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Fish markets facilitate nutrition security in coastal Kenya: Empirical evidence for policy leveraging

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ABSTRACT

Fish markets are key to supporting the availability and accessibility of nutritious food but are often overlooked in food and nutrition research and policy. This study investigated fish markets in coastal Kenya, using data from 223 semi-structured interviews collected through market surveys, and analyzed their potential to meet recommendations for consumption and alleviate malnutrition in a vulnerable coastal population (children under five years). Findings reveal that women small-scale traders dealt in lower quantities of fish per trader than the other traders, yet sold more nutritious fish. Fish shop traders sold enough fish to meet 129% of the recommended intake of fish (10.4 kg cap^{-1} yr^{-1}) for all people within the assessed towns, whereas women small-scale traders sold enough to meet 84% of the intake. All market traders were key to making nutrient-dense fish available, with a 100 g portion of fish providing at least 25% of required intakes, across five nutrients, and women small-scale traders providing over 25% of required intakes across six nutrients for a child under five years. The average cost of a nutritious portion of fish was KES 31 (USD 0.22), ranging from KES 12 (USD 0.08) to 49 (USD (0.34), which provide 33.3% of the required nutrients (averaged across six nutrients), with nutrient-dense fish being notably cheaper. This study contributes empirical evidence on how territorial fish markets support nutrition, which is important for food policy interventions that promote nutritional literacy, address nutrient gaps, and improve postharvest practices and infrastructure for fish quality and safety in Kenya.

1. Introduction

Availability and accessibility of diverse, nutritious, and safe fish is key to supporting food security and reducing malnutrition, especially among vulnerable populations adjacent to fishery resources [1–9]. However, current food policy tends to focus on the availability of food, overlooking an evaluation of what the right food is and whether people are able to access it [10]. Large-scale studies have shown that fish is often one of the most affordable sources of nutritious food [11,12], highlighting the potential for fish to meet the needs of those who need them most [13]. However, although some studies have examined the role of territorial fish markets in supporting nutritional security [14], evaluation of the nutritional contributions they can make, based on the fish supplies traded is still anecdotal, creating a gap in the evidence needed to inform nutrition-sensitive food policies whereby interventions are targeted to improve nutritional security among vulnerable populations.

Territorial fish markets are diverse, can be weakly or strongly formal, supply a range of products, target different consumers, and be controlled by a range of actors [15–18]. Markets can affect the availability and accessibility of food and nutrition security, and are thus key to sustainable development goal number 2: attaining zero hunger by 2030 [19]. The availability pillar of food security refers to the presence of sufficient quantities and qualities of food to satisfy the dietary needs of consumers, being free from adverse substances and acceptable within existing culture [6,20]. This implies that there should be enough fish available on the market that is preferred for local consumption and sourced from available production channels [21]. In coastal Kenya, consumers obtain fish from one or more of the available distribution networks, including local small-scale fishers at the landing sites,

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open-air fish markets, fish shops, supermarkets, and international imports/trade [17,22–24]. Access relates to an individual's or household's economic, social and physical means to acquire food for an adequate dietary intake at a level to ensure that satisfaction of other basic needs are not threatened or compromised; and that adequate food is accessible to everyone, including vulnerable individuals and groups [6,20]. Therefore, for food security, fish markets need to supply enough, affordable, and nutritious food to support the availability and access dimensions of food and nutrition security.

Territorial markets, situated within a specific area, are the primary means through which low-income consumers access fish across Africa [25,26]. Several studies across East Africa have examined the availability and accessibility of fish through territorial markets, focusing on local consumption [27], physical and economic access [1], affordability and availability of preferred fish [28,29]. Other studies examine the influence of perceptions, capital assets, market and power dynamics on who is able to participate in markets, the volumes and species traded, and on value chain development and economic returns [23,30–33]. Although fish trade is recognized as important for nutritional outcomes [27,28,34–37], these studies tend not to incorporate the nutrient content of fish traded, nor evaluate the differentiated role of market actors in tackling malnutrition. Only recently has there been a study on the nutritional contribution of the small pelagic silver cyprinid (locally called "*omena*") in Kenya [14], highlighting the need to capture information for other traded fish taxa.

Here, this study evaluated the role of territorial fish markets in making sufficient quantities of nutritious fish available and affordable, and in doing so, determined the potential contribution of the market traders in providing meaningful nutrients to vulnerable populations. The objectives of the research were to: 1. Characterise the different market traders operating in coastal Kenya; 2. Establish the nutrient quality of fish sold by the different market traders; 3. Evaluate the cost of nutritious fish sold by different market traders; and 4. Determine whether traded fish has the potential to meet the fish consumption and nutrient needs of children under five in the adjacent populations.

2. Materials and methods

2.1. Study sites

Kenya's coastal region consists of six devolved counties: Mombasa, Kwale, Kilifi, Tana River, Lamu and Taita Taveta. Kilifi and Kwale are the most active fishing counties in the region; Kilifi represents 35% of the fishery landing sites, while Kwale represents 25% based on the Kenya Marine Fisheries Frame Survey Report of 2016. Market survey data was gathered from two towns in Kilifi (Malindi and Mtwapa) and one town in Kwale (Ukunda). These towns were purposively selected based on their characteristic mix of urban and rural households, diversity in fish demands and purchasing abilities due to the cosmopolitan nature of the resident populations, high population density, and closeness to productive marine fish landing sites. The human population across these three towns, based on the 2019 national census survey, was 289,884 people. Malindi was the largest town with a population of 166,357 (57.4%) followed by Mtwapa, with a population of 70,990 (24.5%) and Ukunda, with a population of 52,537 (18.1%). Fish form an important part of the diet for most of the residents within the three towns and the small-scale fisheries support many of the adjacent rural communities in terms of food and nutrition, income, and employment [38–40]. Fish traded at the coastal markets are obtained from different sources including coastal and marine fisheries, inland fisheries, aquaculture, and importation. Based on the fish inspection and quality assurance report of 2020, six fish processing establishments exported fish from the coastal region and nine establishments imported fish and fishery products. Most of the imported fish comes from Asian countries, including China, Japan, and Korea and regional countries including Somalia, Djibouti, and Oman. Fish from Lake Victoria (tilapias, Nile perch and freshwater silver cyprinid) are also traded at the coast but sourced from various landing sites within the Lake basin.

2.2. Fish market surveys

Before starting the market surveys, fisheries officers within the jurisdictions of the three towns and the associated fish landing co-management units (also known as beach management units) were briefed on the objective of the surveys through preliminary meetings at their offices. They were asked if there was existing data on the gaps that the survey planned to fill. At all three towns, there was no relevant data except for Mtwapa that had some basic information on existing traders, albeit not aligned to the objective of the survey. Consequently, the survey was conducted to collect novel data on fish trade by market traders during February and March 2021 by the lead author and four trained research assistants. All interviews were conducted in the national Kiswahili language which is the dominant language among the coastal communities.

Three fish market surveys (10 days per survey) were conducted between 13th February and 13th March 2021 in Malindi, Mtwapa, and Ukunda. A total of 223 respondents, categorized as women small-scale traders (n = 109), men small-scale traders (n = 46), fish shop traders (n = 59), and middlemen/dealers (n = 9) (Table 1) were interviewed to identify key traded fish taxa, quantities and prices per unit quantity. The fish shop traders constituted 7 women (12%) and 52 men (88%), while the middlemen/dealers were all men. Although the survey sought to gain proportional representation of the different market traders, this was only possible for the women small-scale traders (approximately 50% were interviewed), men small-scale traders (covered ~ 60%) and fish shop traders (covered ~ 70%) but not for the middlemen/dealers' category because in some cases, traders who fell into the middlemen/dealer category preferred to be considered as fish shop traders. However, the middlemen/dealer category was retained since there were still some respondents who solely identified as middlemen/dealers within the sampling frame and assumed a coverage of 70%.

The fish market survey was done using mixed purposeful sampling, stratified random sampling, and opportunistic sampling designs [41] to be able to capture all required data amidst unpredictable trade operation times associated with COVID-19 time restrictions and erratic fish supplies. Purposive sampling was used to get information from the four categories of market traders while stratified random sampling allowed for subsampling within the women small-scale traders. Opportunistic sampling was used for fish shop traders within the towns. The market survey employed a pre-tested structured questionnaire that was administered through one-on-one interviews with the traders, upon being granted permission to be interviewed. Each interview took between 15 and 45 minutes depending on the nature of trade and whether there were interruptions from respondents due to calls to attend to business. The data obtained included free listing the ten most traded fish taxa, sources of fish, type of market category the respondent identified with, gender of the trader, market location, unit buying price and unit selling price, estimated average quantities traded per day, and number of days traded per month.

Table 1
Summary of the number of traders interviewed at the three towns and the respective market types they represented during this study.

Market traders \ Towns	Malindi	Mtwapa	Ukunda	Total
Women small-scale traders	26	56	27	109
Men small-scale traders	10	12	24	46
Fish shop traders	34	9	16	59
Middlemen/Dealers	5	3	1	9
Total	75	80	68	223

2.3. Description of the fish market traders

The women small-scale traders are fish mongers, also referred to locally as '*mama karangas*', who deal in diverse fish taxa, mainly processed forms of deep fried or sundried fish, although some fish are also sold fresh or frozen to selected consumers [23,33]. Women small-scale traders have been thought to deal in small, cheap fish and restricted to territorial markets targeting low income consumers [23,24]. However, during the market surveys, we found that the women small-scale traders also dealt in large narrow-bodied fishes, such as barracudas, needlefishes, and halfbeaks and would slice them into small pieces before frying and selling. The women small-scale traders generally sold fish in smaller quantities, at price per: piece of fish, portion of fish, pile of several small fishes, or based on measuring containers of different sizes filled with smaller fishes; targeting low income consumers. They seldom weighed their fish for sale using the standard weight of kilograms (kg). Thus, their responses to price per kg was based on their expert estimation of how many pieces or what measure they associated with a kg of fish. The women small-scale traders sell their fish in designated open-air markets, and in temporary sheds within residential areas and along main paths leading to residential homes.

The men small-scale traders deal in similarly diverse taxa as the women small-scale traders but mainly offer mixed small to larger sized fresh or frozen fish for sale, and a small number deal in large amounts of dry fish. The men small-scale traders sell fish along roads, in designated open-air markets and in temporary sheds. Their target consumers include lower middle-class buyers who prefer to buy fresh fish for home use and local small-scale eateries or hotels. Some of these men small-scale traders offer partial fish processing for their consumers in the form of descaling, gutting, and slicing.

Fish shop traders handle fish within formal settings of a shop installed with cold storage freezers, weighing balance, and potable tap water. Their target consumers range from lower middle-class buyers who prefer to buy fresh fish for home use, to local small-scale eateries or hotels. They also act as middlemen/suppliers of fish to the small-scale traders who buy imported frozen mackerels and an assortment of other coastal and marine species for further processing and trade or sale in the same product form. At some landing sites, the fish shop traders owned boats and fishing gears and employed the fishing crew who land and bring the fish catch to the shop. These were clearly observed in Malindi and Mtwapa towns, while it was not observed in Ukunda during the time of the market survey.

Middlemen or dealers refers to traders who act as direct intermediaries between fishermen and an assortment of other fish buyers (the preceding 3 types of traders, export processors and direct consumers). These middlemen/dealers were mainly traders with freezers at the landing sites. They may or may not be owners of boats and fishing gears at the landing sites, but they do facilitate trade of high value fishes that include shellfishes (lobsters, prawns, octopus, and squids) and large fishes for factory processing, or hotel contracts. Some also traded in mixed finfish species, which they bought from fishers and sold to the small-scale traders or direct consumers who preferred buying fish at the landing sites.

2.4. Estimating traded edible fish quantities

Information about traded fish quantities was provided by the respondents as estimated daily traded amounts in kilograms. These weights were first converted into daily traded quantities in tons. Next, the daily traded quantities in tons were multiplied by 365 (number of days in a year), then by a factor of number of days traded per month divided by average number of days per month (30 days) to correct for number of days when trading was not carried out. The number of days traded per month varied from 1 to 30 while the average number of days traded across trader categories was 26.23 days for women small-scale traders, 21.79 days for men small-scale traders, 25.82 days for fish shop traders and 23.79 days for middlemen/dealers.The derived annual quantities were then scaled up to obtain an estimate of traded fish quantities by multiplying by a factor of 2, 1.67 and 1.43 for women small-scale traders, male small-scale traders and fish shop traders/dealers respectively based on survey coverage.

Before determining the nutrient content and supply for traded fish taxa, and where applicable, the above estimated annual traded quantities were converted from reported raw wet weight into edible weights using conversion factors of 0.87 for finfish (based on deboning and gutting), 0.38 for crustaceans and 0.17 for bivalve molluscs [42]. For all other taxa (e.g., octopus and sea cucumbers) and fish that are consumed whole, or reported as processed products, conversion factors were not applied.

2.5. Determining nutrient content, density, and price of traded fish

For each of the 47 fish taxa traded across the four categories of traders, the nutrient content of five micronutrients (calcium, iron, selenium, vitamin A, and zinc) and two macronutrients (total omega-3 PUFA, and proteins) were determined based on modelled estimates available from FishBase [4,43,44]. Where data were reported to species level, species nutrient values were taken directly from FishBase. Where fish type was reported at broader fish taxa level, we used the average nutrient values across species in that fish type grouping that were specific to Kenya's geographical region on FishBase.

The nutrient density of each fish taxa was calculated based on the nutrient content of the fish taxa relative to established recommended nutrient intake (RNI) values. This study used RNI values for children aged under five years as recommended by the FAO and WHO [45] for micronutrients, the Institute of Medicine [46] for proteins' adequate intakes (AI) and for total omega-3 polyunsaturated fatty acids (PUFA) based on the FAO [47]. Coastal counties in Kenya are characterized by high levels of child undernutrition [48–50], we therefore focused on under five years as a vulnerable, and target population group for malnutrition intervention in Kenya. Nutrient density was defined and calculated as the contribution a 100 g portion of fish [51] could make towards the RNI of a target population group (for this study, children under five years) [5,7]. Nutrient density is therefore the sum of the percentage contribution that 100 g of raw fish makes to the recommended dietary intake across all seven nutrients (calcium, iron, selenium, vitamin A, zinc, omega-3 PUFA, and proteins) [7]. The percentage contribution to RNI for each nutrient was capped at 100% to prevent extreme values dominating patterns of variation in density scores for fish taxa with especially high values for some nutrients such as protein and selenium [7]. Nutrient density scores can therefore scale up to a maximum potential value of 700%, where all 7 nutrients are fulfilling recommended nutrient intakes. The weighted average of nutrient density across all reported fish taxa by the four market traders and across the 20 most traded fish taxa were calculated.

To determine the portion size needed to meet 33.3% of recommended nutrient intake across six nutrients (calcium, iron, selenium, vitamin A, zinc, and omega-3 PUFA), the amount or portion size of fish in grams that would be required to meet an average of 33.3% of the recommended nutrient intake across the six nutrients for a child under five years old [5,52,53] was calculated for each of the 47 fish taxa. The contribution of each nutrient is capped at 100%, such that an average of 33.3% of requirements can be met by two nutrients providing 100% of requirement or six nutrients providing 33.3% of the requirements [52,53]. The cost of a portion size that could meet the 33.3% RNI across the six nutrients was then estimated by dividing the weight of this portion size by 1 kg and multiplying by the taxa-specific price of a kg of fish.

2.6. Determining the nutrient supply and potential to meet consumption and nutrient requirements

To determine the potential of the quantities of fish by each trader category to meet annual per capita fish consumption for the total population in Malindi, Mtwapa and Ukunda, the annual traded fish quantities were divided by the total population of people residing in the three towns. The annual per capita fish consumption was then divided with the recommended per capita consumption of 10.4 kg yr^{-1} and multiplied by 100 to obtain the percentage contribution of the traded fish to meet apparent per capita fish consumption.

The nutrient supply for each of the seven nutrients was calculated by multiplying nutrient content of fish taxa by their scaled up edible traded weights. To determine the potential of the nutrient supply by each market type to meet requirements for the population of children under five years in Malindi, Mtwapa and Ukunda, firstly, the nutrient supply for each nutrient was divided by the total population of children in the three towns to get nutrient supply per child. The nutrient supply per child was then divided by the recommended nutrient intake of that nutrient and multiplied by 100 to obtain the percentage contribution of the nutrient supply to the nutrient requirements of the child. The annual population estimate for all the people and for children under five years at the three market towns was sourced from Kenya National Census Survey Report of 2019. This age group was assumed to make up approximately 13% of the total population of the three market towns as per the national level estimate of proportion of children under five years.

2.7. Data analyses

To examine the differences in the average traded fish quantities and unit prices among market traders, the data was first checked for linear model assumptions of normality using visual normal Q-Q plots, distribution histograms and Shapiro-Wilk W test and homogeneity of variance using Levene's test within the free publicly available R 4.0.5 [54]. Due to the lack of normality and homogeneity of variance even after logarithmic transformations of the data, the non-parametric Kruskal-Wallis rank sum tests were applied to examine the differences followed by pairwise Wilcoxon rank sum tests with continuity correction to identify main sources of the differences observed. These analyses were done at alpha 0.05.

The relative associations of the market traders and the 47 traded fish taxa were examined using principal component analysis (PCA) [55,56]. The PCA was preceded by detrended correspondence analysis (DCA) to examine the length of the first axis before deciding which analysis to use [56] whereby PCA and RDA < 3 and $4 <$ CA and CCA criteria was used. The first axis length for the market traders was 2.3 thus the decision for applying PCA to examine key fish taxa by the quantities traded among the different market traders.

3. Results

The research findings are based on responses from fish traders regarding their local knowledge about the fish traded, and business transactional memories. Since the respondents did not share their daily diaries where records of activities were kept, there may be variations in quantities traded and prices indicated based on their recall aptitudes. The interpretation of the results and the discussions are therefore made with due consideration of these limitations and a reflection on the realistic validity of the information by cross checking from fish trade and marketing studies within coastal Kenya.

3.1. Status of fish trade by quantities, prices, and fish taxa

Overall, it was found that the average fish quantities sold per trader across the four market traders varied significantly (Kruskal-Wallis χ^2= 91.5, df= 3, $p < 0.0001$) with a fish shop trader dealing in more fish quantities, followed by a middleman/dealer, man small-scale trader, and lastly woman small-scale trader (Table 2). There were a few cases (n=6) where individual traders dealt in larger volumes (over 50 tons $year^{-1}$), but many of the traders transacted less than 10 tons $year^{-1}$. The quantities of fish sold by the traders varied between 1 and 350 kg per day and on average was approximately 20 kg per day. The overall average unit (per kg) price of fish was found to vary between KES 250 – 500 (USD 1.71 – 3.42) with per unit weight price differences among the market traders not statistically significant (Kruskal-Wallis χ^2= 3.12, df= 3, $p = 0.374$).

Principal component analysis (PCA) of the associations among market traders and traded fish taxa revealed women small-scale traders having greatest factor loadings and contributing to variation on the first axis (29.4%) while men small-scale traders contributed significantly to both the first and second axis, and fish shop traders and middlemen/dealers contributed significantly to the variations along the second axis (27.3%) (Fig. 1, Table 3). The women small-scale traders were associated with the freshwater cyprinid (family Danionidae), mullets (Mugilidae), tilapias (Cichlidae) and surgeonfishes (Acanthuridae) on the first PCA axis while fish shop traders and middlemen/dealers were associated with grunters (Terapontidae), parrotfishes (Scaridae), tripletails (Lobotidae) and Albacores, Bonitos, Kawakawas, Mackerels, Tunas, Wahoos (Scombridae) along the second axis. Three taxa, Portunidae (crabs), Ostreidae (shelled molluscs) and Holothuridae (sea cucumbers) were significant on both the axes but were not highly traded by any of the market traders because of their significantly smaller quantities.

Table 2
Mean annual traded fish quantity per trader for each of the four market categories in coastal Kenya and the mean price per unit weight, (KES - Kenya Shillings, USD - United States of America dollar), quantities with similar superscript letter are not statistically different across the traders.

Market traders	Fish taxa sample size, n	Mean quantities traded, per trader per year, kg	sem (+/-)	Mean unit price (KES)	sem (+/-)	Mean unit price (USD)	Description of the unit of sale by the traders
Women small-scale traders	400	3711.43[c]	242.10	356.90	4.87	2.44	Small: Mostly traded as the number of pieces, piles, cup, or tin measure depending on species. Measures approximated to kg by respondents.
Men small-scale traders	223	4522.29[b]	358.75	384.69	16.60	2.63	Small whole to medium fish: Measured by unit weights as kg or nearest 100 g.
Fish shop traders	348	6681.75[a]	521.51	401.93	13.61	2.75	Small, medium, and large whole fish: Measured by unit weights as kg or nearest 100 g. Too large fishes cut into portable chunks or pieces.
Middlemen/ Dealers	53	4932.56[ab]	699.34	515.28	153.16	3.53	Small, medium, and large whole fish: Measured by unit weights as kg or nearest 100 g. Too large fishes cut into portable chunks or pieces.
Kruskal-Wallis chi-square		91.5		3.12			
Kruskal-Wallis chi-square df		3		3			
Kruskal-Wallis chi-square p value		<0.00001		0.3741			

*sem – standard error of the mean

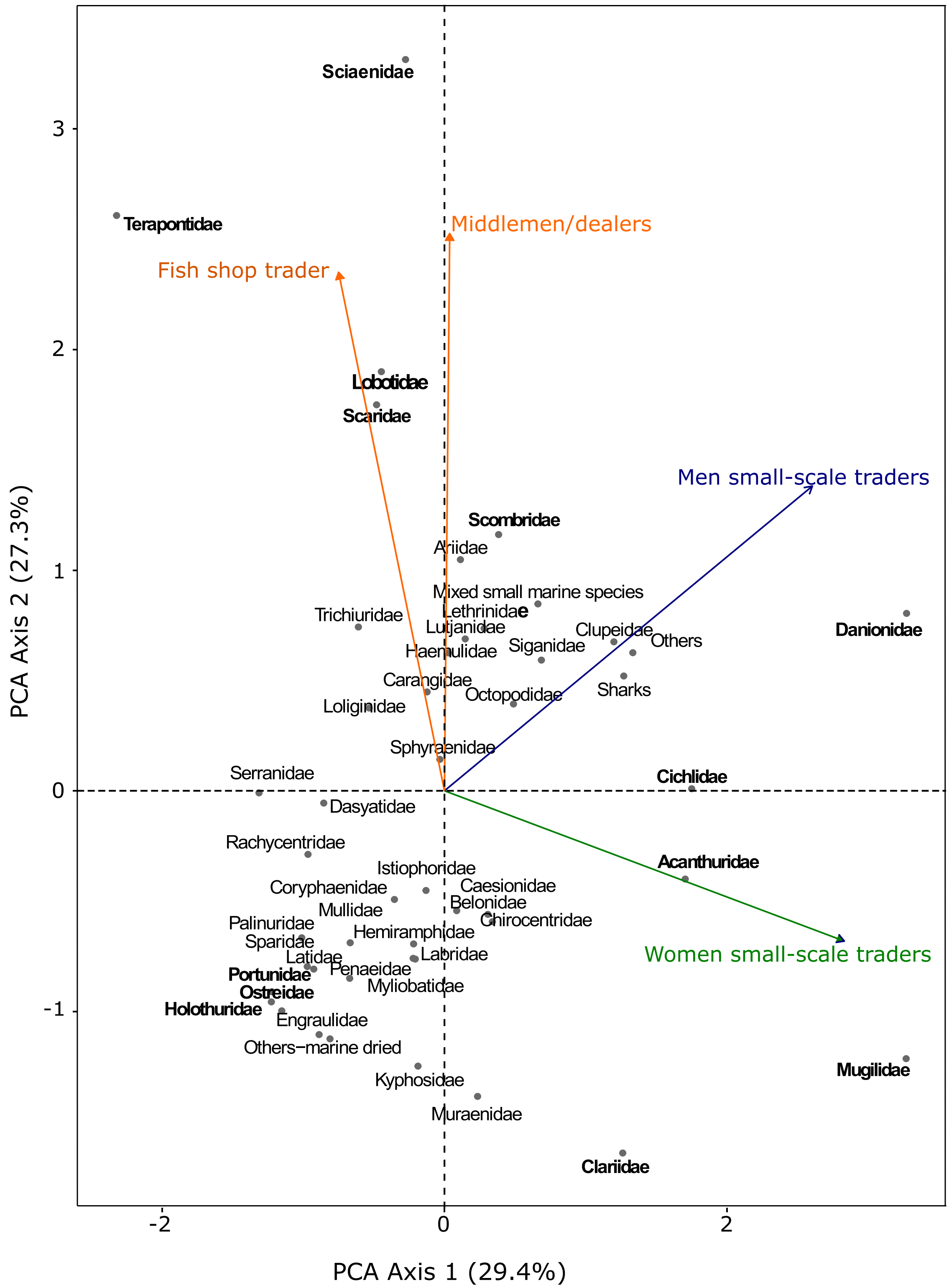

Fig. 1. Principal Component Analysis (PCA) of the association of traded fish taxa and the four market traders based on the quantities of fish transacted, whereby women small-scale traders contributed significantly to the variation on the first axis while fish shop traders and middlemen/dealers contributed significantly to the variation on the second axis and men small-scale traders contributed significantly to both axes; fish families in bold were those contributing significantly to the variations on both axes.

3.2. Nutrient content and density of the main traded fish taxa and by market traders

Women small-scale traders offered fish that were on average, more nutrient dense than other traders. The average nutrient density of a 100 g fish portion sold by women small-scale traders was 388% (Fig. 2A). In contrast, the average nutrient density of a 100 g fish portion sold by the other three market traders ranged from 325% to 328%. The calcium, iron, and zinc content of fishes sold by women small-scale traders was notably (over 30%) higher than that of the other three

Table 3
Significant correlation coefficients of the fish market traders on the first and second PCA axes.

Market traders	Correlation coefficient	p-value
a. PCA 1 (29.4%)		
Women small-scale traders	0.78	< 0.0001
Men small-scale traders	0.72	< 0.0001
b. PCA 2 (27.3%)		
Middlemen/Dealers	0.70	< 0.0001
Fish shop traders	0.65	< 0.0001
Men small-scale traders	0.38	< 0.0001

traders (Fig. 2A). The top 20 most traded fish taxa have sufficient quantities of protein and selenium in a 100 g portion to fully meet requirements for a child under five years. However, there were differences in the nutrient densities of fish taxa for calcium, iron, selenium, vitamin A and zinc. The freshwater silver cyprinid (Danionidae) was the most nutrient-dense for all nutrients except vitamin A, followed by mullets (Mugilidae), sardines (Clupeidae), octopus (Octopodidae) and squids (Loliginidae) (Fig. 2B). One noticeable feature of the nutrient density of the freshwater silver cyprinid (locally called "*omena*") was the high level of calcium and zinc, while the shellfishes (octopus and squids) were nutrient dense with iron. There was evidence of some nutrient density similarities and particular variations across the 20 most traded fish taxa indicating possibilities of the traded fish species being able to complement and/or substitute each other based on the nutrient profiles.

3.3. Fish portion sizes and cost of meeting 33.3% nutrient requirement

It was found that a child under five years would need to consume on average, 85 g of fish from a small-scale woman trader to achieve an average of 33.3% RNI across six nutrients (calcium, iron, selenium, zinc, vitamin A and total omega-3 fatty acids) compared to on average, 92 g, 93 g and 90 g from fish shop traders, men small-scale traders and middlemen/dealers respectively (Table 4). Fish taxa specific portion sizes required to meet an average of 33.3% needs across six nutrients for the top ten most traded fish per trader category are shown in Table 4.

The cost per portion size required to attain an average of 33.3% RNI across six nutrients varied from KES 12 (USD 0.11) to KES 49 (USD 0.44) with a median of KES 30 (USD 0.20) for a median average portion size of 91 g (Fig. 3; Table A.1 in Appendix). There was a narrow demarcation of market traders by price per portion size required to meet nutrient needs for a child under five years, highlighting the fact that prices differed mainly by traded fish taxa (Fig. 3). Fish taxa in quadrat A of Fig. 3 are those that are less nutrient-dense but cheap; those in quadrat B are less nutrient-dense but cost more per portion size; those in quadrat C are the most nutrient-dense and cheap while those in quadrat D, are nutrient-dense but costly. All traders appeared to target fish that were most available, hence their similarities and less divergence on traded fish taxa, with the narrow differentiation indicating commonly traded fish across all the market traders (Fig. 3). There were some differentiations in traded fish where women small-scale traders overall, sold larger quantities of the most nutritious fishes, including silver cyprinids (Danionidae), anchovies (Engraulidae), sardines (Clupeidae), and mullets (Mugilidae) than the other traders.

3.4. Potential of the traded fish to meet consumption and targeted nutrition requirements

Overall, the fish quantities supplied by the fish shop traders had the potential to meet 129% of the town's population annual per capita fish consumption needs at 10.4 kg yr^{-1} followed by small-scale women traders at 84% (Fig. 4A). For the targeted nutrition requirements, it was found that the total quantities of fish traded by the women small-scale traders was sufficient to meet over 80% of the recommended nutrient intakes across all the nutrients, except vitamin A, for all children under five years old within the three towns of Malindi, Mtwapa and Ukunda (Fig. 4B). The fish shop traders sold sufficient quantities of fish to meet over 33% of nutrient requirements for calcium, iron, selenium, zinc, omega-3, and protein whereas the men small-scale traders and middlemen/dealers sold sufficient quantities of fish to meet 33% of nutrient requirements across 3 and 2 nutrients respectively for the target children under five years (Fig. 4B).

4. Discussion

This study reveals that traded fish at coastal markets in Kenya can support local fish consumption and nutrition security, with the most nutrient-dense fish taxa found to be the cheapest and offered by all traders. This is evidenced in the diversity of fish taxa traded at different prices that presents different alternatives for different consumer preferences and financial status.

4.1. Coastal fish markets avail diverse fish taxa, quantities, and prices

Diverse fish taxa are traded in different quantities and prices across the four categories of market traders. The observation of the small fish quantities traded by women small-scale traders could be attributed to the need to sell their fish before it gets spoilt, due to a lack of cold storage and post-processing options (except deep frying and drying) that can extend shelf-life, or limited financial ability to purchase more fish when demand is high [23,24]. The range of fish quantities traded daily by the different market traders falls within the 1–100 kg daily fish volumes transacted by fish traders along the Kenyan coast [33], and that of women small-scale traders that varies between 1 and 18 kg of fish per day, with a few dealing in up to 50 kg [23]. Nonetheless, it has been indicated that fish purchasing capacity of women small-scale traders may decline with rising fish prices which may compel them to cut down on quantities of fish traded [23].

The fish prices per kilogram were not significantly different across the four trader categories, but traders that target different consumers changed the affordability of fish by altering the sizes of portions sold and adding value such as marinating, deep frying or semi-processing prior to sale. For example, fish sold by women small-scale traders are generally considered cheaper [23,24], this is likely because women small-scale traders sell their fish in smaller portions (either pieces or bundle measures) making each exchange more affordable [57]. However, when these smaller portions are aggregated into the standard unit of a kilogram, the price does not significantly differ from the other three market traders. Findings from this study reflect to some extent why the women small-scale traders prefer cheaper small fish and narrow-bodied mixed sizes of other fishes, the latter being cut into several small portions that attract low-income buyers who prefer smaller pre-processed fish portions, thus sustaining profits for this market category as well as offering affordable fish to poor or low-income households. The price range per portion size needed to achieve an average of 33.3% nutrient requirement could be affordable to diverse consumers with different socio-economic statuses.

The fish taxa traded by all traders reveal fish taxa that are characteristic of Kenya's small-scale fisheries [58–60], which are key to harnessing multiple nutritional benefits [61,62]. Further, the observed associations of taxa and market traders seem to mirror similar observations to studies that have investigated fish trade in Kenya [24,31,59]. The diversity of fish traded is key to providing nutritionally rich fish and fish products that are culturally preferred and easily accessed by the poor and other consumers [63], since low diversity can create constraints on consumer choice [64]. Therefore, fish traders' play an important role in linking fishers and consumers through sourcing of a variety of fish species [65].

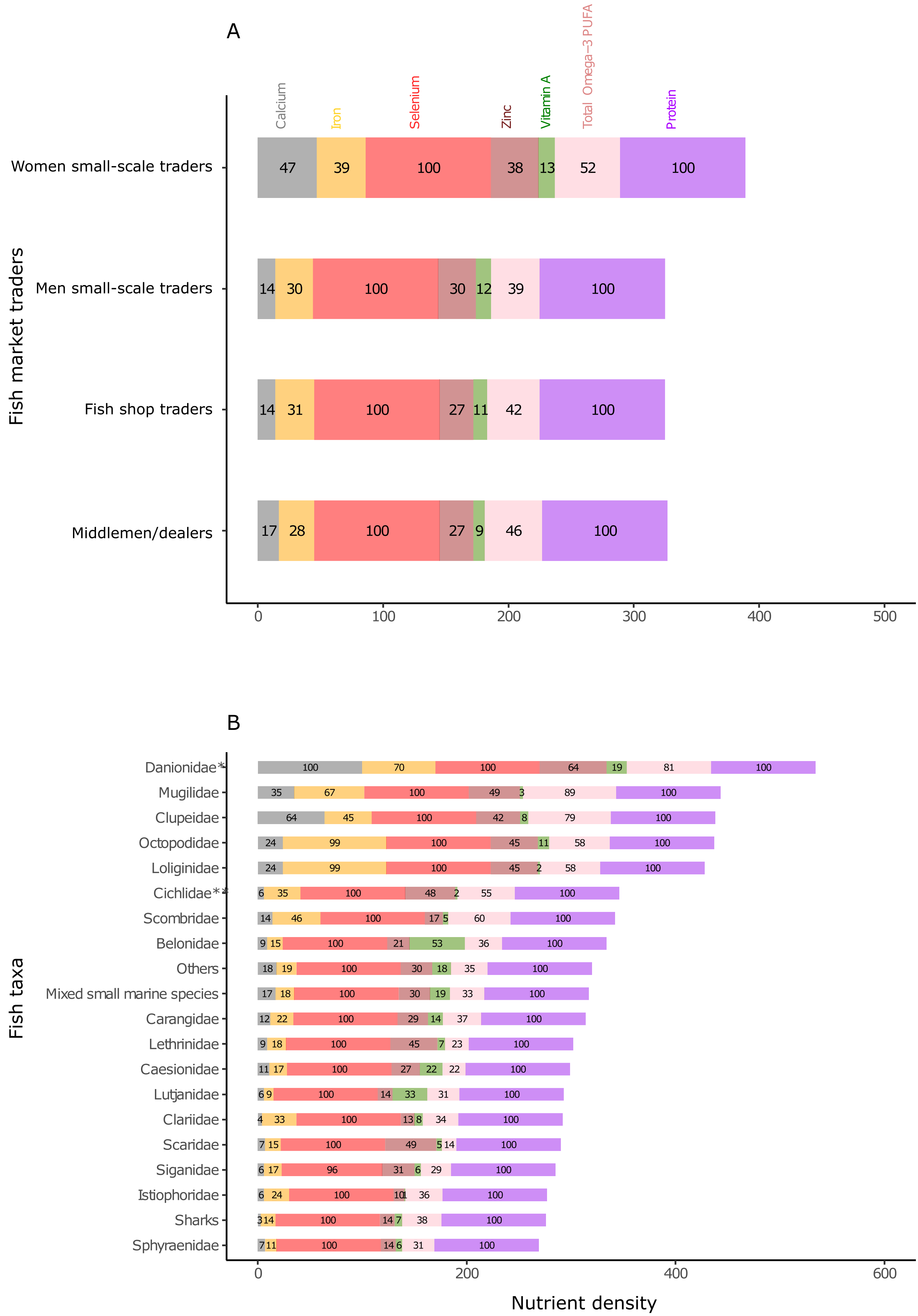

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Fig. 2. Nutrient density expressed as the combined percentage of daily recommended nutrient intake (RNI) of the seven nutrients (calcium, iron, selenium, zinc, vitamin A, omega-3 fatty acids, and proteins) that a 100 g fish portion can supply to a child under five years old, **A** - per market trader category, **B** - across the top 20 fish taxa traded within the coastal markets, Bars represent the percent contribution a 100 g portion of fish provides of 7 key nutrients relative to the recommended nutrient intake (RNI) for a child under five years. For each nutrient, the value within the bar represents the percentage contribution to RNI.

Table 4
Fish market traders, top 10 most traded fish taxa and portion sizes needed to meet an average of 33.3% RNI for a child under five years across six nutrients and the portion price in Kenya Shillings and USA Dollars (1 KES ~ USD 0.0067) obtained during the market surveys.

Fish market traders	Commonly traded fish taxa	Portion size, g required to meet 33.3% RNI across 6 nutrients	Portion price, KES	Portion price, USD
Women small-scale traders	Danionidae	46	16	0.11
	Cichlidae	81	36	0.24
	Clariidae	104	36	0.24
	Scombridae	78	28	0.19
	Sharks	113	43	0.29
	Siganidae	108	38	0.26
	Lethrinidae	99	37	0.25
	Mixed small marine species	92	44	0.30
	Belonidae	86	32	0.22
	Caesionidae	101	33	0.22
Fish shop traders	Scombridae	83	30	0.20
	Siganidae	108	36	0.24
	Lutjanidae	104	37	0.25
	Lethrinidae	99	32	0.21
	Mixed small marine species	92	21	0.14
	Carangidae	93	34	0.23
	Scaridae	105	27	0.18
	Loliginidae	61	29	0.19
	Istiophoridae	113	46	0.31
	Octopodidae	59	20	0.14
Men small-scale traders	Siganidae	108	40	0.27
	Scombridae	82	29	0.20
	Lethrinidae	99	36	0.24
	Lutjanidae	104	40	0.27
	Others	91	24	0.16
	Octopodidae	59	21	0.14
	Caesionidae	101	31	0.21
	Carangidae	93	33	0.22
	Scaridae	105	32	0.22
	Sharks	113	42	0.28
Middlemen/ Dealers	Scombridae	80	29	0.20
	Sciaenidae	76	17	0.11
	Sharks	113	33	0.22
	Siganidae	108	33	0.22
	Lutjanidae	104	35	0.24
	Ariidae	75	13	0.09
	Lethrinidae	99	36	0.24
	Lobotidae	81	17	0.12
	Serranidae	96	29	0.19
	Scaridae	105	31	0.21
Weighted average portion size by fish market traders	Women small-scale trader	85	30	0.20
	Fish shop trader	92	31	0.21
	Men small-scale trader	93	32	0.22
	Middleman/ Dealer	90	30	0.20

4.2. Traded fish contain beneficial nutrients for supporting nutrition security

This study established that the nutrient densities of traded fish highlight the significant role of fish as a nutritious food product [4,7,21,53,66]. Although for many traders, the motivation of fish trade in Kenya is to generate economic profits [24,31], it is also an important livelihood activity creating identity among those employed [23,67]. Findings from this study highlight a third contribution of traded fish in coastal Kenya; as a key source of local nutrition for people's health. This study adds to a growing body of literature on the role of territorial markets in making fish available and affordable for human consumption [1,27–29]. This information on market traders mediating access to and availability of nutritious fish is foundational to supporting policy interventions that are geared towards improving the contribution of fish markets to fish for food and nutrition security.

There were variations in fish nutrient density across traders, all demonstrating that they do provide fish taxa that can be consumed in smaller quantities (average 85 – 93 g) yet achieving significant nutritional outcomes at an average of 33.3% requirement across the six important nutrients. These data for Kenya are consistent with global estimates for reef fish indicating a 90 g portion on average is needed to meet nutritional requirements across six nutrients [5]. This work is further supported by a recent discussion on use of animal sourced foods as part of healthy, sustainable, and ethical diets that highlights small quantities of small dried fish (6 g), dried/smoked fish (15 g) and fresh/frozen fish (68 g) were sufficient to meet 33.3% of requirements averaged across six nutrients [53,68,69]. These studies focused on children under two years meeting requirements for calcium, iron, zinc, vitamin A, vitamin B12, and folate, whereas this study focused on children under five years meeting requirements for calcium, iron, selenium, zinc, vitamin A, and omega-3 fatty acids, nutrients for which data were readily available at species level and which are essential nutrients for children's growth in coastal Kenya. Our findings illuminate the fact that the fish currently made available and accessible by the four market categories have potential to ameliorate hidden hunger among children under five years within the three coastal market towns. This is an important contribution to the knowledge of nutrient content and can help consumers switch their species preferences and be flexible to eating available and accessible nutritious fish offered by the different market traders.

4.3. Territorial fish markets supply fish that can be harnessed to meet consumption and nutrient requirements

The fish quantities traded at the coastal markets supply enough fish to meet the recommended per capita fish consumption of 10.4 kg yr^{-1} based on a 100 g serving per day for two days per week [70]. Based on the combination of six nutrients assessed for the target population, the fish supplied by the different traders provide varied amounts of nutrients with potential to partly meet the nutrient requirements for children under five years. The observation that women small-scale traders supplied fish that can meet over 80% of the recommended nutrient intakes across six of the nutrients for all children under five years old could be linked to their trade in nutrient dense fish such as the small pelagic cyprinids (family Danionidae), mullets, anchovies, and clupeids (mainly sardines) [11,71,72]. Interestingly, apart from being nutrient-dense, these species tend to cost less [11]. The variability in nutrient adequacy by different market traders could be attributed to differences in the fish taxa traded with implications for access by different income

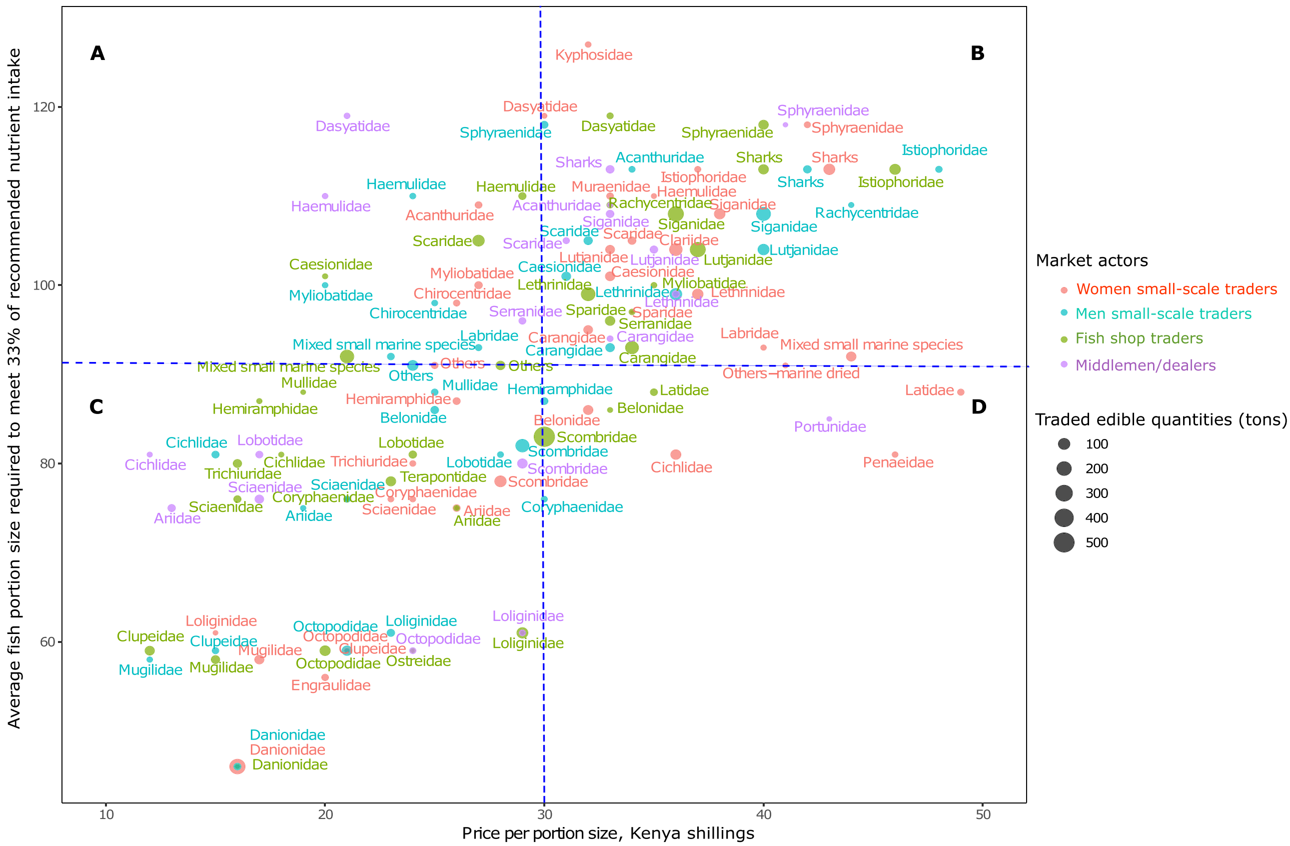

Fig. 3. Relationship between the fish portion size that is required to meet an average of 33.3% RNI target of a child under five years and price per that portion size presented for all the 47 traded fish taxa across the four market traders (the size of the circle represents the total estimated traded quantities per fish taxa at a market type per year); Quadrat A contains less nutritious but cheap fish, B contains less nutritious but expensive fish; C contains more nutritious and cheap fish and D contains more nutritious but expensive fish. The blue dashed lines represent the median price and portion size.

groups. Availability of diverse fish taxa appear to be limited by quantities traded where the most traded volumes were by the fish shop traders. It was clear that the small pelagic cyprinids (family Danionidae) constituted the most traded fish among women small-scale traders, while the family Scombridae dominated the fish shop traders, indicating that preference of what to consume may be compromised by scarcity of desired fish taxa on the market.

While traded fish diversity would be important to meeting diverse consumer preferences, market availability may dictate the options a consumer has access to [33]. For example, women small-scale traders have been mainly associated with small-bodied marine and freshwater species [24,33,67,73]. Additionally, it was found that all traders potentially traded in mixed small marine species albeit in different quantities. Therefore, there is a need to consider the important role played by the diverse market traders in food policy interventions that aim to improve nutrition security due to their uniqueness and complementarity with each other to ensure availability and accessibility of fish. Women small-scale traders tend to bring fish closer to the target consumers' residence while fish shop traders sell fish in shops which require people to travel, and depending on location, and distance, some consumers may opt to buy from the women traders who have brought the fish closer home. Some men small-scale traders were likely to display fresh fish for trade at nearby markets while middlemen/dealers worked with delivery of orders that they aspired to meet or transact at the landing site level upon fish being landed by the fishers.

These results reveal that Kenyan coastal fish markets contribute to availability and accessibility of fish that is nutrient rich, socio-economically accessible and within physical reach by resident coastal populations. However, to achieve this, the market traders seem to rely on a mix of trader attributes that is reflected in different fish quantities transacted. These attributes include investment and technology, diversity of products, proximity to consumers, monetary, nutritional and cultural value of traded fish [74]. Consequently, these attributes can play out as key entry points for improved nutrition-sensitive fish trade that not only avails fish as a trade commodity but incorporates nutrition objectives (such as closing nutrient gaps, improving nutritional literacy, and maintaining the quality, and safety of fish) into their overall strategies. Nutrition-sensitive fish trade could improve human nutrition through a variety of policy instruments and pathways across the four market categories to for example ensure vulnerable populations gain access to nutrient-rich fish. However, this may be faced with challenges such as operational costs, convenience, and disparities in various "power resources" such as social, economic, material, discursive, or symbolic forms of capital [28,65] that would require multi-stakeholder engagement to resolve due to the complexity of food supply and value chains within which fish contained. The narrow differentiation among traded fish taxa could largely be attributed to the higher dependence of the traders on similar sources of fish, majorly the coastal small-scale coral reef fishery. Therefore, management of these fisheries can be tailored to achieve nutritional benefits without compromising biodiversity concerns and sustainability through nutrition-sensitive ecosystem-based approach to fisheries management or attempting novel approaches such as the multi-species maximum nutrient yield (mMNY) model that has been found to have the potential to reduce nutrient gaps for coastal populations, thus maximizing the contribution of wild-caught fish to food and nutrition security [75]. Another option would be to facilitate market traders' coexistence concerning fisheries resource management. This may be achieved by applying management for intermediate resource levels to have high fisheries production, catch and fish body size diversity to achieve sustainability of fisheries production and

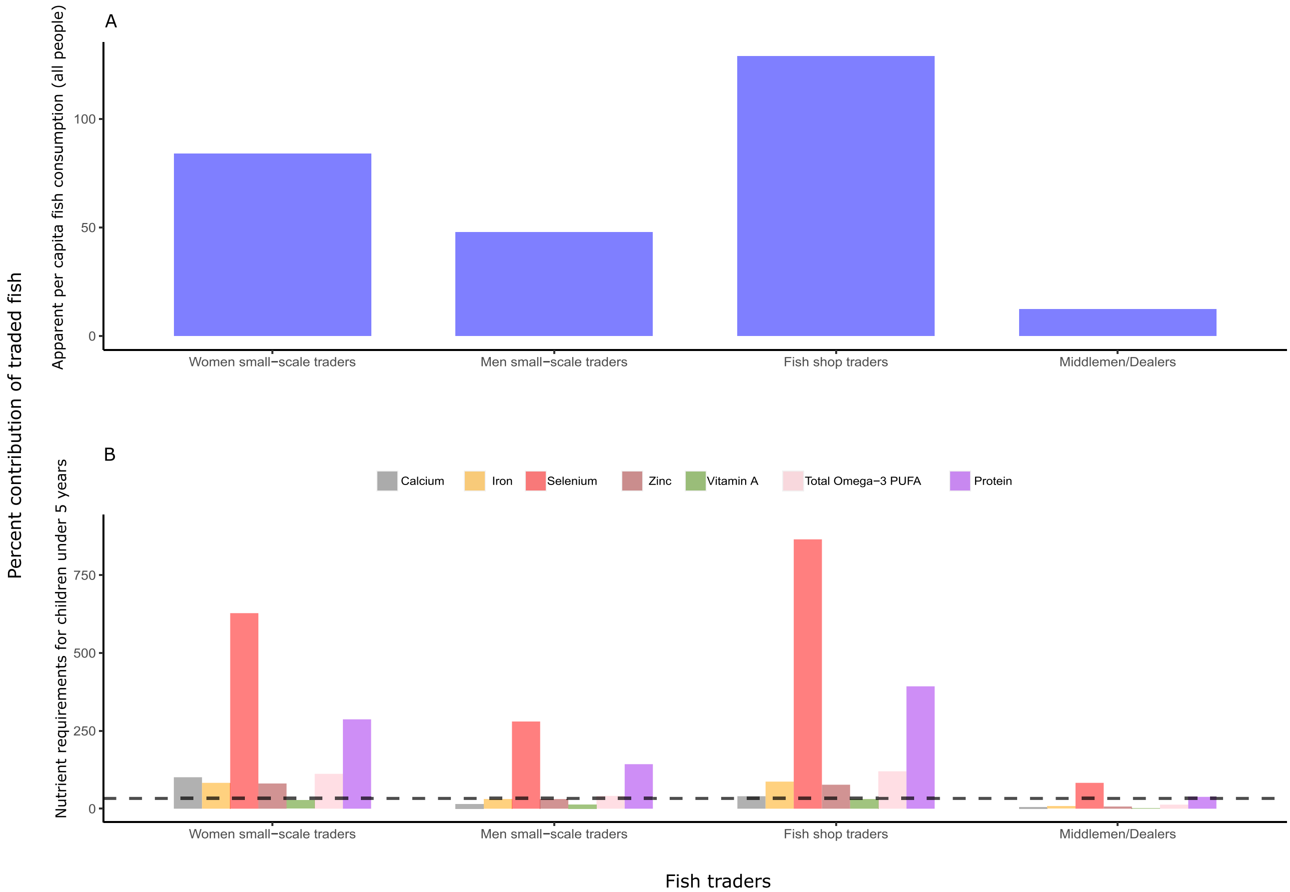

Fig. 4. Percentage contribution of traded fish to A – annual per capita fish consumption of all people within the market locations, B – nutrient requirement of seven nutrients (calcium, iron, selenium, vitamin A, zinc, omega-3 fatty acids and protein) for the target population of children under five years of age residing in the three market towns, the dashed line indicates the 33% cut-off.

posterity of the diverse market actors [24].

5. Conclusions and policy implications

This study identifies how fish trade can support nutritional security, highlighting the need for a better representation in food policy narratives of the role played by different market traders in supplying important nutrients for human health. Better representation of the roles and activities of fish traders, fish markets, and the nutritional quality of fish into Kenya's food policy and framework of agricultural value chains, would support greater nutritional security. These research findings provide an empirical basis of how traded fish could be taken up to support fish markets in being nutrition-sensitive. However, it is advised that while this is considered, management for ecological stability and sustainability should be central since over reliance on one or few fish taxa may lead to declining catches [76]. Further, whilst fish traders are significant actors in resource use, their incentives, actions, behaviors, decisions and willingness to comply with management interventions can either promote or demote efforts to achieve sustainability [24]. Therefore, decisions to ensure fish, fish trade and nutritional outcomes are represented in national food and nutrition security policies will require engaging multiple stakeholders to achieve the goal of a sustainable food system. Improved representation could be achieved through many routes. for example, communication strategies to improve nutritional literacy on the importance of traded fish for human health could draw on the species-specific information on nutrient content reported here, fish supply chain investments into innovations, value addition, trader practices, and infrastructure improvement could be made nutrition-sensitive, by ensuring the quality, quantity, and safety of affordable fish on the market is protected.

This information is useful in shaping peoples' understanding of traded fish as a nutritious food. Consequently, the information should be integrated into the overall food production agenda to support interventions for improved nutritional security. We propose support for interventions that improve the activities of the four fish market categories towards improving availability and accessibility of nutrient-rich fish supplies for local populations. This could help contribute to achieving food and nutrition security commitments that have been made by the national and county governments, as well as international commitments such as the SDG 2 on achieving food security and improving nutrition by 2030. While this study focused on meeting recommended nutrient intakes for children under five years, these can be upscaled to other vulnerable population groups dependent on needs assessment.

CRediT authorship contribution statement

Johnstone O. Omukoto: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nicholas A.J. Graham:** Writing – review & editing, Visualization, Supervision, Methodology. **Christina C. Hicks:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Funding acquisition.

Ethics statement

The coastal market surveys directly involved human subjects, and therefore approval from the Faculty of Science and Technology Research Ethics Committee (FSTREC) of Lancaster University, United Kingdom was sought and granted (FSTREC Reference: FST18132). The market survey was also carried out after research clearance from the Kenya's National Commission for Science, Technology, and Innovation (NACOSTI), License No: NACOSTI/P/21/10978.

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Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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Note

All figures online should be in color.

Appendix

Table A.1
All the traded fish taxa and corresponding portion sizes required to meet 33.3% RNI for children under five years across 6 nutrients and the portion price in Kenya Shillings and USD (1 KES ~ USD 0.0067)

Fish market traders	Traded fish taxa	Portion size, g required to meet 33.3% RNI across 6 nutrients	Portion price, KES	Portion price, USD
Women small-scale traders	Acanthuridae	109	27	0.18
	Ariidae	75	26	0.17
	Belonidae	86	32	0.21
	Caesionidae	101	33	0.22
	Carangidae	95	32	0.21
	Chirocentridae	98	26	0.17
	Cichlidae	81	36	0.24
	Clariidae	104	36	0.24
	Clupeidae	59	21	0.14
	Coryphaenidae	76	24	0.16
	Danionidae	46	16	0.11
	Dasyatidae	119	30	0.20
	Engraulidae	56	20	0.13
	Haemulidae	110	35	0.23
	Hemiramphidae	87	26	0.17
	Istiophoridae	113	37	0.25
	Kyphosidae	127	32	0.21
	Labridae	93	40	0.27
	Latidae	88	49	0.33
	Lethrinidae	99	37	0.25
	Loliginidae	61	15	0.10
	Lutjanidae	104	33	0.22
	Mixed small marine species	92	44	0.29
	Mugilidae	58	17	0.11
	Muraenidae	110	33	0.22
	Myliobatidae	100	27	0.18
	Octopodidae	59	21	0.14
	Others	91	25	0.17
	Others-marine dried	91	41	0.27
	Penaeidae	81	46	0.31
	Scaridae	105	34	0.23
	Sciaenidae	76	23	0.15
	Scombridae	78	28	0.19
	Sharks	113	43	0.29
	Siganidae	108	38	0.25
	Sparidae	97	34	0.23
	Sphyraenidae	118	42	0.28
	Trichiuridae	80	24	0.16
Fish shop traders	Ariidae	75	26	0.17
	Belonidae	86	33	0.22
	Caesionidae	101	20	0.13
	Carangidae	93	34	0.23
	Cichlidae	81	18	0.12
	Clupeidae	59	12	0.08
	Coryphaenidae	76	21	0.14
	Danionidae	46	16	0.11
	Dasyatidae	119	33	0.22
	Haemulidae	110	29	0.19

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Table A.1 (*continued*)

Fish market traders	Traded fish taxa	Portion size, g required to meet 33.3% RNI across 6 nutrients	Portion price, KES	Portion price, USD
	Hemiramphidae	87	17	0.11
	Istiophoridae	113	46	0.31
	Latidae	88	35	0.23
	Lethrinidae	99	32	0.21
	Lobotidae	81	24	0.16
	Loliginidae	61	29	0.19
	Lutjanidae	104	37	0.25
	Mixed small marine species	92	21	0.14
	Mugilidae	58	15	0.10
	Mullidae	88	19	0.13
	Myliobatidae	100	35	0.23
	Octopodidae	59	20	0.13
	Ostreidae	59	24	0.16
	Others	91	28	0.19
	Rachycentridae	109	33	0.22
	Scaridae	105	27	0.18
	Sciaenidae	76	16	0.11
	Scombridae	83	30	0.20
	Serranidae	96	33	0.22
	Sharks	113	40	0.27
	Siganidae	108	36	0.24
	Sparidae	97	34	0.23
	Sphyraenidae	118	40	0.27
	Terapontidae	78	23	0.15
	Trichiuridae	80	16	0.11
Men small-scale traders	Acanthuridae	113	34	0.23
	Ariidae	75	19	0.13
	Belonidae	86	25	0.17
	Caesionidae	101	31	0.21
	Carangidae	93	33	0.22
	Chirocentridae	98	25	0.17
	Cichlidae	81	15	0.10
	Clupeidae	59	15	0.10
	Coryphaenidae	76	30	0.20
	Danionidae	46	16	0.11
	Haemulidae	110	24	0.16
	Hemiramphidae	87	30	0.20
	Istiophoridae	113	48	0.32
	Labridae	93	27	0.18
	Lethrinidae	99	36	0.24
	Lobotidae	81	28	0.19
	Loliginidae	61	23	0.15
	Lutjanidae	104	40	0.27
	Mixed small marine species	92	23	0.15
	Mugilidae	58	12	0.08
	Mullidae	88	25	0.17
	Myliobatidae	100	20	0.13
	Octopodidae	59	21	0.14
	Others	91	24	0.16
	Rachycentridae	109	44	0.29
	Scaridae	105	32	0.21
	Sciaenidae	76	21	0.14
	Scombridae	82	29	0.19
	Sharks	113	42	0.28
	Siganidae	108	40	0.27
	Sphyraenidae	118	30	0.20
Middlemen/Dealers	Acanthuridae	109	33	0.22
	Ariidae	75	13	0.09
	Carangidae	94	33	0.22
	Cichlidae	81	12	0.08
	Dasyatidae	119	21	0.14
	Haemulidae	110	20	0.13
	Lethrinidae	99	36	0.24
	Lobotidae	81	17	0.11
	Loliginidae	61	29	0.19
	Lutjanidae	104	35	0.23
	Octopodidae	59	24	0.16
	Portunidae	85	43	0.29
	Scaridae	105	31	0.21
	Sciaenidae	76	17	0.11
	Scombridae	80	29	0.19
	Serranidae	96	29	0.19
	Sharks	113	33	0.22
	Siganidae	108	33	0.22
	Sphyraenidae	118	41	0.27

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