Fish catch composition of artisanal and bottom trawl fisheries in Malindi-Ungwana Bay, Kenya: a cause for conflict?

Cosmas Munga
Technical University of Mombasa

R. K. Ruwa
Kenya Marine and Fisheries Research Institute (KMFRI)

Julius Manyala
University of Eldoret

Western Indian Ocean J. Mar. Sci. Vol. 13. No. 2, pp. 31 - 46 , 2014

Fish Catch Composition of Artisanal and Bottom Trawl Fisheries in Malindi-Ungwana Bay, Kenya: A Cause for Conflict?

Cosmas N. Munga[1,4, 5], Stephen Mwangi[1], Harrison Ong'anda[1], Renison Ruwa[1], Julius Manyala[2], Johan C. Groeneveld[3] , Edward Kimani[1] and Ann Vanreusel[4]

[1]Kenya Marine and Fisheries Research Institute, PO Box 81651 – 80100, Mombasa, Kenya; [2]University of Eldoret, Department of Fisheries and Aquatic Sciences, PO 1125 – 30100, Eldoret, Kenya; [3]Oceanographic Research Institute, 1 King Shaka Avenue, Durban, South Africa; [4]Gent University, Marine Biology Research Group, Krijgslaan 281 – S8, 9000, Gent, Belgium; [5]Technical University of Mombasa, Department of Environment and Health Sciences, Marine Sciences Section, PO Box 90420, 80100 Mombasa, Kenya.

Keywords: Trawl bycatch, artisanal catch, catch composition, resource user conflict, Malindi-Ungwana Bay, Kenya

Abstract — Artisanal and shrimp bottom trawl fisheries in Ungwana Bay compete for fish resources and this has resulted in unresolved conflict over several decades. Landings of artisanal fishers (2009-2011) and bottom trawl catches (2011) were sampled to compare fish species composition and abundance according to area (inshore; offshore) and season (northeast monsoon - NEM, southeast monsoon - SEM) and identify the species contributing most to catch overlap. The diversity of fish catches was greater in trawl (223 species) than artisanal samples (177) in both seasons. The diversity and catch rates were greater in artisanal samples during the NEM, when most fishing occurs. The diversity was greater in trawl samples during the SEM, when productivity is higher. The offshore trawl catch composition differed from the inshore trawl and artisanal samples; the shared species in the latter two categories were *Galeichthys feliceps*, *Pellona ditchela*, *Johnius amblycephalus*, *Leiognathus equulus*, *Pomadasys maculatus*, *Lobotes surinamensis* and *Otolithes ruber*. Trawl samples contained smaller-sized fish of the shared species than artisanal samples. A shrimp fishery management plan (2010) bans trawling closer than three nautical miles from the coast, and introduces closed fishing seasons and gear modifications, but has not been fully implemented. The artisanal fishery is expected to grow and active management is crucial to reduce resource user conflict.

INTRODUCTION

Malindi-Ungwana Bay in Kenya (hereafter called Ungwana Bay) is a species-rich ecosystem in the tropical Western Indian Ocean where fisheries exploit a variety of crustacean, teleost, elasmobranch and mollusc species. An artisanal fishery in the bay dates back to the 9th century, coinciding with the rise of East African Indian Ocean

Corresponding author: CNM
Email:cosmasnke2001@yahoo.com

trade with Arabia, Persia and India (Fulanda, 2003). Artisanal fishers use traditional and more modern fishing techniques such as collecting by hand and the use of hand and long lines with baited hooks, seine, cast and gillnets, and traps of various designs (Munga *et al*., 2014). Recent estimates place the number of fishers in the bay at >3000, with around 1000 fishing craft ranging from dugout canoes used near the shore to large dhows for open sea fishing (Government of Kenya, 2014). The number of artisanal fishers in Ungwana Bay is expected to increase as a result of population growth (Government of Kenya, 2014). Catches of the fishery comprise a multi-species mix of demersal fishes (50% by weight), pelagic fishes (28%), sharks and rays, octopus and squid, shrimps, lobsters and crabs (Government of Kenya, 2010a; Munga *et al*., 2012, 2014). This species mix is typical of artisanal fisheries in the south west Indian Ocean (SWIO) (Jiddawi & Ohman, 2002; van der Elst *et al*., 2005).

Ungwana Bay also supports an industrial bottom trawl fishery for penaeid shrimps, active since the early 1970s (Fulanda *et al*., 2011; Munga *et al*., 2012), and similar to the trawl fisheries on Sofala Bank (Mozambique) and Tugela Bank (eastern South Africa), and in the Rufiji Delta (Tanzania) and western Madagascar (Fennessy & Everett, 2015). Fulanda *et al*. (2011) describe the Ungwana Bay trawl fleet and fishing gear in detail. Briefly, they comprise steel double rig or outrigger trawl vessels (12-41 m long), towing otter nets and beam trawls, and fitted with blast freezers and freezing holds. Trawl catches include shrimps and a large bycatch of fish, sharks, rays, crustaceans and other invertebrates (Fennessy *et al*., 2004, 2008). Although some of the bycatch is retained and sold, most has low commercial value and is discarded overboard. Discarded fish are mostly dead or damaged by barotrauma, exposure to air or being crushed in the trawl net.

The shrimp trawl bycatch in the SWIO has been estimated at 80 000 to 120 000 t annually (Fennessy *et al*., 2004; Keleher, 2005). Fish discards in Ungwana Bay weighed 1.5 to 7 times more than the retained shrimp (Fulanda *et al*., 2011; Munga *et al*., 2012). Mwatha (2005) recorded more than 90 fish species in catches retained by Ungwana Bay shrimp trawlers, of which the Sciaenidae, Sillaginidae, Mullidae and Pomatomidae (all demersal), Sphyraenidae and Scombridae (pelagic) represented the highest biomass. In the same study, the Leiognathidae and Dasyatidae (demersal), Clupeidae and Carcharhinidae (pelagic) contributed more than 43% to the discarded fishes. Juveniles of *Otolithes ruber*, *Johnius* sp. (both Sciaenidae), and *Pomadasys* sp. (Haemulidae) made up 25% of trawl discards by mass; these are important demersal species in the artisanal fishery (Munga *et al*., 2012).

Shared fishing grounds, catch composition and gear interaction in artisanal and trawl fisheries has given rise to resource user conflict since the early 1990s, despite a regulation that trawlers may only operate beyond three nautical miles (nm) from the shore (formerly five nm; Government of Kenya, 2010a; Munga *et al*., 2012). This conflict is exacerbated by factors such as weakly defined harvest strategies, an increasing number of artisanal fishers, entanglement of fishing gear and trawl discard practices (Fennessy *et al*., 2004; Fulanda *et al*., 2009, 2011). Biodiversity and conservation-based indicators show Ungwana Bay to be ecologically degraded, with a reduced biomass across trophic levels, including shrimps and fish (Swaleh *et al*., 2015). Reduced artisanal catches and escalating human reliance on the sea for food security led to a commercial trawl ban in 2006 (Munga *et al*., 2012). The trawl fishery resumed in 2012 but the spatio-temporal management strategy of Ungwana Bay remains under review.

Initiatives to reduce bycatch have been limited or sporadic in the region, and poorly enforced (see Fennessy *et al*., 2004, 2008). In Kenya, trawl companies are encouraged to land (instead of discard) fish bycatch to satisfy the demand for fish in local markets (FAO, 2007). The overall objective of this study was to evaluate the conflict between the artisanal and bottom trawl fisheries in terms of overlapping fish species composition, and the key commercial species captured by the two sectors. Specific aims were: a) to compare the species composition of artisanal and bottom trawl catches according to area (inshore, offshore) and season (northeast monsoon - NEM, southeast monsoon - SEM); and b) to identify key species that result in the conflict between the two fishing sectors.

METHODS

Study area and field sampling

Ungwana Bay (2°30’- 3°30’S; 40°- 41°E) extends about 200 km along the shoreline of Kenya and has a total trawlable area of about 11 000 km² (Fig. 1). Fisheries are centered around

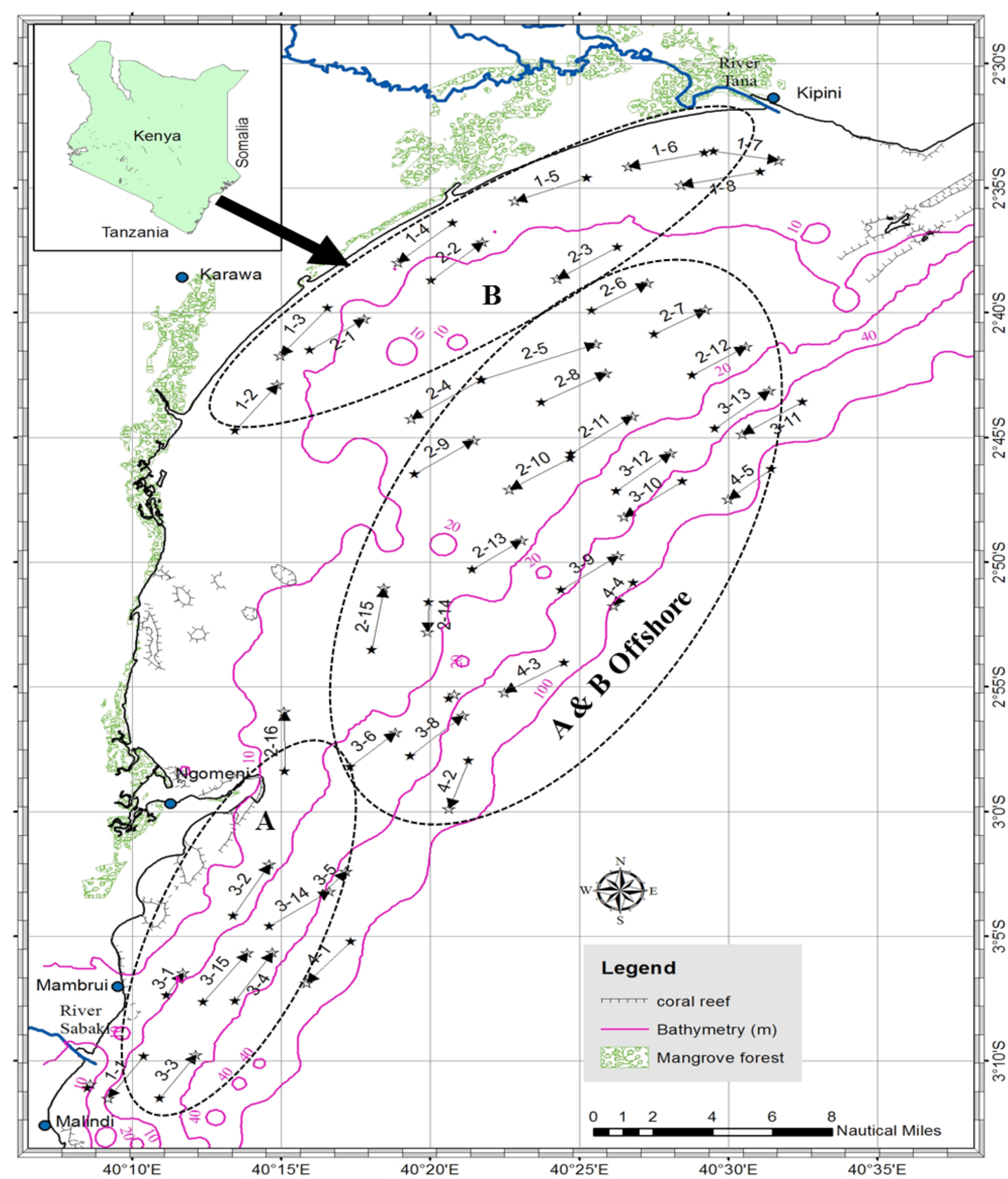

Figure 1. Map of Ungwana Bay, Kenya, showing the groupings of trawl transects in the Sabaki (A) and Tana (B) inshore area, and the offshore area (A & B offshore). Figures on the map indicate the transect number and depth stratum respectively, e.g. 1-2 means transect number 1 in depth stratum 2. Transect 1-1 was incomplete and hence excluded from the survey data. Artisanal catches were sampled at Malindi, Ngomeni and Kipini.

the Tana and Sabaki River estuaries and their shallow offshore banks (see Kitheka, 2013; Kitheka *et al*., 2005). Mangrove forests, patchy reefs, islets, sandy shores and tidal flats are important habitats in the bay. Weather patterns are dominated by large scale pressure systems of the western Indian Ocean, and the dry northeast monsoon (NEM; October to March) and wet southeast monsoon seasons (SEM; April to September) (McClanahan, 1988).

Shore-based catch assessments of artisanal fisheries were conducted in 2009 (June, November, December), 2010 (March, June, September), and 2011 (March, July, September) at Malindi, Ngomeni and Kipini (Fig. 1). Forty-nine visits were made and 84 random day-time catches were sampled. All fish in the samples were identified and measured.

Shrimp bottom trawl surveys were undertaken in January and February (13 days) and May and June (11 days) in 2011, using a leased shrimp trawler (25 m length, 146 t gross register displacement) and trawl net (44.3 m length; 70 mm mesh size in the body and 45 mm in the cod-end; 22.5 m head rope length). Trawls were dragged roughly parallel to the shore, for 1 h at 2.5 knots. The position and depth was recorded at the start and end of each trawl. Totals of 36 (NEM, covering 507.7 nm2) and 41 (SEM, covering 546.4 nm^2) trawls were sampled during the two surveys.

Samples of catches were treated in a manner similar to shore-based samples but, if large, the catch was randomly subsampled. The total catch of each species was calculated by multiplying the subsample by a factor needed to arrive at the total catch weight (see Stobutzki *et al*., 2001; Tonks *et al*., 2008).

Data analyses

Measures of diversity (species richness, S; Shannon-Wiener diversity index, *H'*) were compared between samples of the artisanal and trawl catches (inshore and offshore areas) for the NEM and SEM seasons using ANOVA. Multivariate, non-metric, multi-dimensional scaling (MDS) was used to identify whether area or season affected the composition of the trawl and artisanal catches based on their Bray-Curtis similarity using PRIMER v6 (Clarke & Warwick, 2001). Two-way ANOSIM was used to further assess their spatial and seasonal similarity. The species that contributed most towards dissimilarity were identified using two-way SIMPER analysis. The body size of shared fish species was compared using two-way ANOVA or Kruskal-Wallis in STATISTICA v. 7 to assess whether artisanal and trawl fisheries catch similar life stages.

The swept area (a, nm^2) of each trawl was calculated as:

$$a = D \times h \times X$$

where D is the distance covered in nm: $D = 60\times \sqrt{}\ (Lat1 - Lat2)^2 + (Lon1 + Lon2)^2 \cos 0.5^2\ (Lat1 + Lat2)$, h is the head-rope length (m) and X the fraction of head-rope length equal to the swept path-width (set at 0.5; Pauly, 1980; Sparre & Venema, 1998).

Bycatch rates were calculated as catch (C, kg) divided by the time spent trawling (t, hours) and converted to catch-per-unit-area (CPUA, $kg.nm^{-2}$) by dividing by the swept area: $(C/t) / (a/t) = C/a$)

Total biomass (B, kg) was calculated from:

$$B = \frac{(\overline{C/a}) \times A}{X_1}$$

where *C/a* is the CPUA of all trawls, A is the overall area under investigation and X = 0.5.

Two-way ANOVA, followed by the post hoc Tukey HSD test, was used to test for differences in trawl bycatch rates ($kg.h^{-1}$) according to area and season. Artisanal fishery catch rates ($kg.fisher^{-1}.h^{-1}$) were compared between seasons using ANOVA.

RESULTS

Catch composition in the trawl and artisanal samples

Trawl samples contained 223 species; 158 in the NEM and 161 in the SEM. Artisanal catches comprised 177 species; 148 in the NEM and 90 in the SEM samples. Species richness (S) of artisanal catches was higher in NEM (avg. 12 per sample) than SEM (9) samples. For trawls, S was higher for the SEM (18 inshore; 20 offshore) than the NEM (17 and 15) samples (Fig. 2a). The Shannon-Wiener diversity index (H') for the artisanal catches was higher for the NEM (avg. 1.7 per sample) than the SEM (1.6), while the *H'* for inshore and offshore trawls was higher for the SEM (2.3 in both cases) than the NEM (1.7 and 1.8) samples (Fig. 2b).

S differed significantly between the artisanal and bottom trawl samples (two-way ANOVA: $p < 0.05$) but not between seasons, nor was the fishing sector × season interaction significant ($p > 0.05$, Table 1). *H'* differed

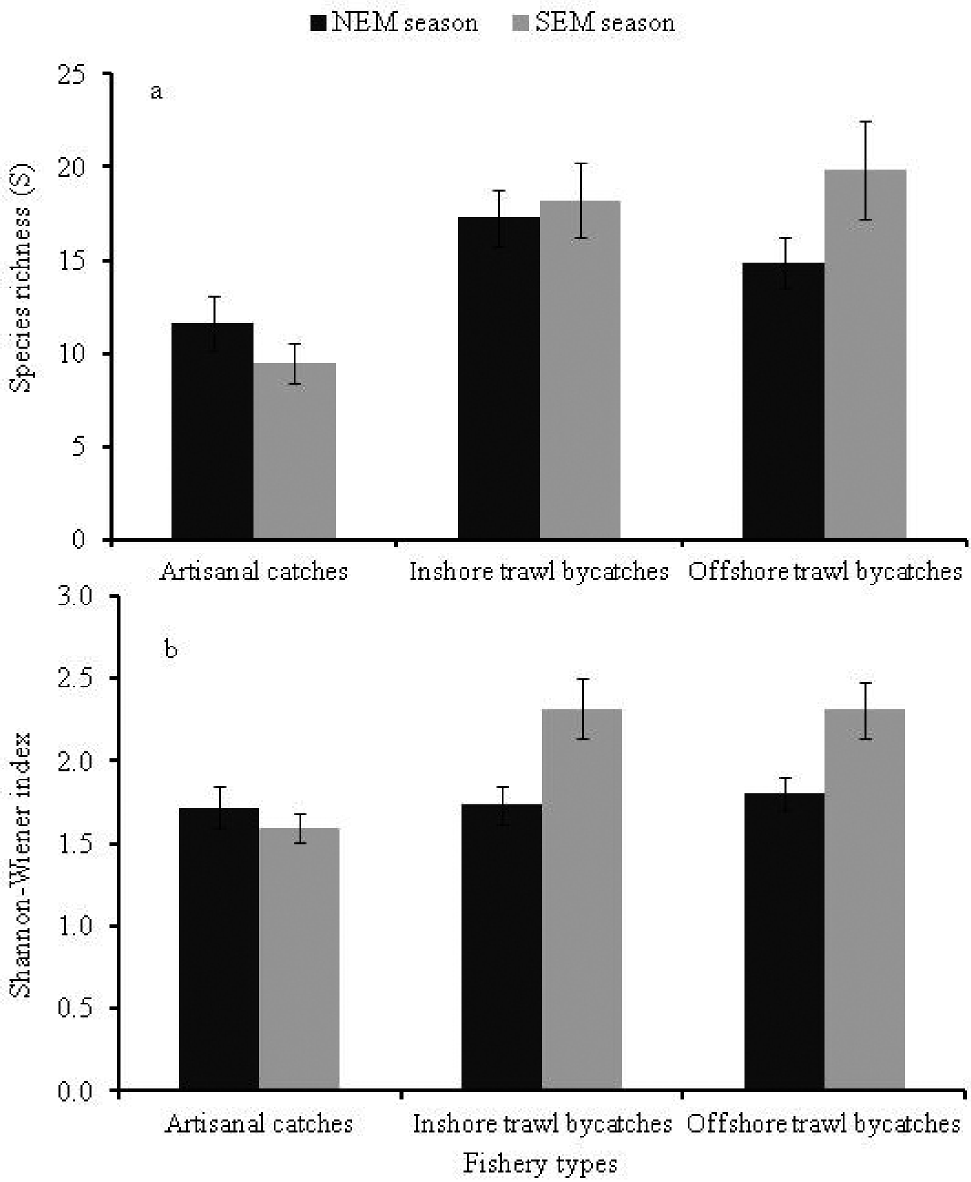

Figure 2. Comparison of a) mean species richness (± SE) and b) and Shannon-Wiener diversity index for artisanal, inshore and offshore trawl bycatches during the northeast and southeast monsoon seasons in Ungwana Bay.

Table 1. Two-way ANOVA comparing fish species richness and Shannon-Wiener diversity for fishing by-catches (artisanal versus trawl), season and interactions (sector × season) in Ungwana Bay (p-values in bold are significant).

			Species richness (*S*)		Shannon-Wiener diversity index (*H'*)	
Factors	Df	Error Df	F	p-value	F	p-value
Fishing sector	2	149	14.718	**<0.001**	6.794	**0.002**
Season	1	149	0.834	0.363	8.178	**0.005**
Fishing sector × Season	3	149	2.726	0.069	5.089	**0.007**

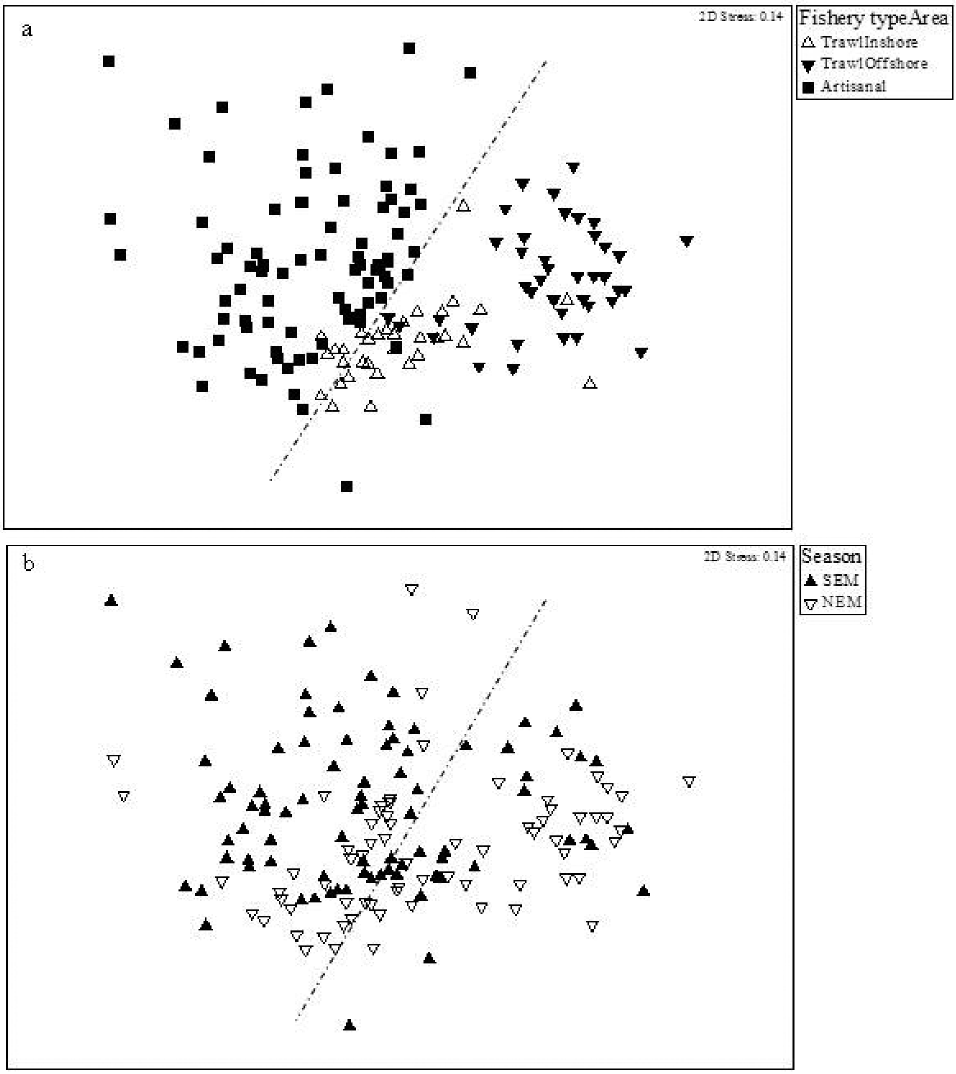

Figure 3. Non-metric MDS plots showing the composition of fish catches in Ungwana Bay a) for the artisanal, inshore and offshore trawl fishing sectors and b) per season (NEM and SEM) in combined artisanal and trawl bycatches. Dotted lines separate artisanal from trawl bycatches.

Table 2. Two-way SIMPER analysis of species contributing most to the dissimilarity (bold values) in the abundance of bycatches (%) in offshore trawl versus artisanal catches in Ungwana Bay, Kenya, showing the percentage contribution of bycatch fish species that yielded an average dissimilarity of 99.0%.

Species	Average abundance		Average dissimilarity	Contribution (%)
	Offshore trawl bycatches	Artisanal catches		
Bothus mancus	**11.96**	0.10	5.62	5.67
Trachinocephalus myops	**11.91**	0.00	5.49	5.54
Lobotes surinamensis	0.00	**7.52**	3.79	3.83
Lutjanus fulviflamma	0.02	**5.85**	3.05	3.08
Callionymus gardineri	**7.34**	0.00	2.96	2.99
Galeichthys feliceps	0.08	**5.20**	2.87	2.90
Psettodes erumei	0.06	**6.41**	2.86	2.89
Pellona ditchela	0.66	**4.09**	2.71	2.74
Peocilopseta natalensis	4.94	0.00	2.63	2.66
Otolithes ruber	0.29	3.90	2.31	2.33
Leiognathus lineolatus	**5.18**	0.03	2.25	2.27

significantly between the fishery sectors and seasons, and for the fishing sector × season interaction (p <0.05, Table 1). Post hoc pair-wise comparisons confirmed higher *S* and *H'* for the trawl than the artisanal samples in both seasons (p <0.05).

The non-metric MDS plots distinguished a difference between the species composition of artisanal and trawl samples (Fig. 3a) and suggested a seasonal effect (Fig. 3b) (two-way ANOSIM: R = 0.317, p = 0.001 and R = 0.088, p = 0.003, respectively). Pair-wise comparisons confirmed that inshore trawl samples differed from those harvested offshore (R = 0.631, p = 0.001), but not from artisanal samples (R = 0.066, p = 0.09). Offshore trawl samples also differed from artisanal samples (R = 0.460, p = 0.001). The dissimilarity was attributed to abundant *Bothus mancus*, *Trachinocephalus myops*, *Callionymus gardineri* and *Leiognathus lineolatus* in offshore samples, versus abundant Lobotes surinamensis, *Lutjanus fulviflamma*, *Galeichthys feliceps*, *Psettodes erumei* and *Pellona ditchela* in artisanal samples (two-way SIMPER, Table 2). A seasonal dissimilarity between the artisanal and trawl samples was attributable to an abundance of *G. feliceps*, *P. ditchela*, *B. mancus*, *Thryssa vitrirostris* and *T. myops* in the NEM, and an abundance of *P. erumei* in the SEM samples.

Seven common species explained the similarity between artisanal and inshore trawl samples (Table 3). Six out of the seven species had a smaller mean body size in trawl than in artisanal samples (p <0.05, Table 4). *Lobotes surinamensis* and *Leiognathus equulus* were larger in NEM than SEM samples (p <0.05, Table 4).

Catch rates and biomass

Trawl bycatch rates and biomass were significantly higher in inshore than offshore samples, and were also higher during the SEM than the NEM (Table 5). Although not significant (ANOVA, p = 0.103), artisanal catch rates were marginally higher in the NEM than the SEM (1.3 versus 0.9 $kg.fisher^{-1}.h^{-1}$).

Table 3. Two-way SIMPER analysis of species contributing most to the similarity in bycatch abundance (%) between inshore trawl (within a similarity of 23.3%) and artisanal catches (within a similarity of 9.3%) in Ungwana Bay, Kenya.

Species	**Average abundance**	**Average similarity**	**% contribution)**
Inshore trawl bycatches			
Galeichthys feliceps	14.65	5.27	22.59
Pellona ditchela	9.12	2.79	11.97
Johnius amblycephalus	6.68	1.95	8.35
Leiognathus equulus	3.54	1.30	5.57
Pomadasys maculatus	4.05	1.10	4.71
Otolithes ruber	2.36	0.84	3.61
Lobotes surinamensis	0.95	0.22	0.96
Artisanal catches			
Lobotes surinamensis	7.52	1.40	14.98
Galeichthys feliceps	5.20	0.80	8.61
Pellona ditchela	4.09	0.70	7.45
Otolithes ruber	3.90	0.58	6.23
Pomadasys maculatus	2.50	0.30	3.17
Leiognathus equulus	1.24	0.13	1.44
Johnius amblycephalus	1.15	0.12	1.33

Table 4. a) Mean total lengths (cm ± SE) of the most abundant shared fish species in artisanal and trawl samples in Ungwana Bay (pooled data per gear type, irrespective of season) and b) seasonal comparison of fish size (pooled data per season, irrespective of gear type). P-values in bold are significant.

a) Species	**Artisanal**	**Trawl**	**N/Error Df**	**Statistic**	**p-value**
Galeichthys feliceps	39.8 ± 1.3	20.5 ± 0.3	357	227.171	***<0.001***
Johnius amblycephalus	14.4 ± 1.8	11.4 ± 2.2	228	51.819	***<0.001***
Pellona ditchela	14.8 ± 0.4	13.6 ± 0.1	787	8.272	***0.004***
Lobotes surinamensis	56.2 ± 0.9	55.1 ± 1.7	298	3.045	0.082
Otolithes ruber	24.3 ± 0.3	18.9 ± 0.2	380	165.400	***<0.001***
Leiognathus equulus	12.5 ± 0.2	13.3 ± 0.1	448	19.218	***<0.001***
Pomadasys maculatus	21.9 ± 0.6	12.9 ± 0.1	289	299.596	***<0.001***
a)Species	NEM	SEM			
Galeichthys feliceps	25.8 ± 0.7	24.4 ± 0.7	357	0.129	0.719
Johnius amblycephalus	11.9 ± 2.5	11.8 ± 2.2	228	0.960	0.328
Pellona ditchela	14.4 ± 0.4	14.0 ± 0.1	787	0.002	0.968
Lobotes surinamensis	59.4 ± 1.3	53.2 ± 1.0	298	12.823	**<0.001**
Otolithes ruber	21.4 ± 0.3	20.9 ± 0.3	380	1.093	0.296
Leiognathus equulus	13.4 ± 0.2	12.7 ± 0.1	448	13.349	**<0.001**
Pomadasys maculatus	17.1 ± 0.4	16.6 ± 0.5	289	2.857	0.910

Table 5. Mean (± SE) fish bycatch rates (kg.h^{-1}) and biomass (kg.nm^{-2}) per trawled area (inshore and offshore) and season (NEM and SEM) in Ungwana Bay. Bycatch rates differed according to area (p <0.001) and season (p = 0.042). Biomass differed according to area (p <0.001) and season (p = 0.044) (Kruskal-Wallis test).

Area	Season	Bycatch rate kg.h^{-1}	Biomass kg.nm^{-2}
Inshore	NEM	123.5 ± 54.5	8,565.9 ± 3,781.5
Inshore	SEM	106.5 ± 17.5	7,427.5 ± 1,221.6
Offshore	NEM	6.2 ± 1.9	631.3 ± 210.0
Offshore	SEM	56.9 ± 19.3	4,067.4 ± 1,306.7

DISCUSSION

The objectives of this study were to evaluate the conflict between the Kenyan artisanal and bottom trawl fisheries in terms of overlapping species composition, and to identify the key shared species of commercial importance. *A priori* assumptions were that trawling would be less selective than artisanal gear (i.e. higher *S* and *H'* values), that biomass would be lower offshore than inshore, near the productive Tana and Sabaki River estuaries (see Munga *et al*. 2013), and that season would affect species diversity in catches of both fisheries because of fluctuations in sea conditions and biological productivity (McClanahan, 1988; Fulanda *et al*., 2009). We also assumed that species composition of offshore trawl catches would differ significantly from those in trawls in inshore waters and artisanal catches, because of depth and habitat preferences, and different exploitation levels.

We obtained higher *S* and *H'* values for trawl (223 fish species) than artisanal samples (177) in both seasons, thus confirming that trawling was less selective than artisanal gear. Trawl nets can catch most organisms in their path, whereas some artisanal gear, such as hook and line, seine or gillnets, are more likely to select specific species or size classes (Gobert, 1994; McClanahan & Mangi, 2004). In this study, trawl catches were sampled onboard fishing vessels immediately after emptying the trawl net onto the deck, and therefore all species were taken into account. Artisanal fishers prefer certain species, but only a few species are considered inedible (Davies *et al*., 2009; Mangi & Roberts, 2006). Most of the catch would therefore have been retained and sampled at landing sites. Nevertheless, some sorting and discarding may have occurred at sea, potentially biasing the S and H' downwards. Even though the sampling method may thus have introduced some bias (i.e. comparing unsorted trawl samples with sorted artisanal samples), our results manifested a highly diverse catch composition typical of tropical shrimp trawl fisheries. This nonselective nature of shrimp trawling has been widely criticized (Jones, 1992; Hall 1996; Kelleher, 2005).

Both the S and H' were higher during the NEM in the artisanal fishery when most fishing takes place (Fulanda *et al*., 2009). Artisanal catch rates were also higher during the NEM. This reflects the effect of adverse sea conditions during the SEM on fishing activities that rely on small craft. Conversely, the fish bycatch of trawlers was more diverse during the SEM, and this confirms trends from long term catch data for Ungwana Bay (Mwatha, 2005; Munga I., 2012). Increased nutrient input and productivity in the bay, resulting from elevated discharge of the Tana and Sabaki Rivers during the rainy SEM, are the most likely factors driving the increase in species composition during the SEM (Kitheka, *et al*., 2005; Kitheka, 2013). The trawl catch rates and total biomass were also higher during the SEM, signifying seasonally increased abundance or higher catchability (see Fulanda *et al*., 2011; Mwatha, 2005).

Trawl bycatch rates and biomass were lower offshore than inshore where productivity is higher near the Tana and Sabaki River estuaries (see Kitheka, 2013; Kitheka *et al*., 2005). It is unlikely that the offshore biomass was lower due to depletions caused by trawling, because most trawling occurs inshore, near the river outflows, where shrimps are more abundant (Munga *et al*., 2013). The most common fish bycatch species in offshore samples were *Bothus mancus*, *Trachinocephalus myops*, *Callionymus gardineri* and *Leiognathus* *lineolatus*; this differed significantly from the most common species in the artisanal and inshore samples (see Table 2). Similarity in the artisanal and inshore trawl fish composition was attributable mainly to their common abundance of *Galeichthys feliceps*, *Pellona ditchela*, *Johnius amblycephalus*, *Leiognathus equulus*, *Pomadysis maculatus*, *Lobotes surinamensis* and *Otolithes ruber*. This similarity was indicative of overlap in resource use patterns, such as targeting similar fishing areas, depths or habitats. These species are commercially important to artisanal fishers and are also, on occasion, retained and landed by the trawl fishery.

The average size of the above species in trawl bycatches was mostly smaller than in artisanal catches. This trend appears to be a result of gear selectivity, rather than a seasonal effect (see Table 4). The hypothesis that juveniles are more abundant during the SEM, when they are caught in large numbers by trawlers, was not be supported by the seasonal size comparison (except for *L. surinamensis* and *L. equulus*). Rather, it is more likely that trawl nets (mesh size 45-70 mm) retain smaller fish than those regularly caught by artisanal fishing gear.

The seven fish species most exploited in Ungwana Bay are *G. feliceps*, *P. ditchela*, *J. amblycephalus*, *L. equulus*, *P. maculatus*, *L. surinamensis* and *O. ruber*, with demonstratable resource user overlap. Therefore they are the most likely subject of conflict between the artisanal and trawl fishing sectors. Fennessy *et al*. (2008) reviewed initiatives to reduce the prawn trawl bycatch in Kenya; these initiatives included a combination of turtle excluder devices (TEDs) for shrimp trawlers, a minimum inshore trawling distance (set at five nm), closed seasons, restrictions on nocturnal trawling, and the closure of the Ungwana Bay shrimp trawling grounds for several years. These measures have been introduced at various times, either as legislation or, intermittently, as permit conditions. Compliance has generally been poor and, thus, management initiatives have largely been ineffective in preventing conflict.

A new shrimp fishery management plan (Government of Kenya, 2010b) limits shrimp trawling to further than three nm from the shore (previously five nm). The management plan further incorporates a closed season for the trawl fishery (November to April) which coincides with the recruitment of shrimps onto offshore banks, and with spawning of fish species caught as trawl bycatch (Mwatha, 2005; Munga *et al*. 2013; Nzioka, 1979). The trawl closure also falls within the main artisanal fishing season during the NEM, and will reduce some physical conflicts such as gear entanglement and market competition. Bycatch reduction devices (BRD) fitted to trawl nets that allow the escape of small-sized and juvenile fishes have not been given sufficient attention, and their testing and successful deployment may further mitigate conflict. The direct benefits of BRDs to users may include reduced catch processing times, improved product quality, improved catch rates and reduced fuel consumption (e.g. Broadhurst 2000; Broadhurst & Kennelly 1997; Salini *et al*., 2000). Artisanal fishing effort is expected to increase in Ungwana Bay (Government of Kenya, 2014) and the implementation and enforcement of the existing management plans are therefore crucial if conflict is to be reduced.

Acknowledgements – We thank the South West Indian Ocean Fisheries Project (SWIOFP) for providing funding and logistical support for this study. CNM was funded by the VLIR UOS PhD program in association with Gent University, Belgium. Technical staff of the Kenya Marine Fisheries Research Institute (KMFRI), and the captain and crew of the FV Vega are thanked for field and analytical assistance. Teresa Athayde coordinated the trawl surveys. A special research licence for the surveys was facilitated by the KMFRI Director and Ministry of Fisheries Development.

References

Broadhurst MK (2000) Modifications to reduce bycatch in prawn trawls: a review and framework for development. Reviews in Fish Biology and Fisheries 10: 27-60

Broadhurst MK, Kennelly SJ (1997) The composite square-mesh panel: A modification to cod-ends for reducing unwanted bycatch and increasing catches of prawns throughout the New South Wales oceanic prawn-trawl fishery. Fisheries Bulletin, Washington 95: 653-664

Clarke KR, Warwick RM (2001) Change in marine communities: An approach to statistical analysis and interpretation, 2nd edition. PRIMER-E: Plymouth, UK, 172 pp

Davies TE, Beanjara N, Tregenza T (2009) Socio-economic perspective on gear-based management in an artisanal fishery in south-west Madagascar. Fisheries Management and Ecology 16: 279-289

FAO (2007) The state of world fisheries and aquaculture 2006. Food and Agriculture Organisation of the United Nations, Rome, 162 pp

Fennessy ST, Everett BI (2015) Shallow water trawl fisheries for crustaceans. In: van der Elst RP, Everett BI (eds). Offshore fisheries of the Southwest Indian Ocean: Their status and the impact on vulnerable species. Special Publication No 10. Durban: South African Association for Marine Biological Research, pp 21-65

Fennessy ST, Mwatha GK, Thiele W (eds) (2004) Report of regional workshop on approaches to reducing shrimp trawl by-catch in the Western Indian Ocean, Mombasa, Kenya, 13 – 15 April 2003. FAO Fisheries Report 734. Food and Agriculture Organisation of the United Nations, Rome, 49 pp

Fennessy ST, Vincent X, Budeba Y, Mueni E, Gove DZ (2008) An update on initiatives to reduce prawn trawl by-catch in the Western Indian Ocean. Western Indian Ocean Journal of Marine Science 7: 217–222

Fulanda B (2003) Shrimp trawling in Ungwana Bay: a threat to fishery resources. African Studies Centre research report 70. In: Hoorweg J, Muthiga N (eds) Recent advances in coastal ecology: Studies from Kenya. Print Partners Ipskamp BV, Leiden, Enschede, pp 233-242

Fulanda B, Munga C, Ohtomi J, Osore M, Mugo R, Hossain MY (2009) The structure and evolution of the coastal migrant fishery of Kenya. Ocean & Coastal Management 52: 459-466

Fulanda B, Ohtomi J, Mueni E, Kimani E (2011) Fishery trends, resource-use and management system in the Ungwana Bay fishery Kenya, Ocean & Coastal Management 54: 401–414

Gobert B (1994) Size structures of demersal catches in multispecies multigear tropical fishery. Fisheries Research 19: 87–104

Government of Kenya (2010a) Fisheries annual statistical bulletin 2010. Ministry of Fisheries Development, Department of Fisheries, Nairobi, 56 pp.

Government of Kenya (2010b) The prawn fishery management plan 2010. Kenya Gazette Supplement No.13. Legal notice No. 20, 8 pp

Government of Kenya (2014) Marine waters fisheries frame survey 2014 report. Ministry of Fisheries Development, State Department of Fisheries, Nairobi, 88 pp

Hall MA (1996) On by-catches. Reviews in Fish Biology and Fisheries 6: 134–155

Jiddawi NS, Öhman MC (2002) Marine fisheries in Tanzania. Ambio 31: 518-527

Jones JB (1992) Environmental impact of trawling on the seabed: A review, New Zealand Journal of Marine and Freshwater Research 26: 59-67

Kelleher K (2005) Discards in the world's marine fisheries. An update. Food and Agriculture Organisation of the United Nations Fisheries Technical Paper No. 470. Food and Agriculture Organisation of the United Nations, Rome, 131 pp

Kitheka JU (2013) River sediment supply, sedimentation and transport of the highly turbid sediment plume in Malindi Bay, Kenya. Journal of Geographical Science 23: 465–489

Kitheka JU, Obiero M, Nthenge P (2005) River discharge, sediment transport and exchange in the Tana estuary, Kenya. Estuarine and Coastal Shelf Science 63: 455-468

Lieske E, Myers R (1994) Collins pocket guide to coral reef fishes: Indo-pacific and Caribbean. Harper Collins Publisher, London, 400 pp

Mangi SC, Roberts CM (2006) Quantifying the environmental impacts of artisanal fishing gear on Kenya's coral reef ecosystems. Marine Pollution Bulletin 52: 1646–1660

McClanahan TR (1988) Seasonality in East Africa's coastal waters. Marine Ecology Progress Series 44: 191-199

McClanahan TR, Mangi SC (2004) Gear-based management of a tropical artisanal fishery based on species selectivity and capture size. Fisheries Management and Ecology 11: 51–60

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 Science 78: 209–219

Munga CN, 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: 9 –102

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

Mwatha GK (2005) Stock assessment and population dynamics of penaeid prawns in the prawn trawling grounds of Malindi-Ungwana Bay: The challenges of managing the prawn fishery in Kenya. WIOMSA/MARG-I/2005-06, 21 pp

Nzioka RM (1979) Observations of the spawning seasons of East African reef fishes. Journal of Fish Biology 14: 329–342

Pauly D (1980) On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal du Conseil international pour l'Exploration de la Mer 39: 175-192

Salini J, Brewer D, Farmer M, Rawlinson N (2000) Assessment and benefits of damage reduction in prawns due to use of different bycatch reduction devices in the Gulf of Carpentaria, Australia. Fisheries Research 45: 1-8

Smith JLB, Heemstra R (1998) Smith's sea fishes. 4th ed. Valiant Publishing, Sandton, South Africa, 578 pp

Stobutzki I, Miller M, Brewer D (2001) Sustainability of fishery by-catch: a process for assessing highly diverse and numerous by-catch. Environmental Conservation 28: 167-181

Sparre P, Venema SC (1998) Introduction to tropical fish stock assessment: Part 1 manual. Food and Agriculture Organisation of the United Nations Fisheries Technical Paper 306/1. Food and Agriculture Organisation of the United Nations, Rome, 407 pp

Swaleh K, Kaunda-Arara B, Ruwa R, Raburu P (2015). Ecosystem-based assessment of a prawn fishery in coastal Kenya using ecological indicators. Ecological Indicators 50: 233-241

Tonks ML, Griffiths SP, Heales DS, Brewer DT, Dell Q (2008) Species composition and temporal variation of prawn trawl by-catch in the Joseph Bonaparte Gulf, northwesten Australia. Fisheries Research 89: 276-293

van der Elst RP, Everret BI, Jiddawi N, Mwatha G, Alfonso PS, Boulle D (2005) Fish, fishers and fisheries of the Western Indian Ocean; their diversity and status, a preliminary assessment. Philosophical Transactions of the Royal Society of London A 363: 263–284

van der Elst RP (1981) A guide to the common sea fishes of Southern Africa. Struik Publishers, Cape Town, South Africa, 398 pp