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Coastal and mangrove economic valuation associated fisheries and problems in Kwale County, Kenya

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Abstract. *Ahmed HA, Mwaura F, Thenya T, Kairo JG. 2022. Coastal and mangrove economic valuation associated fisheries and problems in Kwale County, Kenya. Indo Pac J Ocean Life 6: 17-27.* The coastal fisheries in Kenya are essential to the livelihoods of the coastal communities. They provide employment, income, and food and support other auxiliary industries. Despite the socio-economic importance of coastal fisheries, various anthropogenic andclimate change impact threatened their existence. Fish habitats, including mangroves, coral reefs, and seagrasses, are threatened by human activities such as aquaculture, mangrove extraction, unplanned expansion of coastal cities, and marine pollution. Usually, coastal fisheries are also neglected in key policy-making agendas. That is attributed to inadequate information and a lack of data on the socio-economic contribution of coastal communities engaged in fisheries. This study aimed to estimate the economic value to providecrucial information for policy making of mangrove ecosystem-based coastal fisheries in Kwale County. The study also attempted to establish the coastal fishery production trend for the past decade, to estimate the economic value of mangrove ecosystems to fishery production, and the future of coastal fisheries projecting based on Climate Compatible Development (CCD) and Business As Usual (BAU) scenarios. Combining the primary data from interviews with 242 respondents with secondary data, including a decade of fish catch data, were analyzed, which exhibited a continuous increase from 1,908 tonnes in 2004 to 2,450 tonnes in 2013 coastal fisheries production. The coastal fisheries value was estimated to be Ksh.182 million (US$ 2.2) annually after deducting all fishing-related costs in 2013. This study also estimated that mangrove ecosystems could support the production of 160kg/ha/year, comprable to Ksh.11,610/ha/year (US$ 198/ha/year). Moreover, the estimated values could be much higher than the calculated ones because a considerable amount of fish caught is unrecorded. The future projections reveal that the scenario of Business As Usual (BAU) is not sustainable. Hence, the study demands a shiftto the scenario of Climate Compatible Development (CCD), which incorporates mitigation measures, climate change adaptation, and investment in infrastructure. The study recommendsreviewing the existing fishery policies regarding the unique characteristics of coastal fisheries to ensure sustainable exploitation and address the challenges. The research also recommends further economic studies on the coastal fisheries value chain.

Keywords: Coastal, communities, fish, socio-economic, mangrove

INTRODUCTION

Ecosystems provide various products and services essential to human welfare (Spalding et al. 2010; de Groot et al. 2012; Puligheet al. 2016; Wolsink 2016; Lacy and Shackleton 2017; Palliwodaet al. 2017; Sulistyorini et al. 2018; Muhlisin et al. 2021; Siahaya et al. 2021). However, the environmental goods and services benefits that have been realized are often undervalued in decision-making because organizations and individuals often more consider market prices than the true economic values (Campus and Schuhmann 2012). Economic valuation generates the real economic costs arising from habitat degradation, species loss, and the benefits of rehabilitation activities and conservation, often conveyed in monetary terms (in theory), as a 'universal currency' that is understood by policy-makers and data on the decision-making of limited resources (Turner et al. 2003).

Globally, coastal marine ecosystems and estuarine are the most endangered ecosystems (Halpern et al. 2008). The sum of 50% of the salt marshes, 30% of coral reefs, 29% of seagrasses, and 35% of mangroves, have degraded or lost since 1950 because of intensive and expanding human activities (FAO 2007; Barbier et al. 2011). Moreover, those degradation has resulted in a decline of 33% in fisheries production, 69% in habitat provision (e.g., seagrass, oyster reefs, and wetlands),and 63% in services such as filtering and purification functions (Barbier et al. 2011). The decline of coastal ecosystem services and degradation negatively affect the livelihoods of communities and national economies, particularly in developing countries with the largest populations (UNEP 2011a)

Mangrove forests in subtropical and tropical regions are the most productive ecosystems, providing economic and environmental products and services. They also support coastal fishery production. Over the past decades, unfortunately, the cutting and conversion have resulted in a global decline of these coastal ecosystems (FAO 2007; Spalding et al. 2010), having both economic and environmental adverse impacts in the coastal areas. On the other hand, mangrove forests have huge potential for preventing flooding, climate change mitigation and adaptation, and protection against storms. In addition, mangroves as important carbon sinks, and their removal would release large carbon stocks trapped beneath them (Siikamäki et al. 2012; Pricillia et al. 2021).

The coastal fishery production is intact in mangrove habitats (Hamilton et al. 1989; Rönnbäck 1999), providing a habitat for various fish species. However, due to the turbidity and dense structure, predation on juvenile fishes may be reduced; the trees, branches, aerial roots, and trunks are submerged at high tide, which could inhibit predators through impending sight and movement (Huxham et al. 2004; Nagelkerken et al. 2008). Hence, mangrove ecosystems' degradation makes fish stocks more vulnerable because of their effects on juvenile fish recruitment.

Although mangrove habitats have a vital role are exploited for direct products such as aquaculture, timber production, and firewood and are removed for tourism infrastructure and other uses. For example, mangrove clearance for intensive prawn farming in Asia has reduced the buffering ability andincreased the vulnerability to tsunamis and storms; conservation should understand the relationship between prawns, fish, and mangroves' importance on aquatic ecosystems' at different locations. Moreover, 80-90% of fish caught in South East Asia and Florida, the USA, is associated with mangroves (Rönnbäck 1999; Nagelkerken et al. 2008).

Studies on Tudor creek carried out by Little et al. (1988) and Gazi bay by Kimani et al. (1996), Wakwabi (1999), and Huxham et al. (2004) in Kenya emphasized the importance of mangroves in coastal fisheries. For example, 109 species of fish belonging to 44 families were identified in Gazi bay mangroves, of which 78.5% comprised Atherinidae, Gerreidae, and Clupeidae. Moreover, Huxham et al. (2004) and Mirera et al. (2010) reported while the densities were similar, there was more richness in fish species in forested than un-forested mangrove sites.

Kenya's coastal communities exploit fisheries and mangroves for their livelihoods (ASCLME Project 2011). An estimated amount by UNEP (2011b) to the economic contribution of mangrove fisheries production in Gazi bay, Kenya, is US$ 44/ ha/year. The economic value of the forest of reforested mangroves in Gazi bay was also calculated by Kairo et al. (2009), and their contribution to fisheries production is estimated to be US$113.09/ha/year. However, to the best knowledge, no research has been conducted on estimating the economic value of coastal and mangrove-associated fisheries in Kenya.

The aims of this study are: (i) To determine trends of coastal and mangrove-associated fisheries production in Kwale County over the past 10 years. (ii) To identify mangrove-associated fish species from catch data and their economic value estimation. (iii) Estimate the economic value of coastal fisheries annually in Kwale County. Finally, (iv) Project the future of coastal and mangrove-associated fisheries based on Climate Compatible Development (CCD) and Business As Usual (BAU) scenarios.

MATERIALS AND METHODS

Study area

Geographical location and demographic characteristics

The study area, as shown in Figure1, was located along the Kwale County coastline; Kwale county is on the southern coast of Kenya, neighboring the republic of Tanzania toward the southwest, and the following counties: Kilifi toward thenorth, Mombasa toward the northeast, Taita Taveta toward the west, and the Indian Ocean toward the east. The county covers 8,270.2 km^2 and accounts for 1.42% of Kenya's surface area. The population of this county was 649,931 (49% male and 51% female), with a population density of 79 people per km^2 and a growth rate of 2.6% annually.

Climate

The climate of Kwale County, especially along the Coastal strip, is warm and humid. The county's climate is influenced mainly by two prevailing winds, the South-East Monsoon winds from April to October and North-East Monsoon winds from November to March, which bring changes in temperatures and rainfall. The average annual precipitation along the Kwale County coast lies between 1,000-1,600 mm. The high humidity usually occurs throughout the year, reaching a peak between April-July.

During this decade, the average temperature on the Earth's surface has increased slightly, but Earth's temperature increasing by 1.4-5.8^{0}C is expected during the 21st century. The IPCC's Fourth Assessment Report recognizes the threat climate change poses to the developing world (IPCC 2007). The climate change elements important for Kenya are rainfall (amount and distribution) and temperature (especially the maximum and minimum). The impending climatic change has many possible impacts, including accelerated melting of polar belts glaciers, which can significantly raise sea levels and place many coastal towns and islands such as Lamu, Malindi, Mada Mombasa, and Zanzibar at great risk ofelimination by submergence. The projection from the National Climate Change Response Strategy on the following impacts of climate change on the marine and coastal environment, including Kwale county (Goverment of Kenya 2010). (i) Approximately 4,600 ha or 17% of the land mass in Kenya could be inundated due to a sea level rise of only 0.3 m, thereby affecting coastal development sectors, especially tourism. (ii) Sea rising level will lead to the displacement and submergence of coastal wetlands and result inhigh salinity and accelerated erosion of the shorelines due to the intrusion of saline water into coastal aquifers. (iii) The distribution of mangrove forests will change, particularly for wood/timber products, fisheries, and coastal hazard buffering, thereby jeopardizing the coastal communities' livelihoods that depend on them. (iv) Increased risk of high tides and flooding in lower-lying coastal areas. (v) Coral reef bleaching may increase due to global warming, affecting the coral reef ecosystems, a key tourist attraction.

Coastal fisheries

Kwale County has a coastline that is approximately 110 km long. Coastal fisheries along the coastline are the major source of livelihood for the coastal communities by providing employment, food, and generating income. The coastal fisheries in Kwale county are characterized as less capital intensive, labor intensive, multi-gear and multi-species, and tied to coastal communities and settlements. The locally crafted vessels cannot withstand thedeep rough seas, and the fishing activities are limited to the near shore, approximately 15 km from the county shore. The county has 46 fish landing sites, with limited infrastructure due to remote areas. Only one landing site at Vanga has operational fish storage with a coolingsystem (Republic of Kenya 2012). The tourism industry contributes to the county's economy in the Northern part of Kwale's coastline, where intensive tourism infrastructure is present. In addition, agricultural production that contributes to the county's economy is practiced mainly in the county's hinterlands.

Mangrove ecosystems

Mangrove forests happen along the coastline of Kwale County. These forests border terrestrial forests on the land side and are connected with coral reefs and seagrass beds on the seaside. The county has approximately 6,490 ha of mangrove forests concentrated in four major areas, Gazi, Shimoni, Vanga, and Funzi (Figure 1). All nine mangrove species in Kenya are also found in Kwale county, with Rhizophora mucronata, Avicennia marina, and Ceriops tagal being the dominant species (Huxham et al. 2015). Mangrove forests are of great importance in ecological andeconomic to the county. They are nutrient-rich ecosystems that directly andindirectly support a wide range of food chains, support the coastal fisheries production in the county, and function as habitats and feeding grounds for fish and invertebrates. Mangrove forestsare also exploited for extractive uses such as medicine, timber, and firewood.

Sample Size and Sampling Procedure

A sample of 242 fishermen was randomly selected by first obtaining the list from seven major fishing villages of fishermen in each village from the respective beach management units; Vanga, Funzi, Bodo, Gazi, Majoreni, Shimoni, and Kinondo were interviewed. Then, the fishermen wereinterviewed at the fish landing sites after landing their catch in the afternoon or before they started their fishing expedition in the morning.

Data collection

Primary data

Primary data was generated using a questionnaire survey, focused group discussions, and key informant interviews.

Questionnaire survey

A questionnaire survey was one main tool for information and data gathering. The questionnaire survey (Appendix 1) was divided into three major parts. Part one was on the fishermen's personalinformation to establish their characteristics. Part two engagedfishing-specific questions such as the cost of fishing (labor costs, boat ownership, gear ownership, buying price, and maintenance costs), seasonality, and the third part concerns coastal fisheries management measures (licenses and permits) and opportunities for Climate Compatible Development (CCD). The questionnaire was administered in six fish-landing villages (Vanga, Funzi, Bodo, Gazi, Majoreni, and Kinondo).

Focus group discussion

Furthermore, to collect qualitative data utilizing the focus group discussions by forming groups (7-10 people) consisting of elders, fishermen, and youth to create free discussion with the participants and explore for answers regarding the study's research questions. Finally, for the scenario analysis, scenario panels consisted of experts from stakeholders, including government agencies, local communities, and NGOs, to build storylines for the next 20 years on the coastal fishery sector under both Business as Usual (BAU) and Climate Compatible Development (CCD) scenarios.

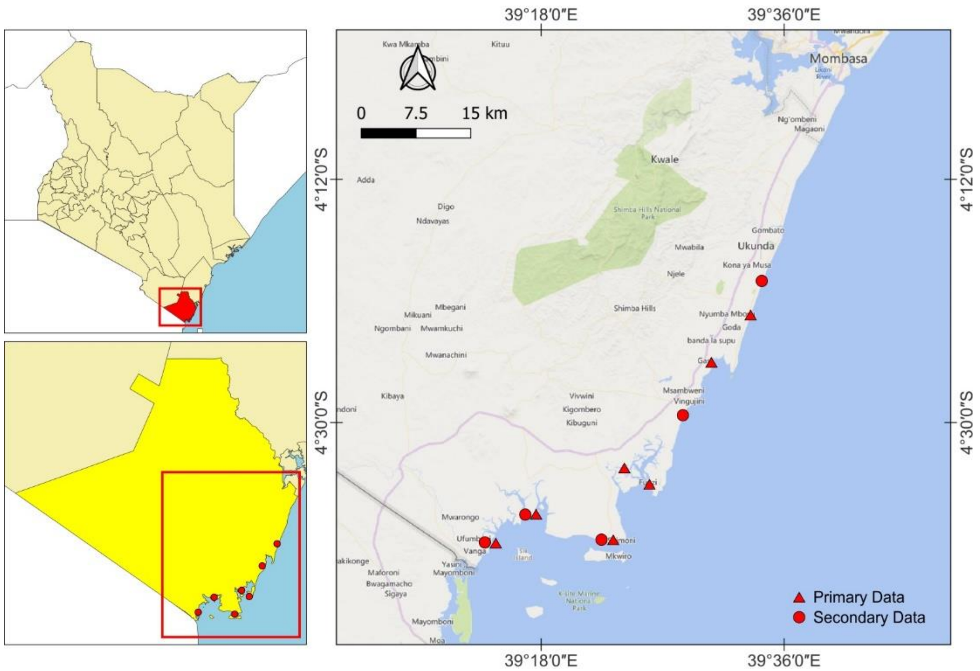

Figure 1. Map of the coastline of Kwale County, Kenya

Key informant interviews

Interviews with key informants were used to collect data from individuals considered to be the village opinion leaders and government officials.

Secondary data

Mostly the secondary data was used in the study obtained from the fisheries department and Kenya Marine and Fisheries Research Institute (KMFRI) . This data was used to construct annual datasets of fish landings, which detail the species of fish landed, the amount of fish landed in kilograms (Kg), and the auctioning pricesof fish in Kenyan shillings (Ksh) at the landing site over 10 years to enable trend analysis. In addition, to identify mangrove-associated species from the catch data, the study also utilized published scientific literature and expert.

Economic valuation methodology

The function of production and market price approaches to economic valuation is commonly used in evaluating coastal and mangrove-associated fisheries; even though they fall under the provisioning category of ecosystem services, a wide range of valuation methods can be applied (Barbier 2000, 2007).

The function of production treats an ecosystem's ecological function or biological resource as an input to the production of marketed output. Therefore, its value is determined by equating it tooutput changes (Barbier 2000). At the same time, applying this method has demanded economic and ecological data requirements. Also, it needs various assumptions, like a Cob-Douglas production function which limits an optimal catch of fisheries model, the elasticities of substitution amonginputs, and long-run competitive equilibrium. Moreover, this approach fails to consider the conceptual problems with biophysical models of ecosystem services and the reality of insufficient data (Parks and Gowdy 2013).

The study uses the market price approach due to the lack of the specific data required for adopting production functions and their inherentcomplexities and suitability to the study's circumstances, e.g., the kind of data available.

Data analysis

Descriptive statistics in average counts were made to determine the coastal fisheries characteristics between sites. Graphical analyses and representation were done in Excel 2007. The estimation model below was used to undertake data analysis and estimate the economic valueof coastal and mangrove-associated fisheries in Kwale County.

Estimation model

$$V = \sum P_{s,y} \times Q_{s,y} - \sum C_{i,y}$$

Fish price ($P_{s,y}$) = market price of fish species *s* in year *y* (Ksh/kg)Fish catch ($Q_{s,y}$) = quantity of fish species *s* in year *y*

Fishing cost ($C_{i,y}$) = Cost of boat + operating costs + cost of gear + labour costs

Where:

Cost of the vessel and gear = $\frac{P_{v,g}}{l_{v,g}+r_{v,g}}$, for boat and gear owners.

$P_{v,g}$ = price of vessel or gear, $l_{v,\,g}$ =life span of vessel or gear in years, $r_{v,g}$ = repairing costs forvessel and gear

The cost of a boat renting was considered for non-boat owners.Operating = fuel used if the motorized.

Cost of gear = the cost of buying or renting gear such as nets.

The estimated profitability of coastal fisheries was the ratio of annual fishing income to annualfishing revenue (Teh et al. 2011).

$$P = \frac{NI}{TR}$$

Where, $NI = TR - TC$

P = profitability, NI = net income per year, TR = total revenue per year, and TC = total cost peryear.

Scenario analysis

The storylines building under the BAU and CCD scenarios and the current management regime of coastal fisheries were first analyzed. Secondly, a scenario panel comprised multidisciplinary experts from institutions, stakeholder organizations, and representatives. The panel comprised government officials (the fisheries department, NEMA, KFS, KMFRI, and CDA), NGO (WWF and wetlands international), academia, and corporate (Base Titanium). Under the guidance of the researcher, the panel identified the drivers and descriptors of change and discussed the scenarios' focal questions. The scenario-building process was based on twoassumptions that were; assumed a continuation of the surrounding coastal fisheries situation of Kwale County under the BAU scenario, while the CCD scenario assumed that major policy shifts are made concerning the management of coastal ecosystems, investing in programs that integrate development with adaptation mechanisms and mitigations. Based on those two scenarios, a storyline was developed on how future coastal fisheries might look under BAUand CCD. This approach follows scenario analysis on the millennium ecosystem assessment methodology (Alcamo et al. 2005).

RESULTS AND DISCUSSION

Demographic characteristics of the respondents

Age and gender

Most respondents were between 25 and 34 years, constituting 31% of the respondents. On the other hand, fishermen below the age of 45 constituted 78% of the respondents. That indicates that most fishermen are youthful, with an average age of 35 years (Figure 2). Regarding gender, 100% of the respondents were male because females do not go on fishing but are engaged in fishing-related activities such as fish processing and marketing.

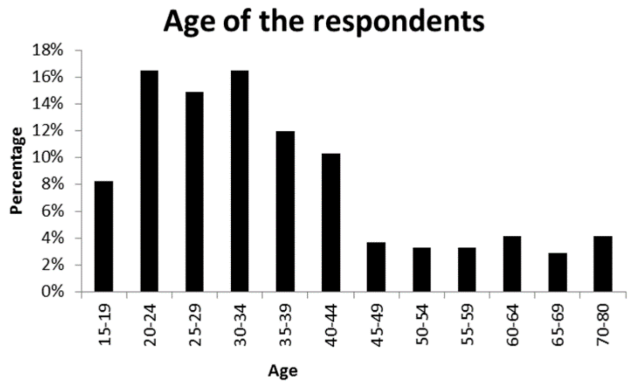

Figure 2. Age of the respondents

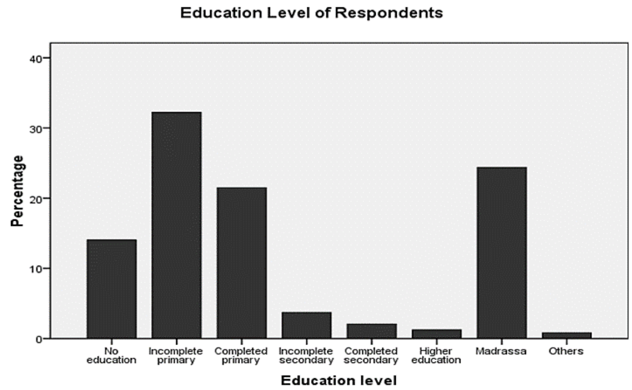

Figure 3. Education level of the respondents

Education and occupation

Primary school dropouts comprised 32.2% of the respondents; 21.5% completed primary school, while 14% had no education. The combined percentage of fishermen with incompleteprimary and complete primary school and no education comprised 68% of the respondents. Secondary school dropouts comprised 4%, and only 2% of the respondents completed secondary school. About 24% attended madrassa schools since most fishermen in Kwale County are Muslims by religion (Figure 3).

From the above discussion, in Kwale County, the level of education among the fishermen can be concluded to be low. That is because the number of schools in the coastal areas is less, and there is a slight motivation for higher education amongst fishing communities as there are only a few higher graduates to motivate younger generations. In addition, that is because of other competing livelihood activities, such as fishing, selling, and farming, that youth get engaged in to support theirfamilies.

Regarding occupation, 85% of respondents reported fishing as their mainstay occupation. In comparison, 15% stated that fishing was a part-time job and engaged in other sources of livelihood,such as farming and business (Figure 4). Furthermore, very few individuals are employed in the civil service due to the low level of formal education.

Vessel and gear types

The exploitation of coastal fisheries in Kwale county by multiple vessels and gears is used. Although locallycrafted dugouts/canoes are the type of vessels most commonly used (61%), it was also found that 20% of the interviewees do not own vessels but rather walk to the sea and fish by diving and swimming (Figure 5). The coastal fishermen use several gears to catch fish from the water;hand lines make up 28% of the gears used, then spear guns (15%) and gill nets (13%) (Figure 6). The survey data shows that the number of respondents who uses illegal fishing gear is 23%(beach sien, spear gun, and monofilament net).

The trend of coastal fisheries

The Kwale County annual production of coastal fisheries from 2004 to 2013 generally exhibited an increasing trend with time, although various. For example, production increased from 1,908 tons in 2004 to 2,450 tons in 2013, reaching its peak in 2009 at 2,530 tons. The price of catch and revenue generated similarly has shown a consistently increasing trend in the past decade, reaching a maximum revenue generation of about Ksh.260 million in2013 (Figure 7).

The total production in 2013 contributed by demersal fish contributed 48%, then by Pelagic fish and Molluscs,26% and 11%, respectively. On seasonality, the lowest production was recorded between April and August (Figure 8).

The economic value of mangrove-associated coastal fisheries

The study identified 14 species of data fish caught in Kwale County associated with mangrove habitats at least during one life cycle stage. In addition, published scientific studies were utilized to identify mangrove-associated fisheries. As a result, mangrove-associated fisheries accounted for 1,036.7 tonnes (42.3%) of the total catch in 2013 and amounted to Ksh.107.8 million (41.5%) of the total revenue from coastal fisheries (Table 1). KwaleCounty has approximately 6,490 hectares of mangrove forests, estimated to contribute close to 160 Kg/ha/year of coastal fishery production and an amount of Ksh.16,610/ha/year in incomegeneration.

The economic value of coastal fisheries

In the base year of the study of 2013, a total fish catch of 2,450.773 tons was recorded in Kwale County, generating estimated revenues of about Ksh.260 million (Ksh.106,091/ton). Furthermore, the cost of fishing operations was estimated to determine the economic values of coastal fisheries (total revenue generated less the total cost of fishing). As a result, Kwale county's annual fishing cost was estimated at Ksh.78 million. The fishing cost comprises the annual average cost of fishing vessels, operating cost, labor cost, and the average cost of fishing gear. The opportunity cost of labor forms the largest component of fishing at Ksh.52 million (67%). Moreover, considering the depreciation cost of fishing vessels and gears, the estimated annual average cost was Ksh.13 million (17%) and Ksh.8 million (10%) of the total cost, respectively. Operating costs, including fuel, constitute the remaining Ksh. 5 million (7%) of the total fishing cost. Therefore, the economic value of coastal fisheries is the total estimated fishing revenue, less the cost associated within, at Ksh.182 million in 2013. This net income hadan average profit margin of 0.7 annually.

Coastal fishery scenarios under Business As Usual (BAU) and Climate Compatible Development (CCD) scenario

Business As Usual (BAU) scenario

The data were analyzed on the current management measuressurrounding coastal fisheries and their enforcement from the survey questionnaire under the BAU scenario. In addition, a scenario panel consisting of multidisciplinary experts from institutions, stakeholder organizations, and representatives identifies the future change drivers that could affect coastal fisheries.

Management measures

This section analyzed the current management issues measures of coastal fisheries, such as licensing, illegal fishing, and changes in catch sizes with time, to provide baseline information for scenario analysis.

Fishing license

The fisheries act regulates the operations of coastal fisheries and mandates fishing permits for fishermen and licensing of vessels and boats (Cap 387). However, among the interviewed fishermen, 51% had neither fishing permits nor boat licenses, 6% owned boatlicenses, 27% had fishing permits, and 16% had both fishing permits and boat licenses (Figure 9).

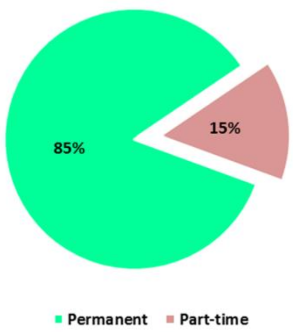

Figure 4. Basis of fishing occupation

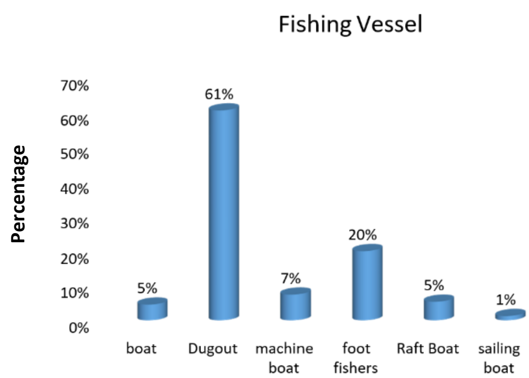

Figure 5. Type of fishing vessel used

Illegal fishing gears

On the occurrence of illegal fishing gear, 47% of the respondents reported using illegal fishinggear, using illegal fishing nets (22%), and dynamite fishing (17%) (Figure 10). Moreover, it was discovered from the FGD and key informant interviews that sometimes the locals/villagerstip off fishermen engaged on impending patrols of law enforcement agencies in illegal fishing. It was also found that to evade law enforcement officers or BMU, the catch from using outlawed gears was not landed at the official landing sites.

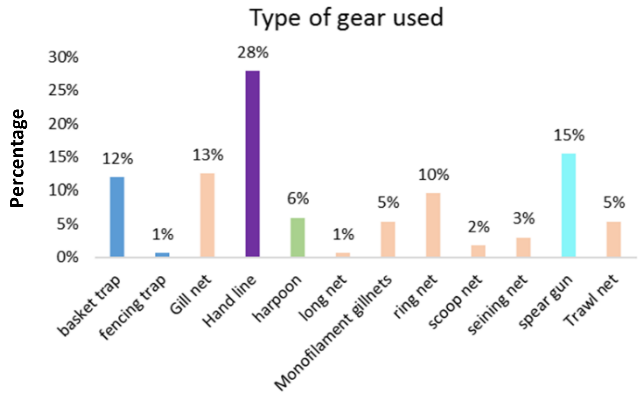

Figure 6. Type of fishing gear used

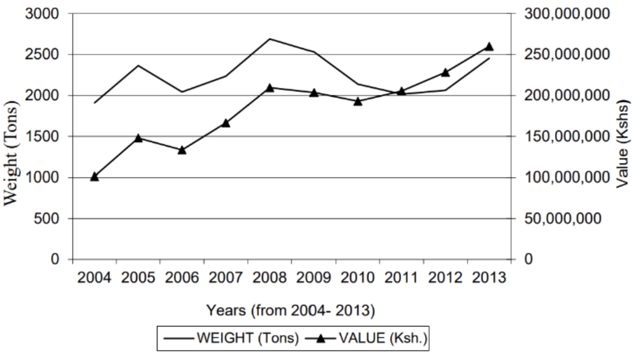

Figure 7. The trend of fish production in Kwale County, Kenya (2004-2013)

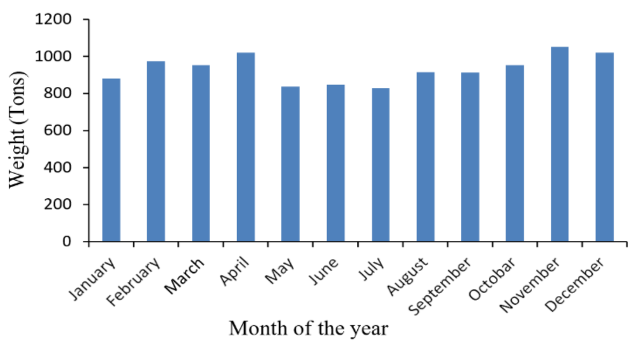

Figure 8. Average monthly production of coastal fisheries from 2005-2013

Table 1. Mangrove-associated fish species in Kwale County, Kenya

		Mangrove-associated species				Total catch landings			
English name	**Family name**	**Mangrove-associated species**	**Ref.**	**% of total catch**	**% of total revenue**	**Weight (Kg)**	**Revenue (Ksh)**	**% catch of total catch**	**% of total revenue**
Dermasals									
Rabbitfish	Siganidae	M	1,4	6.4	7.7	157971	19965860	6.4	7.7
Scavengers	Lethrinidae	M	1,2,4	5.2	5.7	127058	14703370	5.2	5.7
Snappers	Lutjanidae	M	1,2,3,4	3.7	3.8	91271	9923450	3.7	3.8
Parrot fish	Scaridae	M	1,3,4	5.7	5.1	138953	13299830	5.7	5.1
Surgeon	Acanthuridae	M	1, 3	2.6	2.2	64092	5773120	2.6	2.2
Unicorn	*Naso brevirosyris*					59230	5105080	2.4	2.0
Grunter	Haemulidae	M	1, 3	0.8	0.7	20269	1897420	0.8	0.7
Pouter	*Cephalopholis argus*					70526	6296470	2.9	2.4
Black skin	*Gaterin sordidus*					104660	10487610	4.3	4.0
Goatfish	Mulidae	M	1,2	1.5	1.7	36059	4317710	1.5	1.7
Streaker	*Aprion virescens*					34084	3130040	1.4	1.2
Rock cod	Serranidae					71467	7579850	2.9	2.9
Catfish	Aridae					40499	3881280	1.7	1.5
Mixed dem.						152617	14344910	6.2	5.5
Sub-total						1168756	120706000	47.7	46.5
Pelagics									
Cavalla.j.	*Euthynnus pelamis*					40259	4924990	1.6	1.9
Mullets	Mugulidae	M	1,2	3.1	2.8	75602	7370520	3.1	2.8
Mackerel	*Kanaguta*					118355	11396070	4.8	4.4
Barracuda	Sphyranidae	M	1,2,3,4	3.5	3.3	86646	8493780	3.5	3.3
Milkfish	Chanidae	M	1,2,4	1.3	1.2	32330	3115640	1.3	1.2
Kingfish	Scombridae	M	1	1.0	1.2	23664	3222310	1.0	1.2
Queenfish	*Chorinemustol*					17229	1842090	0.7	0.7
Sailfish	Istiophoridae					5660	800480	0.2	0.3
Bonito/tuna	Arangidae					69602	7022840	2.8	2.7
Dolphinfish	Colyphaenidae					12817	1378860	0.5	0.5
Mixed pel.						154307	16900410	6.3	6.5
Sub-total						636471	66467990	26.0	25.6
Sharks/rays	*Carcharhinidae* /others					50815	4392440	2.1	1.7
Sardines	*Clupeidae*	M	1,2	4.7	2.3	116212	5981200	4.7	2.3
Mixed/others						101887	7626865	4.2	2.9
Sub-total						268914	18000505	11.0	6.9
Crustacea									
Lobsters	*Penulirus* spp.					17581	10705350	0.7	4.1
Prawns	*Paenus* spp.	M	5	0.9	1.5	21664	3801400	0.9	1.5
Crabs	Scyllaridae	M	5	1.9	2.3	45406	6001865	1.9	2.3
Sub-total						84651	20508615	3.5	7.9
Miscellaneous									
Bech-de-mer	Holothuroidae					8796	1340110	0.4	0.5
Octopus	*Vugaris* spp.					181334	19967560	7.4	7.7
Squids	*Sepia oligo*					101851	12799370	4.2	4.9
Sub-total						291981	34107040	11.9	13.1
Grand-total				42.3	41.5	2450773	259790150	100.0	100.0

Note: M-Mangrove-associated species; 1. Kimani et al. (1996), 2. Huxham et al. (2004), 3. Lugendo et al. (2007), 4. Crona and Rönnbäck (2007), 5. Huxum (2013)

Changes in catch size

The coastal fisheries' catch size depends on several variables, including time spent fishing, seasonality, and the type of fishing gear and vessel employed. While holding these variables constant, 19% of the interviewed fishermen said there was no change, while 77% reported a change in average catch size as it was in the past 10 years (Figure 11). The respondents who reported the change in catch size (49%) mostly believe that declining fish catch is attributed to climate change and its extreme weather conditions. The focus group discussions also confirmed the decline incatch per fisherman. From interviews with key informants, some fishermen are employing multiple gears and increasing the effort by spending more time at sea while others get engaged in part-time jobs to maintain the fish catch.

Drivers of change

The direct and indirect drivers of change were identified for the scenarios analysis to be plausible and their likely consequences under businesses as usual and climate-compatible development scenarios.

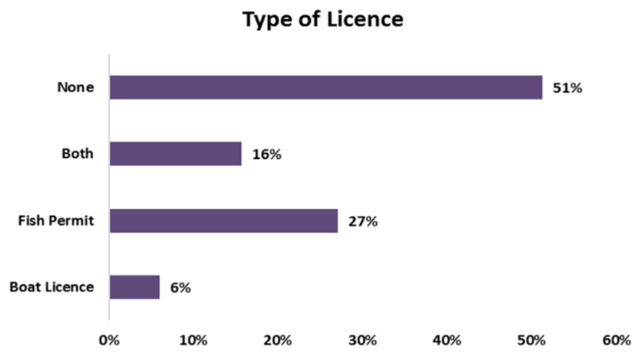

Figure 9. Type of license owned

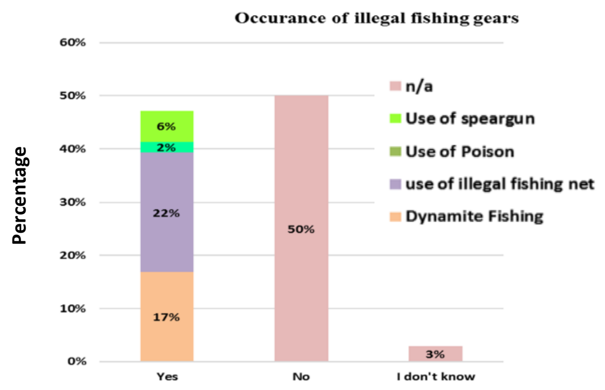

Figure 10. Occurrence of illegal fishing gears

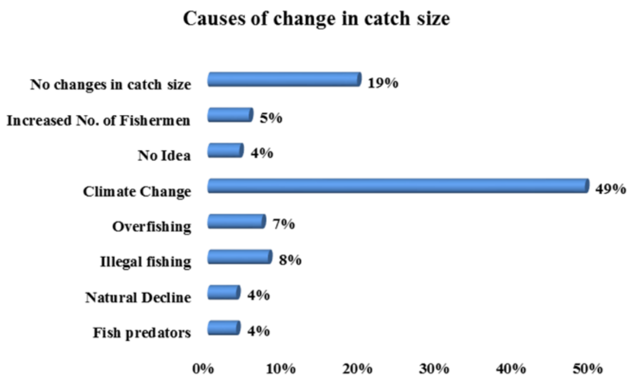

Figure 11. Causes of change in catch size

The scenario panel categorized the direct drivers of changes as positive, neutral, and negative. The positive drivers include restoration and ecosystem conservation (e.g., creation of Locally Managed Marine Areas (LMMA), Marine Protected Areas (MPA), and restoration of mangrove habitats), sustainable resource management, and adoption of environmentally sound technologies. Land use change in coastal areas was identified as a neutral driver, which could have negative or positive impacts depending on thecontext. The negative drivers include habitat destruction (coral reefs, mangroves, and seagrasses), pollution, and overfishing.

The indirect drivers in the context of coastal fisheries were identified as population dynamics, climate change, policy instruments, unsustainable inland and offshore development, and technological innovations. Among the indirect drivers, climate change was identified as the most serious impact it would have on the sustainability of coastal fisheries and their.

Climate Compatible Development (CCD) scenario

The scenario panel projected that under Climate Compatible Development, assuming that major policy shifts are made concerning coastal fisheries management in the 20 years to come. The organ of the Kenyan government that are concerned with environmental development and protection, such as the National Environment Management Agency (NEMA), Kenya Forestry Service (KFS), Fisheries Department, and Kenya Wildlife Service (KWS), will achieve well-coordinated and integrated working practices that will strengthen law enforcement and policy implementation. That will lead to the thorough application of the existing progressive laws, which will encourage and strengthen the existing community-based organizations and the growth of new community-based groups, including Community-Based Organizations(CBO), Community Forest Associations (CFA), and Beach Management Units (BMU). Furthermore, it will promote control of resources and community ownership, especially in fisheries and forestry, and this will further help address inequality and poverty.

The scenario panel further envisioned that the negative effects surrounding coastal fisheries would be addressed in the CCD scenario by adopting development strategies coupled with adaptation and mitigation mechanisms. Adaptation measures include climate-proofing infrastructure, ecosystem adaptation adoption, capacity building, and disaster preparedness. In contrast, mitigation measures would entail better designing cooling storages to reduce energy consumption, technical innovations to reduce fossil fuel use, and protecting and restoring mangrove ecosystems. Those declining temperatures will initially suffer sensitive species from the impacts of climate change, like coastal fisheries. These effects will be addressed through rehabilitating and conservating important habitats, including mangroves and coral reefs, and establishing locally managed marine areas and new marine protected areas. BMUs have become more effective in avoiding overfishing and enforcing appropriate fishing methods through effort-based management systems. The value of the catch will increase through improved fish processing, marketing and value addition chains, new storage and freezing facilities, and increased fish demand. The Kenyans would encourage deep-sea commercial fishing to tackle illegal offshore fishing and create new employment opportunities. The production of aquaculture in theregion doubles under the CCD scenario.

Discussion

The trend of coastal fisheries

The fisheries production increasing trend could be attributed to increasing fishing efforts, which concurs with the findings of Ochiewo (2004) and the Republic of Kenya (2012), who reported on the fishing effort that has been increasing with time, fishing gear, fishing vessels, and the number of fishermen, over time in Kwale County. The increase in fishing efforts is due to the increasing population growth, fish demand, and limited other sources of livelihood.

As shown in (Figure 2), the study has established that the production of fish is high between September and March and low in April and August. That aligns with the findings of Ochiewo (2004) and Benards (2010), who established that seasonal variations of the monsoon winds influenced fishing activities. For example, during the North-eastern (NE) monsoon blows from September to March, fishing activities are intensive due to the calm sea. On the other hand, during the Southeastern (SE)monsoon, this blows between April and August; the sea is rough in this period, and fishing activities are low due to their artisanal vessels cannot resist the rough sea. In the Northeastern season, migratory fishermen from Tanzania with better expertise, fishing vessels, and gears contribute to higher fish production this season.

Mangrove ecosystems and their contribution to coastal fisheries production

The mangroves' contribution to the value of fisheries production depends on many factors, site characteristics, climate variability, the species under consideration, and the presence of predatory competitors and their abundance among them (Faunce and Serafy 2006; Aburto-Oropeza et al. 2008). Nevertheless, the results on mangroves' contribution to the Kwale County coastal fishery production indicate that mangroves are critical to fishery production in the county. For example, in 2013, mangrove ecosystems were associated with 42.3% of the total fish catch and the total revenue at 41.55. In other words, mangroves are attributed to fish production of 160 Kg/ha/year with a value of Ksh. 16610/ha/year (US$ 198/ha/year).

The revenue of mangrove contribution to fisheries production is consistent with Kapetsky (1989), who estimated that the average fin and shellfish production to about 90 kg/ha/year with a maximum yield of 225 kg/ha/year in mangrove areas. However, the calculated results in both catch and value are higher than those estimated by Kairo et al. (2009) and UNEP (2011a,b), managed in Gazi bay, Kenya. For example, Kairo et al. (2009) that estimated the catch of mangrove-associated fin fish to be 94.62 kg/ha/year and a net income of US$ 113.09/ha/year; at the same time, UNEP (2011a,b) calculated the value of fish production on mangroves to be US$ 44/ha/year. This study estimated the higher value of the mangrove contribution to fisheries production could be explained by the spatial coverage of the study and the extensive data compiled that was not used in the previous studies.

Since the fisheries data records are not usually captured, the value within the mangrove forests (on-site) fisheries to the value of mangroves associated with fisheries production could be much higher than estimated. On-site fisheries are also composed of the harvest of resident species, such as the capture of prawns and fish that use mangroves for feeding duringhigh tide and mangrove crabs and oysters, which are harvested for subsistence across the coast of Kenya (Bosire et al. 2012) using hand lines, fence traps, and a range of other gears (Samoilys et al. 2011).

The economic value of coastal fisheries

These findings indicate that the livelihoods and welfare of coastal communities in Kenya are critically related to coastal fisheries. For example, in Kwale County, among the main sources of income generation are coastal fisheries that provide food security through fish consumption and using income derived from buying other stable food such as maize flour. They also support smaller industries such as boat repair and making, tourism, and transport along the coastal villages.

The coastal fishery production in 2013 amounted to Ksh.182 million or (US$ 2.2 million) which is lower than the value estimated by Barnes-Mauthe et al. (2013). They calculated the value of small-scale fisheries in Velodriake, Madagascar, to be US$ 6.9 million, which couldbe because some species with high prices (sea cucumber and Octopus) of the production of small-scale fisheriesare exported to developed countries. The Kwale County coastal fisheries value is higher than that of small-scale fisheries in Navakavu, Fiji, estimated at US$ 790,226 annually by O'Garra (2012). Moreover, the coastal fisheries value compared to thecalculated could be higher because there are unrecorded catch data, constituting 20% of fishermen that are landed in smaller landing sites or caught by foot fishers (Republic of Kenya 2012).

The average profitability ratio calculated (0.7) in Kwale County shows that coastal fisheries are highly profitable and could be a poverty buffer for coastal communities. That aligns with Barnes-Mauthe et al. (2013), who reported an average profitability ratio of (0.87), for small-scale fisheries in Velondriake, Madagascar. In addition, Teh et al. (2011) also found in Sabah, Malaysia, that small-scale fisheries play a significant role in preventing poverty in those coastal communities. Furthermore, Béné et al. (2007) also hypothesized the coastal fisheries importance in poverty prevention which play a major role in coastal zones to food securityand poverty prevention.

Business As Usual (BAU) and Climate Compatible Development (CCD) scenarios

The analysis of the current management regime reveals their weak enforcement even though policies and regulatory frameworks exist. This weak regulation enforcement could beattributed to poor infrastructure in many of the remote fish landing sites, poor financing of the enforcement agencies, and a shortage of monitoring and surveillance equipment. The currently prevailing weak enforcement regime, if not addressed, would result in the longer-term depletion of the stock of coastal fisheries.

The projected climate changes are also expected to affect coastal fisheries and their habitats adversely. Changes in temperature and salinity will affect oceanographic processes such as ocean acidification and upwelling, resulting in coastal fisheries' vulnerability in terms of fish catch and diversity. Climatic factors such as rising sea levels, increasing water temperature, and storms will negatively affect the coastal ecosystems' productive capacity, such as mangroves, sea grasses, and coral reefs, affecting coastal populations' livelihoods. The expected fishing days are to be reduced by bad weather, damaging fishing vessels and gear.

Stockholm Environment Institute (2009) assessed the impact of sea level rise in conjunction withthree IPCC socio-economic scenarios in Kenya that describe population density and growth as well as future GDP (A1FI, A1B, and B1) (Figure 12). The analysis shows that coastal inundation due to rising sea levels would affect people between 10,000 to 86,000 in coastal areas and reduce the area of coastal wetlands such as mangrove forests, coastal forests, and salt marshes. The study further estimated the associated economic costs of $7-58 million annually if adaptation measures are not taken by 2030.

In the Business As Usual (BAU) scenario, no changes will be introduced, and the direct and indirect drivers will behave as they are currently. However, the current population growth, doubled with the limitedother sources of livelihood, will further increase fishing efforts excreted on coastal fisheries and may result in the depletion of the resources. For example, the projection of mangrove loss from 1992 - 2010 was 13.5 %to the 20 years to come; with the BAU scenario 43%, the mangrove cover in Kwale County will be lost by 2032 (Huxham et al. 2015). Furthermore, this mangrove loss will negatively affect the other adjacent fish habitats, seagrasses, and coral reefs throughsedimentation.

Under the country's vision 2030 framework, the proposed development projects in Kwale county, which include bio-fuel projects, sugarcane farming, the construction of a resort city, and the ongoing project on titanium mining, are envisioned to have environmental and social impacts. Under the poor law enforcement regime in the BAUscenario, these projects could lead to the loss of fishing grounds, the degradation of coastalecosystems, and pollution.

The effects combined of the weak enforcement regime, direct and indirect impacts and environmentally insensitive development projects threaten the sustainability of coastal fisheries under the BAU scenario through habitat degradation, overfishing, and reduced fish diversity and catch, which then undermines the coastal fisheries' importance to the welfare of coastal communities.

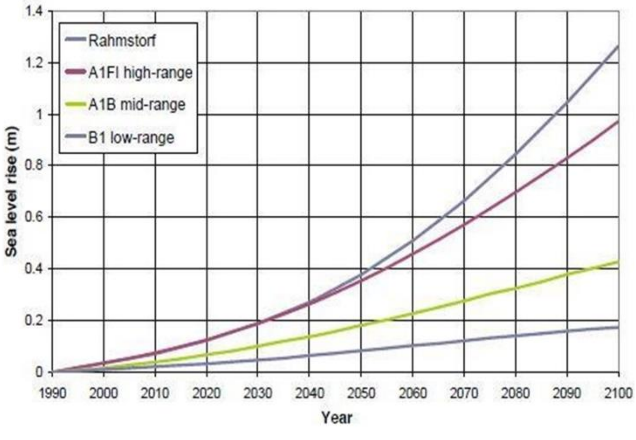

Figure 12. Sea level rise scenario

The stakeholders participating in the scenario-building exercise believed that regulations governing environmental matters and the current policies could contribute to realizing CCD. In the context of coastal fisheries, identifying and achieving the combination of mitigation, adaptation, and development (triple wins) are straightforward. Investments in adaptation measures, such as disaster risk reduction, improved infrastructure, capacity building, and mitigation measures, such as harnessing clean energy in cooling storages and protection and restoration of mangroves, would address to create of alternative sources of employment and the adverse impacts of climatechange. Furthermore, their sustainable utilization and conservation would foster economic development in coastal areas beyond coastal fisheries and contribute to the coastal communities' livelihoods.

Moreover, under both BAU and CCD scenarios, projections will, directly and indirectly, affect coastal fisheries catch and revenue. For example, under the BAU scenario, it is anticipated that within 20 years, mangrove forests will decline by 43% as an essential fishery habitat. An assumption on the corresponding loss in catch and revenue of the mangrove-associated finfish and crustaceans species will result in a loss of 446 tonnes in catch and Ksh.46 million in revenue annually. On the other hand, in the CCD scenario, the catch and revenue of mangrove-associated fisheries are expected to increase through the expansion and rehabilitation of mangrove forests.

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