Western Indian Ocean JOURNAL OF Marine Science

Volume 19 | Issue 1 | Jan – Jun 2020 | ISSN: 0856-860X

Chief Editor José Paula

Western Indian Ocean
JOURNAL OF
Marine Science

Published biannually

Aims and scope: The *Western Indian Ocean Journal of Marine Science* provides an avenue for the wide dissemination of high quality research generated in the Western Indian Ocean (WIO) region, in particular on the sustainable use of coastal and marine resources. This is central to the goal of supporting and promoting sustainable coastal development in the region, as well as contributing to the global base of marine science. The journal publishes original research articles dealing with all aspects of marine science and coastal management. Topics include, but are not limited to: theoretical studies, oceanography, marine biology and ecology, fisheries, recovery and restoration processes, legal and institutional frameworks, and interactions/relationships between humans and the coastal and marine environment. In addition, *Western Indian Ocean Journal of Marine Science* features state-of-the-art review articles and short communications. The journal will, from time to time, consist of special issues on major events or important thematic issues. Submitted articles are subjected to standard peer-review prior to publication.

Manuscript submissions should be preferably made via the African Journals Online (AJOL) submission platform (http://www.ajol.info/index.php/wiojms/about/submissions). Any queries and further editorial correspondence should be sent by e-mail to the Chief Editor, wiojms@fc.ul.pt. Details concerning the preparation and submission of articles can be found in each issue and at http://www.wiomsa.org/wio-journal-of-marine-science/ and AJOL site.

Disclaimer: Statements in the Journal reflect the views of the authors, and not necessarily those of WIOMSA, the editors or publisher.

ISSN 0856-860X

Cover image: Ponta Mazondúe, Inhaca Island, Mozambique (© Jose Paula, 2014)

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

Mumini Dzoga[1,3]*, Danny Simatele[1,2], Cosmas Munga[1,3]

[1] School of Geography, Archaeology and Environmental Studies; Department of Geography and Environmental Studies, University of Witwatersrand, P/B 3, 2050, Johannesburg, South Africa

[2] Centre in Water Research and Development (CiWaRD); School of Geography, Archaeology and Environmental Studies; Department of Geography and Environmental Studies, University of Witwatersrand, P/B 3, 2050, Johannesburg, South Africa

[3] Department of Environment and Health Sciences, Marine and Fisheries Programme, Technical University of Mombasa, P.O. Box 90420-80100, Mombasa

* Corresponding author: muminshaban@yahoo.com

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 (34.0%) while basket traps dominated the Ozi site at 63.6%. 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

http://dx.doi.org/10.4314/wiojms.v19i1.4

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. Aartisanal 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. Surís-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-Álvarez *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 aso 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 habitat types, 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 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.

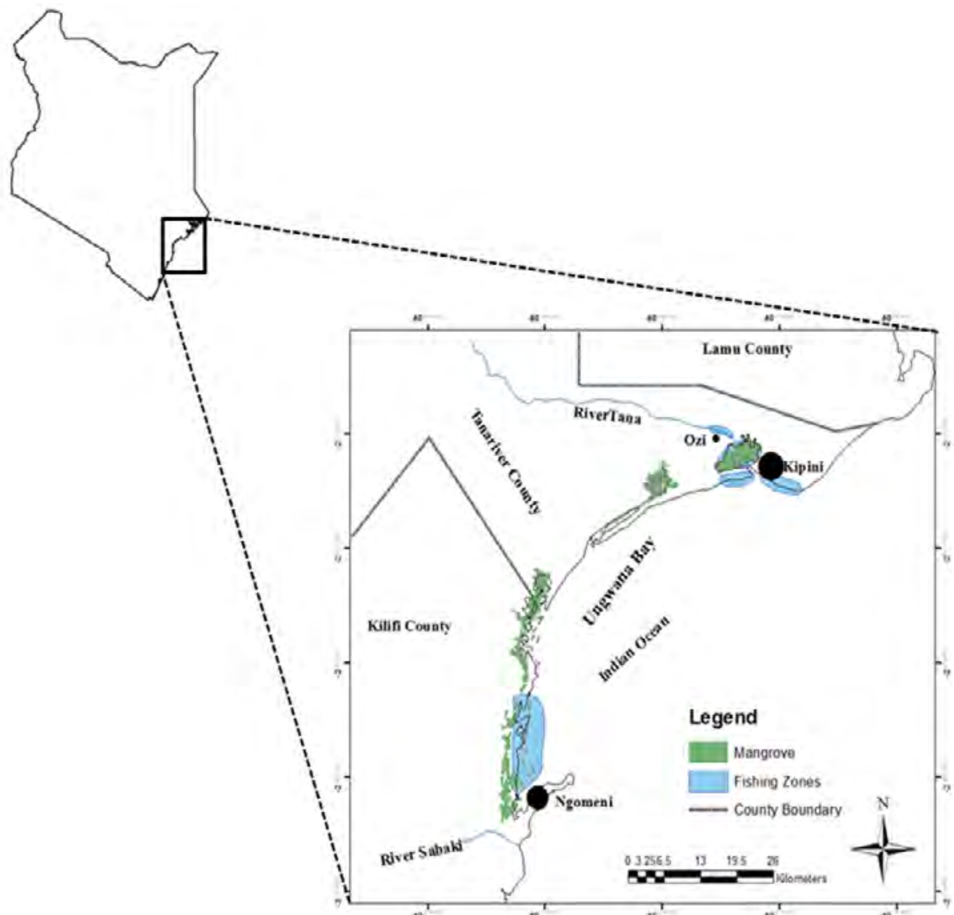

Figure 1. Map showing the fishing zones of Ngomeni, Kipini and Ozi in Ungwana Bay and Lower Tana Delta, Kenya.

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

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.

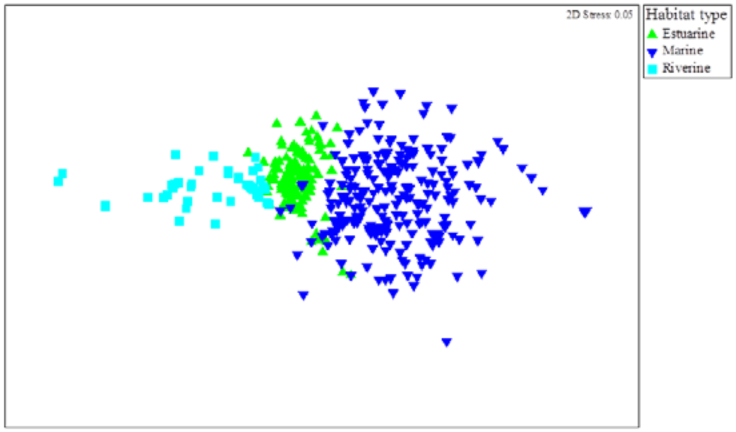

Figure 2. Non-metric MDS plots showing the composition of catches by habitat types in Ungwana Bay and Lower Tana Delta, Kenya based on species abundance from shore-based catch assessments.

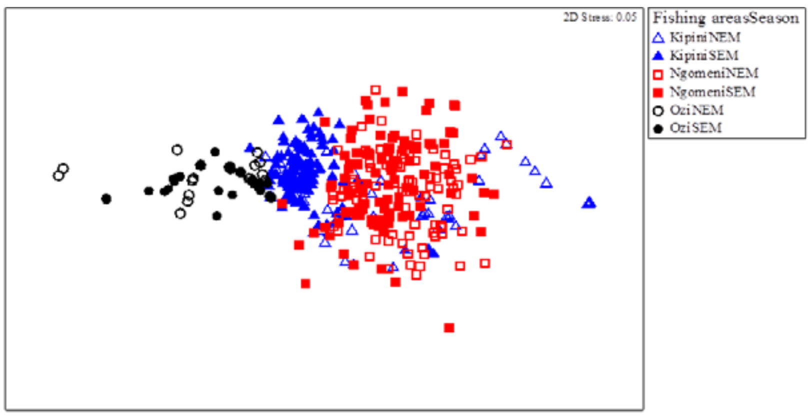

Figure 3. Non-metric nMDS plots showing the composition of catches by fishing zone with season combination in Ungwana Bay and Lower Tana Delta, Kenya based on species abundance from shore-based catch assessments.

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 speanguns (Fig. 5).

Table 1. One-way SIMPER Analysis: Species contributing to the dissimilarity in terms of abundance (%) between habitat types (estuarine *versus* marine) with an average dissimilarity of 97.8%.

	Estuarine habitat	Marine habitat		
Species	**Average abundance (%)**	**Average abundance (%)**	**Average dissimilarity**	**Contribution (%)**
Arius africanus	**40.17**	1.01	19.90	20.35
Otolithes ruber	17.38	1.18	8.71	8.91
Pelona ditchela	**14.78**	0.33	7.48	7.64
Chirocentrus dorab	0.00	**14.00**	7.00	7.16
Pristipomoides filamentosus	0.00	**13.75**	6.88	7.03
Scomberomorus commerson	0.03	**11.73**	5.87	6.00
Pristipomoides sieboldii	0.00	**10.02**	5.01	5.12

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 *Protopterus 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/fisher.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

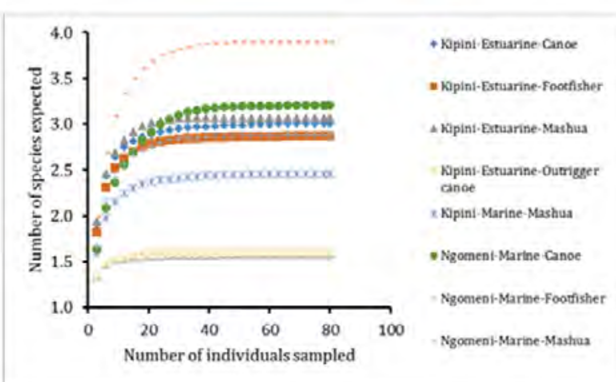

Figure 4. Rarefaction curves showing the expected total number of species caught with increase in sample size for the different fishing zones with habitat and fishing craft combination in Ungwana Bay and Lower Tana Delta, Kenya.

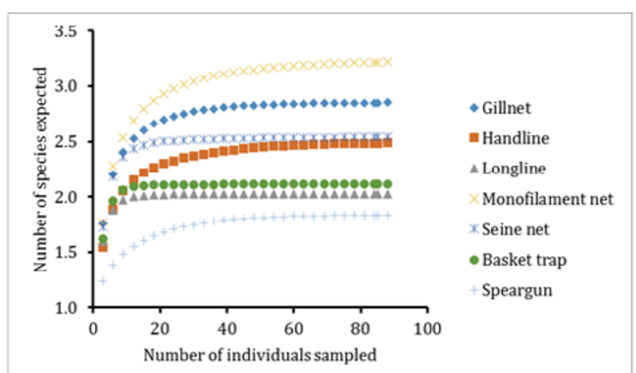

Figure 5. Rarefaction curves showing the total expected number of species caught with increase in sample size for the different types of fishing gears in Ungwana Bay and Lower Tana Delta, Kenya.

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

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		
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		
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

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 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

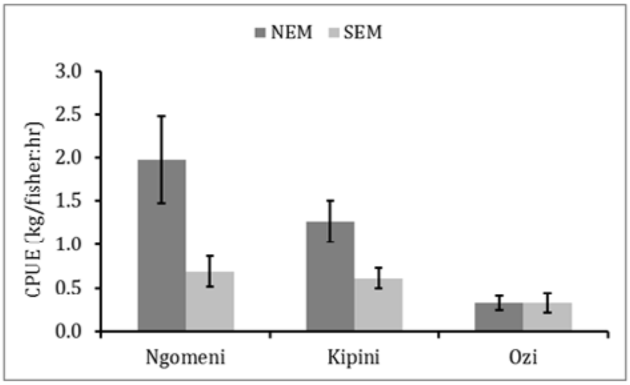

Figure 6. Seasonal catch rate by fishing zone for the Ungwana Bay and Lower Tana Delta artisanal fishery, Kenya.

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* (Kurskal 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

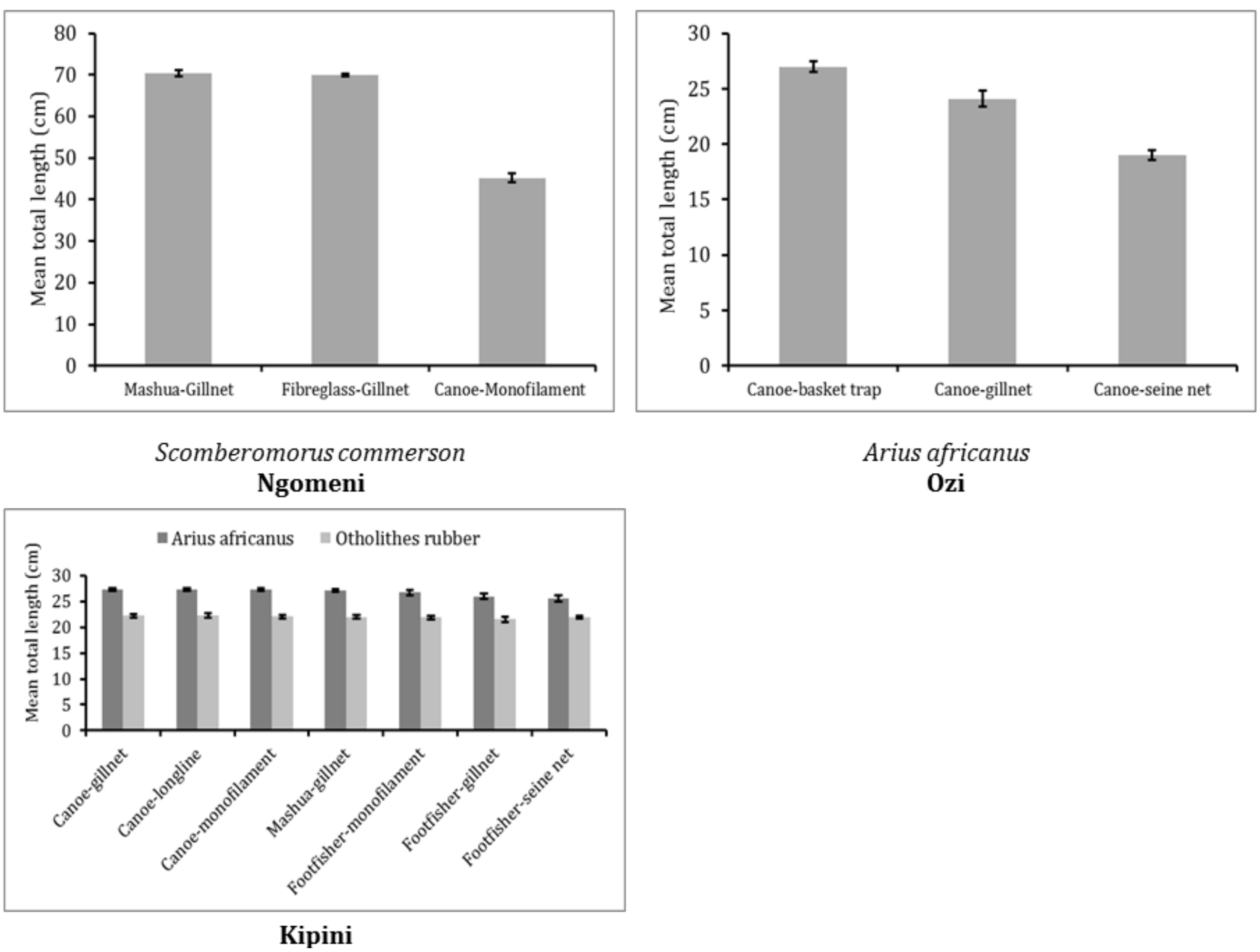

Figure 7. Mean total length of the most abundant fin fish species across zones with craft-gear combination in Ungwana Bay and Lower Tana Delta, Kenya.

key factors contributing to the distinct catch composition across habitat types and fishing areas (Winemiller and Leslile, 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 equiped 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 Nicoyaon 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 the SEM season. Mwangudza *et al.*, (2017) also observed higher catch-rates in the NEM season in Malindi-Ungwna 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 muti-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 syudy 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.

Acknowledgements

This work is part of the PhD programme of Mumini Ndenge Dzoga (SFH150922142954) and funded by the National Research Foundation (NRF) of South Africa. We are sincerely grateful for this opportunity. We are equally grateful to the National Research Fund (NRF) of Kenya for research grants awarded to support part of this study. We are indebted to the support given.

References

Abila R (2010) Economic evaluation of the prawn fishery of the Malindi-Ungwana Bay along Kenya's Coast. Kenya Marine and Fisheries Research Institute, Kisumu, Kenya

Anam R, Mostrada E (2012) Field identification guide to the living marine resources of Kenya. FAO Species Identification Guide for Fishery Purposes. FAO, Rome

Cinner JE, McClanahan TR, Graham NJ, Daw TM, Maina J, Stead SM, Wamukota A, Brown K, Bodin O (2011) Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. Global Environmental Change 22: 12-20

FAO (2012) The state of world fisheries and aquaculture. FAO. 209 pp

Fulanda B (2003) Shrimp trawling in Ungwana Bay: A threat to fishery resources. In: Hoorweg J and Muthiga N (eds) Recent advances in coastal ecology: Studies from Kenya. African Studies Centre, Leiden. pp 233-242

Fuller EC, Samhouri JF, Stoll JS, Levin SA, Watson JR (2017) Characterizing fisheries connectivity in marine social–ecological systems. Journal of Marine Science 74(8): 2087-2096

González-Álvarez J, García-de-la-Fuente L, García-Flórez L, Fernández-Rueda M, Alcázar-Álvarez JL (2016) Identification and characterization of métiers in multi-species artisanal fisheries. A case study in northwest Spain. Natural Resources 7: 295-314

KMFRI (2008) Annual report 2008/9 FY. KMFRI. 68 pp

Laurence F, Verena T, Gilles M, Nathalie C, Marie-Joelle R (2015) Characterizing catches taken by different gears as a step towards evaluating fishing pressure on fish communities. Fisheries Research 164: 238-248

McClanahan T (1998) Seasonality in East Africa's coastal waters. Marine Ecology Progress Series 44: 191-199

Metcalf SJ, Van Putten EI, Frusher S, Marshall NA, Tull M, Caputi, N, Haward M, Hobday AJ, Holbrook NJ, Jennings SM, Pecl GT, Shaw JL (2015) Measuring the vulnerability of marine social-ecological systems: a prerequisite for the identification of climate change adaptations. Ecology and Society 20(2): 35

Munga C, Ndegwa S, Fulanda B, Manyala J, Kimani E, Ohtomi J, Vanreusel A (2012) Bottom shrimp trawling impacts on species distribution and fishery dynamics; Ungwana Bay fishery Kenya before and after the 2006 trawl ban. Fisheries, 78: 209-219

Munga C, Mwangi S, Ong'anda H, Ruwa R, Manyala J, Groeneveld JC, Kimani E, Vanreusel A (2013) Species composition, distribution patterns and population structure of penaeid shrimps in Malindi-Ungwana Bay, Kenya, based on experimental bottom trawl surveys. Fisheries Research 147: 93-102

Munga CN, Omukoto JO, Kimani EN, Vanreusel A (2014) Propulsion-gear-based characterisation of artisanal fisheries in the Malindi-Ungwana Bay, Kenya and its use for fisheries management. Ocean & Coastal Management 98: 130-139

Murase A, Angulo A, Miyazaki Y, Bussing WA, López MI (2014) Marine and estuarine fish diversity in the inner Gulf of Nicoya, Pacific coast of Costa Rica, Central America. Journal of Species Lists and Distribution 10(6): 1401-1413

Mwangudza P, Mlewa C, Munga C (2017) Evaluating the fisheries potential of solar salt works reservoirs at Ungwana Bay, North Coast, Kenya. Western Indian Ocean Journal of Marine Science 16(1): 61-71

Ndoro CK, Kaunda-Arara B, Munga CN, Ruwa R (2014) Influence of seasonality and bathymetry on decapod crustacean community structure in Malindi - Ungwana Bay, Kenya. Western Indian Ocean Journal of Marine Science 13(1): 31-46

Rondeau A, Hanson JM, Comeau M, Surette T (2016) Identification and characterization of important areas based on fish and invertebrate species in the coastal waters of the Southern Gulf of St. Lawrence. Department of Fisheries Oceans, Canadian Science Advisory Secretariat, Research Document 2016/044

Siddique A, Saha D, Rahman M, Hossain MB (2013) Fishing gears of the Meghna River Estuary of Chandpur Region, Bangladesh. DAMA International 2(1): 9

Siddons SF, Pegg MA, Klein GM (2017) Borders and barriers: Challenges of fisheries management and conservation in open systems. River Research and Applications 33: 578-585

Surís-Regueiro JC, Santiago JL (2014) Characterization of fisheries dependence in Galicia (Spain). Marine Policy: 99-109

Winemiller KO, Leslie MA (1992) Fish assemblages across a complex, tropical freshwater/marine ecotone. Environmental Biology of Fishes 34: 29-50