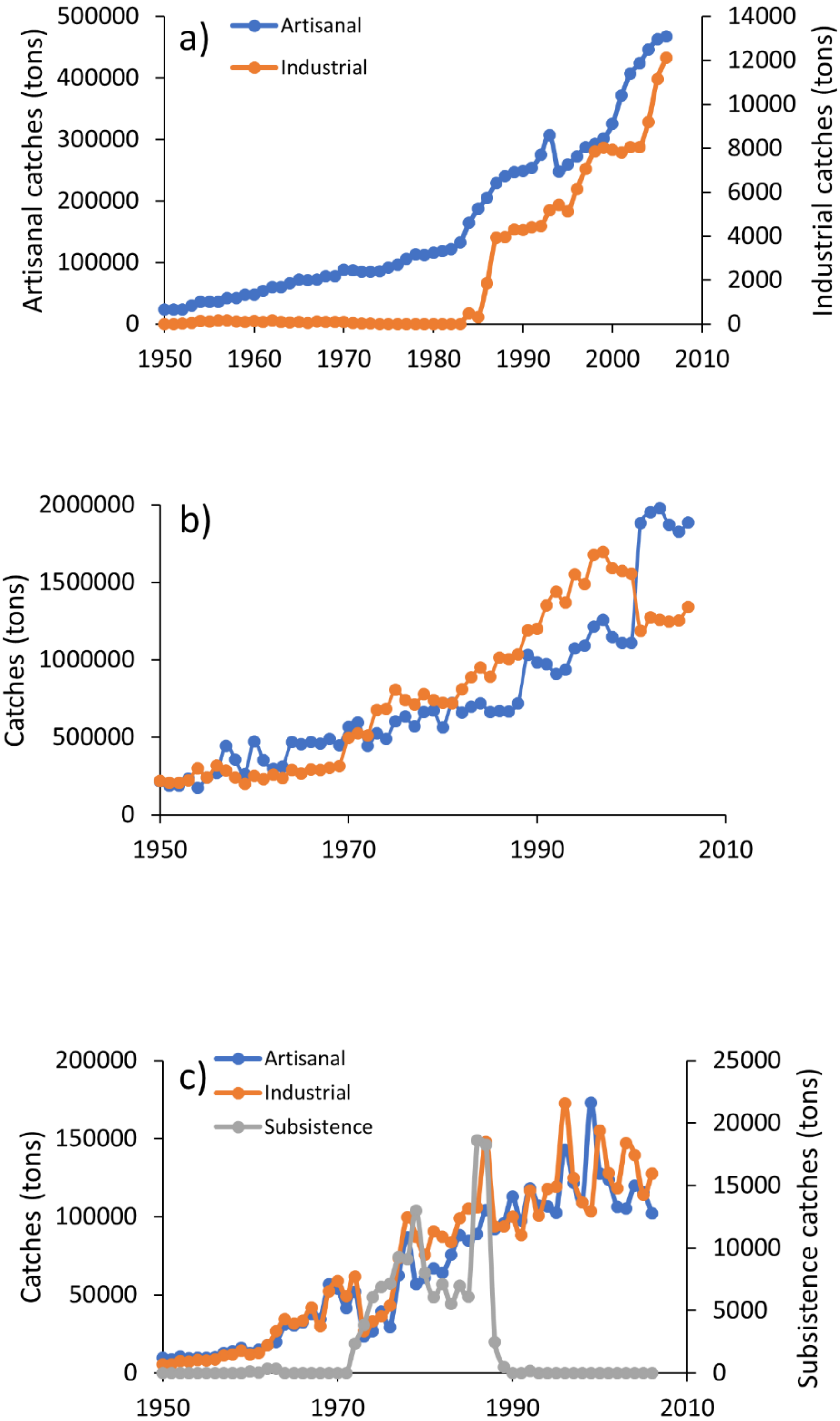

a)
Marine
Inland
Aquaculture
Total
Catches (tons)
4000000
3000000
2000000
1000000
0
1950
1970
1990
2010
b)
Catches (tons)
10000000
8000000
6000000
4000000
2000000
0
1950
1970
1990
2010
c)
Catches (tons)
500000
400000
300000
200000
100000
0
Aquaculture catches (tons)
30000
25000
20000
15000
10000
5000
0
1950
1970
1990
2010

Figure 2



a)
Artisanal
Industrial
Artisanal catches (tons)
Industrial catches (tons)
500000
400000
300000
200000
100000
0
14000
12000
10000
8000
6000
4000
2000
0
1950
1960
1970
1980
1990
2000
2010
b)
Catches (tons)
2000000
1500000
1000000
500000
0
1950
1970
1990
2010
c)
Artisanal
Industrial
Subsistence
Catches (tons)
Subsistence catches (tons)
200000
150000
100000
50000
0
25000
20000
15000
10000
5000
0
1950
1970
1990
2010

Figure 3

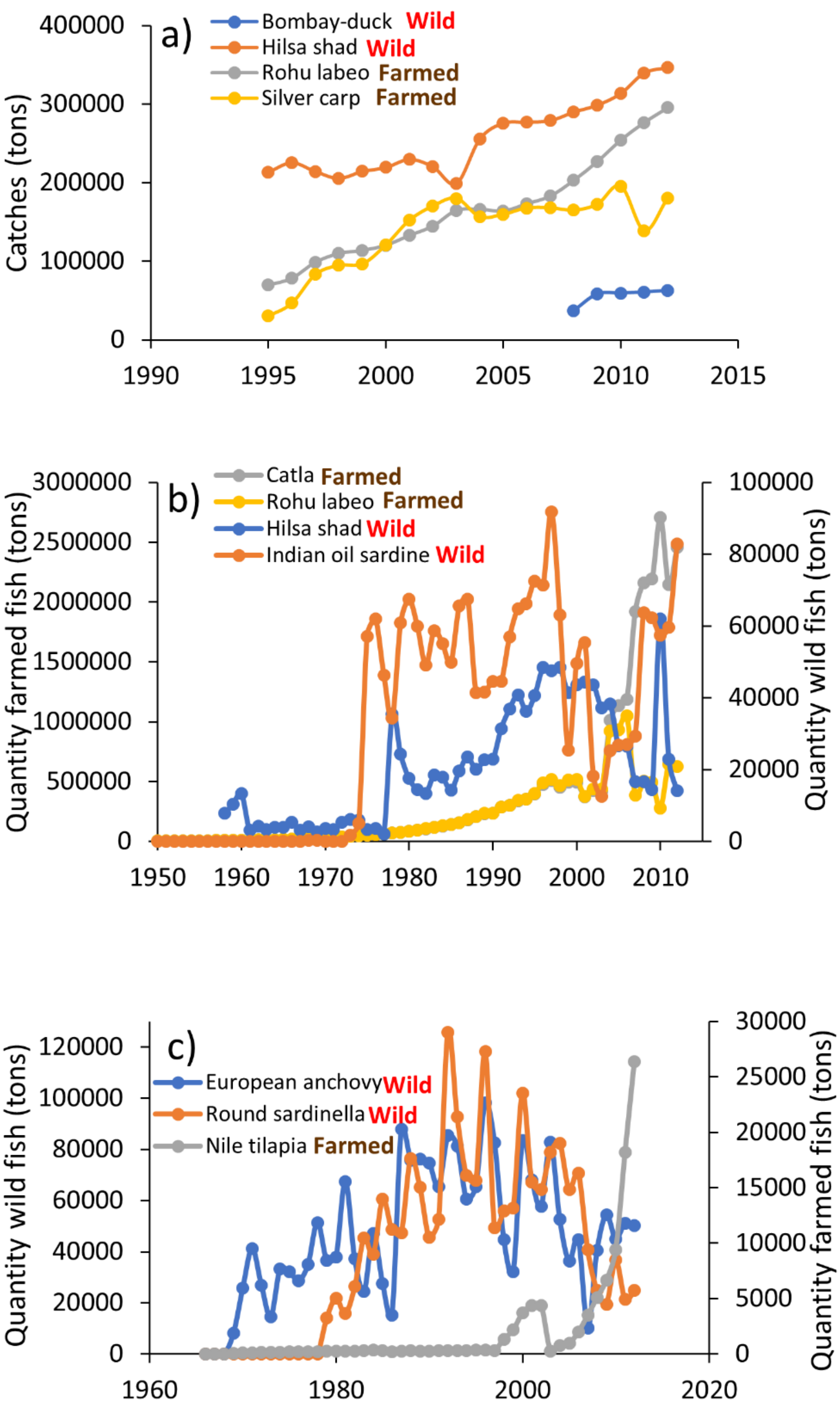

a)
Bombay-duck Wild
Hilsa shad Wild
Rohu labeo Farmed
Silver carp Farmed
Catches (tons)
0
100000
200000
300000
400000
1990
1995
2000
2005
2010
2015
b)
Catla Farmed
Rohu labeo Farmed
Hilsa shad Wild
Indian oil sardine Wild
Quantity farmed fish (tons)
Quantity wild fish (tons)
0
500000
1000000
1500000
2000000
2500000
3000000
0
20000
40000
60000
80000
100000
1950
1960
1970
1980
1990
2000
2010
c)
European anchovy Wild
Round sardinella Wild
Nile tilapia Farmed
Quantity wild fish (tons)
Quantity farmed fish (tons)
0
20000
40000
60000
80000
100000
120000
0
5000
10000
15000
20000
25000
30000
1960
1980
2000
2020

Figure 4

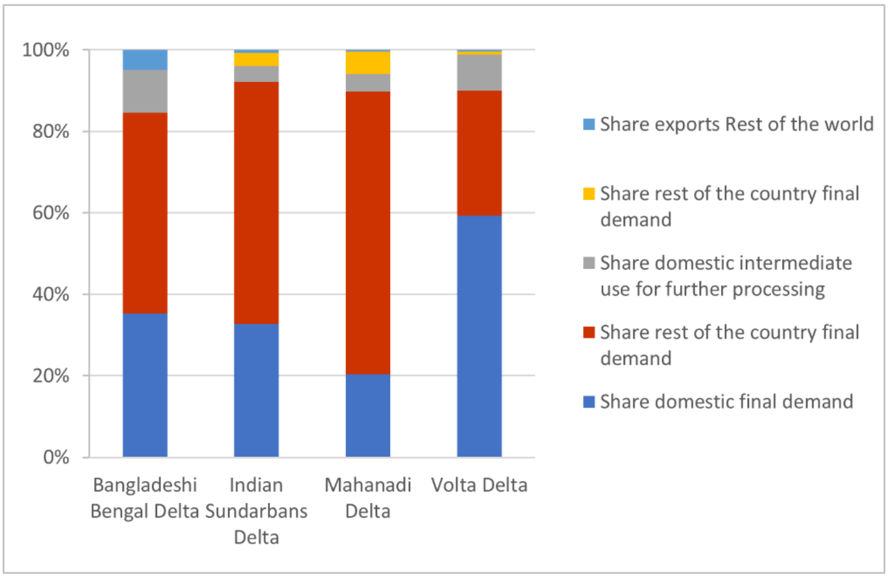
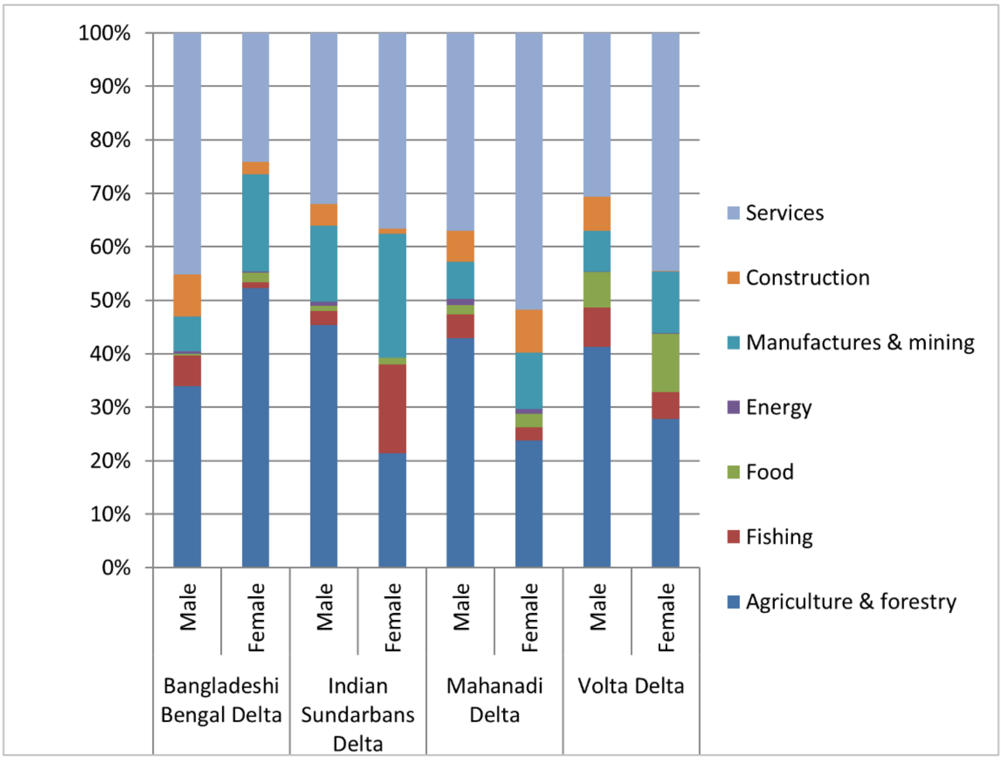

100%
80%
60%
40%
20%
0%
Bangladeshi Bengal Delta
Indian Sundarbans Delta
Mahanadi Delta
Volta Delta
Share exports Rest of the world
Share rest of the country final demand
Share domestic intermediate use for further processing
Share rest of the country final demand
Share domestic final demand

Figure 5


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Male
Female
Male
Female
Male
Female
Male
Female
Bangladeshi Bengal Delta
Indian Sundarbans Delta
Mahanadi Delta
Volta Delta
Services
Construction
Manufactures & mining
Energy
Food
Fishing
Agriculture & forestry

Appendix

Table A1. Main fished species in Bangladesh. Average (yearly) landings data are calculated on global capture data available at http://www.fao.org/fishery/statistics.

MARINE				
Common name	**Scientific name**	**Occurrence**	**Importance**	**Average landings (tonnes) 1950-2006**
Hilsa shad	*Hilsa kelee*	native	commercial	145323
Bombay duck	*Harpadon nehereus*	native	commercial	55637
Yellowfin tuna	*Thunnus albacares*	native	commercial	29
Seerfishes (mackerel type)	several species			21
Indo-Pacific blue marlin	*Makaira mazara*	native	commercial	17
Albacore tuna	*Thunnus alalunga*	native	commercial	9
Sharks rays and skates	several species			4
Black marlin	*Istiompax indica*	native	commercial	2
Swordfish	several species			2
Bigeye tuna	*Thunnus obesus*	native	commercial	2
FRESHWATER				
Common name	**Scientific name**	**Occurrence**	**Importance**	**Average landings (tonnes) 1950-2006**
Hilsa shad	*Hilsa kelee*	native	commercial	85473
AQUACULTURE				
Common name	**Scientific name**	**Occurrence**	**Importance**	**Average landings (tonnes) 1950-2006**
Roho labeo	*Labeo rohita*	native	commercial	165427
Striped catfish	*Pangasianodon hypophthalmus*	introduced	commercial	149931
Silver carp	*Hypophthalmichthys molitrix*	introduced	commercial	137774
Catla	*Catla catla*	native	commercial	135414
Mrigal carp	*Cirrhinus cirrhosus*	native	commercial	102963
Tilapia	*Oreochromis mossambicus*	native	commercial	67372

Table A2. Main fished species in India (east coast). Average landings data are calculated on global capture data available at http://www.fao.org/fishery/statistics.

MARINE				
Common name	**Scientific name**	**Occurrence**	**Importance**	**Average landings (tonnes) 1950-2006**
Indian oil sardine	*Sardinella longiceps*	Native	Commercial/mainly sold for consumption	172441
Drums or croakers	*Protonibea diacanthus*	Native	Commercial/Sold mainly for medicinal purpose (the swim bladder of main importance)	147779
	Pama pama	Native	Commercial/mainly sold for consumption	
	Panna microdon	Native	Commercial/mainly sold for consumption	
	Otolithes ruber	Native	Commercial/mainly sold for consumption	
Bombay duck	*Harpadon nehereus*	Native	Commercial	110890
Herring (or wolf herring)	*Chirocentrus dorab*	Native	Commercial	107053
Smooth Back Herring	*Raconda russeliana*	Native	Commercial	
Indian mackerel	*Rastrelliger kanagurta*	Native	Commercial	97149
Cutlass fishes (Ribbon fish)	Family Trichiuridae	Native	Commercial	68150
Large head ribbonfish	*Trichiurus lepturus*	Native	Commercial	
Small headae ribbonfish	*Lepturacanthus savala*	Native	Commercial	
Anchovies	*Stolephorus indicus*	Native	Commercial	58844
	Coilia dussumieri	Native	Commercial	
	Coilia reynaldi	Native	Commercial	
	Setipinna phasa	Native	Commercial	
Lizard Fish	*Saurida tumbil*	Native	Commercial	
Pomfrets	*Pampus argenteus*	Native	Commercial	
	Pampus chinensis	Native	Commercial	

	Parastromateus niger	Native	Commercial	
Seer Fish	*Scomberomorus commersoni*	Native	Commercial	
	Scomberomorus guttatus	Native	Commercial	
Mullets	*Mugil parsia*	Native	Commercial	
	Mugil tade	Native	Commercial	
Tuna	*Euthynnus affinis*	Native	Commercial	
Soles (Flat Fish)	*Cynoglossus arel*	Native	Commercial	
	Cynoglossus cynoglossus	Native	Commercial	
	Cynoglossus bilineata	Native	Commercial	
Penaeid Prawns	*Penaeus monodon*	Native	Commercial	
	Penaeus indicus	Native	Commercial	
	Penaeus semiculcatus	Native	Commercial	
	Metapenaeus monoceros	Native	Commercial	
	Metapenaeus dobsoni	Native	Commercial	
Non-Penaeid Prawns	*Acetes indicus*	Native	Non-commercial but important for the estuarine food chain of Bay of Bengal	
Crabs				
Mud Crab	*Scylla serrata*	Native	Commercial	
Sea crab	*Portunus sanguinolentus*	Native	Commercial	
Sea crab	*Portunus pelagicus*	Native	Commercial	
Sea crab	*Charybdis cruciata*	Native	Commercial	
FRESHWATER				
Common name	**Scientific name**		**Importance**	**Average landings (tonnes) 1950-2006**
Freshwater fishes nei	Several species		Commercial	357759
Cyprinids nei	Several species	Native	Commercial	264779
Roho labeo	*Labeo rohita*	Native	Commercial	
Catla	*Catla catla*	Native	Commercial	
Mrigal carp	*Cirrhinus cirrhosus*	Native	Commercial	
Freshwater siluroids nei	Several species			89198
Hilsa shad	*Hilsa kelee*	Native		31176
AQUACULTURE				

Common name	**Scientific name**	**Occurrence**	**Importance**	**Average landings (tonnes) 1950-2006**
Catla	*Catla catla*	Native	Commercial	391910
Roho labeo	*Labeo rohita*	Native	Commercial	218314
Silver carp	*Hypophthalmichthys molitrix*	Introduced	Commercial	144144
Common carp	*Cyprinus carpio*	Introduced	Commercial	134161
Mrigal carp	*Cirrhinus cirrhosus*	Native	Commercial	128152
Grass carp	*Ctenopharyngodon idella*	Introduced	Commercial	69059

Table A3. Main fished species in Ghana. Average landings data are calculated on global capture data available at http://www.fao.org/fishery/statistics.

MARINE				
Common name	**Scientific name**	**Occurrence**	**Importance**	**Average landings (tonnes) 1950-2006**
European anchovy	*Engraulis encrasicolus*	native	highly commercial	28883
Round sardinella	*Sardinella aurita*	native	highly commercial	27867
Bigeye grunt	*Brachydeuterus auritus*	native	commercial	8929
Madeiran sardinella	*Sardinella maderensis*	native	commercial	7738
Chub mackerel	*Scomber japonicus*	native	commercial	4933
Red pandora	*Pagellus bellottii*	native	commercial	3753
Crevalle jack	*Caranx hippos*	native	commercial	3200
West African ilisha	*Ilisha africana*	native	minor commercial	2899
Atlantic bumper	*Chloroscombrus chrysurus*	native	commercial	2722
Skipjack tuna	*Katsuwonus pelamis*	native	Commercial/export	
Yellowfin tuna	*Thunnus albacares*	native	Commercial/export	
FRESHWATER				
Common name	**Scientific name**	**Occurrence**	**Importance**	**Average landings (tonnes) 1950-2006**
Tilapia	*Tilapia busumana*	native	commercial	10333
Nile perch	*Lates niloticus* [1]	native	commercial/export	4300
AQUACULTURE				
Common name	**Scientific name**	**Occurrence**	**Importance**	**Average landings (tonnes) 1950-2006**
Nile tilapia	*Oreochromis niloticus*	native	commercial	1188
North African catfish	*Clarias gariepinus*	native	commercial	446
African bonytongue	*Heterotis niloticus*	native	highly commercial	20