Adapting the Inland Fisheries and Aquaculture to Socio-Economic Challenges of Climate Change in Nigeria: The Needs for Enhanced Extension Capabilities

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Abstract: The threats of climate change to human society and natural ecosystems have been elevated to a top priority since the release of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in 2007. Climate change is projected to impact broadly across ecosystems, societies and economics, increasing pressure on all livelihoods and food supplies, including those in the fisheries and aquaculture sector. Some of the most important inland fisheries in the world are found in semi-arid regions. Production systems and livelihood in arid and semi-arid areas are at risk from future climate variability and change; their fisheries are no exception. This paper using available literature from web reviews the importance of fisheries to livelihoods and poverty reduction, and the threats posed by climate change to fisheries and aquaculture. In order to maintain the important nutritional, economic, cultural and social benefits of fisheries, in the face of climate change, planned adaptation at scales from local to national level is required. Key strategies include facilitating peoples geographical and occupational mobility, improving inter-sectoral water and land-use planning, and promoting resilient aquaculture systems that cope with seasonal and episodic water deficits.
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1. Introduction

World population is predicated to reach nine billion by 2050, resulting in increased global food needs in the first half of this century (McMichael, 2001). The capacity to maintain food supplies for an increasing and expectant population will depend on maximizing the efficiency and sustainability of the production methods in the wake of global climatic changes that are expected to adversely impact the former. A recent analysis of global food production within the Special Report on Emission Scenarios (SRES) of the Inter Governmental Panel on Climate Change (IPCC), when linked to the food trade system model indicates that the world will be able to feed itself well into the next century, a heartening conclusion. However, the model that demonstrated this outcome was based on the production of developed countries, which are expected to benefit mostly from climate change. This compensated for the declines projected in the terrestrial food crops of developing countries, suggesting that regional differences in crop production are likely to grow stronger with time (Parry *et al.*, 2004). Perhaps aquaculture, an industry of the developing world, may provide a different scenario in relation to its contribution to our future food needs.

Humans and fish have been inextricably linked for millennia, not only because fish is an important source of animal protein, providing many millions of livelihood means and food security, but also from an evolutionary view point. Of all current animal protein food sources for humans, only fish is predominantly harvested from wild origins as opposed to others which are of farmed origin. Overall, there have been significant changes in global fish production and consumption patterns (Delgado *et al*., 2003) with a major shift in dominance over a 25 – year period towards developing countries and China. This changing scenario is accompanied by one in which supplies from capture fisheries are gradually being superseded by farmed and/or cultured supplies, accounting for close to 50 percent of present global fish food consumption (FAO, 2008).

Over the last decade or so, especially among the public, climate change, its impacts and consequences have been used rather indiscriminately and loosely. Climate change, defined and interpreted variously, but supported by rigorous and robust scientific data and analyses, is accepted as a reality even though it is still refuted by a few (Lomborg, 2001). As a result, it is commonly agreed that our lives will be impacted in many ways by climate change and one of primary ways will be food production and the associated environments (IPCC, 2007a).

Food fish production, as is the case in all other primary production sectors, is expected to be influenced and or impacted to varying degrees by climate change and the manifestations thereof are expected to occur in varying forms and to varying degrees in different parts of the world. However, unlike other animal food production sectors, food fish production is divisible into two sub-sectors: capture fisheries which overly depend on naturally recruited and occurring wild populations, the great bulk (approximately 85 to 90 percent) of which are in the oceans; and the cultured or farmed food fish sub-sector, that is growing in relative importance and is popularly referred to as "aquaculture" (FAO, 2001; 2003).

The majority of the world's two hundred million fisher-folk (Fishers and other fish workers and their dependents) live in areas that are highly exposed to human-induced climate change, and depend for a major part of their livelihood on resources whose distribution and productivity are known to be influenced by climate variation (Allison *et al, 2*005). It is therefore the impacts of climate change on the small-scale fisheries of inland and coastal waters that are perhaps of greatest relevance and concern to poverty reduction.

For inland waters, projected changes in surface water availability are the most obvious threat to fisheries production, as one might expect (Welcomme, 2001), so the projected decline in surface water availability in many parts of Africa (de Wit and Stankiewcez, 2006), for example, is an obvious threat to fisheries production. Inland waters are of particular importance to the poor due to their accessibility and potential for integration within farming systems (Ahmed *et al*, 2005; Parry *et al*, 2007).

Globally, aquaculture has expanded at an average annual rate of 8.9% since 1970, making it the fastest growing food production sector. Today, aquaculture provides about half of the fish for human consumption, and must continue to grow because declining-capture fisheries will be unable to meet demands from a growing population (FAO, 2007). Based on current per-capita consumption targets and population growth trends, aquaculture is considered by many as the only means of satisfying the world's growing demand for aquatic food products.

Directly and indirectly aquaculture could contribute to the livelihood economic growth and a diversification strategy in the face of environmental change (Allison et al, 2007; Bene *et al*, 2006; Heck *et al*, 2007). For example, fisheries and aquaculture employ over 50 million people worldwide, a quarter of them in aquaculture, and 98% of this total are from developing countries (FAO, 2007). In a global export business worth nearly eight billion dollars annually, African export earnings from fishery products and service is calculated to be over 2.7 billion dollars per year, and fisheries sectors in countries such as Namibia, Uganda, Ghana and Senegal contribute over 6% to their national GDPs (FAO, 2007). Fish is also an important cheap source of protein. It supplies at least 50% of the essential animal protein and mineral intake of 400 million people from the poorest African and south Asian countries (World Bank, 2004; FAO, 2007). Often, fish landing sites and centers of the cash economy in otherwise remote areas; they stimulated the kind of monetization of the rural economy that is seen by current mainstream development policy makers as the means to reduce rural poverty.

The multiple benefits that fisheries contribute to poverty reduction are threatened by climate change that decreases production, affects human health, threatens to damage or destroy physical assets, or all of the above. Fishery and aquaculture benefits are also potentially reduced through the increase in uncertainty that climate change brings. The incentives for long-term management of resources may be reduced and the additional risks of investing in aquaculture development may reduce potential investment by the poorer, more risk-averse sectors of rural society. It is therefore important to understand how climate change might impact the poverty reduction function of fisheries and aquaculture and how this impact might be reduced through appropriate development intervention policy. These concerns for climate-induced threats to fisheries take place in the context of widespread overexploitation of the capture sector fisheries, which increases the risks of stock collapse in association with climate-related stresses. These issues are compounded by other potential effects of climate change on natural resources, economics, and livelihoods and other broad environmental degradation and demographic change (Allison *et al*, 2007).

2. Scope and Objectives

This paper is based on a desk review of available literature. Data relating to climate change in relation to fisheries and aquaculture are very limited in Nigeria, hence information was accessed mainly through web search and it is presented primarily for raising awareness and policy discussions. This paper highlights the potentials of fisheries and aquaculture in poverty reduction and the achievement of Millennium Development Goals. It also discusses the effects of climate change on fisheries and aquaculture and proposes resilience aquaculture systems capable of adapting to envisaged future climate change.

3. The Global Importance of Fisheries and Aquaculture

Fisheries play an important role in the world food economy. Fisheries are a source of employment for about 200 million people who depend directly upon ocean fishing for their livelihoods. Fish is the primary source of protein for some 950 million people worldwide and represents an important part of the diet of many more. In less than 50 years, the world's average per capital consumption of fish has almost doubled. Globally, fish provide about 16% of the animal protein consumed by humans, and are a valuable source of minerals and essential fatty acids. Fish is the primary source of omega-3 fatty acids in the human diet. Omega-3 fatty acids are critical nutrients for normal brain and eye development of infants, and have preventative roles in a number of human illnesses, such as cardiovascular disease, lupus, depression and other mental illnesses (World Fish Center, 2002; FAO 2003).

Because 70% of the fish meal used in diets for fish and crustaceans is used to produce diets for salmonids, marine fish and shrimp, there production sectors are the focus of most research with respect to the use of alternative protein sources. Numerous studies have been conducted to evaluate the effects of replacing various percentages of fish meal in diets for these fish, and, without exception, none has successfully replaced 100% of fish meal without reducing fish performance (Stickney *et al*, 1996). At best, 50% of fish meal in diets for salmon and trout can be replaced by soy protein concentrate, and 25-30% with soybean meal. Similar findings have been reported in studies of wheat gluten meal, corn gluten meal, and rapeseed protein concentrate. For the most part, formulated fish diets are used to produce high-value fish for export. In underdeveloped countries, increased production of low value fish that are consumed by local populations will depend upon the use locally-available, low-cost feed ingredients that can be combined to produce prepared feeds to increase productivity of community ponds and waterways (Medale *et al*, 1998).

Fish contain essential oils and vitamin A – that are part of normal brain development. Traditional infant formulas used in West Africa are often based upon fish products. "About 60% deaths in the under-five are group are attributed to malnutrition, with mineral, vitamin and protein deficiencies standing out as leading causes. In many parts of the continent, fish has been the main source of these vital nutrients, especially among the poor. Fish consumption during pregnancy and lactation further improves the nutritional and health status of women, thus reducing susceptibility to diseases". (CGIAR, 2006).

4. The Millennium Development Goals and Fisheries in Africa

Africa, and in particular Su-Saharan, stands out as facing tremendous difficulties in achieving even modest progress towards the Millennium Development Goals (MDGs). Today, over 46% of Africans live in absolute poverty – a figure that is steadily rising. Life expectancy has fallen further to 46 years; in some countries to below 35 years. Child mortality and malnutrition, HIV/AIDS and other diseases continue to paralyze social and economic development. In this dire situation, innovative and diversified interventions are needed, including support to growth sectors in local economies (World Fish Center, 2005).

Fish already makes a vital contribution to the food and nutritional security of 200 million Africans and provides income for over 10 million mostly small-scale fishers, farmers and entrepreneurs engaged in fish production, processing and trade (World Fish Center, 2005). The contributions of fisheries to the MDGs are of two kinds: direct contribution to specific goals and indirect support to all the goals through enhanced livelihoods. It is a strength of fisheries, and in particular of small-scale fisheries, that it enables millions of poor fishers, processors and traders to diversify their livelihood strategies on the basis of income and commercial skills while at the same time supplying vast numbers of poor consumers with essential nutrition (CGIAR, 2006).

5. The Nigerian Climate

Observational records have shown that Africa has been warming throughout the 20th century at a rate of about 0.05°C per decade, amounting to an increase of approximately 0.5°C. The warming has been more significant in the period June-November each year. The most significant change to Africa's climate has been a long-term reduction in rainfall in the semi-arid regions of West Africa. In the Nigerian Sahel region, there has been a 25% decrease in precipitation on average in the last 30 years (Nkomo *et al*., 2006). However, the reduction in precipitation has been more moderate in other parts of Africa.

In the past 30 years, both droughts and floods have increased in frequency and severity on the continent. The regularity of drought periods has been a notable aspect of Nigerian climate in recent years, especially in the drier regions in the north. Well publicized droughts in the 1970s and 1980s significantly affected West Africa in the 20th century and they severely affected large areas of northern Nigeria and the Sahel region (DFID, 2009). These drought periods are indications of the large variability in climate across tropical Africa, the most serious effects of which are usually felt at the drier margins of agricultural zones or in the regions occupied primarily by pastoral groups.

In recent years, Africa has seen more frequent flood and cyclone episodes. The Nigerian delta has in particular seen a marked increase in flooding in the last few decades (Nkomo *et al*., 2006). Dust storms (which are partly due to changes in land use such as grazing and deforestation) in the some parts of the Sahel have also increased, particularly between the 1950s and 1980s (Elasha *et aI*., 2006). The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report explains that during 1961 to 2003, the average sea level rose by 1.8 ± 0.5 mm per year. While sea level rise varies between regions, Nigeria's entire coastline has been affected by this observed rise (IPCC, 2007a). Such a rise will have already led to an increase in coastal erosion and exacerbated flooding damages,

Nigeria has a tropical climate with variable rainy and dry seasons, depending on the location. In the southeast of Nigeria it is hot and wet most of the year, but it is dry in the southwest and farther inland. In the north and west, a savannah climate with marked wet and dry seasons prevails, while a steppe climate with little precipitation is found in the far north. Generally speaking the length of the rainy season decreases from south to north. In the south (lie rainy season lasts from March to November, compared lo the far north, where it lasts from mid-May to September. In the south and the southeast especially, precipitation is heavier with over 3,000 mm of rain a year (compared with about 1,800 mm in the southwest). Rainfall decreases progressively a way from the coast and the far north receives no more than 500 mm a year (DFID, 2009).

In the south of the country, temperature and humidity remain relatively constant throughout the year, while (he seasons vary considerably in the north. On the coast the mean monthly maximum temperatures are steady throughout the year, remaining about 32 °C at Lagos and about 33 °C at Port Harcourt; the mean monthly minimum temperatures are approximately 22 °C for Lagos and 20 °C' tor Port Harcourt (DFID, 2009). When considering Nigeria by climatic region, three regions emerge: the far south, the far north, and the rest of the country. The far south is defined by its tropical rainforest climate, where annual rainfall is 2,300 to 3,200mm a year. The tar north (i.e. Sahel region) is defined by its almost desert-like climate, where rain is less man 800 mm per year. The rest of the country, everything in between the far south and the far north, is savannah, and rainfall is between 800 mm and 2,300 mm per year.

Available data from the Tyndall Centre for Climate Change Research, which is also used in the IPCC assessments, has been used to provide a best estimate scenario for temperature and precipitation changes in Nigeria. The best estimates for 2010 - 2050 were calculated from an average of the three different IPCC 'Special Report on Emissions Scenarios' (SRES) for the region.

A low scenario has been calculated by using guidance from the Stern Report (multiplying the best estimate by a factor - in this case of 0.57). The high estimates are based on IPCC assessments for temperature and rainfall, but on latest research findings for sea level rise (IPCC, 2007b).

Climate models suggest that Africa's climate will generally become more variable, but different authors have often stated conflicting views on the future of Africa's climate. For example, a more humid regime is predicted in the Sahel by Brooks (2004), based on observations since the 1990s of an amelioration of the regional climate with more rainfall. Other studies indicate that these general trends may include hidden variations (Hulme *et al*., 2001).

A global rise in sea level is expected to significantly affect Nigeria's coastline. The current IPCC predictions are a rise in sea level of between 18 and 59 cm by 2100 relative to 1980-1999, depending on the scenario (IPCC, 2007a). As such, this study assumes there to be an increase of potentially 40cm by 2050 for the best estimate. The general consensus in the scientific community is that extreme events will continue to increase and become more severe across the continent. However, the IPCC has stated that there is insufficient information on which to assess possible changes in the spatial distribution and frequency of tropical cyclones affecting Africa. However, it is thought that a further 1°C rise in surface sea temperature in the Atlantic will create the conditions required to create hurricanes off the coast of Nigeria.

A general increase in high-rainfall events is expected, coupled with the expected increase in atmospheric water vapour. The probability of extremely warm seasons is 100% for West Africa, with a 22% probability of extremely wet seasons. The IPCC has further predicted that 1 in 5 seasons will be extremely wet in the 21st century in West Africa (IPCC, 2007b). In terms of more recent study predictions highlighting positive feedback warming and stronger climate change, signals from observations have not been focused on Nigeria in particular. Thus a direct translation and downscaling of the recent findings on temperatures and sea level rise to Nigeria in terms of changes to precipitation, the frequency of extreme events etc on a local level, is not possible.

6. Pathways of Impact: Climate Change, Inland Fisheries and Aquaculture

There are multiple and rather complex pathways through which climate change can affect the productivity and distribution of inland fishery resources and the resilience of fisheries and their associated livelihood and economic linkages. Impacts of climate change are an additional burden to other poverty drivers such as declining fish stocks, HIV/AIDS, conflict and insecurity, lack of savings, insurance and alternative livelihoods. There may also be increased health risks for the poor. For example, cases of cholera outbreaks in Bangladesh coastal communities were found to increase following ElNino-related flooding (Allison *et al,* 2007). Effects on agriculture and water resources will also potentially reduce water and food security. In combination, projected climate, population and market changes could have major negative effects on local fish supply in regions such as the Mekong Basin, or West Africa, where fish is an essential component of peoples' diet (Allison *et al*, 2005).

The impacts of physical and biological changes on fisheries communities will be as varied as the changes themselves. Both negative and positive impacts could be foreseen, their strength depending on the vulnerability of each community, the combination of potential impacts (sensitivity and exposure) and adaptive capacity. Impacts would be felt through changes in capture, production and marketing costs, changes in sales prices, and possible increases in risks of damage or loss of infrastructure, fishing tools and housing. Fishery-dependent communities may also face increased vulnerability in terms of less stable livelihoods, deceases in availability or quality of fish for food, and safety risks due to fishing in harsher weather conditions and further from their landing sites. Within communities and households, existing gender issues related to differentiated access to resources and occupational change in markets, distribution and processing, where women currently play a significant role, may be heightened under conditions of stress and increased competition for resources and jobs stemming from climate change (FAO, 20008 B).

In aquaculture, where production processes (such as choice of species, feeding and restocking) are under greater human control, increasing seasonal and annual variability in precipitation and resulting flood and drought extremes are likely to be the most significant drivers of change in inland aquaculture. Reduced annual and dry season rainfall and changes in the duration of the growing season are likely to have implications for aquaculture and create greater potential for conflict with other agricultural, industrial and domestic users in water-scarce areas. These impacts are likely to be felt most strongly by the poorest fish farmers, whose typically smaller ponds retain less water, dry up faster, and are therefore more likely to suffer shortened growing, seasons, reduced harvests and a narrower choice of species for culture (Handisyde *et al.,* 2006).

Furthermore, impacts on aquaculture could be positive or negative, arising from direct and indirect impacts on the natural resources aquaculture requires, namely water, land, seed, feed and energy. As fisheries provide significant feed and seed inputs, the impacts of climate on them will also, in turn, affect the productivity and profitability of aquaculture systems. Vulnerability of aquaculture-based communities will stem from their resource dependency and exposure to extreme weather events. Climate changes could increase physiological stress on cultured stock. This would not only affect productivity but also increase vulnerability to diseases and, in turn, impose higher risks and reduce returns to farmers. Interactions of fisheries and aquaculture subsectors could create other impacts. For example, extreme weather events could result in escapes of farmed stock and contribute to reductions in genetic diversity of the wild stock, affecting biodiversity more widely (FAO, 2008 b).

These impacts will be combined with other aspects affecting adaptive capabilities, such as the increased pressure that ever larger coastal populations place on resources; any political, institutional and management rigidity that negatively impacts on communities' adaptive strategies; deficiencies in monitoring and early-warning systems or in emergency and risk planning; as well as other non-climate factors such as poverty, inequality, conflict and disease. However, new opportunities and positive impacts emerging from such areas as changes in species and new markets also could be part of future changes. So far, these opportunities are not well understood but, nevertheless, are possible. A community's ability to benefit also will depend on its adaptive capacity.

7. Planned Adaptation to Climate Change in Fisheries and Aquaculture

In this section, plausible adaptive measures for combating or mitigating the impacts of climate change on aquaculture are examined. We propose a set of principles that combine the strategic and tactical elements of adaptation to provide a coherent basis upon which to build resilient small-scale fisheries and aquatic resource production systems. The following principles and elements are thus suggested.

Enabling diverse and flexible livelihood strategies: Livelihoods that combine activities that vary in their climate-response and sensitivity will be more adaptable to climate change. These can be supported in policy through removal of barriers to geographical mobility (such as requirements to be a full- time resident to access a fishery) and disincentives to diversification (such as commodity-based taxes on traded goods.

Supporting flexible, adaptive institutions: Co-management approaches to fisheries can benefit local communities by giving them work control over their resources. However, if new institutions for management are not based on an understanding of livelihoods and of current coping strategies, and lack understanding of the relationship between living thing and their environment they can increases communities vulnerabilities to climate variability. Traditional institutions (rules, customs, taboos) in climate-sensitive environments have tended to be flexible, to accommodate the impacts of climate variability. Examples may include the integration of land and water resource tenure, access to rather than barriers to access to common property resource by the poor in times of crisis or scarcity, and maintenance of reciprocal resource access arrangements as social insurance mechanism.

Aquaculture Diversification

In many countries and regions, there is s clear tendency to diversify farmed species and technologies. In evolutionary terms, it is commonly understood that diversity provides the ground for natural selection and for adaptation. It can also be proposed that culturing more species provides a form of insurance and offers better adaptation possibilities under different climate change scenarios, especially unexpected events such as diseases or market issues.

Diversification requires educating consumers and providing them with adequate information about new species and products, hand in hand with the successful transfer of the technologies to new practitioners. National and global policies can facilitate aquaculture diversification while strengthening the consolidated species. Diversification can be part of an insurance programme for the sector at the country and regional levels.

Technological Innovation: In aquaculture, technological innovations similar to those in agriculture can be pursued. There are species that are tolerant of brackish water that can cope with salinisation, for example. A shift towards aquaculture based on recirculation systems can help reduce water requirements and to insulate farming operations from the external environment to some degree. Selective fish breeding, can contribute to developing fish that have different thermal optima, growth characteristics, feed conversion, efficiencies, diseases tolerance and so on. Fisheries and fish folk can also change fishing gear, species and marketing chains to accommodate different species, and production processes that are flexible in the fishery sector (Mahon, 2002; Allison *et al*, 2007). A further category of technological innovation is multi-sectoral in nature. The rising number of reservoirs being built in response to water resource demands for agriculture, power generation, flood control and domestic water supply are creating opportunities for new fisheries. Both technological and institutional innovations are possible in these new water bodies and a variety of fish production strategies such as ranching (stocking the water body with cultured juvenile fish), cage aquaculture and communal ownership arrangements are developing to exploit the productive potential of these water bodies and add value to these water-resource developments.

Developing Risk Reduction Initiatives: Risk reduction initiatives seek to address vulnerabilities through early warning systems, timely seasonal weather forecasts, market information systems and disaster recovery programmes. Information and communication technologies are being widely utilized in fisheries and appropriate information services will find a ready market and existing means of dissemination (Cranston and Holmes, 2007). The value of proactive risk reduction initiatives in fisheries is illustrated by Red Cross programmes in Vietnam, where assistance to coastal communities to replant depleted mangrove swamps has improved physical protection from storms. This has reduced the cost of maintaining coastal defence (dykes) and saved lives and property during typhoon seasons. Mangrove restoration has also improved fisheries livelihoods through the harvesting of crabs, shrimps and mollusk (WDR, 2001). In inland waters, similar benefits may be achieved through focus on maintaining areas of natural wetland vegetation (such as reed swamp) which act as refuge for fish population during drought periods.

Aquaculture Insurance: An adaptive measure that will help limit bankruptcies in aquaculture business as a result of losses caused by climate change is to encourage aquaculture participants to take insurance against damage to stock and property from extreme climate events. Appropriate insurance cover will at least ensure that finance is available to recommence operations.

Aquaculture Zoning and Monitoring: Adequate site selection and aquaculture zoning can be an important adaptation measures to climate change. When selecting aquaculture sites, it is very important to determine likely threats through risk assessment analysis. When selecting the best locations for aquaculture farms, particularly in coastal and more exposed areas, weather related risks must be considered

The Needs for Enhanced Extension Capabilities

Small scale fishers and farmers in developing countries require additional education and training to help them determine markets capacities for their products. Larger producers need additional education and technical assistance with marketing plans that include basic information on market network.

Participatory technology development (PTD), pioneered by the workers in the fields of farming systems research and extension and agroecology has been found to be a very successful approach when applied to enhance the sustainability of fisheries and aquaculture farming systems. PTD has been called "participatory learning for action". PTD uses assessment tools to enable fishers and farmers to analyze their own social ecological situation and to develop a common perspective on natural resources management and fisheries/food production at the local level. PTD involves group facilitation methods, methods for interviewing and dialogue, and visualization/diagramming methods. In farming and fishing systems PTD approaches the natural and social ecological sciences come together in a very unique form of interdisciplinary environmental scholarship. Fixed answers derived from fisheries/agriculture/aquaculture experiment stations and passed down to farms in a top-down manner are too inflexible and cannot solve the problems of sustainability which require more site specific, integrated social and ecological methodologies. Aquaculture farmers and coastal fishers are innovative groups in their communities, and traditional extension roles a given which should be embraced as a set of unique opportunities for collaborative work – not challenged or fought. By initiating a new era of cooperative research with fishers/farmers, a more detailed and very intimate knowledge of the natural and social ecology of farming/fishing systems can be combined with useful scientific knowledge to evolve sustainable aquaculture and fisheries ecosystem.

8. Conclusion

Over the last two to three decades, aquaculture has successfully established itself as a major food sector providing a significant proportion of the animal protein needs across all communities irrespective of living standards. It has done so through many adversities during which it has shown resilience and adaptability. As in all food producing sectors, aquaculture now confronts another major challenge, that of the impacts of climate change. It is likely that aquaculture, in view of its resilience and adaptability and its cultivation of a wide array of species/species groups will be able to respond positively to climate change impacts. In order to do so, there needs to be related policy, institutional and socio-economic changes, backed up and supplemented by relevant technical development. Preferably, there should be a holistic approach and one that works from the bottom up rather than top-down. Only by incorporating indigenous knowledge and obtaining cooperation at grass root level will it be possible for adaptive changes to be implemented effectively and in a timely manner. This is because, the great bulk of aquaculture is small-scale, and peasantry.

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