

Challenges of Sustainable Marine Fishing in Ghana

Eric K. W. Aikins

Abstract—Traditionally, Ghana is a marine fishing country. The fishing industry dominated by artisanal marine fishing helps Ghana to meet its fish and protein requirements. Also, it provides employment for most coastal dwellers that depend on fishing as their main economic enterprise. Nonetheless, the marine fishing industry is confronted with challenges that have contributed to a declining fish production in recent past decade. Bad fishing practices and the general limited knowledge on sustainable management of fisheries resources are the limiting factors that affect sustainable fish production and sustainable marine biodiversity management in Ghana. This paper discusses the challenges and strategies for attaining and maintaining sustainable marine fishing in Ghana as well as the state of marine fishing in Ghana. It concludes that an increase in the level of involvement of local fishers in the management of fisheries resources of the country could help local fishers to employ sustainable fisheries resources exploitation methods that could result in an improvement in the spatio-economic development and wellbeing of affected fishing communities in particular and Ghana in general.

Keywords—Pair trawling, sargassum, spatio-economic development, sustainable marine fishing.

I. INTRODUCTION

MARINE fishing is the most prevalent fishing activity in Ghana. It accounts for over 80 percent of the total fish consumption of the country [1]-[3]. Fish species commonly found in Ghana's territorial marine waters are both pelagic and demersal in nature [4], [5].

Pelagic fish is found in the Pelagic Zone (above the continental shelf) of the marine habitat. The Pelagic Zone is the biggest of the entire marine habitat. As a result, pelagic fish characterizes the fishes that are found close to the sea surface or open waters. They are highly mobile and migratory in nature. Examples of pelagic fish usually harvested in Ghana are sardinella, skipjack, yellow fin, bumper, mackerel, anchovy and burrito [2], [4], [5]. On the other hand, demersal fish is found in the Demersal Zone of the marine habitat. The Demersal Zone represents the marine habitat below the continental shelf and close to the seabed or sea floor. Thus, demersal fishes are found close to the seabed and are benthic in nature. Examples of demersal fish commonly harvested in Ghana are lujanidae (snappers), serranidae (groupers) and polynemidae (threadfins) [4].

Spatio-economic-wise, marine fishing is widespread in the coastal regions of Ghana (Fig. 1). Coastal fishing communities of Ghana cover about 550 km of coastline and a 24,300 sqkm continental shelf area (coastal fishing waters), which stretches from Afloa (East) to Half Assini (West) [1]-[4]. As an age-old

occupation in Ghana marine fishing serves not only as the main stay of the economies of the fishing communities of Ghana but also as a way of life of the affected coastal communities. The establishment of the State Fishing Corporation (1961), the Tema harbor (1962) and the Tema boat yard (1962) signifies the importance of marine fishing to Ghana and the spatio-economic development of the country [4]-[7].

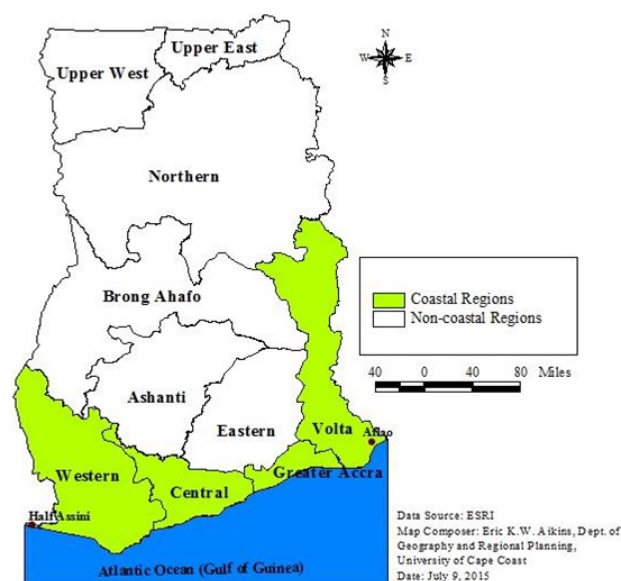


Fig. 1 A map of Ghana showing the coastal regions of Ghana

Food and nutrition security-wise, marine fishing provides Ghana with the required quality and quantity of fish that are needed to cater for the protein requirements of the population. It forms one of the key contributors to the achievement and attainment of food and nutrition security of the country [6]-[9]. Fishing is thus considered to be one of the key pillars of food and nutrition security and sustainable development [5]-[7], [10]. As a result, sustainable fishing could not be considered an option for the sustainable development of Ghana. Rather, it is considered an integral part of the country's effort at sustaining its current food and nutrition security and development levels that are capable of aiding the country climb the development ladder from its current lower middle income status into the upper middle income status category in the nearest future [5]-[8], [11]. Relatedly, sustainable fishing is considered to be a key tenet of sustainable development that is capable of helping the country to achieve the needed food and nutrition security and good health for its workforce. In practice, good health forms part of the key building blocks needed for the sustainable production of a healthy workforce that are required for the attainment of

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sustainable development goals both in the short and long terms [5]-[9], [11].

Consequently, this paper discusses the challenges that this age-old industry faces as well as the effective strategies that could be employed to help the country to achieve sustainable marine fishing (sustainable marine resource exploitation) and obtain the required spatio-economic development benefits of marine fishing. Also, the paper provides suggestions for future research on the harmful ecological effects of pair trawling, the negative impact of the frequent deposition of Sargassum on the coast of Ghana and the need for the development and application of an integrated fisheries management framework that could help the country to exploit its fisheries resources in a sustainable manner.

II. DEVELOPMENT OF MARINE FISHERIES IN GHANA

The development of marine fisheries in Ghana can be grouped into four main periods:

A. Pre-Colonial Subsistence Marine Fishing (1700s-Early 1900s)

This period represents the simplest form of artisanal marine fishing in Ghana. During this period, marine fishing was done with rudimentary equipment and gears such as dugout canoes, paddles, hooks and smaller capacity nets that allowed for shorter distance daily commute fishing [2], [4], [12]. Also, fishing was done mainly to provide fish for food to the affected fishers' families and communities. Economic-wise, this era reflects a period of domestic fish production within the country with very limited international fish trade along the Atlantic coast [4], [12]. Social-wise, fishers were not concerned with the economic gains of their occupation but saw their enterprise as an obligation to honor the trade, tradition and culture of their fathers and to provide their families and communities with their needed fish requirements.

B. Post-Colonial Subsistence Marine Fishing (1700s-Early 1900s)

This period saw an improvement in the mode and orientation of marine fishing in Ghana. First, the focus of fishing changed from subsistence to commercial fishing. During this period, fishing was done mainly as a means of livelihood rather than a response to a traditional obligation. Second, this period was characterized by the use of large canoes and locally built boat, outboard motors, large nets and other modern fishing gears and equipment. The need for the modification and modernization of fishing during this period could be explained by the increase in demand for fish that was created by the growing Ghanaian population. For instance, in the quest for Ghana to improve on its marine fish production, the Department of Fisheries imported two 30-footer motorized fishing boats on experimental basis in 1946. Following the success of this venture, the Boatyard Corporation was established in 1952 to help produce engine powered wooden vessels (boats) that have bigger capacity and could reach longer distances than the traditional artisanal canoes [12].

C. Period of Active State Participation in Commercial Marine Fishing (1960s-1980s)

This period saw an active state participation in the development, strengthening and expansion of the young Ghanaian commercial marine fishing industry. In recognizing the immense economic potential of fishing to the spatio-economic development of Ghana, the first democratic government of Ghana included fishing in its ten-year development plan [4]. Subsequently, spurred by the aim of the state to cater for the fish needs of the growing Ghanaian population and the desire of the state to take advantage of the good international market that fishing offers, the government of Ghana and its development partners provided the needed economic impetus for the modernization and expansion of the commercial marine fishing industry in Ghana as a means of helping the country achieve a faster economic growth and development. For instance, the State Fishing Corporation (1961), Commercial Tuna Factory (1962), the Tema Harbor (1962) and the Tema Boatyard (1962) were established to increase marine fish production and provide the needed trade support, equipment and technical support to the growing commercial marine fishing industry in Ghana [4]-[7], [12]. However, the unfavorable political and harsh economic conditions (frequent coups d'état and economic mismanagement through lack of proper governance) that the country faced between 1970 and 1980 eroded the profits and development contributions of the marine fishing industry. In practice, these profits could have been ploughed back into the marine fishing industry to make it more sustainable and productive [4], [12]. Also, large scale poaching in Ghanaian territorial waters by foreign vessels and the declaration of the Exclusive Economic Zones in 1982 prevented a relatively large proportion of Ghanaian vessels from fishing in viable foreign waters. This mainly resulted in overfishing in Ghanaian waters and the consequent decline in fish production, particularly in the semi-industrial marine fishing sector [4], [12], [13]. Finally, this led to the collapse of most state-owned fishing enterprises including the State Fishing Corporation and the collapse and downsizing of some privately owned fishing enterprises including the Mankoadze Fishing and Ocean Fisheries [4], [12].

D. Period of Privatization and Active Private Participation in Sustainable Commercial Marine Fishing (1990s to Present)

This period represents the current state of fisheries in Ghana. Following the period of political and economic instability of the 1970s-1980s, the government of Ghana through its economic recovery program privatized most of the failing state-owned companies including the state-owned fishing enterprises [14], [15]. This has resulted in an increased in private ownership and participation in the marine fishing industry, particularly in the semi-industrial and industrial marine fishing industries. However, the state still plays a vital role in the development of marine fishing in Ghana through its regulatory and collaborate efforts (outsourcing of potential investors, development of efficient procedure for the attainment of fishing license) with other foreign countries on

fisheries development as well as engaging in joint local ventures that help with fisheries development in Ghana [2], [4], [7], [8], [12], [16], [17]. Currently, marine fishing in

Ghana is dominated by three main forms of fishing, namely the artisanal, semi-industrial and industrial forms of fishing (Figs. 2 (a)-(d)) [18]-[21].



Fig. 2 (a)-(d) Types of marine fisheries in Ghana

III. THE STATE OF MARINE FISHERIES IN GHANA

Principally, the state of marine fisheries in Ghana is characterized by the three main types of fishing; artisanal or canoe fishing, semi-industrial fishing and industrial fishing [2], [4]-[7].

A. Artisanal or Canoe Fishing

The artisanal or canoe fishing is the most prevalent type of marine fishing in Ghana. Mainly, it involves the use of dugout canoes, outboard motors and fishing net. Except for the migratory purposes where fishermen travel to far away distant communities for fishing, artisanal fishing is mainly a daily relatively short distance commute fishing activity that usually ends in less than 12 hours. It is practiced by fishermen in almost all coastal fishing communities in Ghana (Figs. 2 (a)-(d)). In Ghana, about 70 percent of the country's total fish requirement is met through marine artisanal fishing. Additionally, it accounts for 80 percent of the total marine annual fish catch of the country [2], [6]. This makes marine artisanal fishing the major provider of the country's protein requirement [2], [6]. Specifically, it accounts for about 60 percent of the country's animal protein source [2], [4], [5]. Also, it provides the needed raw materials to the fish and food processing industries and the tourism and hospitality industries of the country. Spatio-economically, it provides employment to about 60 percent of women in the coastal fishing communities of Ghana who are mostly uneducated and have limited opportunity to be employed by the formal economic sectors of Ghana [5], [6], [11], [22]. In all, it is estimated that the fisheries sub-sector dominated by the marine artisanal fishing type provides employment to about 500,000 people (fishermen, fish processors, traders and boat builders) [4].

B. Semi-Industrial Fishing

This type of marine fishing involves the use of some modern equipment and improved ways of fishing that make it lesser capital intensive. Usually, it involves the use of large locally built 30-90 horse power engine boats with or without refrigerators and smaller landing base [2]. As a result, fishermen engaged in this type of fishing spend considerable fewer days at sea than their counterparts in industrial marine fishing. Fishing communities, where semi-industrial marine fishing is mainly practiced, include Tema and Sekondi (Figs. 2 (a)-(d)).

C. Industrial Fishing

Mainly, this is a capital intensive form of marine fishing. Usually, it involves the use of foreign built fishing boats with 30-200 horse power engines and other modern fishing equipment (refrigerators) and techniques [2]. As a result, fishermen engaged in this type of marine fishing are able to travel considerable long distances in search of fish and spend considerable number of days at sea. This type of marine fishing is common to Tema (one of the two harbor cities of Ghana) (Figs. 2 (a)-(d)).

IV. SPATIO-ECONOMIC DEVELOPMENT AND SUSTAINABLE MARINE FISH PRODUCTION IN GHANA

A. Spatio-Economic Development of Marine Fishing in Ghana

Generally, marine fishing is a spatio-economic activity. First, coastal communities (spatial input), where marine fishing is done, provide the needed raw materials (primarily, the marine habitat and human resources that reside in affected coastal communities) that aid in the increasing landing and processing of fish for both domestic and commercial purposes.

The provisions of space, therefore, offer the needed basic economic building blocks (marine habitat and human resources) that interact to produce the required fish for sale to generate income as well as to meet the protein needs of affected communities. Also, space (geographies of affected fishing communities) provides the necessary enabling commercial environment for the operation of vibrant and profitable marine fishing economic enterprises that are commonly found in coastal areas of Ghana. Second, profit (economic output) generated from marine fishing activities and fish production provides the needed economic gains (income) that are usually used to acquire the needed raw materials such as canoes or boats, nets and fuel that form the main inputs of the local marine fishing industry. Traditionally, some of the profits generated from the spatio-economic benefit of marine fishing are used to cater for kin folks,

contribute to social and cultural development of affected communities (building of schools, health posts and markets) and for the betterment of their socio-economic wellbeing, which invariably leads to an overall improvement in spatial (physical) infrastructural development (e.g. building of houses and schools) of affected fishing communities [11], [22]. Generally, the improved spatial infrastructure (improvement in the general conditions of schools, health posts and markets) leads to an improved socio-economic wellbeing of the human resource (healthy and knowledgeable workforce) of affected communities. Consequently, the improved human resources in turn help in the organization of basic resources available in their communities (space) for the sustainable production of the required quality and quantity of fish that could help affected local marine fishing communities generate sustainable profit and income [11], [22].

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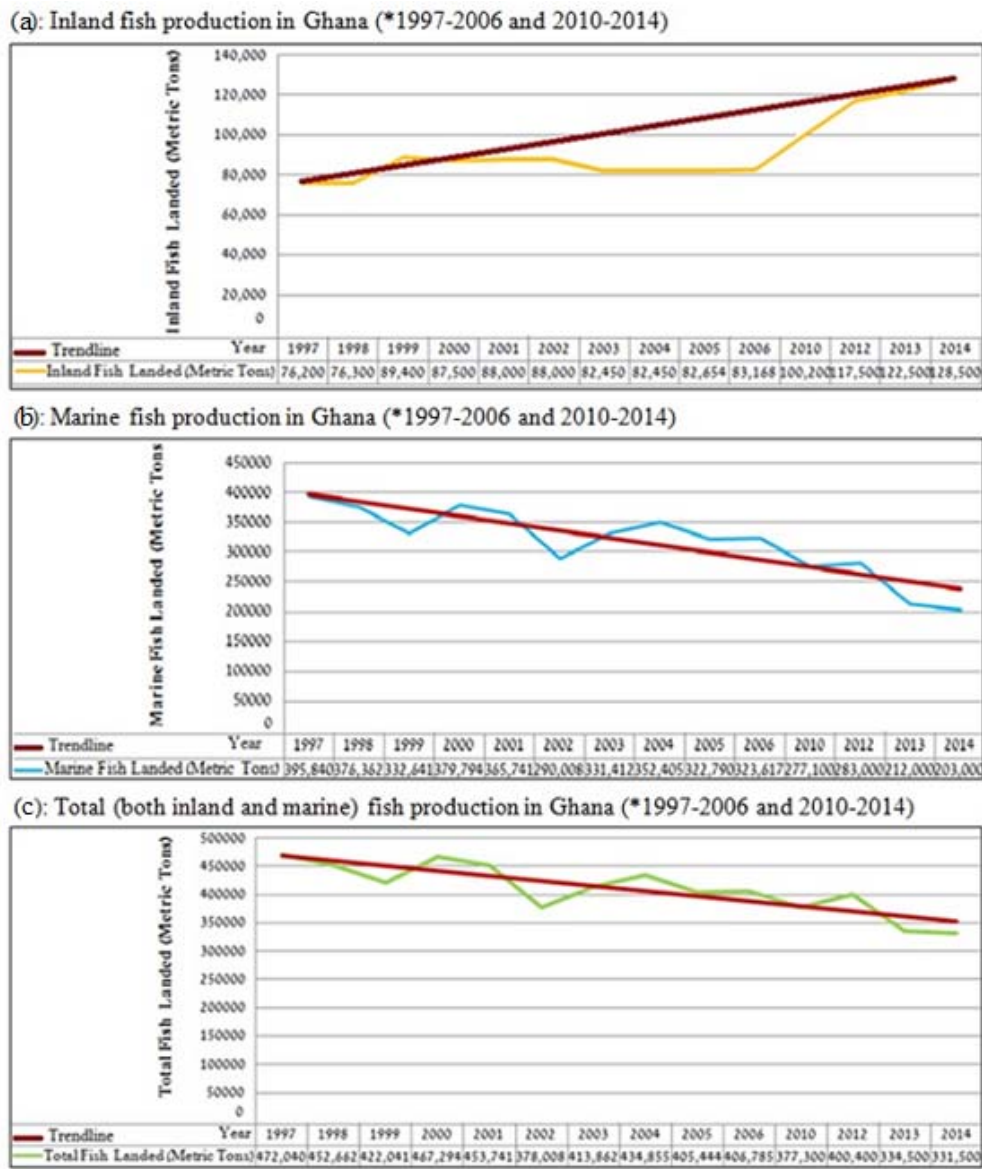


Fig. 3 (a)-(c) Fish production trend in Ghana (1997-2014). Data were retrieved from [4], [28]

Specifically, marine fishing as a spatio-economic activity (both local and modern industrial activities) contributes to increased employment, poverty reduction and increased local and national revenue generation [4], [5]-[8], [11], [22]. Additionally, it enhances national income generation in Ghana [4]-[7]. For instance, in 2006 the fishing industry, a subsector of the ministry of Agriculture accounted for 4.4 percent GDP and 11 percent Agriculture Gross Domestic Product (AGDP) of the Ghanaian economy [4]. Also, fishing is considered to be one of the key foreign exchange earners of Ghana. For instance, in 2000 and 2011, Ghana earned over US\$ 78.5 million and US\$256 million respectively from fish export [4], [23]. Currently, it accounts for about 5 percent of AGDP [4], [24].

Food and nutrition security-wise, fishing of which marine fishing forms a major component accounts for about 10 percent of the animal protein intake requirement of the country [2], [4], [6], [7]. Ghana with an annual fish consumption of 850,000 metric tons forms one of the highest fish consumption countries in the world [7]. Specifically, the country's average per capital fish consumption of between 20-25 kg is relatively higher than that of the world's average of 13 kg [4]. In general, about 75 percent of fish produced in Ghana is consumed locally, which accounts for 22.4 percent in household expenditure [4].

Comparatively, the contribution of the fisheries sub-sector to GDP has waned over the years. For instance, between the 1993 and 2006 fiscal years, the fisheries sub-sector's contribution to GDP decreased from 6 percent to 3.9 percent, respectively [4]. This may be explained by the observed decline in fish catch over the years (Figs. 3 (a)-(c)) mainly due to overfishing, lack of or limited good fisheries management systems, lack of or limited modern fisheries infrastructure and poaching by foreign vessels [2], [4], [7], [13], [25], [26].

B Sustainable Marine Fish Production in Ghana

In general, the trend in marine fish catch has been largely unstable and decreasing in nature (Figs. 3 (a)-(c)). The general decreasing trend in marine fish production may be explained by the unsustainable marine fishing practices employed by local fishers and foreign trawlers in the territorial waters of Ghana, lack of or limited supply of premix (fuel) and the general increases in premix price and fishing equipment, lack of or limited refrigeration or storage facilities, large scale poaching by foreign vessels, seasonal fluctuations in annual fish catch within the July-September bumper harvest season, use of unapproved methods of fishing including the use of explosives (dynamites), chemicals (DDT) and nets with unapproved mesh sizes as well as the worsening general economic, social and political conditions (political and economic instability) that Ghana experienced from the late 1960s to the early 2000s [2], [7], [12], [25]-[27]. For instance, the total quantity of marine fish landed declined from 395,840 MT in 1997 to 323,617 MT in 2006 (Figs. 3 (a)-(c)). Also, the trend of fish production in Ghana with respect to total fish landed (both marine and inland fisheries) shows a marginal decreasing trend. For instance, the total quantity of fish landed

in Ghana (from both marine and freshwater source) decreased from 472,040 MT in 1997 to 406,785 MT in 2006 (Figs. 3 (a)-(c)) [4], [17], [27]. Similarly, Figs. 3 (b) and (c) shows that the periods 2010-2014 saw a further decrease in both total quantities of fish produced (from 377,300 MT in 2010 to 331,500 MT in 2014) and total marine fish landed (from 277,100 MT in 2010 to 203,000 MT in 2014) [2], [28]. This signifies a general continual decrease in marine fish production and the persistence of the factors or challenges (problems) that limit sustainable marine fishing in Ghana [2]. The observed general decreasing trend in marine fish production in Ghana between 1997 and 2014 (Figs. 3 (a)-(c)) may be explained by some pertinent challenges and problems that limit sustainable marine fishing in Ghana [4], [7], [9], [13], [29].

V. CHALLENGE OF SUSTAINABLE MARINE FISHING IN GHANA

The marine fishing industry, though, an age-old occupation in most coastal communities in Ghana is beset with many persisting challenges that largely limit its sustainable productive capacity. Some of these challenges include:

A. Overfishing

Traditionally, overfishing characterizes a fishing activity where fish resources are exploited over and above the fish reproductive capacity of affected marine ecosystems. Spatially, overfishing negatively affects the stability as well as the sustainable reproduction of fish in affected marine ecosystems. Additionally, over fishing negatively affects the spatio-economic wellbeing of affected fishing communities that depend on the marine habitat for their spatio-economic sustenance [7], [8], [13], [30]. As a measure to curb overfishing and its associated negative spatio-economic consequences, this study underscores the need for affected local fishing communities to look for alternative sources of livelihood that could help reduce the current levels of overfishing and overdependence on artisanal fishing as the major economic enterprise of affected local coastal fishing communities [7], [11], [30].

B. Limited Use of Sustainable Modern Techniques of Fishing and Over-reliance on Subsistence (Traditional) form of Fishing

In practice, the limited use of sustainable modern techniques of fishing and the general over reliance on the subsistence traditional artisanal fishing coupled with poor and harmful fishing practices such as the use of DDT and dynamite for fishing negatively impact the ecological stability of affected marine habitat, sustainable fish reproduction and production in affected marine habitats as well as the spatio-economic development and general wellbeing of fishers in affected local coastal fishing communities [7], [8], [13], [26]. Usually, overreliance on subsistence traditional artisanal marine fishing leads to economic losses as fishermen in affected marine fishing communities tend to land lesser quantities of fish than expected. First, the use of traditional methods of fishing lower the ability of fishermen to land the

expected quantity of fish that is required to meet their operational cost and help them make reasonable profits. Second, some of the techniques that are used in the modern day artisanal marine fishing such as the use of un-prescribed nets (nets with smaller mesh size), light aggregating machines, DDT and dynamites lower the reproductive capacities of affected marine habitats. Relatedly, through these bad fishing practices large quantities of fish tend to be destroyed (wasted) in the process of local artisanal fishers extracting fish resources from the affected marine habitats [25], [26].

As a means of controlling both economic losses and fish losses that are mainly encountered through the use of unsustainable and less productive traditional fishing practices and marine ecosystem destructive fishing practices, this study suggests an enhancement of the subsistence traditional artisanal marine fishing that is capable of transforming (positively) the prevailing traditional system of marine fishing into an improved system of fishing, which could contribute substantially to the overall quantity and quality of fish landed per annum [4].

C. Limited Collaboration on Sustainable Management of Marine Fisheries Resources

Limited participation of affected local fishing communities and the undermining of the role of Community Base Fishing Management Committees (CBFMCs) limit the effective collaboration on the sustainable management and conservation of fisheries resources in Ghana [5], [6]. For instance, the collapse of CBFMCs due in part to the lack of sponsorship of CBFMCs activities after the end of term of the World Bank sponsorship left the affected fishing communities with little avenue for channeling their grievances to the government of Ghana and its development partners on the problems of fishing in Ghana [7]. Within the period of their effective operations, the CBFMCs remained the most recognizable collective representation of the efforts of the fishing community in Ghana. Additionally, the CBFMCs were committed to addressing the needs of fisher folks as well as contributing to the sustainable management of the country's marine fish resources [6], [7]. Nonetheless, very little was done by the government and other stakeholders to provide the needed support and financial resources for the effective operation of the CBFMCs. For instance, [31] noted that local fishers (fish-workers world-wide) need to be heard and listened to so as to help them obtain the support that they need to help them contribute meaningfully to the sustainable management of fisheries resources. Similarly, [28] noted that the government of Ghana needs not to underestimate the capabilities and abilities of Chief fishermen, the CBFMCs and other traditional groups in the sustainable management of the country's fisheries resources. Relatedly, some studies argue that any barrier that is put in the way of fishers to prevent them from channeling their grievances to the appropriate government officials and agencies for redress and support largely constitutes an undermining of the role of CBFMCs and the representative Chief fishermen that represent the interest of artisanal fisher [5], [17], [32]-[34]. For instance, [5] observed

that the top-down other than the bottom-up management approach that characterizes the CBFMCs to a larger extent undermines the activities of Chief fishermen that serve as representatives of the local fishing communities. In practice, the undermining of the efforts of Chief fishermen and CBFMCs largely undermines the Hen Mpoano initiative sponsored by USAID that seeks to encourage the co-management of Ghana's fisheries resources through a collaborative and all stakeholder participatory workshops and seminars that provide the necessary platform for effective dialogue among all fisheries stakeholders [8], [17]. For instance, the 2003 Ghana coastal fisheries dialogue organized by the Hen Mpoano initiative expressed the need for the active inclusion of artisanal fishers in the management of Ghana's fisheries resources. The meeting observed that the inclusion of artisanal fishers in the management of fisheries resources in the country would provide artisanal fishers (who are mostly represented by CBFMCs) with the necessary knowledge and legal backing that they need to make them contribute meaningfully to fisheries management in Ghana [8], [17], [32], [33].

D. Limited Local Knowledge and Participation in the Maintenance and Conservation of Marine Biodiversity

Principally, the level of knowledge and participation of artisanal marine fishers and residents of local coastal fishing communities in the maintenance and conservation of marine biodiversity in Ghana is low. The general low level of education of fishers and the limited-inclusion of artisanal marine fishers in the management and conservation of Ghana's marine biodiversity explains this. Also, limited enforcement of fisheries Act 625 that mandates the sector minister to open and close the fishing season where necessary for the effective conservation, management and use of marine resources in the spirit of achieving a sustainable marine biodiversity and conservation limits the complete adherence to effective biodiversity management and conservation policies that are capable of helping Ghana to achieve a sustainable marine biodiversity, conservation and sustainable fish production. Similarly, limited establishment of marine biodiversity management enforcement agencies that are tasked and adequately equipped to help stop or limit the dumping of untreated liquid and solid waste into the sea, the continuing harvesting of sea endangered species such as the sea turtle for consumption as delicacies, the non-stop all week long (24/7) trawling, pair trawling, the use of light aggregating device in fishing (lighting from rigs), the use of chemicals such as DDT and carbides, and the use of explosives such as dynamites for easy fish harvest limit Ghana's efforts at attaining sustainable marine biodiversity and sustainable fish production [5], [6], [8], [25], [35]-[38].

E. Pair Trawling

Pair trawling is a form of fishing where two trawlers move shoulder to shoulder with a net sandwiched between them that scope the marine habitat between the two trawlers for any available fish that could be trapped [38]-[45]. Usually, the

types and sizes of fish caught are based on the net's mesh size. In practice, the length and depth of pair trawling cover both the pelagic and benthic communities where fishing breeding and feeding communities are located. Consequently, pair trawling lowers the productive capacity of affected marine

habitats through the destruction and disruption of fish breeding (reproduction) and feeding (nurturing) habitats of affected marine ecosystems that usually require a stable and undisturbed habitat for fish reproduction and production (breeding and feeding) [38]-[45].

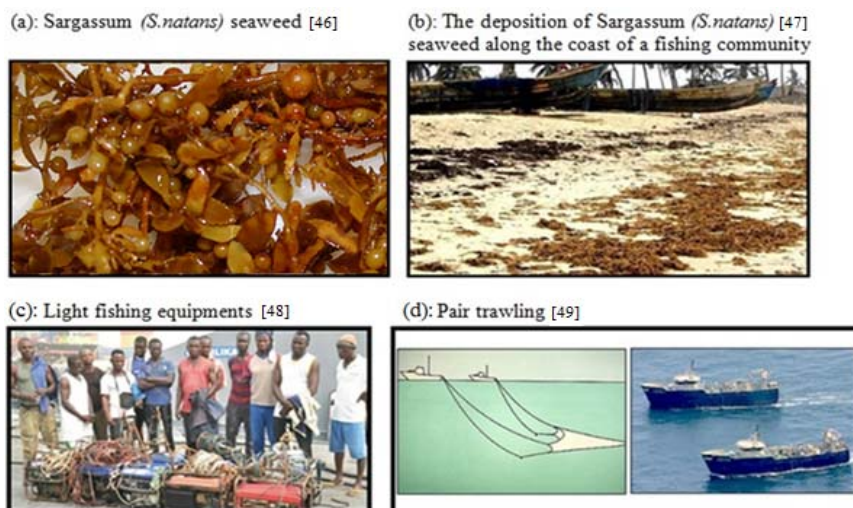


Fig. 4 (a)-(d) Challenges of marine fishing and the impact of Sargassum (*S. natans*) deposition on the coast of Ghana

Also, pair trawling results in the removal of sea weeds and plankton, which provide fish with the required food resources needed for proper growth, survival and reproduction [38], [39], [41], [43]. For instance, the recent increase in the deposition of the Sargassum seaweed on the shores of coastal areas of Ghana may be attributed to the increased and sustained pair trawling along the coast of Ghana (Figs. 4 (a)-(d)) [39], [41], [43], [46]-[49]. Similarly, through pair trawling smaller fish that is not mature for food is extracted from their habitats. This affects the level of available potential mature fish resources and reserves on which the local marine fishing industry depends [37], [41]. The development of the term “Saeko” among some fishers in the Central Region of Ghana (by-catch or residue fish from trawlers) typifies the increase catch of smaller and unwanted fish species by trawlers that are traded off to local fishermen for money, local food and craft commodities. Also, through pair trawling, particularly mid-water to bottom water pair trawling some ecologically sensitive marine animals and sea endangered species such as sea turtle, sharks, dolphins and small fish get removed from their habitat accidentally [13], [38], [39], [41], [45], [50], [51]. For instance, the unintended catch of sea turtle and small fish through pair trawling along the coast of Ghana could destabilize the affected marine habitats, reduce marine biodiversity, and limit sustainable fishing in the long run.

Currently, “Saeko” is an accepted form of fish production in some local fishing communities in Ghana. The inability of fishermen to catch fish within the traditional borders of artisanal marine fishing explains this. Generally, a relatively large proportion of fishermen travel farther distances than normal to catch fish in recent times. The result is that, on the average, fishermen consume more fuel resources than normal

before they are able to land reasonable quantities of fish the values of which are often lower than their operational costs. Therefore, the assistance of trawlers through the provision of “Saeko” (by-catch) is considered a lucrative option regardless of the harmful effects of trawling, particularly pair trawling along the coast of Ghana. Evidently, pair trawling is still being practiced along the coast of Ghana. For instance, fishermen in Elmina, Axim, and Half Assini caught on camera fishermen (reportedly foreign vessels) pair trawling in the territorial waters of Ghana [52], [53].

F. The Use of Unapproved Methods of Fishing

The use of unapproved methods of fishing including the use of DDT, carbides, dynamite, light aggregating device (Figs. 4 (a)-(d)) and unapproved (small) mesh size for the harvesting of fish, particularly juvenile fish has largely contributed to the lowering of Ghana's fish productivity levels over the past two decades [2], [5], [6], [25], [35]. For instance, the mean fish production of Ghana (about 400,000 metric tons) is about 50 percent lower than the estimated annual fish requirement of about 820,000 metric tons [4], [5]. The lower productivity of the fishing industry in Ghana may be explained by the total quantity of fish that is wasted due to the use of unapproved method of fishing. For instance, the use of explosives (dynamite) and chemicals (DDT and carbide) causes physical harm to the catch [5], [6], [25], [36]. On the other hand, the use of light aggregating machines does not cause physical harm to the catch. Instead, the light intensity disrupts the sleep of affected fish, which leads to the dazing of the fish over a longer period of time. Usually, fishers take advantage of the confused state of the fish and trap them for a harvest. Although fish harvested by this means is less poisonous and

relatively healthier for human consumption, the repeated use of this technique in fishing creates an unhealthy habitat for the affected fish that moves farther away from affected habitats to newer and healthy habitats to enjoy a better sleep and a healthier environment. The use of light aggregating devices (unapproved method) in fishing represents one of the reasons why fishers currently travel considerable long distances before they are able to find fish to harvest [30]. As a result of the use of unapproved method of fishing, the fishing industry in Ghana is able to produce only 40 percent of its fish requirement locally and import the remaining shortfall (60 percent) from other countries [4], [5], [25], [54].

G. Lack and Increase of Premix Fuel Price and Fishing Equipment

Seasonal and unexpected increases in the price of fishing gear and fuel (premix) affect the general operation and productivity of the marine fishing sector. Generally, increases in the price of fishing gear such as nets and net accessories as well as premix fuel increase the operational and production cost of fishers. In a country where avenues for bank loans are limited and a relatively large proportion of business start-up capitals are locally mobilized (self or from family relations), frequent increases in the price of fishing inputs limit the ability of affected fishers to obtain additional income to help them meet their operational cost. As a result, a larger proportion of the affected fishers are unable to meet the operational cost of competing for fish that are currently scarce and located in farther distances away from their hitherto traditionally not too long a distance habitats. Particularly, increases in premix fuel price set limits for the productive capacity of the fishing industry in Ghana. This is because, currently due to the long distance commute for fishing fishers usually require larger quantities of premix fuel for a single trip of fishing that are expensive and sometimes lacking. In the case where premix is available and sold at the government approved price, usually fishers do not obtain the needed quantity of premix from this source. This is because fishers are expected to ration the available fuel provided. Consequently, affected fishers obtain the shortfall from other secondary sources that are usually poorer in quality and expensive [34], [55].

Related to the frequent increase in the price of premix fuel is the problem of frequent premix fuel shortages, particularly and most discouragingly during the August-September fish bumper harvest season that largely limits the efforts of affected fishers in deriving the best maximum fishing output during the fish bumper harvest season [34], [54].

H. The Impact of Sargassum (S. Natans) Seaweed Deposition on Sustainable Fish Production in Ghana: A Recent Challenge

Related to the negative ecological impact of pair trawling on fish production in Ghana is the increase migration and deposition of nutritious and planktonic seaweeds, mainly Sargassum on the coast of Ghana (Figs. 3 (a)-(d)). Sargassum is a brownish algae commonly found in tropical oceans. They are commonly found attached to rock surfaces on the seafloor

where they are nurtured and reproduce. Principally, Sargassums are benthic species but they become pelagic after they have been shaken off from their stable habitat on the reefs (rock surfaces) by a rough weather [56]-[58]. On the other hand, the Sargassum *S. natans* species that are commonly found along the Atlantic Coast and in Ghana are holopelagic in nature and are able to float freely and undergo vegetative reproduction on the sea surface. Traditionally, Sargassum (*S. natans*) serves as a marine habitat and a source of nutritious food for some pelagic marine animals and fish species (Tuna and Dolphin). Additionally, it serves as the home (habitat) for some ecologically sensitive marine animals (sea turtle) in the benthic community [59]. Figs. 4 (a)-(d) shows an example of Sargassum (*S. natans*) seaweed deposition along the coast of a marine fishing community in Ghana.

VI. CAUSES AND CONSEQUENCES OF INCREASED SARGASSUM (*S. NATANS*) SEAWEED DEPOSITION ON THE COAST OF GHANA

The causes of the increased deposition of Sargassum (*S. natans*) on the coast of Ghana are twofold: natural (caused by strong ocean current) and anthropogenic (induced by human or manmade activities).

First, increased deposition of Sargassum (*S. natans*) on the coast of Ghana is believed to be caused by strong ocean current (natural means) with associated strong sea wave actions that shake loose and move loose free floating Sargassum (*S. natans*) and deposit them on the beaches of affected coastal communities devoid of any human influence [56]-[58], [60], [61]. For instance, some officials of the Tullow Oil Company (crude oil exploring and exploiting company in Cape Three Point, Western Region of Ghana) attributed the recent increase in the deposition of Sargassum (*S. natans*) along the coast of Cape Three Point to a natural cause rather than the consequence of any human activity [35].

Second, some stakeholders of the marine ecosystem in Ghana, particularly local artisanal marine fishers believe that human activities (anthropogenic) such as pair trawling, overfishing and oil exploration and exploitation under pin the current wave of increased deposition of Sargassum (*S. natans*) on the coast of affected marine fishing communities in Ghana [34], [42]-[44], [51], [61]. For instance, fishermen in Cape Three Point attribute the increasing deposition of Sargassum (*S. natans*) on their coast to the recent discovery and drilling of oil in their portion of the Atlantic Ocean (Gulf of Guinea). In relation to this observation, some affected fishers appealed to the government of Ghana to inform the Tullow Oil Company to control its oil exploratory activities in order to help reduce the increasing deposition of Sargassum (*S. natans*) on their coast [35].

In reacting to the allegation made by the Cape Three Point fishers, the Tullow Oil Company explained that the increasing deposition of Sargassum on the coast of Cape Three Point in recent years is a result overfishing rather than the ills of oil exploration [35], [59]. Relatedly, [59] indicates that the increase deposition of Sargassum (*S. natans*) on the coast of Ghana may be attributed to the way and manner that fish is harvested in recent times rather than the impact of oil

exploration and production. Similarly, pair trawling and the use of some unapproved methods of fishing such as the use of dynamite in fishing are suspected to be associated with the increased deposition of Sargassum (*S. natans*) on the coast of Ghana. For instance, [42] found that changes or alterations in seabed bathymetry and higher trawling frequencies are related. Also, [43] noted that bottom trawling disturbs the stability and growth of the benthic plankton community. Furthermore, [44] indicated that bottom trawling is one of the extensive fishing activities by humans (anthropogenic activity) that negatively impacts affected seabed through the destruction of sea floor habitat (benthic community) and marine ecosystem that usually limits marine biodiversity [36], [37], [51], [62]. Additionally, the blasting of dynamites results in the destruction of fish and the removal and deposition of some ecologically sensitive sea bottom to surface organisms such as Sargassum along the coast of affected fishing communities [25], [56]-[58]. Also, increased mid-water to bottom water pair trawling is suspected to be associated with the removal of Sargassum from their natural settings onto the beach [25], [41], [45].

The increase use of pair trawling and other unsustainable methods of fishing do not only deprive the affected fish of their required food and stable ecological habitats but also they distress and disturb the ecological stability of affected marine habitat and ecosystem of affected coastal areas [5], [6], [35], [38]-[45], [62].

VII. CONSEQUENCES OF SARGASSUM (*S. NATANS*) SEAWEED DEPOSITION ON MARINE FISHING

The consequences of increased Sargassum (*S. natans*) seaweed deposition on the coast of Ghana may be grouped into two; negative environmental consequences and decline in fish production and increased operational cost of marine fishing:

A. Negative Environmental Consequences

Ecological-wise, frequent and large volume deposition of Sargassum (*S. natans*) along the coast signifies an immense marine ecological disturbance and damage, especially where the removal of Sargassum from the benthic community to the pelagic community and to the shores of affected coastal communities is manmade (by pair trawling and the use of dynamite) [5], [6], [35], [38]-[45], [62]. For instance, [39] noted that the type of fishing gear and sediment suspension have the tendency of influencing the redistribution of dinoflagellate cysts (marine plankton). Also, [41] indicated that bottom trawling negatively affects marine regional nutrient budget through the release of nitrogen and silica in affected marine habitats that has the tendency of causing changes in the successional organization of soft-sediment infaunal (bottom or benthic fauna) communities. Similarly, [42] indicated that beam trawling disrupt the seabed through the contact of the fishing gear with the seabed that negatively affects sedimentation and resuspension of sediments of the affected sea water column [38]. Relatedly, [41] explained that the removal of epifauna through bottom trawling reduces the

complexity and diversify of fishes in the benthic community (benthic marine biodiversity).

Although, some fishers associate the presence of Sargassum (*S. natans*) along the coast of affected local fishing communities in Ghana with the presence of ample fish in the seas of affected fishing communities [59], the negative environmental consequences of Sargassum (*S. natans*) deposition along the coast of affected local coastal fishing communities on sustainable fishing far out-weight the benefits associated with increased Sargassum deposition, especially where the cause of the Sargassum deposition is manmade (pair trawling and the use of dynamite). For instance, the unintended removal of Sargassum and some ecologically sensitive marine animals such as sea turtle, sharks and dolphins through pair trawling destabilize affected marine habitat, reduce marine biodiversity and limit sustainable fishing in the long run [5], [6], [35], [37], [39]-[51], [62].

B. Decline in Fish Production and Increased Operational Cost of Fishing

The recent frequent deposition of Sargassum (*S. natans*) on the coast of Ghana and the general reduction in sea water quality that limit fish reproduction and invariably the quantity of fish available to fishers are considered to be related to the recent declines in fish production in Ghana [5], [6], [35], [59]. This is because, generally planktonic seaweeds such as Sargassum (*S. natans*) provide fish with nutritious food as well as stable ecological habitat that facilitates and maintains fish reproduction and growth [39]-[62]. For instance, [43] stated that bottom trawling negatively affects marine habitat processes including nutrient regeneration. Also, [41] noted that the removal of colonial epifauna (epibenthos) that provides conducive habitat for shrimp, polychaetes, brittle stars and small fish reproduction and growth limits benthic marine animals and fish diversity and re-reproduction. Furthermore, fishermen in Shama, Discove, Axim and Half Asini in Ghana believe that the exploration activities of oil mining companies, particularly the blasting of rocks under the sea send to the surface volumes of Sargassum that limits marine fishing activities in affected fishing communities [35], [59]. For instance, [59] indicated that the presence of large volumes of Sargassum (*S. natans*) in the sea clog the engine of outboard motors of fishers and limit their efforts in travelling longer distances in search of fish [35]. Furthermore, the report indicated that the presence of Sargassum (*S. natans*) in the sea destroy the nets of fishers, which invariably contributes to an overall increase in the operational cost of fishers through frequent repairs and purchasing of new nets and other fishing inputs [35].

VIII. STRATEGIES FOR ACHIEVING SUSTAINABLE FISHING IN GHANA

As a means of helping Ghana achieve sustainable fish production, the present study outlines the following strategies:

A. Increased Collaboration on Sustainable Management and Conservation of Marine Fisheries Resources

Increased collaboration on sustainable management and conservation of marine fisheries resources could be achieved through the inclusion of all marine fisheries stakeholders, particularly artisanal marine fishers in the management and conservation of marine fisheries resources in Ghana. As a measure to achieving an increased and improved collaboration among stakeholders of the marine fishing industry, the present study suggests the reintroduction of the Community Based Fishing Management Committees (CBFMCs) with greater grass root participation (bottom-up marine fisheries management approach) in the management and conservation of marine fisheries resources financed through a locally generated fund. Additionally, the present study suggests an implementation of effective cost sharing mechanism where the government of Ghana could provide a start-up income (seed money) for the re-establishment and management of CBFMCs. The re-established CBFMCs could then be managed and sustained by the beneficiary local fishing communities through local revenue generation through the sale of community fuel (premix) as well as local taxes and fines that could be imposed on offenders of local and national marine fishing regulations. It is expected that the reestablishment of the CBFMCs could help the local fishers to be re-represented in all national activities relating to the achieving and attaining of sustainable marine fishing and sustainable management and conservation of fisheries resources in Ghana. This initiative could help the country to achieve sustainable fish production, sustainable food and nutrition security, maintain sustainable poverty reduction efforts, improve spatio-economic development in affected coastal fishing communities as well as help the country to improve on its social wellbeing and sustainable development efforts both in the short and long terms [7], [8], [10], [11], [22], [25], [62].

B. Improved Knowledge and Community Participation in the Maintenance and Conservation of Marine Biodiversity

Although the subject of marine biodiversity management and conservation requires some level of education, the general appreciation of the need for a sustainable management and conservation of marine fisheries resources could not be daunting to the local marine fisher. Hence, a full inclusion of artisanal marine fishers in the management and conservation of Ghana's marine resources as alluded to by the 2003 Ghana coastal fisheries dialogue organized by the Hen Mpoano initiative could be implemented without delay [36], [25], [17].

C. Limiting of Pair Trawling Activities

Due to the harm that pair trawling cause to the marine ecosystem and sustainable fish management and production the government of Ghana and other stakeholders of the marine fishing industry in Ghana could intensify sea patrols. A collaborative effort by the local marine fishers and the designated government fishing law enforcement agencies could help discourage and limit the practice of pair trawling

and excessive trawling activities along the coast of Ghana [25], [52]. Also, close monitoring of business activities of some government and local marine fisheries officials who own trawlers and are actively involved in the fishing business could be done to prevent conflict of interest with respect to them not following in full the established fishing rules and regulations as owners of trawlers and canoes [34]. Additionally, this effort could help check excessive favor takings and the temptation of affected persons favoring their acquaintances, business partners and friends that are usually exempted from the strict complains to the established fishing rules and regulations to the detriment of sustainable fish production efforts of the country. Similarly, this effort could help to prevent some of the regulatory officials and public influential persons from taking favors from trawlers and fellow canoe owners, particularly foreign owned trawlers to the disadvantage of law abiding local marine fishers and trawlers in particular and the Ghanaian marine fishing industry as a whole. Generally, it is difficult for players of a game to remain fair if they are part of the officiating team.

D. The Use of Improved Sustainable Methods of Fishing

The use of improved sustainable method of fishing through the use of appropriate modern fishing techniques that are locally and environmentally friendlier (use of fuel economy outboard motors, fishing boats and fast moving big canoes with some form of modern refrigeration facilities) could help Ghana to improve on the productive capacity of its subsistence traditional artisanal marine fishing, which is by far the most prevalent type of marine fishing in Ghana. The use of improved method of fishing and fishing technology could contribute substantially to the overall improvement in the quality and quantity of marine fish landed per annum [4]. For instance, with the used of improved fishing technology Singapore in present times contributes substantially (more than 30%) to tropical fish production in the world [4].

E. Increased and Timely Supply of Subsidized Premix Fuel

Timely supply of premix fuel all year round, particularly during the fish bumper harvest season (August-September) in Ghana could ease-off the pressure imposed on fishers by the perennial shortage of premix fuel. Intended premix fuel shortages (artificial shortages), hoarding and illegal resale of government subsidized premix fuel due to frequent premix shortages, particularly during the bumper harvest period (August) negatively affect the level of annual seasonal fish production. Short supply or long delays in the supply of premix to affected fishing communities largely frustrates and discourages marine fishers who consider this once a year bumper harvest period a prime business period within which affected fishers work hard to defray larger portions of their investment cost and generate additional income for the expansion of already existing fishing businesses. Thus, a general improvement in the quantity of premix fuel supplied to coastal fishing communities in Ghana at the official subsidized prices could help eliminate negative consequences of perennial premix fuel shortages that often results in the

payment of bribes for the timely supply of premix to the needed fishing communities and the payment of unapproved high prices for available premix fuel. Also, it could discourage the hoarding of premix fuel by premix fuel service providers that usually leads to premix fuel shortage as well as help eliminate nepotism and cronyism that are commonly associated with premix fuel shortages, particularly during the fish bumper harvest season.

IX. CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

A. Conclusions

To conclude, this paper observes that the recent frequent pair trawling and the deposition of Sargassum (*S. natans*) along the coast of Ghana limit the activities of marine fishers and negatively affect sustainable marine fish production in Ghana in the long run. The application of modern techniques and sustainable methods of fishing forms one of the main factors that are capable of halting the current declining levels of marine fish production and contribute to the expected increase in sustainable fish production in Ghana.

Additionally, the paper observes that the involvement of local marine fishers in the management of fisheries resources of Ghana could help the country improve on the management and sustainable exploitation of the required marine fisheries resources that are capable of transforming positively the spatio-economic wellbeing of affected local coastal fishing communities in Ghana.

B. Suggestions for Future Research

In respect of the preceding discussions and conclusions, this paper suggests that further research could be conducted along the coast of affected fishing communities in Ghana in order to help provide scientific explanations for the effects of trawling, particularly pair trawling as well as the causes and consequences of the increased deposition of Sargassum along the coast of Ghana. Specifically, this research could cover the impact of the increased deposition of Sargassum on fisheries resource management and conservation in Ghana. Further, the paper suggests the development of an integrated fisheries management framework through research that considers local artisanal fishers as equal collaborators in the quest for and achievement of sustainable marine fisheries management and conservation in Ghana.

Finally, the paper suggests the application of a bottom-up fisheries management approach instead of the top-down fisheries management approach that is commonly practiced in most developing countries including Ghana. The paper notes that the application of a bottom-up fisheries management approach could help to address the fishing needs of local fishers and increase their full participation in the management and conservation of local fisheries resources.

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