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Cover image: Woman collecting ascideans at Ponta Mazondue, Inhaca Island, Mozambique (© José Paula, 2005)

Codend mesh size of beach seine nets influences fish species and size composition in Lamu, north coast, Kenya

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Abstract

Beach seine nets are commonly used in reef lagoons in Kenya, with potentially destructive impacts on reefs and other habitats. The species composition and size frequency of catches made by nets with codend mesh sizes of 25 mm, 38 mm and 44 mm were evaluated for samples collected during three sampling trips in the Lamu area between 2014 and 2016. A total of 98 fish species belonging to 41 families were recorded. Most species with highest diversity (D = 10.67) were caught by the 25 mm codend mesh, followed by the 38 mm (D = 6.69) and 44 mm meshes (D = 3.04), respectively. Size frequencies of dominant species *Leptoscarus vaigiensis*, *Siganus sutor* and *Lethrinus lentjan* depended on the codend mesh size sampled, with the 25 mm mesh retaining more immature individuals than the other two meshes. It is concluded that codend mesh size influences catch properties of beach seine nets used in Lamu, and that introducing a minimum mesh size would reduce the proportions of juvenile fishes landed.

Keywords: Beach seine, Species composition, Size frequency, Codend mesh size, Fisheries management, Kenya.

Introduction

Fishing with beach seine nets in reef lagoons contributes substantially to food security and economic activity in coastal villages in Kenya (FAO, 2011). Beach seining is particularly common in the Lamu area on the north coast, where it has been assimilated into the fishing culture after being introduced by migrant fishers about 30 years ago (FiD, 2015). Beach seining is considered to be a destructive fishing gear, and its use has been banned in Kenya since 2001 (Kenya Gazette Notice No. 7565 Vol. CIII. No. 69, 2001). Nevertheless, many artisanal fishers do not comply with the ban (McClanahan *et al.,* 2005), and the number of beach seine nets in the marine artisanal fishery has remained relatively constant, with frame surveys reporting 139 nets (2008), 211 nets (2012) and 193 nets (2014) over the past decade (FiD, 2015). Cinner *et al.* (2009) suggested that fishers do not comply with the ban because of lack of alternative employment opportunities. Noncompliance with regulations undermines the effectiveness of fisheries management (Madrigal-Ballestero *et al.,* 2013; Turner *et al.,* 2014; Pomeroy *et al.,* 2015).

The physical effects of beach seining on reefs and associated habitats have been well documented (McClanahan & Mangi, 2001). Areas affected by beach seining often have significantly smaller corals and a lower density of coral colonies (Mangi & Roberts, 2006). Dragging a net across the seafloor leads to resuspension of bottom sediment, increasing turbidity and smothering benthic organisms (Jones, 1992). It also removes or crushes epibenthic organisms such as corals, seagrasses and sponges (Sainsbury *et al.,* 1997). Beach seine nets are long and mobile, and can therefore affect large areas of seafloor habitats where they are frequently used (McManus, 1997; Auster, 1998; Watling & Norse, 1998).

Beach seining captures a range of fish species and sizes that occur in the intertidal and shallow subtidal zones (Gough *et al.,* 2009), and the codend mesh size used will determine the selectivity of the gear (FAO, 2011). Using a small mesh size is likely to capture a larger proportion of juvenile fishes (Nunoo & Azuma, 2015), and the lead line of the net may also destroy fish spawning grounds while being dragged over the seafloor. Fisheries regulations that specify a minimum mesh size can be used to manipulate the selectivity properties of gear, to reduce the proportion of juvenile fishes smaller than a given size in catches. Mesh size can also be adjusted to reduce catches of non-target species, through size selectivity (MacLennan, 1992; 1995). Knowledge of fishing gear selectivity is therefore important within the context of fisheries management. The effects of codend mesh sizes on the species composition and size of fish caught by beach seine nets in Lamu was assessed.

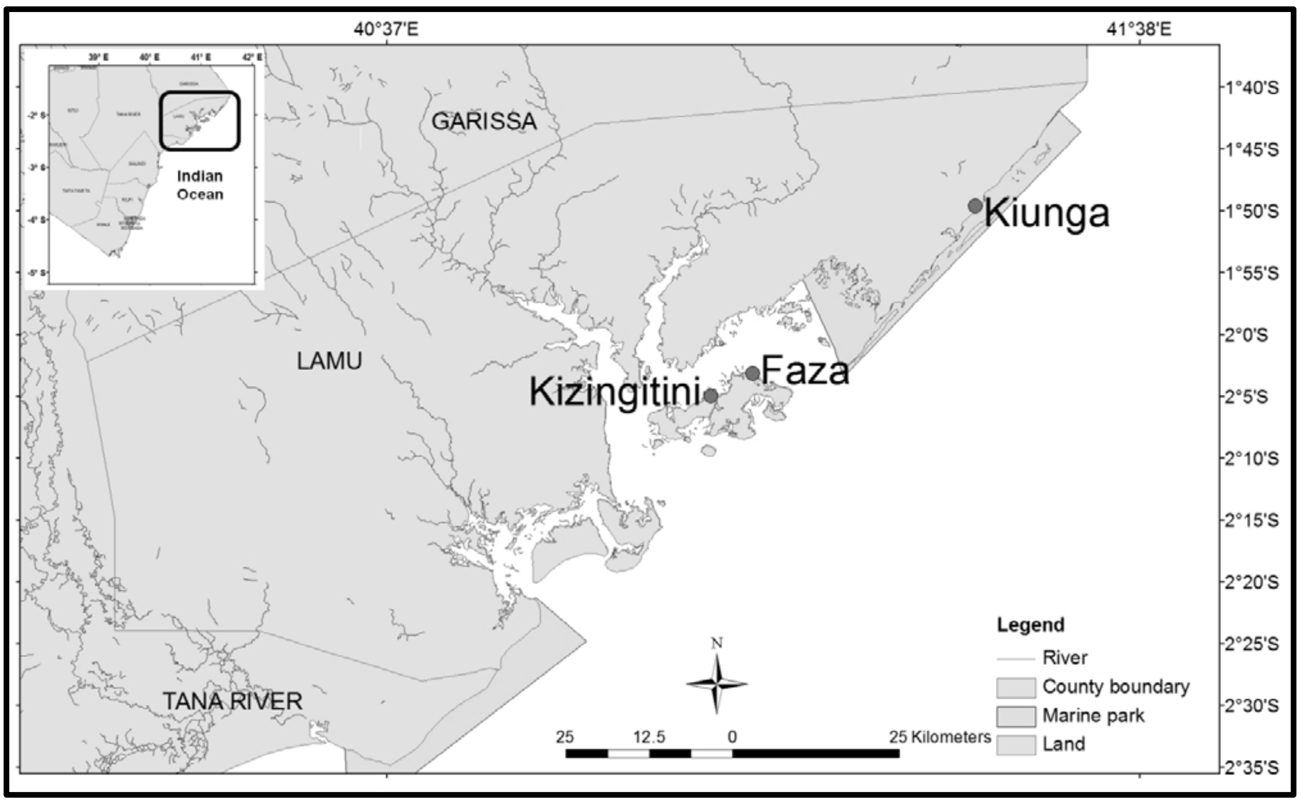

Figure 1. A map of the north coast Kenya, with dark filled circles showing the sampling sites in Lamu.

Materials and methods

Catch assessment surveys were carried out on 1st–7th May 2014, 6th–12th March 2015, and 9th–14th May 2016 at the main beach seine fishing grounds in Lamu (Kiunga, Faza, Kizingitini) (Fig. 1). The area is highly productive with rich fishing grounds influenced by northeast and southeast monsoon winds. The sampled beach seines comprised of a seine body with different nominal codend mesh sizes of 25mm, 38mm and 44 mm, with anterior and posterior wings attached, which is hauled by up to 30 fishers at a time. The upper part of the net is maintained on the surface by a float line (150 – 400 m long) and the footrope on the seafloor comprises a lead line with sinkers to prevent fish from escaping the enclosure. The wings are attached to hauling ropes (FAO, 2011).

A representative catch sample was collected with a bucket from 33 hauls (Table 1), after removing marine litter. The sub-sample of the catch was identified to species level using field guides (Smith & Heemstra 1986; Lieske & Myers, 1994). Fish total length (TL) was measured to the nearest 1 mm using a fixed ruler on a fish measuring board, and individual weights were recorded to the nearest 0.01 g using a weighing balance. Fish were grouped into length class categories to enable a comparative analysis between codend mesh sizes.

Simpson's Diversity Index was used as a measure of diversity for individual mesh sizes, because it takes into account the number of species present, as well as the relative abundance of each species. The index was calculated using the equation:

$$D = \sum (n(n-1))/((N(N-1)),$$

where n is the number of individuals of each species, and N is the total number of individuals of all species. A non-parametric Kruskal–Wallis test was used to compare the fish retained by the three mesh sizes, based on the mean ranks of groups. Mesh selectivity was also determined from size frequencies of the dominant species caught by the different codend mesh sizes, based on the assumption that the community is the same. The length at maturity (L_{mat}) of dominant species was obtained from Hicks & McClanahan (2012) and the proportion of fish smaller than L_{mat} retained by the different mesh sizes was calculated.

Results

Species composition included bony fishes, crustaceans, mollusks, cephalopods and echinoderms. Some 98 species belonging to 41 families were collected and the catch was dominated by three major families; namely Scaridae, Siganidae, and Lethrinidae. The main families that were caught and retained by the 25 mm mesh, but escaped from 38 mm and 44 mm mesh, were small-bodied fish species including Apogonidae (*Apogon fragilis*, *Ostorhinchus taeniophorus*, *Taeniamia fucata*), Monocanthidae (*Cantherhines fronticinctus*), Clupeidae (*Amblygaster sirm*) and Labridae (*Stethojulis strigiventer*).

In terms of numbers of fish, 25 mm and 38 mm meshes caught mostly *Leptoscarus vaigiensis,* followed by *Siganus sutor* and *Lethrinus lentjan,* whereas similar numbers of *L. vaigiensis* and *S. sutor* were caught by the 44 mm mesh (Table 2). In term of weight, *S. sutor* dominated the catch made with the 44 mm mesh, followed by *L. vaigiensis and L. lentjan*. Catches made by the 38 mm mesh were dominated by *L. vaigiensis,* followed by *S. sutor* and *L. lentjan* (Table 3). The Simpson index indicated that the samples caught with the 25 mm mesh had the highest diversity (D = 10.67), followed by the 38 mm mesh (D = 6.69) and the 44 mm mesh (D = 3.04).

Mesh selectivity for the three dominant species differed significantly (Kruskal-Wallis test, $p<0.05$; *L. vaigiensis* H = 87.09, *S. sutor* H = 34.61, and *L. lenjan* H = 179.82*)*. Some 48.0% of *L. vaigiensis* retained by the 25 mm mesh were smaller than the 15.1 cm L_{mat}. Similarly, 90.2% of *S. sutor* caught with the 25 mm mesh were smaller than the L_{mat} of 20.2 cm, and 88.7% of *L. lentjan* were also smaller than the L_{mat} of 20.3 cm (Fig. 2).

Some 53.1% of *L. vaigiensis* landed by the 38 mm mesh, 50% of *S.sutor*, and 60% of *L. lentjan* were smaller than

Table 1. Summary of the field surveys.

Year	Season	Haul No.	Sampled amount (A, kgs)	Catch amount (B, kgs)	Sampling ratio (A/B)	Nominal codend mesh sizes (mm)
2014	SEM	1	9,0	20,0	0,45	25
2014	SEM	2	20,74	250,0	0,08	38
2014	SEM	2	19,26	150,0	0,13	44
2015	NEM	1	6,2	100,0	0,06	25
2015	NEM	4	17,42	93,0	0,19	25
2015	NEM	2	4,94	120,0	0,04	38
2015	NEM	3	27,76	65,0	0,43	38
2015	NEM	2	10,7	50,0	0,21	38
2015	NEM	1	4,2	15,0	0,28	44
2016	SEM	9	25,5	250,0	0,10	25
2016	SEM	3	13,3	227,0	0,06	38
2016	SEM	3	21,0	1530,0	0,01	38

Table 2. Species composition by count (%) by codend mesh sizes.

	Numbers	1367	789	229
	D	10,67	6,69	3,04
Family	**Species**	**25 mm**	**38 mm**	**44 mm**
Scaridae	*Leptoscarus vaigiensis*	18,6	26,1	40,2
Lethrinidae	*Lethrinus lentjan*	13,8	6,3	1,7
Siganidae	*Siganus sutor*	13,2	25,9	40,2
Lethrinidae	*Lethrinus mahsena*	10,8	5,1	7,9
Terapontidae	*Pelates quadrilineatus*	5,2	0,8	0,0
Gerreidae	*Gerres oyena*	4,9	1,3	0,0
Scaridae	*Scarus psittacus*	3,8	1,0	0,0
Siganidae	*Siganus canaliculatus*	3,7	5,3	0,0
Scaridae	*Scarus ghobban*	3,2	1,3	0,4
Lethrinidae	*Lethrinus nebulosus*	2,6	1,6	2,6
Sphyraenidae	*Sphyraena flavicauda*	2,3	5,4	1,7
Mullidae	*Parupeneus rubescens*	2,1	0,3	0,0
Lutjanidae	*Lutjanus fulviflamma*	1,7	0,6	0,4
Scombridae	*Sarda sarda*	1,7	0,1	0,0
Labridae	*Stethojulis strigiventer*	1,4	0,0	0,0
Haemulidae	*Plectorhinchus gaterinus*	1,0	0,9	0,0
Hemiramphidae	*Hemiramphus far*	0,7	1,9	0,0
Labridae	*Cheilio inermis*	0,4	1,6	2,6
Plotosidae	*Plotosus lineatus*	0,4	0,1	0,0
Gobiidae	*Priolepis cincta*	0,4	0,0	0,0
Scaridae	*Scarus sordidus*	0,4	0,0	0,0
Sphyraenidae	*Sphyraena jello*	0,4	0,0	0,0
Haemulidae	*Plectorhinchus flavomaculatus*	0,4	1,9	2,2
Clupeidae	*Amblygaster sirm*	0,3	0,0	0,0
Leiognathidae	*Karalla daura*	0,3	0,1	0,0
Siganidae	*Siganus stellatus*	0,3	0,1	0,0
Sepiidae	*Squid*	0,3	0,0	0,0
Scaridae	*Calotomus spinidens*	0,3	3,2	0,0
Apogonidae	*Apogon fragilis*	0,2	0,0	0,0
Lethrinidae	*Lethrinus microdon*	0,2	0,0	0,0
Apogonidae	*Ostorhinchus taeniophorus*	0,2	0,0	0,0
Haemulidae	*Scolopsis ghanam*	0,2	0,1	0,0
Apogonidae	*Taeniamia fucata*	0,2	0,0	0,0
Monacanthidae	*Cantherhines fronticinctus*	0,2	0,0	0,0
Carangidae	*Caranx ignobilis*	0,2	0,1	0,0
Apogonidae	*Cheilodipterus quinquelineatus*	0,2	0,3	0,0
Carangidae	*Gnathodan speciousus*	0,1	0,3	0,0
Tetraodontidae	*Arothron hispidus*	0,1	0,3	0,0
Chanidae	*Chanos chanos*	0,1	0,3	0,0
Fistulariidae	*Fistularia petimba*	0,1	0,3	0,0
Lutjanidae	*Lutjanus gibbus*	0,1	0,4	0,0
Monacanthidae	*Paramonocanthus frenatus*	0,1	0,3	0,0
Clupeidae	*Sardinella gibbosa*	0,1	0,3	0,0
Scombridae	*Rastrelliger kanagurta*	0,0	0,3	0,0
Ephippidae	*Platax teira*	0,0	0,5	0,0
Labridae	*Halichoeres scapularis*	0,0	0,3	0,0
Lethrinidae	*Lethrinus harak*	0,0	0,4	0,0
Serranidae	*Dermatolepsis striolata*	0,0	0,5	0,0
Serranidae	*Epinephelus coioides*	0,0	0,5	0,0
Serranidae	*Epinephelus malabaricus*	0,0	0,3	0,0
Pomacentridae	*Abudefduf sexfasciatus*	0,0	0,5	0,0

Table 3. Species composition by weight (%) by codend mesh sizes.

Family	Species	25 mm	38 mm	44 mm
Carangidae	*Caranx ignobilis*	24,5	0,0	0,0
Siganidae	*Siganus sutor*	15,3	18,9	38,0
Scaridae	*Leptoscarus vaigiensis*	15,1	26,2	33,3
Lethrinidae	*Lethrinus lentjan*	11,9	5,9	1,2
Lethrinidae	*Lethrinus mahsena*	4,1	1,6	2,8
Siganidae	*Siganus canaliculatus*	3,2	5,6	0,0
Gerreidae	*Gerres oyena*	2,6	0,6	0,0
Sphyraenidae	*Sphyraena jello*	1,9	0,0	0,0
Hemiramphidae	*Hemiramphus far*	1,8	3,0	0,0
Terapontidae	*Pelates quadrilineatus*	1,8	0,3	0,0
Scombridae	*Sarda sarda*	1,7	0,1	0,0
Sphyraenidae	*Sphyraena flavicauda*	1,5	9,5	4,8
Scaridae	*Scarus psittacus*	1,3	0,2	0,0
Scaridae	*Scarus ghobban*	1,3	1,1	0,1
Lutjanidae	*Lutjanus fulviflamma*	1,3	0,7	0,1
Sphyraenidae	*Sphyraena putnamae*	1,0	0,0	0,0
Mullidae	*Parupeneus rubescens*	1,0	0,1	0,0
Chanidae	*Chanos chanos*	1,0	0,5	0,0
Haemulidae	*Plectorhinchus flavomaculatus*	0,8	6,7	6,3
Lethrinidae	*Lethrinus nebulosus*	0,6	2,2	7,0
Tetraodontidae	*Arothron hispidus*	0,4	0,5	0,0
Carangidae	*Gnathodan speciousus*	0,4	0,0	0,0
Labridae	*Cheilio inermis*	0,3	1,8	4,8
Siganidae	*Siganus stellatus*	0,3	0,0	0,0
Scombridae	*Scomberoides tol*	0,3	0,0	0,0
Sepiidae	*Squid*	0,3	0,0	0,0
Scaridae	*Calotomus spinidens*	0,1	0,9	0,0
Haemulidae	*Plectorhinchus schotaf*	0,1	0,8	0,0
Chirocentridae	*Chirocentus dorab*	0,1	0,2	0,0
Gobiidae	*Amblygobius albimaculatus*	0,1	0,1	0,0
Monacanthidae	*Cantherhines fronticinctus*	0,1	0,0	0,0
Scaridae	*Scarus sordidus*	0,1	0,0	0,0
Lethrinidae	*Lethrinus elongatus*	0,1	0,0	0,0
Plotosidae	*Plotosus lineatus*	0,1	0,7	0,0
Fistulariidae	*Fistularia petimba*	0,0	0,2	0,0
Lutjanidae	*Lutjanus gibbus*	0,0	0,3	0,0
Albulidae	*Albula glossodonta*	0,0	2,8	0,0
Serranidae	*Epinephelus coioides*	0,0	2,1	0,0
Ephippidae	*Platax teira*	0,0	1,0	0,0
Scaridae	*Calotomus carolinus*	0,0	0,8	0,0
Lethrinidae	*Lethrinus borbonicus*	0,0	0,8	0,0
Lethrinidae	*Lethrinus harak*	0,0	0,7	0,0
Haemulidae	*Diagramma pictum*	0,0	0,6	0,0
Acanthuridae	*Acanthurus dussumieri*	0,0	0,6	0,0
Toxopneustidae	*Tripneustes gratila*	0,0	0,0	1,6

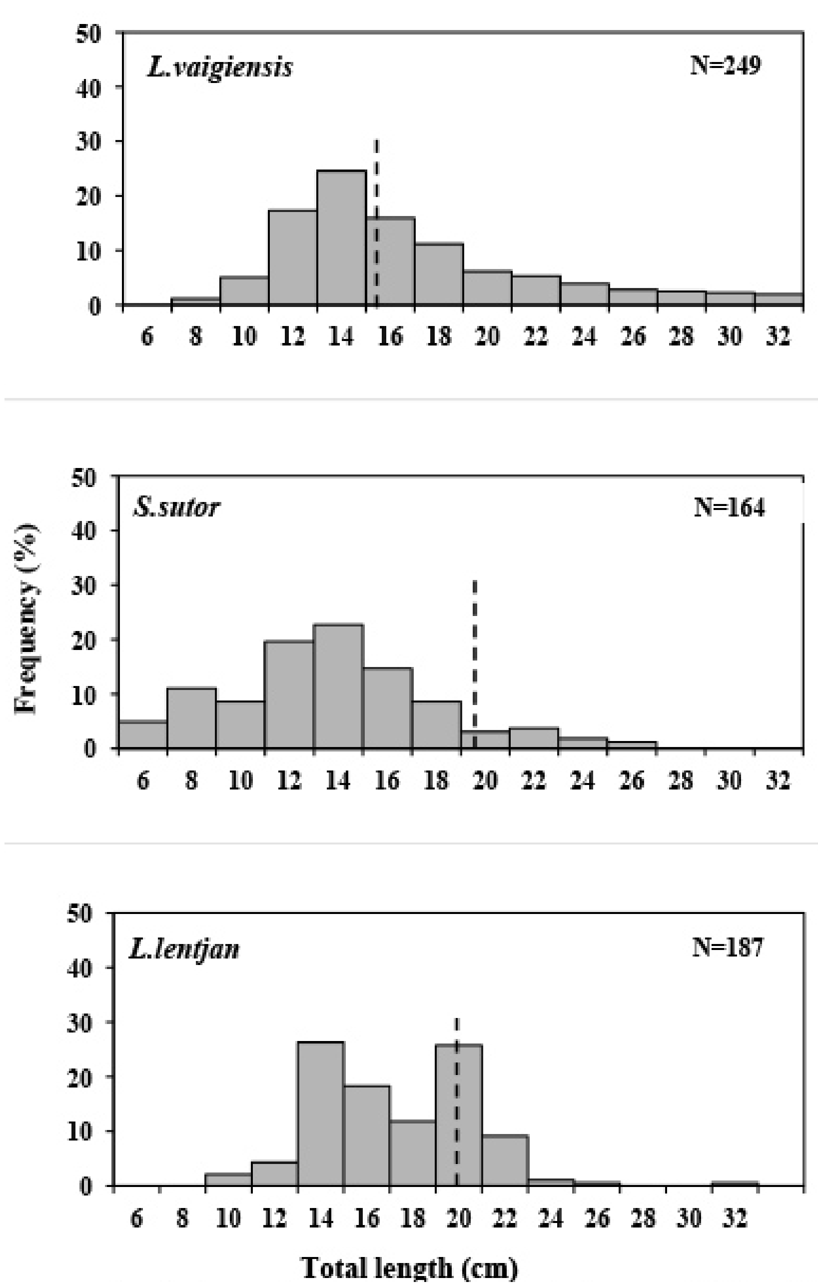

Figure 2. Comparative size frequency graphs for 25 mm codend mesh size of the three dominant species. Dotted lines designated the size of L_{mat}.

the respective L_{mat} estimates (Fig. 3). Only 14.1% of *L. vaigiensis* retained with the 44 mm mesh were smaller than L_{mat}. However, the 44 mm mesh also retained substantial proportions of immature (< L_{mat}) *S. sutor* (76.9%) and *L. lentjan* (60%) (Fig. 4). The sample size of *L.lentjan* was small, and may have affected the results. Overall, the results confirm that the 25 mm mesh size retained proportionally more individuals smaller than the L_{mat} than the 38 mm and 44 mm meshes (Fig. 5).

Discussion

Comprehensive studies on the species composition and size structure of beach seine catches and the effects of gear selectivity on target species are limited in Kenya, where the use of beach seines are prohibited, although not strictly enforced. Attempts to replace beach seine nets with other gear types have been ineffective, and the use of beach seines persists. As an alternative to prohibiting beach seines, implementing a larger mesh size might reduce the impacts on exploited fish populations. Therefore, we analyzed fish caught with different codend mesh sizes, to assess species and size selectivity.

Beach seines with fine mesh codends are active fishing gears known for efficiently capturing a wide range of fish sizes including small, immature individuals

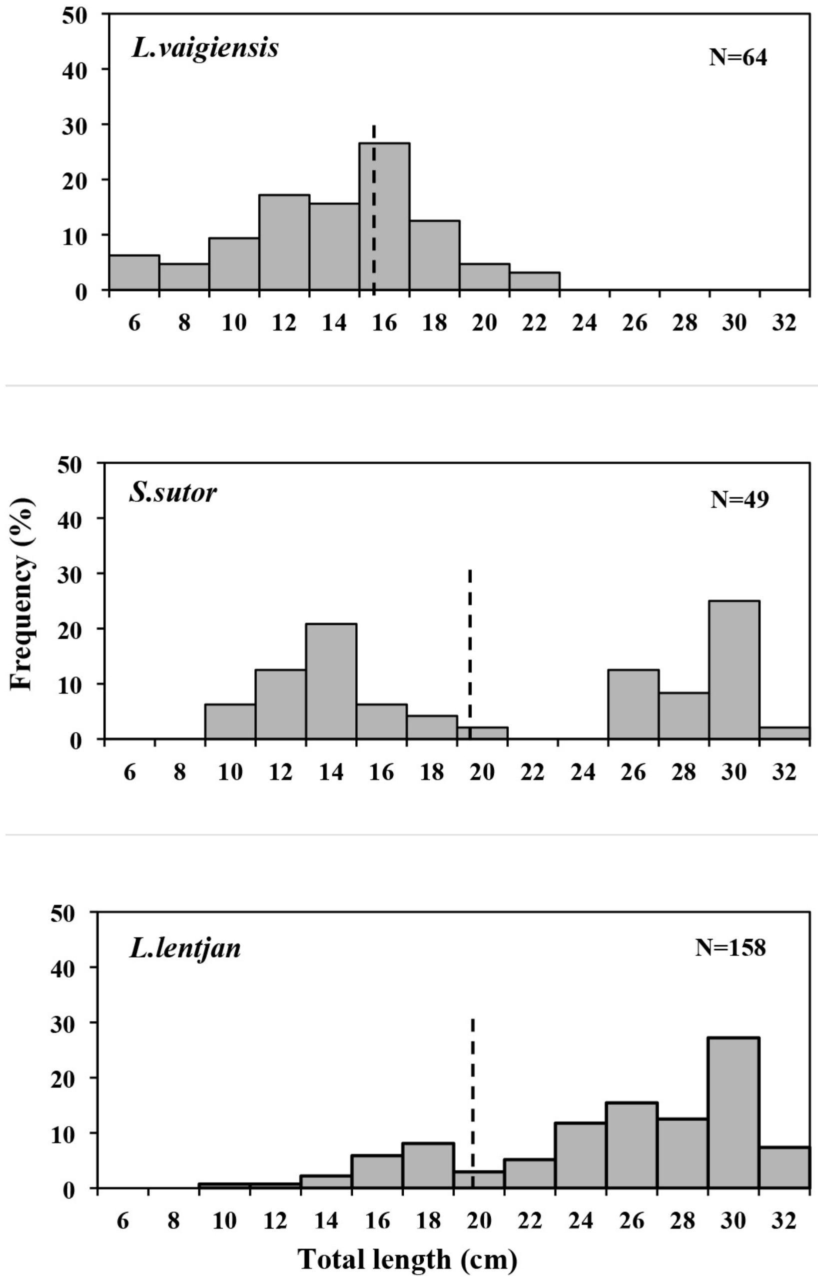

Figure 3. Comparative size frequency graphs for 38 mm codend mesh size of the three dominant species. Dotted lines designated the size of L_{mat}.

(Mangi & Roberts, 2006). Beach seines are also known to catch a high diversity of fish species, but with only a few species dominating by weight or numbers (Gell & Whittington, 2002). The results from the present study support the findings by Cinner *et al.* (2009) and Unworth & Cullen (2010) that beach seine catches are dominated by seagrass fish assemblages and coral reef affiliated species that utilize sea grass meadows for feeding.

Catches made with 25 mm mesh were most diverse, because the finer mesh retained small-bodied species, such as *A. fragilis*, *O. taeniophorus*, and *T. fucata* which may escape through the 38 mm and 44 mm meshes. Similar results were observed in various studies in South Africa (Lasiak, 1984), Ghana (Nunoo et *al.,* 2007) and the western Aegean Sea (Stergiou *et al.,* 1997). Lasiak (1984) confirmed that the species diversity reflects differences in sampling techniques, length and mesh size of gears used, and the differences in the shore-zone fish assemblage.

The 25 mm mesh caught both mature and immature *L. vaigiensis, S. sutor* and *L. lentjan*. These are the most abundant and commercially important species for the Kenyan artisanal fisheries (Hicks & McClanahan,

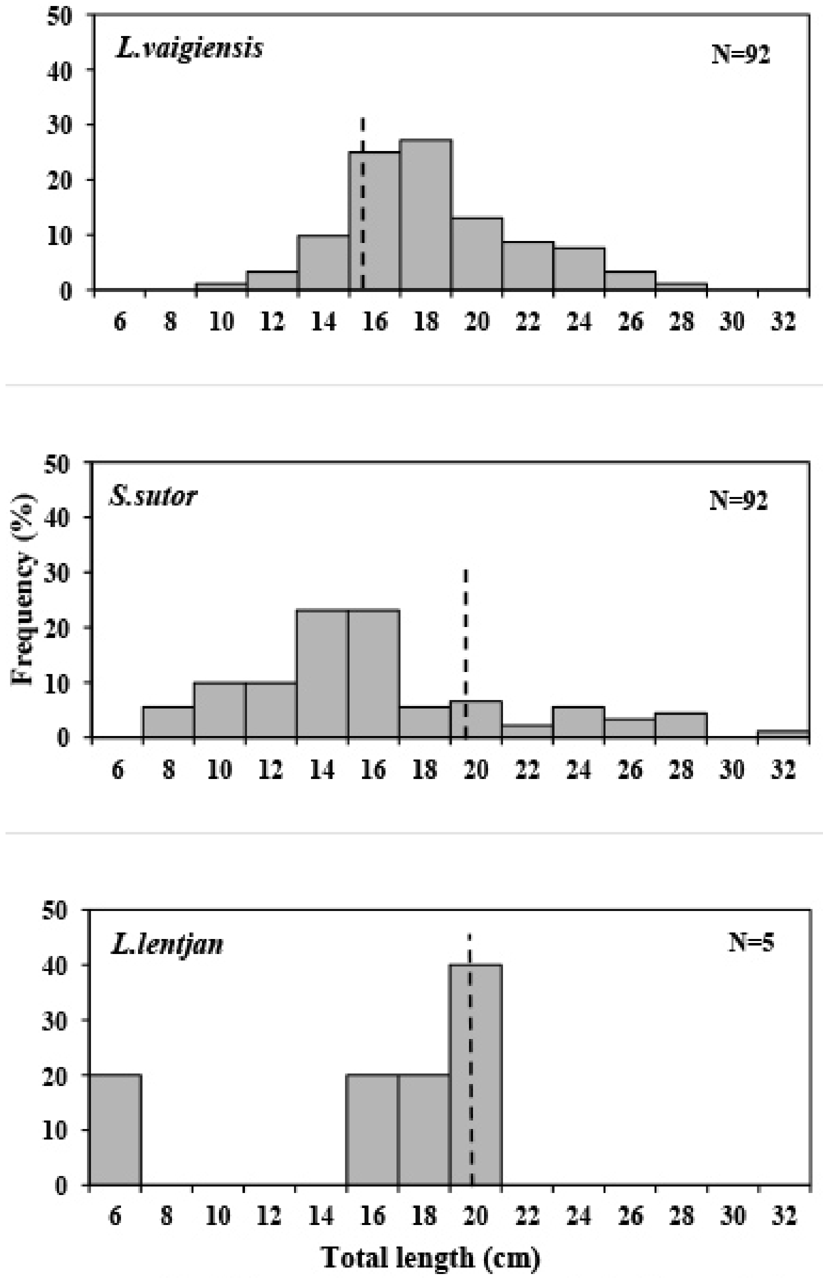

Figure 4. Comparative size frequency graphs for 44 mm codend mesh size of the three dominant species. Dotted lines designated the size of L_{mat}.

2012). Using the 38 mm and 44 mm meshes generally increased the size at first capture of these species, but also reduced the quantity of fish caught by the gear. This poses a conundrum, because the Lamu fishing communities depend on fish for food security and economic activity, and reducing catch rates by increasing mesh size may affect their income. At the same time, the natural resource-base may be under stress from over-harvesting of juvenile fish by small mesh sizes. The concerns surrounding the capture of juvenile fish are that potential yields may be reduced by growth overfishing, or that too few individuals survive to maturity, resulting in recruitment overfishing (Hutchings & Lamberth, 2002).

It is suggested that an appropriate mesh size is introduced (not a biological optimum, but larger than 25 mm mesh) through stakeholder agreements or voluntary action by fishers. This is already practiced by some fishers in Lamu, who use nets with 38 mm and 44 mm codend mesh sizes. An experimental procedure to collect sufficient data to support robust selectivity analysis is suggested. Reliable measurements of mesh size should be considered during stock assessments, when

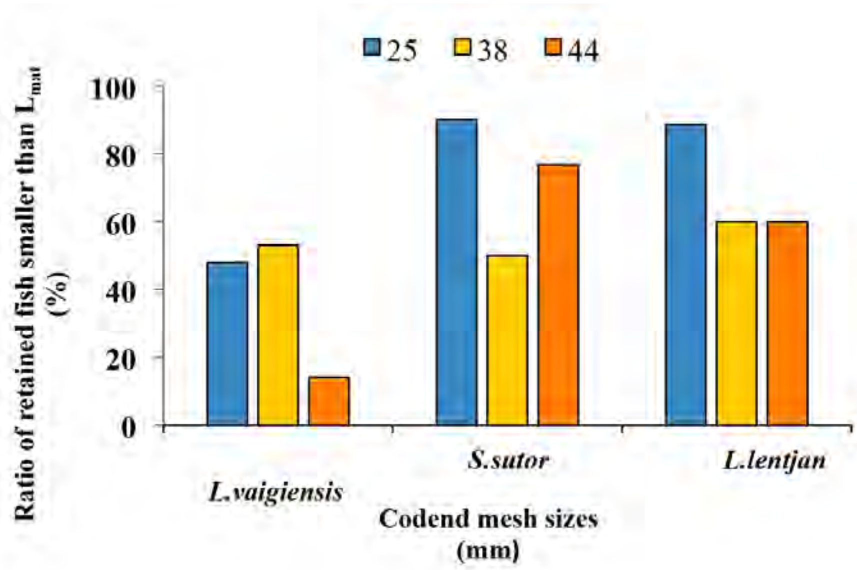

Figure 5. Ratios (%) of the three dominant species $<L_{mat}$ retained by different codend mesh sizes.

estimating fishing mortality rates. Moreover, enforcement officers and net makers should ensure fishers use recommended codend mesh sizes. By regulating mesh sizes, and without outright banning of beach seine nets, fisheries managers should be able to control fishing mortality of smaller species and immature individuals of dominant larger species. It is recommended that further research on selective fishing methods, including standardization of codend mesh sizes, is carried out.

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