Regional Studies in Marine Science 44 (2021) 101706

Contents lists available at ScienceDirect

Regional Studies in Marine Science

journal homepage: www.elsevier.com/locate/rsma

Socio-economic prospects and problems in under-exploited offshore marine fisheries: The case of Fish Aggregating Devices (FADs) in Kenya coastal fisheries

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ARTICLE INFO

Article history:
Received 15 August 2019
Received in revised form 29 March 2020
Accepted 22 February 2021
Available online 2 March 2021

Keywords:
Western Indian Ocean (WIO)
Kenya coast
Marine fishing
Fish Aggregation Devices (FADs)

ABSTRACT

Existing fishing methods and traditional vessels used by artisanal fishers in Kenya coast confine them to overfished sheltered reef areas and are not efficient enough to harvest a scattered resource. Fish Aggregation Devices (FADs) have been proposed as a new technological frontier with better prospects for capture of high valued fish species like tuna, thus improving income to coastal fishers. However, the reception of this technology by artisanal fishers has not been assessed in spite of implementation of various experimental FADs projects in the region. This study provides socio-economics insights with which to view the current status of Kenya's FADs fishery. Survey data was collected through a combination of questionnaires and participant observations. Results reveal that fishing activities are still undertaken within the shallow protected waters of the barrier reef by artisans who operate small non-mechanized crafts. Fishing time is still relatively high (7hrs/day) even though the most prevalent gear is the traditional basket trap (43%). The modal daily income for fishers averaged at KES 400 (∼US$3.9). Only 13% of the fishers were adequately aware of FADs, among whom, FAD fishers who had been engaged in previous experimental projects rated FADs as highly effective (72%). The shortcomings of FADs included: increase in theft and vandalism of equipment (50%), attraction of illegal fishers (25%), and fisher–fisher conflicts due to little sensitization. Overall, fishers viewed FADs projects as unsustainable, since the required expertise is scarce while the equipment is expensive. We recommend the need for development of a user-right friendly approach to communal fishing offered by the FADs framework, and the fabrication of these FADs from locally available materials in order to enable fishers and local industry to run and advance the technology.

1. Introduction

As the international community grapples with the challenges of a changing climate, one of the most pressing issues is food scarcity caused by fish shortages (Sealite, 2015). The 2007–2008 world food crisis and the food riots that erupted in at least 14 countries in Africa during that time, taught us that the consequences of food crises can be high in terms of political stability and economic development.

World total marine catch was 79.3 million tons in 2016, representing a decrease of almost 2 million tons from 2015 (FAO, 2018a). Fisheries are important for food, nutrition and employment of 10% of the global population within Africa, many of whom struggle to maintain livelihoods (Bennett et al., 2018). Marine and coastal fisheries in sub-Saharan Africa are largely characterized by crowded near-shore fisheries with non-motorized traditional fishing vessels which cannot efficiently explore and exploit off-shore fisheries, thus limiting their effective competition in global industrial fisheries (Mamauag et al., 2013). For instance, one anecdotal joke concerning off-shore Somali fisheries in the Western Indian Ocean (WIO) is that, *"With one out of every seven Somali children dying before their fifth birth day, Somalia is the only country where people are dying of malnutrition whereas fish are dying of old age"*.

Many developing countries are largely characterized by low levels of technological capacities contrary to their enormous

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https://doi.org/10.1016/j.rsma.2021.101706
2352-4855/

endowment with natural resources (Cirera and William, 2017). In spite of dwindling marine fish catches worldwide, there are prospects for increasing fish landings in Africa's coastal fisheries by enabling small-scale fishers to adapt new fishing technologies that can increase their catch by exploiting previously unexploited or under-exploited fisheries off-shore (Tim et al., 2018). Off-shore pelagic species like tuna and tuna-like species are the most highly valued fish in the international market compared to demersal fish catches that dominate near shore fishing areas — which are already subject to depletion from Malthusian overfishing (Jentoft et al., 1998; Hauck and Sowman, 2001; Ronaldo and Coleen, 2007). Tuna contributes about US$ 42 billion in end value to the global economy each year, making it the world's most valuable fish (Pew et al., 2016).

Kenya has a 640 km coastline with an Exclusive Economic Zone (EEZ) of 230,000 km^2 and an extended continental shelf of 103,320 km^2 UNCLOS (1982). The Kenyan coastal waters lie within the upwelling region of the Indian Ocean, thus locating Kenya marine fisheries within the richest tuna belt of the South Western Indian Ocean (SWIO) where 25% of the world's tuna are caught (GES, 1997; WWF, 2014; Luc van and Nathalie, 2017). Whereas available data indicates that in 2014, the Western Indian Ocean (WIO) region (in which Kenyan coastal fisheries lie) produced about 902,203 tons of tuna species worth US$ 6.5 billion, Kenya marine fisheries produced only 0.023% (212 tons) of the tuna catches in spite of its strategic location (Macfadyen, 2016a; Macfadyen et al., 2016b; IOTC, 2018). This is because Kenya marine fisheries is mostly (80%) small-scale artisanal operating in the coastal near-shores (Ikiara, 1999; McClanahan and Mangi, 2004); with traditional fishing gears and methods that are not efficient enough to harvest a scattered resource (Samoilys et al., 2011). Prevailing landed catches are relatively very low in Kenya's coastal fisheries at an aggregate of 9000 tons against an estimated fishery potential of 150,000–300,000 tons off-shore (KNBS, 2017; WWF, 2014; Okemwa, 2018). This fishery potential is far much greater that the national annual fish landings in Kenya which amount to about 130,000 metric tons; 93% of which originate from fresh water sources. In addition, the high valued tuna and tuna like species found within Kenya's EEZ can be commercially exploited to improve fisheries contribution to Kenya's GDP which now stands at only 0.5%. Global tuna prices averaged at US$ 3.55 (Range US$1.55–8.28) in first two quarters of 2018, implying that if off-shore tuna and tuna like species are efficiently exploited in Kenya, the nation could earn additional US$532 million against the current annual national fisheries earnings of US$185 million (FAO, 2018b). Currently though, out of Kenya's total coastal fish landings, about 1000 tons comprise of off-shore pelagic species, with 32% (322 tons) being high valued tunas (IOTC, 2018). This implies that Kenya is harvesting only 0.3%–0.7% of its offshore fisheries potential.

Tuna species show a natural behavioural tendency to associate to floating objects, probably as meeting points, a spatial reference point or feeding points (Bromhead et al., 2002). Artisanal fishermen have exploited this tendency since the 17th Century by constructing artificial floating objects to attract and aggregate these fish for easier capture (Mitchel de and Allain, 1998). Of late, several oceanic purse seine fleets have also capitalized on the efficiency of this method, thereby deploying modern Fish Aggregating Devices (FADs) at sea in order help in targeting tunas (Morgan, 2011). This study assessed the viability FADs fishery as one of the alternative fishing technologies for Kenya marine artisanal fishers to improve livelihood outcomes through exploitation of high valued tuna and tuna-like species.

A FAD is any method, object or construction used for facilitating the harvesting of fish by attracting and thus aggregating them (Bergstrom, 1983; Sasikumar et al., 2015). FADs would benefit Kenyan coastal fishers through aggregation of high valued pelagic species like tuna and reducing fish search time, fuel consumption and fishing pressure on inshore and offshore bottom-fish resources (Mbaru, 2012). Therefore, FADs are expected to result into positive social and economic benefits for Kenya through increased marine fish catches, better monetary value for fish and production of relatively higher Catches Per Unit Effort (CPUEs) for fishers (Alexandra, 2016; IPNLF, 2016). However, FADs could also aggregate juvenile tunas and by-catch thereby contributing to overfishing risks (Gilman, 2011; Morgan, 2011; Bailey and Sumaila, 2018).

FADs have been successfully used in South-East Asia, Western Pacific and Indian Ocean countries (David et al., 2004; Beverly et al., 2012; Marc, 2013). Within the South West Indian Ocean (SWIO) region, some countries are either in the process of conducting trials on FADs or have fully developed FADs fisheries (Laurent et al., 2013; Senedhun, 2013). At the moment, the concept of FADs is not completely new in Kenya coast (Mbaru et al., 2018). Artificial FADs were initiated in Kenya during the South-West Indian Ocean Fisheries Project (SWIOFP, 2005–2011), whose objective was to identify and study exploitable offshore fish stocks within the project area (Mozambique, Madagascar, Comoros, Kenya, Tanzania, and South Africa). The FADs project under SWIOFP was largely experimental. In, the Kenya Coastal Development Project (KCDP, 2011–2017) purposed to build on the lessons learnt from SWIOFP's experiments towards developing a viable FADs fishery in Kenya coast. Whereas fabrication and deployment of deep water and subsurface FADs and participatory mapping with fishers near FAD areas were achieved, KCDP gained very minimal success with regards to adoption of FADs fishery by Kenyan coastal artisanal fishermen.

This study therefore provides socio-economics insights on the Kenyan FADs fishery, with respect to prospects and challenges in its uptake by the coastal artisanal fishers.

2. Materials and methods

2.1. Study area

The Diani-Chale channel (04°.44′–04°.22′S and 39°.54′–39°.61′E), where the primary data was collected, lies on the South of Kenya's 640 km long coastline. The specific fish landing sites where field data was collected were Mwaembe, Munje, Mkunguni and Shimoni (see Fig. 1). Fishing in the study area is mainly artisanal small-scale using paddled dug-out canoes which are concentrated within an area of 10 nm from the shore. This study area was chosen mainly because previous projects like the SWIOFP and KCDP had introduced artificial trial FADs to fishers in these areas. Under KCDP, the trial FADs were assembled at Mwaembe and deployed jointly with the fishermen in the adjacent offshore sites.

Mkunguni landing site is well served with feeder roads leading to Msambweni town, which serves as a ready market for fresh and value added fish. Munje is densely covered by vegetation with a small opening which fishers use to access the landing site. This site has no permanent structures and the beach space is open to the sea with a relatively distant reef, hence tides are relatively stronger in this site. Shimoni is a relatively large landing site situated at Shimoni village centre. It houses a spacious and fully functional fish banda with Beach Management Unit (BMU) offices, fish weighing scales and freezers. This landing site is protected from the open sea by the Wasini Island which is fringed with mangroves and is famed for offering good fishing conditions due to its close proximity to the Kisite — Mpunguti Marine Protected Area (MPA). Fishers of Shimoni are very diverse in terms of origin and gears. Due to its relative richness in fish catches, Shimoni attracts many other coastal fishermen in Kenya and Tanzania (especially fishermen from Pemba and Tanga).

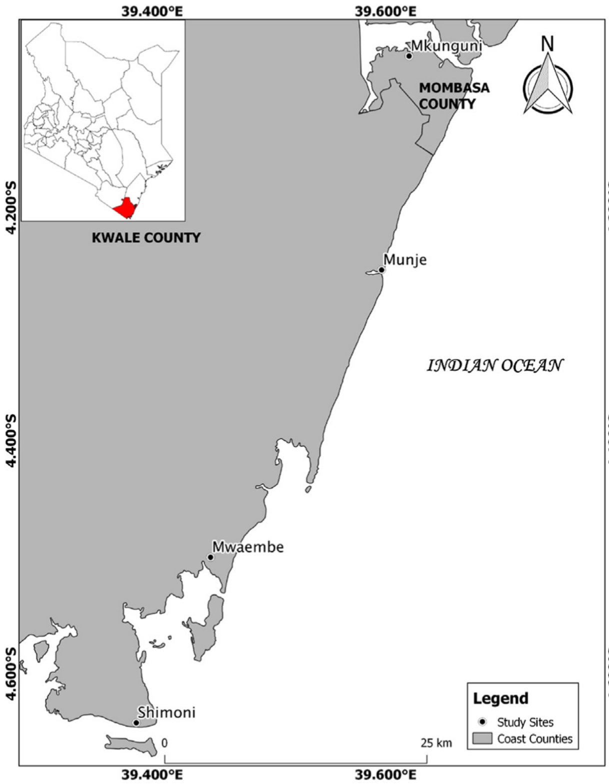

Fig. 1. Map of Kenya Coast showing the study area.

2.2. Data collection and analyses

Primary field survey data was collected from December 2015 to January 2016 on the perceptions of artisanal Kenya coastal fishers with regards to adoption FADs fishery in Kenya Coast. This study also used three secondary data sets: Kenya Marine Fisheries Frame Survey 2016 (KMFFS, 2016), KMFRI Catch Assessment Survey 2016 (KMFRI CAS), and IOTC Nominal Catches Database (IOTC-2018-DATASETS-NCDB.xls at www.iotc.org/data/datasets) in order to establish the status of Kenya marine fisheries and historical trends and prospects from tuna and tuna-like species in the Indian Ocean. The primary data was mainly sourced through a semi-structured fisher's specific questionnaire and direct observation techniques. Interviews were mostly carried out at the sites where the fishers landed their catch. Field guides were engaged by the research team in each site to identify artisanal fishers who explored off-shore pelagic fisheries like the long liners. Specific open-ended questions in the interview sheets enabled the enumerators to probe answers, follow-up original questions and to pursue new lines of questions. Periodically, the research team convened during data collection to discuss any emerging grey areas and to compare and harmonize any challenges in the questioning format. Direct observation (overt and covert) was important in assessing activities (watch and record events) as they occurred in the study surrounding thus enabling the researchers to better identify and understand fishing dynamics and develop further probing lines during the interviews and informal interactions with the fisher communities. The fishing activities examined at different landing sites were captured photographically. Secondary data sets and publications were also consulted in areas where data was scanty or where validity and quality of information was wanting.

Information from the interviews and secondary sources were pooled and analysed using an in-depth descriptive analysis and

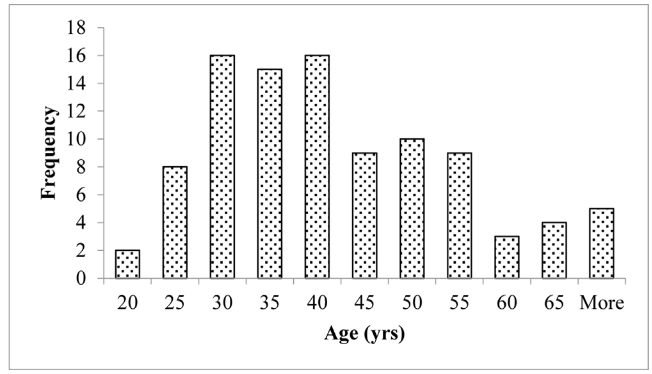

Fig. 2. Age distribution among respondents.

elementary tests for relationships in Microsoft Excel and the SPSS software.

3. Results and discussion

3.1. Sample description

3.1.1. Socio-demographic characteristics

A total of 98 career artisanal fishermen were interviewed in four Kenya coastal fish landing sites, namely: Munje (35), Mkunguni (31), Shimoni (17), and Mwaembe (15). All respondents were males. Gender distribution is an important socio-cultural construct that brings to fore the differences in roles, functions, entitlements and deprivation of men and women. Male dominance in this study could be attributed to both the physiological and cultural advantages that fishing offers to males, especially in the traditional African set up.

The ages of interviewees ranged from 19 to 81 years, with an average age of 41 years (see Fig. 2). Ideally, over 80% of respondents fell within the typical active working class in Kenyan society which spans 18–60 years. Eighty four percent (84%) of the fishermen were married, 13% single and the rest divorced. The average household size in the four sites was 7 persons.

Generally, Kenya coastal fishers fall within the most economically productive age group of the population with relatively strong family and marital unity which implies better prospects for household resource mobilization towards achievement of social and financial security. Nonetheless, the household size was considered to be relatively high indicating a high dependency ratio. This implies that coastal fishermen bear significant financial burden to support members of the household who are not gainfully employed. This situation could "push" the fishermen to exert excessive fishing pressure on supportive fisheries resources in order to acquire additional income to support the unemployed household dependants. However, this situation is bound to result in overfishing and habitat degradation as well.

3.1.2. Fishing dynamics in experimental the FADs sites

The fishers interviewed were very well experienced in their trade. Their fishing experience varied from 2 months to 60 years, and averaged at 18.7 years. This outcome enhances the validity of our results by indicating that our target respondents were relatively very well conversant with fishing activities in Kenya coast. Fishing was found to be practised on an average of 6 days in a week during the North East Monsoon (NEM) and 4 days in a week during the South East Monsoon (SEM) (see Fig. 3). In addition, the artisanal fishing unit spent an average of 7 h/day fishing during the NEM, and fewer hours during the SEM. Fishing days and hours are lesser during SEM due heavy rains and strong waves

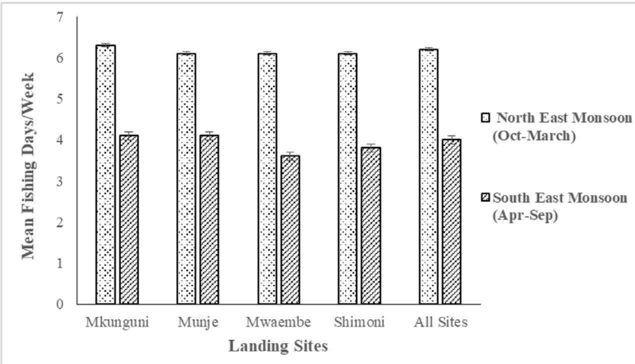

Fig. 3. Average fishing days per week across seasons.

that characterize this season. Since FADs aggregate fish, coastal artisanal fishermen could potentially benefit from reduced fishing days and fish search time by their (FADs) adoption, however, this could also lead to overfishing.

All the fishermen reported that they usually chose their fishing grounds mainly considering prospects for more catch; suitability to the fishing gears being used, and for protection from the rough sea. Only 15% of the fishers indicated that they had at one point explored the outer-reef or further off-shore fishing grounds. About 59% of these fishers used dug out canoes, 20% used traditional crafts known as ngarawa, 7% used traditionally wooden-built small boats known as Mtumbwi, 7% used motorized fibre boats (7%), 7% were foot fishers (7%), and the rest used *mashua* which is a larger traditional sail boat. The main mode of propulsion was paddles and the vessel crew was composed of an average of 3 fishers who doubled up on roles of steering the vessel as well fishing. The average distance offshore travelled by Kenya coastal fishers was found to be 7 km, and this distance ranged from 0.15 km to 100 km. Most of the fishing vessels that artisans use cannot access richer fish species like tunas that are resident further offshore. Whereas FADs would provide a good window for artisans to explore deeper into the ocean with prospects of better catches, there would be an equal need for modernizing fishing vessels at the Kenya coast in order to enable the fishermen to reach the FADs deployed off-shore.

The various fishing gears and methods used by the fishermen included traditional basket traps (41%), long lines (24%), gill nets (17%), hand lines (11%) and spear guns (5%). Whereas, each fisher had his preferred fishing method and gear, it was further established that the fishers used more than one method or gear depending on the fishing ground and season. This was explained as an income diversification strategy to cushion against losses resulting from inefficiencies of the main fishing gear or method. The basket trap was the most preferred gear because it highly reduced fish search time, hence enabling the fisher to attend to other social and livelihood obligations. This gear is itself a trapping FAD, usually deployed near shore to avoid physical damage and loss from strong current drifts. Since artificial FADs are relatively more stable in stronger currents besides reducing fish search time, but with more prospects for high valued pelagic species catches, this study intimates a likelihood of the fishers in this region to adopt FADs if these beneficial aspects are clearly communicated to them.

3.1.3. Fish catches and income in the experimental FADs sites

The average fish catch per fisher per day was 8 kg and it varied by vessel and gear type. About 91% of the fishers sold their fish directly to fish traders who included wholesalers and retail women who fried the fish before selling locally in the village markets. The rest of the fishers sold their catch to the local Beach Management Unit (BMU), which is a co-management organ for the local beach and fisheries stakeholders. Prospects for credit and working capital were found to be the main pull factors that attracted fishermen to sell directly to specific wholesale fish traders in order to build trust. Fishing income was found to be relatively erratic due to variations in catches across the fishing seasons and therefore credit facilities were very vital in smoothening income for fishers. The median daily net income per fisher was KES 1000 (~US$10) (see Table 1), while the modal income – which indicates the amount of money that many fishers reported repeatedly to have taken home from fishing – was KES 400 (~US$4). Whereas the mean daily net income was found to be KES 1463 (~US$15), it was not regarded as a better measure of central tendency in this case owing to observed large variations in the income of interviewed fishermen.

The demand for fish within the fishing localities was observed to be relatively high, but there was no well established fish market in any of the fishing villages and fish prices fluctuated a lot by catch quantities, season and buyer characteristics. Non-locals and tourists were found to pay relatively higher prices for the same fish quantities and types than their counter-parts from among the local fishing communities, especially when the price was determined by haggling. Fish prices were relatively higher in SEM when catches were low than in NEM when catches were higher. About 71% of the fishers preserved the freshness of their fish prior to sale because fresh fish attracted quick sale and better prices among traders and end-consumers. This preservation was basic and mainly involved sprinkling the fish with salty sea water. No fisherman reported to have practiced any value addition technique whose objective transcended preservation of fish freshness. Since it is foreseen that FADs could increase fish catches, especially high valued pelagic species, the absence of a well structured fish market and poor preservation and value-addition mechanisms and facilities in the study area would be disadvantageous to the desired economic outcomes from the proposed technology.

3.1.4. Perception of fishers in relation to FADs

3.1.4.1. Awareness of artificial FADs. The fishers were evaluated on their level awareness of artificial FADs on a four point likert scale. Overall, 38% were not aware, 32% were less aware, 17% were aware, and the rest were very aware. The awareness levels varied across fishing beaches (see Fig. 4). The level of awareness of artificial FADs was higher in sites where deployment teams from past projects had previously worked closely with the local fishermen at the experimental stage. For example, in Mwaembe, Mkunguni and Munje fishing beaches, Smartfish and KCDP projects had been active with FADs deployment. *It needs to be emphasized that the question on awareness was with respect to artificial FADs and did not capture awareness levels of either traditional FADs or the concept of fish aggregation by use of sheltering objects at sea which the fishermen were very familiar with.*

The various aspects of awareness that this research examined included hearing about, seeing and fishing around FADs. Eighty three percent (83%) of respondents had heard about FADs, from their local BMU meetings (66%), other fishers (17%), marine interest groups and individuals (9%), State Department of Fisheries (SDF-Kenya) and KMFRI (5%), and project consultants who were contracted to deploy FADs in their fishing sites through KCDP's and SWIOFP's FADs components. Out of those who had heard about FADs, only 60% stated that they had actually seen FADs. A proportion of 71% had seen the artificial FADs deployed by the experimental teams in the deep sea adjacent to their fishing grounds. Other fishers saw FADs at the experimental assembly point within Mwaembe beach, at KMFRI where FADs were kept,

Table 1
Fisher's daily income (Mean ± SD) across the sampled landing sites in South Coast Kenya.

Statistic		Fish landing site				South coast overall
		Mkunguni	Munje	Mwaembe	Shimoni	
	Mean	1567.74	930.86	1518.00	2372.19	**1462.94**
	±SD	±1500.01	±665.10	±1557.05	±2695.07	**±1646.18**
1KES = ∼US$0.01	Median	1000.00	700.00	1000.00	1200.00	**1000.00**
	Minimum	200.00	260.00	300.00	300.00	**200.00**
	Maximum	7500.00	4000.00	6000.00	8330.00	**8330.00**
N		**31**	**35**	**15**	**16**	**97**

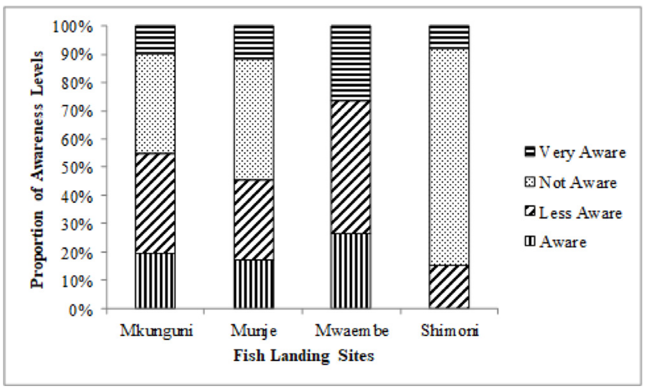

Fig. 4. Level of awareness of FADs in fish landing sites.

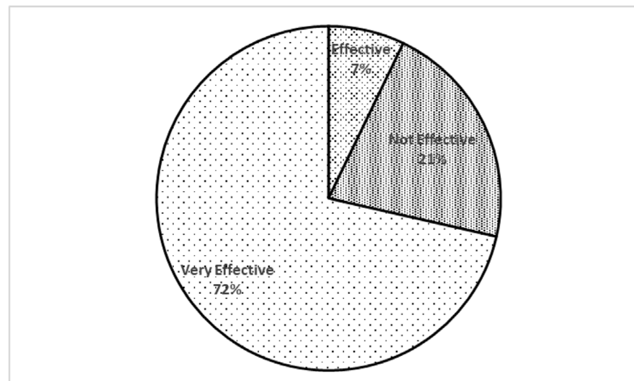

Fig. 5. Perceptions on effectiveness of FADs in fishing.

or on wall pictures pinned at their local BMU offices. The fishers described artificial FADs as composed of "*a flag, buoy and an anchor*". Some fishermen however, had seen traditionally constructed FADs deployed in *Wasini* and *Chuka* fishing grounds which were adjacent to Shimoni beach. These fishers were very conversant with the concept of fish aggregation and explained that traditional FADs in Wasini "*were made of makuti (palm leaves) and trees; making them temporary house-like structures stacked and immersed*". Only 13% of fishers indicated that they had fished around experimental FADs moored off-shore and which were adjacent to their specific fishing grounds.

It was quite remarkable that 98% of all fishers interviewed stated that they wished to know more about FADs. The main reasons that the fishers provided as to why they would wish to know more about FADs included: to understand the mechanism of fish aggregation leading to increased catches; to understand how to make and deploy FADs; and to assess whether the adoption of artificial FADs is economically feasible. The level of sensitization influences the uptake of any technology; hence, more sensitization ought to be done to Kenya coastal fishers on artificial FADs before rolling out any programme on their adoption. Properly undertaken, the proposed sensitization activity would prove to be an appropriate "ice-breaker" useful for "softening the ground" for adoption of this relatively "new" technology to Kenyan coastal fishers.

3.1.4.2. Usage of FADs. It was further established that among those who fished around experimental FADs, the fishing duration ranged from just once to a period of 7 years. In addition, 48% of them stated that they had enough knowledge on FAD making and fishing; explaining that they had been involved in fabrication, deployment and test-fishing around FADs by the consultants in various FADs trial projects within their fishing grounds. Moreover, 56% of the trial FAD fishers indicated that they had noticed specific changes around the deployed FADs, namely: diversity of aggregated species (50%); increase in fish catch (40%); and better sizes of fish catch (10%). On the flip side, 22% of the FAD fishers disclosed that artificial FADs introduced negative impacts such as theft and vandalism of expensive FADs equipment (50%); attraction illegal and non career fishers (25%), and fisher–fisher conflicts (25%) from loss of fishing grounds and little sensitization.

A proportion of 72% (see Fig. 5) of the fishermen indicated that artificial FADs were an effective and better fishing method on the basis of three benefits: more fish catches (55%), reduced fishing effort (27%), and attraction of diverse species (18%). Since close to 80% of fishermen perceive FADs as effective in fishing method, there is further need to establish the actual socio-ecological and economic impacts of FADs in order to evaluate its actual costs and benefits to coastal fishermen. The prevailing positive perception on effectiveness of FA Ds indicates that the fishermen were enthusiastic about FADs; this paints good prospects for the adoption agenda.

In spite of the positive preliminary perceptions of trial FADs, the respondents listed some suggestions for consideration and improvement before further attempts are made to upscale the FAD technology in Kenya coast. They included:

i. Need for a protection/security framework for the FADs deployed at sea in order to secure them from vandalism and/or theft which are rampant within the study area. In this respect, the respondents reported that nearly all the experimental FADs deployed by previous projects were either stolen of vandalized by corrupt and poverty stricken fishermen who perceived the FADs equipment as more expensive and readily available than the fish they were deployed to aggregate. *"It is important to deter fishers from fishing FADs equipment instead of fishing fish"* inferred one respondent;

ii. Need for initial expansive sensitization on the concept, prospect, fabrication, deployment and fishing from FADs for local fishers and BMUs in order to allay fears on resource intrusion by "*alien*" projects and people;

iii. Ensuring that FADs are deployed in areas that are clearly marked and demarcated in order to avoid navigational calamities through accidents;

4. Conclusion and recommendations

In order to encourage the social acceptability of FADs technology by interested traditional fishers, their artisanal vessels should be motorized in order to enable them to fish beyond the reef where FADs are deployed. In addition, whereas coastal fishers are enthusiastic about the positive outcomes from FADs, this study has established that inadequate sensitization was done at the point of deployment of experimental FADs, and this consequently worked against adoption of this technology. Besides, skills on how to fabricate the artificial FADs that were deployed were not transferred to the coastal fishers by the consultants. Likewise, the import materials that were used to assemble the experimental artificial FADs were beyond the ability of local artisanal fishers to acquire and maintain.

In light of the highlighted prospects and problems of FADs fishery, we therefore recommend the following:

(a) Further exploration and research on innovative and economical options in fabrication of FADs, especially by use of indigenous knowledge and locally available materials, in order to cut down on importation costs, as well as to attract local industry.
(b) An extensive sensitization exercise on artificial FADs should be done to fisheries stakeholders at all pilot sites prior to deployment or upscaling in order to clear any "grey areas" which could impede successful implementation;
(c) Formulation of a comprehensive FADs management framework that is cognisant of the dynamics of fisher conflicts in Kenya coastal fisheries; and

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding

This work was supported by the Kenya Coastal Development Project (2011–2017; P094692) within component one (1) on Sustainable Management of Fisheries Resources. All authors approved the version of the manuscript to be published.

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