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Nutrient composition of 19 fish species from Sri Lanka and potential contribution to food and nutrition security

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ABSTRACT

Fish is an important part of the Sri Lankan diet. However, existing data on the nutrient composition of fish in Sri Lanka is highly outdated and limited. The aim of this study was to report the nutrient composition of commonly consumed marine fish species in Sri Lanka and assess the potential contribution of selected key nutrients in fish to recommended nutrient intakes (RNI). Fish were sampled during a survey with research vessel *Dr. Fridtjof Nansen* around Sri Lanka. Species were categorised as either small (< 25 cm, n = 12) or large (> 25 cm, n = 7), and three composite samples from each species were analysed using accredited methods. Small species commonly consumed whole contained significantly higher concentrations of micronutrients such as calcium (960 mg/100 g), iron (3.3 mg/100 g), zinc (2.1 mg/100 g), vitamin A (295 µg/100 g), and EPA and DHA (0.14 and 0.32 g/100 g, respectively) than larger species where only the fillet is consumed. Several species were identified to contribute ≥25 % of the RNI of women of reproductive age for multiple essential nutrients. These data may represent an important contribution to the future development of the Sri Lankan food composition database.

1. Introduction

Seafood, particularly fish, play a crucial role in global food and nutrition security (FNS) as it represents an important and nutrient-dense animal source food, especially in many low- and middle-income countries (LMICs) (Béné et al., 2016; FAO, 2018d). In Sri Lanka, a small island nation located in the Bay of Bengal completely surrounded by the Indian Ocean, marine fisheries play a key role in the country's social and economic life (FAO, 2006). Apparent per capita fish consumption was estimated to be 31.4 kg per year in 2016 (FAO, 2019). Fish and fish products are estimated to comprise approximately 55 % of total animal protein intake per capita (FAO, 2018d) and are therefore considered the most important source of animal protein in the Sri Lankan diet (Ministry of Fisheries and Aquatic Resources Development, 2016). Marine species are estimated to account for 81 % of total fish consumption (Needham and Funge-Smith, 2014). However, malnutrition remains widespread with a 15 % prevalence rate of wasting in children between 0–59 months; this is considered one of the highest wasting rates in the world (FAO, 2018a; WFP, 2018). The rates of both wasting and stunting have remained unchanged for the past 10 years, with 17 % of children suffering from stunted growth (WFP, 2017). Available data also suggest a high prevalence of micronutrient deficiencies, particularly vitamin A, calcium, iron, folate, and zinc. Limited data are available for other nutrients such as vitamin D, vitamin B_{12}, selenium, and iodine (Abeywickrama et al., 2018; WFP, 2018).

Poor dietary diversity is a leading cause of malnutrition (FAO,

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2018b). Fish represent a relatively cheap and easily available mean for nutritional diversification in several LMICs where diets depend heavily on a narrow range of staple foods (FAO, 2018d; Hicks et al., 2019). Regardless of the inherent nutritional variance in marine species due to habitat, region, season, and edible parts, most marine fish species share a quantity of unified nutritional characteristics and are considered an important source of several essential nutrients in the human diet (EFSA, 2005; Larsen et al., 2011; Murray and Burt, 2001). Fish is a good source of key nutrients such as highly bioavailable animal protein (Larsen et al., 2011), marine long-chain omega-3 polyunsaturated fatty acids (n-3 LCPUFA), including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), and numerous micronutrients, including vitamin A, vitamin B_{12}, vitamin D, zinc, selenium, and iodine. Fatty fish are generally regarded the best source of fatty acids (especially EPA and DHA) and fat soluble vitamins, whereas lean fish generally are regarded the best source of iodine (EFSA, 2014; VKM, 2014). Furthermore, fish enhances the bioavailability of minerals such as iron and zinc from cereal and tuber based diets, thus including even small quantities of fish in the diet may provide a range of essential nutrients otherwise lacking in diets predominantly centred on grains and tuber crops (FAO, 2018d; Kawarazuka and Bene, 2011; Lim et al., 2013).

Scientific documentation and quantitative information on the role of fish for FNS in LMICs are generally scattered and/or lacking; leaving fish rather absent in the development of nutrition-based approaches directed to improve FNS (FAO, 2018d; Hicks et al., 2019; Kawarazuka and Bene, 2011). Knowledge on the nutrient composition of foods, or food composition data, are essential in providing the foundation for almost all aspects of nutrition and represent a basic and invaluable tool to improve FNS. Reliable and up-to-date food composition data are of fundamental importance to a multitude of nutrition based activities, such as establishing and assessing nutrient requirements, epidemiological research, clinical practice, government policy development and implementation, food regulation and manufacturing, and for educational purposes (Greenfield and Southgate, 2003). The Sri Lankan food composition table was first published in 1979 and consisted of 90 % borrowed values from the Indian food composition table. Since then, only minor efforts have been made to further update and develop the food composition table (FAO, 2018c; Thamilini et al., 2019). Despite the distinct importance of fish in the Sri Lankan diet, existing food composition data do not reflect the large diversity of species available for consumption in the country (Thamilini et al., 2019).

The aim of this paper was to generate analytical data on the composition of selected nutrients in commonly consumed marine fish species in Sri Lanka. Further, we compared the potential contribution of selected key nutrients to recommended nutrient intakes (RNI) for 19−50-year-old non-pregnant, non-lactating, healthy females of reproductive age. The specific nutrients considered were calcium, iron, zinc, and vitamin A, which are of known public health concern in Sri Lanka and are often considered problematic to obtain in the rice-dominant diet present in Sri Lanka (Bailey et al., 2015; UNICEF, 2018; WHO and FAO, 2004).

2. Materials and methods

This paper uses data collected through scientific surveys with the research vessel (R/V) *Dr. Fridtjof Nansen* as part of the collaboration between the EAF-Nansen Programme and the National Aquatic Resources Research and Development Agency (NARA) in Sri Lanka. The EAF-Nansen Programme is a partnership between the Food and Agriculture Organization of the United Nations (FAO), the Norwegian Agency for Development Cooperation (Norad), and the Institute of Marine Research (IMR), Bergen, Norway, for sustainable management of the fisheries of partner countries (FAO, 2019).

Table 1
Overview of species sampled, tissue, number of composite samples, and number of fish in each composite sample.

Scientific name	Tissue sampled	Number of composite samples	Number of specimens in each composite sample
Small fish			
Amblygaster sirm	Whole fish	3	25
Auxis thazard	Whole fish	3	25
Decapterus macrosoma (1)[a]	Whole fish	3	25
Decapterus macrosoma (2)[a]	Whole fish	3	25
Encrasicholina devisi	Whole fish	3	50
Equulites elongatus[b]	Whole fish	3	25
Leiognathus dussumieri	Whole fish	3	25
Photopectoralis bindus (1)[a]	Whole fish	3	25
Photopectoralis bindus (2)[a]	Whole fish	3	25
Rastrelliger kanagurta	Whole fish	3	25
Sillago ingenuua	Whole fish	3	25
Stolephorus indicus	Whole fish	3	25
Large fish			
Carangoides fulvoguttatus	Filet	3	5
Diagramma pictum	Filet	3	5
Lethrinus olivaceus	Filet	3	5
Lutjanus lutjanus	Filet	3	5
Nemipterus bipunctatus	Filet	3	5
Selar crumenophthalmus	Filet	3	5
Sphyraena jello	Filet	3	5

[a] Species sampled twice on two separate locations. The respective trawling coordinates of each species can be located in Appendix B.
[b] For this species, each composite sample consisted of 50 individual fish in order to obtain enough sample material.

2.1. Sampling of fish

Sampling was carried out during a survey in Sri Lankan territorial sea by R/V *Dr. Fridtjof Nansen*, starting from the north coast near the Indian border to the north-western coast of Sri Lanka from June 24th to July 15th, 2018 (Appendix A). Pelagic and demersal trawls were continuously unloaded on the deck, before the catch subsequently was sorted and identified by on-board taxonomists. Fish were selected for sampling based on the species' importance to local food habits, as advised by Sri Lankan marine and food scientists on board. Sample preparations were carried out on whole fish or fish fillets consistent with their local usage in diets; samples of 'small' fish (< 25 cm) were prepared with the head, tail, viscera, skin, and bones intact, whereas only the fillet was used when preparing samples of 'large' fish (> 25 cm) (Table 1). Species were prepared as triplicate composite samples, where each composite sample consisted of 25 randomly selected individuals for small fish and 5 randomly selected individuals for large fish. Samples were then prepared as wet and freeze-dried samples, as described by Reksten et al. (2020), before shipment to the IMR laboratories in Bergen, Norway for further analyses.

2.2. Analytical methods

Analyses of proximate components and vitamins and minerals were performed in singular parallels at the IMR laboratories in Norway. The analytical methods used for the determination of crude protein, crude fat, fatty acids, and vitamins and minerals are described in detail by Reksten et al. (2020).

2.3. Determination of crude protein and – fat and fatty acids

Crude protein was determined by burning the sample material in pure oxygen gas in a combustion tube (Leco FP 628, Leco Corporation, Saint Joseph, MI, USA) at 950 °C. The nitrogen was detected with a thermal conductivity detector (TCD, Leco Corporation, Saint Joseph, MI, USA) and the content of nitrogen was calculated from an estimated average of 16 % nitrogen per 100 g protein (AOAC, 1995). Crude fat was extracted with ethyl acetate and filtered before the solvent evaporated and the fat residue was weighed. The method is standardised as a Norwegian Standard, NS 9402 (Norwegian Standard 9402 (Norsk standard), 1994). For the determination of fatty acids, lipids from the samples were extracted according to Folch et al., 1957, and analysed using a gas liquid chromatograph (GLC) as previously described (Lie and Lambertsen, 1991; Torstensen et al., 2004).

2.4. Determination of vitamins and minerals

The concentration of vitamin A_1 (sum all-trans retinol and 13-, 11-, 9 cis retinol) and A_2 was determined using analytical high-performance liquid chromatography (HPLC) (normal phase) and a Photo Diode Array detector (PDA, HPLC 1260 system Agilent Technologies, Santa Clara, CA, USA) (Comitè Europèen de Normalisation; EN12823-1, 2000). Determination of vitamin D_3 was performed using a preparative HPLC column and ultra violet detector (Comitè Europèen de Normalisation; EN 12821, 2009). For vitamin B_{12} (cobalamin) determination, microorganisms (*Lactobacillus delbruecki* –ATCC 4797) were added and incubated at 37 °C for 22 h (Angyal, 1996). The concentrations of minerals were determined by Inductively Coupled Plasma-Mass Spectrometry (iCapQ ICPMS, ThermoFisher Scientific, Waltham, MA, USA) equipped with an auto-sampler (FAST SC-4Q DX, Elemental Scientific, Omaha, NE, USA) after wet digestion in a microwave oven (UltraWave, Milestone, Sorisole, Italy), as described by Julshamn et al. (Julshamn et al., 2001; Julshamn et al., 2007).

2.5. Data management and presentation of data

All analytical values were exported from Laboratory Information Management System (LIMS) to Microsoft® Office 365 Excel 2013 version 15.0 for calculation of means and standard deviations (SD). If not otherwise specified, the data are presented as means ± SD per 100 g of the three composite samples of each species of fish, reported to the same units of expression and rounding procedures as advised in the FAO guidelines "*Food composition data*" (Greenfield and Southgate, 2003). Statistical analyses were performed using GraphPad Prism 8.3.0. The data on fatty acids, potassium, and magnesium did meet the assumption of normality (tested using D'Agostino-Pearson normality test), thus, differences were considered significant by an unpaired Student *t*-test when $p < 0.05$. Data on vitamin A_1, A_2, B_{12}, and D and all other minerals did however not meet the assumption of normality, thus, differences were considered significant by Mann-Whitney t-tests (non-parametric) when $p < 0.05$. For samples presenting values < LOQ, values are presented as the unadjusted LOQ value for the respective species. When calculating the mean value of nutrients where one or more samples presented values < LOQ, the respective LOQ was divided by 2 as suggested by Helsel (Helsel, 2006).Vitamin A components are presented as μg/100 g of the vitamin A isomers retinol (the sum of 13-, 11-, 9-cis and all-trans retinol (A_1)) and 3.4 didehydro-all-trans retinol (A_2). Vitamin D is presented as the amount of vitamin D_3 present in the sample, as the amount of vitamin D_2 is considered negligible in fish (Gibson, 2005, pp. 85, 106; Lock et al., 2010).

2.6. Calculation of potential contribution to recommended nutrient intakes

The potential contribution of each species to daily RNI was calculated in reference to the recommendations for 19 – 50-year-old non-pregnant, non-lactating, healthy females of reproductive age. The micronutrients of interest were calcium, iron, zinc, and vitamin A. For both iron and zinc, the RNI vary according to estimated overall dietary bioavailability, which is dependent on the presence of other enhancers and inhibitors in the diet (WHO and FAO, 2004). Due to a lack of comprehensive national dietary data and nutrition studies in Sri Lanka, estimating an appropriate level of bioavailability is challenging. The typical Sri Lankan diet was here assumed to best fit the criteria of low (10 %) bioavailability for iron and low (15 %) bioavailability for zinc, due to the presence of large amounts of phytates and lesser amounts of animal protein in the diet. For vitamin A, FAO adopted the term "recommended safe intake" due to a lack of data to derive a mean requirement for any specific group. The recommended safe intake for vitamin A is expressed as μg retinol equivalents (RE), where 1 μg retinol = 1 RE (WHO and FAO, 2004). Values for vitamin A_1 were included in the calculations, whereas values for vitamin A_2 were excluded due to the small amount present and the possibly reduced biological activity of dehydroretinol isomers (Shantz and Brinkman, 1950; La Frano et al., 2018). The various species' contribution to the RNI of the selected nutrients were calculated in reference to a standard Sri Lankan serving size of fish (30 g), as in accordance to the Sri Lankan food-based dietary guidelines (FBDG), and a 100 g portion of fish for comparison (Ministry of Health in Sri Lanka and WHO, 2011). For simplicity, the values were calculated for raw fish, as this was the analysed state of the samples.

3. Results

3.1. Sample characteristics

This study included 19 commonly consumed fish species in Sri Lanka. An overview of the identification details of each species sampled, including the scientific name, English name (common name), Sinhalese and Tamil names when available, the natural habitat, and weight and length characteristics of each species are presented in Table 2. For small species, the average weight per fish was 21 ± 15 g, whereas the mean length was 11.3 ± 3.1 cm. For the large species, average length varied from 16 – 88 cm, and the weight from 78 – 2885 g.

3.2. Proximate composition

The protein, fat, and percentage of dry matter of the samples, expressed as g/100 g edible portion, are presented in Table 3. All species may be categorised as relatively good sources of protein, with a mean protein content for small species of 18.96 g/100 g and an average value for large species of 20.52 g/100 g. According to total fat content, nine of the twelve small species are categorised as intermediate (2–8 % total fat) and all large samples are categorised as lean (< 2% total fat) according to the Norwegian and Danish categorisation of lipid content in percentage of total body weight (EFSA, 2005).

3.3. Fatty acid composition

The mean of all small species presented a significantly higher content of both EPA and DHA compared to that of large species (0.135 g/100 g and 0.0345 g/100 g, respectively for EPA, $p < 0.0001$, and 0.322 g/100 g and 0.143 g/100 g, respectively for DHA, $p < 0.0001$) (Table 4). The EPA content ranged from 0.0117 to 0.250 g/100 g (1.9–13%), whereas the DHA content ranged from 0.0410 to 0.467 g/100 g (7.1–29.9%). Of the sampled fish, the small species *Rastrelliger kanagurta* was identified as the most significant source of EPA, whereas the small species *Amblygaster sirm* was the most significant source of DHA.

Table 2
Identification details and overview of species sampled during the 2018 Nansen survey around Sri Lanka[a].

Scientific name	English name[b]	Sinhalese name	Tamil name	Habitat[b]	Average weight (g)[c]	Average length per individual fish (cm)[c]
Small fish						
Amblygaster sirm	Trenched sardinella	Hurulla[d]	Keerimeen saalai	Pelagic	278 ± 20	10.5
Auxis thazard	Frigate tuna	Alagoduwa[d]	Urulan soorai	Pelagic	1180 ± 27	16.2
Decapterus macrosoma (1)	Shortfin scad	Linna	Mundakan kilichchi	Pelagic	763 ± 23	13.5
Decapterus macrosoma (2)	Shortfin scad	Linna	Mundakan kilichchi	Pelagic	273 ± 22	9.2
Encrasicholina devisi	Devis' anchovy	Halmessa	Neththili	Pelagic	219 ± 1	10.5
Equulites elongatus	Slender ponyfish	Karalla	Karal	Demersal	183 ± 8	7.7
Leiognathus dussumieri	Dussumier's ponyfish	Karalla[d]	Vari karai	Demersal	637 ± 56	10.6
Photopectoralis bindus (1)	Orangefin ponyfish	Karalla	Tatnam-kare	Demersal	245 ± 20	7.4
Photopectoralis bindus (2)	Orangefin ponyfish	Karalla	Tatnam-kare	Demersal	228 ± 10	7.5
Rastrelliger kanagurta	Indian mackerel	Kumbalava	Kanang keluththi	Pelagic	610 ± 6	12.5
Sillago ingenuua	Bay whiting	–[e]	Kelangan	Demersal	1099 ± 24	16.3
Stolephorus indicus	Indian anchovy	Halmassa[d]	Neththili	Pelagic	676 ± 10	13.2
Large fish						
Carangoides fulvoguttatus[f]	Yellowspotted trevally	Thumba parawa[d]	Manjal parai	Reef-associated	168 ± 31	20.5 ± 1.5
Diagramma pictum	Painted sweetlips	Gobaya	Kallu kallewa	Reef-associated	1694 ± 906	47.9 ± 7.5
Lethrinus olivaceus	Long-face emperor	Uru hota[d]	Thinan	Reef-associated	1886 ± 2275	46.4 ± 17.4
Lutjanus lutjanus[f]	Bigeye snapper	Hunu ranna[d]	Nooleni	Demersal	317 ± 58	27.5 ± 1.8
Nemipterus bipunctatus[f]	Delagoa threadfin bream	–[e]	Cundil	Demersal	78 ± 45	16.3 ± 3.2
Selar crumenophthalmus	Bigeye scade	Bolla[d]	Choopparai	Reef-associated	174 ± 45	21.3 ± 1.7
Sphyraena jello	Pickhandle barracuda	Silava[d]	Jeela	Reef-associated	2885 ± 557	88.5 ± 5.6

[a] Values are presented as means ± standard deviations (SD) and are based on length and weight values (prior to any handling) of the included species.
[b] Information on English names and habitats were obtained through the global species database "FishBase" (Froese and Pauly, 2019).
[c] Weight and length measurements are expressed as the mean of the composite sample consisting of n number of fish for small species, and per individual fish for large species. The length of small species was calculated as a mean value of the first composite sample during the survey, thus, no SD is presented.
[d] Sinhalese name have been confirmed using the global species database "FishBase" (Froese and Pauly, 2019).
[e] The Sinhalese names of all species were not available.
[f] Species categorised as large fish (although their length was < 25 cm) based on input on the eating practice of the current species given by the local scientists on board.

Table 3
Analytical values of the proximate composition of the 19 fish species sampled from Sri Lanka[a].

	n[b]	Protein g/100 g	Fat (total) g/100 g	Dry matter %
Small Fish				
Amblygaster sirm	3	21 ± 0.6	2.6 ± 0.2	25.8 ± 0.4
Auxis thazard	3	20 ± 0.0	2.2 ± 0.0	25.0 ± 0.4
Decapterus macrosoma (1)	3	18 ± 0.0	2.0 ± 0.3	24.3 ± 0.2
Decapterus macrosoma (2)	3	19 ± 1.0	2.7 ± 0.2	24.1 ± 0.8
Encrasicholina devisi	3[c]	19 ± 0.6	2.4 ± 0.2	23.8 ± 0.3
Equulites elongatus	3	18 ± 0.6	2.5 ± 0.1	23.0 ± 0.2
Leiognathus dussumieri	3	17 ± 0.8	2.2 ± 0.2	26.3 ± 0.5
Photopectoralis bindus (1)	3	19 ± 0.0	1.6 ± 0.1	24.3 ± 0.2
Photopectoralis bindus (2)	3	19 ± 0.0	2.4 ± 0.3	24.7 ± 0.5
Rastrelliger kanagurta	3	19 ± 0.6	3.0 ± 0.2	24.6 ± 0.2
Sillago ingenuua	3	20 ± 0.6	1.7 ± 0.1	25.3 ± 0.4
Stolephorus indicus	3	20 ± 0.0	1.7 ± 0.1	24.1 ± 0.3
Mean for small species		19 ± 1.1	2.2 ± 0.5	24.6 ± 0.9
Large fish				
Carangoides fulvoguttatus	3	22 ± 0.0	1.3 ± 0.3	23.4 ± 0.5
Diagramma pictum	3	20 ± 0.0	0.50 ± 0.3	21.5 ± 0.5
Lethrinus olivaceus	3	21 ± 1.5	1.1 ± 0.7	22.5 ± 0.3
Lutjanus lutjanus	3	19 ± 0.0	0.90 ± 0.1	21.2 ± 0.2
Nemipterus bipunctatus	3	19 ± 1.7	1.2 ± 0.3	22.4 ± 0.2
Selar crumenophthalmus	3	22 ± 0.6	1.0 ± 0.2	26.3 ± 0.2
Sphyraena jello	3	21 ± 0.6	0.51 ± 0.1	21.7 ± 0.6
Mean for large species		21 ± 1.5	0.93 ± 0.4	22.7 ± 1.7

[a] Values are presented as means ± standard deviations (SD) of the 19 fish species analysed in triplicates, expressed as the nutrient content per 100 g raw, edible sample.
[b] Number of composite samples analysed. For large species (> 25 cm), 5 fish are included in each composite sample, whereas for small species (< 25 cm), 25 fish are included in each composite sample.
[c] For this species, each composite sample consisted of 50 individual fish in order to obtain enough sample material.

3.4. Vitamin content

The vitamin A, vitamin B_{12}, and vitamin D content are presented in Table 5. The Vitamin A_1 content ranged from 2.7 μg/100 g to 2000 μg/100 g, whereas vitamin A_2 was undetected (values < LOQ) in five large species and ranged up to 46 μg/100 g. Significant differences between large and small species were found for both vitamin A_1 and A_2 ($p < 0.0001$ for both). The total vitamin A content ($A_1 + A_2$) was generally low in all large species compared to small species, where the mean content for vitamin A_1 was 6.9 μg/100 g and 280 μg/100 g in large and small species, respectively. This was also seen for vitamin A_2, where the mean of small species was 15 μg/100 g and the mean of large species 0.74 μg/100 g. Furthermore, the small species *Leiognathus dussumieri* presented extraordinary high values compared to the rest of the species (2000 μg/100 g and 46 μg/100 g for vitamin A_1 and A_2, respectively), both large and small. The mean vitamin B_{12} content for small species was 12 μg/100 g, whereas the mean for large species was 3.0 μg/100 g, thus presenting a significantly higher concentration in small species compared to large species ($p < 0.0001$). The vitamin D content was undetected (values < LOQ) in six species and ranged up to 7.3 μg/100 g. Small species presented a sligthly higher mean of vitamin D compared to large species (3.6 μg/100 g and 2.4 μg/100 g, respectively), although not significantly higher.

3.5. Mineral composition

The mean mineral contents in small species significantly exceeded those of large species for all minerals except for potassium (Table 6). Overall, the small species *Leiognathus dussumieri* averaged higher than the other species in calcium, iron, iodine, phosphorus, selenium, and zinc content and the second highest in magnesium content. The calcium content varied considerably with a range from 7.9 mg/100 g in the large species *Sphyraena jello* to almost 300 times higher in the small species *Leiognathus dussumieri* with a value of 2300 mg/100 g. The mean

Table 4
Analytical values of the fatty acid composition of the 19 fish species sampled from Sri Lanka[a].

Species	n[b]	Sum SFA g/100 g (%[c])	Sum MUFA g/100 g (%[c])	Sum PUFA g/100 g (%[c])	Sum n-3 g/100 g (%[c])	Sum n-6 g/100 g (%[c])	EPA g/100 g (%[c])	DHA g/100 g (%[c])
Small fish								
Amblygaster sirm	3	0.597 ± 0.03 (36.8)	0.188 ± 0.01 (11.6)	0.761 ± 0.04 (47)	0.652 ± 0.03 (40.3)	0.104 ± 0.004 (6.4)	0.129 ± 0.04 (8.0)	0.467 ± 0.02 (28.9)
Auxis thazard	3	0.432 ± 0.04 (32.4)	0.122 ± 0.01 (9.1)	0.707 ± 0.07 (53)	0.606 ± 0.06 (45.5)	0.0990 ± 0.01 (7.4)	0.130 ± 0.02 (9.8)	0.399 ± 0.04 (29.9)
Decapterus macrosoma (1)	3	0.313 ± 0.06 (32.8)	0.159 ± 0.03 (16.7)	0.432 ± 0.06 (45.6)	0.329 ± 0.05 (34.8)	0.0987 ± 0.01 (10.4)	0.0563 ± 0.01 (5.9)	0.242 ± 0.03 (25.6)
Decapterus macrosoma (2)	3	0.665 ± 0.11 (35.3)	0.274 ± 0.05 (14.4)	0.856 ± 0.08 (45.7)	0.700 ± 0.07 (37.4)	0.146 ± 0.01 (7.8)	0.246 ± 0.04 (13)	0.339 ± 0.008 (18.2)
Encrasicholina devisi	3[d]	0.537 ± 0.02 (37.3)	0.178 ± 0.01 (12.4)	0.633 ± 0.02 (43.9)	0.527 ± 0.01 (36.6)	0.101 ± 0.00 (7.0)	0.120 ± 0.004 (8.3)	0.342 ± 0.02 (25.3)
Equulites elongatus	3	0.550 ± 0.08 (35.6)	0.212 ± 0.03 (13.7)	0.677 ± 0.06 (44)	0.538 ± 0.04 (35)	0.136 ± 0.01 (8.9)	0.112 ± 0.01 (7.2)	0.361 ± 0.025 (23.5)
Leiognathus dussumieri	3	0.764 ± 0.09 (38.8)	0.357 ± 0.05 (17.9)	0.714 ± 0.04 (36.4)	0.482 ± 0.03 (24.6)	0.223 ± 0.01 (11.4)	0.167 ± 0.02 (8.5)	0.219 ± 0.006 (11.2)
Photopectoralis bindus (1)	3	0.640 ± 0.07 (37.8)	0.252 ± 0.03 (14.8)	0.698 ± 0.06 (41.1)	0.509 ± 0.05 (30)	0.180 ± 0.02 (10.6)	0.128 ± 0.01 (7.6)	0.297 ± 0.03 (17.5)
Photopectoralis bindus (2)	3	0.673 ± 0.05 (37.4)	0.254 ± 0.02 (14.1)	0.754 ± 0.04 (42)	0.548 ± 0.04 (30.5)	0.197 ± 0.01 (11)	0.141 ± 0.01 (7.8)	0.323 ± 0.02 (18)
Rastrelliger kanagurta	3	0.893 ± 0.10 (35.8)	0.329 ± 0.09 (13.1)	0.96 ± 0.10 (43.9)	0.784 ± 0.07 (31.5)	0.303 ± 0.03 (12.1)	0.250 ± 0.02 (10)	0.416 ± 0.04 (16.7)
Sillago ingenuua	3	0.329 ± 0.05 (35.3)	0.155 ± 0.05 (16.6)	0.381 ± 0.06 (40.8)	0.270 ± 0.04 (28.9)	0.110 ± 0.02 (11.7)	0.0500 ± 0.006 (5.4)	0.169 ± 0.03 (18.1)
Stolephorus indicus	3	0.385 ± 0.05 (37.6)	0.109 ± 0.01 (10.6)	0.478 ± 0.06 (46.6)	0.398 ± 0.05 (38.8)	0.0767 ± 0.01 (7.5)	0.0733 ± 0.01 (7.1)	0.292 ± 0.03 (28.6)
Mean for small species		0.565 ± 0.18 (36.1)	0.216 ± 0.08 (13.8)	0.682 ± 0.20 (44.2)	0.529 ± 0.15 (34.5)	0.148 ± 0.07 (9.4)	0.135 ± 0.06 (8.2)	0.322 ± 0.09 (21.8)
Large fish								
Carangoides fulvoguttatus	3	0.279 ± 0.12 (37.7)	0.151 ± 0.07 (20.1)	0.258 ± 0.05 (36.5)	0.153 ± 0.004 (21.5)	0.100 ± 0.01 (14.4)	0.0410 ± 0.01 (5.6)	0.0743 ± 0.009 (10.8)
Diagramma pictum	3	0.282 ± 0.12 (43.5)	0.152 ± 0.07 (23.1)	0.151 ± 0.02 (25.7)	0.085 ± 0.01 (14.4)	0.0663 ± 0.01 (11.3)	0.0233 ± 0.003 (3.9)	0.0410 ± 0.006 (7.1)
Lethrinus olivaceus	3	0.198 ± 0.25 (28.6)	0.126 ± 0.18 (14.9)	0.222 ± 0.17 (48.2)	0.174 ± 0.15 (35.3)	0.0450 ± 0.02 (12.6)	0.0127 ± 0.02 (1.9)	0.137 ± 0.11 (29.9)
Lutjanus lutjanus	3	0.145 ± 0.02 (33.4)	0.071 ± 0.02 (16.3)	0.198 ± 0.02 (45.8)	0.156 ± 0.02 (36)	0.0420 ± 0.01 (9.8)	0.0190 ± 0.002 (4.4)	0.124 ± 0.01 (28.6)
Nemipterus bipunctatus	3	0.295 ± 0.07 (35.2)	0.114 ± 0.03 (13.5)	0.389 ± 0.03 (47.3)	0.294 ± 0.02 (35.8)	0.0910 ± 0.01 (11)	0.0513 ± 0.01 (6.2)	0.210 ± 0.006 (25.7)
Selar crumenophthalmus	3	0.465 ± 0.04 (35.2)	0.194 ± 0.02 (14.6)	0.612 ± 0.04 (46.5)	0.489 ± 0.03 (37)	0.123 ± 0.01 (9.3)	0.0830 ± 0.007 (6.3)	0.347 ± 0.02 (26.4)
Sphyraena jello	3	0.0738 ± 0.01 (29.1)	0.0265 ± 0.00 (10.4)	0.121 ± 0.01 (47.9)	0.089 ± 0.01 (35.1)	0.0321 ± 0.01 (12.7)	0.0117 ± 0.002 (4.6)	0.0700 ± 0.009 (27.8)
Mean for large species		0.248 ± 0.16 (34.7)***	0.119 ± 0.085 (16.1)***	0.279 ± 0.17 (42.6)***	0.206 ± 0.15 (30.7)***	0.0712 ± 0.03 (11.6)***	0.0345 ± 0.03 (4.7)***	0.143 ± 0.11 (22.3)***

Abbrevations: DHA: docosahexaenoicacid; EPA: eicosapentaenoicadic; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; SD: standard deviation, SFA: saturated fatty acid.

[a] Values are presented as means ± SD of the 19 fish species analysed in triplicates, expressed as the nutrient content per 100 g raw, edible sample.

[b] Number of composite samples analysed. For large species (> 25 cm), 5 fish are included in each composite sample, whereas for small species (< 25 cm), 25 fish are included in each composite sample.

[c] Values given in percentage of total fatty acids.

[d] For this species, each composite sample consisted of 50 individual fish in order to obtain enough sample material.

*** p = ≤ 0.0001. Significant differences in the fatty acid concentrations when comparing the means of small and large fish species as a group.

values of calcium for small and large species showed significant variations with a mean content of 960 mg/100 g for small species and 100 mg/100 g for large species ($p < 0.0001$). A similar significant variation between small and large species was also observed for iron, where the mean iron content was 3.3 mg/100 g and 0.51 mg/100 g for small and large species, respectively ($p < 0.0001$). For iron, a considerable variation amongst the small species was also observed, in which *Leignathus dussmuieri* ranged far above all other species with a peak value of 10 mg/100 g.

3.6. Potential contribution to RNI

The species' potential contribution to the RNI of calcium, iron, zinc, and vitamin A are presented in Figs. 1–4. Small species eaten whole were in general significantly more nutrient dense in terms of these micronutrients than whole fish where only the fillet is consumed.

As illustrated by the RNI for calcium presented in Fig. 1, several small species may potentially contribute ≥100 % of the daily RNI of 1000 mg/day when a portion of 100 g of fish is consumed, and five of

Table 5
Analytical values of the vitamin A, vitamin B_{12}, and vitamin D content in the 19 species sampled from Sri Lanka[a].

Species	n[b]	Vitamin A_1 µg/100 g	Vitamin A_2 µg/100 g	Vitamin B_{12} µg/100 g	Vitamin D_3 µg/100 g
Small fish					
Amblygaster sirm	3	70 ± 0.0	24 ± 2.0	14 ± 1.2	3 ± 1
Auxis thazard	3	110 ± 5.8	6.3 ± 1.5	12 ± 1.5	7.3 ± 0.6
Decapterus macrosoma (1)	3	170 ± 21	8.7 ± 1.5	16 ± 1.0	< 1[c]
Decapterus macrosoma (2)	3	103 ± 5.8	12 ± 4.7	20 ± 1.5	4.3 ± 1.5
Encrasicholina devisi	3[d]	93 ± 31	9.7 ± 3.5	9.7 ± 0.5	2.3 ± 0.6
Equulites elongatus	3	160 ± 35	10 ± 2.0	8.6 ± 0.4	6.7 ± 2.1
Leiognathus dussumieri	3	2000 ± 150	46 ± 4.1	8.1 ± 0.2	< 1[c]
Photopectoralis bindus (1)	3	150 ± 25	7.3 ± 0.6	5.7 ± 0.3	3 ± 1
Photopectoralis bindus (2)	3	140 ± 29	6.0 ± 1.0	4.7 ± 0.4	2.7 ± 0.6
Rastrelliger kanagurta	3	100 ± 5.8	16 ± 0.6	18 ± 0.6	4.7 ± 0.6
Sillago ingenuua	3	230 ± 46	23 ± 3.5	17 ± 1.2	< 1[c]
Stolephorus indicus	3	100 ± 31	11 ± 1.5	5.4 ± 0.6	7 ± 2
Mean for small species		280 ± 520	15 ± 11	12 ± 5.1	3.6 ± 2.5[e]
Large fish					
Carangoides fulvoguttatus	3	3.8 ± 3.7	< 0.5[f]	0.64 ± 0.04	< 1[c]
Diagramma pictum[g]	3	–	–	–	–
Lethrinus olivaceus	3	11 ± 16	< 0.5[h]	1.4 ± 0.1	3 ± 2
Lutjanus lutjanus	3	2.7 ± 0.1	< 0.5[f]	1.5 ± 0.2	< 1[c]
Nemipterus bipunctatus	3	2.7 ± 0.4	< 0.5[f]	1.2 ± 0.2	4.3 ± 0.6
Selar crumenophthalmus	3	9.3 ± 0.6	< 0.5[f]	12 ± 1.2	< 1[c]
Sphyraena jello	3	12 ± 5.5	2.8 ± 1.1	1.3 ± 0.2	5.7 ± 0.6
Mean for large species		6.9 ± 7.1***	0.74 ± 1.1[e,***]	3.0 ± 4.1***	2.4 ± 2.3[e]

Abbrevations: LOQ: limit of quantification; SD: standard deviation.
[a] Values are presented as means ± SD of the 19 fish species analysed in triplicates, expressed as the nutrient content per 100 g raw, edible sample.
[b] Number of composite samples analysed. For large species (> 25 cm), 5 fish are included in each composite sample, whereas for small species (< 25 cm), 25 fish are included in each composite sample.
[c] Value below LOQ of 1.0 µg/100 g.
[d] For this species, each composite sample consisted of 50 individual fish in order to obtain enough sample material.
[e] Values < LOQ were divided by 2 to be able to calculate the mean.
[f] Value below LOQ of 0.5 µg/100 g.
[g] No data on vitamin analyses for the large species *Diagramma pictum* is available due to insufficient sample material.
[h] Two composite samples were below the LOQ of 0.5 µg/100 g, whereas one composite sample was 1.6 µg/100 g.
*** p = ≤ 0.0001. Significant differences in the vitamin concentrations when comparing the means of small and large fish species as a group.

twelve small species were identified to potentially contribute ≥30 % of the RNI when a standard Sri Lankan FBDG serving size is consumed. All small species (with the exception of *Rastrelliger kanagurta*) were identified to potentially contribute at least 500 mg of calcium when a portion of 100 g is consumed, thus accounting for ≥50 % of the RNI. Two of the small species, *Leiognathus dussumieri* and *Sillago ingenuua*, were also identified to potentially contribute > 50 % of the RNI when a 30 g portion is consumed.

The results for zinc are presented in Fig. 2. The RNI for zinc is estimated to be 9.8 mg/day, a value that far exceeds the calculated contribution from any of the species. However, three species (all small fish): *Leiognathus dussumieri, Equulites elongatus,* and *Photopectoralis bindus* were identified to potentially contribute ≥25 % of the daily RNI for zinc in a 100 g portion, whereas a single Sri Lankan FBDG serving size was estimated to contribute ≤10 % of the RNI for all species.

The assumed RNI for iron of 29.4 mg/day is also a value that far exceeds the contribution of any single species of fish (Fig. 3); the species with the highest iron content, *Leiognathus dussumieri*, was identified to potentially contribute approximately 10 % of the daily RNI in a standard portion of 30 g, whereas a 100 g portion may account for ≥30 % of the RNI.

The results for vitamin A_1 are presented in Fig. 4, and as illustrated by the graph, the small species *Leiognathus dussumieri* contains by far the highest content of vitamin A_1 of the sampled species. Even a single serving of 30 g of this particular species may ensure the recommended safe intakes of 500 µg RE/day for the reference group. Several other small species were also found to potentially contribute around 50 % of the recommended safe intakes when a 100 g portion is consumed, whereas all large species were found to contribute minimally to vitamin A_1.

4. Discussion

This paper presents comprehensive analytical information on a large amount of nutrients in several commonly consumed marine fish species caught off the coast of Sri Lanka. All species included in this paper may be significant dietary sources of protein, numerous micronutrients, and essential fatty acids if included in the diet. The content of several micronutrients such as calcium, iron, zinc, vitamin A, and EPA and DHA were however significantly higher in small species consumed whole, including bones, skin, and viscera, compared to larger fish species where only the filet is consumed. Several species were also identified to have the potential to contribute substantially to the RNI of women of reproductive age for multiple nutrients important for FNS in Sri Lanka. Very few studies have been conducted on the quantification of micronutrient content in marine fish commonly consumed in LMICs. This is currently the first study to analyse the vitamin A, B_{12}, and D content in marine fish species in Sri Lanka, and the second study to quantify the mineral composition; nutrients that are of particular public health significance given the prevalence estimates of vitamin and mineral

Table 6
Analytical values of the mineral content in the 19 species sampled from Sri Lanka[a].

Species	n[b]	Calcium Ca mg/100 g	Iron Fe mg/100 g	Iodine I µg/100 g	Magnesium Mg mg/100 g	Phosphorus P mg/100 g	Potassium K mg/100 g	Selenium Se µg/100 g	Sodium Na mg/100 g	Zinc Zn mg/100 g
Small fish										
Amblygaster sirm	3	500 ± 100	3.0 ± 0.2	280 ± 0.0	63 ± 1.6	540 ± 58	390 ± 12	110 ± 10	290 ± 5.8	1.9 ± 0.1
Auxis thazard	3	550 ± 87	3.4 ± 0.2	39 ± 2.1	43 ± 1.7	540 ± 49	350 ± 17	83 ± 4.0	160 ± 12	1.6 ± 0.2
Decapterus macrosoma (1)	3	1100 ± 240	5.8 ± 1.0	54 ± 3.0	63 ± 3.2	740 ± 93	370 ± 15	230 ± 23	173 ± 5.8	1.8 ± 0.1
Decapterus macrosoma (2)	3	650 ± 170	3.6 ± 0.3	123 ± 12	48 ± 1.5	590 ± 84	380 ± 12	46 ± 1.0	170 ± 12	1.4 ± 0.2
Encrasicholina devisi	3[c]	550 ± 98	1.7 ± 0.1	177 ± 15	83 ± 7.0	510 ± 59	300 ± 5.8	56 ± 2.0	460 ± 17	2.4 ± 0.1
Equulites elongatus	3	640 ± 150	2.1 ± 0.1	84 ± 6.1	55 ± 1.2	560 ± 67	390 ± 5.8	46 ± 3.0	200 ± 5.8	2.7 ± 0.1
Leiognathus dussumieri	3	2300 ± 460	10 ± 1.2	360 ± 27	75 ± 6.1	1200 ± 290	310 ± 15	88 ± 5.0	180 ± 5.8	3.0 ± 0.1
Photopectoralis bindus (1)	3	1300 ± 260	1.7 ± 0.4	74 ± 8.5	66 ± 3.8	910 ± 110	400 ± 5.8	38 ± 2.0	200 ± 5.8	2.6 ± 0.1
Photopectoralis bindus (2)	3	1000 ± 140	1.4 ± 0.1	170 ± 15	55 ± 1.2	760 ± 61	390 ± 12	38 ± 2.0	190 ± 5.8	2.5 ± 0.1
Rastrelliger kanagurta	3	490 ± 25	3.2 ± 0.2	95 ± 2.7	49 ± 0.6	520 ± 12	420 ± 10	53 ± 1.0	180 ± 5.8	1.3 ± 0.0
Sillago ingenuua	3	1800 ± 440	1.6 ± 0.4	84 ± 14	52 ± 12	910 ± 270	360 ± 27	56 ± 6.0	150 ± 12	1.3 ± 0.2
Stolephorus indicus	3	620 ± 55	2.0 ± 0.3	20 ± 0.6	51 ± 1.7	590 ± 36	440 ± 10	44 ± 0.0	160 ± 0.0	2.2 ± 0.1
Mean for small species		960 ± 590	3.3 ± 2.5	130 ± 100	58 ± 12	700 ± 240	370 ± 40	74 ± 52	210 ± 85	2.1 ± 0.6
Large fish										
Carangoides fulvoguttatus	3	17 ± 5.7	0.81 ± 0.02	39 ± 13	36 ± 1.7	310 ± 12	530 ± 15	3.7 ± 1.0	61 ± 1.7	0.5 ± 0.01
Diagramma pictum	3	23 ± 17	0.45 ± 0.04	103 ± 13	29 ± 0.6	250 ± 12	470 ± 12	46 ± 4.0	50 ± 1.5	0.4 ± 0.01
Lethrinus olivaceus	3	42 ± 39	0.22 ± 0.1	75 ± 12	31 ± 2.9	280 ± 40	510 ± 47	44 ± 1.0	44 ± 2.1	0.3 ± 0.01
Lutjanus lutjanus	3	65 ± 45	0.38 ± 0.04	20 ± 0.6	32 ± 1.2	260 ± 32	450 ± 15	43 ± 1.0	37 ± 2.1	0.3 ± 0.01
Nemipterus bipunctatus	3	490 ± 350	0.40 ± 0.2	23 ± 0.6	38 ± 3.5	500 ± 150	440 ± 70	39 ± 2.0	68 ± 20	0.6 ± 0.2
Selar crumenophthalmus	3	53 ± 58	1.1 ± 0.2	26 ± 0.6	36 ± 0.6	280 ± 23	430 ± 5.8	77 ± 5.0	60 ± 7.0	0.7 ± 0.3
Sphyraena jello	3	7.9 ± 0.5	0.21 ± 0.01	22 ± 0.6	34 ± 1.7	270 ± 10	490 ± 25	44 ± 2.0	42 ± 6.1	0.4 ± 0.01
Mean for large species		100 ± 200***	0.51 ± 0.3***	44 ± 31**	34 ± 3.5***	310 ± 96***	470 ± 46***	47 ± 13*	52 ± 13***	0.4 ± 0.2***

[a] Values are presented as means ± standard deviation (SD) of the 19 fish species analysed in triplicates, expressed as the nutrient content per 100 g raw, edible sample.
[b] Number of composite samples analysed. For large species (> 25 cm), 5 fish are included in each composite sample, whereas for small species (< 25 cm), 25 fish are included in each composite sample.
[c] For this species, each composite sample consisted of 50 individual fish in order to obtain enough sample material.
* p = ≤ 0.01. Significant differences in the mineral concentrations when comparing the means of small and large fish species as a group.
** p = ≤ 0.001. Significant differences in the mineral concentrations when comparing the means of small and large fish species as a group.
*** p = ≤ 0.0001. Significant differences in the mineral concentrations when comparing the means of small and large fish species as a group.

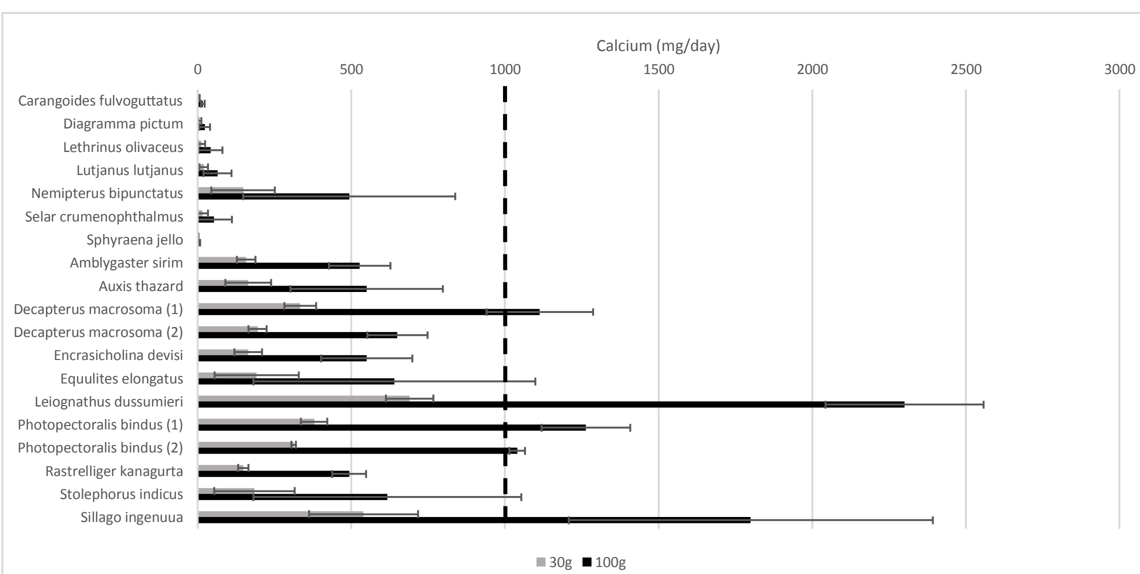

Fig. 1. The various species' calcium content in one serving size of 30 g and a portion of 100 g in reference to the average recommended nutrient intake (RNI) of 19-50-year-old women of reproductive age. The recommended nutrient intake of calcium for this group is estimated to be 1000 mg/day, as indicated by the bold line, and the whiskers represent the standard deviations of the means.

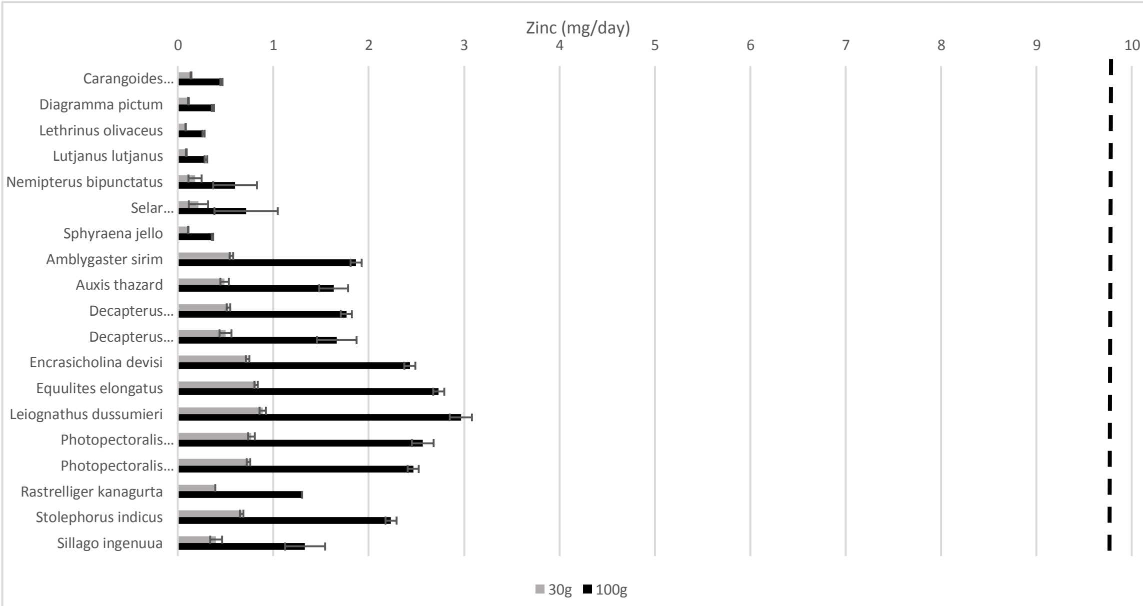

Fig. 2. The various species' zinc content in one serving size of 30 g and a portion of 100 g in reference to the recommended nutrient intake (RNI) of 19-50-year-old women of reproductive age. The recommended nutrient intake of zinc for this group with an assumed low (15 %) dietary bioavailability is estimated to be 9.8 mg/day, a value that exceeds the contribution from the serving sizes of any single species. The whiskers represent the standard deviations of the means.

deficiencies in the country (Abeywickrama et al., 2018).

4.1. Vitamin content

There seem to be a general assumption within the scientific literature that due to the fat-soluble nature of both vitamin A and vitamin D, fatty fish fillet typically contains greater concentrations of these vitamins than lean fish, in which the majority of these vitamins are concentrated in the liver (Huss, 1995; Lu et al., 2007; Murray and Burt, 2001). However, the results presented in this paper somewhat deviate from this general assumption; there seemed to be a random variation in the vitamin D content between species, with no clear pattern attributed to neither fat nor size categorisations; even lean fish species contained remarkable amounts of vitamin D. Conversely, a clear pattern emerged for vitamin A, with small species containing significantly higher concentrations compared to large species. This could possibly be explained by inclusion of the liver and eyes of small fish species (Roos et al., 2002, 2007b). It should also be highlighted that none of the sampled species

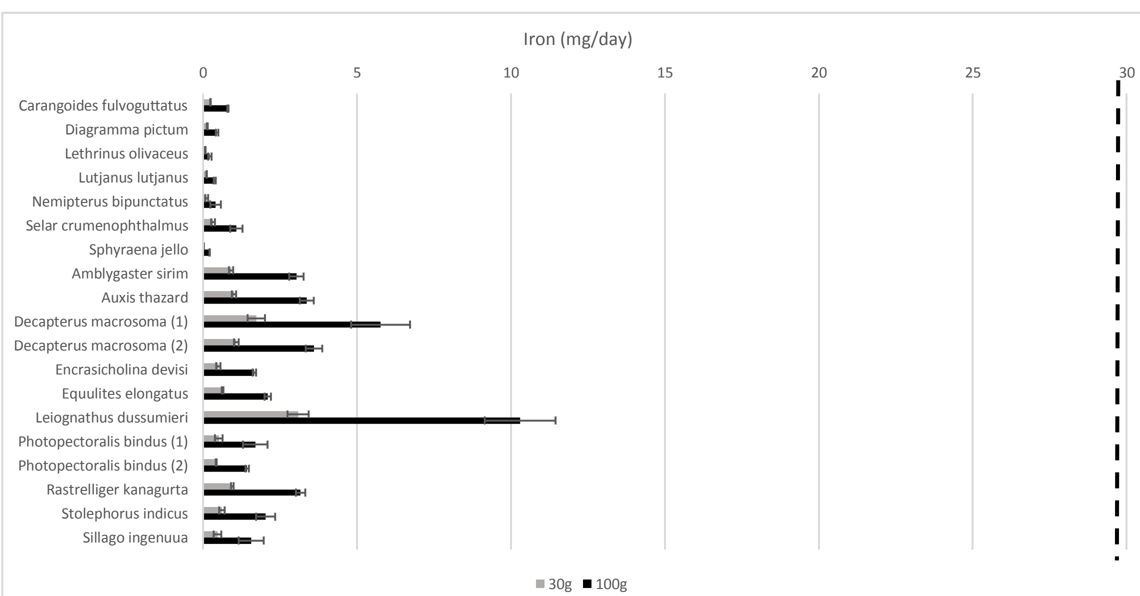

Fig. 3. The various species' iron content in one serving size of 30 g, and a portion of 100 g in reference to the recommended nutrient intake (RNI) of 19–50-year-old women of reproductive age. The recommended nutrient intake of iron for this group with an assumed low (10 %) dietary bioavailability is estimated to be 29.4 mg/day, a value that far exceeds the contribution from any serving size of any of the species. The whiskers represent the standard deviations of the means.

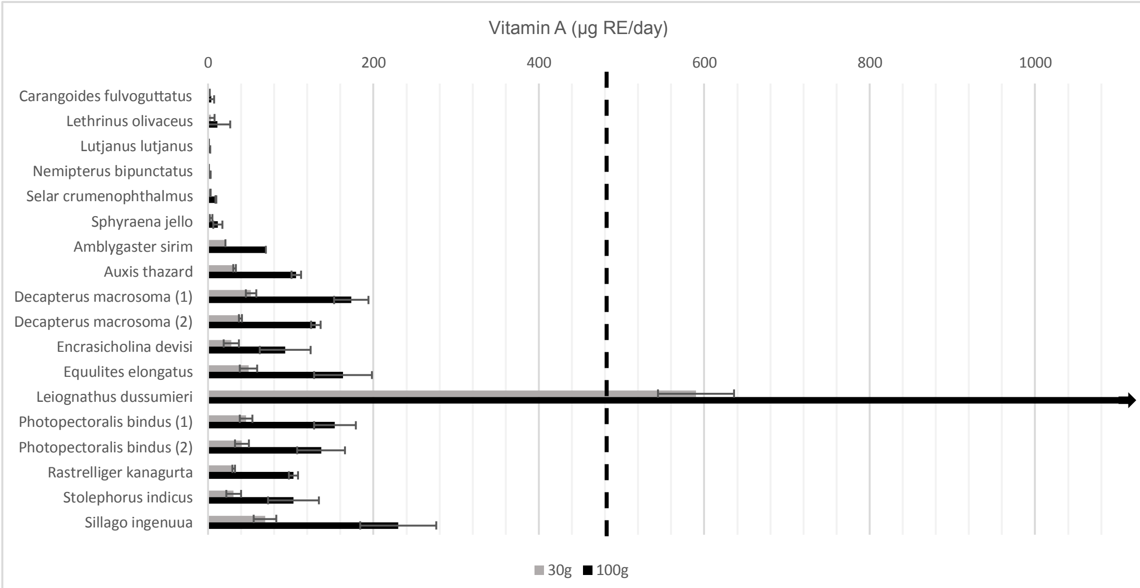

Fig. 4. The various species' vitamin A_1 content in one serving size of 30 g and a portion of 100 g in reference to the recommended safe intakes for 19-50-year-old women of reproductive age. The recommended safe intake of vitamin A_1 for this group is estimated to be 500 µg retinol equivalent (RE)/day (where 1 µg retinol (A_1) = 1 RE), as indicated by the bold line. The small arrow implies the continuation of the line beyond the axis, and the whiskers represent the standard deviations of the means.

in this study had a particularly high fat content. Other plausible explanations may be variations in dietary composition, age, sex, season, and climate, as previously discussed in other studies where the vitamin D content in fish was not in line with the general assumption that fatty fish contain higher vitamin D content than lean fish (Lu et al., 2007; Mattila et al., 1995; Ostermeyer and Schmidt, 2005). High concentrations of vitamin A in small species was also seen in a study from Bangladesh, where reported values for vitamin A (vitamin A_1 and A_2 combined) ranged from 2680 RE/100 g in the small indigenous species (SIS) mola (*Amblypharyngodon mola)*, a species that is commonly consumed whole, to < 30 RE/100 g in the edible parts (filet only) of larger cultured species (Roos et al., 2002). These exceptionally high concentrations of vitamin A found in the SIS correspond to the levels discovered in this study for the small marine species *Leiognathus dussumieri*. The high vitamin A levels may imply caution of the consumption of these species over longer periods to avoid toxicity, especially for vulnerable groups like pregnant women (WHO and FAO, 2004). Roos et al. further reported that > 50 % of the vitamin A in mola was concentrated in the retina of the fish, whereas another 40 % was concentrated in the viscera. This may explain our findings, where small fish which had the head and viscera included in the analysis presented a significantly higher content of vitamin A compared to large fish where only the filet was included in the analysed sample (Roos et al., 2002). Furthermore, we reported a significant difference in vitamin A_2 concentrations between large and small species. Vitamin A_2 is thought to be produced in high concentrations almost exclusively in freshwater fish, and most marine fish species have been reported to have insignificant amounts (La Frano and Burri, 2014; La Frano et al., 2018). In this study, the vitamin A_2 concentration was < LOQ in all but one of the large species, however, all of the small species had concentrations > LOQ, implying that vitamin A_2 is present in significant concentrations in marine fish species as well.

4.2. Mineral content

The high content of several important minerals in small fish species may be naturally attributed to the inclusion and exclusion of various parts of the fish (bones, skin, head, viscera, etc.) in the analysed samples, and which parts of the fish that are consumed are therefore of great importance for FNS, as argued by Bogard et al. (Bogard et al., 2015). For example, approximately 99 % of the accumulated calcium and 80 % of the phosphorus is stored in the bones, teeth, and scales of the fish, whereas the remaining 1% is distributed throughout the organs and tissues (FAO Aquaculture Development and Coordination Programme (ADCP), 1980; Malde et al., 2010). The calcium in small, soft-boned species commonly consumed whole have in previous studies been confirmed to be of high bioavailability (Hansen et al., 1998; Larsen et al., 2000), and small fish may therefore be considered a rich source of calcium in comparison to larger fish species where the bones are not eaten and discarded as plate waste (Roos et al., 2003). The importance of minimising plate waste was also accentuated in a Sri Lankan study from 2012, where five species of tuna (amongst them *Auxis thazard*, also included in this paper) were analysed for several nutrients. According to the results, the skin of all sampled species of tuna contained the highest levels of potassium, calcium, zinc, and magnesium, and the authors concluded with the importance of consuming various parts of the fish to reap the most nutritional benefits (Karunarathna and Attygalle, 2012). Furthermore, a 60 % loss of total iron in the Cambodian SIS, *E. longimanus*, was reported when the head and viscera were removed, which implies that populations that are prone to iron deficiency, such as women of reproductive age, could be optimising their use of locally available nutrient-dense foods (Roos et al., 2007a). However, higher concentrations of calcium, iron, and zinc have also been detected in the muscle tissue of species from tropical thermal regimes (Hicks et al., 2019).

4.3. Contribution to recommended nutrient intakes and importance to food and nutrition security in Sri Lanka

Bogard et al. (2015) evaluated the contribution of various SIS and larger marine and freshwater species to the RNI of pregnant and lactating women and infants, and their results showed that several small species were identified to potentially contribute ≥25 % of the RNI of three or more micronutrients for both groups when a standard portion

(50 g/day and 25 g/day, respectively) is consumed, but only one of the larger species was identified to do the same (Bogard et al., 2015). These results are in line with the results of this paper, where all small species were identified to potentially contribute substantially more than large species to the RNI of all micronutrients for women of reproductive age. Small species often have a significantly lower market value than larger species, and are therefore assumed to be more easily accessible and commonly consumed in poor households, thus playing an important role to FNS by diversifying the diets of the poor (Kabahenda et al., 2011; Kawarazuka and Bene, 2011; Roos et al., 2007b). Amongst food-based strategies to improve FNS in LMICs, dietary diversification is recognised as a sustainable and cost-effective solution that addresses multiple micronutrient deficiencies at once (Demment et al., 2003; FAO, 2018b; WHO, 1991). As evidenced by this paper, fish is a rich source of several micronutrients. Because some species are considerably more nutrient-dense than others – and therefore much more likely to meet the daily RNI of key, nutritionally vulnerable populations – it is essential to have accurate and reliable food composition data that captures both inter and intra-species variability. This will facilitate the creation of robust fish-based food strategies that diversify diets otherwise dominated by staple foods. Small fish species as a source of micronutrients have been given little attention in the scientific literature so far, but due to their high nutrient content and affordability, could be used as a key component in strategies aimed at reducing micronutrient deficiencies and improving FNS in developing countries with prevalent micronutrient deficiencies like Sri Lanka (Hicks et al., 2019; Kawarazuka and Bene, 2011).

4.4. Strengths and limitations

According to Greenfield and Southgate (2003), the number of subsamples included per analytical sample should be calculated from the variance of the nutrient composition of the food product in order to achieve means with reasonable levels of confidence. This was not performed in this paper; however, all analytical values were based on samples consisting of at least fifteen individual fish. This is in accordance with most standards where at least ten units are used to reflect the variability in composition, but optimally, a higher number of samples are required for certain nutrients due to the intra-species variability present in various foods (Gibson, 2005, p. 76; Greenfield and Southgate, 2003). Additionally, pooling is similar to averaging, thus reducing the effect of the biological variation present in each sample, and does not allow one to look into the variation within the sample (Caudill, 2012). The data presented in this paper are of high quality as the samples were analysed at a national reference laboratory, using accredited methods. The analytical data reported in this study may therefore represent an important contribution to the future compilation and further development of the Sri Lankan food composition table. The nutrient composition of foods, including fish, is known to vary with season, environment, and maturity, however such variations were not accounted for in this study (FAO, 2017; Greenfield and Southgate, 2003). When using food composition values to estimate the potential RNI, it is important to be aware that such values indicate the total amount of the nutrient available within the food rather than the amount actually absorbed by the body (Gibson, 2005, p. 65). As the bioavailability of nutrients in most foods have not yet been quantified, these factors along with local processing techniques such as drying and smoking, were not considered in the calculations for this paper, where only values for raw, unprocessed fish were estimated, and an assumption of 100 % bioavailability was presumed.

5. Conclusions

In this paper we have described the concentrations of several nutrients in nineteen commonly consumed marine fish species from Sri Lanka. All fish species are a good source of key nutrients when included in the diet, but the results of this paper show that small fish commonly consumed whole, including head, bones, and viscera, are significantly more nutrient dense compared to fillet samples of larger species, especially regarding micronutrients such as calcium, iron, zinc, vitamin A, and EPA and DHA. Several species have been identified to have the potential to contribute substantially to the RNI of women of reproductive age for multiple micronutrients important for FNS in Sri Lanka, of which the small species *Leiognathus dussumieri* presented noticeably higher levels of most micronutrients compared to other species. Improved knowledge through enhanced and up-to-date food composition data of commonly consumed fish species will allow for the promotion of particularly nutrient-dense fish to be used in food-based strategies to combat common nutrient deficiencies in the country. However, as evidenced by this paper; a wide range of nutrients are present in various concentrations in different species, thus promoting a diverse diet is preferred to improve overall FNS in Sri Lanka, as even small amounts of fish in the diet can diversify diets otherwise dominated by staple foods. The analytical data presented here may represent an important contribution to the future development of the Sri Lankan food composition table.

Declaration of Competing Interest

None.

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CRediT authorship contribution statement

Amalie Moxness Reksten: Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Thiruchenduran Somasundaram:** Investigation, Writing - review & editing. **Marian Kjellevold:** Conceptualization, Methodology, Validation, Resources, Writing - review & editing, Supervision, Project administration, Funding acquisition. **Anna Nordhagen:** Writing - review & editing. **Annbjørg Bøkevoll:** Formal analysis, Writing - review & editing. **Lauren Michelle Pincus:** Writing - review & editing. **Abu Ansar Md. Rizwan:** Writing - review & editing. **Al Mamun:** Writing - review & editing. **Shakuntala Haraksingh Thilsted:** Writing - review & editing. **Thaung Htut:** Writing - review & editing. **Inger Aakre:** Conceptualization, Validation, Writing - review & editing, Supervision.

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Appendix A

Fig. A1

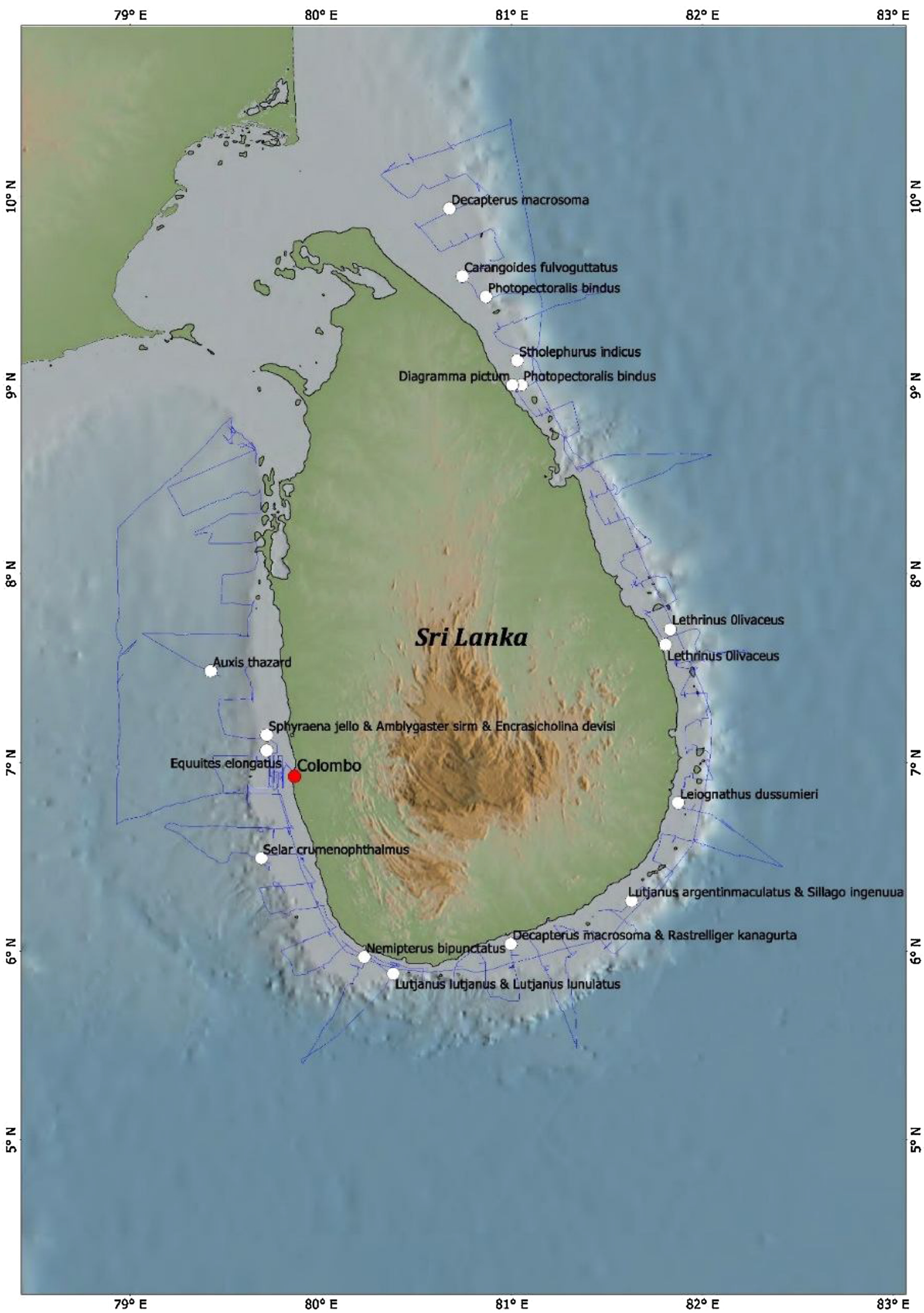

Fig. A1. Map of the Nansen cruise track around Sri Lanka, including sample locations and the scientific names of the fish sampled in each location (station). For more detailed coordinates of each sample location, see Appendix B.

Appendix B

Table B1

Table B1
Coordinates of the starting and ending positions of the trawl where the samples were collected during the 2018 survey around Sri Lanka.

Scientific name	English name[a]	Start position[b]	End position[b]
Small fish			
Amblygaster sirm	Trenched sardinella	7.15, 79.71	7.12, 79.71
Auxis thazard	Frigate tuna	7.49, 79.42	7.46, 79.50
Decapterus macrosoma (1)	Shortfin scad	9.94, 80.67	9.92, 80.70
Decapterus macrosoma (2)	Shortfin scad	6.04, 80.99	6.04, 81.0
Encrasicholina devisi	Devis' anchovy	7.15, 79.71	7.12, 79.71
Equulites elongatus	Slender ponyfish	7.06, 79.71	7.03, 79,70
Leiognathus dussumieri	Dussumier's ponyfish	6.79, 81.87	6.77, 81.9
Photopectoralis bindus (1)	Orangefin ponyfish	9.47, 80.86	9.45, 80.90
Photopectoralis bindus (2)	Orangefin ponyfish	9.00, 81.05	8.98, 81.10
Rastrelliger kanagurta	Indian mackerel	6.04, 80.99	6.04, 81.00
Sillago ingenuua	Bay whiting	6.22, 81.47	6.22, 81.5
Stolephorus indicus	Indian anchovy	9.13, 81.03	9.15, 81.0
Large fish			
Carangoides fulvoguttatus	Yellowspotted trevally	9.58, 80.74	9.59, 80.00
Diagramma pictum	Painted sweetlips	9.00, 81.00	8.98, 81.00
Lethrinus olivaceus	Long-face emperor	7.71, 81.83	7.68, 81.80
Lutjanus lutjanus	Bigeye snapper	5.88, 80.38	5.88, 80.40
Nemipterus bipunctatus	Delagoa threadfin bream	5.97, 80.23	5.96, 80.30
Selar crumenophthalmus	Bigeye scade	6.49, 79.69	6.44, 79.70
Sphyraena jello	Pickhandle barracuda	7.15, 79.71	7.12, 79.70

[a] Information on English names were obtained through the global species database "FishBase" (Froese and Pauly, 2019).
[b] GPS coordinates expressed as latitude and longitude, respectively, in reference to the starting and ending position of the trawl where each fish species was sampled from.

References

Abeywickrama, H.M., Koyama, Y., Uchiyama, M., Shimizu, U., Iwasa, Y., Yamada, E., et al., 2018. Micronutrient status in Sri Lanka: a review. Nutrients 10 (11). https://doi.org/10.3390/nu10111583.

Angyal, G., 1996. Methods for the Microbiological Analyses of Selected Nutrients. AOAC International, Gaithersburg, MD.

AOAC, 1995. Crude Protein in Meat and Meat Products, Combustion Method, 16th Ed. Method 992.15. AOAC, Arlington, VA, USA.

Bailey, R.L., West Jr., K.P., Black, R.E., 2015. The epidemiology of global micronutrient deficiencies. Ann. Nutr. Metab. 66 (Suppl. 2), 22–33. https://doi.org/10.1159/000371618.

Béné, C., Arthur, R., Norbury, H., Allison, E.H., Beveridge, M., Bush, S., et al., 2016. Contribution of fisheries and aquaculture to food security and poverty reduction: assessing the current evidence. World Dev. 79, 177–196. https://doi.org/10.1016/j.worlddev.2015.11.007.

Bogard, J.R., Thilsted, S.H., Marks, G.C., Wahab, M.A., Hossain, M.A.R., Jakobsen, J., Stangoulis, J., 2015. Nutrient composition of important fish species in Bangladesh and potential contribution to recommended nutrient intakes. J. Food Compos. Anal. 42, 120–133. https://doi.org/10.1016/j.jfca.2015.03.002.

Caudill, S.P., 2012. Use of pooled samples from the national health and nutrition examination survey. Stat. Med. 31 (27), 3269–3277. https://doi.org/10.1002/sim.5341.

Comitè Europèen de Normalisation; EN 12821, 2009. Foodstuffs – Determination of Vitamin D by High Performance Liquid Chromatography - Measurement of Cholecalciferol (D3) or Ergocalciferol (D2). NS-EN 12821.

Comitè Europèen de Normalisation; EN12823-1, 2000. Foodstuffs – Determination of Vitamin a by High Preformance Liquid Chromatography- Part 1: Measurement of All-trans-Retinol and 13-cis-Retinol. NS-EN 12823-1.

Demment, M.W., Young, M.M., Sensenig, R.L., 2003. Providing micronutrients through food-based solutions: a key to human and national development. J. Nutr. 133 (11), 3879S–3885S. https://doi.org/10.1093/jn/133.11.3879S.

EFSA, 2005. Opinion of the Scientific Panel on contaminants in the food chain [CONTAM] related to the safety assessment of wild and farmed fish. EFSA J. 3 (7). https://doi.org/10.2903/j.efsa.2005.236.

EFSA, 2014. Scientific opinion on health benefits of seafood (fish and shellfish) consumption in relation to health risks associated with exposure to methylmercury. EFSA J. 12 (7). https://doi.org/10.2903/j.efsa.2014.3761. Retrieved from.

FAO, 2006. FAO Fishery Country Profile: The Democratic Socialist Republic of Sri Lanka. Retrieved from. http://www.fao.org/fi/oldsite/FCP/en/LKA/profile.htm.

FAO, 2017. International Network of Food Data Systems (INFOODS): Food Composition Challenges. Retrieved from. http://www.fao.org/infoods/infoods/food-composition-challenges/en/.

FAO, 2018a. FAO in Sri Lanka: Programmes in Sri Lanka. Retrieved from. http://www.fao.org/srilanka/programmes-and-projects/programmes/en/.

FAO, 2018b. FUTURE SMART FOOD: Rediscovering Hidden Treasures of Neglected and Underutilized Species for Zero Hunger in Asia, Executive Summary. Bangkok, Thailand. .

FAO, 2018c. International Network of Food Data Systems (INFOODS): Asia. Retrieved from. http://www.fao.org/infoods/infoods/tables-and-databases/asia/en/.

FAO, 2018d. The State of World Fisheries and Aquaculture. Retrieved from. http://www.fao.org/documents/card/en/c/I9540EN/.

FAO, 2019. The EAF-Nansen Programme. Retrieved from. http://www.fao.org/in-action/eaf-nansen/en/.

FAO Aquaculture Development and Coordination Programme (ADCP), 1980. Fish Feed Technology. FAO, Rome, Italy.

Folch, J., Lees, M., Sloane Stanley, G.H., 1957. A simple method for the isolation and purification of total lipides from animal tissues. J. Biol. Chem. 226 (1), 497–509.

Froese, R., & Pauly, D. FishBase. Retrieved from: www.fishbase.org.

Gibson, R.S., 2005. Principles of Nutritional Assessment, second ed. Oxford University Press, Inc., New York, USA.

Greenfield, H., Southgate, D.A.T., 2003. In: Burlingame, B.A., Charrondiere, U.R. (Eds.), Food Composition Data - Production, Management and Use, second ed. FAO, Rome, Italy.

Hansen, M., Thilsted, S.H., Sandstrom, B., Kongsbak, K., Larsen, T., Jensen, M., Sorensen, S.S., 1998. Calcium absorption from small soft-boned fish. J. Trace Elem. Med. Biol. 12 (3), 148–154. https://doi.org/10.1016/s0946-672x(98)80003-5.

Helsel, D.R., 2006. Fabricating data: how substituting values for nondetects can ruin results, and what can be done about it. Chemosphere 65 (11), 2434–2439. https://doi.org/10.1016/j.chemosphere.2006.04.051.

Hicks, C.C., Cohen, P.J., Graham, N.A.J., Nash, K.L., Allison, E.H., D'Lima, C., et al., 2019. Harnessing global fisheries to tackle micronutrient deficiencies. Nature. https://doi.org/10.1038/s41586-019-1592-6.

Huss, H.H., 1995. Quality and Quality Changes in Fresh Fish: FAO Fisheries Technical Paper - 348. FAO, Rome, Italy.

Julshamn, K., Dahl, L., Eckhoff, K., 2001. Determination of iodine in seafood by inductively coupled plasma/mass spectrometry. J. AOAC Int. 84 (6), 1976–1983.

Julshamn, K., Maage, A., Norli, H.S., Grobecker, K.H., Jorhem, L., Fecher, P., 2007. Determination of arsenic, cadmium, mercury, and lead by inductively coupled plasma/mass spectrometry in foods after pressure digestion: NMKL interlaboratory study. J. AOAC Int. 90 (3), 844–856.

Kabahenda, M.K., Amega, R., Okalany, E., Husken, S.M.C., Heck, S., 2011. Protein and micronutrient composition of low value fish products commonly marketed in the Lake Victoria region. World J. Agric. Sci. 7 (5), 521–526.

Karunarathna, K., Attygalle, M., 2012. Nutritional evaluation in five species of tuna. Vidyodaya J. Sci. 15.

Kawarazuka, N., Bene, C., 2011. The potential role of small fish species in improving micronutrient deficiencies in developing countries: building evidence. Public Health Nutr. 14 (11), 1927–1938. https://doi.org/10.1017/s1368980011000814.

La Frano, M.R., Burri, B.J., 2014. Analysis of retinol, 3-hydroxyretinol and 3,4-didehydroretinol in North American farm-raised freshwater fish liver, muscle and feed. Aquac. Nutr. 20, 722–730.

La Frano, M.R., Cai, Y., Burri, B.J., Thilsted, S.H., 2018. Discovery and biological relevance of 3,4-didehydroretinol (vitamin A2) in small indigenous fish species and its potential as a dietary source for addressing vitamin A deficiency. Int. J. Food Sci. Nutr. 69 (3), 253–261. https://doi.org/10.1080/09637486.2017.1358358.

Larsen, Thilsted, S.H., Kongsbak, K., Hansen, M., 2000. Whole small fish as a rich calcium source. Br. J. Nutr. 83 (2), 191–196.

Larsen, R., Eilertsen, K.-E., Elvevoll, E.O., 2011. Health benefits of marine foods and ingredients. Biotechnol. Adv. 29 (5), 508–518. https://doi.org/10.1016/j.biotechadv.2011.05.017.

Lie, Ø., Lambertsen, G., 1991. Fatty acid composition of glycerophospholipids in seven tissues of cod (Gadus morhua), determined by combined high-performance liquid chromatography and gas chromatography. J. Chromatogr. B Biomed. Sci. Appl. 565 (1), 119–129. https://doi.org/10.1016/0378-4347(91)80376-N.

Lim, K.H.C., Riddell, L.J., Nowson, C.A., Booth, A.O., Szymlek-Gay, E.A., 2013. Iron and zinc nutrition in the economically-developed world: a review. Nutrients 5 (8), 3184–3211. https://doi.org/10.3390/nu5083184.

Lock, E.-J., Waagbø, R., Wendelaar Bonga, S., Flik, G., 2010. The significance of vitamin D for fish: a review. Aquac. Nutr. 16 (1), 100–116. https://doi.org/10.1111/j.1365-2095.2009.00722.x.

Lu, Z., Chen, T.C., Zhang, A., Persons, K.S., Kohn, N., Berkowitz, R., et al., 2007. An evaluation of the vitamin D3 content in fish: is the vitamin D content adequate to satisfy the dietary requirement for vitamin D? J. Steroid Biochem. Mol. Biol. 103 (3), 642–644. https://doi.org/10.1016/j.jsbmb.2006.12.010.

Malde, M.K., Bügel, S., Kristensen, M., Malde, K., Graff, I.E., Pedersen, J.I., 2010. Calcium from salmon and cod bone is well absorbed in young healthy men: a double-blinded randomised crossover design. J. Nutr. Metab. 7 (1), 61. https://doi.org/10.1186/1743-7075-7-61.

Mattila, P., Piironen, V., Uusi-Rauva, E., Koivistoinen, P., 1995. Cholecalciferol and 25-Hydroxycholecalciferol contents in fish and fish products. J. Food Compos. Anal. 8 (3), 232–243. https://doi.org/10.1006/jfca.1995.1017.

Ministry of Fisheries and Aquatic Resources Development, 2016. Annual Performance Report. Retrieved from. . https://www.parliament.lk/uploads/documents/paperspresented/performance-report-ministry-of-fisheries-aquatic-2016.pdf.

Ministry of Health in Sri Lanka, WHO, 2011. Food Based Dietary Guidelines for Sri Lankans. Retrieved from. second edition. . http://www.fao.org/3/a-as886e.pdf.

Murray, J., Burt, J.R., 2001. The Composition of Fish. Retrieved from. http://www.fao.org/wairdocs/tan/x5916e/x5916e01.htm.

Needham, S., Funge-Smith, S.J., 2014. The Consumption of Fish and Fish Products in the Asia-pacific Region Based on Household Surveys. RAP Publication 2015/12. 87pp. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand.

Norwegian Standard 9402 (Norsk standard), 1994. Atlantic Salmon. Measurement of Fat and Colour, first edition. (Atlantisk laks. Måling av fett og farge. Første utgave).

Ostermeyer, U., Schmidt, T., 2005. Vitamin D and provitamin D in fish. Eur. Food Res. Technol. 222 (3), 403. https://doi.org/10.1007/s00217-005-0086-y.

Reksten, A.M., Bøkevoll, A., Frantzen, S., Lundebye, A.-K., Kögel, T., Aakre, I., Kjellevold, M., 2020. Sampling protocol for the determination of nutrients and contaminants in seafood - the EAF-Nansen Programme. MethodsX (submitted).

Roos, N., Leth, T., Jakobsen, J., Thilsted, S.H., 2002. High vitamin A content in some small indigenous fish species in Bangladesh: perspectives for food-based strategies to reduce vitamin A deficiency. Int. J. Food Sci. Nutr. 53 (5), 425–437. https://doi.org/10.1080/0963748021000044778.

Roos, N., Islam, M.M., Thilsted, S.H., 2003. Small indigenous fish species in Bangladesh: contribution to vitamin A, calcium, and iron intakes. J. Nutr. 133 (11 Suppl. 2), 4021s–4026s. https://doi.org/10.1093/jn/133.11.4021S.

Roos, N., Thorseng, H., Chamnan, C., Larsen, T., Gondolf, U.H., Bukhave, K., Thilsted, S.H., 2007a. Iron content in common Cambodian fish species: perspectives for dietary iron intake in poor, rural households. Food Chem. 104 (3), 1226–1235. https://doi.org/10.1016/j.foodchem.2007.01.038.

Roos, N., Wahab, M.A., Chamnan, C., Thilsted, S.H., 2007b. The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. J. Nutr. 137 (4), 1106–1109. https://doi.org/10.1093/jn/137.4.1106.

Shantz, E.M., Brinkman, J.H., 1950. Biological activity of pure vitamin A2. J. Biol. Chem. 183, 467–471.

Thamilini, J., Silva, K.D.R.R., Sirasa, M.S.F., Samarasinghe, W.L.G., 2019. Food Composition Data in Sri Lanka: Past, Present and Future. Department of Applied Nutrition, Faculty of Livestock, Fisheries and Nutrition, Wayamba University of Sri Lanka, Colombo, Sri Lanka.

Torstensen, B.E., Frøyland, L., Ørnsrud, R., Lie, Ø., 2004. Tailoring of a cardioprotective muscle fatty acid composition of Atlantic salmon (Salmo salar) fed vegetable oils. Food Chem. 87 (4), 567–580.

UNICEF, 2018. Micronutrients. Retrieved from. https://www.unicef.org/nutrition/index_iodine.html.

VKM, 2014. Benefit-risk assessment of fish and fish products in the Norwegian diet - an update. Scientific Opinion of the Scientific Steering Committee. VKM Report 15 [293 pp]. Retrieved from. https://vkm.no/download/18.2994e95b15cc54507161ea1a/1498222018046/0a646edc5e.pdf.

WFP, 2017. Sri Lanka Country Strategic Plan (2018-2022). Retrieved from. https://documents.wfp.org/stellent/groups/public/documents/eb/wfp293168.pdf.

WFP, 2018. Sri Lanka Country Brief (July 2018). Retrieved from. https://docs.wfp.org/api/documents/WFP-0000073780/download/?_ga=2.258986122.1656034917.1540369897-557958096.1540369897.

WHO, 1991. National Strategies for Overcoming Micronutrient Malnutrition. Retrieved from Geneva, Switzerland. .

WHO, FAO, 2004. Vitamin and Mineral Requirements in Human Nutrition. Retrieved from Geneva, Switzerland:. second edition. . https://apps.who.int/iris/bitstream/handle/10665/42716/9241546123.pdf?ua=1.