# Chapter 13: Climate change impacts, vulnerabilities and adaptations: Southern Asian fisheries in the Arabian Sea, Bay of Bengal and East Indian Ocean

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# Impacts of climate change on fisheries and aquaculture

## Synthesis of current knowledge, adaptation and mitigation options

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*Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options.*
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# Chapter 13: Climate change impacts, vulnerabilities and adaptations: Southern Asian fisheries in the Arabian Sea, Bay of Bengal and East Indian Ocean

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## KEY MESSAGES

- Pakistan, India, Bangladesh, Myanmar and Maldives are among the countries most affected by climate change and weather events.
- There is strong socio-economic pressure from population growth, presence of dams and irrigation needs, heavy metal and waste pollution, habitat modification and destruction, illegal fishing, and insufficient infrastructure, skills credit and welfare.
- Inland fisheries captures are high and interlinked with the marine environment in countries where fisheries are important for employment, exports and income generation.
- Artisanal and subsistence fisheries are important in the region; however, the number of artisanal boats is decreasing probably as a result of over-exploitation and overcapacity.
- Marine maximum potential productivity is likely to decrease in those regions because of climate change, but that potential is not being achieved at present because of overfishing. This suggests that climate change impacts on specific fisheries can be partly mitigated by improving fisheries management.
- In many countries, government institutions have long-term plans that recognize the likely impacts of climate change. With limited resources, they are trying to establish and enforce fisheries management measures which can increase the resilience of communities to climate change.
- A lack of resources and scientific knowledge is often addressed through internationally funded cooperative research and support programmes that encourage ecosystem- and community-based approaches and science-driven management advice.
- International fisheries safety and sustainability certifications are a successful driver of change and have the potential to improve infrastructure, people training, commodity values, diversify markets and support the ecological sustainability of the activities of associated industries.
- Increased economic stability of fishers and associated industries through easy and low-cost access to insurance, welfare, credits and minimum wages is being promoted through government and non-government agencies; however, they can only reach a very small number of the people whose livelihoods are impacted by climate change.

## 13.1 FISHERIES OF THE REGION

### 13.1.1 Sensitivity and dependency of fisheries communities and livelihoods to climate change

The South and Southeast Asian (SA) countries in the Arabian Sea, Bay of Bengal and East Indian Ocean consist of the following: Bangladesh, India, Indonesia, Malaysia, Maldives, Myanmar, Pakistan, Sri Lanka and Thailand. These countries share similarities in their fisheries environment and socio-economics and this chapter, through examples taken from different countries, presents an overview of current and projected impacts of climate change in the region and the responses of countries to these changes and their impacts on marine fisheries. Maldives is also addressed in Chapter 12 on the Western Indian Ocean. Most SA countries fall in the region of heavy rainfall in the monsoon belt. As a result, they have many rivers, frequent floods and river bank erosion in delta regions. These factors contribute to a variety of ecosystems of high biodiversity and natural capital richness such as mangroves, wetlands and coral reefs (Tittensor *et al.*, 2010), but also to their vulnerability and the vulnerability of associated communities to climate change (Allison *et al.*, 2009; Barange *et al.*, 2014; Hossain *et al.*, 2018). Deltas (e.g. Ganges–Brahmaputra–Meghna delta in Bangladesh and India, Mahanadi delta in India, Indus delta in Pakistan and Ayeyarwady delta in Myanmar) are areas with fertile soils that contribute to maintaining the mangrove forests, which provide protection for the coast from erosion and sea level rise, while also providing refuge for young fish and serving as an important carbon sink (Salik *et al.*, 2015). During dry seasons, the water stored in wetlands is discharged slowly towards nearby habitats, helping to regulate the water levels and, during monsoons, wetlands such as marshes and ponds, store large amounts of water, reducing the pressure of flooding (NICRA-CIFRI, 2016). Coral reefs form some of the most diverse and sensitive ecosystems at a distance from deltas and other freshwater influxes (Heron *et al.*, 2016).

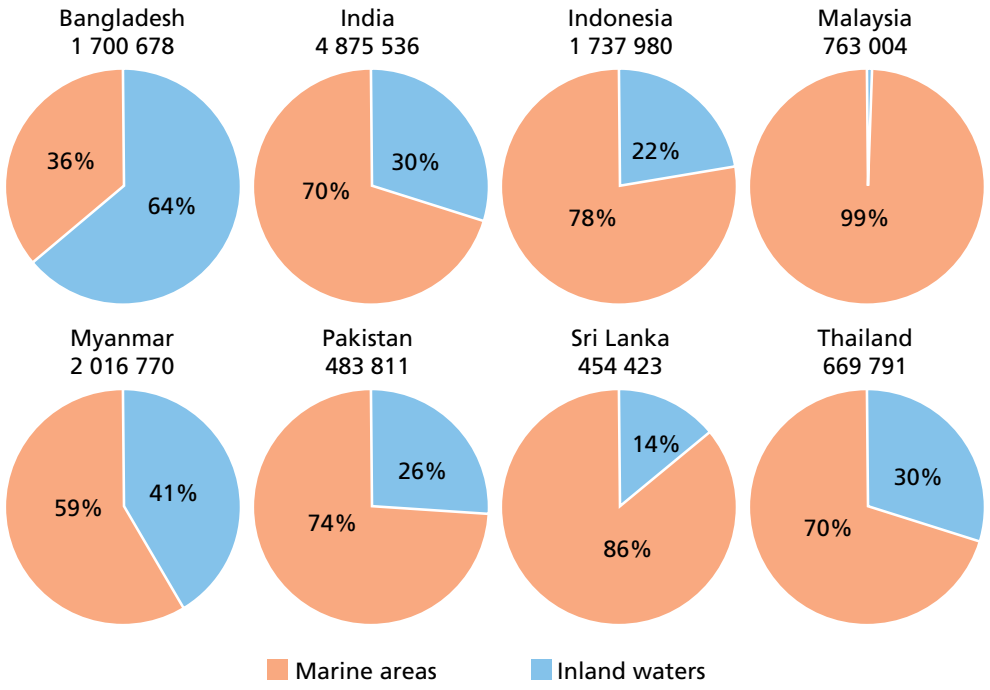
Bangladesh, Pakistan and Maldives are among the national economies most vulnerable to future impacts of climate change on fisheries and aquaculture (Allison *et al.*, 2009; Blasiak *et al.*, 2017). Bangladesh used to be ranked first among countries vulnerable to climate change (Ahmed, Diffenbaugh and Hertel, 2009) but research and development programmes might subsequently have contributed to reducing its vulnerability to sixth position (Kreft, Eckstein and Melchior, 2016). Four SA countries are among the ten countries considered to be most affected by climate change and weather events during the last two decades (Kreft, Eckstein and Melchior, 2016): Myanmar (second), Bangladesh (sixth), Pakistan (seventh) and India. In 2014 and 2015, India was placed fourth and tenth respectively in this ranking because of floods caused by unseasonal rainfall and it suffered from one of the deadliest heatwaves in world history, followed by a much weaker monsoon than normal. In general, poorer developing countries are hit much harder than more developed countries and these results further emphasize the vulnerability of developing countries to climatic risks, even though the absolute monetary losses may be much higher in more developed countries. The Maldives is composed of low islands that face the prospect of submergence during the twenty-first century (Nicholls and Cazenave, 2010). Sri Lanka is vulnerable to tsunami, which destroyed 65 percent of its fishing fleet in 2005 (De Silva and Yamoa, 2007).

### 13.1.2 Basic information on value of fisheries and its socio-economics: some examples

The relative contributions of marine and inland fisheries differ across the region, as illustrated by the examples presented here. The proportion of inland catches is larger than marine catches in Bangladesh (Figure 13.1). SA countries are rich in brackish water species (e.g. hilsa shad [*Tenualosa ilisha*], prawns) which have life cycles in both marine water and rivers. Widely distributed species are likely to be impacted by climate

change and are among the top fished species in SA countries (hilsa shad, Indian oil sardine [*Sardinella longiceps*], Bombay duck [*Harpadon nehereus*], Indian mackerel [*Rastrelliger kanagurta*], Indian salmon [*Eleutheronema tetradactylum*], small tunas [e.g. skipjack tuna], other mackerels [*Auxis* spp. and *Decapterus* spp.], and squids). These species have high economic and cultural value (e.g. hilsa shad in Bangladesh and Myanmar; ILO, 2015; Fernandes *et al.*, 2016a). Bombay duck, gobies, anchovies, bivalves, drums, croakers and shrimps are likely consumed by the poorest people (Ullah *et al.*, 2014; Fernandes *et al.*, 2016a).

FIGURE 13.1
**Examples of the average total national catch (metric tonnes) and the percentage contributions to those catches of wild captured fish from inland and marine waters for 2010 to 2016 (aquaculture is excluded)**




*Source:* FAO Fisheries and Aquaculture statistics.

Fishing is an important socio-economic activity in SA countries. Fish products are a substantial source of animal protein (up to 50 percent to 80 percent in Bangladesh, Pakistan and Sri Lanka) and contribute up to four percent of the gross domestic product in Bangladesh, Indonesia, Pakistan and Sri Lanka (Ali *et al.*, 2015; Bogard *et al.*, 2015; Dey *et al.*, 2008; DoFB, 2016; FRSS, 2017; Harkes *et al.*, 2015; Mruthyunjaya *et al.*, 2004; De Silva and Yamoa, 2007) and reaches 44 percent of coastal communities' GDP in Sri Lanka (Sarathchandra *et al.*, 2018). Fisheries and related industries are also an important source of employment in SA countries, e.g. seven to eight percent of the working population in Bangladesh and Indonesia, and particularly in rural areas (DoFB, 2016; Kathun, 2004; Hoegh-Guldberg *et al.*, 2009; Pakissan, 2017; SIDATIK, 2015). While full-time fishers are common in all countries (e.g. approximately 65 percent of all fishers in India, but only about 16 percent in Myanmar), it is often a part-time or occasional activity, sometimes involving children (Ali *et al.*, 2015; DAHDF, 2014; ILO, 2015).

Fisheries are also an important source of foreign income and, for example, India fishery products (shrimps, prawns, ribbon fish [*Trichiurus lepturus*], oil sardine and mackerel) represent about 13 percent of the total agricultural exports (Shinoj *et al.*, 2009). Hilsa is the top exported marine fish species of Myanmar and Bangladesh. Myanmar

exports mainly to China, Thailand, Malaysia, Singapore, Japan, Bangladesh and the EU (ILO, 2015), while Bangladesh exports frozen seafood products to more than 50 countries, including Belgium, United Kingdom of Great Britain and Northern Ireland, the Netherlands, Germany, the United States of America , China, France, the Russian Federation, Japan and Saudi Arabia. In Pakistan, about 35 percent of the fish and fishery products are exported to EU, Japan, the United States of America , China, Saudi Arabia, the United Arab Emirates, Malaysia, the Republic of Korea, China, Hong Kong SAR, Sri Lanka and Singapore (Pakissan, 2017).

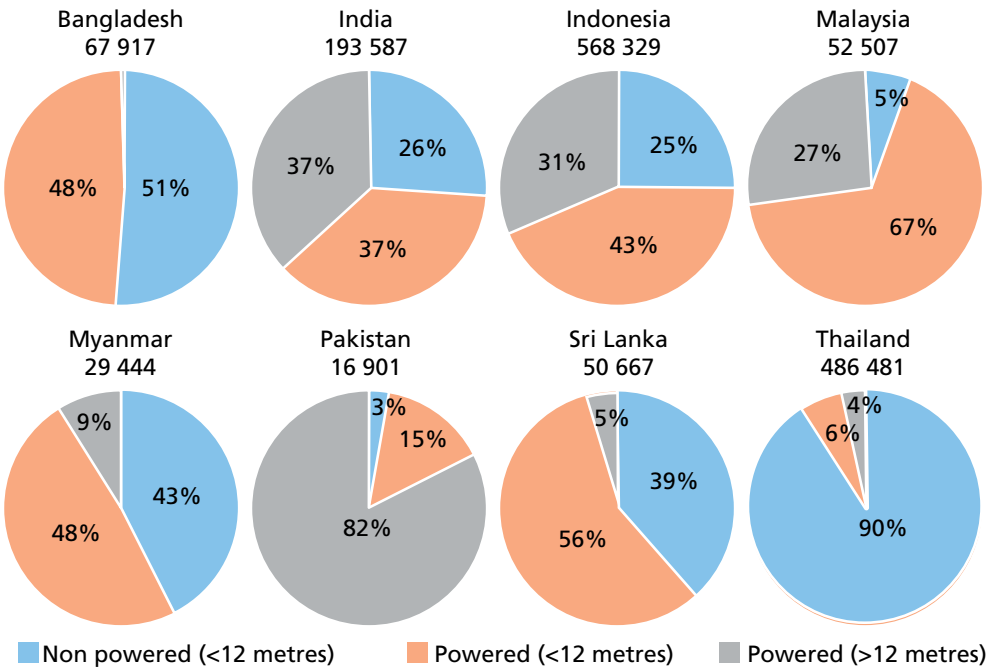
### 13.1.3 Basics of the structure and management of the fisheries of the region: some examples

*Fisheries structure*

Industrial and artisanal are the two main fisheries sectors in the SA countries (Vivekanandan, 2011) and illustrated in Figure 13.2. Artisanal fisheries involve the use of small mechanized and non-mechanized vessels, as well as nets deployed from the banks of rivers and coastal shores. Indonesia has an important tuna longline and purse seine fleet in the East Indian Ocean. Despite the general prevalence of artisanal and subsistence fisheries, there has been a trend in the last ten years of a decline in the number of small vessels and an increase in larger vessels that fish offshore. For example, in Myanmar the number of small fishing boats decreased by 15 percent in 2013 compared to 2009 figures, while locally owned offshore vessels increased by 45 percent (ILO, 2015). The reason could be high overfishing in nearshore waters driven by increases in the coastal populations (Fernandes *et al.*, 2016a). Large motorized and industrial fisheries often concentrate in one or a few ports in SA countries, for example in Myeik Township (Tanintharyi Region) and Yangon in Myanmar (ILO, 2015), Chittagong in Bangladesh (Hossain and Hasan, 2017), and Karachi harbour in Pakistan (Pakissan *et al.*, 2017).

FIGURE 13.2

**Examples of the total numbers and percentage contributions of different types of registered vessels for some SA countries**




*Source:* FAO Fisheries and Aquaculture statistics for year 2016 (except for Thailand where only 2015 statistics are available, and Indonesia). Since FAO fleet statistics for Indonesia have not been updated since 2011, we used DGCF (2015). PBS (2012) shows a larger proportion of small, non powered vessels (53 percent of the total) in Pakistan. Vessels data include all the country's fisheries, not only fisheries taking place in the East Indian Ocean region.

*Fisheries management*

The SA countries are developing fisheries management measures to increase the resilience of the sector to climate change despite limited capacity for implementation and enforcement. Some examples of recent developments in management measures include:

- *Limits to fishing gear.* The Myanmar government increased the mesh size for prawn trawl nets and finfish trawl nets (ILO, 2015) and various devices to reduce by-catch have been introduced. In shoreline areas (from five to ten kilometres) trawling and other forms of mechanized fishing are not permitted in India (FFCI, 2015).
- *Licensing schemes and seasonal closures.* In Myanmar (ILO, 2015), licenses for the monsoon fishing season have been cut by 25 percent and the length of season has been reduced from 90 days to 45 days. Foreign fishing vessels have been banned and the operations of large fishing companies reduced by 35 percent from April to August. India has undertaken licensing prohibitions on certain fishing gear or sizes and has established closed seasons and areas such as a "monsoon fishing ban" (FFCI, 2015).
- *Protection of nursery grounds.* Bangladesh banned the catching, possession, transport and trading of juvenile hilsa (jatka) between 1 November and 31 May every year, established hilsa sanctuaries, and introduced a ten day fishing ban in major spawning grounds.
- *Encourage alternative livelihoods.* In Bangladesh, hilsa fishers were provided with food-grains to live with and to start alternative activities (FRSS, 2017).
- *Limiting fish aggregating devices (FADs).* As an example, in 2014 Indonesia introduced around 12 new laws for management of the ever-increasing number of FADs in that country.
- *Introduction of monitoring and control tools.* For example, Thailand has introduced a vessel monitoring system (VMS) and logbooks, and every entry and exit to port of fishing vessels must be reported (DoFT, 2015).

## 13.2 OBSERVED AND PROJECTED IMPACTS OF CLIMATE CHANGE ON THE MARINE ENVIRONMENT RELEVANT TO FISHERIES

### 13.2.1 Physical and chemical

SA countries are very sensitive to cyclones, floods, droughts, rainfall, sea level rise and changes in temperature and salinity because they have long and highly populated coastlines (Das *et al.*, 2016; Hossain *et al.*, 2018). For example, Sri Lanka has experienced major floods and droughts in the last decade and rainfall variability is expected to increase (Esham *et al.*, 2018). Cyclones and hurricanes of categories 3, 4 and 5 are strongly influenced by sea surface temperatures (Ahmed, Occhipinti-Ambrogi and Muir, 2013; Knutson and Tuleya, 2004; Webster *et al.*, 2005). These countries' responses to cyclones have reduced the resulting deaths, however, economic losses are still large. For example, in 2007 Cyclone Sidr affected the livelihoods of around 8.9 million people and economic losses were estimated at USD 1.67 billion (Ahmed, Occhipinti-Ambrogi and Muir, 2013). The frequency of droughts has recently increased in Bangladesh (Habiba, Takeuchi and Shaw, 2010). In addition, sea level rise and glacier melting in the Himalayas are foreseen consequences of global warming that are likely to increase the problems of inundations in Bangladesh as two-thirds of the country is less than five metres above sea level (Ahmed, Occhipinti-Ambrogi and Muir, 2013): sea level rise in the Bay of Bengal will result in intrusion of saline water approximately 50 km further inland in Bangladesh than at present (Jakobsen *et al.*, 2005). Coastal zones of Thailand have experienced increases of sea level at the rate of 3 mm to 10.5 mm per year in the last two decades (Panpeng and Ahmad, 2017). In the Indus delta in Pakistan, an

increase in mean annual air temperature of 1.47 °C between 1951 and 2010 and a mean annual decrease of 78.4 mm in precipitation over the same period has been estimated (Salik *et al.*, 2015), with projections showing that the annual temperature could rise by another 1.15 °C by 2040 and up to 4.19 °C by the end of the century (Salik *et al.*, 2015). Sea surface temperature has increased by 0.2 °C to 0.3 °C along the Indian coast in the last 45 years, and it is projected to increase by 2.0 °C to 3.5 °C by the end of the century (Vivekanandan, 2011; Vivekanandan, Hermes and O'Brien, 2016). During the southwest monsoon, wind speeds and coastal upwelling have strengthened, resulting in higher concentrations of chlorophyll along the Kerala coast (Vivekanandan, 2011). The IPCC (2014) report provides an estimate of 4 °C increase in the ocean heat content in the Indian Ocean between 1960 and 2010. The Arabian Sea and Bay of Bengal are forecast to be among the marine areas with highest increases in temperature and precipitation by the end of century, with forecasts of increases of 4 °C and 40 percent precipitation under the high emission scenario for these two areas. The IPCC (2014) report also states that oxygen minimum zones are progressively expanding in the Indian Ocean.

### 13.2.2 Biological and ecological

There is only sparse specific literature looking at future scenarios in SA countries and regions (e.g. Bay of Bengal and Arabian Sea). Most literature is composed of global studies that have assessed that SA countries are among the countries more dependent on fisheries and more likely to be impacted by climate change. For example, 90 percent of inland fisheries occur in Africa and Asia (Cochrane *et al.*, 2009), where temperature increases are expected to exceed the global annual mean warming (Christensen *et al.*, 2007). Coral bleaching is likely to be an annual event in the future and reefs could soon start to decline and become only a remnant in the Indian seas between 2050 and 2060 (Vivekanandan, 2011). Mangroves in tropical regions are sensitive to global warming, which impacts the extent and composition of mangroves (Vivekanandan, 2011). The occurrence of harmful algal blooms seems to have become more frequent, intense and widespread and to cause considerable mortality of fish in the Arabian Sea and the Bay of Bengal (do Rosário Gomes *et al.*, 2014; Martin and Shaji, 2015; Vivekanandan, 2011). There is a relationship between the increasing surface temperature and the incidence of infectious diseases (e.g. dengue; Paul and Tham, 2015) and this has became a major public health issue in Sri Lanka (Sirisena and Noordeen, 2014).

## 13.3 EFFECTS OF CLIMATE CHANGE ON STOCKS SUSTAINING THE MAIN FISHERIES

### 13.3.1 Distribution, abundance, seasonality and fisheries production

Bioclimate envelope approaches have predicted a 30 percent to 70 percent increase in fish catch potential in high latitudes and a 40 percent drop in the tropics (Cheung *et al.*, 2010; Chapter 4). In a more recent study (Barange *et al.*, 2014), climate change was predicted to decrease total productive potential in South and Southeast Asia, driven by a temperature increase of approximately 2 °C by 2050, despite increased primary production by small phytoplankton. Oxygen concentrations might decrease in many areas of the ocean and vertical shifts in oxygen depth distribution will potentially influence tunas and food webs in the Arabian Sea and the Bay of Bengal (Mislan *et al.*, 2017). While these studies do not agree on the magnitude of change, given that they consider different numbers of drivers and uncertainties (Payne *et al.*, 2016), there is much agreement on areas of impact and direction of this impact and key drivers (temperature, acidification and hypoxia). A regional study forecast large decreases in potential catch of two key commercial species (hilsa shad and Bombay duck) in the Bay of Bengal (Fernandes *et al.*, 2016a). However, this study also showed that if the existing

high overfishing is reduced to a sustainable level, then climate change impacts can be partly mitigated. It has been reported that the small pelagics such as the oil sardine and Indian mackerel have extended their distributional boundary to northern and eastern latitudes, contributing to fisheries in the last two decades (Vivekanandan, 2011). The threadfin breams have been found to have shifted the timing of their spawning towards cooler months off Chennai (Vivekanandan, 2011). Oil sardine and Indian mackerel could benefit from increased temperature (Salim, Shridhar and Fernandez, 2017). However, local benefits resulting from changes in the distribution of species driven by climate change could be only temporal (Fernandes *et al.*, 2017). Shellfish species can be the most impacted by changes in temperature and pH (Fernandes *et al.*, 2017; Queirós *et al.*, 2015) and fish species could see their average size reduced (Queirós *et al.*, 2018), while changes in the seasonality of species such as threadfin bream are also expected (Salim, Shridhar and Fernandez, 2017). Exotic carp species, tilapia, pangas and koi, considered invasive species, expanded massively in Bangladesh, which could have been driven by climate change (FRSS, 2017).

### 13.3.2 Other non-climate stressors

Non-climate stressors can exacerbate impacts from climate change. Population growth and socio-economic drivers are highly likely to be a higher short-term source of stress to the environment and the livelihoods depending on it than climate change. Several of these stresses are highlighted in this (general) and the next section (fisheries specific).

*Pollution*

Heavy metal pollution affects ecosystem biodiversity through reproductive impairment and increased incidence of diseases (Kibria *et al.*, 2016b; Wu *et al.*, 2007). Invertebrates and fish accumulate metals from the environment, which can pose risks to humans through seafood consumption (Kibria *et al.*, 2016a). Agricultural, domestic and industrial wastes directly discharged into rivers are the main causes of metal pollution in Chittagong, Bangladesh (Kibria *et al.*, 2016a). Schmidt, Krauth and Wagner (2017) estimated that 95 percent of plastic polluting the world's oceans comes from just ten rivers including the Ganges (India and Bangladesh), Brantas (Indonesia) and Indus (Pakistan).

*Dams*

Impacts such as lower river flows because of the presence of dams and increased evaporation as a result of climate change are exacerbated by the construction of dams and increased demand for irrigation water (Cruz *et al.*, 2007; Salik *et al.*, 2015). Large dams may adversely affect small-scale fisheries downstream (Hallwass *et al.*, 2013; Chapter 19), particularly in the nursery areas of specific key species (Bhaumik, 2015).

*Habitat modification and destruction*

Unsustainable practices include coral mining, anchoring in reef areas and destructive fishing methods, such as cyanide fishing, dynamite fishing and the use of fine mesh nets (Burke *et al.*, 2011). Nowadays, 93 percent of Indonesia's coral reefs are at risk from these threats (Burke *et al.*, 2011). The Indus Delta in Pakistan hosts 97 percent of the country's total mangrove forests, which have suffered a 70 percent reduction associated with cutting for fuel wood and clearing land for agriculture, housing and industrial uses (Abbas *et al.*, 2013; Zaheer *et al.*, 2012). Similarly, Indonesia and Sri Lanka have lost 40 percent to 50 percent of their mangroves in the last three decades as a result of aquaculture development (Harkes *et al.*, 2015; Murdiyarso *et al.*, 2015).

### 13.3.3 Additional stress from fishing and post-harvest operations

*Shrimp post-larval collection for aquaculture*
The 80 hatcheries in Bangladesh can provide only 30 percent of the demand (Ahmed, Occhipinti-Ambrogi and Muir, 2013) and therefore farming of prawn (*Macrobrachium rosenbergii*) and shrimps (*Penaeus monodon* and *Metapenaeus* spp.) remains largely dependent on the capture of wild postlarvae (Ahmed *et al.*, 2013; Hossain and Hasan, 2017) in Bangladesh and Myanmar.

*Overfishing and overcapacity*
In many areas, fishing has become unrewarding as the catch per unit effort is extremely low, but poor fishers still try to catch whatever they can and thus contribute to destroying the natural resource (Ferrol-Schulte *et al.*, 2015; FRSS, 2017; ILO, 2015; Vivekanandan, 2011). The catch rate of elasmobranchs in coastal and shelf waters off India appears to be declining because of overfishing (Croll *et al.*, 2016). The export market has likely driven increased fishing effort and technological innovation leading to increased harvest and declines in local populations of Mobula species in Indonesia (Dewar, 2002; Heinrichs *et al.*, 2011). Overfishing in Malaysia might have been exacerbated by capacity-enhancing subsidies with capacity at 135 percent to 200 percent of the level needed to harvest the maximum sustainable yield (MSY; Ali *et al.*, 2015). Hilsa shad has been fished at two to three times MSY levels in Bangladesh (Fernandes *et al.*, 2016a). India also experiences overfishing in species such as Bombay duck and Indian mackerel (Fernandes *et al.*, 2016b). The Bay of Bengal Large Marine Ecosystem (BOBLME) project estimated that, for Myanmar, current catches are twice MSY levels (BOBLME, 2010). Thailand stock assessments report that current fishing effort is between 5 percent and 33 percent greater than MSY levels, depending on the species and regions (Derrick *et al.*, 2017).

*Illegal, unreported and unregulated activities*
Illegal, unreported and unregulated (IUU) fishing and piracy contributes to overfishing and insecurity in the sector. It remains a pervasive problem in the Asian region and its clandestine and illegal nature makes IUU fishing difficult to detect and deter (BOBLME, 2015; FAO, 2016). In Bangladesh, coercion of fishers by boat owners and captains and lack of enforcement of fishing regulations and maritime laws have been identified as barriers to adaptation (Islam *et al.*, 2014).

*Lack of skills, education and infrastructure*
Low levels of education, skills and climate literacy are acknowledged in SA countries as a limitation to adapting to climate change (Ahmed, Occhipinti-Ambrogi and Muir, 2013; ILO, 2015; Salik *et al.*, 2015; Vivekanandan, 2011). Lack of leadership has also been identified as a limitation to adaptation in Thailand (Bennett *et al.*, 2014). The lack of infrastructure constrains ice use for preserving catches, the cost of which represents 54 percent of the total costs for vessels (fuel only eight percent) in Myanmar (ILO, 2015).

*Lack of economic stability*
Credit services flow from the individual players who are at the top of the value chain to other actors, and fishers are trying to escape what becomes a "sweet prison" by avoiding loans so that they can search for options to get a better price for their catch (ILO, 2015). This problem could be exacerbated by a lack of finance and risk management literacy among those dependent on fisheries for their livelihoods (Ahsan, 2011). Corruption and inequitable distribution of wealth have been listed as factors that may constrain the ability of Thai to adapt (Bennett *et al.*, 2014).

*Gambling and crime*

Gambling and crime could be a new problem in some cities with high concentrations of fisheries activity, which have experienced rapid development such as Cox's Bazar, in Bangladesh (Lincoln, 2014).

## 13.4 RESPONSES (ADAPTATION)

Sustainable management of international fisheries has been estimated to have the potential to increase global fisheries production by ten percent (Cheung *et al.*, 2017), which could also translate into an additional increase of the value of fish products at local scales (Bundy *et al.*, 2017; Coll *et al.*, 2013). There are many options available for adaptation in fisheries, many of which benefit or provide an advantage to small-scale fishers and fish farmers (Miller *et al.*, 2018). These include actions that increase the resilience and adaptive capacity of communities and ecosystems, particularly by reducing other stresses such as social (poverty, inequality) and environmental stresses (overfishing, habitat destruction, pollution) (Cheung *et al.*, 2010; IPCC, 2007). Development agencies, regional fisheries management organizations (e.g. Indian Ocean Tuna Commission) and regional fisheries bodies (e.g. Bay of Bengal Programme–Intergovernmental Organization and the Southeast Asian Fisheries Development Center) as well as other regional organizations (e.g. Indian Ocean Commission, Regional Organisation for Protection of the Marine Environment, Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden, and South Asia Cooperative Environment Programme) can direct efforts to document, understand and apply proven successful adaptation mechanisms. For example, the Asia-Pacific Fishery Commission has carried out consultative workshops on climate change and fisheries with assessments and recommendations (FAO, 2011a; Sriskanthan and Funge-Smith, 2011). In considering adaptation approaches, it should be recognized that traditional management systems may support sustainable livelihoods, but they may also reinforce the social positions of those who oversee them, at the expense of less privileged members of the community. This can hinder equitable development (Neiland, Madakan and Béné, 2005).

### 13.4.1 Migration of people

Migration is a socially embedded process, which is perceived as arising from low adaptive capacity of the individuals or the communities coping with stressful changes (Adger, 1999, 2003; Brooks, Adger and Kelly, 2005). However, considering the broader perspective of migration, it can be established that migrations enhance the adaptive capacity of any community to cope with climate change (Barnett and Webber, 2010; Hossain *et al.*, 2018). Seasonal migration to locations where fish are available are common in fisheries, particularly small-scale or artisanal fisheries. This phenomenon can be exacerbated and complicated by the need to follow changes in geographical distribution of fish species because of climate change. A one metre rise in sea level could displace an additional 17 million people in Bangladesh, who will then act as "climate refugees" (Hossain *et al.*, 2012). Cyclones have also had a high impact in coastal communities, which can exacerbate migration (Hossain *et al.*, 2018). Deltas and low-elevation coastal zones are known for significant urbanization trends and land use change (e.g. Meyer *et al.*, 2016) and associated high movement of people, mainly for economic reasons (e.g. Foresight, 2011).

### 13.4.2 Community-based adaptation

An adaptation plan must be in line with the community's needs, abilities and interests. This requires that the community must be included in the planning, which will empower them by enabling them to posit their own ideas (Grafton, 2010; Shaffril, Samah and D'Silva, 2017). This empowerment can be based on local property rights-

based approaches (Allison and Ellis, 2001; Costello and Kaffine, 2010). Fishers' sense of belonging to their place of residence has been identified as leading to strong cooperative behaviour and social reciprocity in Malaysia and Pakistan, which has the effect of strengthening social relationships as an adaptation measure (Salik *et al.*, 2015; Shaffril, Samah and D'Silva, 2017). All the SA countries are developing the needed community collaboration and organizations for community-based fisheries management although at different scales and with different intensities. An important element is the existence of fishers' and industrial associations such as Fish Farmers Development Agencies in India (DAHDF, 2014) or Myanmar Fisheries Federation (ILO, 2015). An ecosystem approach to fisheries (EAF) at local scales should protect and restore fish recruitment and key habitats, explore livelihoods diversification and improve co-management systems (Table 2 in FAO, 2012). EAF strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties about nature and human components of ecosystems and their interactions to apply an integrated approach to fisheries that considers the impacts of fishing on the environment and other sectors, and at the same time considers the impacts of other sectoral influences (including climate change) on fisheries (Garcia *et al.*, 2003; Heenan *et al.*, 2015).

### 13.4.3 National climate change policies and long-term action plans

The need for policy that considers climate change has been acknowledged within SA countries. Malaysia and Myanmar (Shaffril, Samah and D'Silva, 2017) emphasize enhanced coordination and the adoption of systematic and targeted education and awareness on climate change for non-governmental and community-based organizations. Malaysia and Indonesia have adopted EAF as a national guiding principle in their policies and planning. Pakistan is developing localized action plans such as the National Climate Change Policy of 2013 and the Framework for Implementation of Climate Change Policy for the period of 2014 to 2030 (Salik *et al.*, 2015). India has several ongoing policy plans (DAHDF, 2014; Salim, Shridhar and Fernandez, 2017) that include: 1) Climate Change Action Programme; 2) National Action Plan on Climate Change 2008; 3) Indian Network for Climate Change Assessment; and 4) Twelfth Five-Year Plan and Climate Change. In Bangladesh end of century planning is under development considering outcomes from the ESPA-DELTA research project. Indonesia is also developing a National Climate Change Adaptation Plan. Sri Lanka has developed the National Climate Change Policy and the National Climate Change Adaptation Strategy (Marambe *et al.*, 2015).

### 13.4.4 Food safety and sustainability certifications

Change in the industry driven by certification requirements might have the effect of increasing the catch values, thereby mitigating potential catch volume reductions arising from climate change. Certifications are opening international markets, which account for 75 percent of the global fish trade (EU, Japan, and the USA) for SA countries. China is growing in importance as an importing country and aims to improve quality of fish imports, requiring that all Myanmar marine-product exports to China must be subjected to inspection to ensure that they match the same import regulations as imposed by the EU (ILO, 2015). Bangladesh's export success is because of the export of quality shrimp and introducing sanitary and hazard control procedures and traceability regulations according to the requirements of the EU and the United States of America (FRSS, 2017) after overcoming many problems to meet international food safety and quality standards (BBS, 2001; Golub and Varma, 2014). An importers' ban forced the local industry to act by investing to upgrade plant infrastructure, train employees and audit sanitary facilities (Cato *et al.*, 2003). The government, together with external donors, also invested in laboratory upgrades and employee training to meet the requirements of sanitary and hazard control standards (Dey *et al.*, 2010). Indonesian

companies are also working on getting international sustainability certifications to avoid losing European, American and Japanese markets. Thailand receiving a "yellow card" status from the EU has triggered a fishing vessels survey and the development of monitoring tools (VMS and logbooks) and landings control (Derrick *et al.*, 2017).

### 13.4.5 Alternative and diversified livelihoods

Recent work has started to assess the adaptive capacity of fisheries management to confront climate change (Leith *et al.*, 2014; Melnychuk, Banobi and Hilborn, 2014), and has identified economic resilience attributes for a given fishery (van Putten *et al.*, 2013), livelihood diversification options (Leith *et al.*, 2014) and the role of cooperation in addressing equity concerns as economic instruments for resource management (Pascual *et al.*, 2014). The increase in types of fishing gears in Myanmar is a strategy of fishers to cope with declining catch (ILO, 2015), despite a growing awareness by government that it can further aggravate overfishing. The Force of Nature Aid Foundation, a non-profit agency in Malaysia, has demonstrated the importance of skills diversification as one of the ways to empower communities (Shaffril, Samah and D'Silva, 2017). One example of such mechanisms is the diversification of livelihood systems, such as switching between farming and fishing in response to seasonal and interannual variation in fish availability. However, it must be considered that fishers are strongly attached to their work (Shaffril, Samah and D'Silva, 2017). For example, communities in Thailand have been quite varied in their capacity to adapt to alternative non-fisheries livelihoods (Bennett *et al.*, 2014). However, the promotion of non-fishing, non-environment-related income-producing activities should be intensified among small-scale fishers, which would reduce their dependence on the sea and diversify their income (Shaffril, Samah and D'Silva, 2017). As the financial dependence of their families on small-scale fishers is typically very high (Shaffril *et al.*, 2013), it would be advantageous to offer such alternative skills not only to small-scale fishers, but also to their families. Training efforts in Myanmar led to 40 fishery training courses in aquaculture, fisheries management, English and computer literacy, and market access requirements during 2013 to 2014 (ILO, 2015). Cultivating aquatic algae in India for food and pharmaceutical purposes and for production of biodiesel is an alternative livelihood that has been a positive response to climate change (Vivekanandan, 2011).

On industrialized continents such as Europe, North America, and Australia, recreational fisheries can represent the primary fisheries sector in inland waters (Christensen *et al.*, 2007). Recreational fisheries provide substantial additional value because they can also boost other tourism industries (Cooke *et al.*, 2016; Paukert *et al.*, 2017). Even in emerging economies, inland recreational fisheries are expanding as a result of angling tourism and increasing domestic participation (India, Gupta *et al.*, 2015; Malaysia, Teh and Teh, 2014). A lack of scientific knowledge on the basic biology of sport fish species, targeting of threatened species, and the absence of region- or species-specific angling regulations for recreational fisheries are identified as the challenges associated with this sector in India. Moreover, governance structures need to be strengthened, as multiple agencies are currently assuming some responsibility for recreational fishing, but none is tasked explicitly with its sustainable development and management (Gupta *et al.*, 2015).

### 13.4.6 Socio-economic stability: insurances, welfare, credits and minimum wage

Many small-scale fishers face risks each time they operate their fishing routine because of the lack of safety-at-sea training and adequate equipment, which hinders their capacity to adapt to changes as result of climate change. The National Fisherman's Association of Malaysia has introduced an affordable insurance protection scheme (Shaffril *et al.*, 2013), while India has the National Scheme of Welfare of Fishermen (DAHDF, 2014). Less than 20 percent of the total population have access to formal

financial services in Myanmar and Bangladesh, with lower rates in rural areas (ILO, 2015; Jahan, Ahsan and Farque, 2017). The United Nations Development Programme Human Development Initiative has contributed to the development of microfinance operations in Myanmar and an increasing access of small-scale fishers to finance with low or zero interest rates (Shaffril *et al.*, 2017). The FAO Regional Fisheries Livelihoods Project has facilitated micro-finance services in some SA countries (ILO, 2015). Peer savings networks are usually comprised of people from similar social networks, financial strata, and occupation (ILO, 2015). Low wages and insecurity resulting in high employee turnover is leading some companies to offer long-term employee recognition programmes and meal and transportation subsidies as well as training programmes (ILO, 2015). In Thailand, Bennett *et al.*, (2014) identified the importance for fishers' adaptation of access to credit, social bonding, equity, access to land and local ownership, suitability of sites for tourism, and hiring of local labourers.

### 13.4.7 Marine protected areas, ecological restoration and spatial planning

Establishment of marine protected areas can be an effective tool for conserving fish stocks, biodiversity and increasing fish production (FAO, 2011b; Hilborn, *et al.*, 2004; Lubchenco *et al.*, 2003). They have been promoted as a solution to fisheries collapses in some instances, because of their potential positive spill over effects, for some species, for adjacent fisheries with potentially substantial benefits for artisanal fisheries (Costello and Polasky, 2008; Lester *et al.*, 2009; White *et al.*, 2008). Series of linked marine reserves have been proposed as a logical response to protect shifting species ranges arising from climate change (Hannah, 2008; Jones, Qiu and De Santo, 2013). Bangladesh has established more than 500 fish sanctuaries throughout the country (FRSS, 2017) including the Saint Martin Island, the Sundarbans (mangrove forest) and a marine reserve (covering 698 km$^2$) in the Bay of Bengal to protect and preserve the breeding grounds of marine flora and fauna. It has also developed a MPA policy framework (BOBLME and IUCN, 2014).

Ecological restoration has been practised as a means of rehabilitating ecosystems and habitats that have been degraded or impaired through human use or other causes, such as climate change, with evidence of increased biodiversity and improved ecosystem function, but has been expensive and of limited coverage (Timpane-Padgham, Beechie and Klinger, 2017). Marine spatial planning is a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives (Ehler and Douvere, 2009; Muñoz *et al.*, 2017; Sale *et al.*, 2014). Novel approaches can use ecosystem models to consider socio-economic activities as well as climate scenarios in areas with sparse biological data using methodologies that have been tested in rich data areas (Queirós *et al.*, 2016), aided by improved data collection and geographical information systems (DAHDF, 2014). All these can be, with effective and participatory planning, examples of win-win adaptation measures (Grafton, 2010).

### 13.4.8 International research and collaboration programmes

Projections of fish distribution, abundance and catches need to be developed for planning better management adaptations (Vivekanandan, 2011). Lack of data (e.g. oceanographic surveys) and scientific knowledge is a constraint to this aim (Maung-Saw-Htoo-Thaw *et al.*, 2017). However, it is starting to change with initiatives such as the 2nd International Indian Ocean Expedition (IIOE-2), a five-year programme of oceanographic research that started in the Indian Ocean in 2015. Several international scientific research programmes are also addressing those needs. BOBLME[1] in the Bay of Bengal (Maldives, India, Sri Lanka, Bangladesh, Myanmar, Thailand, Indonesia

[1] http://www.boblme.org/

and Malaysia) aims to improve the lives of the coastal populations through improved regional management of the Bay of Bengal environment and its fisheries. The EAF-Nansen Project[2] in Myanmar aims to strengthen regional and country specific efforts to reduce poverty and create conditions to achieve food security through development of sustainable fisheries management regimes, and specifically through the application of the ecosystem approach to fisheries in several developing countries in all regions of the world. ESPA-DELTA[3] in Bangladesh aims to provide policymakers with the knowledge and tools to enable them to evaluate the effects of policy decisions on the poorest people's livelihoods using the latest state-of-art ecosystem models and scenarios (climate and socio-economic). DECCMA[4] in India, Bangladesh and Ghana aims to analyse the impacts of climate change and other environmental drivers across contrasting deltas in Africa and Asia as well as the processes of migration as an adaptation strategy, also considering the gender dimension. USAID Indonesia Marine and Climate Support developed the Indonesia Fisheries Information System (I-Fish), a tool for Coastal Habitats (I-CATCH), which aims to help in enacting 25 new laws and regulations around fisheries and marine resource management. This project also trained 2 225 government personnel on marine affairs management. These and other initiatives provide valuable support for increasing knowledge and informing planning and decision-making.

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