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Characterisation of artisanal catches in selected fishing areas of the Lower Tana Delta and Malindi-Ungwana Bay, Kenya

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Abstract
Shore-based assessment of fisheries resources in Ngomeni, Kipini and Ozi fishing areas of Malindi-Ungwana Bay and the Lower Tana Delta on the north coast of Kenya was conducted from January to December 2017 to establish catch composition, species richness, and fishing effort (catch-rate, number and types of fishing gears and crafts) in the marine, estuarine and riverine habitats. Distinct catch composition (R = 0.27, P < 0.05) was observed across the three habitats. Catch composition differed significantly spatially and seasonally across the three fishing areas, and between the north east (NE) and south east (SE) monsoon seasons (R = 0.332, P < 0.05). The wolf herring, Chirocentrus dorab, was the most abundant fish species in Ngomeni, centrally located in Malindi-Ungwana Bay, while the catfishes, Arius africanus and Clarias gariepinus, were the most abundant species in Kipini and Ozi, respectively. Gillnets operated from dhows (mashua) and fibre-reinforced plastic (FRP) boats in Ngomeni (marine), and canoes using-basket traps in Ozi (riverine), landed significantly larger Spanish mackerel, Scomberomorus commerson, and sea catfish, Arius africanus (Kruskal Wallis test: Df = 2; F = 197.141; p < 0.001; Df = 2, F = 490, p < 0.001), respectively. Species diversity by area in combination with habitat and type of fishing craft showed higher diversity for Ngomeni in the marine habitat with mashua fishing crafts than in Kipini. Significantly different catch rates (Df = 2, F = 10.43, p < 0.001; Df = 1, F = 5.897, p < 0.021) were observed in the three (3) fishing areas and during the NE monsoon and the SE monsoon, respectively. Canoes were the most common fishing craft used, especially in Ngomeni, accounting for 37.1%, and 97.5% in Ozi, while mashua crafts accounted for 44.5% of the total fishing craft in Kipini. Monofilament nets were most common in Ngomeni (84.0%) while basket traps dominated the Ozi site at 68.6%. The Kipini area was dominated by handlines (28.8%). It is therefore evident that the three (3) fishing areas of the Malindi-Ungwana Bay and Lower Tana Delta showed significant differences in catch composition and size of fish caught, attributed partly to the variation in habitat types and fishing methods between the sites. Overall, the Ngomeni area was characterized by more advanced fishing craft with the majority powered by engines, including mashua and FRP boats, compared to Kipini and Ozi fishing areas where canoes were dominant.

Keywords: Artisanal fisheries, Catch composition, Malindi-Ungwana Bay, Lower Tana Delta, Kenya
Introduction
The value of fisheries resources to humanity has been extensively reviewed in numerous socio-economic systems (Cinner et al., 2011; FAO, 2012; Metcalf et al., 2015) and still receives special attention globally due to the dynamic nature of coastal and marine socio-ecological systems (Fuller et al., 2017). Fisheries systems need to be regularly assessed in order to understand their current status. Artisanal fisheries, especially in the tropics, have been variously characterized by different studies.

Rondeau et al. (2016) identified and characterized important sites for fish and invertebrates in the coastal waters of the Gulf of St. Lawrence, Canada with the aim of conserving and managing endangered species. Suris-Regueiro and Santiago (2014) described the relationship between coastal and marine fisheries dependency and employment by characterizing income and employment from fisheries in Galicia, Spain. Some studies have acknowledged the challenge on enhancing artisanal fisheries management due to their open access nature (KMFRI, 2008; González-Alvarez et al., 2016; Siddons et al., 2017). Other studies have narrowed the focus and characterized catch by different gears in different sites to determine fishing effort for fisheries management (Laurence et al., 2015; Munga et al., 2014).

Despite the significance of coastal and marine fisheries in supporting the commercial and subsistence fishery sub-sectors in the Malindi-Ungwana Bay and the Lower Tana Delta on the north coast of Kenya, the main fishing areas have not been extensively. The majority of the studies have concentrated on fisheries resources of the estuarine and marine environments, neglecting the riverine habitat (Abila, 2010; Munga, et al., 2012; Munga, et al., 2014). Studies have however described the impact of the semi-industrial bottom trawl fishery on the artisanal fishery, and the resultant conflict arising from targeting the same species and accessing the same fishing grounds (Munga et al., 2014). Variations in the seasonality and bathymetry of decapod crustacean communities have also been studies (Ndoro et al., 2014). The trawl fishery is responsible for very high bycatch (71.9%) in the Bay (Fulanda, 2003). Importantly, these studies have demonstrated the effectiveness of government regulations that were imposed on the bottom trawl prawn fishery which had previously negatively impacted the fishery (KMFRI, 2008).

The Ungwana Bay ecosystem can be categorized into marine, estuarine and riverine habitats. The three main fishing areas are located at Ngomeni in the south of the bay, and Kipini and Ozi further north in the bay. This paper characterizes the artisanal catches in the three main fishing areas with reference to habitats types. Comparisons are made between seasonal and spatial (habitats) catch composition by species and size, and fishing effort in terms of catch rates, fishing craft and quantity of gear.

Materials and methods
Study area
The study was conducted in the Malindi-Ungwana Bay and lower Tana Delta on the north coast of Kenya covering the fishing areas of Ngomeni, Kipini and Ozi (Fig. 1). Ngomeni and Kipini are located within the bay while Ozi is located in the Lower Tana Delta on the Tana River. These areas experience two seasons annually; the North East Monsoon (NEM) from October to March, and the South East Monsoon (SEM) from April to September (McClanahan, 1998). The Malindi-Ungwana Bay and Lower Tana Delta are among the richest ecosystems along the Kenyan coast and support both artisanal and commercial fisheries (shrimp bottom trawl) and other socio-economic activities (Abila, 2010).

Data collection
Concurrent shore-based catch assessment surveys were carried out for 8 days of every month from January to December 2017 in Ngomeni, Kipini and Ozi fishing areas. Catch and landings were sorted to species level, and total weight (kg) by species recorded with a weighing balance, while individual total length (TL, cm) was measured using a measuring board. The species were identified using the FAO Species Identification Guide for marine resources in Kenya (Anam and Mostarda, 2012). For large catches, the total weight was first measured, and then a homogenous sub-sample was randomly taken from the catch where different fish species were separated before measurements were done. For small catches, a similar procedure was followed but without sub-sampling. The fishing time (hrs), type of fishing craft, crew size and the type of fishing gear used were recorded.

Data analyses
Seasonal catch rate (kg/fisher.hr−1) was calculated for each fishing area. In each area, the total weight for each month was divided by the total number of crew (catch/fishers, W/f), and then divided by the total number of fishing hours from the same month (W/f.hr−1). The seasonal average catch rates were then computed for
each area. The Non-Metric Multidimensional Scaling (nMDS) technique was used to determine whether distinct seasonal catch composition existed across habitats, and also across fishing areas. Differences in catch rates between seasons and across fishing zones were determined using the 2-way ANOVA test. Since data was non-parametric, transformed data log (X+1) was used for the 2-way ANOVA parametric test, and homoscedascity of variances was tested using the Levene’s test at p > 0.05. One-way ANOSIM was used to test significant difference in the seasonal catch composition across habitats and across the fishing areas. In both cases, 1-way SIMPER analysis was performed to identify which fish species contributed to the dissimilarity. Pair-wise comparison was conducted using the post hoc (Tukey HSD) test. These tests were conducted using STATISTICA statistical software v.7. Microsoft Excel was used to determine the mean length of the most abundant species in each fishing zone with craft-gear combination. The differences in species length between the different craft-gear combinations were tested using the non-parametric Kruskal-Wallis test. Rarefaction curves were used to determine species diversity across fishing zones with habitat and craft-gear combination. Craft and gear frequencies as well as the frequencies of the 5 most abundant species in each fishing zone were also determined using Microsoft Excel.

**Results**

**Composition of fin fish species in Ungwana Bay and Lower Tana Delta**

During the study period a total of 191 fish species were identified, comprising 104 species recorded in the NEM season and 87 species in the SEM season. Kipini landed 33.4 Mt during the survey period followed by Ngomeni with 29.9 Mt, while Ozi landed the lowest catches with 2.2 Mt. From these landings, a total of 19,943 individuals were sampled in Malindi-Ungwana Bay and Lower Tana Delta during the study.
Non-Metric Multidimensional (nMDS) plots showed distinct separation of samples across habitat types (Fig. 2). One-way ANOSIM indicated a significant difference in sample composition across the habitat types ($R = 0.27; P < 0.001$). Results of pair-wise comparison tests confirmed significant differences in the composition of samples across all habitat types ($P < 0.05$ in all cases). A distinct fin fish composition was also observed across the fishing areas with season (Fig. 3). Similarly, 1-way ANOSIM indicated a significant difference in sample composition across fishing areas with season ($R = 0.332; P < 0.001$). Results of pair-wise comparison tests confirmed significant differences in the composition of samples across all fishing areas with season ($P < 0.05$ in all cases), except Ozi which indicated no significant seasonal difference ($R = 0.003; P < 0.421$). Results of SIMPER analysis showed that while *Arius africanus*, *Otolithes ruber* and *Pelona ditchela* contributed most to the dissimilarity in the estuarine habitat, *Chirocentrus dorab*, *Pristipomoides filamentosus*, *Scomberomorus commersoni* and *Pristipomoides sieboldii* contributed most to the dissimilarity in the marine habitats of Kipini and Ngomeni (Table 1).

**Species richness and abundance**

Based on fishing areas, habitat and fishing craft type, rarefaction curves showed that the Ngomeni-marine-*mashua* category recorded the highest number of species, followed by the Ngomeni-marine-canoe category, while Kipini-estuarine-outrigger canoe, and Ozi-riverine-canoe categories recorded the lowest number of species (Fig. 4). Based on the types of fishing gear used, the rarefaction curves showed that monofilament nets caught the highest number of species, followed by gillnets, seine nets, handlines, basket traps, longlines and spearguns (Fig. 5).
For the Ngomeni fishing area, the 5 most abundant fish species sampled were *C. dorab*, *S. commersoni*, *Thunnus albacares*, *Euthynnus affins* and *Rastrelliger kanagurta* (Table 2). For Kipini, the 5 most abundant species were *A. africanus*, *O. ruber*, *P. ditchela*, *Argyrops spinifer* and *P. filamentosus* (Table 2). *C. gariepinus*, *A. africanus*, *P. limbatus*, *Oreochromis niloticus* and *Protoptera annectens* were the 5 most abundant fish species captured in Ozi (Table 2).

### Artisanal fishing gear and craft
Comparisons on the types of artisanal fishing gear used in the study area showed that basket traps were most common in Ozi fishing area at 63.6%, followed by handlines (28.8%) in Kipini, and monofilament nets (34%) in Ngomeni (Table 3). Analysis of the fishing-craft types indicated that canoes were most common in Ozi (97.5%) with foot fishers accounting for ~2.5%. Canoes were also most common in Ngomeni (37.1%) followed by *mashua* craft (32.6%), and FRP craft and foot-fishers at 26.4% and 3.9%, respectively. *Mashua* craft were most common in Kipini (44.5%), followed by foot-fishers (28.5%) and canoes (27.0%).

### Fishing effort and species sizes
During the study period, the mean catch rate (kg/isher.hr⁻¹) in the Malindi-Ungwana Bay and Lower Tana Delta was higher during the NEM season than the SEM season in Ngomeni and Kipini fishing areas (Fig. 6). However, the Ozi fishing area showed marginal differences of catch-rate between the seasons (Fig. 6). Generally, the Ngomeni fishing area recorded the highest catch-rate followed by Kipini and Ozi, respectively (Fig. 6). The Two-way ANOVA test indicated a
significant difference in catch rate across fishing zones (Df = 2, \( F = 10.43, p < 0.05 \)) and between the seasons (Df = 1, \( F = 5.897, p < 0.05 \)). The Tukey HSD post-hoc pairwise comparison test confirmed that the catch-rates were significantly different between Ngomeni and Ozi as well as Kipini and Ozi (\( p < 0.05 \) both cases). The seasonal catch rate was significantly higher in the NEM than the SEM season for Ngomeni (\( p < 0.05 \)), but not for Kipini and Ozi (\( p = 0.82 \) and \( p = 1.00 \), respectively).

Based on species caught with craft-gear combination, \( S. \) commersoni was the most abundant species in Ngomeni while \( A. \) africanus and \( O. \) ruber were the most abundant in Kipini, with \( A. \) africanus also being most abundant in Ozi (Fig. 7). In Ngomeni, the gillnets used with FRP boats and mashua landed significantly larger individuals than those landed by monofilament nets with canoes (Kruskal Wallis test: Df = 2; \( F = 197.141; p < 0.05 \)). The Pair-wise comparison test confirmed

### Table 2. Five most abundant fin fish species by fishing zone in Ungwana Bay and Lower Tana Delta, Kenya.

| Species                     | Ngomeni number of individuals sampled | (% ) |
|-----------------------------|--------------------------------------|------|
| \( Chirocentrus \) dorab    | 1560                                 | 31.2 |
| \( Scomberomorus \) commerson | 644                                 | 12.9 |
| \( Thunnus \) albacares     | 228                                  | 4.6  |
| \( Euthynnus \) affinis     | 185                                  | 3.7  |
| \( Rastrelliger \) kanagurta | 180                                  | 3.6  |

### Kipini

| Species                     | Number of individuals sampled | (% ) |
|-----------------------------|------------------------------|------|
| \( Arius \) africanus       | 2396                         | 26.6 |
| \( Otolithes \) ruber       | 1426                         | 15.8 |
| \( Pelona \) ditchela       | 1261                         | 14   |
| \( Argyrops \) spinifer     | 583                          | 6.5  |
| \( Pristipomoides \) filamentosus | 566                   | 6.3  |

### Ozi

| Species                     | Number of individuals sampled | (% ) |
|-----------------------------|------------------------------|------|
| \( Clarias \) gariepinus    | 2672                         | 44.9 |
| \( Arius \) africanus       | 1829                         | 30.8 |
| \( Plotosus \) limbatus     | 748                          | 12.6 |
| \( Oreochromis \) niloticus | 522                          | 8.8  |
| \( Protopterus \) annectens | 158                          | 2.7  |

### Table 3. Composition of artisanal fishing gear types sampled in Ungwana Bay and Lower Tana Delta, Kenya.

| Types of gear               | Kipini (Freq %) | Ngomeni (Freq %) | Ozi (Freq %) |
|-----------------------------|-----------------|------------------|--------------|
| Basket traps                | 1 0.2           | 0 0.0            | 180 63.6     |
| Gillnets                    | 174 27.4        | 144 27.0         | 34 12.0      |
| Handlines                   | 183 28.8        | 174 32.5         | 1 0.4        |
| Longlines                   | 51 8.0          | 11 2.1           | 19 6.7       |
| Monofilament nets           | 159 25.0        | 182 34.0         | 0 0          |
| Ring nets                   | 0 0.0           | 3 0.7            | 0 0          |
| Scoop nets                  | 0 0.0           | 1 0.2            | 0 0          |
| Seine nets                  | 68 10.6         | 1 0.2            | 40 14.1      |
| Skin diving                 | 0 0             | 1 0.2            | 0 0          |
| Spearguns                   | 0 0             | 18 3.1           | 9 3.2        |
significant differences between mashua-gillnet and canoe-monofilament, and between FRP boat-gillnet and canoe-monofilament ($p < 0.05$ in both cases). All the craft-gear combinations used in Kipini landed significantly larger sizes of *A. africanus* and *O. ruber* (Kruskal Wallis test: Df = 6, $F = 327$, $p < 0.05$), except foot fisher-monofilament ($p = 0.09$). In the Ozi fishing area, the canoe-basket trap landed significant larger specimens of *A. africanus* than canoe-gillnet and canoe-seine net (Kruskal Wallis test: Df = 2, $F = 490$, $p < 0.001$). The pair-wise comparison test confirmed significant differences between canoe-basket trap and canoe-gillnet, and canoe-basket trap and canoe-seine net ($p < 0.05$ in both cases).

**Discussion**

Fisheries of the Malindi-Ungwana Bay and Lower Tana Delta on the north coast of Kenya focus on resources associated with marine, estuarine and riverine habitats. Ngomeni, Kipini and Ozi fishing areas show distinct fisheries catch composition attributed to differences in habitat type. Ngomeni is exclusively a marine habitat while Ozi is entirely riverine. Kipini is composed of both estuarine and marine habitats. Though not investigated in this study, the differences in environmental elements (nutrients, temperature, depths and turbidity) in different habitat types are the
key factors contributing to the distinct catch composition across habitat types and fishing areas (Winemiller and Leslie, 1992; Munga et al., 2013). For example, Winemiller and Leslie (1992) observed that the differences in environmental variables (depth, water type, substrate type and turbidity) in habitats determined the distinct assemblage of fish resources in tropical freshwater and marine ecotones. Munga et al. (2013) also made similar observations where the differences of depth, turbidity and season in Malindi-Ungwana Bay were the main environmental factors driving the distinct composition of panaeid shrimp species. The variations in environmental parameters in the 3 habitats are likely to be the key factors for the distinct catches experienced by the artisanal fisheries in Ngomeni, Kipini and Ozi.

In this study it was found that the marine habitat is rich in species diversity compared to the estuarine and riverine habitats. High species richness was observed in catches made by mashua boats in Ngomeni fishing zone. The mashua boats are equipped with outboard engines and sails and are able to exploit fisheries resources over longer periods during the year by accessing deeper offshore waters with high species diversity and landings (Munga et al., 2014). However, estuarine habitats are generally characterized by higher species diversity than the marine and riverine habitats. Murase et al. (2014) for instance, observed a higher species diversity in the estuarine habitat (53.6%) than the marine habitat (46.4%) in the gulf of Nicoya on the Pacific coast of Costa Rica. In the present study, the higher species diversity in the marine habitat may be attributed to the differences of fishing effort in the three (3) fishing areas. The Ngomeni fishing area (marine habitat) recorded the highest catch-rate compared to Kipini and Ozi. In addition to habitat and craft, high species richness was also associated with gillnets commonly used with mashua boats, leading to a catch with the highest species diversity (Munga et al., 2014).

Ngomeni, Kipini and Ozi reported different catch-rates associated with different fishing gears and craft. Ngomeni had considerably better fishing crafts including mashua and FRP boats. Kipini fishers also employed mashua boats but not the FRP boats, while FRP boats were absent in Ozi. The seasonal catch-rate was the during NEM season than the SEM season. Mwangudza et al., (2017) also observed higher catch-rates in the NEM season in Malindi-Ungwana Bay. The differences in weather conditions between the NEM and SEM seasons are a key factor in determining differences in catch-rates between the seasons (Munga et al., 2014) because the NEM season is characterized by warm temperatures and calm waters while the SEM season is associated with cool temperatures and rough waters (McClanahan, 1998).

In Ngomeni, the most abundant species landed with craft-gear combination was *S. commerson*. Largest fish were landed by mashua-gillnets confirming the observation made by Munga et al. (2014). This was associated with the ability of mashua boats (fitted with larger mesh-sized gillnets) to access offshore areas and larger fish (Munga et al., 2014). Like other tropical estuarine habitats, Kipini is characterized by a multi-gear and multi-species fishery. *A. africanus* and *O. ruber* were the most abundant species in Kipini, caught by seven (7) different craft-gear combinations. Siddique et al., (2013) made similar observations on multi-gear and multi-species catches in the estuarine habitat of the Meghna River, Bangladesh. *A. africanus* was also the most abundant species in the Ozi fishing area with canoe-basket trap combinations landing the largest sizes of this species. The Ozi fishing area borders on the Kipini estuarine habitat and is occasionally characterized by brackish waters which supports some of the marine-estuarine species including *A. africanus*.

**Conclusion**

Ngomeni, Kipini and Ozi fishing areas in Malindi-Ungwana Bay and the Lower Tana Delta have distinct catch compositions attributed to the existence of marine, estuarine and riverine habitats. The fishing zones are also characterized by different catch-rates mostly associated with differences in fishing methods. Marine habitats in the study area are rich in species diversity with larger sized individuals compared to the estuarine and riverine habitats. While mashua-gillnets and canoe-basket traps landed the largest sizes of the most abundant species in Ngomeni and Ozi respectively, multi-craft and gear combinations landed the largest fish in Kipini. Marine habitats were associated with larger sized individuals, suggesting that artisanal fishers would benefit from appropriate fishing crafts such as mashua and FRP boats to enable them to exploit the deeper offshore waters. It is recommended that artisanal fishers in these fishing areas are assisted to obtain the craft necessary to venture into the deeper marine habitats, which appear under-exploited, compared to the estuarine and riverine habitats.
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