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A socio-ecological system perspective on trade interactions within artisanal fisheries in coastal Kenya

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Abstract

Assessments of coastal artisanal fisheries are progressively adopting a social-ecological system (SES) approach as an effective means to accumulate knowledge and integrate findings on different aspects of the fisheries. Ostrom's SES framework was used to guide assessment of interactions between and within the harvesting and supply-chain processes and the effect of external drivers, seasonal monsoons and tourism, on both processes in a coastal artisanal fishery system in Gazi Bay, Kenya. Specific analyses focused on seasonal catch composition, key resource user groups involved in the fish trade and the resource units traded by each user group. The snowball method was used to identify key resource user groups within the fishery sector, who were then interviewed using semi-structured questionnaires (n = 60). Additionally, existing annual shore-based catch assessment and monthly fish landings data for the years 2014 and 2015 were incorporated for analysis of artisanal catch properties (species composition and weight). Comparison of seasonal catch composition was carried out using sample-based rarefaction curves. Higher fish landings and higher species diversity were recorded during the North-East Monsoon season. Further, a simple fish harvesting-supply network comprising of six key resource user groups (i.e. hotels, fish processing companies, dealers, small-scale fish processors (mama karanga), fish mongers and fishers) was outlined. The tourism industry, through hotels, creates a high demand for fish coinciding with a higher catchability and supply during the calm North-East Monsoon season and consequently, dealers hire migrant fishermen to target pelagic fish. Evidence of interactions within and between different fishery sub-systems, as well as the effect of monsoon seasons and tourism on the exploitation and market dynamics of the multispecies fishery, highlight the need for comprehensive management plans to strengthen self-organization among resource users and to increase adaptive capacity within the fishery system.

Keywords: artisanal fishery, socio-ecological system, Gazi, south coast Kenya

Introduction

Coastal artisanal fisheries (CAFs) are an important source of food and livelihood to millions of people globally (Barnes-Mauthe *et al.*, 2013). CAFs are characterized by a diversity of activities both in the catch harvesting and supply/processing chain processes. Fishing in this sub-sector is commonly characterized by the use of small-sized fishing crafts coupled with low technology investment, the application of multiple fishing gears and landing of multiple species (Nagelkerken, 2009; Balogun *et al.*, 2011). On the other

hand, the supply/processing chain activities show a distinct differentiation of roles (for example between gender), with different intensity in labour and subsistence operations both in fish processing and selling (Béné *et al.*, 2010).

Previous studies on CAFs have often focused on the harvesting and supply chain processes as two independent entities, leaving a crucial knowledge gap on attributes and implications of the interactions between the two processes (Garcia, 2007; Garcia *et al.*,

2008). CAFs are however increasingly being perceived as complex and highly interlinked social-ecological systems (SESs), based on their multiple biophysical and social properties, structural organization, role partitioning and types of problems they face (Basurto *et al.*, 2013). Various SES frameworks have been proposed to integrate harvesting and supply chain studies of CAFs, however, the Ostrom (2009) framework is often conveniently used to describe and characterize SESs in an integrated manner, giving ecological and social systems a near-equal weight (Johnson *et al.*, 2019). It was decided to adopt the Ostrom framework (Fig. 1) since it fits the nature and objectives of the study as: (i) it integrates social and ecological aspects and their interactions; (ii) it is applicable to CAFs and; (iii) it includes qualitative and quantitative data.

The Ostrom SES framework conceptualizes the two-way relationship between social and ecological systems from an anthropogenic perspective while guiding an approach to analyse relationships between individual variables in an SES quantitatively (Virapongse *et al.*, 2016).

The framework has four primary sub-systems of an SES that interact with and affect each other (Fig.1): (i) the resource system (i.e. the CAF itself); (ii) the resource units (i.e. different fish species/sizes landed and traded within the CAF); (iii) the governance systems (e.g., the national and county governments, self-organizing groups such as Beach Management Units (BMUs) and other organizations that manage the fishery); and (iv) the resource user groups (e.g., individuals who fish and sell the fish). The Ostrom framework further proposes a set of 53 second-level variables, building on the main attributes of each subsystem, while providing the option to choose other second-level variables or add a deeper level of variables according to the particularities of the analyzed SES (McGinnis and Ostrom, 2014; Ostrom, 2009).

Social-ecological studies have outlined the potential of ecological, economic and institutional processes to influence the relationship between market demand and ecosystem health (Armsworth *et al.*, 2010). For instance, considering the supply chain processes of a CAF, a trader who buys from a fisher may also
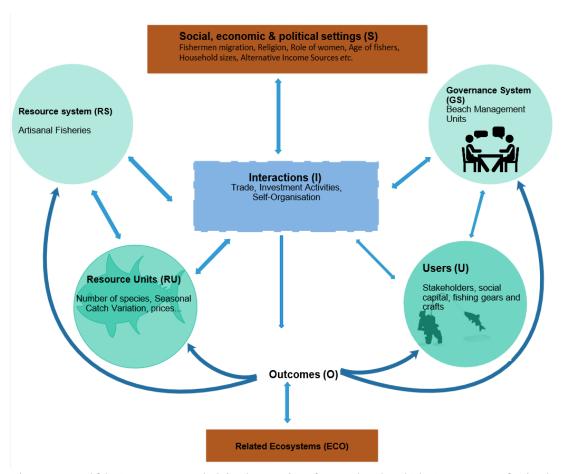

Figure 1. Artisanal fisheries as an SES: On the left is the revised SES framework, with multiple-tier components fitted in the context of coastal artisanal fisheries. On the right are the 53 subsections of the SES. This study focuses across the subsections highlighted in green (adopted from Ostrom, 2009).

provide capital for fuel, ice for storage/preservation, fishing gears and even finance the boat and demand specific types of fish (based on species, size or geographical location) from the fishers. The nature of the market demand in turn impels the fishers to fish selectively, leading to dramatic changes in aquatic ecosystems such as a change of the mean size of individuals within populations, general change in trophic interactions and loss of certain fish species (Jennings and Kaiser, 1998; Pauly *et al.*, 1998; Myers and Worm, 2003; Kinnison *et al.*, 2009; Shackell *et al.*, 2010). For example, in La Paz, Mexico, increase in market supply of medium-sized Pacific red snapper (*Lutjanus peru*), due to tourism-driven demand, was shown to result in a reduced supply and price of large fish species (Reddy *et al.*, 2013).

In Kenya, where coastal fisheries are largely artisanal, both the catch harvesting, and supply/processing chain activities have been studied but mostly in a piecemeal, non-integrated manner. Catch harvesting is heavily influenced by climatic seasons, with higher fishing effort and catches during the calm, dry North-East Monsoon (NEM) season, from October to March than during the rough and cool South-East Monsoon (SEM) season between April and September (McClanahan, 1988; Van der Elst *et al.*, 2005). Moreover, catch harvesting is mainly restricted to the inshore lagoons along the continuous fringing reef, and mangrove creeks (Munga *et al.*, 2012). Further, several studies on post-harvest processes such as the role of women in fish trade (Matsue *et al.*, 2014), the change in fish transport culture (Gerlach, 1963), the involvement of middlemen in fish trade (Crona *et al.*, 2010; Crona and Rosendo, 2011), value addition and fish marketing by traders in local markets (Wamukota, 2009) have been conducted separately along the Kenyan coast.

This study uses Ostrom's framework (Fig.1) to steer the integrative assessment of the processes between and within the harvesting and supply-chain processes (including catch processing) in Kenyan artisanal fisheries. Although the Ostrom framework provides for the four aforementioned dimensions, the focus in this study is on generating knowledge about the outcomes resulting from interactions (investment/trade (I5) and self-organizing (I7) activities) between two key dimensions, resource units and resource user groups, as well as the impact of external factors such as climatic seasonality (which describes the environmental conditions where the resources are located) and market forces influencing trade in order to postulate the outcome.

Within each of the two dimensions, a subset of second-level variables have been further highlighted, which are readily measurable or have been proposed by existing literature to directly influence the harvesting and supply-chain processes in a CAF (Basurto *et al.*, 2013; Ostrom, 2009). Within the resource units, the second-level variables focused on include economic value (RU4), number of units (RU5), and spatial and temporal distribution (RU7). For the resource user groups the number of users (U1), social economic attributes of users (U2), norms/social capital (U6) and technology used (U9) (Fig.1), are considered.

Materials and methods
Study area
The study was conducted in Gazi village, on the south coast of Kenya, near the townships of Msambweni and Ukunda, and about 50 km from the city of Mombasa (Fig. 2). The site was selected since it is an active research area with substantial existing scientific information, covered by the Kenya Marine and Fisheries Research Institute's Gazi field station. Research at Gazi is mainly concentrated on mangroves, seagrass and coral, and on the human interactions associated with these.

Gazi is a coastal fishing village with about 4000 inhabitants, according to the 2009 Kenya population census. The village is adjacent to Gazi Bay, which comprises a shallow channel of approximately 4 km long fringed by mangrove forest dominated by the species *Sonneratia alba* and *Rhizophora mucronata* (Bosire *et al.*, 2003). Gazi Bay, fronting the channel, is approximately 1.5 km² and is protected by the Chale Peninsula to the east and a coast-fringing reef to the south (Kimani *et al.*, 1996). The coral reefs largely contribute to the fish communities of adjacent seagrass and mangroves (Okechi and Polovina, 1995; Bennett *et al.*, 2001).

The Gazi fishing area, fish landing site and public beach are managed by the Gazi Beach Management Unit (BMU). BMUs were developed under the Fisheries Beach Management Legislation 2007, which aims at promoting stewardship and sustainable exploitation of fisheries resources by all stakeholders in collaboration with the national and county governments. BMUs have jurisdiction over a beach, the geographical area that constitutes a fish-landing station and is adjacent to the local fishing grounds (Oluoch *et al.*, 2008). Fish is locally traded in Gazi village with external markets for excess fish found in the nearby townships of Msambweni and Ukunda as well as the city of Mombasa.

In the past four decades, there has been a substantial immigration of fishermen, both permanent and seasonal, especially from Pemba Island in Tanzania, who continually transform Gazi's fishery sub-sector with their relatively efficient fishing capability (Ochiewo,

Data collection

Three data sets were collected and used to identify and quantify the resource units and the resource user groups. In the first set, the snowball method, which involves interviewing individuals from ini-

Figure 2. Map showing the study sites. Sites 1 and 2 are the main and alternative landing sites respectively in Gazi. The alternative landing site 2 is mostly used during the NEM. Number 3 is Gazi village (Adapted from Bosire et al. (2003)).

2004). However, other than small scale artisanal fisheries trade, which is the main source of income, there are relatively few alternative livelihood opportunities in the village (Richard and Stephen, 2012).

tial resource user groups, who in turn identify new stakeholder categories and contacts (Reed *et al.*, 2009), was used to identify key resource user groups in the trade chain. The initial respondents of the

interviews were identified using key informants from Gazi BMU and the Kenya Marine and Fisheries Research Institute (KMFRI). Resource user group semi-structured questionnaires (Hay, 2000; Young *et al.*, 2018) were employed for data collection. Two sets of questionnaires were developed – for the fishers and the trader groups. The questionnaires were developed using split and funneling questions, which were brainstormed beforehand with guidance of experienced researchers from KMFRI and fishery officers from the Kenya State Department of Fisheries. The respondents were informed about the aim of the study and were requested to give consent before being interviewed. Data recorded included the respondent's fish suppliers and /or customers, amount and type of fish traded, fish processing methods, challenges faced in their trade, and cost of doing the trade. Additional demographic information including age, gender, alternative income-generating activities, amongst others, were recorded where applicable. The questionnaires were written in English but administered in Kiswahili, the national language, when appropriate. In total, the questionnaires were administered to 60 respondents across the different resource user groups. Additional information was collected through non-participant observations and telephone surveys (when impossible to physically reach the respondents) using the same questionnaires.

The second dataset comprised of existing shore-based catch assessment data from January 2013 to April 2014 for the Gazi fishing area that was obtained from KMFRI, was used for analysis of resource units, i.e. catch composition (species and weight). Additional data captured (but not presented in this study) included fishing craft and gear types (technology), and fishing grounds (resource system) accessed.

The final dataset on resource units included existing catch data (from January 2011 to June 2016), obtained from the Gazi BMU and the Kwale County Fisheries Department (KCFD). The data included aggregated total monthly weights (in kg) of sharks and rays, crustaceans, mollusks (octopuses, sea cucumbers and squids), and major demersal and pelagic fishes from the fish markets, listed against their respective prices per kg for Gazi and the entire Msambweni area. This data set compliments the second one, since BMU catch records are obtained from a wide pool of fishermen over a long period, given that BMUs, through the Beach Management Units Regulations, 2007 of the Management and Development Act, have the primary rights over fish landing sites and are required to provide data on catches in order to ensure sustainable fisheries.

Data analysis

Responses to the questionnaire sections surveying catch acquisition practices, i.e. fishing method, fishing effort, composition and weight of the catch (among fishermen), and amount of fish stock purchased per trading day (among different trader categories) was used to estimate how much fish was traded by each resource user groups. This was done by finding the median of the fish amount respondents indicated they purchased or sold per day in each season. The median was preferred as the measure for central tendency due to the skewed nature of the data obtained from each respondent group.

Sample-based rarefaction curves analyses were applied to the second dataset, to assess for variation in catch by season. This analysis is based on the observation that species richness obtained from a sample (*n*) of plots increases with sampling efforts (Gotelli and Colwell, 2001). As the curve approaches an asymptote it shows that few or no new species may occur in additional sampling units (Bacaro *et al.*, 2012). The curves are interpreted by checking the expected number of species at a given sampling effort (number of samples). This was followed by the SIMPER analysis, to calculate the contribution of each species (%) to the dissimilarity between each season. SIMPER analysis is calculated from the Bray-Curtiss dissimilarity matrix, with the last two columns showing the contributions for each species in descendant order, and it is accumulative (Gibert and Escarguel, 2019).

Finally, the third dataset was visualized for monthly variations in total catch weight amounts using trend lines, whereas pie charts were used to indicate the percentage weight contribution of each catch group to the total catch for the Gazi landing site between 2011 and 2015.

Results
Seasonal variation of resource units
Based on the catch data (dataset 2), higher landings were observed during the NEM season compared to the SEM season in all years (Fig. 3). In total, 73 species belonging to 36 families were identified from the total number of 889 and 839 individuals sampled during the SEM and NEM seasons, respectively. Landings
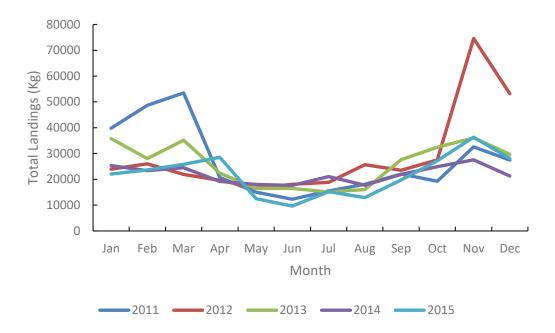
Figure 3. Total monthly landings (kg) for the period between 2011 and 2015 showing high quantities in NEM (October to March) and relatively low SEM landings (April to September) for Gazi landing site.

were dominated by bony fishes (92 %), mollusks (4 %), sharks and rays (2 %), and decapod crustaceans (2 %) (Fig. 4). Rarefaction curves analysis indicated more species were available during the NEM than SEM season (Fig. 5). A dissimilarity of 86.1 % between the two seasons was mainly caused by 16 species (summarized in Table 1) which were more abundant in the SEM than NEM.
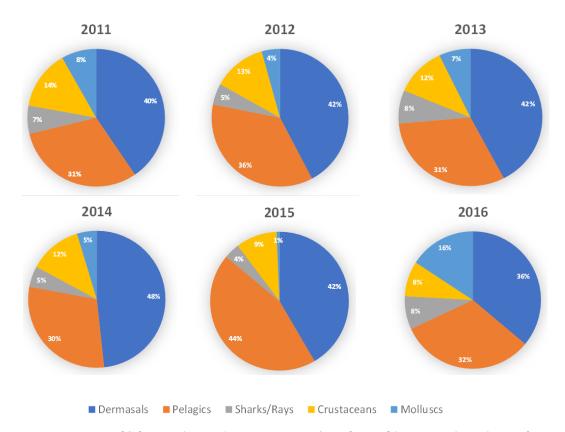

Figure 4. Proportion (%) of different catch groups between year 2011 and 2016 for Gazi fishing area on the south coast of Kenya based on existing catch data (source: Kwale County Fisheries Department).
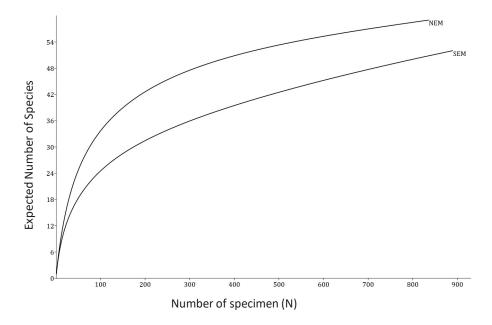
Figure 5. Rarefaction curves comparing expected species per number of individuals sampled during the NEM versus the SEM at Gazi landing site, Kenya.

Table 1. SIMPER results showing a seasonal dissimilarity of 86.1 %, based on catch composition, between the NEM and SEM at Gazi landing site, Kenya. The dissimilarity was caused by the 16 most abundant species listed herein.

	NEM	SEM			
Species	**Av. Abundance (%)**	**Av. Abundance (%)**	**Av. Dissimilarity**	**Contribution (%)**	**Cumulative (%)**
Hyporhamphus affinis	0.33	1.22	11.20	0.67	13.32
Calotomus carolinus	0.62	1.19	10.97	0.87	13.04
Katsuwonus pelamis	0.22	1.05	9.24	0.58	10.99
Carangoides ferdau	0.34	0.20	6.96	0.73	8.27
Anampses caeruleopunctatu	0.54	0.51	5.65	0.81	6.71
Himantura uarnak	0.19	0.61	5.15	0.82	6.12
Aphareus furca	0.22	0.17	3.66	0.51	4.36
Kyphosus cinerascens	0.08	0.58	3.63	0.72	4.31
Caranx melampygus	0.29	0.59	3.24	0.58	3.85
Istiompax indica	0.23	0.87	3.03	0.47	3.60
Lutjanus sp.	0.28	0.24	2.59	0.44	3.08
Cephalopholis argus	0.24	0.18	2.57	0.59	3.05
Carcharhinus melanopterus	0.08	0.55	2.14	0.53	2.54
Aetobatus narinari	0.10	0.04	2.08	0.40	2.48
Lethrinus harak	0.18	0.18	1.85	0.47	2.19
Lutjanus argentimaculatus	0.10	0.30	1.53	0.50	1.82
Chanos chanos	0.23	0.12	1.40	0.35	1.66

Further, analysis of dataset 3 indicate higher catch proportions of pelagic fish from 2011 to 2014 and demersals for year 2015 and 2016 (Fig. 3)

Resource user groups operations

In total, 6 key resource user groups, comprising of 32 fishermen, 16 retailers, 5 major fish dealers, 1 representative of a Fish Processing Company (FPC) and representatives of 6 hotels were identified and interviewed (Fig. 6). The retailers were further classified into two groups: fish mongers (selling unprocessed fish) and mama karanga (women who process and cook the fish before selling it). Figure 6 (b) provides a description of each actor category.

Nearly all the interviewed fishermen had prior agreements or preferred traders to whom they sell their catch, with 50 % of them preferring to sell to middlemen (dealers), 27 % to fish mongers, and 23 % to small-scale fish processors (mama karanga). No fishermen were recorded selling their catch directly to consumer markets, hotels or FPCs. Dealers on the other hand, hire or employ fishermen and possess fishing gears and crafts which they lend to the hired fishermen. All the interviewed dealers responded that they hired fishermen specifically from Pemba in Tanzania, during the NEM season. Remuneration and sharing of profits between the dealers and fishermen are catch percentage-based. For instance, one dealer reported buying the fish from the fishermen at $1/kg and selling it at $1.45/kg. The fishermen further give an additional 20 % of their revenue ($1) to the dealer as a gear-hiring fee and shared the remaining amongst themselves.

Although dealers mainly supply the hotels and Fish Processing Companies (FPC), they also supply to other traders including small-scale fish processors and fish mongers, especially during the low-landings SEM season (Fig. 7). Thus, dealers play an integral role in the trade; directly financing the fishermen, providing key links between fishermen and others, facilitating acquisition of fish by other resource user groups, and hence smoothing the trade.

Both small-scale fish processors and fish mongers purchase fish directly from the fishermen. However, none of them reported directly hiring fishermen; instead, most of these traders extend loans to the fishermen by means of cash, boat fuel and lighting to those who fish at night (Fig.7). None of the hoteliers interviewed had direct investments in the fishery trade. However, the FPC reported that they owned three fishing boats on different parts of the coast which were lent out to fishermen.
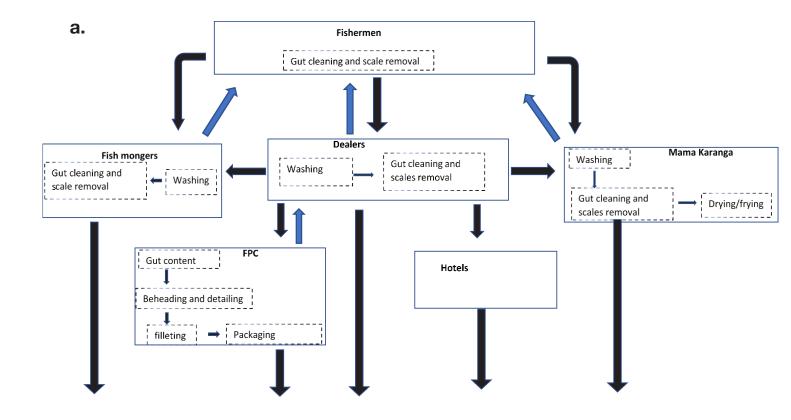
Resource units traded within actor groups

On average, fish dealers purchase more fish (between 100 and 700 kg per day depending on season) than small-scale fish processors and fish mongers with a range of between 10 and 30 kg per day each. The three categories of traders are not highly selective with regard to the type of fish as neither listed preference to any specific fish size or species. Hoteliers on the other hand buy the fish depending on demand, which is higher during the peak tourism period that is between July and December, coinciding with the NEM season (Fig. 7). For instance, one of the hoteliers indicated they buy between 8 and 60 kg per week depending on season. In addition, they have a higher preference for the pricey high trophic level fish species that are large and fleshy such as tuna and kingfishes (Scombridae), red snappers (Lutjanidae), and mullets (Mugilidae).

Finally, the FPCs trade in relatively large amounts of fish compared to the other resource user groups and are supplied with fish by many dealers from Gazi and other fishing areas. During the NEM season, procuring is more oriented towards finfish, amounting to between 5 and 15 tons of fish per day and shifts towards crustaceans and mollusks in the SEM which reduces the catch to between 3 and 8 tons per day.

Catch processing

Catch processing varied with the form of catch, individual catch size or the agreement between the resource user groups. For instance, de-gutting by fishermen is restricted to the large fish species such as *Coryphaena hippurus* (Coryphaenidae) and to some elasmobranchs species (sharks and rays). Fishermen removed the claws of crustaceans (lobsters and crabs) on a case-by-case basis before weighing and selling to the traders. The rest of the catch is sold unprocessed to the other traders (Fig. 6). Dealers also hire workers to process (mostly cleaning and removing scales) the catch that is sold to hotels and FPCs but not when selling it to the small-scale fish processors and fish mongers. Processing by FPCs is more comprehensive and normally involves scaling and de-gutting, filleting, and beheading (Fig. 6). It is also tailored to suit the customer or market demand; for instance, fish destined for South African markets is processed to fillet form whereas thise for the Saudi Arabian market could be filleted or frozen whole.

a.

Fishermen

Gut cleaning and scale removal

Fish mongers

Gut cleaning and scale removal ← Washing

Dealers

Washing → Gut cleaning and scales removal

Mama Karanga

Washing ↓ Gut cleaning and scales removal → Drying/frying

FPC

Gut content ↓ Beheading and detailing ↓ filleting → Packaging

Hotels

Consumer Markets

b.

Fishermen	✓ Involved in capture and landing of fish
Dealers	✓ Buys fish in large amounts (>50kg/day) ✓ Hires fishermen, owns many fishing gears and boats ✓ Transports fish in relatively large amounts ✓ Own freezing facility and permanent-structured fish shops
Fish Mongers	✓ Trade in <50kg fish/day ✓ Include individuals vending along roads, open air markets and in temporally sheds
Mama Karanga	✓ Sell in small quantities ✓ Fry fish prior to selling it
Fish Processing Companies (FPC)	✓ Highly selective in species and size ✓ Conduct Advanced processing of fish *e.g.* produce fish fillets ✓ May be involved in exporting

Figure 6 (a). Schematic representation of the catch supply chain on the south coast of Kenya, showing the main resource users (block boxes) and processing within each resource user group (dashed boxes). The flow direction of fish / products is shown by the black arrows, whereas direct investments, which include fishing gear, boats and credit are indicated by the blue arrows. The key users (U) are briefly defined and described in Table (b).
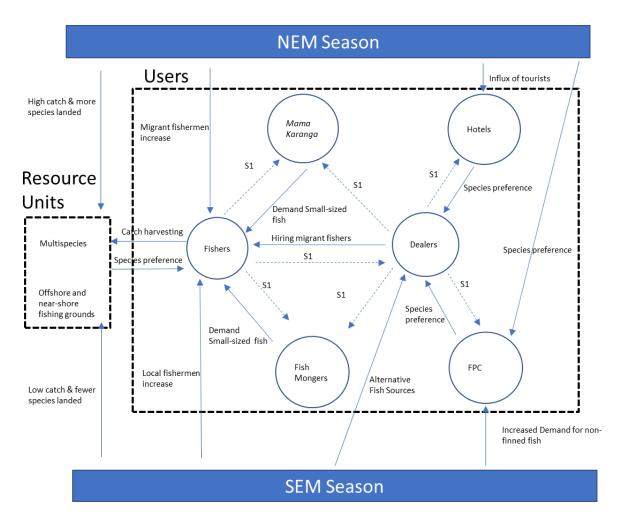
Figure 7. Interactions (dashed arrows) and implications (block arrows) between Resource Units (RU) and Users (U) components in the Gazi CAF system. S1 indicates supply chain direction among users as elaborated in Figure 6. The top and bottom block boxes are the contrasting calm NEM and rough SEM seasons respectively. NEM season coincides with the peak tourism season, which results in high fish demand from hotels. FPCs also demand large pelagic fish during the NEM and finance the dealers to secure their supply. The dealers in turn hire migrant fishermen during the NEM, increasing fishing effort which in turn results to landing of more species (see Fig. 3). In contrast, low tourism and rough sea conditions during the SEM results in low fishing effort with low catch and fewer species landed.

Discussion
Resource units
Previous studies have indicated distinct seasonal variation in finfish catches along the Kenyan coast. Lower catches during the wet SEM season was attributed to low fishing effort owing to the rough sea conditions hampering artisanal fishing activities (McClanahan, 1988; Agembe *et al.*, 2010). Furthermore, during the calm NEM season, fishermen access a wider variety of fishing grounds, operate in larger areas, across a wider range of habitats while using a variety of fishing gears and methods, hence landing higher catches. Contrasting studies however report that more species are landed during the SEM than NEM season, attributing this to fishermen concentrating their efforts around the inner reef, with a higher habitat complexity

(McClanahan, 1988; Van der Elst *et al.*, 2005; Wamukota, 2009; Agembe *et al.*, 2010; Munga *et al.*, 2012).

Organization of resource user groups
According to the Government of Kenya (2016), there were about 13,000 artisanal fishermen along the Kenyan coastline, each playing a key role in sustaining a fish trade network for suppliers, processors and traders. The documented fishermen-trader agreements are important as they provide means for fishermen to secure income and fish market access during the surplus NEM season. Similarly, traders are assured of stock and labour especially from the migrant Pemba fishermen (Wamukota *et al.*, 2015). These localized social and economic networks remain important to the economy and social

components of the communities even as other sectors of the country's economy such as mining, agriculture and tourism experience rapid growth.

Since low quantities of fish are landed and sourced locally among different resource user groups during the SEM season, some users have means of sourcing fish stocks externally during this season (Fig. 7). For instance, the dealers reported operating fish retail shops which outsource imported Chinese fish from the fish market in Mombasa, at an even lower cost. Fish mongers and small-scale fish processors in turn source this fish from these retail shops. Other studies Crona, 2006; Bodin and Crona, 2008; Cinner *et al.*, 2010); Daw *et al.*, 2011) documented various alternative income-generating activities that different users engage in to supplement their income during this low season.

The resources user chains, (Fig. 6) in this CAF system are relatively short and poorly organized compared to similar systems elsewhere. For instance, around Lake Victoria in Kenya, fishermen are registered within cooperatives which are used as channels for selling fish to FPCs; while the FPCs may have arrangements for directly hiring fishermen (Abila and Jansen, 2007). Furthermore, it is apparent that the fish-processing methods as well as the processing links are very basic, hence a large proportion of fish reaches target markets in an unprocessed state. This contrasts with other tropical CAFs in areas such as Ghana, Sierra Leone, and Cameroon where a range of processing methods such as smoking, fermenting, sun-drying, grilling and frying are applied prior to transporting fish to different markets (Essuman, 1992; Nfotabong *et al.* 2009; Kallon *et al.* 2017).

Interactions between the resource units and user groups within the CAF system

CAFs, just like other socio-ecological systems, are characterized by numerous, complex vertical and lateral interactions between and within the four key components proposed by Ostrom (2009): resource user groups, resource units, resource system, governance systems and expected outcomes (see Fig. 1). The interactions, which have multiple stable states, comprise the catch harvesting and supply processes as well as management procedures. In Kenya, transition between the multiple stable states is normally initiated by seasonal change in accessibility of fishing grounds, market availability as well as change in fishing technology (see Fig. 7). Thus, notwithstanding the socio-economic importance attached to CAFs by

the country, their operations and stability are usually characterized by a high degree of uncertainty due to their heavy dependency on the external forces of tourism and climatic seasonality (Fulton *et al.*, 2011).

The demand, supply and catchability of fish are highest during the NEM season and relatively lower during the SEM (See Fig. 7). As such, hotels and FPCs buy more fish during the NEM season; FPCs due to abundant supply, and hotels due to increased demand created by the tourism influx between December and March. Both users have a preference for the high-priced, large pelagic finfish and lobsters, which mostly occur in offshore fishing grounds (Crona *et al.*, 2010). Therefore, seasonal demand created by the two user groups may directly influence the type of fish that is sought as well as the fishing effort variation within the CAF (Fig. 7). This is reflected by the dealers who hire migrant fishermen from Pemba during the NEM season, with better offshore fishing skills. Increase in fishing effort as well as a wider variety of fishing habitats accessed during NEM in turn results in more fish species landed during this season (Fig. 7). Notwithstanding the costs of importing migrant fishermen's labour, dealers consider these fishers to be easily available and more efficient compared to the local fishermen, especially during the NEM season, who in most cases are less competent compared to the more effective migrant fishermen (Samoilys *et al.*, 2017).

Although patterns in numbers of migrant fishermen in Kenya have been well documented, details on the variation in number of local fishers during the overlapping NEM-peak tourism season are contrasting. For instance, Daw *et al.* (2011) stated that the number of fishermen increases as more people take advantage of the calm sea hence engaging in fishing activities, whereas Tuda *et al.* (2008) observed that the number of fishermen decreases since local communities may prefer to be employed in tourist-related work which is better paying.

While both hoteliers and representatives of FPCs reported preference of certain species of fish, size of catch has previously been described as the main factor determining the market to which the fish is shipped or brought (Crona *et al.*, 2010). The small and medium-sized catch, for both the high and low-priced species, are mainly purchased by the small-scale fish processors and fish mongers. These categories of fish are destined for the local markets and

have a special relevance to local food security since they are the easiest to access and the most affordable source of animal protein for the majority of people in the local communities (Creel, 2003). However, the small-sized fish are often caught from lagoons and inshore fishing grounds using mainly unselective and destructive fishing gears such as beach seines. With the growing human population in these areas, the demand for these unsustainably harvested fish continues to grow, hence compromising the state of fish stocks and the integrity of the shallow coastal habitats which serve as fishing grounds.

On the other hand, increased demand for large pelagic species in the market can result in an increase of their market price and can encourage more fishermen to overexploit these species. For instance, there are records of increased use of spearguns, an illegal traditional fishing gear, in Gazi during the NEM season, as fishermen target highly priced parrotfishes (Scaridae), grouper (Serranidae), snappers (Lutjanidae), rabbitfishes (Siganidae), octopus (Octopodidae) and lobsters (Nephropidae) (Fonteneau *et al*., 2013; Tuda *et al*., 2016). If uncontrolled, the selective harvesting of large species can cause a change in trophic composition, where overexploitation of such species results in their decrease, and eventually fishermen end up targeting other less valuable species from lower trophic levels (Pauly *et al*., 1998).

Conclusion

The socio-ecological system framework (Fig. 7) provides a structured and systematic way to describe and analyze coastal artisanal fisheries in Kenya – showing the composition and interactions between and among the multiple elements in this sectoral system. Moreover, both the socio-economic and ecological sub-systems of a coastal artisanal fishery are dynamic and co-evolve because of their interaction and in response to common external drivers such as season and tourism. Knowledge of how resource user groups organize within the supply chains and how this organization influences harvesting preferences and behavior can be important in strengthening both the socio-economic and ecological resilience within a coastal artisanal fishery through management of their adaptive cycles, with an aim of sustaining the resource units and ecosystem services at multiple scales. Moreover, such information can enable coastal artisanal fishery managers to anticipate more accurately how relationships and feedbacks within their system, intended or unintended, affect the achievement of management objectives.

Secondly, both the demand and supply or availability of the resource units (fish) increase simultaneously during the meteorologically calm, high-tourism NEM season. When both demand and supply increase, there is an increase in the equilibrium output which determines the general market price where fish tend to be more expensive during the SEM season (Fig.7). Combining this fact with the common property nature of the fishery resource, there is a risk of overexploitation of the resource units as well as a dissipation of the income yielded from these resources. To avoid a collapse of the coastal artisanal fishery, management plans taking into consideration the interactive nature of catch harvest and market dynamics should be formulated and implemented in close collaboration with all key resource users.

Finally, this study tracked two key sub-systems (resource user groups and resource units) plus their second-level variables (the amount and type of catch, the number of resource users etc.) and the outcomes of their interactions (Fig. 1 and Fig. 7). The choice of sub-systems and variables to study was guided by the key research question, "How is the artisanal fisheries trade organized in a coastal artisanal fishery like that on the Kenyan coast?" However, this still leaves a knowledge gap on interactions and outcomes between other sub-systems and key variables within this socio-ecological system. Therefore, this study recommends further, complementary studies on the same topic, based on Ostrom's SES model.

Acknowledgements

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