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Impacts of climate change on aquaculture and fisheries: an integrated approach for adaptation and mitigation

M. Aminur Rahman[1]*, Kaniz Fatema Kanon[1], Md. Jamadul Islam[1], Shoumik Mojumdar[1], Al-Amin Ashik[2], Mohammad Habibur Rahman Molla[3]

[1] *Department of Fisheries and Marine Bioscience, Faculty of Biological Science and Technology, Jashore University of Science and Technology, Jashore 7408, Bangladesh*
[2] *Institute of Marine Sciences, University of Chittagong, Chittagong 4331, Bangladesh*
[3] *Department of Biological Sciences, Faculty of Science, King Abdulaziz University, Jeddah, 21589, Saudi Arabia*

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Abstract

The impacts of climate change, owing to their potentially vast reach and scale, embody a critical challenge for fisheries and aquaculture, and the livelihood of many coastal countries including Bangladesh, most specifically the fishing communities living close to these resources. The fisheries and aquaculture sector in the coastal areas is subjugated by export-oriented saltwater shrimp and freshwater prawn farming. However, different variables including drought, cyclone, flood, salinity, rainfall, sea level rise, and sea surface temperature have profound antagonistic effects on shrimp and prawn production. Fishery resources are very sensitive to the seashore, river flows and elevation of the lake, and variations related to ocean, coastal and wildlife productivity. Adoption of climate change with such high exposure to climate risks is becoming an important concern for fisheries organizations. Although fisheries have always had to cope with variable production and unpredictable changes in weather, future climate change will bring shifts in climatic means and in the frequency and severity of extreme events that are beyond the coping capacity of even the more flexible and adapted fishery systems. Considering vulnerability in fishery production systems to the effects of climate change on coastal aquaculture, it is still worth investing in building the capacity of fishery production systems to adapt future climate change scenarios. The main reason is that the most options for building adaptive capacity are also required to manage fish stocks effectively and to reduce the poverty and vulnerability of fishing-dependent people.

Keywords: Climate change; Adaptation; Fisheries; Aquaculture; Coastal area

*e-mail: amin2019@just.edu.bd / aminur1963@gmail.com

1 Introduction

The marginal people of coastal area are depended on aquatic and marine ecosystem, which is partially or fully influenced by climate change. In this study, main focuses have been given on the potential impact of climate change and the details of concurrent situation of fisheries as well as comprehensive adaption activities (Lindegren and Brander, 2018). Fisheries are expanding day by day behind the expectation of human protein demand and fish feed. Sharing of some examples will help in planning and expanding of adaption in fisheries, which will give the initial idea for policymakers, researchers, organizers, stakeholder and other practitioners, who are mainly engaged to develop fisheries and aquaculture sector in the world. The local and global food supply are depended on fisheries and aquaculture that are vital sources for the fulfillment of their livelihoods and nutrients demand. Aquatic food has essential minerals and unsaturated fatty acid that are related to export and import in many countries and thus has been getting popularity for trading around the world. At least 15% of animal protein are for more than 4 billion peoples, mostly representing from developing countries (FAO, 2012). Some regions and states, especially the small island countries are showed the higher percentage that represented up to 50% of animal protein. However, fisheries and aquaculture sector employs almost 43.4 million peoples, where a significant number comes from developing countries. They involved in aqua product processing, marketing, distribution, and supply, wherein up to another 200 million peoples throughout the world are engaged (Cochrane et al., 2009).

Alike with other coastal communities, the peoples of the Kingdom of Saudi Arabia (KSA) are concerned about the climate change scenarios that were observed by the survey of 128 countries in 2008 and perceived the upcoming threat from environmental degradation. The results showed that 49% individual people were concerned about climate change and 40% people knew about the threat of global warming caused by anthropogenic activities (Gallup, 2009). Probably the most worrying threat to our fisheries and aquaculture at the present time is global warming. There are several surveys conducted by the Arab Forum for Environment and Development where 98% individuals agreed that climate is changing and 81% believed that climate change is a serious problem for the fisheries sector. The 92% respondents thought that climate change is influenced by the human activities, arising from different sources such as fossil fuel, excessive use of energy and reduction of resources (Saab, 2009). Furthermore, 36% people responded that the Government of KSA was not taking enough steps, whereas 44% went to opposite, and 20% did not response on their questions. There has been no respondent who said that climate change has no impact for their country. Although global warming is a serious issue, there are steps that government and individuals can take to reduce its effects. The Government of KSA gave priority to health, pure water and food followed by the safeguard of coastal area. There are potential ways to solve these problems, or at least reduce the effects. For that reasons, those surveys were also asked to select three most important measures necessary to mitigate the problems, which may help to minimize and adapt the effect of climate change.

This is to say first of all, the predominant factors resulting in the warming of the earth are the emission of energy. Therefore, changing of consumption patterns, mostly reducing the use of energy, was the principal measure selected, followed by education and awareness. Ratifying and implementing international agreements can act as also a regulator. Although no data were

found on the level of awareness on climate change within the farmers in the KSA, the majority felt that the climate in the country is changing and that the trend is toward less moisture with an increase of drought severity and frequency. Many farmers also recognized extreme events such as floods as another indicator of climate change. During the 2010 season, date producers noticed unusual early blooming of palm trees as further evidence of a change in the climate (Oihabi, 2010).

This summary provides a brief outline of the adverse effect of climate change on fisheries and aquaculture around the world. The following section reviews the possible corrosion and adaptation options of different types of fisheries and aquatic organisms. The following adaptation activities are categorized by the different scale as well as established in the world, especially in developing countries. This review of adaptive actions is not complete – there are other resources that give additional in-depth evaluations of adaptation. Nevertheless, this review aims to focus on the variety of adaptation activities, specially addressing the fundamental impact on fisheries and aquaculture which will add more value in the fisheries management.

2 Impacts of climate change

The effect of global climate change directly or indirectly hampered fisheries and aquaculture sector through the several environmental phenomena such as sea level rising, ecological changes, ocean acidification, happening of extreme events and so on (Figure 1). Therefore, many targeted populations range and productivity habitat, environment and food web. As a result, it increased the production cost of fisheries and aquaculture as well as caused adverse impacts on the fishing community livelihoods and safety (Daw et al., 2009; Badjeck et al., 2010). Furthermore, physiological parameters are probably affected the growth, reproduction and mortality and thus needs adaptation to this changing scenario (Brander, 2010). In addition, the ecosystems that fish lived in, would be affected with indeterminate impact on fishery catch potential. Aquatic organisms including the fish species will possibly change their movements as cold water species and warmer water species both of which are predictable to shift poleward (Beare et al., 2004a; Beare et al., 2004b).

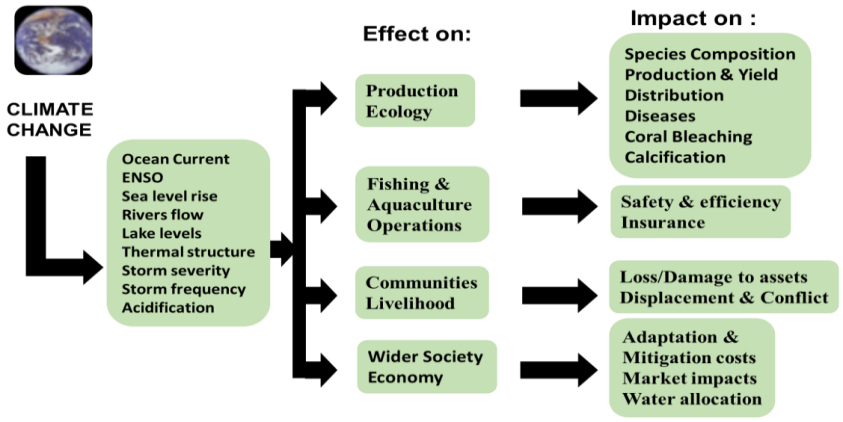


Figure 1. Diagrammatic representations of the effects of climate change on fisheries and aquaculture (Allison, et al., 2009).

Sea level rise, flooding and storm surges may have positive and negative influences on ocean biota, whereas anthropogenic activities also add more negative consequences. Among the most unique ecosystem, coral reefs are vulnerable to changes in sea level rise, temperature and ocean acidity. Costal people are depended on these resources, which ensure the nutrition, food security and coastal protection. It also has large impacts on inland fisheries, which are the vital source of protein. However, it will be affected by increasing salinity in the coastal area and affected the soil for cultivation. Furthermore, the exclusive economic zones (EEZ) are affected by this climate change where small-scale fisheries are depleted through the low catch potential of many tropical and subtropical countries (Beare et al., 2004a; Rahman et al., 2018).

On the other hand, offshore fisheries are decreased day by day as reported in the Mediterranean study. In the higher trophic level, it effected by warming of water which directly impact on biota abundance, survival, growth, migration, reproduction and phenology (Marba et al., 2015). The lethal mortality event happened in the early 1980s by heat wave and progressive warming that are attributed to climate change (Lejeusne et al., 2010). It causes most species shifted to colder place from warmer place. Examples of changes in species distribution and local abundance related to warming are widespread with two characteristic patterns: meridionalization: the northward extension, colonization and enhancement of the rmophilic species into the colder north Mediterranean regions (Lloret et al., 2015) and tropicalization: the increasing introduction and range extension of thermophilic, non-indigenous species, including Lessepsian species from the Red Sea and from the Indo-Pacific region (more than 900 species reported) (Boero et al., 2008). In the Black Sea, a progressive trend of arrival of Mediterranean species (mediterranization) is also evident, comprising phyto- and zooplankton, benthic invertebrate and fish species, along with species native to the Atlantic and Indo-Pacific Oceans (Shifanova and Ozturk, 2010).

The changes of physiological factor such as warming water, sea level rising, shifts in salinity, oxygen and other ocean condition that are directly or indirectly impact on marine organism and their associated fisheries. In Arabian Gulf are among them where climate change impact on serious condition by the hamper on marine biodiversity and fisheries catches. Meanwhile, there are conducted different projects based on habitat suitability and selected 55 species including fish and non-fish species by using separate ecosystem model. Finally, they have conducted vulnerability assessment of national economy to find out the impact on fisheries by climate change. As a result, the increase of local extinction up to 35% from past to present, which focuses mostly species richness. Furthermore, this ecosystem model shows that in near future, catch potential will be decreases in many western sides of the Gulf, affected Qatar and the UAE, with more than 26% decline in future. Bahrain and Iran both countries will be the most vulnerable to climate change by measuring of the socio-economic indicator (Wabnitz et al., 2018).

Some new ecological environments and opportunities can be formed by sea level rising in the coastal area. New habitats may be created for aquatic biota by melting polar ice (Easterling et al., 2007). The new opportunities will be come for increasing salinity by flooding coastal area which open new area for mangrove forest and aquaculture. Aquaculture and small-scale fisheries possibly will come to be accessible as aquatic biota change geographical position, and nearly extends in the ocean may exercise increased productivity, which accelerate the fisheries

production. The productivity of inland fishery will be exaggerated by increasing water temperatures, eutrophication, stratification, toxicity of pollutants and variability in water availability. Finally, the hostile water quality and lack of dissolved oxygen will affect the overall productivity of aquatic organisms.

The followings are the ways and consequences in which climate change may directly or indirectly affect fisheries and aquaculture:

a) Extreme events like floods, droughts, and storms increase the safety and efficiency of fishing operations and increase the structural damage and obstructions in coastal and riparian houses, services and healths.
b) The rise of the ocean, the headwaters of major rivers and the environmental changes will have an indirect impact on the melting of the glaciers and the wetland environment, livelihood and the production of fish in the ocean.
c) Changes in water temperature, ocean precipitation and ocean current dynamics affect the flow of rivers and areas covered by wetlands. The wetlands are one of the richest ecosystems that not only have the enormous environmental and socioeconomic benefits but also significantly support the distribution, habitat and production of fish stocks. Ocean acidification can affect aquaculture and shellfish fisheries, along with aquatic food chain. As the sea surface temperature continues to rise, climate change may represent the single greatest threat for coral belching events - the building of the rock and their mortality-related ecosystem and fisheries.
d) The complexity of climate change will also have indirect effects on aquaculture and fisheries through price-induced changes in inputs and aquaculture decisions as well as technological innovations.

3 Present trends and status of world's fisheries

A significant variation is found in specific fishing and population status in the global fisheries sector. Overexploitation, habitat alterations and pollution are directly causing threat to fresh and marine water species (Hilborn et al., 2003, Allan et al., 2005). Illegal, unreported and unregulated with destructive fishing in the marine environment are also creating threats as well as vulnerable to devastate, while introducing species are yielding to increase struggle for native species. These practices are related to damage the ecosystem and habitats of many species, which are leading to the impacts on bioerosion (Bellwood et al., 2003), food (Jahncke et al., 2004), predation (Myers et al., 2007), and transportation of nutrients (Allan et al., 2005). In addition, fishing can unintentionally generate hereditary choice pressure on stocks (Hutchings, 2000) with consequences on maturation, age and growth rates. In many industrialized fisheries (Hilborn et al., 2003), management, overinvestment and overcapacity are gradually hampered the fishing ground by overfishing. The fish population are decreased by overfishing which have fundamental threat to fish stock. It is not economically viable and lead to decline fisheries productivity (Hsieh et al., 2006). These heavy pressures of climate change affect the fisheries and aquaculture to a greater extent. Although, fishing pressure is minimized in Marine Protected Area (MPA) due to the strick restriction and control imposed by the government. Therefore ecosystem based fisheries management should have to take necessay steps to save the

habitat and species.

Aquatic products are used to be an important income source as a fish meal (such as shrimp, prawn, small fish, ribbon fish, oil sardine and mackerel), which contributed 13% of the total exports around the world (Shinoj and Mathur, 2008). Furthermore, the main export fish of Myanmar and Bangladesh is Hilsa. Bangladesh export to more than fifty countries around the world such as Belgium, United Kingdom of Great Britain and Northern Ireland, the Netherlands, Germany, the United States of America, China, France, the Russian Federation, Japan Saudi Arabia etc., whle Myanmar exports mainly to Asian countries such as China, Thailand, Malaysia, Singapore, Japan and the EU. About 35 percent of the fish and fishery products are exported by Pakistan 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).

The Arab region has s lots of resources but there have been limited water resources with low efficiency of food production. There has an importance of coastal zone because of oil and other marine resources. There are only 18,000 km inhabited area from total 34,000 km coastal zone in the Arab region. The coastal zone of Arab region is mostly called economical hub of the country and major cities and economic activities are lies in thereby. Immensely abundant cultivation terrestrial is in low lying, marginal area including Nile Delta, and popular tourist activities depend on marine and coastal assets, like coral reefs and associated fauna (Lachs and Oñate-Casado, 2020). The Arab region have been suffered by extreme climate phenomena such as high rates of environmental disasters - desertification, droughts, sand and dust storms, heat waves and flash floods (Massoud et al., 2003).

4 Approaches of mitigation and adaptation

Approaches of Mitigation and Adaptation to environmental change usually comprises activities such as CO_2 and GHGs that whichever decrease the amount of carbon dioxide (CO_2) and other greenhouse gases (GHGs) in the atmosphere or prepare society for the impacts associated with climate change via adaptation. The effectiveness of mitigation and adaptation activities depends on the temporal and spatial scale of impacts and action goals, and the context of the activity. Each activity will not be appropriate in every time and place, so achievement requires consideration of how actions are customized to the local situation and how they are applied.

4. 1. Adaptation of Aquaculture

Adaptation of aquaculture to climate change will vary depending on the involvement of stakeholders, their level of financial capacity, location and the type and scale of aquaculture taking place. Appropriate policy making, species diversification, improved culture practices, and mangrove planting should be promoted in the changing environment. Adaptation can be planned or autonomous (i.e. regular response to environmental alteration or planned action on the basis of climate-induced changes). The autonomous adaptation in fisheries may be shifting due to the timing or areas of fishing as species arrives earlier/later or shifting to the new locations. Planned adaptation includes research funding for finding appropriate species, which

are resistant to the changes of salinity and temperature for aquaculture.

4. 2. Adaptation of Fisheries

Adaptation in fisheries and aquaculture can have a different principle and governance system, (i.e. community capacity build-up or technical support) that act in the several sectors, not limited on fisheries and aquaculture sectors. The adaptation can be addressed in the short- and long-term impact, thereby management sometime disagree with adaptation. Short term response such as extreme storm where coping activities is very short time because of result in undermining adaptation activities.

4. 3. Adaptation of Mangrove Forest

Adaption find out primary solution and not usually emphasis on water bodies and aquatic organism. Mangrove is one of them which protect from the storm surge and coastal erosion, is used for primary recovery for adaption. Mangrove will positively impact on fisheries, biodiversity, ecosystem services and their livelihood of coastal area which is not related to the primary purpose of adaptation. Although, it is effect surrounding all of things in their related ecosystem. However, mangrove has economical, ecological, social impact on their living people. Mangrove not only provide shelter in the coastal area but also it creates a fundamental habitat for nursery fish and other organisms. It has great contribution of aquatic biodiversity as well as providing water filtration services. The mangrove ecosystem provides income from the collection of crustaceans, mollusks and fish, inhabiting in that areas. Ecological services contain the task of mangroves as nurseries for economically significant fisheries, especially for shrimp. Mangroves also provide homes for many crustaceans, mollusks, insects, reptiles, birds, and monkeys (Wells et al., 2006). The location is subjected to high tidal variation, monsoon, tropical cyclones and flooding, the larger incidence of which tends to damage structure and cause devastating loss of life. The storm surge heights of cyclones in 1970, 1974, and 1991 were at least 8 m. As an estimate, near about 500,000 people lost their lives during the incident (Islam, 2002). Mangroves protect lives and goods in the coastal area. As for example, around 10,117 ha of mangrove forest area at Chakaria in Bangladesh was rehabilitated entirely into shrimp farms within ten years (1985-1995). In the 1970s, this area was covered with mangrove forest and people were protected from storm surge. After established fisheries, the absence of mangrove forests in the area could not adequately buffer storm surge, resulting in deaths following the devastating cyclones in 1991 and 1994 (Islam, 2002).

4. 4. Adaptation of Capture Fisheries

Adaptation in capture fisheries are regulating fishing in maximum sustainable yield (MSY) where all fishers are catching fish in sustainable levels. Different types of management tools (monitoring, precautionary principles and adaptive management) are applied to control catch limits such as recruitment, reproductive success, growth and survival for establishing capture fisheries. Furthermore, time management have required for controlling vessel and gear types for new fisherman, which help to adaptive situation in capture fisheries by changing support of fishing community. This lead to reduce fishing power and saving ecosystem. However, it also assist to grow open access fisheries and build up more than previous time, where fisherman get

profit by maintaining time and gear types for fishing. On the other hand, there have another way to give emphasis on transboundary issues, if aquatic organism moves towards territorial waters.

Sustainable utilization and management of international fisheries has been estimated to have the potentiality to increase the global fisheries production by 10% (Cheung et al., 2009), which could also translate into an additional increase of the value of fishery products at native scale (Coll et al., 2013; Bundy et al., 2017). Small scale fishermen are getting advantages from different sources of adaptive management (Miller et al, 2018). These include activities that increase the resilience and adaptive capacity of community and ecosystems, particularly by decreasing other stresses such as social (such as inequality and proverty) and environmental problems (viz., habitat destruction, pollution and overexplotation (IPCC, 2007; Cheung et al., 2010).

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, 2011). In considering adaptation initiatives, 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 et al., 2005).

4. 5. Cooperative and Collaborative Management in Adaptation

The cooperation, discussion and decision making will be required between neighboring regions and countries, including modifying or developing fishing rules and regulation with management. Even though the adaptation is context-specific, a number of adaptation activities, which can be used in fisheries and aquaculture perspectives (Shelton, 2014). These include (but not limited to):

4. 5. 1. Reduce external stressors on ecological environment

The destructive fishing (such as fishing with poisons and toxic substances) and the land-based pollution sources (such as modern farming and municipal overflow using pesticides and insecticides) should need to be controlled.

4. 5. 2. Identify and protect valuable areas

The effects of climate change, influenced by the hydrological cycle as well as the downstream and upstream activities (e.g. dam building leading to siltation, or basin development leading to pollution runoff) might have be minimized (MRC, 2005).

4. 5. 3. Warning and forecasting systems

Safety measurements in the sea by implementing advanced warning and prediction systems (local circulation news, everyday newspaper, radio, TV etc.), concerning the proper rough weather events and accelerating storm severity.

4. 5. 4. Onshore storage facilities

Enough onshore facilities for crafts (e.g. ships and boats) and fishing gears can help to prevent damage of loss from extreme events (e.g. cyclones, storms, hurricanes etc.).

4. 5. 5. Disaster risk management

Generally, disasters risk management refer to avoid risk from new events by protecting infrastructure as well as increasing public concerns. The infrastructure is divided by two ways "hard" options such as seawalls and flood reservoirs, or "soft" options such as buffer zones via afforestation or reforestation of mangroves.

4. 5. 6. Mainstreaming

Integrated fisheries and aquaculture sectors entirely into food security policies and climate change adaptation at the national level (draft and enact where non-existent) to ensure incorporation into broader development planning. This will also include trade-offs, negotiations and planning with other industries affecting fisheries and aquaculture (e.g. dams, irrigation infrastructure, agricultural and urban runoff).

4. 5. 7. Partnership and capacity building

Different stakeholders (i.e. government organizations (GOs), non-government organizations (NGOs), international non-government organizations (INGOs), research and academic organizations, different private sectors, civil society and local communities) should need to be included in the climate change planning not just technically focused sectors such as science and meteorology departments or fisheries/interior agencies. Partnerships among the above stakeholders are vital for holistic climate change in adaptive planning.

4. 5. 8. Financial mechanisms

From the above content, it is very important to find out the potential financial tools for capacity building among the various stakeholders. There is need to add national and international insurance for making good incentive and generate active disincentive. These approaches are new for public sector and need to integrate by through the market mechanism where private sector is totally controlled and integrated to some extent by the public sector through market mechanisms.

4. 5. 9. Appreciation of prospects

New approaches can be created such as promotion of aquaculture-based livelihood where estuarine/coastal areas are inundated and agriculture is no longer possible.

4. 5. 10. Knowledge from the earlier

The questions that usually arise and need to be solved are: what have the community done and how have decision-making progressions operated under highly flexible and extremely risky factors? What types of issues people address in the previous year? How it applied in several situations for solving the risks?

4. 5. 11. Valuable information

Investigation and documentation of valuable ideas and where to acquire it (e.g. future projections of fish production, decision-making tools under uncertainty and its application).

4. 5. 12. Linking among local, national, regional and global policies and programs

Links and relationship will be required among the sectoral and spatial agendas, strategies, and programs. Climate change will influence marginal people, food security, infrastructures and additional areas within and among nations. Furthermore, climate change will possibly cause spatial movement of both people and fisheries with aquaculture resources, necessitating robust local structures to address these changes, and their implications. At the global level, climate change affects the worldwide market, trade, and strategies at the same time as the present development.

4. 5. 13. Spatial planning

This consists terrestrial and marine zoning for arrangement of aquaculture services (terrestrial and subtidal systems) and mangrove areas to balance aquaculture requirements with shoreline protection and terrestrial development with rising sea levels. Furthermore, it is very important to set up long term goal for ongoing coastal activities which are shifted landwards.

4. 5. 14. Monitoring

The above information will be applied for adaptive management as well as contribute to understand what impacts are happening. Because climate change will introduce changes outside the scope of experience for many species and people, it is very important to collect information on what and when these changes are happened. As more is learned and understanding becomes more refined, the communities will be better to able to take decisions that result in benefits for both the fishery and aquatic environment as well as the peoples who highly depend on it.

4. 5. 15. Policy and management considerations

The fishery will follow, probably poleward for many species as some aquatic populations shift their range. This may induce socio-economic variations as people move to follow the population, or as old fisheries become less profitable and new ones come to be available. The strategies which are flexible and support easy access and exit into new fisheries and out of those that are declining can ease both socio-economic impacts from changing fisheries and prevent overfishing of the edges of stocks as they move away (Pinsky and Fogarty, 2012). Appropriate practices for improved fisheries and aquaculture management (e.g. the FAO Code of Conduct for Responsible Fisheries, precautionary principles, adaptive and ecosystem management) and integrated management for coastal and near shore fisheries can improve resilience and increase

system efficiency. Overall, removal of incentives for overfishing and capacity reductions is vital to safeguarding sustainable fisheries.

4. 5. 16. Safety in sea

In rough weather condition, additional security at the sea is more essential, and can be invested in the big ships that are safer than small ones. If these are capable of accessing seasonal pelagic species and small enough to also for demersal fish species in other seasons, safety during harvesting would be increased and year-round harvesting options made available. Nevertheless, to prevent overcapacity, these vessels might have to replace smaller fishing vessels rather than connect to the fleet.

4. 5. 17. Ghost fishing

As the severity of storm increases, it is likely that more gears, for example, lobster traps, will be lost. Such lost gear can cause fish mortality as well as degradation of habitat. However, there are some measures that can decrease their effects. Along with the gear retrieval programs, certain gear could be designed to reduce impacts if lost. For instance, traps could have biodegradable escape panel, so that trapped animals would have the ability to escape.

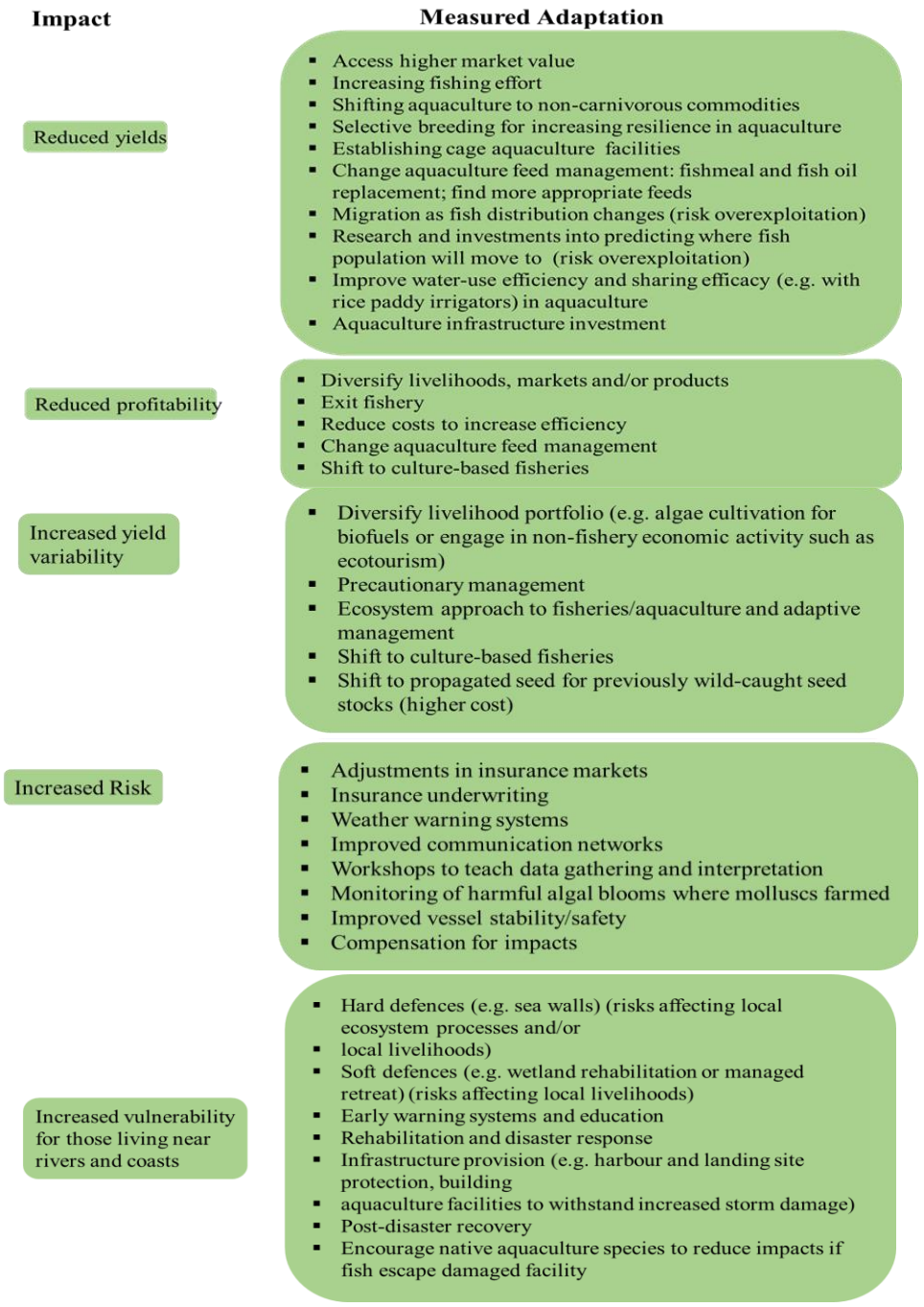
4. 6. Antibiotic and Climate Change Driven New Hassles

The excessive amount of antibiotics applying in aquaculture farms at the present time have been mixed with river and sea water by climate has driven forces such as excessive rainfall, flood, cyclone, typhoon etc. Aquaculture has been developed rapidly over the few decades to fulfill the demand for protein of human being worldwide. However, this sector is challenged with the various kinds of disease and bacterial infections due to the climate change and therefore, antibiotics are using to overcome this situation (Rodgers and Furones, 2009). The presence of bacteria with multiple antibiotic resistances found in food products has become a threat to public health as there is potential that the carried or acquired genes are transferred to other bacteria of clinical significance (Zulkifli et al., 2009). Some antibiotics which are commonly used in food-producing animals are also used in human medicine, reducing the antibiotic's efficiency when treating infections and increasing the morbidity and mortality associated with diseases. The resistance limits the choice of antibiotics for the disease treatment (Holmstrom et al., 2003). Nevertheless, there have been limited data on the antibiotic resistance of bacteria in fish and other cultured organisms sampled directly from fish farms as well as the aquaculture environment (Cantas et al., 2013). Therefore, the use of antibiotics in fish needs to be monitored from time to time to evaluate the emergence and spread of bacterial resistance towards antimicrobial agents.

5 Potential adaptation measures in fisheries and aquaculture

In addition to the above-mentioned general adaptation measures, the number of potential adaptations to specific impacts is summarized in Table 1 (De Silva and Soto, 2009; Shelton, 2014).

Table 1. Potential adaptation measures in fisheries and aquaculture.



5. 1. Ecosystem-based Approach

The ecosystem-based approach to aquaculture and fisheries management are required to facilitate critical coastal ecosystems to adjust to the climate change impacts and to reduce the dangers from other environmental pressures. Adaptation measures are well-known by farm managers and decision makers, but political will and action are largely lacking. In order to construct resilience to the climate change effects as well as derives sustainable welfares, aquaculture and fisheries managers and policy makers are required to adopt and follow the best practices, such as those mentioned in the FAO Code of Conduct for Sustainable Fisheries (FAO, 2012), the purpose of which is to set international standards of behavior for responsible practices with a view to ensuring the effective conservation, appropriate management and

sustainable development of living aquatic resources, with due respect for the ecosystem and biodiversity. These exercises are required to be integrated more effectively with the proper management of river basins, mangroves, watersheds and coastal regions.

5. 2. Coastal Protection and the Living Shorelines Approach

Some living shoreline approaches (LSA) such as natural vegetation, sands and some rocks are used to protect habitat and shorelines. These include oyster reefs, wetland plants, some stone, sand fill, fiber "logs" and submerged aquatic vegetation (Currin, et al., 2010). The approaches have many benefits compared to the "hard" coastal protection practices (e.g. bulkheads, seawalls, and riprap) as they are able to (but not limited to):

- maintain shoreline dynamics and sand movement.
- reconstruct eroded or maintain shorelines through trapped sands.
- reduce wave strength, storm surges and floodwaters.
- provide important habitats and maintain coastal ecosystem function.
- maintain as cheaper approach than many "hard" alternatives.
- filter pollutants and nutrients from water.
- function as carbon sequestration (aquatic vegetation and wetlands absorb and store carbon dioxide).

Despite the fact that many benefits obtained from LSA, there have been some circumstances, where it might not be considered as the most exact one, and it may need to be utilized in concurrence with the structural "hard" approaches". The shortcomings of the LSA are as follows:

- It is less effective in areas where most of the shoreline is already hardened.
- It is less suitable in high-wave energy environment.
- Due to a new approach, it can be difficult to find experts for planning and installation.
- Limited information is available on the effectiveness for different types of shorelines and various coastal power regimes and storm conditions.

Livelihood, health care and education access in coastal areas with strong infrastructure should need to be maintained. However, "hard" approaches like sea walls and riprap may have many negative environmental impacts and may even increase erosion elsewhere. Trade-offs between coastal protection approaches may not be easy to build and may involve expensive alternatives (e.g. moving a road to some distance inland or increasing erosion farther along the coastline).

The followings are the list of specific examples of adaptation actions and strategies such as those found in Table 1. These activities have either been implemented or under the process of implementation. Nevertheless, the list is not comprehensive, but just the samples of activities, which are presently addressing the climate change impacts on aquaculture and fisheries.

a) Pond excavation and land shaping.
b) Introduction of locally available indigenous fish species.
c) Individual credit supports.
d) Awareness buildup.
e) Small-scale homestead pens.
f) Trap pond management.

g) Cage aquaculture.
h) Participatory assessment of fish farmer vulnerabilities.
i) Recommendations for aquaculture practices.
j) Training workshops and publications.
k) Extension and hatchery capabilities strengthened.
l) Technology and methods adapted and transferred to local conditions and species.
m) Integrated resource management planning.
n) Integrated rice–fish farming system.
o) MPA monitoring training.
p) Innovative insurance scheme.
q) Coastal restoration and rehabilitation.
r) Wetland conservation management strategy.

From the above discussions, it appears that climate has considerable influence on the major coastal resources of Bangladesh. Thus, changes in the climate are most likely to affect the availability of these resources to fisher communities for maintaining their livelihood, health, education and income. Our present review also affords a vital starting point towards directing the future research into the vulnerability of fishery-based livelihood systems to climate change and variability. Further work is required so as to move towards an improved characterization of vulnerability and to identify the most appropriate means for communities and households to cope with and adapt to the impacts of climate change. However, on the basis of the findings of this research, it could be concluded that efforts to reduce livelihood vulnerability in the coastal fishing communities should be multifaceted in order to simultaneously tackle exposure, sensitivity and adaptive capability.

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Conflict of interests

The authors declare that there are no competing interests.

References

Allan, J. D., Abell, R., Hogan, Z. E. B., Revenga, C., Taylor, B. W., Welcomme, R. L., & Winemiller, K. (2005). Overfishing of inland waters. *BioScience*, *55*(12), 1041-1051. https://doi.org/10.1641/0006-3568(2005)055[1041:OOIW]2.0.CO.

Allison, E.H., Perry, A.L., Badjeck, M.C., Neil Adger, W., Brown, K., Conway, D., Halls, A.S., Pilling, G.M., Reynolds, J.D., Andrew, N.L., & Dulvy, N. K. (2009). Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, *10*(2), 173-196. https://doi.org/10.1111/j.1467-2979.2008.00310.x

Badjeck, M. C., Allison, E. H., Halls, A. S., & Dulvy, N. K. (2010). Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy*, *34*(3), 375-383. https://doi.org/10.1016/j.marpol.2009.08.007

Beare, D. J., Burns, F., Jones, E., Peach, K., Portilla, E., Greig, T., Mckinzie, E., & Reid, D. (2004a). Observations on long-term changes in the prevalence of fish with southern biogeographic affinities in the North Sea. *Marine Ecology Progress Series, 284*, 269–279.

Beare, D., Burns, F., Jones, E., Peach, K., Portilla, E., Greig, T., McKenzie, E., & Reid, D. (2004b). An increase in the abundance of anchovies and sardines in the north-western North Sea since 1995. *Global Change Biology*, *10*(7), 1209-1213. https://doi.org/10.1111/j.1529-8817.2003.00790.x

Bellwood, D. R., Hoey, A. S., & Choat, J. H. (2003). Limited functional redundancy in high diversity systems: resilience and ecosystem function on coral reefs. *Ecology Letters*, *6*(4), 281-285. https://doi.org/10.1046/j.1461-0248.2003.00432.x

Beare, D., Burns, F., Jones, E., Peach, K., Portilla, E., Greig, T., McKenzie, E., & Briand, F. (2008). I–Executive Summary of CIESM workshop climate warming and related changes in Mediterranean marine biota. In *CIESM Workshop Monographs* (Vol. 35, pp. 5-21).

Brander, K. (2010). Impacts of climate change on fisheries. *Journal of Marine Systems*, *79*(3-4), 389-402. https://doi.org/10.1016/j.jmarsys.2008.12.015

Bundy, A., Chuenpagdee, R., Boldt, J.L., de Fatima Borges, M., Camara, M.L., Coll, M., Diallo, I., Fox, C., Fulton, E.A., Gazihan, A., & Shin, Y. J. (2017). Strong fisheries management and governance positively impact ecosystem status. *Fish and Fisheries*, *18*(3), 412-439. https://doi.org/10.1111/faf.12184.

Cantas, L., Shah, S.Q., Cavaco, L.M., Manaia, C.M., Walsh, F., Popowska, M., Garelick, H., Bürgmann, H., & Sørum, H. (2013). A brief multi-disciplinary review on antimicrobial resistance in medicine and its linkage to the global environmental microbiota. *Frontiers in Microbiology*, *4*, 96. doi:10.3389/ fmicb.2013.00096.

Cheung, W. W., Lam, V. W., Sarmiento, J. L., Kearney, K., Watson, R., & Pauly, D. (2009). Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries*, *10*(3), 235-251. doi: 10.1111/j.1467-2979.2008.00315.x

Cheung, W. W., Lam, V. W., Sarmiento, J. L., Kearney, K., Watson, R. E. G., Zeller, D., & Pauly, D. (2010). Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Global Change Biology*, *16*(1), 24-35. https://doi.org/10.1111/j.1365-2486.2009.01995.x

Cochrane, K., De Young, C., Soto, D., & Bahri, T. (2009). Climate change implications for fisheries and aquaculture. *FAO Fisheries and Aquaculture Technical Paper*, *530*, 212. https://www.ipcinfo.org/fileadmin/user_upload/newsroom/docs/FTP530.pdf

Coll, M., Libralato, S., Pitcher, T. J., Solidoro, C., & Tudela, S. (2013). Sustainability implications of honouring the Code of Conduct for Responsible Fisheries. *Global Environmental Change*, *23*(1), 157-166. https://doi.org/10.1016/j. gloenvcha.2012.10.017

Currin, C. A., Chappell, W. S., & Deaton, A. (2010). Developing alternative shoreline armoring

strategies: the living shoreline approach in North Carolina. *In:* Shipman H., Dethier M. N., Gelfenbaum G., Fresh K. L., & Dinicola R. S., editors. Puget Sound shorelines and the impacts of Armoring – Proceedings of a State of the Science Workshop. Reston VA: U.S. Geological Survey, pp. 91–102. http://hdl.handle.net/1834/30714

Daw, T., Adger, W. N., Brown, K., & Badjeck, M. C. (2009). Climate change and capture fisheries: potential impacts, adaptation and mitigation. *In*: Cochrane, K. De Young, C., Soto, D., & Bahri, T., editors. Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. *FAO Fisheries and Aquaculture Technical Paper*. No. 530. Rome, FAO. pp.107–150.

De Silva, S. S., & Soto, D. (2009). Climate change and aquaculture: potential impacts, adaptation and mitigation. *In*: Cochrane, K. De Young, C., Soto, D., & Bahri, T., editors. Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. *FAO Fisheries and Aquaculture Technical Paper*. No. 530. Rome, FAO. pp.151–212.

Easterling, W. E., Aggarwal, P. K., Batima, P., Brander, K. M., Erda, L., Howden, S. M., Kirilenko, A., Morton, J., Soussana, J. F., Schmidhuber, J., & Tubiello, F. N. (2007). Food, fibre and forest products. *In:* Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., & Hanson, C.E., editors. Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, UK: Cambridge University Press, pp. 273–313.

FAO. (2011). APFIC/FAO Regional consultative workshop "Implications of climate change on fisheries and aquaculture: challenges for adaptation and mitigation in the Asia-Pacific Region" 24–26 May 2011, Kathmandu, Nepal. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2011/17, 52 pp. http://www.fao.org/3/a-ba0084e.pdf

FAO. (2012). The State of World Fisheries and Aquaculture – 2012. Rome, Italy, 209 p. http://www.fao.org/fishery/sofia/en

Gallup. (2009). Awareness of Climate Change and Threat Vary by Region. www.gallup.com/poll/124652/awareness-climate-change-threat-varyregion.aspx

Hilborn, R., Branch, T. A., Ernst, B., Magnusson, A., Minte-Vera, C. V., Scheuerell, M. D., & Valero, J. L. (2003). State of the world's fisheries. *Annual Review of Environment and Resources*, *28*(1), 359-399. https://doi.org/10.1146/annurev.energy.28.050302.105509

Holmström, K., Gräslund, S., Wahlström, A., Poungshompoo, S., Bengtsson, B. E., & Kautsky, N. (2003). Antibiotic use in shrimp farming and implications for environmental impacts and human health. *International Journal of Food Science & Technology*, *38*(3), 255-266. https://doi.org/10.1046/j.1365-2621.2003.00671.x

Hsieh, C. H., Reiss, C. S., Hunter, J. R., Beddington, J. R., May, R. M., & Sugihara, G. (2006). Fishing elevates variability in the abundance of exploited species. *Nature*, *443*(7113), 859-862. https://doi.org/10.1038/nature05232

Hutchings, J. A. (2000). Numerical assessment in the front seat, ecology and evolution in the back seat. *Marine Ecology Progress Series*, *208*, 299-303. https://www.jstor.org/stable/24863827

IPCC. (2007). Summary for policymakers. In: Solomon, S., Qin, D., Manning, M., Chen, Z.,

Marquis, M., Averyt, K.B., Tignor, M., and Miller, H.L., editors. Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Cambridge, UK. https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ ar4_syr_spm.pdf.

Jahncke, J., Checkley Jr, D. M., & Hunt Jr, G. L. (2004). Trends in carbon flux to seabirds in the Peruvian upwelling system: effects of wind and fisheries on population regulation. *Fisheries Oceanography*, *13*(3), 208-223. https://doi.org/10.1111/j.1365-2419.2004.00283.x

Islam, M. R. (2002). Vulnerabilities, Opportunities and Emerging Issues as Transpired from Four Regional Workshops. PDOICZM.WP003, Dhaka, Bangladesh.

Lachs, L., & Oñate-Casado, J. (2020). Fisheries and Tourism: Social, Economic, and Ecological Trade-offs in Coral Reef Systems. In: Jungblut, S., Liebich, V., & Bode-Dalby, M., editors. YOUMARES 9 – The oceans: Our research, our future: Proceedings of the 2018 conference for Young Marine Researcher in Oldenburg, Germany, Springer International Publishing, 243–260. https://doi.org/10.1007/978-3-030-20389-4_13

Lejeusne, C., Chevaldonné, P., Pergent-Martini, C., Boudouresque, C. F., & Pérez, T. (2010). Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea. *Trends in Ecology & Evolution*, *25*(4), 250-260. https://doi.org/10.1016/j.tree.2009.10.009

Lindegren, M., & Brander, K. (2018). Adapting fisheries and their management to climate change: A review of concepts, tools, frameworks, and current progress toward implementation. *Reviews in Fisheries Science & Aquaculture*, *26*(3), 400-415. https://doi.org/10.1080/23308249.2018.1445980

Lloret, J., Sabatés, A., Muñoz, M., Demestre, M., Solé, I., Font, T., Casadevall, M., Martín, P., & Gómez, S. (2015). How a multidisciplinary approach involving ethnoecology, biology and fisheries can help explain the spatio-temporal changes in marine fish abundance resulting from climate change. *Global Ecology and Biogeography*, *24*(4), 448-461. https://doi.org/10.1111/geb.12276

Marbà, N., Jordà, G., Agusti, S., Girard, C., & Duarte, C. M. (2015). Footprints of climate change on Mediterranean Sea biota. *Frontiers in Marine Science*, *2*, 56. https://doi.org/10.3389/fmars.2015.00056

Massoud, M. A., Scrimshaw, M. D., & Lester, J. N. (2003). Qualitative assessment of the effectiveness of the Mediterranean action plan: wastewater management in the Mediterranean region. *Ocean & Coastal Management*, *46*(9-10), 875-899. https://doi.org/10.1016/S0964-5691(03)00068-1

Miller, D. D., Ota, Y., Sumaila, U. R., Cisneros-Montemayor, A. M., & Cheung, W. W. (2018). Adaptation strategies to climate change in marine systems. *Global Change Biology*, *24*(1), e1-e14. https://doi.org/10.1111/gcb.13829

Mekong River Commission (MRC). (2005). Overview of the Hydrology of the Mekong Basin. *Mekong River Commission, Vientiane*, *82*.

Myers, R. A., Baum, J. K., Shepherd, T. D., Powers, S. P., & Peterson, C. H. (2007). Cascading effects of the loss of apex predatory sharks from a coastal ocean. *Science*, *315*(5820), 1846-

1850. https://doi.org/10.1126/science.1138657

Neiland, A. E., Madakan, S. P., & Béné, C. (2005). Traditional management systems, poverty and change in the arid zone fisheries of Northern Nigeria. *Journal of Agrarian Change*, *5*(1), 117-148. https://doi.org/10.1111/j.1471-0366.2004.00096.x

Oihabi, A. (2010). Personal communication. FAO-KSA Programme Coordination Unit. Riyadh, Kingdom of Saudi Arabia.

Pakissan. (2017). A brief on fisheries on Pakistan [online]. In: Pakissan.com. http://www.pakissan.com/english/allabout/fisheries/a.brief.on.fisheries

Pinsky, M. L., & Fogarty, M. (2012). Lagged social-ecological responses to climate and range shifts in fisheries. *Climatic Change*, *115*(3), 883-891. https://doi.org/10.1007/s10584-012-0599-x

Rahman, M. A., Lee, S. G., Molla, M. H. R., Asare, O. E., Megwalu, F., Jahan, B., & Shaikh, M. M. (2018). Fisheries management and governance in Bangladesh. *MOJ Ecology & Environmental Sciences*, *3*(6), 381-385. https://doi: 10.15406/mojes.2018.03.00117

Rodgers, C. J., & Furones, M. D. (2009). Antimicrobial agents in aquaculture: practice, needs and issues. IRTA-Centre d'Aquicultura, Ctra. PobleNou, SantCarles de la Rapita, Tarragona, Spain. *In:* Rodgers, C. J., & Basurco, B., editors. The Use of Veterinary Drugs and Vaccines in Mediterranean Aquaculture, Zaragoza, Spain: CIHEAM. *Options Méditerranéennes*, *86*, 41-59. http://om.ciheam.org/article.php?IDPDF=801061

Saab, N. (2009). Arab public opinion and climate change. In: Tolba, K.M., & Saad, W.N., editors. Arab Environment climate change. Impact of climate change on Arab Countries. *Report of the Arab Forum for Environment and Development*, ISBN: 9953-437-28-9.

Shelton, C. (2014). Climate change adaptation in fisheries and aquaculture: Compilation of initial examples. *FAO Fisheries and Aquaculture Circular*, (8088), I. FAO. Rome, Italy, 34 pp.

Shinoj, P., & Mathur, V. C. (2008). Comparative advantage of India in agricultural exports vis-à-vis Asia: a post-reforms analysis. *Agricultural Economics Research Review*, *21*(347-2016-16823), 60-66. doi: 10.22004/ag.econ.47361

Shifanova, T. A., & Ozturk, B. (2010). Trend on increasing Mediterranean species arriaval into the Black sea. *In:* Briand F., editor. CIESM Workshop Monographs No 39. Climate Forcing and Its Impact on the Black Sea Biota. CIESM, Monaco, pp. 75–93.

Wabnitz, C.C., Lam, V.W., Reygondeau, G., Teh, L.C., Al-Abdulrazzak, D., Khalfallah, M., Pauly, D., Palomares, M.L.D., Zeller, D., & Cheung, W. W. (2018). Climate change impacts on marine biodiversity, fisheries and society in the Arabian Gulf. *PloS One*, *13*(5), e0194537. https://doi.org/10.1371/journal.pone.0194537

Wells, S., Ravilious, C., & Corcoran, E. (2006). In the front line: Shoreline protection and other ecosystem services from mangroves and coral reefs. Cambridge, UK: UNEP–World Conservation Monitoring Centre, 33 pp.

Zulkifli, Y., Alitheen, N. B., Raha, A. R., Yeap, S. K., Marlina, S. R., & Nishibuchi, M. (2009). Antibiotic resistance and plasmid profiling of Vibrio parahaemolyticus isolated from cockles in Padang, Indonesia. *International Food Research Journal*, *16*(1), 53-58.