Routledge
Taylor & Francis Group

Journal of the Indian Ocean Region

ISSN: 1948-0881 (Print) 1948-108X (Online) Journal homepage: https://www.tandfonline.com/loi/rior20

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To cite this article: Peter Musembi, Bernerd Fulanda, James Kairo & Michael Githaiga (2019) Species composition, abundance and fishing methods of small-scale fisheries in the seagrass meadows of Gazi Bay, Kenya, Journal of the Indian Ocean Region, 15:2, 139-156, DOI: 10.1080/19480881.2019.1603608

To link to this article: https://doi.org/10.1080/19480881.2019.1603608

Published online: 10 May 2019.

JOURNAL OF THE INDIAN OCEAN REGION
2019, VOL. 15, NO. 2, 139–156
https://doi.org/10.1080/19480881.2019.1603608

Species composition, abundance and fishing methods of small-scale fisheries in the seagrass meadows of Gazi Bay, Kenya

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ABSTRACT
Fisheries are important sources of livelihoods to coastal communities. In the tropics fishing is conducted from mangroves, seagrass meadows to coral reefs. Studies on fisheries in the tropics have focused on coral reef fisheries, with little attention to seagrass meadows and mangroves. Using creel survey and in-depth interviews, this study assessed species composition, abundance and exploitation methods of fisheries from the seagrass meadows of Gazi Bay, Kenya. Eighty-five species were recorded with 8 species accounting for 75.7% of the total catch dominated by *Leptoscarus vaigiensis*, accounting for 30.9% of the total catch. Five dominant gears were observed: basket traps, hook and stick, handlines, nets and spear-guns. Basket traps were the most dominant accounting for 75.1% of the total catch by volume. These results underscore the value of the seagrass meadows to supporting fisheries. Gear management measures should be implemented for sustainability of the seagrass habitat and associated fisheries.

ARTICLE HISTORY
Received 30 October 2018
Accepted 25 March 2019

KEYWORDS
Blue carbon; Seagrass meadows; Small-scale fisheries; Indian Ocean; food security; Kenya

Introduction

Fisheries resources are important to coastal communities, providing food and income and enhancing coastal livelihoods (McClanahan, Allison, & Cinner, 2013; McClanahan, Maina, & Davies, 2005). Small-scale fisheries dominate marine fisheries in the majority of developing countries. In most parts of the Western Indian Ocean (WIO) region, small-scale fisheries contribute 93–98% of the marine catch and comprises the main income-generating activity and a major source of protein for local communities (Rehren, Wolff, & Jiddawi, 2018; Samoilys et al., 2015; Tuda, Wolff, & Breckwoldt, 2016). These fisheries are characterized by open access, low technology, multi-species and multi-gear, with catches landed in multiple sites (de la Torre-Castro, Di Carlo, & Jiddawi, 2014; Kaunda-Arara, Rose, Muchiri, & Kaka, 2003; McClanahan & Mangi, 2004). For example, 13 fishing gears (Samoilys, Osuka, Maina, & Obura, 2017) and 163 species (McClanahan & Mangi, 2004) have been recorded in the small-scale artisanal fisheries in Kenya, and the case is likely replicated in other countries of the WIO including Tanzania, and Mozambique among others. These

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characteristics, coupled with high dependence on marine resources by adjacent communities make small-scale artisanal fisheries particularly complex to assess and manage.

Small-scale artisanal fisheries in Kenya and in the region have been extensively studied. The contribution of these fisheries to local food security and livelihoods, catch composition, catch rates, trends and management interventions have been widely discussed (Fulanda et al., 2009; Kaunda-Arara et al., 2003; McClanahan & Mangi, 2004; McClanahan, 2008; Samoilys et al., 2017; Tuda et al., 2016). Similar to global and regional trends, local catch rates indicate declining small-scale fisheries due to additive and synergistic effects of overfishing, habitat degradation, use of destructive fishing methods and emerging phenomena such as climate change, consequently harming peoples' source of food and livelihoods (McClanahan, 2008). These challenges have not been sufficiently addressed especially in the WIO and are threatening coastal systems and peoples' livelihoods (Samoilys et al., 2017).

Studies on tropical marine fisheries have historically focused on coral reef associated fisheries (Nordlund, Erlandsson, De la Torre-Castro, & Jiddawi, 2010) despite evidence that the fisheries are carried out throughout the whole seascape of coral reefs, mangrove forests and seagrass meadows (Unsworth & Cullen, 2010). Seagrass fisheries are widespread, contribute significantly to small-scale fisheries catches and support coastal livelihoods, especially in the Indo-Pacific which has the greatest seagrass species diversity (de la Torre-Castro & Ronnback, 2004; de la Torre-Castro et al., 2014; Gullstrom et al., 2002; Nordlund et al., 2010; Nordlund, Cullen-Unsworth, Unsworth, & Gullstrom, 2018; Unsworth & Cullen, 2010). However, information on seagrass fisheries and their contribution to small-scale fisheries are still limited as is information on the impacts of these fisheries on the ecosystem. Understanding the contribution and dynamics of different habitats within the coastal seascape to fisheries productivity and local livelihoods is critical to inform effective governance and management for the sustainability of fisheries and their habitats especially within the ecosystem-based management framework.

Seagrass meadows are highly productive ecosystems and their structural complexity is of significance to fisheries, providing refugia against predators, sites for attachment especially of settling eggs and food for various species (Farina, Tomas, Prado, Romero, & Alcoverro, 2009; Gullstrom, Bodin, Nilsson, & Ohman, 2008). Their connectivity with other adjacent ecosystems enhances cross-habitat utilization by species and thus supports the productivity of adjacent habitats (Heck et al., 2008). Consequently, seagrass meadows are critical foraging, refugia and nursery grounds for numerous species of finfish, shellfish and invertebrates that are exploited for subsistence, recreational and commercial purposes (Cullen-Unsworth & Unsworth, 2013; Jackson, Rowden, & Attrill, 2001; Orth et al., 2006; Unsworth & Cullen, 2010). The location of seagrass meadows in shallow nearshore waters make them easily accessible for exploitation with minimal gear requirement (Unsworth, Nordlund, & Cullen, 2018). For example, gleaning (the use of simple gears or hand collection to exploit invertebrates in the intertidal zone during low tide) is a dominant activity in tropical and subtropical regions and a source of food to coastal communities (Nordlund et al., 2010; Unsworth & Cullen, 2010). However, such fisheries are rarely monitored nor are the catches reported (Nordlund et al., 2010; Unsworth & Cullen, 2010). Data and information on fisheries associated with seagrass meadows such as species assemblages and the exploitation methods is scarce. Furthermore, the majority of the seagrass associated fisheries are usually categorized as coral reef fisheries limiting reporting on the value of seagrass ecosystems in supporting fisheries. Consequently, these critical ecosystems have continued to receive little attention, more often being neglected in fisheries management plans.

Seagrass meadows are also important in provision of other ecosystem services. They form one of the most efficient carbon sinks by capturing and storing huge stocks of carbon and have been suggested to have potential for mitigating the impacts of climate change (Duarte et al., 2010; Githaiga, Kairo, Gilpin, & Huxham, 2017; Hejnowicz, Kennedy, Rudd, & Huxham, 2015). Seagrass meadows contribute to nutrient cycling in coastal waters through their uptake from the water column, and storage in biomass and sediment. Through dissipating the energy of waves and currents, they stabilize sediments and prevent erosion. Globally, seagrass meadows are facing increasing threats and are rapidly declining from both natural and anthropogenic disturbances (Duarte, 2002; Orth et al., 2006; Waycott et al., 2009). The location of seagrass in shallow nearshore areas make them particularly vulnerable to over exploitation and other human and land-based disturbances (Waycott et al., 2009).

This study assessed species composition, abundance and exploitation methods of fisheries from the seagrass meadows of Gazi Bay. Specifically, the study evaluated species composition, abundance, catch rates, size structure and exploitation methods. This will contribute to understanding the role of different habitats within the coastal seascape to fisheries productivity and local livelihoods to inform effective governance and management for the sustainability of the fisheries and their habitats. Knowledge about the relative contribution of these fisheries is also useful in fulfilling the government agenda on sustainable blue economy and food security.

Materials and methods

Study Site

The study was conducted over a period of 12 months from September 2017 to August 2018 in Gazi Bay, southern Kenya. The bay is a shallow, tropical coastal water system at 4° 25′ S, and 39° 30′ E, with extensive mangrove forests fringing the landward side, coral reefs sheltering the bay from the eastern seaward side, and extensive seagrass meadows in the continental reef shallow waters (Figure 1). The bay covers a surface area of about 17 km^2 (Bouillon, Dehairs, Velimirov, Abril, & Borges, 2007). Twelve seagrass species reported in eastern coast of Africa have been recorded in the bay occurring either as monospecific or mixed stands in both the subtidal and intertidal zone (Coppejans, Beeckman, & De Witt, 1992, Githaiga et al., 2017). Four of these species are dominant including *Thalassodendron ciliatum, Thalassia hemprichii, Enhalus acoroides,* and *Syringodium isoetifolium*, accounting for about 70% of the seagrass cover in the bay (Coppejans et al., 1992; Githaiga et al., 2017). The bay's seagrass meadows are reported to be some of the largest and almost contiguous meadows along the Kenya coast, covering an estimated area of 8 km^2 (Samoilys et al., 2015). The tidal range of the bay is between 1.4 m during neap tide and 3.2 m during spring tide (Kitheka et al., 1996). A greater area of the bay is exposed during low spring tide allowing the local fishers to harvest fish and invertebrate resources by foot using sticks and hand collection. Recently, there has been seaweed farming in the bay in areas with seagrass meadows (pers. observ).

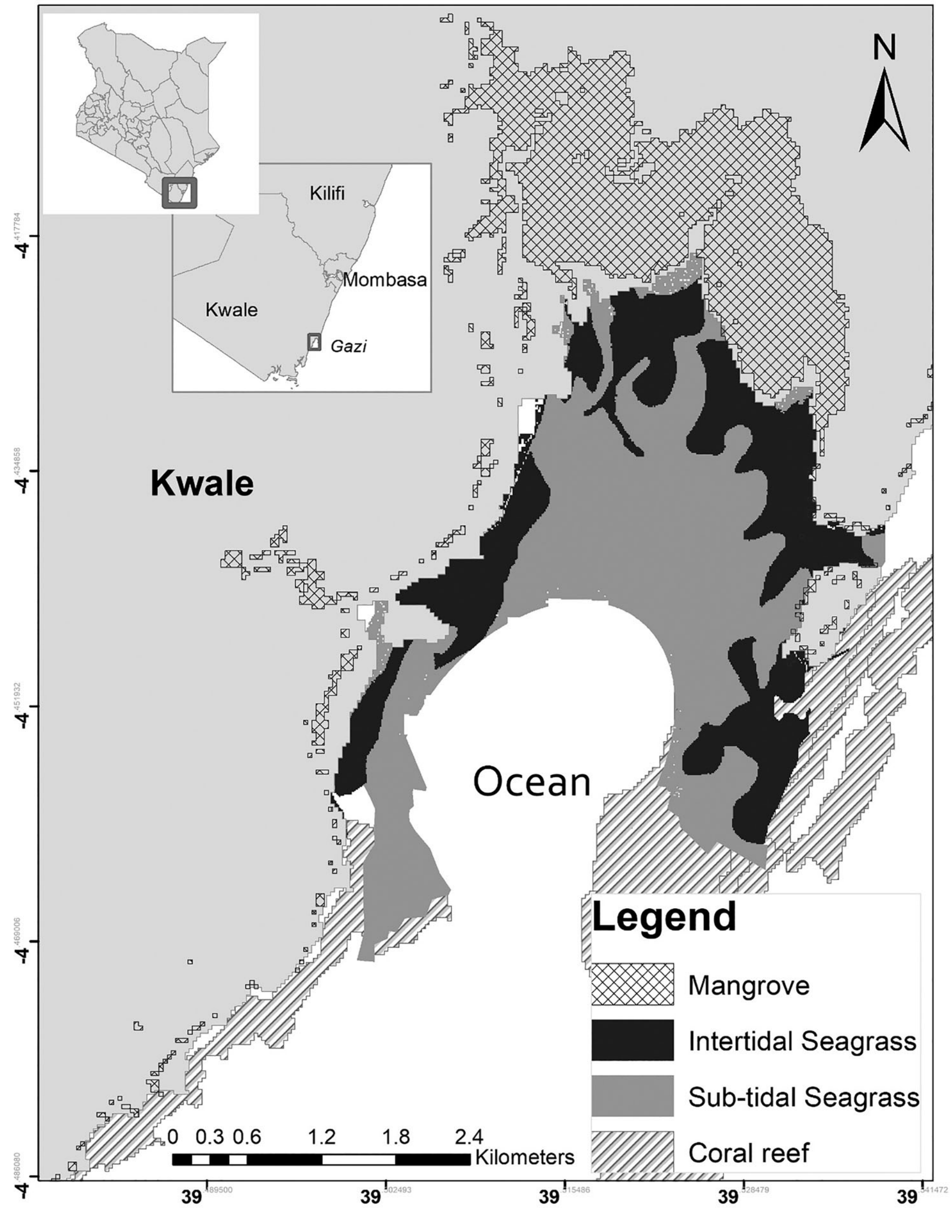

Figure 1. Map showing the location of Gazi Bay with associated habitats mangrove, coral reefs and seagrass ecosystems.

Fishing patterns in the bay are influenced by the large-scale pressure systems of the Western Indian Ocean region including the wet South East Monsoons (SEM) and the drier North East Monsoons (NEM). The SEM runs from April to September and is characterized by strong winds and rough sea conditions. Fishing activities during this season are concentrated within the inshore waters and sheltered areas of the bay. The NEM runs from October to March and is characterized by calmer sea conditions allowing fishers to go further offshore exploiting the deeper waters and fisheries resources of the outer reefs (McClanahan, 1988; Tuda et al., 2016).

Fishing and fishery related activities are dominant activities in the bay and it is one of the most active landing sites on the south coast, supporting a small-scale artisanal multi-gear and multi-species fishery (Kimani, Mwatha, Wakwabi, Ntiba, & Okoth, 1996). In the past four decades there has been immigration by fishers from Pemba in Tanzania that have introduced small-scale purse-seine fishing. (Ochiewo, 2004). Occasionally, resource conflicts occur between immigrants and local fishers about fishing grounds, market access as well as conflicts with fishery managers about licenses.. Generally, there has been concern about substantial decline in the fisheries due to overexploitation and use of destructive gears in the area (McClanahan et al., 2008; Tuda, 2018).

Fishery survey method and data collection

The study employed two approaches for the field surveys and data collection; (i) in-depth Key Informant Interviews (KIIs) with resource users including fishers, traders, input suppliers and managers and (ii) fishery creel survey or catch assessment surveys to enumerate landed catch and species composition for evaluation of the resource use patterns and spatial extent in the bay as well as the trends in the fish landings.

Fishery creel surveys

Monthly fishery creel or catch assessment surveys (CAS) were conducted over a period of one year from September 2017 through August 2018 at the main landing sites of Gazi Bay. Fish catch from 167 catch events were sampled and catch data recorded. Catch data including total weight (TW, kg), total numbers (TN), species landed, number of individuals of each species, fishing gear used, fishing grounds visited and crew size for each fishing trip were recorded. Further, a random subsample from the catch was taken and individual fish weighed to the nearest 0.1 g (BW, g) and standard lengths measured using a measuring tape to the nearest 0.1 cm (SL, cm). Species identification was done using identification keys adopted from the FAO species catalogs and field guides (Anam & Mostrada, 2012; Lieske & Myers, 2001; Richmond, 2011). Species that could not be identified in the field were photographed using GoPro® Hero3$^+$ camera for subsequent reference identification.

Key informant interviews (KIIs)

Key informant interviews were conducted to collect socio-economic data and information using questionnaires with open-ended questions to assess fisheries exploitation patterns in the seagrass meadows of the bay, status of fisheries landings and catch trends (supplementary materials). A total of 32 respondents were interviewed on perceptions in exploited fisheries assemblage, fisheries exploitation activities carried out in the seagrass meadows, perceived change in catches, spatial change in the seagrass cover and the benthic habitats. All the interview questions were translated to the local Swahili and Digo languages wherever the need arose.

Data analysis

Data was entered and stored in Microsoft Excel and analyzed using R statistical programs (R Core Team, 2018). The nominal Catch Per Unit Effort by gear was calculated as kg/fisher/trip by dividing the total catch weight by the number of fishers in a boat.

CPUE (by gear)

$$\text{CPUE} = \frac{\text{Total catch (kg) by gear or vessel}}{\text{Total number of fishers (Nos.) per gear or vessel}}$$

Relative Abundance (RA) of different species was calculated as:

$$\text{R.A} = \frac{\text{Number of individual per species}}{\text{Total number of individual of all species}} \times 100$$

Size frequency distribution was plotted for the top four dominant species; *Leptoscarus vaigiensis* (Quoy & Gaimaird, 1824), *Scarus ghobban* (Forsskål, 1775), *Lethrinus lentjan* (Lacépède 1802) and *Lutjanus fulviflamma*, (Forsskål 1775). Juvenile retention rates were determined by calculating the proportion of landed individuals below length at first maturity (L_{mat}). Values for L_{mat} were obtained from Mangi and Roberts (2006) and Fishbase (www.fishbase.org).

Data was tested for normality and homogeneity of variance using Shapiro–Wilk statistic and the data did not fit the assumptions of normality. Kruskal–Wallis tests were used to test for statistical significance of differences in Catch Per Unit Effort (CPUE) in different gears. Dunn's-test for multiple comparisons of independent samples with *Bonferroni p*-value adjustment was used for posthoc pairwise comparison. Shannon-Weiner diversity index was employed to calculate the species diversity index by gear. The alpha level of all statistics was placed at 0.05.

Results

Catch species composition

A total of 85 species from 41 families were recorded from the catch assessment surveys. Scaridae, Lutjanidae and Lethrinidae were the most dominant families accounting for 69.5% of the total catch by number (Figure 2(a)). Eight species accounted for 75.7% of the total catch by abundance dominated by *L. vaigiensis* (30.8%), *S. ghobban*, (10.2%), *L, fulviflamma* (10.1%), *L. lentjan* (7.6%), *Lethrinus nebulosus* (6.1%), *Plotosus lineatus* (4.3%), *Siganus sutor* (3.6%) and *Parupeneus barberinus* (2.9%) (Figure 2(b)). Families and species whose catch composition as less than 1% were combined and categorized as 'others'.

Fishing gear composition

Five fishing methods were observed in the seagrass meadows of Gazi Bay; basket traps, hook and stick (gleaning), handlines, nets and spear-guns. Cast nets, monofilament nets, gillnets and reef seines were pooled into the category 'nets'. The basket trap was the most dominant gear contributing 75.1% of the total catch by abundance followed by hook and stick/hand collection (10.8%), nets (7.8%), handline (4.9%) and spear-gun (1.4%) (Table 1). Basket traps also recorded the greatest richness with 45 species and

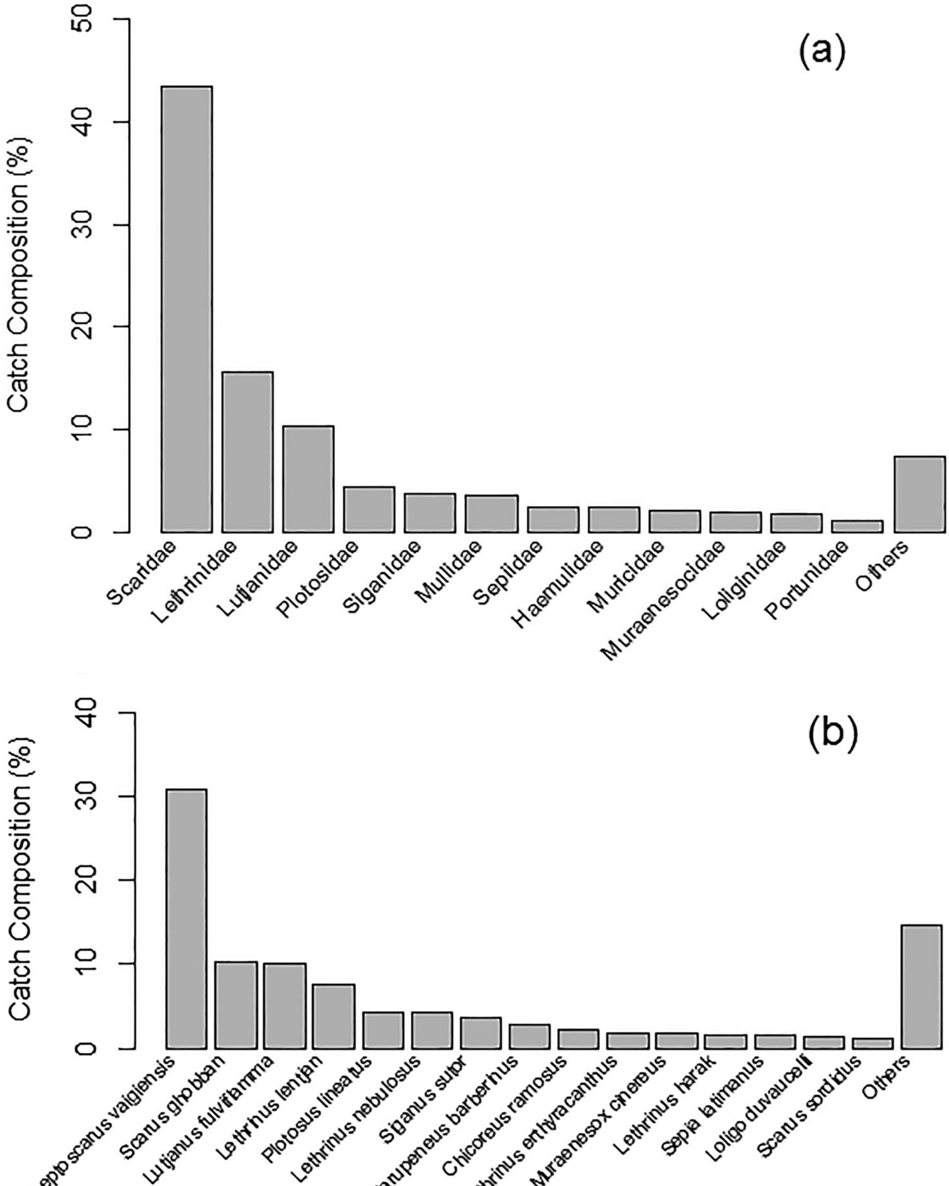

Figure 2. Catch composition (by numbers) of families (a) and species (b).

caught over 90% of the top 7 dominant species. This was followed by fishing nets (33 species), hook and stick (23 species), spear-gun (17 species) and hadnline (14 species) (Table 1). *L. vaigiensis* dominated basket traps catches followed by *S. ghobban* and *L, fulviflamma. Chicoreus ramosus, Muraenesox cinereus* and *Sepia latimanus* dominated hook and stick in decreasing order. Handlines were dominated by *L. fulviflamma, L. lentjan* and *Lentrinus harak.* Catches from nets were dominated by *P. lineatus, S. sutor and L. fulviflamma* while the spear-gun was dominated by *Scarus psittatus, Octopus vulgaris* and

Table 1. Species diversity, proportion of catch and CPUE of different fishing gears.

Gear type	Number of species	Diversity Index 'H'	Proportion of total catch (%)	CPUE
Basket traps	45	2.2	75.1	3.5 ± 1.7
Hook and stick	23	2.5	10.8	3.4 ± 1.7
Spear gun	8	2.5	1.4	3.3 ± 2.4
Handlines	23	2.0	4.9	2.6 ± 1.2
Nets	33	2.4	7.8	3.5 ± 1.2

Acanthurus xanthopterus. Spear-gun recorded the highest Shannon-wiener index ('H') with 2.49 followed by hook and stick, nets, basket trap and handline (Table 1).

The overall catch rate across all gears was 3.4 ± 1.6 kg/fisher/trip. The catch rate was highest in basket traps; 3.5 ± 1.7 kg/fisher/day while spear-gun recorded the lowest catch rate; 2.6 ± 1.2 kg/fisher/day (Table 1). There was significant variation in CPUE among the fishing gears (Kruskal–wallis, $p < 0.05$) (Figure 3) Posthoc pairwise comparison revealed significance difference between basket trap and handline, basket traps and nets and basket traps and spear gun. (Table 2).

Length frequency of dominant species

The length distribution of the four dominant species sampled ranged between 8.8 and 32.60 cm. *L. vaigiensis* individuals sampled ranged between 11.30 and 23.3 cm (mean: 16.81 ± 2.3 cm), *S. ghobban* ranged between 10.7 and 32.60 cm (mean: 16.07 ± 5.3 cm), *L. lentjan* ranged between 8.8 and 29.70 cm (mean: 15.83 ± 6.9 cm) while the length of *L. fulviflamma* ranged between 10.0 and 25.1 cm (mean: 16.70 ± 3.3 cm). The mean lengths of *L. lentjan* and *S. ghobban* were below length at first maturity. Forty-three percent of individuals from the top four dominant species consisted individuals below the length at first maturity (L_{mat}). All *S. ghobban* individuals landed were below length at first maturity while *L. lentjan* recorded 70.5%. *L. vaigiensis* and *L. fulviflamma* recorded 22.3% and 28.2% of immature individuals respectively. The dominant gear basket trap recorded 46.6% of the top species below length at first maturity (Figure 4).

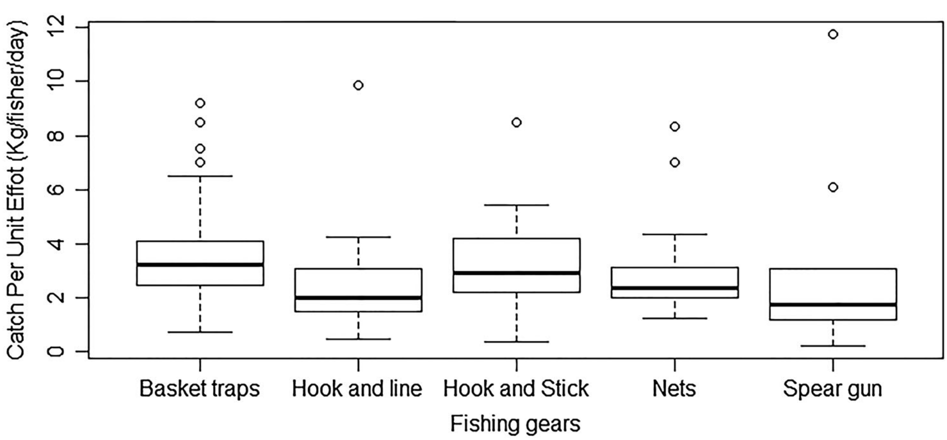

Figure 3. Variations in the Catch per Unit Effort (CPUE, kg/fisher/day) among different gears used in Gazi Bay.

Table 2. *p*-value for Posthoc pairwise comparison for different fishing gears.

	Basket Traps	Handline	Hook and Stick	Nets
Handline	0.030	–	–	–
Hook and Stick	0.425	0.162	–	–
Nets	0.047	0.640	0.291	–
Speargun	0.015	0.783	0.095	0.447

Community perception on species assemblage, exploitation, catch trends and seagrass status

Six five percent of the respondent mentioned parrotfish (*pono*) as a dominant species exploited from the seagrass meadows. Other common species that were mentioned included emperors (*changu*), snappers (*tembo*), rabbitfish (*tafi*), eels (*mikunga*), cuttlefish (*madome*) and goatfish (*mkundaji*). All these species were among the dominant species from the catch assessment.

Basket traps were reported as common gear used within the seagrass meadows in the bay. Hook and stick are also frequently used during low spring tides (*bamvua*). Handlines within the bay are used in channels which fishers can access by foot and can stand when fishing. Different kinds of nets including discarded mosquito nets are used in the bay. Most nets are used seasonally when conditions are too rough to venture out. Spear-guns are used occasionally, mostly in coral reefs areas as species easily hide in seagrass areas.

The fishers among the respondents reported that their catch rates range between 3 and 8 kg/fisher/trip with an average of 3.0 kg/fisher/trip. They also reported that the catch rate

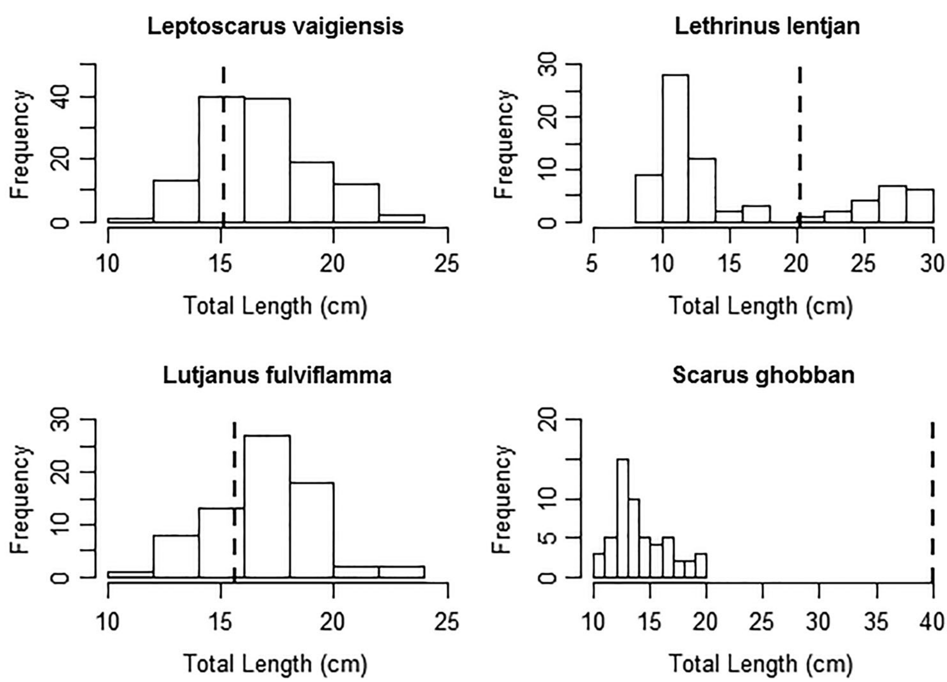

Figure 4. Size frequency distribution of four dominant species with Length at first maturity (Lmat) (blackline) for *L. vaigiensis* (15.1 cm), *L. lentjan* (20.3 cm), *L. fulviflamma* (15.6 cm), *S. ghobban* (40.0 cm).

has declined over the years as they used to catch up to 15 kg/fisher/trip in the last 20–30 years. Eighty percent of the respondent reported that the sizes of individual fish have decreased over the years and they catch much smaller fish now, 17% reported that the fish sizes have remained the same while 3% did not know.

Seventy-seven percent of the respondent reported that seagrass cover has declined over the last decades, 17% reported it has remained the same while 6% reported that it has increased. Destructive fishing methods most notably the use of beach seines was the top reason for seagrass decline with 67% of the respondent mentioning it. Other reason mentioned were sedimentation, increased exploitation due to increasing number of fishers, seaweed farming, boat activities and climate change.

Discussion

This study assessed the fisheries assemblages and exploitation patterns in the seagrass meadows of Gazi, Bay, southern Kenya through creel and interview-based surveys. The results showed high diversity of species and exploitation methods in small-scale fisheries that use the seagrass meadows of the bay. This provides evidence that seagrass meadows are key ecosystems supporting the small artisanal fisheries through provision of fishing grounds, nursery grounds and support species from adjacent habitats that are exploited by local communities. These results contribute to a growing body of knowledge that support the role of seagrass meadows in fisheries productivity and livelihood support. de la Torre-Castro and Ronnback (2004) observed that seagrass areas were the most preferred fishing grounds and yielded larger catch and higher revenue compared to coral reefs and mangrove forests in Chwaka Bay, Zanzibar. A global review reported extensive seagrass fisheries in all the regions of the world (Nordlund et al., 2018) while Unsworth et al. (2018) highlighted the role of seagrass meadows in supporting global fisheries production and their negligence in management and conservation.

High species diversity observed in this study is common in tropical marine fisheries and has been previously reported in coral reef fisheries (Kimani et al., 1996; McClanahan & Mangi, 2001). Over last decades due to increasing and selective pressure on certain fisheries only are few species have been reported to dominate catch in these fisheries (Hicks & McClanahan, 2012; McClanahan & Mangi, 2002; Samoilys et al., 2017). A similar pattern was observed in this study. A trend that has been suggested to mask species-specific decline in that dominant species tend to be overexploited. Three among the most dominant species in this study; *L. vaigiensis*, *L. lentjan* and *S. sutor* have been previously reported as overexploited (Hicks & McClanahan, 2012).

The high diversity of exploitation methods observed in this study suggests high exploitation pressure and gear competition in the seagrass meadows of the bay. Four of the dominant gears recorded in this survey – basket traps, nets, handline and spear gun – are among the most dominant fishing gears along the Kenyan coast targeting reef species (Gomes, Erzini, & McClanahan, 2014; Okello et al., 2010; Samoilys et al., 2017). This indicates that common gears used in different shallow marine habitats are also employed in seagrass meadows. Additionally, handline, gillnets, hand collection and spear gun observed in this study have also been recorded in a global analysis of major fishing methods in seagrass meadows (Nordlund et al., 2018) further suggesting some similarity in seagrass exploitation worldwide.

An assessment of impacts of fishing in Gazi Bay observed that fishing was the major contributor of mortality to exploited species in the bay (Tuda, 2018). Multiple gears exert different pressure on exploited species and associated habitats. For example, basket traps are known to cause limited physical damage to habitats (Mangi & Roberts, 2006) but they are also highly non-selective and capture a high number of immature individuals (McClanahan & Mangi, 2004). Similar observations were made in the current study. Handline is a relatively sustainable gear because it is more selective in targeting individuals and has limited impact to the environment (Nordlund et al., 2018). However, it is also known to target species of higher trophic level, can exert fishing pressure down the food web and capture immature individuals (Hicks & McClanahan, 2012).

Hook and stick/gleaning was the second dominant fishing by abundance although it is only carried out during spring low tide. The method recorded unique invertebrate species such as *C. ramosus* and *S. latimanus* locally known as *dodo* and *dome* respectively that are rarely reported in coral reef fisheries. The presence of a large seagrass meadow that is exposed during low spring tides provides an area that can be easily accessed and exploited with limited investment such as using hook and stick or bare hands. Gleaning in seagrass ecosystems is widely carried out in the region (Nordlund et al., 2010; Unsworth & Cullen, 2010) and elsewhere in the world (Anderson, Mills, Watson, & Lotze, 2011) and is acknowledged as an easy and cheap exploitation methods and important in provision of food and income for adjacent communities. However, this method is mostly unreported, unregulated and its contribution to small-scale fishery is ignored (Unsworth et al., 2018). In addition, its impact to the habitats and exploited resources is not well-known, although it has been suggested to have negative effects on community structure and seagrass cover through species over extraction and excessive trampling (Nordlund et al., 2010). It is important to better understand this fishing method and its role in small-scale fisheries and impact to the habitat assessed and monitored.

Spear-guns are illegal in Kenya (Kenya Gazette Notice No. 7565), although it is still widely used in Gazi Bay and in most parts of the south coast (Tuda & Wolff, 2015). Although it is more selective and catches larger individuals, it can cause mechanical damages to habitats (Hicks & McClanahan, 2012) and can put selective pressure on certain slow-moving species such as parrotfish. Beach seine, another illegal gear was previously widely used around the area (Tuda, Nyaga, Maina, Wanyonyi, & Obura, 2008) and was suggested as one of the causes of seagrass loss in the area. It has however been successfully eliminated (pers. Comm. BMU Chairman).

The presence of a controversial seasonal small-scale purse seine (ring-net) fishery in Gazi has an influence on fishing patterns in the seagrass meadows within the bay. The ringnet fishery mostly targets small and medium pelagic offshore species and has been suggested to reduce fishing pressure on near-shore demersal fisheries stocks (Okemwa et al., 2017). Frequent environmental and socio-economic concerns and conflicts have arisen due to the use of the gear in shallow areas, including concerns about its landing of juveniles and its environmental impacts (Maina, Samoilys, Alidina, & Osuka, 2013; Munga et al., 2015). There currently exist a draft Ringnet Fishery Management Plan in Kenya to regulate and ensure its proper use.

All gears investigated in this study captured juvenile individuals, suggesting the need for gear-based management to ensure the sustainability of the fishery and ecosystem health. Several gear-management interventions have been recommended in small-scale fisheries in the country. Modification of basket traps to include an escape gap has been found to significantly reduce the proportion of immature individuals (Gomes et al., 2014). Increasing the legal minimum mesh size of gillnets can also reduce the proportion of immature individuals (Hicks & McClanahan, 2012). Non-compliance on previous gear-restrictions in Kenya such as speargun and beach seine suggest the need for sufficient consultation, awareness, and stricter enforcement.

The high proportion of immature individuals is expected in seagrass meadows owing to their nursery functions. Common tropical fishes such as lethrinids, lutjanids and siganids have been recorded abundantly in nearshore seagrass meadows (Gell & Whittington, 2002). The nursery function of seagrass meadows is vital in enhancing the fisheries productivity of adjacent habitats such as coral reefs and mangrove forests.

The catch rate by gear was slightly higher than previously recorded (Tuda et al., 2016) in the same area for all the gears except hand line. Generally, catch rates in artisanal fisheries in Kenya have declined over the last decades (Samoilys et al., 2017). This was also mentioned in the interviews. This has been suggested to indicate declining fisheries resulting from high fishing pressure, the use of destructive fishing methods and habitat degradation (Mangi & Roberts, 2006; McClanahan & Abunge, 2014; Tuda & Wolff, 2015). With increasing deterioration of adjacent productivity habitats due to climate-related impacts such as bleaching of coral reefs there are prediction that seagrass meadows would become more exploited by adjacent communities (Unsworth et al., 2018) calling for an urgent need for their conservation.

Gazi Bay has experienced a reduction in seagrass cover at a rate of 1.68% per year in the last two decades (Harcourt, Briers, & Huxham, 2018). This has been attributed to destructive fishing, most notably beach seining according to the conducted interviews. Other reasons such as sedimentation have also been mentioned (Harcourt et al., 2018). Modification of existing fishing methods and strict enforcement of existing legislation can promote sustainable fisheries for both seagrass meadows and adjacent habitats. For example, the numerous herbivore species using the seagrass meadows as nursery grounds are important in promoting the resilience of coral reefs which are currently severely affected by climate change related mortality through mediating coral and macroalgae balance.

Conclusion

This study highlighted that seagrass supports small-scale fisheries in Gazi Bay through provision of fishing grounds and supporting fisheries that use adjacent habitats through provision of nursery grounds. Consequently, they support local communities through provision of food and livelihoods. A high diversity of species is supported by the seagrass meadows and are exploited by varied fishing methods. Recognition of the value of seagrass is increasing both locally and globally with increasing calls to recognize seagrass meadows as critical habitats that provide numerous ecosystem services. However, the translation of these calls to conservation and management action is still limited and more effort should be directed to raising awareness of these critical habitats to resource users, managers and policy makers.

Acknowledgements

The authors would like to thank Gazi Beach Management Unit (BMU), particularly, the Chairman, Mr. Juma Mkuu; for the participation in data collection and mobilizing fishers. Field work was made possible through PUNGUZA project funded Additional support for the study was through Pwani University to which we are very grateful. We also thank James Mbugua and Fredrick Mungai for their assistance map production.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was funded by British Council Newton Fund [grant number 275670159].

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Appendix

Species composition, abundance and fishing methods of small-scale fisheries in the seagrass meadows of Gazi Bay, Kenya (2018)

Local knowledge and socio-economic questionnaire

Date:……………………………………

1. Gender:
   - ☐ Male
   - ☐ Female

2. Age:
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………

3. Level of education:
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………

4. What activity are you involved with in the bay?
   ………………………………………………………………………………………………………
   …………………………………………………………………………………………

5. How many years have you been involved with this activity?
   ………………………………………………………………………………………………………
   …………………………………………………………………………………………

6. Where do you carry out this activity?
   ………………………………………………………………………………………………………
   …………………………………………………………………………………………

7. Why do you carry out this activity in this area?
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………
   ……………………………………………………………………………………

8. What other activities are carried out in the same area?
   ………………………………………………………………………………………………………
   …………………………………………………………………………………………

9. How frequently do you go out at sea?
   ………………………………………………………………………………………………………
   …………………………………………………………………………………………

10. What type of fish do you catch?
    ………………………………………………………………………………………………………
    …………………………………………………………………………………………

11. What type of fishing gear do you use?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

12. How many other people do you know that use the same fishing gear as you?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

13. What other fishing methods are used in the area that you fish?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

14. What type of vessel do you use?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

15. Are there seasons you don’t go out to the sea? Y/N Why?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

16. On average how much Kg do you catch per day?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

17. Which are the dominant fish that you catch?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

18. How much do you sell one Kg for?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

19. Does the price of catch differ by species? By season? How? Why?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

20. Does your catch differ between now and when you started fishing?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

    B. If yes, how does it differ?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

    C. Why do you think the catch has changed?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

21. Has the condition of the seagrass area that you fish changed? Y/N Has it become better or worse?
    ……………………………………………………………………………………………………
    ………………………………………………………………………………………

B. Why do you think it has become better or worse?
………
………………………………………………………………………………………Are there any other uses for seagrass meadows?
………
………………………………………………………………………………………

B. If yes, why are seagrass meadows used?
………
………………………………………………………………………………………Are there any cultural uses of seagrass that are or used to be carried out in the meadows or with seagrass?
………
………………………………………………………………………………………

Thank you!