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Ecological and socio-economic assessment of Kenyan coastal fisheries: the case of Malindi-Ungwana Bay artisanal fisheries versus semi-industrial bottom trawling[1]

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This study explores and describes the status of the fisheries resources in the Malindi-Ungwana Bay, Kenya. In addition to shrimp bottom trawling, the bay also supports a variety of artisanal fishing techniques with associated resource-use conflict experienced for quite some time until a ban on bottom trawling was imposed. This study therefore, focuses on a before and after the trawling ban effect on shrimp populations and finfish bycatch distribution and abundance, and the characterisation of artisanal finfish catches in terms of catch composition, catch-per-unit-effort, and mean trophic level by vessel-gear categories. Apart from providing the current status of exploitation level of the fisheries resources, the scientific information generated from this study is also useful for the revision of the shrimp fishery management plan that was formulated with inadequate scientific and background information during the six year bottom trawling ban in the bay.

Key words: Shrimp bottom trawling, artisanal catches, resource-use conflict, Malindi-Ungwana Bay, Kenya

The ecological consequences of, and socio-economic interactions between the small scale artisanal fishery and the semi-industrial bottom trawl fishery, as well as artisanal fishers' alternative livelihoods and perceptions of bottom trawling have been analysed for the Malindi-Ungwana Bay, Kenya. The bay is located between the latitudes 2°30'S and 3°30'S, and the longitudes 40°00'E and 41°00'E covering a coastal area of about 200 km long. Bottom trawling targets shrimps but at the same time produces bycatch. Both artisanal fishing and bottom trawling have been practiced for several decades in the bay since the 1960s. With time, conflicts emerged ostensibly due to excessive trawl bycatches otherwise targeted by the artisanal fishers, the perceived environmental degradation, and

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the damage of artisanal fishing gear by the trawlers. The oversupply of retained trawl bycatches to the local fish markets resulted in cheap fish prices that competed unfairly with fish sold by the artisanal fishers. This conflict persisted for some time until a ban on bottom trawling was imposed in September 2006. This thenpaved the way for the formulation of the shrimp fishery management plan, six years after the trawling ban. This study therefore, determined the status of the fisheries of the Malindi-Ungwana Bay, before and after the trawling ban and analysed artisanal fishers' alternative livelihoods and their perceptions of shrimp bottom trawling after the ban was lifted in July 2011.

First, a retrospective analysis of some historical data on artisanal and trawl annual catches before and after the ban was conducted. Further, shore-based artisanal catch assessments after the trawl ban between 2009-2011 covering the dry Northeast Monsoon (NEM) and the wet Southeast Monsoon (SEM) seasons were conducted after every three months annually, and catch composition, catch-per-unit-effort (CPUE) and mean trophic level were analysed by vessel-gear combination. In addition, two experimental bottom trawl surveys covering both the NEM and SEM seasons identified the composition, distribution patterns and abundance of penaeid shrimps and associated finfish bycatches in the bay. The socio-economic assessment identified alternative livelihoods for the different categories of artisanal fishers operating in the bay, and the Net Present Value (NPV) calculated the economic viability for each artisanal fishing category. Finally, using semi-structured interviews, the artisanal fishers' perceptions of shrimp trawling in the bay were also identified.

The results of the before and after bottom trawling ban for both trawl and artisanal catches were based on aggregated catch data. Artisanal catches of mostly finfish species showed a decline before the ban, but rapidly recovered within 2 years after the ban. The artisanal shrimp catches were low at less than 100 t annually and this remained unchanged six years before and two years after the trawling ban. On the other hand, commercial shrimp catches showed a gradual decline before the ban from 550 t in 2001 to 250 t in 2006, and the shrimp to bycatch ratio was 1:1.5 compared to values in early reports of 1:7 in 1999. A distinct artisanal catch composition was evident between the fishing areas of Tana and Sabaki of the extensive Malindi-Ungwana Bay. This distinct composition was attributed to more abundant freshwater fish families of Claridae, Cichlidae and Protopteridae in Tana, and more abundant marine fish families of Carangidae, Siganidae, Carcharhinidae and Lethrinidae including mixed pelagic and mixed demersal fish groups in Malindi. Current catch data using shore-based assessments and experimental trawl surveys before the ban was lifted provided a detailed status of the Malindi-Ungwana Bay fisheries resources.

The shore-based artisanal catch assessment described the finfish catch composition (total number of species caught, sizes and mean trophic levels), and catch-per-unit-effort (CPUE) for each of the most popular vessel-gear categories used in the bay. Specific vessel-gear category combinations instead of the traditional gear-based approach, offers better alternative insights for monitoring catches therefore, supporting fisheries management. A total of 4,269 finfish individuals belonging to 178 species and 66 families were sampled by the 5 most popular vessel-gear categories used in the bay. Significant differences in species composition existed between the different vessel-gear categories with the highest number of species caught by the canoe-gillnet and the lowest number caught by the foot-handline category. The CPUE was not significantly different between vessel-gear, although this was on the average highest for canoe-gillnet and *mashua*-gillnet, and lowest for foot-handline. The highest mean trophic level of 4.0 was recorded for the mashua-gillnet and the lowest of 3.4 and 3.2 recorded for the canoe-gillnet and foot-seine net respectively. The *mashua*-gillnet, canoe-gillnet and foot-seine net were singled out as the most suitable units for monitoring the artisanal fisheries in the bay for catching individuals of the highest mean trophic level and largest sized in *mashua*-gillnet, the highest number of species caught in canoe-gillnet, and the smallest sized individuals in foot-seine net.

Results of the shallow water experimental trawl surveys showed distinct penaeid species composition and abundance patterns between the near shore areas of the Tana and Sabaki estuaries, attributed mainly to depth, turbidity and season. *Penaeus semisulcatus* was more abundant at the Sabaki area, where it was deeper with a muddy bottom and less turbid waters. *Fenneropenaeus indicus* was more abundant in the Tana area, a shallower, more turbid area with sandy-mud sediments. *Penaeus monodon*, *Penaeus japonicus* and *Metapenaeus monoceros* were found in both areas, suggesting wider tolerance to environmental conditions. The shrimp total biomass and catch rates were significantly higher during the wet SEM season, and decreased with increasing depth. Small-sized *M. monoceros* and *P. monodon* individuals were abundant during the SEM season, whereas large ones with ripe and spent gonads were more common during the dry NEM season. Seasonal patterns in gonad maturity were less clear for *F. indicus* and *P. semisulcatus*. The length at first maturity (L_{50}) varied among the penaeid shrimp species. The L_{50} was largest for *Penaeus monodon* (41.9 mm) followed by *Fenneropenaeus indicus* (37.4 mm), *Metapenaeus monoceros* (36.0 mm) and *Penaeus semisulcatus* (33.4 mm). These differences in length at first maturity suggested the different species in the bay started spawning at different sizes, an important biological reference for sustainable resource exploitation.

The finfish bycatches associated with the experimental trawl surveys differed in catch rates, biomass and composition by area and season. Catch rates and biomass were significantly higher in the inshore than in the offshore area of the bay, and were distinct in composition, while less pronounced differences existed between the seasons. The Shannon-Wiener diversity index was significantly higher during the wet SEM season, but no differences were found between the inshore and offshore areas, nor was there a significant interaction effect. A total of 158 fish species in 61 families were identified during the dry NEM season, and 161 species in 57 families during the wet SEM. However, only 7 families contributed for 66.6% by mass during the NEM whereas 10 families contributed for 59.7% during the SEM. Comparison of the artisanal catches and trawl bycatches indicated that the inshore trawl bycatches showed a larger overlap with the composition of artisanal catches than offshore trawl bycatches. This larger overlap between the inshore trawl bycatches and artisanal catches was mainly attributed to 7 common and most abundant artisanal fish species confirming a localised inshore resource-use overlap between the artisanal and bottom shrimp trawling, whereas these 7 species were mostly absent in the offshore trawl bycatches. Further, significantly smaller sized individuals of these 7 species occurred in the trawl bycatches posing a potential risk for low recruitment of these fish species with continued bottom trawling. Also species diversity in both inshore and offshore trawl bycatches was significantly higher than in artisanal catches further confirming the possible resource-use overlap between the two fishery types in the Malindi-Ungwana Bay.

The socio-economic assessment using questionnaires in semi-structured interviews of 151 individuals indicated that livelihood diversification in Malindi-Ungwana Bay was common among the artisanal fishers. At least five categories of artisanal fishers were identified: full time fishers, fishers with additional fish trading and other micro-businesses, fishers who used acquired skills for generating extra income, fishers who practiced additional subsistence farming, and fishers with additional part time paid-up jobs. Livelihood diversification among artisanal fishers should be encouraged although with proper choices depending on the economic viability. In this study, the full time fishers were associated with relatively higher mean daily catches and incomes compared to the rest of the fishers with additional livelihood sources. However, the Net Present Value of the different artisanal fishing categories was highest for those artisanal fishers with additional livelihood sources of fish trading and other micro-businesses, part time paid-up jobs, and those who used their acquired skills for making extra income. The Net Present Value was low for those fishers who also undertook subsistence farming, and for the full time fishers suggesting that these were not economically viable options for the artisanal fishers. The majority of artisanal fishers from all fishing categories except those who engaged in part time paid-up jobs perceived a negative impact of shrimp trawling mostly due to its associated damage to artisanal fishing gear, fish habitat, and excessive bycatch of species that are also targeted by the artisanal fishers.

Several conclusions are derived from this study. Before the bottom shrimp trawling ban in September 2006, the activity showed some negative impact due to highly fluctuating and reduced overall artisanal catches and the trawl shrimp catches. This impact was however, not pronounced for the artisanal shrimp catches signifying low or acceptable exploitation level. The artisanal fishery is multigear, multispecies and multifleet in nature as observed for the Malindi-Ungwana Bay. The *mashua*-gillnet, canoe-gillnet and foot-seine net were therefore identified as suitable fishing units for monitoring the artisanal catches in the bay. The relatively higher mean trophic level range of between 3.2-4.0 signified that fisheries resources in the Malindi-Ungwana Bay were still sustainably exploited. The shrimp catch rates and biomass in the bay, decreased with increase in depth and away from the shore, and were significantly higher during the wet SEM season. The Tana and Sabaki estuaries significantly differed in shrimp composition, with the shallower and more turbid Tana estuary characterised by more abundant *Fenneropenaeus indicus* and the deeper and and less turbid Sabaki estuary characterised by more abundant *Penaeus semisulcatus*. The fish species: *Galeichthys feliceps*, *Pellona ditchela*, *Johnius amblycephalus*, *Leiognathus equulus*, *Pomadasys maculatus*, *Otolithes ruber* and *Lobotes surinamensis* were more abundant both in artisanal catches and trawl bycatches and therefore, the potential species for resource overlap and conflict between bottom trawling and the artisanal fishery in the inshore area of the bay. The Net Present Value of artisanal fishing increased with some additional livelihood sources but not with subsistence farming or when full time fishing was undertaken alone. The majority of artisanal fishers from all fishing categories except those who engaged in part time paid-up jobs perceived a negative impact of shrimp trawling.

This study concludes with the following recommendations:

- Revision of the shrimp fishery management plan for the Malindi-Ungwana Bay taking into consideration findings of this study for an Ecosystem Approach to Fisheries (EAF). This is because the present shrimp fishery management plan was formulated with relatively little scientific information available by then.
- Regular monitoring for long term data of fish and shrimps on the identified biological and fishery aspects of mean sizes, mean trophic levels, catch composition, catch-per-unit-effort and size at first maturity (L_{50}) using the proposed *mashua*-gillnet, canoe-gillnet, foot-seine net and bottom trawl.
- The nature of artisanal fishing operation in nearshore is not sustainable due to increased pressure on the resources, weather and seasonal changes. The Kenya Government through the State Department of Fisheries, should initiate a program to equip artisanal fishers with modern fishing vessels and gear to enable them access offshore resources so as to prevent over-exploitation of the nearshore fisheries resources. This will also help to improve the living standard of the local fishermen through increased catches.
- Enforcement of the minimum offshore trawling distance of 3 nm, regular use of onboard observers on trawlers to document target and bycatch species, mandatory use of Bycatch Reduction Devices, observation of the closed trawl season, and sustained prohibition of night trawling unless under research purposes.

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