Seasonal variation in mineral concentrations of four marine fish species retained by fishers in Vanga and Msambweni, Kenya

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Abstract

Marine fish is a rich source of minerals in the diet of humans, but seasonal variation in fish mineral concentrations is relatively unstudied. We investigated seasonal mineral concentrations among four marine fish species retained by small scale fishers in Msambweni and Vanga fishing villages in Kenya. The fish species were Siganus sutor (rabbitfish) in Msambweni and Decapterus macarellus (mackerel scad), Sphraena forsteri (bigeye barracuda) and Sphyraena obtusata (obtuse barracuda) in Vanga. Mineral concentrations were quantified in 120 fish specimens (60/season) and their mineral supplementation potential evaluated. The concentrations of Potassium (K), Magnesium (Mg), Zinc (Zn), Iron (Fe) and Iodine (I) were determined using Inductively Coupled Plasma Optical Emission Spectrometry. K, Mg, Zn and I levels in fish samples varied between seasons with higher concentrations during the wet and cool southeast monsoon (SEM) season (April to October). However, Fe concentration was significantly higher during the dry and warm northeast monsoon (NEM) (November to March). S. fosteri recorded the highest concentrations of Mg (72.29 mg/100g in SEM) and Fe (3.63 mg/100g in NEM) and their mineral supplementation potential evaluated. The concentrations of Potassium (K), Magnesium (Mg), Zinc (Zn), Iron (Fe) and Iodine (I) were determined using Inductively Coupled Plasma Optical Emission Spectrometry. K, Mg, Zn and I levels in fish samples varied between seasons with higher concentrations during the wet and cool southeast monsoon (SEM) season (April to October). However, Fe concentration was significantly higher during the dry and warm northeast monsoon (NEM) (November to March). S. fosteri recorded the highest concentrations of Mg (72.29 mg/100g in SEM) and Fe (3.63 mg/100g in NEM). S. sutor was the richest source of K (410.21 mg/100g in SEM). These two species also recorded the highest concentration of I (57.6 μg/100g in SEM) while D. macarellus had the highest Zn concentration (5.84 mg/100g in SEM). Mineral concentrations were dependent on fish species as well as season, influencing the mineral intake in Msambweni and Vanga villages.

Keywords: fish minerals, seasonal variation, small-scale fisheries, south coast of Kenya
Iron, Zinc and Iodine in a large portion of the population especially in developing countries, which are key elements for normal body functioning (Abeywickrama et al., 2018; Fiorentini et al., 2021; Kumssa et al., 2021). Potassium regulates blood pressure, muscle contraction and stimulates effective transmission of nerve impulses which is necessary for effective functioning of nerves within the human body (Mogobe et al., 2015; Kumssa et al., 2021). Iron is key for the synthesis of haemoglobin in red blood cells which increases the efficiency of oxygen transport to all body parts (Alas et al., 2014). Zinc plays an important role in enzyme reactions as well as cell growth and division (Alas et al., 2014; Mohanty and Singh, 2018). Iodine from marine fish is necessary for thyroxine hormones which regulate body metabolism, shields against goitre, and in children it is a requirement for normal growth and mental development (Pal et al., 2018). Magnesium plays a crucial role in various physiological functions such as protein synthesis, membrane integrity, hormone secretion, nerve function, blood pressure regulation, and various metabolic processes (Schwalfenberg and Genuis, 2017). Marine fish are rich sources of these essential mineral elements when consumed in adequate amounts (Zaman et al., 2014).

Fish is an essential nutrient dense animal food source for numerous households in the world (Ajayi, 2016; Reksten et al., 2020b). The nutritional composition of fish plays a role in promoting the health of consumers in both developed and third world countries (Béné et al., 2015). Fish supplies crucial micronutrients including minerals, fatty acids and vitamins which are imperative to prevent malnutrition (Bennet et al., 2018; Chan et al., 2019). Fish is an essential source of minerals such as Calcium, Phosphorus, Potassium, Magnesium, Zinc, Iron, Fluorine, Selenium and Iodine (Ahmad et al., 2018). These mineral elements contribute to stimulation of metabolic and physiological activities, subsequent growth and development and maintaining proper health of living organisms (Abdulkarim et al., 2015). Insufficiency of mineral elements in the human body causes mineral deficiency diseases such as anaemia, goitre, genetic disorders, poor growth and development (Bhandari and Banjara, 2014: Mogobe et al., 2015).

Fish are a rich source of minerals which they absorb from water and the feed material they consume (Lall and Tibbetts, 2009). Mineral composition of marine fish is relatively higher compared to freshwater fish and can differ according to season as well as biological traits (Nurnadia et al., 2013; Palanikumar et al., 2014). Composition of minerals in marine fish species ranges between 0.1 to 1.5 % of individual wet weight (Nurnadia et al., 2013). However, geographical locations and seasons influence feed composition, which consequently affect the biochemical composition of fish muscle including mineral concentrations (Olgunoglu et al., 2014; Shija et al., 2019). Further, findings by Abdulkarim et al. (2015) show that mineral content of marine fish is influenced by climatological differences between the warm and dry northeast monsoon (NEM) and the wet and cool southeast monsoon (SEM) seasons. Fish mineral levels are largely determined by the availability of nutrients in water and the type of diet, which varies with seasons (Khitouni et al., 2014). Marine fish do not supply the same level of nutrients throughout the year (Barkat et al., 2022).

Artisanal fisheries form a fundamental source of food for many regions, especially developing nations (Thilsted et al., 2016; Lancker et al., 2019). Along the Kenya coast, these fisheries support over 13,000 small scale fishers (Fondo et al., 2014; Wanyonyi et al., 2017). Fish forms an integral part of the diet among local residents along the Kenyan coast (Mwakaribu et al., 2022). On the south coast in particular which is an active fishing area, fish harvested by artisanal fishers are especially salient for the overall health of local inhabitants (Agembe et al., 2010). Without it, natives could not afford to consume sufficient proteins, omega-3 fatty acids, or crucial micronutrients such as vitamin A, Iron, Calcium, Potassium, Magnesium, Zinc and Iodine on a regular basis. However, no information is available on mineral composition of Siganus sutor, Decapterus macarellus, Sphyraena forsteri and Sphyraena obtusa in which are among the most retained fish species from the artisanal fisheries on the south coast of Kenya (Mwakaribu et al., 2022). Taking into consideration the importance of fish in maintaining human health, this study determined the seasonal concentrations of K, Mg, Zn and I in fish samples, and assessed the potential of fish as a remedy for mineral deficiency. This study hypothesized that mineral concentration in fish samples is influenced by season and species type.

Materials and methods

Study area

This study was conducted in Msambweni and Vanga fishing areas on the south coast of Kenya. Msambweni is located more than 50 km from the city of Mombasa, situated at S 04046’53”, E 039048’13” and Vanga further south at the border with Tanzania situated at
S 04039°37″, E 039013°11″ (Oongo et al., 2015; Fig. 1).
Both sites started as small fishing villages but have been developing rapidly over time, characterized by improved infrastructure and increasing population. The sites are among the most active fishing areas in Kenya where the artisanal fishery is considered a major source of livelihood (Agembe et al., 2010). Fishing grounds in these areas have been reported to be rich in biological diversity and provide a vital food source and boosts the economy and wellbeing of the local fishing communities (KCDP, 2016). Fishing activities mainly occur within nearshore reef lagoons characterised by artisanal multi-gear and multi-fleet operators targeting and landing multiple species (Agembe et al., 2010), and are highly influenced by the NEM and SEM seasons.

**Data collection**

*Fish sampling and preparation for mineral analysis*

Following one year of shore-based catch assessments, *Siganus sutor* from Msambweni, *Decapterus macarellus, Sphraena forsteri* and *Sphyraena obtusata* from Vanga were identified as the most retained fish species for local home consumption (Mwakaribu et al., 2022). A total of 60 fresh specimens were randomly collected from the respective fish landing sites adding up to 120 specimens sampled in both NEM and SEM season. Sampled fish specimens were measured for individual total length (TL) (cm) and weight (g), gutted, cleaned, wrapped in plastic foil to maintain freshness, labelled, and transported in polystyrene cooler boxes topped with ice to the Kenya Marine and Fisheries Research Institute (KMFRI) for further analysis in the natural products and postharvest technology laboratory.

Seasonal mineral content composition of K, Mg, Zn, Fe and I in the sampled fish specimens was determined according to the Association of Official Analytical Chemists (AOAC) analysis method (AOAC, 2012; Kiczorowska et al., 2019). Inductively Coupled
Plasma Optical Emission Spectrometry (ICP-OES) was used to quantify the mineral levels. In the laboratory, the samples were washed with deiodized water, deboned, head and fins removed, filleted (AOAC, 2000), followed by pounding fleshy portions of the fish using a porcelain crucible. During the procedure for mineral quantification of K, Mg, Zn and Fe, 2.5 g of pounded fish flesh was weighed using an analytical weighing balance, ground in porcelain crucible then dried using a hot plate. Afterwards, the samples were incinerated at 550 °C overnight using a muffle furnace and then treated with 5 ml 6 M hydrochloric acid (HCl), and 10 ml of 0.1 M nitric acid (HNO₃) (AOAC 2012: Mogobe et al., 2015; Njinkoue et al., 2016). For Iodine quantification, 0.2 g of fish sample was weighed and then treated with 5 ml of 6 M nitric acid and 2 ml concentrated hydrogen peroxide before being mounted on a microwave digester. The solutions were left for a duration of 2 hours before being transferred to volumetric flasks topped with 50 ml ultra-pure water and used for determination of mineral content (Mogobe et al., 2015).

Data and statistical analyses
Sizes of sampled fish specimens were subjected to statistical test to determine differences in fish sizes between seasons using 1-way ANOVA for parametric data and the Kruskal-Wallis test for non-parametric data. For mineral content analysis, 1-way ANOVA was also used to test for significant differences in fish mineral concentration in sampled fish species between seasons. STATISTICA version 7 statistical software was used for the statistical tests at a significance level of p < 0.05, and homogeneity of variances confirmed using the Levene’s test accepted at p > 0.05 as a requirement for using the ANOVA parametric test.

Results
Size variation of randomly sampled fish specimens
Sizes of the fish specimens varied between seasons (Table 1). Sphyraena obtusata and Decapterus macarellus were significantly larger in SEM compared to NEM season (1-way ANOVA, p < 0.05 in both cases). Results of 1-way ANOVA confirmed that Siganus sutor were larger in the NEM season than SEM season (df = 1, f = 51.340, p = 0.000). Kruskal-Wallis test indicated that Sphyraena forsteri were significantly larger in the NEM season than SEM season (p = 0.000).

Mineral concentration of sampled fish specimens
Results of mineral concentration varied widely among these fish species and to some extent concentrations differed between the seasons (Table 2). Seasonal variability of K, Mg, Zn, Fe and I levels in fish samples was evident.

Mineral concentration in Sphyraena obtusata
Results of 1-way ANOVA indicated that Fe concentration was significantly higher in the warm NEM season (2.59 ± 0.024 mg/100g) than in the wet SEM season (0.64 ± 0.016 mg/100g) (df =1, f = 4382.580, p = 0.000). The same test confirmed that K concentration was significantly higher in the SEM season (384.25 ± 3.051 mg/100g) than the NEM season (255.57 ± 2.627 mg/100g) (p = 0.000). Mg concentration was higher in SEM than NEM but not significantly different (Kruskal-Wallis test (p = 0.070). Zn concentration was significantly higher in SEM than NEM (2.69 ± 0.034; 1.45 ± 0.006 mg/100g) (Kruskal-Wallis: p = 0.000). Similar I concentration of 13.48 ± 0.807 mg/100g and 14.93 ± 0.793 mg/100g were recorded for NEM and SEM, respectively and this was not significantly different (1-way ANOVA: df = 1, f = 1.631, p = 0.210) (Table 2).

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>Area</th>
<th>Mean Weight (g)</th>
<th>Mean Length (cm)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siganus sutor</td>
<td>Rabbitfish</td>
<td>Msambweni</td>
<td>320 ± 16.7 (NEM) vs 172.3 ± 12.7 (SEM)</td>
<td>28.8 ± 0.55 (NEM) vs 22.8 ± 0.60 (SEM)*</td>
<td>30</td>
</tr>
<tr>
<td>Sphyraena forsteri</td>
<td>Bigeye barracuda</td>
<td>Vanga</td>
<td>34.3 ± 0.8 (NEM) vs 25.6 ± 1.9 (SEM)</td>
<td>18.7 ± 0.08 (NEM) vs 16.6 ± 0.36 (SEM)*</td>
<td>30</td>
</tr>
<tr>
<td>Sphyraena obtusata</td>
<td>Obtuse barracuda</td>
<td>Vanga</td>
<td>49.8 ± 5.1 (NEM) vs 132.1 ± 11.4 (SEM)</td>
<td>21.3 ± 0.80 (NEM) vs 31 ± 1.01 (SEM)*</td>
<td>30</td>
</tr>
<tr>
<td>Decapterus macarellus</td>
<td>Mackerel scad</td>
<td>Vanga</td>
<td>41.9 ± 0.1 (NEM) vs 66.2 ± 1.8 (SEM)</td>
<td>16.8 ± 0.14 (NEM) vs 19.0 ± 0.16 (SEM)*</td>
<td>30</td>
</tr>
</tbody>
</table>
Table 2. Results of seasonal mineral composition by fish species sampled over the study period. The symbol * indicates a statistically significant difference at p < 0.05.

<table>
<thead>
<tr>
<th>Species</th>
<th>K(mg/100g)</th>
<th>Mg(mg/100g)</th>
<th>Zn(mg/100g)</th>
<th>Fe(mg/100g)</th>
<th>I(µ/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. obtusata</td>
<td>255.57 ± 2.627 (NEM) vs 384.25 ± 3.031 (SEM)*</td>
<td>36.23 ± 0.807 (NEM) vs 38.30 ± 0.366 (SEM)</td>
<td>1.45 ± 0.006 (NEM) vs 2.69 ± 0.034 (SEM)*</td>
<td>2.59 ± 0.024 (NEM) vs 0.64 ± 0.016 (SEM)*</td>
<td>13.48 ± 0.807 (NEM) vs 14.93 ± 0.793 (SEM)*</td>
</tr>
<tr>
<td>D. macarellus</td>
<td>242.12 ± 3.548 (NEM) vs 304.19 ± 2.759 (SEM)*</td>
<td>35.26 ± 0.752 (NEM) vs 47.56 ± 0.509 (SEM)*</td>
<td>1.49 ± 0.035 (NEM) vs 5.84 ± 0.054 (SEM)*</td>
<td>2.31 ± 0.029 (NEM) vs 2.06 ± 0.024 (SEM)*</td>
<td>13.87 ± 0.213 (NEM) vs 18.33 ± 0.412 (SEM)*</td>
</tr>
<tr>
<td>S. forsteri</td>
<td>246.25 ± 4.716 (NEM) vs 382.28 ± 3.802 (SEM)*</td>
<td>33.42 ± 0.658 (NEM) vs 72.29 ± 1.525 (SEM)*</td>
<td>2.69 ± 0.037 (NEM) vs 4.51 ± 0.107 (SEM)*</td>
<td>3.63 ± 0.021 (NEM) vs 1.52 ± 0.032 (SEM)*</td>
<td>14.04 ± 0.165 (NEM) vs 17.53 ± 0.240 (SEM)*</td>
</tr>
<tr>
<td>S. sutor</td>
<td>248.78 ± 3.109 (NEM) vs 410.21 ± 3.546 (SEM)*</td>
<td>26.63 ± 0.320 (NEM) vs 57.96 ± 0.926 (SEM)*</td>
<td>0.65 ± 0.023 (NEM) vs 3.79 ± 0.051 (SEM)*</td>
<td>2.75 ± 0.037 (NEM) vs 2.76 ± 0.038 (SEM)</td>
<td>35.40 ± 0.859 (NEM) vs 37.60 ± 1.679 (SEM)*</td>
</tr>
</tbody>
</table>

Mineral concentration in *Decapterus macarellus*

The concentration of Fe in *D. macarellus* was significantly higher in NEM (2.31 ± 0.029 mg/100g) than SEM season (2.06 ± 0.024 mg/100g) (1-way ANOVA: df = 1, f = 44.000, p = 0.000). K and Mg concentrations were significantly higher in SEM than NEM season (Kruskal-Wallis test: p = 0.000). The concentration of I was also significantly higher in SEM (5.84 ± 0.054 mg/100g) than NEM season (1-way ANOVA: df = 1, f = 10.760, p = 0.000). For this species I concentration ranged between 242 and 410 mg/100 g. Findings by Reksten et al. (2013) and Nordhagen et al. (2015) who further asserted that season is an essential source of K, Mg, Zn, Fe and I. However, the concentrations of these minerals in the selected fish species was largely influenced by species type and seasons. This confirms to the work of Varljjen et al. (2013) and Abdulkarim et al. (2015) who revealed that fish do not supply similar concentrations of minerals to consumers, as nutritive value of fishes differ with species and seasons. The present study therefore allows the hypothesis to be accepted that the levels of K, Mg, Zn, Fe and I are indeed significantly influenced by fish species and seasons. Varying climatological conditions between the warm northeast monsoon (NEM) and cool southeast monsoon (SEM) seasons may have caused the variation in concentration of minerals in the selected fish species. Similar variations in fish mineral concentration were also reported by Abdulkarim et al. (2015) who further asserted that season is an important factor that alters the mineral concentration in fish considerably. In all fish species investigated in the present study, K was the most dominant mineral followed by Mg. The lowest recorded mineral concentration in fish specimens in this study were I, Fe and Zn. Similar studies by Reksten et al. (2020a) and Nordhagen et al. (2020) also observed lower concentrations of these three minerals in fish muscles compared to Mg, K, Ca and Na concentrations. Zn concentration ranged between 0.5 and 6.13 mg/100 g which is similar to results reported by Nurnadia et al. (2013) and Zaman et al., (2014).

Mineral concentration in *Sphyraena forsteri*

The concentration of Mg in this fish species was significantly higher in SEM (72.29 ± 1.525 mg/100g) than NEM season (14.04 ± 0.165 mg/100g) (1-way ANOVA: df = 1, f = 720.940, p = 0.000). K and Mg concentrations were significantly higher in SEM season than NEM season (Kruskal-wallis test: p = 0.000 for both cases). Zn concentration was significantly higher in SEM season (246.25 ± 4.716 mg/100g) than NEM season (34.22 ± 0.658 mg/100g) (1-way ANOVA: df = 1, f = 44.000, p = 0.000). The concentration of I was also significantly higher in SEM than NEM season (1-way ANOVA: df = 1, f = 104.990, p = 0.000) (Table 2).

Mineral concentration in *Siganus sutor*

In this species Fe concentration was similar in both seasons (2.75 ± 0.037; 2.76 ± 0.038 mg/100g for NEM and SEM, respectively). The concentrations of K, Mg, Zn and I were significantly higher in SEM than NEM season (p < 0.05 in all cases) (Table 2).

Discussion

In reference to the recommended dietary intake for minerals (DRI, 2001; World Health Organization, 2004), this study confirmed that *S. sutor* (rabbitfish), *D. macarellus* (mackerel scad), *S. forsteri* (bigeye barracuda) and *S. obtusata* (obtuse barracuda) are an essential source of K, Mg, Zn, Fe and I. However, the concentrations of these minerals in the selected fish species was largely influenced by species type and seasons. Among the sampled species, Potassium concentrations ranged between 242 and 410 mg/100 g. The results agree with findings by Nordhagen et al. (2020) whose K concentration in fish ranged between 177 and 513 mg/100 g. Findings by Reksten et al. (2020a) on
Potassium content in fish were within the same range. K concentration in the four selected species was significantly higher in the SEM season compared to NEM season. Abdulkarim et al. (2015) reported that macro minerals such as K and Mg were higher in the wet season than the dry season. The species S. sutor had the highest concentration of Potassium compared to the other species with concentration ranging between 248 and 410 mg/100 g. A similar study by Wahyuningtyas et al. (2017) reported that S. sutor is a richer source of K than Mg, Fe and Zn. Adequate levels of K in S. sutor makes it a preferable diet for K supplementation especially for pregnant and lactating women who require levels of 4,000 mg/day and 4,400 mg/day, respectively (Strohm et al., 2017). S. forsteri, S. obtusata and D. macarellus are also key sources for K with sufficient levels ranging between 304 to 384 mg/100 g in the wet and cool SEM season.

The Mg concentration in all the sampled species across the study sites ranged between 26.6 and 72.2 mg/100 g. Results of this study agree with the findings of Reksten et al. (2020a) who reported Mg concentration in fish muscles ranging between 29 and 75 mg/100 g. These results were also similar to findings of Nordhagen et al. (2020) who found Mg concentrations in fish muscles ranging between 18 and 57 mg/100 g. However, Mg concentrations in the present study were significantly higher during the wet and cool SEM season ranging between 38 and 72 mg/100 g. A study conducted by Abdulkarim et al. (2015) revealed the same results which indicated Mg concentration in Rastrineobola argentea to be 72.96 mg/100 g in SEM season and 54.73 mg/100 g in the warm NEM season. The species S. forsteri had the highest Mg concentration of 72.2 mg/100 g during the SEM season making it a suitable supplement for Mg. This species could be a suitable dietary component for active male adults who require Mg concentrations of 420 mg/day, children who require Mg concentrations ranging between 80 mg/day and 240 mg/day depending on their age, pregnant mothers who need 360 mg/day and lactating mothers who require 400 mg/day (Grober et al., 2015). S. sutor, S. forsteri and D. macarellus are also preferable sources of Mg with concentrations of between 26 and 57 mg/100 g and are also more nutritious during the SEM season compared to NEM season.

Zn composition in all the selected fish samples ranged between 0.64 and 5.84 mg/100 g. These results were in line with those presented by Nurnadia et al. (2013), and Kawarazuka and Bennet (2011) where Zn content in fish species ranged between 0.15 and 20 mg/100 g. Wahyuningtyas et al. (2017) also reported the mean Zn concentration in Siganus sutor to be 1.13 mg/100 g, which matches these results where Zn in S. sutor ranged between 0.65 and 3.79 mg/100 g. D. macarellus had the highest zinc content (1.49-5.84 mg/100 g) compared to the other species making it a good meal to supplement zinc deficiency. Findings of Khalaf et al. (2012) also indicated that D. macarellus which recorded zinc levels of between 0.95 and 14.3 mg/100 g, is a better source of Zn compared to D. macrosoma and D. russelli. This makes D. macarellus a good choice of meal for children who require between 12 and 23 mg/day of Zn subject to their age, teenagers who need 34 mg/day and all adults including pregnant and lactating mothers who need 40 mg/day for effective normal body functioning (Institute of Medicine, Food and Nutrition Board, 2001).

Fe content among the studied fish samples ranged between 0.64 and 3.68 mg/100 g with significantly higher concentrations in the warm NEM season. Palanikumar et al. (2014), Zaman et al. (2015), Reksten et al. (2020a), Reksten et al. (2020b) and Nordhagen et al. (2020) reported similar results ranging from 0.2 and 7.01 mg/100 g. Palanikumar et al. (2014) further reported the mean Iron concentration in S. obtusata species to be 0.05 mg/100 g. However, S. forsteri recorded the highest Fe concentration of 3.63 mg/100 g thus forming a preferable part of the diet especially for lactating mothers who require 10 mg/day, pregnant mothers who require 27 mg/day and females who require between 15 and 18 mg/day to make up for the iron lost during their menstruation period (Clifford et al., 2015). S. obtusata, D. macarellus and S. sutor are also recommended dietary items to prevent iron deficiency due to their significant concentrations of Fe ranging between 0.64 and 2.76 mg/100 g.

Iodine (I) content in selected fish specimens ranged between 18.48 and 57.60 µg/100 g. Nordhagen et al. (2020) reported similar results where I levels in various fish species ranged between 6.7 and 160 µg/100 g. Previous studies by Reksten et al. (2020a) and Reksten et al. (2020b) also reported similar concentrations of I in fish ranging between 22 and 280 µg/100 g. In the selected fish species for this present study, S. sutor showed the highest levels of I, followed by D. macarellus, S. forsteri and S. obtusata in that order. All these species can be used as key dietary constituents to prevent I deficiency especially in pregnant mothers who require 220 µg/day and lactating mothers who need 290 µg/day (DRI, 2001; Alvarez-Pedrerol et al., 2010).
All these species were richer in I during the wet and cool SEM season than the warm NEM. Abdulkarim et al. (2015) also reported that fish are richer in I during the wet season compared to the dry season. S.sutor highly recommended for pregnant and lactating mothers due to their high concentrations of Iodine.

All the sampled fish species in this present study were found to be richer in minerals during the wet and cool SEM than warm and dry NEM season. This could be attributed to the availability of more nutrients and dietary materials as well as an increase in minerals washed into the sea from land through various freshwater inlets (Abdulkarim et al., 2011; Abdulkarim et al., 2015). For Vanga, long rains during the SEM season are linked to high nutrient influx from the river Umba, Mwena and Ramisi into Vanga and Jimbo fishing grounds (Opello et al., 2006; Wanyonyi et al., 2017). However, Fe content for D.macarels, S.obtusata and S.forsteri was significantly higher in the NEM season than the SEM season but S.sutor content was unaffected by these seasons. According to Kessler et al., 2020, dust, which is higher in the warm and dry NEM season compared to the wet and cool SEM season is a very important source of Fe to the ocean. Additionally, Fe content in fish muscles could be higher, lower or unaffected by seasons depending on the geographical conditions Abdulkarim et al. (2011).

Conclusions
This study reveals that fish is a rich source of K, Mg, Zn, Fe and I which has the potential to contribute to good nutrition of local fishing communities if consumed in adequate amounts. As a result, fish intake can be used to combat malnutrition and remedy various nutritive deficiencies and health problems. However, only small amounts of fish are retained for home use by artisanal fishers in both Msambweni and Vanga (Mwakaribu et al., 2022). The variability in fish mineral concentration is dependent on fish species as well as the seasonal dynamics. Selected fish elemental analysis indicated that marine fish are richer in minerals during the SEM than the NEM season. Conversely, Fe content in fish is higher in NEM than SEM season. The local fishing communities on the south coast of Kenya could increase fish consumption to supplement deficiencies for K, Mg, Zn and I, especially during the SEM season, and Fe deficiency during the NEM season. This study should be extended to the entire Kenya coast focussing on a wide range of fish species in order to identify the best species to supplement particular mineral deficiencies and the best time to consume more fish.

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