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Potential Impacts of Climate change and Climate Variations on the coastal Marine fisheries

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Potential Impacts of Climate Change and Climate Variations on the coastal marine fisheries of the South-West Indian Ocean Region

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Summary

Climate change threatens world fisheries. As temperatures rise, fish populations will decline and disappear in some regions, especially in the tropics. Fish is an essential protein source for 3.2 billion people, providing 17 per cent of the world's animal protein. It is a lifeline for many developing countries, including the EA-SA-IO region, that relies on fish for 70 per cent of their nutrition. The local fishing communities contribute the least to global CO_2 emissions but face existential threats. Despite the pledges Paris Agreement on Climate Change 2015, there has been no substantial progress in Global Decarbonisation. The world is sleepwalking into a +2°C or worst scenario with disastrous consequences for the topical coastal and island states. To balance the pessimism of climate science and the optimism of local communities about their lives and livelihoods, ECOFISH will do what it took to promote fish sovereignty for the well-being and shared prosperity of the coastal fishing communities. The proposed network will provide scientific evidence to support national projects for the Green Climate Fund (GCF) and other multilateral development agencies. Informed policy-making and management measures are critical for mainstreaming appropriate climate-smart and "no-regret" investments to build the resilience of fragile fisheries resources and ecosystems for the present and future generations. Circular economy applies to the coastal fisheries - from hook to plate - to ensure sustainable harvest and consumption of seafood, i.e., fish food sovereignty for the local fishing communities. The creation of a Regional Coastal Marine Fisheries-Climate-Environment Outlook Network assesses and monitors the socio-economic and ecological impacts of climate change and biodiversity degradation in fishing communities. ECOFISH will share its learning investments, knowledge acquisition, and best practices in climate-smart and sustainable small-scale fisheries through this paper.

1.0 Introduction

Climate change is intensifying more rapidly than expected. The last five years have been the warmest on record; natural disasters are becoming more intense and frequent, while the previous years witnessed unprecedented extreme weather events worldwide. Alarmingly, *global temperatures are on track to increase by at least 3°C towards the end of the Century* – which is twice the limit to avoid the most severe economic, social, and environmental upends in the world's tropical regions. The near-term impacts of climate change will intensify the planetary emergencies, including loss of life and livelihoods, extreme poverty and inequalities, and geopolitical instability. *Failure of climate change mitigation and adaptation* is considered the No 1 risk by impact and No 2 by likelihood for the next 10 years[3]. Biodiversity loss has severe implications for humanity, from the collapse of functional services and health systems to the disruption of food webs. It is essential for maintaining human well-being, livelihoods, and wealth creation. The world's 7.6 billion people represent just 0.01% of all living creatures by weight, but humankind has caused the loss of 83% of all wild mammals and half of all plants. *Biodiversity loss and ecosystem collapse are among the top five global risks*. For example, clearing over 35% of the world's mangroves for human activities has exposed coastal people's habitats to risk from floods and sea-level rise. If today's mangroves were lost, 18

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[2] *Based on the works carried out by ECOFISH, the technical paper contributes to the workshop on "Enhancing Integration of ocean-based adaptation and mitigation actions in addressing climate change" organised by Africa Group of Negotiators Experts Support held on 16-18 May 2021 in Nairobi, Kenya*.

[3] *World Economic Forum – Global Risk Report 2019.*

million more people would be flooded yearly (an increase of 39%), and annual damages to property would increase by 16% ($82 billion). *Therefore, protecting and restoring natural ecosystems is vital to fighting climate change*. Nature-based solutions could provide 37% of the cost-effective CO_2 mitigation needed by 2030 to maintain global warming within 2°C[4].

Climate change threatens world fisheries. The significance of coastal fishing as "safety nets" for food and nutrition security and the livelihoods of local communities is high in Sub-Saharan Africa. As temperatures rise, fish populations will decline and disappear in some regions, especially in the tropics. The challenges of the capture fisheries sub-sector are often underestimated or overlooked because researchers and policymakers tend to focus on agriculture as the primary source of food supply for the growing global population. However, *fish is an essential protein source for 3.2 billion people, providing 17 per cent of the world's animal protein*. It is a lifeline for many developing countries, including the Sub-Saharan African region, that relies on fish for 70 per cent of their nutrition. Improved fisheries management and setting aside climate-smart marine protected areas can provide a refuge for nurturing fragile fish stocks. A circular economy approach, i.e., the sustainable harvest and consumption of seafood, can increase the resilience of fish stocks. However, a drastic reduction of GHG emissions on a global scale must remain a top priority.

Various pathways and impacts of ocean warming and extreme weather events (EWE) on the coastal marine fisheries ecosystems are well-documented in existing scientific and peer-reviewed literature. These direct pathways include increased sea surface temperatures (SST), sea-level rise (SLR), change in rainfall patterns and intensification of tropical storms. The indirect drivers include ocean stratification and acidification change in nutrients, currents, and salinity levels. *The intervention is to create a Coastal Fisheries-Climate Outlook Network to assess and predict the impacts of climate change and EWE on the productivity of the coastal marine ecosystems and fish production. It will also evaluate the cascading socio-economic consequences on fishing communities' fish market, trade, and national economies*. The most vulnerable or invisible groups and informal stakeholders, including children, women, and older people, engaged in subsistence fishing and associated activities for their livelihoods and food security, require special attention.

Despite the significant progress in advancing global climate change science research, the conduct of viable *scientific and socio-economic impact studies* at the regional and national levels is lagging. There is still some severe data gap and caveats to understanding the impacts of climate change and climate variability on the local socio-ecological systems. The local impacts differ significantly from the global and regional climate change averages. For instance, the first Marine Protected Areas established worldwide during the early 90s have focused mainly on biodiversity factors without integrating climate change. The refugia for aquatic resources in our region need to be identified and documented. Though there is a correlation between extreme weather events and the impacts of climate change at the local level, it is not grasped by the fishing communities. Moreover, local communities tend to interpret extreme weather events as climate change which is not so. These shortcomings are partly responsible for the misunderstanding or scepticism of the impacts of climate change in the local socio-ecological context.

There is a lack of adequate and reliable scientific knowledge and information on fish stocks and ecosystems supporting the major marine fisheries and the relative impacts of climate change pathways on the fish supply chains in the EA-SA-IO maritime region. Therefore, there is an urgent need for downscaled modelling to assess the potential impact of climate change on the fisheries economy of the region. *"We manage what*

[4] *IPCC Ocean and Cryosphere Special Report, Sept 2019. Refer to Annexe 1*

we can measure". This intervention intends to build a set of indicators/markers of the Fisheries-Climate nexus for driving science-based climate-compatible fisheries policies, strategies, and management plans at national and regional levels.

2.0 Overview of the African Fisheries and Aquaculture Sector

In 2017, Africa produced nearly 12 million tonnes of fish, representing 7 % of the global catch of 173 million tonnes. This figure included 3.0 million tonnes from inland fisheries, 2.2 million tonnes from aquaculture and 6.7 million tonnes from marine capture fisheries. Over the same period, the African continent contributed about 3.4 % to the total value of global fish imports of US$ 146.3 billion) and 4.6 % to the value of global fish export of US$ 156.5 billion [5]. The marine fisheries of the EA-SA-IO region hold a contrasting landscape where 90% of the coastal fisheries resources are harvested in the inshore waters by small-scale subsistence and traditional artisanal fishing. Generally, these fisheries are mostly poorly regulated, open access and informal economy. The catch is for household consumption and any surplus sold locally. Africa's average per-caput fish consumption is less than 10 kg, i.e., less than half the global average and is projected to decline to 7 kg by 2030 if appropriate measures are not expedited. In some coastal countries, namely Tanzania, Kenya and Sudan, inland fish production is much higher than the marine fisheries. The relatively high post-harvest physical and economic losses in the subsistence and traditional artisanal fisheries represent a severe socio-economic and ecological issue not getting adequate policy consideration.

Most fishers in the commercial, artisanal fisheries are fish workers. The fishing assets are owned mainly by fish traders and outside investors (shadow owners) without interest in sustainable fishing. The fishers, as the front liners, are often blamed for overfishing and unethical fishing practices, whereas the real profiteers are officially unknown to the government agencies. The surplus profits are rarely reinvested in the industry. So, business-as-usual is sustainable for the local fishing communities, the fisheries ecosystems, and the national economies. However, the governments cannot invest in the hard and soft infrastructures or create a proper enabling environment for connecting the local communities to the economic mainstream. The open-access policy in the artisanal fisheries initially sought as a social safety net against endemic unemployment and food insecurity for the local population has failed and has become a politically sensitive issue. The nearshore fisheries are dwindling. The existing fishing capabilities (assets and technologies) and supply-chain ecosystems are insufficient to venture farther offshore. As a result, alternative sustainable livelihood opportunities are scarce in the coastal areas. Therefore, fishing communities are trapped in an existential threat which is the cause of the growing disconnect between the local communities and the Governments. The remaining 10 % of the regional fisheries catch/landings comprise industrial value chains that target high-value fish species such as tunas, shrimps, and lobsters, mainly for the export markets. They are vertically integrated, locally-based foreign corporations that have obtained attractive economic and fiscal incentives from the coastal states. For instance, the landed value of the tuna fisheries in the WIO (FAO Fishing Zone 57) is approximately US$ 2 billion annually, and 34 % of it is attributed to the WIO states (US$ 684 million), which is composed of industrial tuna fisheries (US$ 231 million) and coastal small-scale tuna fisheries (US$ 433 million)[6]. The aggregated fisheries licence revenue is estimated at US$ 21 million annually. These industrial fisheries are relatively well-managed, but there is no record of their direct and indirect contribution to the national economies.

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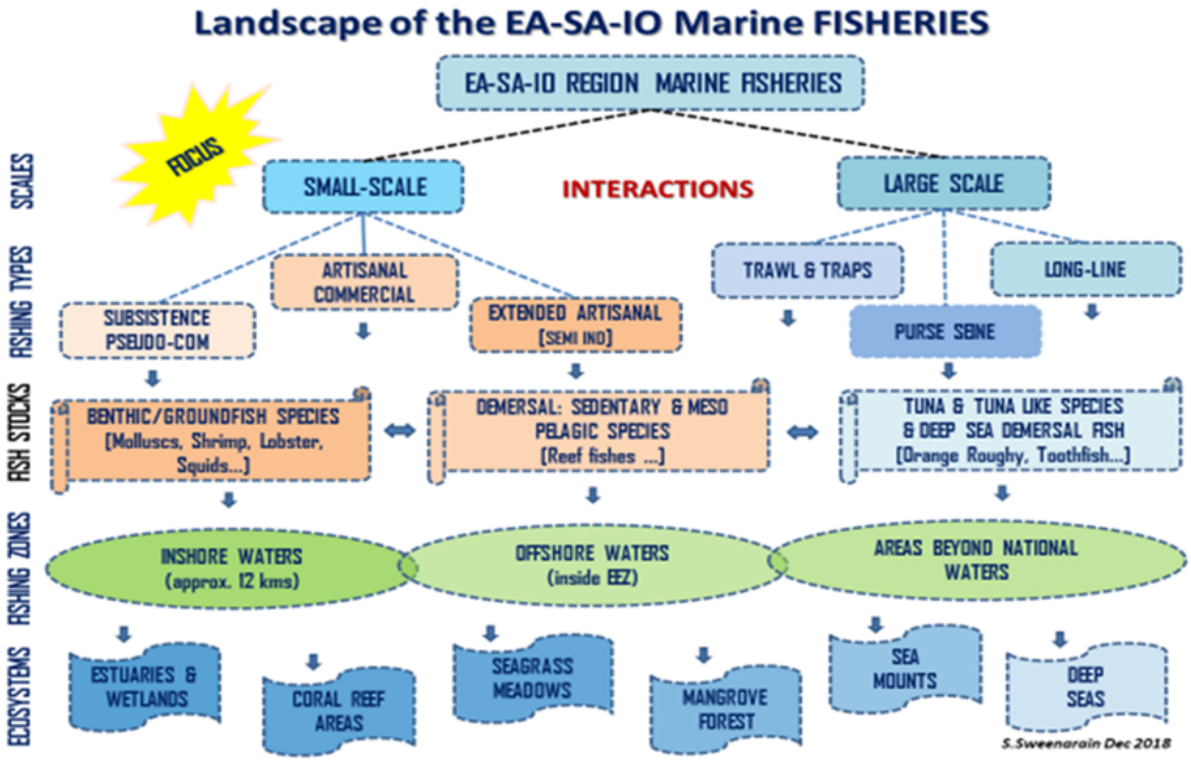
[5] *FAO. 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome.*

[6] *Sweenarain, S (World Bank - WIOFish 1, 2018). Cost-Benefit Analysis and Sustainable Financing of a Regional Fisheries Framework Agreement for the shared tuna fisheries resources in the Southwest Indian Ocean Basin.*



The Western Indian Ocean generates approximately US$22 billion of economic benefits annually, and the share of the marine fisheries is about 11%, i.e., US$ 2.4 billion[7]. Since the UN Convention on the Law of the Sea, 90% of fish resources and 55% of other natural renewable and non-renewable resources are located inside the EEZ of the coastal states[8]. Blue Economy would provide the impetus for these developing coastal and island states to muster the needed capacities to strengthen their marine economy amidst environmental risks, including climate change. Sustainably managed, the economic benefits derived from the marine fisheries can be enhanced by 2 to 3 times in the longer term. However, a recent study by the World Bank[9] shows that global marine fisheries are an underperforming asset, and the difference between potential and actual net economic benefits is estimated at US$ 88 billion per year, equivalent to half of the value of the global seafood trade. The share of WIO marine fisheries is about US$ 5 billion per year. If timely climate adaptation measures are not implemented urgently, the socio-economic benefits derived from the marine fisheries in the tropical region will decline significantly.

The marine fisheries sub-sector has the economic potential to support the cost of its sustainable development and management. As a rule of thumb, the foregone *economic rent or government revenue* in the form of direct and indirect taxes is currently estimated at US$ 240 million per year, and it can be increased progressively to US$ 480 million upon the sustainable rehabilitation and modernisation of the coastal fisheries. However, instead of fuelling economic growth and shared prosperity in those underdeveloped states, the financial resources are leaked out of the economic mainstream. It is a textbook example of the *paradox of poverty amidst plenty* that aggravates economic inequalities and multi-dimensional poverty in the coastal fishing communities. The root cause of the declining productivity of the

[7] *WWF 2015, Reviving the WIO Ocean Economy – Actions for Sustainability.*
[8] *Global Marine Atlas 2018.*
[9] *World Bank Group 2016, The Sunken Billions (revisited)*

coastal fisheries is population growth, overfishing and unethical fishing practices. In addition, land-based and marine pollutions aggravate the direct and indirect impacts of ocean warming. *In other words, there is an urgent need for science-based policy-making and management actions*[10] *to ensure sustainable fisheries.*

The economic and social contribution of the fisheries sector is frequently underestimated in the national accounts. The outcome is both the cause and effect of a lack of disaggregated data on the different branches/segments of the sub-sector interacting with society and the economy. The information asymmetry may partly explain the ongoing political procrastination in managing this complex and politically sensitive sector. As a result, the Gross Domestic Product (GDP) does not reflect the development potentials of the industry in terms of net economic benefits or economic rents, its contribution to employment, food security and cultural diversity. An increase in GDP may result from increased fishing costs rather than raised productivity or net benefits. All may seem fine until a complete collapse of the fisheries. Therefore, these conventional macroeconomic indicators must be complemented by other meaningful measures, including their socio-economic impacts and environmental sustainability, such as the status of fish stocks and long-term profitability. Generally, the fisheries sector's contribution to national and regional economies is more significant than the official statistics. Commercial fishing constitutes the economic base for an extended value chain through processing, marketing, retailing, and the food service industry. In addition, subsistence fisheries are essential for food security and rural livelihoods. The economic measures do not fully integrate the economics of the informal sector.

In keeping with the preceding narratives, a new type of thinking is required to unleash the development potential of coastal fisheries as a growth sector. The capture fisheries sector must be reformed to optimise economic performance and environmental sustainability. The proposed intervention will enhance objective policy coherence between the economic, social, ecological and governance imperatives for sustainable and inclusive fisheries. It will empower the national fisheries agencies to maximise cross-sector synergies to balance divergent policies for achieving a triple-win.

3.0 Potential Impact of Climate Change on Global Fisheries

Climate change is causing global warming. The scientific communities under the IPCC acknowledge with the highest confidence that human-induced emissions of Green House Gas (GHG) into the atmosphere are responsible for climatic change and *more frequent extreme weather events*[11]. However, the changes are not spread evenly across the world, and developing economies that have contributed the least to climate deregulation, namely the least developed and low–lying coastal countries and the Small Island Developing States, are affected the most. Therefore, *climate change is widening the existing economic inequalities* in the world[12]. According to the IPCC Global Climate Models (GCM), if the GHG emissions continue at the current rate, global temperature will increase by 2.6 – 4.8 degrees Celsius (°C), and sea levels, 0.45 - 0.82 metre (m) higher than the present status by the turn of this Century. To save humankind from the predicted climatic Anthropocene, the UNFCCC recommends maintaining the average global warming since the pre-industrial times below *2°C and lowering it to 1.5°C soon*. According to IPCC AR 5, the world had already emitted two-thirds of the maximum aggregated quota of GHG to meet the threshold of 2°C in 2011. However, *the 2°C target is no less than the death penalty for the low-lying nations and the SIDS*, mostly in

[10] *Cf. FAO Fisheries Performance Analysis Toolkit, 2020*

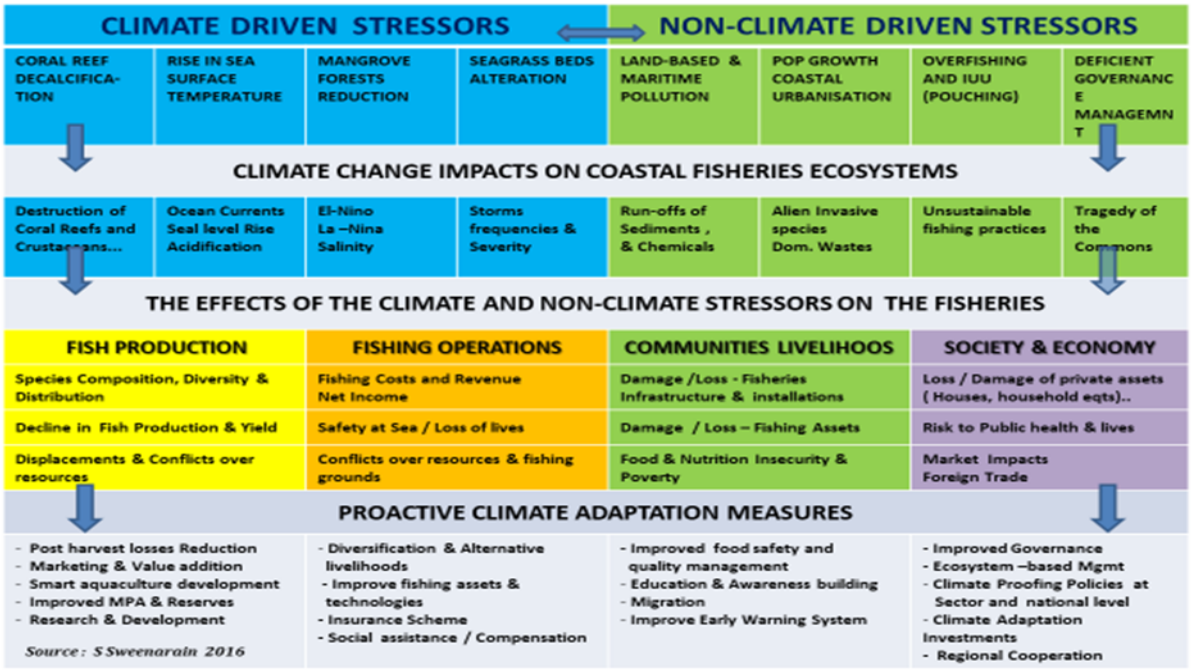
[11] *IPCC, Fifth Assessment Report – Fisheries Summary 2014.*

[12] *It is a global moral indignation that the world largest polluters have systematically avoided the debate on climate compensation at the Paris Climate Summit 2015 to relieve the sufferings of the Low-lying coastal states and Small-Island Developing States that include most of least developed and fragile states of the Sub-Saharan African region. There is sentiment among these aggrieved nations that the International Community has failed deliver on Climate Justice.*

tropical and subtropical regions. They would be suffering from irreversible damages at 1.5°C. Therefore, limiting the effects of climate change would require an immediate and more stringent reduction of GHG from the world's largest economies/polluters. The oceans represent 70% of the planet's surface and provide vital services to sustain humankind, including providing food from fisheries and aquaculture. However, the ability of these marine ecosystems to maintain their productivity is reduced by the cascading effects of ocean warming.

Fisheries provide 3 billion people worldwide with about 20% of their average animal protein intake. Over 500 million people in Africa and Asia's poorest countries rely on marine fisheries for food and income[13]. Global warming affects the ecology of the coastal and oceanic ecosystems through the change in the food webs and biophysical features of the targeted fish species. Other induced effects of sea surface temperature rise, such as acidification, sea-level rise, algal blooms, and hypoxia, undermine the productivity of marine fisheries' habitats. Many coastal species are threatened by extinction due to the combined effects of climate change and other interconnected human and environmental stressors such as overfishing, unsustainable fishing practices and land and ocean-based pollution. *Based on the +2°C scenario, the potential loss of the global fisheries by 2050 is estimated between US$ 17 and 41 billion per year*[14]. Coral reefs support 10–12% of all fish caught in tropical countries and 20–25% harvested by developing island nations[15]. Acidification will cause a decline in global reef fish and shellfish production between 2020 and 2060. Adaptation is possible in some cases but very difficult in others. The estimated total cost of adaptation for fisheries globally from 2010 to 2050 is USD 30 billion per year.

Fig 3 - Climate & Non-Climate driven Impacts on Coast Marine Fisheries



3.1 Physical and chemical changes in the Ocean

Oceans absorb 30% of the global CO_2 emissions, lowering the pH of the water and causing *ocean acidification*. Bivalve molluscs such as mussels and oysters, corals and plankton that form shells from

[13] *FAO World Fisheries Report, 2018*
[14] *IPCC Assessment Report (AR) No 5, Fisheries Summary, Page 5*
[15] *IPCC AR 5, Fisheries Summary, Page 8*

calcium carbonate are all at risk. Ocean acidification may also have direct effects on fish behaviour and physiology. Rapid changes in chemical and physical conditions in the oceans have already affected the *distribution and abundance* of marine organisms and ecosystems. Changes to the distribution of fish populations are affecting the *composition of catches*. For example, the range limits of many intertidal species in the North Pacific and North Atlantic have shifted by 50 km per decade. In the Indian Ocean, the migratory pattern of the tuna and tuna-like species is moving Eastward. These displacement rates are generally faster than land species and seriously disrupt the food webs, i.e., the prey-predator relationship. The potential impacts and risks include the following:

i) Physical and chemical changes to the ocean lead to a loss of marine biodiversity;
ii) Changes in the level of seafood production, with initial decreases at low latitudes and increases at high latitudes;
iii) Potentially increased overfishing and unethical fishing practices (fishing down the web) due to a decline in the coastal fisheries resources and ecosystems.
iv) Degradation of tropical and cold-water coral reefs owing to decalcification resulting from ocean acidification;
v) Increased in harmful algal blooms, which threaten ecosystems and fisheries

3.2 Changes in the Level of seafood production

From 1998 to 2010, *concentrations of chlorophyll – an indicator of net primary production* – in the Tropical oceans, including the Indian Ocean, decreased by about 10% due to climate change or weather variability. However, Climate change is projected to cause a further decline of 9% over the 21st Century in these open ocean regions. Rising temperatures reduce the oxygen-carrying capacity of the ocean, which limits the maximum body size that large fish can achieve. As a result, *catches of smaller fish* are predicted for the future. In addition, the number of *'dead zones depleted in oxygen* is increasing, affecting coastal ecosystems and fisheries by inhibiting growth. The primary cause of dead zones in coastal regions is the nutrient run-off from land, exacerbated by warming water.

As seawaters continue to warm, scientists are confident that the *productivity of many fisheries will change*. Due to projected warming, spatial shifts of marine species will cause high-latitude invasions and high local extinction rates in the tropics and semi-enclosed seas relative to 2005 levels and based on a global 2°C warming scenario. As a result, species intensity and catch potential are projected to increase, on average, at mid and high latitudes and decrease at tropical latitudes. *However, not all fish will adapt, and some stocks may die out*. Such changes are likely to increase the vulnerability of the coastal and island developing countries, which depend directly on fisheries for food and income, and who cannot target other stocks or extend the range of their activity due to financial or technical limitations.

3.3 Collapse of some coastal reef fisheries

*When defining fishing opportunities, the migration of fish stocks will also pose new challenges to governments and regional fisheries management organisation*s. For example, changes in temperature, oxygen levels and food availability in the ocean will likely alter the distribution and abundance of top predator species such as tuna in the Pacific and Indian Oceans, with stocks in both oceans predicted to shift eastwards. These subtle changes undermine the fisheries economy, particularly the small-scale value chains of the island and coastal states of the tropical and subtropical regions.

Under most climate change scenarios, more than half of the world's coral reefs are at medium or high risk of degradation. Reefs support high levels of biological diversity and provide critical habitats for fisheries. *Coral reefs support 10–12% of all fish caught in tropical countries and 20–25% captured by developing island nations*. However, many of these nations exploit their coral reef fisheries unsustainably.

3.4 Economics of Fish Redistribution

Fisheries yield is projected *to increase by 30–70% in high latitudes and fall by 40–60% in the tropics and Antarctica, based on +2°C warming*. Large species, such as tuna in the Pacific and Indian Oceans, are likely to shift eastwards. *Global loss of landings is projected at USD17 to 41 billion by 2050*. The options are:

i) Undertake vulnerability assessments
ii) Strengthen coastal zone management
iii) Reduce aquaculture dependence on fishmeal

3.5 Dead Zones Are Becoming More Common

The extent of *oxygen-depleted 'dead zones'* in coastal waters is increasing. These are caused by high levels of nutrient run-off from land, exacerbated by higher water temperatures and ocean acidification. The extent of 'oxygen minimum zones (OMZs) caused by ocean warming also increases in the open ocean. These waters are oxygen-poor in the mid-layers and cannot support sizeable active fish. The options are:

i) Reassess and reinforce marine protected areas;
ii) Protect mangrove forests, sea-grass beds, and salt marshes.

3.6 Ocean's Chemistry is Changing at an Unprecedented Rate

Ocean acidification – the result of enhanced carbon dioxide uptake from the air – puts commercially important fish and shellfish at risk. *The ocean's pH has fallen by 0.1 since pre-industrial times, roughly corresponding to a 30% increase in acidity*. If CO2 emissions continue to rise at the current rate, a further pH drop of 0.3 by 2100 is projected. Thus, the change in ocean surface pH by 2100 under the 'business-as-usual scenario: 0.6 more acidic.

3.7 Negative Effects on Shellfish

Shellfishes are particularly vulnerable to ocean acidification and other changes in ocean chemistry. Therefore, if ocean pH continues to fall, the overall global production of shellfish fisheries will likely decrease. The main options are:

i) Reduce non-climate change-related stressors;
ii) Policies to reduce fossil fuel use across economies will affect the seafood industry.

3.8 Coral Reefs at Risk

Coral reef ecosystems are declining rapidly, with the risk of the collapse of some coastal fisheries. If CO2 emissions continue to rise at the current rate, coral reef erosion will likely outpace reef building during this Century. Incidences of coral bleaching resulting from increasing temperatures are also likely to grow, with a consequent loss of support and habitat for fisheries and other marine creatures. As a result, coastal protection, food resources, and tourism income are all at risk. Thus, the propagation of new habitats, such as artificial reefs, to act as nurseries in areas where coral destruction occurs is needed.

4.0 Integration and Way Forward

The small-scale marine fisheries can be differentiated into two distinct segments based on their interconnectedness to the specific coastal fisheries ecosystems: sedentary and oceanic fisheries. The sedentary fisheries include the demersal and benthic aquatic marine resources such as the reef and herbivorous fishes, molluscs and crustaceans that live in the coral reef areas, mangroves, forests, sea-grass beds and shallow waters of the lagoons, estuaries, and wetlands. These coastal fisheries ecosystems are mostly over-exploited and polluted by land-based and maritime effluents in densely populated areas. The coastal oceanic or pelagic fisheries target tuna and associated large pelagic fishes in the nearshore open sea or around artificial fish aggregating devices. Some small pelagic fishes are also caught seasonally in the lagoon. The coastal tuna fisheries are not evenly developed in the region. The artisanal fisheries of Comoros and Reunion Island rely on coastal tuna resources due to the limited lagoon and nearshore continental

shelves. Mauritius is also engaged in developing artisanal tuna fisheries as an alternative to relieve its lagoon from overfishing. Over the past decades, several Kenya, Mozambique, and Tanzania programmes tested Coastal Tuna fishing with FAD deployment but have not been promoted as a commercial fishery. Most of the SSF is impacted diversely by the different climate change pathways.

The Paris 21st Conference of Parties on Climate Change (COP 21) is committed to limiting global warming to +2°C and eventually down to +1.5°C to relieve the low lying least developed countries and the Small Island Developing States (SIDS) from unavoidable collateral damages by the turn of this Century. In the Indian Ocean, from 1998 - to 2010, the Net Primary Productivity decreased by 10 % and is predicted to decline further. It will impact the presence and abundance of marine living aquatic resources in the region. The average sea surface temperatures (SST) and sea-level rise (SLR) in the WIO range from global trends. However, they differ significantly across the local coastal marine ecosystems, with diverse consequences on the productivity of the artisanal fisheries. However, the effects of climate change are still not understood as seasonal and inter-annual climatic variations by the coastal fishing communities. They have developed, over time, some adaptation strategies to cope with these changes. However, these measures are inadequate to establish proactive climate change adaptations and long-term resilience in the SSF. Scientific evidence points to positive interactions and mutually reinforcing systems between ocean warming and climatic variations, including the inter-annual phenomena such as El Nino and La Nina that would further aggravate the conditions of the marine fisheries. Local communities relying on coastal fisheries for their livelihoods must be informed of the silent threats of climate change to fisheries ecosystems concerning their economic activities. A bottom-up approach is necessary to document the current effects of climate change and variations in the local socio-ecological environment. The mainstreaming of climate change adaptation measures has not fully been captured by the national policy and institutional frameworks of the fisheries sector, particularly the SSF, because of a lack of reliable scientific and empirical observations on the potential climate risks.

The drivers of climate change disrupt the food chain and prey/predator relationship, directly affecting the productivity of the fisheries ecosystems and fish production. Fish stocks tend to move steadily towards cooler waters while heat-tolerant/pH-resistant species drive away from the endogenous fish species from their traditional habitats. The migratory pattern of tuna stocks is also changing subtly across the oceans. A peer-review study showed that the surface tuna resources in the WIO are moving farther easterly at approximately one kilometre per decade. These climatic impacts will have severe socio-economic consequences on the coastal and oceanic fisheries of the region. Therefore, it is crucial to collect scientific and techno-economic information on the current and future climate impacts on the fisheries sector to anticipate policy actions at the national and regional levels.

The sustainability of the socio-economic benefits derived from the coastal fisheries in the WIO countries is seriously challenged by the poorly regulated open-access regime, lack of basic socio-economic and dedicated fisheries infrastructure; outdated fishing assets and fishing technologies; neglected fish value chains, value addition activities and market infrastructure and supply chain logistics, trained workforce as well as ineffective fisheries management and governance systems. The climate and non-climate (environmental and human-induced) factors are also culprits of the current situation, but they have been adequately documented. Under the present business-as-usual scenario, the human and environmental stresses on SSF will intensify until they reach the tipping point. It will be a catastrophe for approximately 50 million people dependent on the coastal fisheries for livelihoods and food/nutrition security. A decrease in the fish stocks availability and accessibility or catchability generally observes the direct impacts of climate change and variations on inshore fishing. A decline in the total catch, species mix, and spatial distribution of the marketed fish species affect fishing costs and revenue. The operating costs tend to increase because of a decrease in the landings and changes in the catch composition, an increase in the number of non-fishing days due to bad weather at sea, and extended fishing trips as more time is required for cruising to

more distant fishing areas, increase in post-harvest losses in the absence of adequate preservation practices and higher cost of repair and maintenance. The market demand for fresh/chilled fish and seafood is driven by other factors such as the quantity and quality of the landed products, the purchasing power of the consumers, and cheaper substitutes, particularly from inland or farmed fish products. Though food prices, including fish, will increase worldwide, the escalating cost of fishing in the SSF coastal fisheries might not be fully compensated in developing countries. The confounding factors include the absence of organised primary markets, the low purchasing power of the consumers, widespread subsistence fishing and open access, poor value chains and marketing logistics and direct competition with cheaper imported wet fish.

The impacts of climate change will also hit fish and seafood exports in the WIO countries. However, the involvement of artisanal fisheries in regional and international trade is still insignificant in these countries. Except for Madagascar and Seychelles, artisanal fisheries are produced in these countries for domestic consumption. It is a paradox that ocean states like Mauritius, and Reunion Island are overly dependent on imported fish and seafood to satisfy their domestic consumption. Comoros, Madagascar, and Seychelles are self-sufficient, but their per-caput fish consumption varies significantly. For instance, in 2014, the per-caput fish consumption in Madagascar was 7.4 kg, much lower than the African average of 9.6 kg. Over 90 % of the fish production in Africa, including the Easterly countries, is harvested from the continental waters. With a per-caput fish consumption of 64 kg, Seychelles is the highest rating in the WIO. It has significant export potential for high-value reef fishes but is constrained by geo-economic factors common to the SIDS. The SSF of Comoros is overly dependent on tuna resources and is about to launch the first export-oriented vertically integrated tuna fishing and processing project. However, this development has not systematically anticipated potential climate risks. Smallholder fisheries are the main supplier of affordable food and fish to the local population. Therefore, it is critical to proactively mainstream climate change adaptation measures into the fisheries management governance system. If appropriate measures are not taken promptly, it is most likely that the per-caput fish consumption will follow a downward-sloping curve. Since locally harvested marine fish would become scarce, these coastal countries might resort to imports and/or restrict fish and seafood exports to satisfy domestic demands.

The regional industrial tuna fishing and canning value chains, an extended segment of the European tuna markets, are under climate risks due to the observed subtle but steady change in the migratory patterns of the tuna stocks in the Indian Ocean. They are moving away from the traditional surface tuna fishing grounds of the WIO. The multi-million-dollar canned tuna industry is at stake as these environmental changes would affect its competitiveness at this critical time when the World Trade Organisation is challenging the ACP-EU Preferential Trade Agreement. It is most likely that the supply of raw tuna from the region will decline. It will eventually impact the future Fisheries Partnership Agreement between the EU and the ACP countries of the WIO. Some tuna packers are shifting their operations to countries closer to emerging tuna fishing grounds, such as Bangladesh and Sri Lanka, to anticipate these long-term climate-induced changes and build their comparative advantage on export markets. As a result, fish and Seafood exporters of the WIO region might face stricter competition in their traditional markets from exporters from other regions whose fisheries are less affected by ocean warming and are managed more sustainably.

Over the past decades, the WIO countries have participated in over 30 regional and national climate-related programmes focusing on Research, Evaluation and Policy Formulation; Dissemination of Knowledge and Awareness building; Capacity building and Community-based adaptation. In addition, most of them have undertaken a Vulnerability Analysis of their critical economic and environmental sectors. However, the national climate policies have focused more on the land-based sectors than their marine counterparts. Generally, the Ministries of Environment and Integrated Coastal Zones Management look after the social and ecological issues of the coastal and marine areas. However, these interventions have no direct interest in artisanal fisheries' environmental and socio-economic aspects. To cope with this policy gap, the relevant

public agencies must integrate climate-smart strategies into the existing coastal marine fisheries policy and regulatory frameworks.

The combined effects of climate and non-climate stressors are wicked problems affecting the coastal marine fisheries' socio-ecological sustainability and long-term resilience. Some of those factors are manageable, while others are unmanageable. Therefore, relieving the coastal marine ecosystems from human-induced stressors, including overfishing and unsustainable fishing practices, including IUU fishing maritime and land-based pollution, is critical. These environments may uphold their natural resilience to the pathway of ocean warming and extreme weather events. When anticipated well in advance, climate adaptation strategies can be based on a no-regret or triple-win approach. The following points are part of any Climate Change Adaptation Strategy in coastal marine fisheries:

i)	*Awareness building on the potential impacts of climate change and the possible proactive adaptation measures in the fishing communities;*
ii)	*Mainstreaming Climate Change Adaptation Strategy into the existing Regional Fisheries Policies and Management strategies at the EA-SA-IO level.*
iii)	*Improved communication and coordination among the various Environment, Sustainable Development and Ocean Governance policies and programmes at national, regional, and international levels*
iv)	*Participatory ecosystem-based management and governance in the coastal fisheries, with emphasis on the integrated coastal management that incorporates various interrelated multilateral environment agreements, including climate change and biodiversity protection, under the same umbrella;*
v)	*Smart Investments in climate-proofing fisheries infrastructure and fishing assets;*
vi)	*Development of smart aquaculture and fish farming projects to boost the supply of fish;*
vii)	*Social security and Insurance Scheme to protect the fishing communities;*
viii)	*Alternative/ Complementary Sustainable livelihoods for the fishing communities, such as blue carbon projects and environmental stewardship;*
ix)	*Science-Technology and innovation in leading the process of promoting climate-resilient fishing operations;*
x)	*Improved safety at sea through training and sharing of real-time weather information;*
xi)	*Review of Marine Protected Areas and Reserves strategies to integrate climate risks;*

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