Original Article

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

Athman Mwakaribu[1,2], Cosmas Munga[1*], Paul Njihia[3]

[1] Department of Environment and Health Sciences, Marine and Fisheries Programme, Technical University of Mombasa, PO Box 90420 – 80100, Mombasa, Kenya;

[2] Kenya Fisheries Service, PO Box 48511, Nairobi, Kenya;

[3] Department of Pure and Applied Sciences, Technical University of Mombasa, PO Box 90420 – 80100, Mombasa, Kenya

Western Indian Ocean
JOURNAL OF
Marine Science

Open access

Citation:
Mwakaribu A, Munga C, Njihia P (2023) Seasonal variation in concentrations of selected minerals in four of the most retained marine fish species by small scale fishers in Vanga and Msambweni on the south coast of Kenya. Western Indian Ocean Journal of Marine Science 22(2): 125-133 [doi: 10.4314/wiojms.v22i2.9]

Received:
Maio 18, 2023

Accepted:
October 13, 2023

Published:
December 12, 2023

*** Corresponding author:**
ckamunga2014@tum.ac.ke

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). *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

Introduction
Micronutrients refer to minerals and vitamins required by the body in trace amounts but their impact on overall body health is critical (Awuchi *et al.*, 2020). Micronutrient deficiency is a universal subject with specifically higher prevalence rates in underdeveloped nations (Abeywickrama *et al.*, 2018) with wide spread impacts exhibited in vulnerable groups such as children, women, the middle and old aged (Tulchinsky, 2010). Nutritional deficiency has been observed to be most regular in underdeveloped regions of sub-Saharan Africa and South Asia (Black *et al.*, 2013). An estimated two billion people worldwide and one out of three people in developing countries are affected by vitamin and mineral deficiencies, particularly Zinc, Iron and Iodine making them susceptible to diseases such as anaemia and goitre (Abeywickrama *et al.*, 2018; Borwankar *et al.*, 2007).

Available data shows high prevalence rates for specified micronutrient deficiency for Potassium, Magnesium, 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 Aldulkarim *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 macurellus*, *Sphyraena forsteri* and *Sphyraena obtusata* 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" (Ogongo *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.

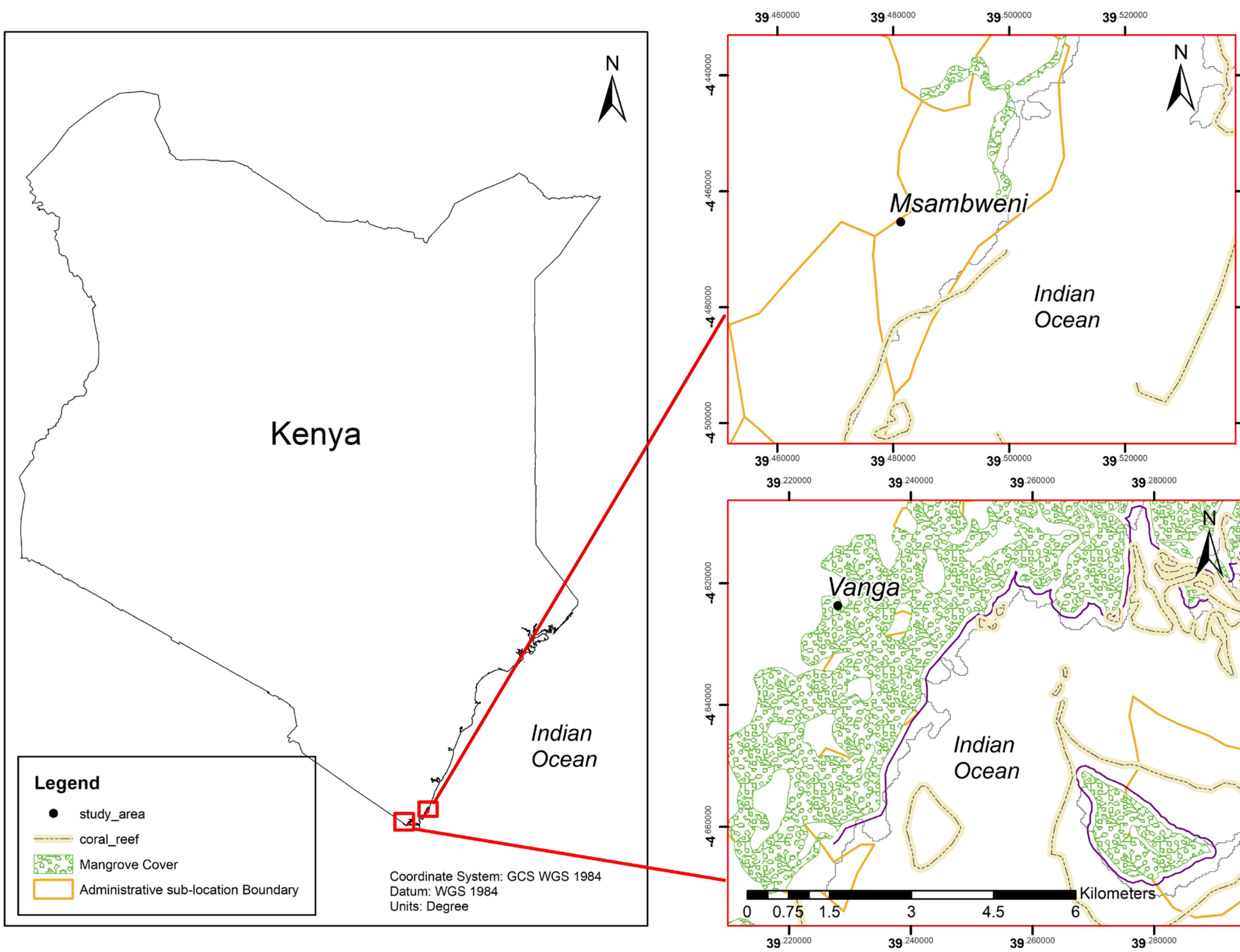

Figure 1. Location of Msambweni and Vanga fishing areas, south coast of Kenya, where retained fish for household consumption was monitored over the study period (Mwakaribu *et al.*, 2022).

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 ^{0}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 (HNO_3) (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 1. Mean ± SE total length and weight of fish specimens sampled for mineral content analysis. The symbol * indicates a statistically significant difference at p < 0.05.

Species	Common name	Area	Mean Weight (g)	Mean Length (cm)	n
Siganus sutor	Rabbitfish	Msambweni	320 ± 16.7 (NEM) *vs* 172.3 ± 12.7 (SEM)	28.8 ± 0.55 (NEM) *vs* 22.8 ± 0.60 (SEM)*	30
Sphyraena forsteri	Bigeye barracuda	Vanga	34.3 ± 0.8 (NEM) *vs* 25.6 ± 1.9 (SEM)	18.7 ± 0.08 (NEM) vs 16.6 ± 0.36 (SEM)*	30
Sphyraena obtusata	Obtuse barracuda	Vanga	49.8 ± 5.1 (NEM) *vs* 132.1 ± 11.4 (SEM)	21.3 ± 0.80 (NEM) vs 31 ± 1.01 (SEM)*	30
Decapterus macarellus	Mackerel scad	Vanga	41.9 ± 0.1 (NEM) *vs* 66.2 ± 1.8 (SEM)	16.8 ± 0.14 (NEM) vs 19.0 ± 0.16 (SEM)*	30

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.

Species	K(mg/100g)	Mg(mg/100g)	Zn(mg/100g	Fe(mg/100g)	I(μ/100g)
S. obtusata	255.57 ± 2.627 (NEM) vs 384.25 ± 3.051 (SEM)*	36.23 ± 0.807 (NEM) vs 38.30 ± 0.366 (SEM)	1.45 ± 0.006 (NEM) vs 2.69 ± 0.034 (SEM)*	2.59 ± 0.024 (NEM) vs 0.64 ± 0.016 (SEM)*	13.48 ± 0.807 (NEM) vs 14.93 ± 0.793 (SEM)
D. macarellus	242.12 ± 3.548 (NEM) vs 304.19 ± 2.759 (SEM)*	35.26 ± 0.752 (NEM) vs 47.56 ± 0.509 (SEM)*	1.49 ± 0.035 (NEM) vs 5.84 ± 0.054 (SEM)*	2.31 ± 0.029 (NEM) vs 2.06 ± 0.024 (SEM)*	13.87 ± 0.213 (NEM) vs 18.33 ± 0.412 (SEM)*
S. forsteri	246.25 ± 4.716 (NEM) ± 382.28 ± 3.802 (SEM)*	33.42 ± 0.658 (NEM) vs 72.29 ± 1.525 (SEM)*	2.69 ± 0.017 (NEM) vs 4.51 ± 0.107 (SEM)*	3.63 ± 0.021 (NEM) vs 1.52 ± 0.032 (SEM)*	14.04 ± 0.165 (NEM) vs 17.53 ± 0.240 (SEM)*
S. sutor	248.73 ± 3.109 (NEM) vs 410.21 ± 3.546 (SEM)*	26.63 ± 0.320 (NEM) vs 57.96 ± 0.926 (SEM)*	0.65 ± 0.023 (NEM) vs 3.79 ± 0.051 (SEM)*	2.75 ± 0.037 (NEM) vs 2.76 ± 0.038 (SEM)	35.40 ± 0.859 (NEM) vs 57.60 ± 1.679 (SEM)*

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 season than NEM season (Kruskal-wallis test: p = 0.000 for both cases). Zn concentration was significantly higher in SEM (5.84 ± 0.054 mg/100g) than NEM (1.49 ± 0.035 mg/100g) (1-way ANOVA: df = 1, f = 10.760, p = 0.000). The concentration of I was also significantly higher in SEM than NEM (1-way ANOVA: df = 1, f = 104.990, p = 0.000) (Table 2).

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 (33.42 ± 0.658 mg/100g) (1-way ANOVA: df = 1, f = 720.940, p = 0.000). For this species I concentration was also higher in SEM (17.53 ± 0.240 mg/100g) than NEM (14.04 ± 0.165 mg/100g) (1-way ANOVA: df = 1, f = 155.94, p = 0.000). The Kruskal-Wallis test confirmed that K, Fe and Zn concentrations were significantly higher in SEM than NEM season (p < 0.05 in all cases) (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 (1-way ANOVA: 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. This confirms to the work of Varljen *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).

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 3.63 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 13.48 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. Albdulkarim *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.macarelus*, *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.

Acknowledgements

The authors are grateful to the Western Indian Ocean Marine Science Association (WIOMSA) which funded this study through a MARG I research grant. We thank our field assistants Mr Joshua Omweri (KMFRI) and Mr Dennis Oigara (Vanga Assistant Fisheries Officer, Kwale County) for helping with species identification which was useful in selection of samples. We thank KMFRI for the laboratory space and Ms Winnie Jefwa, a laboratory technician, for her assistance in mineral analysis of selected fish samples.

References

Abdulkarim B, Sulaiman M, Bolorunduro PI, Balogun JK (2011) Seasonal variations in the proximate and mineral contents of three freshwater fish species of the families *Mochokidae*, *Mormyridae* and *Schilbedae* from Mairuwa Reservoir, Faskari, Katsina State Nigeria. Journal of Biological and Environmental Sciences 8 (3): 7-12

Abdulkarim B, Bwathondi POJ, Benno BL (2015) Seasonal variations in the mineral composition of some commercially important fish species of Lake Victoria- Tanzania. International Journal of Agricultural Sciences 5 (3): 426-434

Abeywickrama HM, Koyama Y, Uchiyama M, Shimizu U, Iwasa Y, Yamada E, Ohashi K, Mitobe Y (2018) Micronutrient status in Sri Lanka: A review. Nutrients 10 (1583): 1-20

Agembe S, Mlewa CM, Kaunda-Arara B (2010) Catch composition, abundance and length-weight relationships of groupers (Pisces: Serranidae) from inshore waters of Kenya. Western Indian Ocean Journal of Marine Science 9 (1): 91-102

Ajayi CO (2016) Food security status of artisanal fishers and concerns of bycatch in Nigeria. Asian Research Journal of Agriculture 2 (2): 1-10

Ahmad RS, Imran AA, Hussain MB (2018) Nutritional composition of meat. In: Arshad MS (ed) Meat Science and Nutrition: 61-77 [doi: 10.5772/intechopen.77045]

Alas A, Ozcan MM, Harmankaya M (2014) Mineral contents of head, caudal, central fleshy part, and spinal columns of some fishes. Environmental Monitoring Assessment 186 (2): 889-894

Alvavez-Pedrerol M, Ribas-Fito N, Rodriguez A, Soriano D, Guxens M, Mendez M, Sunyer J (2010) Iodine sources and iodine levels in pregnant women from an area without known iodine deficiency. Clinical Endocrinology 72 (1): 81-86

AOAC (2000) Association of Official Analytical Chemists. Official Methods of Analysis. Vol. II, 17th Edition, AOAC, Washington DC: 237-242

AOAC (2012) Official methods of analysis of AOAC International, 19th ed. AOAC International, Gaithersburg, MD, USA, Official Method 2008.01. Revised October 2013.

Awuchi CG, Igwe VS, Amagwula I, Echeta CK (2020) Health benefits of micronutrients (vitamins and minerals) and their associated deficiency diseases: A systematic review. International Journal of Food Sciences 3 (1): 1-32

Barakat I, Saad A, Nisafi I (2022) Influence of seasonal variation on the biochemical composition of both sexes of the round sardinella *Sardinella aurita* (Valenciennes, 1847) caught in the marine water of Lattakia Governorate (Syria). Journal of Materials and Environmental Science 13 (7): 747-775

Black RE, Victoria CG, Walker SP, Bhutta ZA, Christian P, Onis M (2013) Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet 382 (9890): 427-451

Béné C, Barange M, Subasinghe R, Pinstrup-Andersen P, Merino G, Hemre G, Williams, M (2015) Feeding 9 billion by 2050 –Putting fish back on the menu. Food Security 7: 261-274 [doi: 10.1007/s12571-015-0427-z]

Bennet A, Patil P, Kleisner K, Rader D, Virdin J, Basurto X (2018) Contribution of fisheries to food and nutrition security. Current Knowledge Policy and Research 18: 1-46

Bhandari S, Banjara MR (2014) Micronutrients deficiency, a hidden hunger in Nepal: Prevalence, causes, consequences and solutions. International Scholarly Research Notices 2015: 1-9 [doi:10.1155/2015/276469]

Borwankar R, Sanghvi T, Houston R (2007) What is the extent of vitamin and mineral deficiencies?: Magnitude of the problem. Food and Nutrition Bulletin 28 (1): 174-181

Chan YC, Tran N, Pethiyagoda S, Crissman CC, Sulser TB, Phillips MJ (2019) Prospects and challenges of fish for food security in Africa. Global Food Security 20: 17-25

Clifford J, Niebaum K, Bellows L (2015) Iron: An essential nutrient. Food and Nutrition Series 9 (356): 1-3

Dietary Reference Intakes (DRI) (2001) Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Institute of Medicine (US) Panel on Micronutrients. Washington (DC). National Academies Press (US. pp. 258-488 [doi: 10.17226/10026]

Fiorentini D, Cappadone C, Farruggia G, Prata C (2021) Magnesium: biochemistry, nutrition, detection, and social impact of diseases linked to its deficiency. Nutrients 13 (4): 1136 [doi: 10.3390/nu13041136]

Fondo EN, Kimani EN, Munga CN, Aura CM, Okemwa G, Agembe S (2014) A review on Kenyan fisheries research: 1970-2009. Western Indian Ocean Journal of Marine Science 13 (2): 143-162

Grober U, Schmidt J, Kisters K (2015) Magnesium in prevention and therapy. Nutrients 7: 8199-8226 [doi:10.3390/nu7095388]

Institute of Medicine, Food and Nutrition Board (2001) Dietary reference intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. National Academy Press, Washington, DC

Kawaruzka N, Bennet C (2011) The potential role of small fish species in improving micronutrient deficiencies in developing countries: building evidence. Public Health Nutrition 14 (11): 1927-1938

Kessler N, Armoza-Zvuloni R, Wang S, Basu S, Weber PK, Stuart RK, Shaked Y (2020) Selective collection of iron-rich dust particles by natural Trichodesmium colonies. The ISME Journal 14: 91-103

Khalaf MA, Al-Najjar T, Alawi M, Disi AA (2012) Levels of trace metals in three fish species *Decapterus macrellus*, *Decapterus macrosoma* and *Decapterus russelli* of the family carangidae from the Gulf of Aqaba, Red Sea, Jordan. Natural Science 4 (6): 362-367

Khitouni IK, Mihoubi NB, Bouain A, Rebah FB (2014) Seasonal variation of the chemical composition, fatty acid profiles and mineral elements of *Diplodus annularis* (Linnaeus, 1758) caught in the Tunisian coastal water. Journal of Food and Nutrition Research 2 (6): 306-311

Kiczorowska B, Samolinska W, Grela ER, Bik-Malodzinska M (2019) Nutrient and mineral profile of chosen fresh and smoked fish. Nutrients 11: 1448 [doi: 10.3390/nu11071448]

Kumssa DB, Joy EJM, Broadley MR (2021) Global trends (1961–2017) in human dietary Potassium supplies. Nutrients 13 (4): 1369 [doi: 10.3390/nu13041369]

Lall SP, Tibbetts SM (2009) Nutrition, feeding, and behaviour of fish. Veterinary Clinics of North America - Exotic Animal Practice 12 (2): 361-372

Lancker K, Fricke L, Schmidt JO (2019) Assessing the contribution of artisanal fisheries to food security: A bioeconomic modelling approach. Food Policy 87: 101740

Mogobe O, Mosepele K, Masamba WRL (2015) Essential mineral content of common fish species in Chanoga, Okavango Delta, Botswana. African Journal of Food Science 9 (9): 480-486

Mohanty BP, Singh SD (2018) Fish and human nutrition. Aquaculture in India. Narendra Publishing House, Delhi, India. pp 561-581

Mwakaribu A, Munga C, Dzoga M, Njihia P, Mulala D (2022) Retained fish catches of artisanal fishers is dependent on fishing area, season and fishing gear type: A case study from the south coast of Kenya. Western Indian Ocean Journal of Marine Science 21 (2): 11-23

Njinkoue JM, Gouado I, Tchoumbougnang F, Ngueguim JHY, Ndinteh DT, Fomogne-Fodjo CY, Schweigert FJ (2016) Proximate composition, mineral content and fatty acid profile of two marine fishes from Cameroonian coast: *Pseudotolithus typus* (Bleeker, 1863) and *Pseudotolithus elongatus* (Bowdich, 1825). NFS Journal 4: 27-31

Nordhagen A, Rizwan AA, Aakre I, Reksten AM, Pincus LM, Bøkevoll A, Mamun A, Thilsted TH, Somasundaram T, Kjellevold M (2020) Nutrient composition of demersal, pelagic and mesopelagic fish species sampled off the coast of Bangladesh and their potential contribution to food and nutrition security- The EAF-Nansen Programme. Foods 9: 730

Nurnadia AA, Azrina A, Amin I, Mohd Yunus AS, Mohd Izuan Effendi H (2013) Mineral contents of selected marine fish and shellfish from the west coast of Peninsular Malaysia. International Food Research Journal 20 (1): 1338-1343

Olgunoglu IA (2014) Review on omega-3 (n-3) fatty acids in fish and seafood. Journal of Biology, Agriculture and Healthcare 7 (12): 38-45

Opello G, Nguli M, Machua S, Tole M, Massa H, Mwangi S, Ong'anda H (2006) Land-based activities, pollution sources and levels in water and sediment in the coastal and marine area of Kenya: Draft report, UNEP-GEF WIO-LaB Project- Addressing Land Based Activities in the Western Indian Ocean, Mombasa, Kenya.1-44 pp

Pal J, Shukla BN, Maurya AK, Verma HO, Pandey G, Amitha G (2018) A review on role of fish in human nutrition with special emphasis to essential fatty acid. International Journal of Fisheries and Aquatic Studies 6 (2): 427-430

Palanikumar M, Annathai RA, Shakila JR, Shanmugam SA (2014) Proximate and major mineral composition of 23 medium sized marine fin fishes landed in the Thoothukudi Coast of India. Journal of Nutrition and Food Sciences 4 (1): 1-7 [doi:4172/2155-9600.1000259]

Reksten AM, Joao-Correia-Victor AM, Nascimento-Neves EB, Christiansen SM, Ahern M, Uzomah A, Lundebye AK, Kolding J, Kjellevold M (2020a) Nutrient and chemical contaminant levels in five marine fish species from Angola—The EAF-Nansen Programme. Foods 2020 9: 629 [doi:10.3390/foods9050629]

Reksten AM, Somasundaram T, Kjellevold M, Pincus L, Nordhagen A, Bøkevoll A, Pincus LM, Rizwan AA, Mamun A, Thilsted SH, Htut T, Aakre I (2020b) Nutrient composition of 19 fish species from Sri Lanka and potential contribution to food and nutrition security. Journal of Food Composition and Analysis 91: 103508

Schwalfenberg GK, Genius SJ (2017) The importance of magnesium in clinical healthcare. Scientifica 4179326: 1-14 [doi: 10.1155/2017/4179326]

Shija SMY, Shilla DA, Mihale MJ (2019) Variation of proximate contents in selected marine fish from Tanzanian coast due to seasonality and processing methods. Huria Journal 26 (1): 30-49

Strohm D, Ellinger S, Leschik-Bonnet E, Matretzke F, Heseker H (2017) Revised reference values for Potassium intake. Annals of Nutrition and Metabolism 71: 118-124 [doi:10.1159/000479705]

Thilsted SH, Thorne-Lyman A, Webb P, Bogard JR, Subasinghe R, Phillips MJ, Allison EH (2016) Sustaining healthy diets: the role of capture fisheries and aquaculture for improving nutrition in the post-2015 era. Food Policy 61: 126-131

Tulchinski TH (2010) Micronutrient deficiency conditions: Global health issues. Public Health Reviews 32 (1): 243-255

Varljen J, Sulic S, Brmalj L, Obersnel V, Kapovic M (2013) Lipid classes and fattyacid composition of *Diplodus vulgaris* and *Conger conger* originating from Adriatic-sea. Food Technology Biotechnology 41: 149-156

Wahyuningtyas LA, Nurilmala M, Sondita MFA, Taurusman AA, Sudrajat AO (2017) Nutrient profile of Rabbit fish (*Siganus* spp.) from the Kepulauan Seribu (Thousand Islands) Jakarta, Indonesia. International Food Research Journal 24 (2): 685-690

Wanyonyi I, Karisa J, Gamoyo M, Mbugua J (2017) Factors influencing migrant fisher access to fishing grounds. Western Indian Ocean Journal of Marine Science 16 (2): 27-39

World Health Organization (WHO) (2004) Vitamin and mineral requirements in human nutrition, 2nd ed. World Health Organization.

Zaman MM, Naimul N, Abu-Tareq MA, Nasima K (2014) Nutrient contents of some popular freshwater and marine fish species of Bangladesh. Bangladesh Journal of Zoology 42 (2): 251-159