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Nutrient composition of important fish species in Bangladesh and potential contribution to recommended nutrient intakes

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ABSTRACT

Fish, in Bangladesh where malnutrition remains a significant development challenge, is an irreplaceable animal-source food in the diet of millions. However, existing data on the nutrient composition of fish do not reflect the large diversity available and have focused on only a few select nutrients. The purpose of this study was to fill the gaps in existing data on the nutrient profiles of common fish in Bangladesh by analysing the proximate, vitamin, mineral and fatty acid composition of 55 fish, shrimp and prawn species from inland capture, aquaculture and marine capture fisheries. When comparing species, the composition of nutrients of public health significance was diverse. Iron ranged from 0.34 to 19 mg/100 g, zinc from 0.6 to 4.7 mg/100 g, calcium from 8.6 to 1900 mg/100 g, vitamin A from 0 to 2503 μg/100 g and vitamin B12 from 0.50 to 14 μg/100 g. Several species were rich in essential fatty acids, particularly docosohexaenoic acid in capture fisheries species (86–310 mg/100 g). The potential contribution of each species to recommended nutrient intakes (RNIs) for pregnant and lactating women (PLW) and infants was calculated. Seven species for PLW and six species for infants, all from inland capture, and all typically consumed whole with head and bones, could potentially contribute ≥25% of RNIs for three or more of these nutrients, simultaneously, from a standard portion. This illustrates the diversity in nutrient content of fish species and in particular the rich nutrient composition of small indigenous species, which should guide policy and programmes to improve food and nutrition security in Bangladesh.

1. Introduction

In Bangladesh, fish is an irreplaceable animal-source food in the diet of millions, both in terms of quantity – accounting for approximately 60% of animal protein intake at 18.1 kg consumed per person per year – and frequency of consumption, far exceeding that of any other animal-source food (Belton et al., 2014). The country possesses diverse and abundant aquatic resources with 267 freshwater fish species (Thilsted, 2010), and an annual production of 3.1 million tonnes (Belton and Thilsted, 2014). Bangladesh is also one of many developing countries to experience the proliferation of aquaculture, now the world's fastest growing food production sector, during a period of decline in capture fisheries (Belton and Thilsted, 2014).

While remaining largely successful in increasing supply to meet the demand of a growing population, the extent to which the growth of aquaculture has been able to mitigate reduction in dietary diversity and micronutrient intake from the diverse but waning capture fisheries sector, focusing on only a few select large species, is questionable (Belton et al., 2014). Despite improvement in some food and nutrition security indicators (JPGSPH and HKI, 2012), malnutrition, largely caused by inadequate micronutrient intake, remains widespread with 41% of children under five years suffering from stunted growth (NIPORT et al., 2013). The fisheries and aquaculture sector has been recognised as a key resource in tackling food and nutrition security issues and features prominently in the national development agenda (Government of the Peoples Republic of Bangladesh, 2005a,b, 2006, 2011).

Knowledge of the nutrient composition of important foods is an invaluable tool in understanding the links between food

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production, access and nutrient intakes, and in devising policies and programmes such as development of improved production technologies (Thilsted and Wahab, 2014a), to ensure that food supply optimally fulfils population nutrient requirements. However, despite the clear importance of fish in the Bangladeshi diet, existing composition data do not reflect the large diversity of species available for consumption and have only focused on a few select nutrients rather than comprehensive nutrient profiles. The recently published Food Composition Table for Bangladesh is a useful compilation of existing composition data on important foods (including a number of fish and fish products); however, the data come from a large number of sources including regional databases with varying sampling and analytical methods, some of which are now several decades old (INFS, 2013).

The primary objective of this study was to document comprehensive nutrient composition profiles of important fish, shrimp and prawn species in Bangladesh with a specific focus on small indigenous species (SIS). Species and nutrient components selected for analyses were chosen to 'fill the gaps' in existing data (Roos et al., 2002), using rigorous sampling and analytical methods, as well as to extend the data to include more species diversity. The secondary objective was to estimate the potential contribution of fish, shrimp and prawn species to recommended nutrient intakes (RNIs) during the first 1000 days of life, which means for women throughout pregnancy and lactation, and for infants from age 7 to 23 months. Specific nutrients considered are iron, zinc, calcium, iodine, vitamin A and vitamin B12, which are of known public health concern in Bangladesh (Craviari et al., 2008; Fischer et al., 1999; ICDDRB et al., 2013). Data presented in this paper are the most comprehensive collection on the nutrient composition of important fish, shrimp and prawn species in Bangladesh, both in terms of the number of species and the nutrient components analysed, to date.

2. Materials and methods

2.1. Sampling protocol

The sampling method was constrained by the nature of rural fish markets in this context, largely dependent on the activities of small-scale fishermen whose supply is unpredictable. As a result, single pooled samples of 54 fish, shrimp and prawn species commonly available during the monsoon season, were collected at local markets and fish landing sites in Mymensingh, Sylhet, Khulna and Cox's Bazar districts in Bangladesh as shown in Fig. 1, from July–September 2012. Additionally, one small fish species (*Amblypharyngodon mola*) was sampled both from the market (assumed to be from an inland capture source) and from a homestead pond in Dinajpur district (referred to as Mola$_{(cultured)}$). The number of fish collected for each sample was dependent on the average size of each fish species but was a total of approximately two kilograms for each sample. For small fish species (<500 g per fish), a single pooled sample of up to several hundred individual fish (to make a total sample of approximately two kilograms) was collected, for medium fish (500–750 g per fish), a single pooled sample of four individual fish, and for larger fish (>750 g per fish), a single pooled sample of two individual fish. Samples were packed in polyethylene bags at the collection site and transported in an insulated ice box lined with ice chips and away from direct sunlight, to a nearby laboratory facility.

2.2. Sample preparation

The identification details of each sample including common Bangla name, scientific name, location of sample collection and sample preparation details are shown in Table 1. In this paper,

Fig. 1. Fish sampling locations in Bangladesh.
Adapted from (Center for Intercultural Learning, 2012).

samples are referred to by the common Bangla name and are grouped according to the three dominant fish production sectors: inland capture, inland aquaculture and marine capture fisheries. Samples were cleaned by local fisher-folk to obtain raw, edible parts according to traditional practice. Depending on the fish species, edible parts may or may not include the head, viscera, scales, bones and other parts (Table 1). To avoid contamination of samples, non-metal equipment such as plastic cutting boards, buckets and strainers, and ceramic cutting knives were used to obtain raw edible parts. Fish samples were washed with deionised water after cleaning and before being packed in polyethylene bags and stored in a deep freezer at −18 °C. Frozen samples were transported in an insulated box, lined with dry ice to laboratories in New Zealand and Denmark for nutrient composition analysis. The temperature of fish samples was measured upon receipt at the testing facilities to ensure that the samples had remained frozen during transportation. Fish species were homogenised as per raw edible parts prior to analysis and subsamples of the homogenate were taken, with size appropriate for individual analytical tests (10–100 g). For several species, the homogenate included bones, and for others, bones were removed prior to homogenisation if they are typically discarded as plate waste, as shown in Table 1.

2.3. Analytical methods

The analytical methods for each nutrient component, and corresponding limits of quantitation (LOQ) and reproducibility are summarised in Table 2.

2.3.1. Analyses completed at AsureQuality Limited Laboratory, Auckland, New Zealand

For proximate components (protein, fat, moisture, ash), vitamin B12 and folate, standard analytical methods as per the Association of Official Analytical Chemists (AOAC) were used, as listed in Table 2. Minerals (except iodine and selenium) were analysed

Table 1
Identification details of fish, shrimp and prawn samples and anatomical parts removed prior to analysis.

Common Bangla name	Scientific name	Collection district	Anatomical parts excluded prior to analysis
Inland capture			
Small indigenous fish species (SIS)			
Baim	*Mastacembelus armatus*	Mymensingh	Bones, viscera, fins, skin, dorsal spine, snout
Bele, Bailla	*Glossogobius giuris*	Mymensingh	Viscera, fins, scales
Boro Kholisha	*Colisa fasciata*	Mymensingh	Viscera, fins, scales
Chanda	*Pseudambassis ranga*	Khulna	Viscera, fins
Chapila	*Gudusia chapra*	Mymensingh	Viscera, fins, scales
Chela	*Chela cachius*	Mymensingh	Viscera, fins, scales
Darkina	*Esomus danricus*	Mymensingh	Viscera, scales
Dhela	*Osteobrama cotio cotio*	Mymensingh	Viscera, fins, scales
Ekthute	*Hyporhamphus limbatus*	Khulna	Viscera, fins
Foli	*Notopterus notopterus*	Mymensingh	Bones, viscera, fins, scales, operculum
Golsha	*Mystus cavasius*	Mymensingh	Bones, viscera, fins, barbell
Guchi	*Mastacembelus pancalus*	Mymensingh	Viscera, fins
Gutum	*Lepidocephalichthys guntea*	Mymensingh	Viscera, fins
Jat Punti	*Puntius sophore*	Sylhet	Viscera, fins, scales
Kachki	*Corica soborna*	Mymensingh	No parts removed
Kajuli, Bashpata	*Ailia coila*	Sylhet	Bones, viscera, fins, scales
Kakila	*Xenontedon cancila*	Mymensingh	Bones, viscera, fins, snout
Koi	*Anabas testudineus*	Mymensingh	Bones, viscera, fins, scales, gills
Kuli, Bhut Bailla	*Eleotris fusca*	Khulna	Viscera, fins, scales
Magur	*Clarias batrachus*	Mymensingh	Bones, viscera, gills, barbell
Meni	*Nandus nandus*	Mymensingh	Viscera, fins, scales, gills, operculum
Modhu Pabda	*Ompok pabda*	Mymensingh	Bones, fins, viscera
Mola	*Amblypharyngodon mola*	Mymensingh	Viscera, fins, scales
Mola (cultured)[a]	*Amblypharyngodon mola*	Dinajpur	Viscera, fins, scales
Rani, Bou	*Botia dario*	Sylhet	Viscera, fins
Shing	*Heteropneustes fossilis*	Mymensingh	Bones, viscera, barbell, gills
Taki	*Channa punctatus*	Mymensingh	Bones, viscera, fins, scales
Tara Baim	*Macrognathus aculeatus*	Mymensingh	Viscera
Tengra	*Mystus vittatus*	Mymensingh	Viscera, barbel
Tit Punti	*Puntius ticto*	Mymensingh	Viscera, fins, scales
Large fish species			
Gojar	*Channa marulius*	Sylhet	Bones, viscera, fins, scales, gills
Ilish	*Tenualosa ilisha*	Khulna	Bones, viscera, fins, scales
Jatka Ilish	*Tenualosa ilisha (juvenile)*	Sylhet	Bones, viscera, fins, scales
Shol	*Channa striatus*	Sylhet	Bones, viscera, scales, gills, fins
Shrimp/prawn			
Harina Chingri	*Metapenaeus monoceros*	Khulna	Viscera, shell, legs, tail
Najari Icha	*Macrobrachium malcolmsonii*	Mymensingh	Viscera, shell, legs, tail
Inland aquaculture			
Indigenous major carps			
Catla	*Catla catla*	Mymensingh	Bones, viscera, fins, scales, gills
Mrigal	*Cirrhinus mrigala*	Mymensingh	Bones, viscera, fins, scales, gills
Rui	*Labeo rohita*	Mymensingh	Bones, viscera, scales, fins, gills, snout, operculum
Introduced fish species			
Common Carp	*Cyprinus carpio*	Khulna	Bones, viscera, fins, scales, gills, operculum
Grass Carp	*Ctenopharyngodon idella*	Mymensingh	Bones, viscera, fins, scales, gills, operculum
Silver Carp	*Hypophthalmichthys molitrix*	Mymensingh	Bones, viscera, gills, fins, operculum
Thai Pangas	*Pangasianodon hypophthalmus*	Mymensingh	Bones, viscera, gills, fins, operculum
Majhari Thai Pangas	*Pangasianodon hypophthalmus (juvenile)*	Sylhet	Bones, viscera, fins, barbel
Thai Sarpunti	*Barbonymus gonionotus*	Mymensingh	Bones, viscera, fins, scales, gills, operculum
Tilapia	*Oreochromis niloticus*	Mymensingh	Bones, viscera, fins, scales, gills
Majhari Tilapia	*Oreochromis niloticus (juvenile)*	Mymensingh	Bones, viscera, fins, scales, gills
Marine capture			
Foli Chanda	*Pampus argenteus*	Khulna	Bones, viscera, fins
Kata Phasa	*Stolephorus tri*	Cox's Bazar	Viscera
Lal poa	*Johnius argentatus*	Cox's Bazar	Viscera, fins, scales
Maita	*Scomberomorus guttatus*	Cox's Bazar	Bones, viscera, fins, scales
Murbaila	*Platycephalus indicus*	Cox's Bazar	Bones, viscera, fins, scales
Parse	*Liza parsia*	Khulna	Bones, viscera, fins, scales, gills
Tailla	*Eleutheronema tetradactylum*	Cox's Bazar	Bones, viscera, fins, scales
Tular Dandi	*Sillaginopsis panijus*	Cox's Bazar	Bones, viscera, fins, scales

[a] Mola is a SIS typically sourced from inland capture fisheries; however, Mola is now included in homestead pond polyculture with carps (Thilsted and Wahab, 2014c).

using the inductively coupled plasma optical emission spectrometry (ICP-OES) method (APA et al., 2012). Iodine and selenium were analysed using the inductively coupled plasma mass spectrometry (ICP-MS) method (APA et al., 2012). Vitamin D and E were analysed using high performance liquid chromatography (HPLC) (Brubacher et al., 1985). Fatty acid composition was analysed using gas liquid chromatography (GLC) (Bannon et al., 1985).

2.3.2. Analyses completed at the National Food Institute, DTU, Denmark

Analyses of vitamin A, B12, D, E and folate in 29 species were carried out in Denmark where all tests were conducted in accordance with standard ISO17025 of the International Organization for Standardization, as summarised in Table 2 (ISO, 2005). Vitamin A, D and E were analysed using HPLC. Quantification of

Table 2
Analytical methods used for nutrient composition analysis of fish, shrimp and prawn samples.

Analyte	Units	Method reference[a]	LOQ[b]	Reproducibility
Analyses conducted at AsureQuality, New Zealand				
Proximate components				
Protein	g/100 g	Block digestion (AOAC 981.10)	0.1	$0.2\sqrt{\text{Result}}$
Fat (total)	g/100 g	Acid hydrolysis (AOAC 948.15)	0.1	0.5%
Moisture	g/100 g	Air drying (AOAC 950.46)	0.1	0.8%
Ash	g/100 g	Direct method (AOAC 920.153)	0.1	0.8%
Minerals				
Iron	mg/kg	Acid Digest, ICP OES (APA et al., 2012)	0.62	7%
Zinc	mg/kg	Acid digest, ICP OES (APA et al., 2012)	1.5	7%
Calcium	mg/kg	Acid Digest, ICP OES (APA et al., 2012)	2.8	8%
Iodine	μg/kg	TMAH Digestion, ICP MS (APA et al., 2012)	0.02	10%
Selenium	mg/kg	TMAH Digestion, ICP MS (APA et al., 2012)	0.02	7%
Phosphorus	mg/kg	Acid Digest, ICP OES (APA et al., 2012)	3.3	8%
Magnesium	mg/kg	Acid digest, ICP OES (APA et al., 2012)	0.74	7%
Sodium	mg/kg	Acid Digest, ICP OES (APA et al., 2012)	2.7	8%
Potassium	mg/kg	Acid Digest, ICP OES (APA et al., 2012)	3.3	8%
Manganese	mg/kg	Acid digest, ICP OES (APA et al., 2012)	0.05	7%
Sulphur	mg/100 g	Acid digest, ICP OES (APA et al., 2012)	0.02	7%
Copper	mg/kg	Acid digest, ICP OES (APA et al., 2012)	0.1	8%
Chromium	mg/kg	Wet Oxidation, ICP MS (APA et al., 2012)	0.05	10%
Vitamins				
Vitamin B12	μg/100 g	Surface plasmon resonance (AOAC 2011.16)	0.2	12%
Vitamin D3	IU/100 g	HPLC (Brubacher et al., 1985)	20	16%
Vitamin D2	IU/100 g	HPLC (Brubacher et al., 1985)	20	16%
Vitamin E (α-tocopherol)	IU/100 g	HPLC (Brubacher et al., 1985)	0.11	10%
Vitamin E, γ, δ tocopherols)	IU/100 g	HPLC (Brubacher et al., 1985)	0.01	10%
Folate	μg/100 g	Optical biosensor assay (AOAC 2011.05)	8	12%
Fatty Acids	mg/100 g	GLC (Bannon et al., 1985)	10	12%
Analyses conducted at National Food Institute, DTU, Denmark				
Vitamins				
Vitamin A (all components)	μg/100 g	HPLC (Roos et al., 2007a)	10	19%[c]
Vitamin B12	μg/100 g	Microbiological assay (Nord, 1960)	0.03	13%[c]
Vitamin D3	μg/100 g	HPLC (CEN, 2009)	0.05	10%[c]
25OHD3	μg/100 g	HPLC (CEN, 2009)	0.1	–[d]
Vitamin E (α-tocopherol)	mg/100 g	HPLC (CEN, 2000)	0.02	9.9%[c]
Folate	μg/100 g	Microbiological assay (CEN, 2003)	0.2	18%[c]

[a] AOAC, Association of Official Analytical Chemists, http://www.aoac.org; ICP OES, inductively coupled plasma optical emission spectrometry; TMAH, Tetramethylammonium hydroxide; ICP MS, inductively coupled plasma mass spectrometry; HPLC, high performance liquid chromatography; GLC, gas liquid chromatography.
[b] LOQ, limit of quantitation.
[c] Values are based on analyses of fish samples in this data set.
[d] Not applicable as no result returned a detectable quantity.

vitamin A activity included all-*trans*-retinol, 13-*cis*-retinol, all-*trans*-3,4-dehydroretinol and 13-*cis*-3,4-dehydroretinol. Dehydroretinol is expected to demonstrate 40% of the biological activity of retinol (Shantz and Brinkman, 1950) and possibly up to 110% (Riabroy and Anumihardjo, 2011). For vitamin D, the CEN-method was modified to include quantitation of 25-hydroxy vitamin D3 (Jakobsen et al., 2007). Vitamin B12 was determined by microbiological assay using *Lactobacillus delbrueckii* as the test organism (Nord, 1960), and folate was determined using *Lactobacillus casei* as the test organism (CEN, 2003).

2.4. Presentation of results

All proximate components and minerals were analysed in duplicate and presented here as the mean, reported to the same number of significant figures as per original analytical results. For some samples a result of 'none detected' is given when a quantifiable result was found for one replicate but the corresponding duplicate returned a result below the LOQ. All minerals (except sulphur) were reported in metric units per kg of raw, edible parts but are presented here as metric units per 100 g raw, edible parts for ease of use. Energy was calculated using Atwater factors from assayed proximate components (Merill and Watt, 1973). Due to resource limitations, vitamins and fatty acids were analysed singly and presented here as per analytical results. Vitamin A components are presented as μg/100 g of 13-*cis*-retinol, 13-*cis*-3,4-dehydroretinol, all-*trans*-retinol, all-*trans*-3,4-dehydroretinol and β-carotene and then total vitamin A in retinol activity equivalents (μg RAE/100 g) has been calculated according to the following conversion factors: 1 μg all-*trans*-retinol = 1 μg RAE, 1 μg 13-*cis*-retinol = 0.75 μg RAE (Ames et al., 1955), 1 μg all-*trans*-3,4-dehydroretinol = 0.4 μg RAE, 1 μg 13-*cis*-3,4-dehydroretinol = 0.4 μg RAE (Shantz and Brinkman, 1950), 1 μg β-carotene = 0.08 μg RAE (Ottin et al., 2006). Species analysed for vitamin D and E at *AsureQuality* were reported in International Units per 100 g of raw edible parts (IU/100 g) and were converted to *International System of Units* (SI) units (μg/100 g) using the following conversion factors: vitamin D2 (μg/100 g) = vitamin D2 (IU/100 g) × 0.025, vitamin D3 (μg/100 g) = vitamin D3 (IU/100 g) × 0.025 and vitamin $E_{(tocopherol)}$ (mg/100 g) = vitamin $E_{(tocopherol)}$ (IU/100 g) × 0.67 (FAO/INFOODS, 2012). Fatty acid components are presented here as per analytical results and total n-6 polyunsaturated fatty acids (PUFA) and n-3 PUFA were calculated from the fatty acid profile. All results are presented as per 100 g raw, edible parts. The composition of nutrients of public health significance, vitamins and fatty acids, in relation to RNI's have been discussed in the results section.

2.4.1. Previously published data on nutrient composition of fish species

Data on the mineral content of 13 species and vitamin A content of 20 species had previously been published using similar sampling methods and therefore these analyses were not repeated but have been included in the presentation of results here for completeness. In this pre-existing data, minerals (except selenium) were analysed by atomic absorption spectrometry (AAS), selenium was analysed using inductively coupled plasma atomic emission spectrometry (ICP-AES), and vitamin A was analysed using HPLC (Roos, 2001). Due to slight differences in methodology for mineral analysis in previous data and newly presented data, care should be taken in making comparisons across species.

2.4.2. Statistical analyses of results

Descriptive statistics of the data are presented including the range and mean, rounded to the same number of significant figures as original analytical results. Pearson's correlation coefficients were calculated using STATA (version 12.1, StataCorp, College Station, TX, USA), to describe the linear dependence of fat, moisture and energy for all 55 species; and ash and various minerals for 41 species for which all mineral compositions were analysed.

2.5. Calculation of potential contribution to recommended nutrient intakes

The potential contribution of each species to RNIs of nutrients of interest during the first 1000 days was calculated first by assigning an average RNI target for each nutrient as shown in Table 5, for pregnant and lactating women (PLW) to account for variations in requirements throughout the three trimesters of pregnancy and first 12 months of lactation, and for infants to account for variations in requirements throughout the period from age 7 to 23 months (FAO/WHO, 2004); then by calculating the contribution from a standard portion of each species (50 g/day for PLW and 25 g/day for infants) as a percentage of the average RNI. The nutrients of interest considered here are iron, zinc, calcium, iodine, vitamin A and vitamin B12. The RNIs for iron and zinc further vary according to estimated overall dietary bioavailability which is dependent on a number of factors including the presence of animal-flesh foods, phytates and other factors; and are therefore provided according to four and three dietary bioavailability categories, respectively. The typical Bangladeshi diet based on polished rice, fish and vegetables is assumed to fit best with criteria used to define the '10% bioavailability' category for iron, and 'moderate bioavailability' category for zinc (FAO and WHO, 2004).

3. Results and discussion

3.1. Proximate composition

The energy, protein, fat, moisture and ash composition of all 55 species are shown in Table 3. The total energy content varied greatly with a range of 267–1020 kJ/100 g which is related to variation in fat content in the different species, as evidenced by a correlation coefficient of 0.98. The total protein content in fish species ranged from 11.9 to 20.6 g/100 g and can be assumed to be of high dietary quality, being an animal-source protein (WHO, 2007). The fat content ranged from 0.3 to 18.3 g/100 g. Fat generally varies much more widely than other proximate components of fish, and usually reflects differences in the way fat is stored in particular species but may also be affected by seasonal/lifecycle variations and the diet/food availability of the species at the time of sampling (Ababouch, 2005). For example, bottom dwelling species such as the indigenous major carps are

Table 3
Energy, protein, fat, moisture and ash content of fish, shrimp and prawn species.[a]

	Nutrient content per 100 g raw edible parts				
	Energy kJ	Protein g	Fat g	Moisture g	Ash g
Inland capture					
Small indigenous fish species (SIS)					
Baim	381	17.9	1.7	78.6	1.0
Bele, Bailla	292	16.6	0.4	80.3	3.1
Boro Kholisha	354	15.2	2.5	77.0	5.2
Chanda	400	15.5	3.8	76.2	4.7
Chapila	385	15.5	3.8	78.4	3.4
Chela	349	15.2	2.4	79.4	2.9
Darkina	384	15.5	3.2	77.1	4.2
Dhela	387	14.7	3.8	78.1	3.7
Ekthute	360	17.9	1.7	76.7	4.1
Foli	384	20.5	0.6	76.7	1.4
Golsha	479	16.8	5.1	76.8	1.0
Guchi	394	17.9	2.6	77.7	2.2
Gutum	431	17.2	3.9	76.7	2.6
Jat Punti	541	15.7	7.2	73.2	3.5
Kachki	267	11.9	1.9	85.4	1.7
Kajuli, Bashpata	751	17.1	12.6	70.0	0.7
Kakila	329	17.1	1.2	80.2	1.8
Koi	737	15.5	12.8	70.5	1.0
Kuli, Bhut Bailla	330	16.9	1.2	78.9	3.1
Magur	326	16.5	1.3	81.3	1.1
Meni, Bheda	338	16.7	1.7	78.5	3.6
Modhu Pabda	619	16.2	9.5	73.9	0.9
Mola	445	17.3	4.5	75.6	3.5
Mola (cultured)	412	14.7	4.6	77.3	4.0
Rani, Bou	654	14.9	10.6	70.8	3.2
Shing	374	19.1	1.9	79.2	1.0
Taki	306	18.3	0.6	80.7	2.1
Tara Baim	387	17.2	2.6	79.4	2.3
Tengra	428	15.1	4.6	76.6	3.7
Tit Punti	385	15.4	3.4	77.5	3.8
Large fish species					
Gojar	286	17.1	0.3	82.6	1.0
Ilish	1020	16.4	18.3	60.2	1.4
Jatka Ilish	618	19.0	7.7	71.8	2.5
Shol	310	18.7	0.3	81.0	1.2
Shrimp/prawn					
Harina Chingri	333	17.6	1.0	79.5	2.2
Najari Icha	364	15.7	2.2	77.9	3.3
Inland aquaculture					
Indigenous major carps					
Catla	267	14.9	0.7	84.1	1.0
Mrigal	363	18.9	1.1	78.9	1.1
Rui	422	18.2	3.0	77.7	1.0
Introduced fish species					
Common Carp	381	16.4	2.9	80.0	1.0
Grass Carp	341	15.2	1.1	80.2	1.1
Silver Carp	435	17.2	4.1	77.8	1.5
Thai Pangas	925	16.0	17.7	65.5	0.9
Majhari Thai Pangas	360	18.6	1.4	79.2	1.4
Thai Sharpunti	466	18.4	4.4	76.2	1.6
Tilapia	390	19.5	2.0	77.6	1.8
Majhari Tilapia	412	19.0	2.6	77.5	1.3
Marine capture					
Foli Chanda	320	17.2	0.9	82.1	0.7
Kata Phasa	357	17.6	2.1	77.4	4.1
Lal Poa	381	18.1	2.4	75.2	5.3
Maita	405	20.5	1.1	76.5	1.0
Murbaila	310	18.8	0.3	80.6	1.6
Parse	813	16.1	14.3	67.8	1.2
Tailla	425	20.6	2.2	76.5	1.1
Tular Dandi	345	19.3	0.6	78.8	1.6

[a] All data are newly reported values.
$n = 1$ pooled sample.

typically lean fish, storing fat in the liver (Ababouch, 2005), whereas, migratory fish such as Ilish have a higher content of dark muscle which tends to be rich in fat (Alam et al., 2012). The moisture content of fish species ranged from 60.2 to 85.4 g/100 g and, as expected was negatively correlated with fat and energy content (correlation coefficient of −0.91 and −0.95 respectively). Ash content ranged from 0.7 to 5.3 g/100 g and is positively correlated with mineral content, particularly calcium, phosphorus, magnesium and zinc, with correlation coefficients of 0.98, 0.95, 0.85, and 0.74 respectively. The large variation in ash content is likely related to inclusion of bones as edible parts in some species, which would lead to higher ash content in these.

3.2. Mineral composition

The iron, zinc, calcium, iodine, selenium, phosphorus, magnesium, sodium, potassium, manganese, sulphur and copper composition for all species are shown in Table 4.

3.2.1. Iron

Iron content varied considerably with a range from 0.34 to 19 mg/100 g and a mean value of 2.6 mg/100 g. Three species of fish and one species of prawn were identified that would meet ≥25% of the RNI for PLW and infants: Chapila, Darkina, Mola and Najari Icha (Table 5). These results show a greater range in iron content compared to a values reported in the global FAO/INFOODS database on fish and shellfish (excluding molluscs) (FAO/INFOODS, 2013). Of interest is that iron content of cultured Mola (19 mg/100 g) is much higher than previously reported values for capture Mola (5.7 mg/100 g). This may be partly attributable to sampling variability, methodological differences in analysis of iron content, or may reflect real differences in the accumulation of iron in this species based on differing environmental conditions. The true nature and magnitude of these differences should be further investigated. Overall, the data presented here indicate that several species (all from inland capture fisheries) may contribute significantly to dietary iron intakes in Bangladesh which is of high bioavailability as an animal-source food (FAO and WHO, 2004). This may have important policy implications given the public health significance of iron deficiency in Bangladesh, with prevalence recently estimated at 10.7% in preschool aged children and 7.1% in adult women (ICDDRB et al., 2013), and the well documented negative effects of deficiency on physical and cognitive development, pregnancy outcomes, morbidity and mortality.

3.2.2. Zinc

Zinc concentration varied considerably from 0.6 to 4.7 mg/100 g with a mean content of 1.9 mg/100 g. These results are within the range of fish and seafood reported elsewhere (FAO/INFOODS, 2013). Four species were identified that would meet ≥25% of the RNI for PLW; Chela, Darkina, cultured Mola and Rani, and two species: Chela and cultured Mola, which would meet ≥25% of the RNI for infants, from a standard portion (Table 5). A further seven species of fish and one species of prawn (all of which are capture species) would meet 20–25% of RNIs for PLW (Dhela, Ekthute, Kachki, Kata Phasa, Mola, Najari Icha, Tengra, and Tit Punti) and a further six species of fish and one species of prawn would meet 20–25% of RNIs for infants (Darkina, Dhela, Ekthute, Mola, Najari Icha, Rani and Tit Punti). In light of recent estimates of a national prevalence of zinc deficiency in 57.3% of women and 44.6% of pre-school aged children in Bangladesh (ICDDRB et al., 2013), several SIS and prawn species could contribute significantly to dietary zinc intake, also taking into consideration that zinc in animal-source foods is highly bioavailable (FAO and WHO, 2004).

3.2.3. Calcium

Calcium content ranged considerably from 8.6 to 1900 mg/100 g with a mean content of 600 mg/100 g. These results are within the range of fish and seafood reported elsewhere (FAO/INFOODS, 2013). As would be expected, calcium content was much higher in species in which bones are commonly consumed and included in the edible parts. Fourteen species were identified that would meet ≥50% of the RNI for PLW, and 18 species that would meet ≥50% of the RNI for infants (Table 5). Calcium deficiency nationally has not been evaluated, however, it has been implicated in the development of rickets, estimated to affect 550,000 children in 2008 (Craviari et al., 2008; Fischer et al., 1999; ICDDRB, 2009), and in a study in two rural subdistricts of Bangladesh, it was estimated no women or young children had diets adequate in calcium, attributable to low food intake and low dietary diversity (Arsenault et al., 2013). In developed countries, dairy products tend to be the primary source of dietary calcium; however, this is not the case in Bangladesh where frequency of dairy consumption is very low (Belton et al., 2014; JPGSPH and HKI, 2012). The data presented here further support the conclusion that in Bangladesh, SIS eaten whole, with bones are a significant source of highly bioavailable dietary calcium (Larsen et al., 2000; Roos et al., 2007a,b).

3.2.4. Iodine

Iodine was below detectable limits in eight of the 55 species, and ranged up to 120 μg/100 g, with a mean of 22 μg/100 g. Only one species of prawn (Najari Icha) would contribute to ≥25% of the RNI, and one species of fish (Darkina) would contribute ≥20% of the RNI, for PLW and infants (Table 5). The iodine content of foods tends to be largely dependent on environmental conditions. Marine fish and seafood tend to be rich dietary sources with a mean composition of 83 μg/100 g in marine fish reported elsewhere (FAO/WHO, 2004); however, this was not particularly evident in the marine species analysed here, with a range of only 6.9–41 μg/100 g. This is the first study in which the iodine content of fish, shrimp and prawn in Bangladesh was analysed. The composition of iodine in inland capture species reported here was within the range of fish and seafood reported elsewhere (FAO/INFOODS, 2013), but most species are unlikely to be a significant source of dietary iodine.

3.2.5. Selenium, phosphorus, magnesium, sodium, potassium, manganese, sulphur, copper and chromium

The contents of these minerals were analysed for data completeness but they are not associated with significant public health concerns currently, and therefore, their nutritional significance is not discussed here. Selenium content of foods varies significantly according to surrounding environmental conditions. The selenium content in species analysed here showed a wide range from 5 to 110 μg/100 g, consistent with data reported elsewhere (FAO/INFOODS, 2013). Phosphorus content ranged from 110 to 1000 mg/100 g, with higher composition in fish species with bones included in edible parts, also consistent with values reported elsewhere (FAO/INFOODS, 2013). The ranges of magnesium (21–57 mg/100 g), sodium (26–110 mg/100 g) and potassium (58–350 mg/100 g) content were broadly consistent with ranges for other fish and seafood reported elsewhere (FAO/INFOODS, 2013). Manganese content ranged from 0.010 to 2.8 mg/100 g and is higher than results reported elsewhere (FAO/INFOODS, 2013), which may be related to water pollution (Törnqvist et al., 2011). Sulphur content ranged from 160 to 300 mg/100 g and is higher than results reported in the FAO/INFOODS global database, although consistent with results reported elsewhere in the literature (Vlieg et al., 1991). Copper content ranged from 0 to 1.2 mg/100 g with highest values found in shrimp and prawn, far

Table 4
Mineral composition of fish, shrimp and prawn species.

	Nutrient content per 100 g raw edible parts											
	Iron	Zinc	Calcium	Iodine	Selenium	Phosphorus	Magnesium	Sodium	Potassium	Manganese	Sulphur	Copper
	mg	mg	mg	µg	µg	mg	mg	mg	mg	mg	mg	mg
Inland capture												
Small indigenous fish species (SIS)												
Baim	1.9[a]	1.1[a]	449[a]	13	12[a]	–	35[a]	47[a]	322[a]	–	–	–
Bele, Bailla	2.3	2.1	790	25	31	520	38	56	210	2.3	200	0.030
Boro Kholisha	4.1	2.3	1700	20	26	910	44	61	210	2.0	190	0.046
Chanda	2.1[a]	2.6[a]	1153[a]	24	22[a]	–	45[a]	61[a]	206[a]	–	–	–
Chapila	7.6[a]	2.1[a]	1063[a]	13	13.4[a]	–	41[a]	57[a]	281[a]	–	–	–
Chela	0.84	4.7	1000	19	32	590	39	28	85	0.60	170	0.052
Darkina	12[a]	4.0[a]	891[a]	81	12[a]	–	38[a]	110[a]	200[a]	–	–	–
Dhela	1.8	3.7	1200	9.5	29	660	39	37	110	0.60	170	0.046
Ekthute	1.5	3.6	1300	11	28	770	51	52	140	0.73	240	0.030
Foli	1.7	1.6	230	nd	22	270	34	53	280	0.078	260	0.058
Golsha	1.8	1.3	120	13	41	180	26	33	210	0.22	220	0.039
Guchi	2.7[a]	1.3[a]	491[a]	19	45[a]	–	34[a]	52[a]	294[a]	–	–	–
Gutum	3.3	2.5	950	16	36	650	57	45	240	0.46	190	0.054
Jat Punti	2.2[a]	2.9[a]	1042[a]	20	9.5[a]	–	39[a]	53[a]	203[a]	–	–	–
Kachki	2.8[a]	3.1[a]	476[a]	6.0	7.5[a]	–	26[a]	38[a]	134[a]	–	–	–
Kajuli, Bashpata	0.82	1.2	110	7.1	27	140	22	26	130	0.17	200	0.059
Kakila	0.65	1.9	610	37	29	450	35	49	190	0.47	240	0.046
Koi	0.87	0.60	85	nd	19	160	21	31	260	0.052	190	0.052
Kuli, Bhut Bailla	0.79	2.0	980	31	49	580	39	55	190	0.29	210	0.030
Magur	1.2	0.74	59	22	22	210	26	61	350	0.021	180	0.050
Meni, Bheda	0.84	1.6	1300	13	29	810	44	68	250	1.4	210	0.029
Modhu Pabda	0.46	0.90	91	7.0	27	150	23	47	230	0.073	190	0.042
Mola	5.7[a]	3.2[a]	853[a]	17	5[a]	–	35[a]	39[a]	152[a]	–	–	–
Mola (cultured)	19	4.2	1400	33	19	700	49	31	58	1.9	160	0.047
Rani, Bou	2.5	4.0	1300	25	31	820	45	48	160	1.5	170	0.094
Shing	2.2	1.1	60	nd	31	220	37	54	300	0.038	230	0.057
Taki	1.8[a]	1.5[a]	766[a]	18	15[a]	–	35[a]	47[a]	260[a]	–	–	–
Tara Baim	2.5[a]	1.2[a]	457[a]	13	15[a]	–	34[a]	46[a]	290[a]	–	–	–
Tengra	4.0[a]	3.1[a]	1093[a]	28	24[a]	–	36[a]	57[a]	203[a]	–	–	–
Tit Punti	3.4[a]	3.8[a]	1480[a]	19	10[a]	–	47[a]	61[a]	187[a]	–	–	–
Large fish species												
Gojar	0.43	0.60	9.3	14	37	150	23	30	300	0.018	230	0.015
Ilish	1.9	1.2	220	37	40	300	27	44	280	0.25	210	0.12
Jatka Ilish	2.5	1.8	500	34	41	430	32	58	280	0.40	250	0.12
Shol	0.41	0.73	96	nd	42	210	27	42	350	0.10	260	0.017
Shrimp/prawn												
Harina Chingri	2.7	1.3	550	26	42	290	45	85	210	0.57	190	0.49
Najari Icha	13	3.3	1200	120	34	320	52	75	200	2.8	190	1.2
Inland aquaculture												
Indigenous major carps												
Catla	0.83	1.1	210	18	27	260	28	74	310	0.070	170	0.029
Mrigal	2.5[a]	1.5[a]	960[a]	15	19[a]	–	39[a]	71[a]	266[a]	–	–	–
Rui	0.98	1.0	51	20	29	210	28	61	330	0.051	200	0.038
Introduced fish species												
Common Carp	1.1	2.2	37	13	22	180	26	67	300	0.020	190	0.033
Grass Carp	0.46	0.91	54	nd	31	190	27	73	300	0.018	170	0.034
Silver Carp	4.4[a]	1.4[a]	903[a]	nd	12[a]	–	34[a]	96[a]	225[a]	–	–	–
Thai Pangas	0.69	0.65	8.6	nd	19	150	21	47	250	0.010	220	0.023
Majhari Thai Pangas	2.7	1.1	59	17	11	160	21	81	260	0.092	170	0.086
Thai Sharpunti	1.6	1.8	270	38	22	280	29	72	240	0.073	250	0.036
Tilapia	1.1	1.2	95	11	26	190	26	81	280	0.052	240	0.031
Majhari Tilapia	1.6	1.4	120	nd	52	220	26	52	320	0.13	270	0.041
Marine capture												
Foli Chanda	0.34	0.66	31	9.4	78	110	21	55	160	0.024	190	nd
Kata Phasa	1.6	3.1	1500	10	56	840	55	92	130	0.38	220	0.023
Lal Poa	1.7	2.1	1900	41	110	1000	54	110	150	0.60	230	0.042
Maita	0.49	0.70	34	14	57	200	31	49	290	0.051	250	0.040
Murbaila	1.7	0.79	150	19	51	230	29	90	330	0.012	250	0.033
Parse	1.3	0.84	66	6.9	20	160	23	53	270	0.036	220	0.032
Tailla	0.60	0.90	37	26	46	200	30	74	330	0.010	300	0.051
Tular Dandi	2.1	0.89	230	20	52	250	30	100	240	0.14	260	0.036

[a] Data previously published by Roos (2001).
–, no data available.
nd, not detected. Limit of detection for iodine: 0.01 µg/kg (equivalent to 0.001 µg/100 g).
$n = 1$ pooled sample.

Table 5
Potential contribution of fish, shrimp and prawn species in a standard portion[a], to average daily RNI[b,c] (%) for PLW[d] and infants (7–23 months).

	Iron (mg)		Zinc (mg)		Calcium (mg)		Iodine (µg)		Vitamin A (µg RAE)[e]		Vitamin B12 (µg)	
	PLW	Infant	PLW	Infant	PLW	Infant	PLW	Infant	PLW	Infant	PLW	Infant
Average daily RNI	15	7	7.9	4.1	1040	467	200	90	829	400	2.7	0.8
Inland capture												
Small indigenous fish species (SIS)												
Baim	6	7	7	7	22	24	3	4	2	2	32	54
Bele, Bailla	8	8	13	13	38	42	6	7	1	1	39	66
Boro Kholisha	14	15	15	14	82	91	5	6	3	3	103	173
Chanda	7	8	16	16	55	62	6	7	20	21	119	200
Chapila[f]	25	27	13	13	51	57	3	4	4	5	129	218
Chela[f]	3	3	30	29	48	54	5	5	8	8	104	176
Darkina[f]	40	43	25	24	43	48	20	22	40	41	231	391
Dhela[f]	6	6	23	23	58	64	2	3	55	57	87	147
Ekthute	5	5	22	22	63	70	3	3	6	6	56	94
Foli	6	6	10	10	11	12	0	0	-	-	37	63
Golsha	6	6	8	8	6	6	3	4	-	-	-	-
Guchi	9	10	8	8	24	26	5	5	5	5	46	77
Gutum	11	12	16	15	46	51	4	4	5	5	162	273
Jat Punti	7	8	18	18	50	56	5	5	3	3	74	125
Kachki	9	10	20	19	23	25	2	2	5	5	66	111
Kajuli, Bashpata	3	3	8	7	5	6	2	2	1	1	76	128
Kakila	2	2	12	11	29	33	9	10	6	6	54	90
Koi	3	3	4	4	4	5	0	0	18	18	44	74
Kuli, Bhut Bailla	3	3	13	12	47	52	8	8	2	2	26	44
Magur	4	4	5	4	3	3	5	6	1	2	89	151
Meni, Bheda	3	3	10	10	63	70	3	3	4	4	17	28
Modhu Pabda	2	2	6	5	4	5	2	2	-	-	-	-
Mola[f]	19	20	20	20	41	46	4	5	151	156	148	249
Mola (cultured)[f]	63	68	26	25	67	75	8	9	134	139	109	184
Rani, Bou[f]	8	9	25	24	63	70	6	7	1	2	119	200
Shing	7	8	7	7	3	3	0	0	2	2	236	398
Taki	6	6	9	9	37	41	4	5	8	9	29	48
Tara Baim	8	9	8	7	22	24	3	3	5	5	96	162
Tengra	13	14	20	19	53	59	7	8	1	1	65	109
Tit Punti	11	12	24	23	71	79	5	5	1	1	125	210
Large fish species												
Gojar	1	2	4	4	0	0	3	4	-	-	10	17
Ilish	6	7	7	7	11	12	9	10	1	1	43	72
Jatka Ilish	8	9	11	11	24	27	8	9	1	1	37	63
Shol	1	1	5	4	5	5	0	0	-	-	22	38
Shrimp/prawn												
Harina Chingri	9	9	8	8	26	29	6	7	-	-	26	44
Najari Icha[f]	42	45	21	20	58	64	30	33	0	0	0	0
Inland aquaculture												
Indigenous major carps												
Catla	3	3	7	7	10	11	4	5	1	1	24	41
Mrigal	8	9	9	9	46	51	4	4	1	1	103	174
Rui	3	4	6	6	2	3	5	6	1	1	93	158
Introduced fish species												
Common Carp	4	4	14	13	2	2	3	3	-	-	-	-
Grass Carp	2	2	6	6	3	3	0	0	-	-	-	-
Silver Carp	15	16	9	9	43	48	0	0	-	-	10	17
Thai Pangas	2	2	4	4	0	0	0	0	2	2	28	47
Majhari Thai Pangas	9	9	7	6	3	3	4	5	1	1	259	438
Thai Sharpunti	5	6	11	11	13	14	10	11	1	1	41	69
Tilapia	4	4	7	7	5	5	3	3	1	1	13	22
Majhari Tilapia	5	6	9	9	6	6	0	0	1	1	46	78
Marine capture												
Foli Chanda	1	1	4	4	1	2	2	3	-	-	28	47
Kata Phasa	5	6	20	19	72	80	3	3	-	-	24	41
Lal Poa	6	6	13	13	91	102	10	11	-	-	37	63
Maita	2	2	4	4	2	2	4	4	-	-	30	50
Murbaila	6	6	5	5	7	8	5	5	-	-	9	16
Parse	4	5	5	5	3	4	2	2	-	-	0	0
Tailla	2	2	6	5	2	2	7	7	-	-	16	27
Tular Dandi	7	8	6	5	11	12	5	5	1	1	31	53

[a] Standard portion is assumed to be 50 g/day for PLW and 25 g/day for infants.
[b] RNI, recommended nutrient intake.
[c] See section 2.5 for explanation of calculation of average daily RNI.
[d] PLW, pregnant and lactating women.
[e] µg RAE, retinol activity equivalent.
–, nutrient composition not analysed, therefore unknown contribution to RNI.
[f] Shaded species are those that could potentially contribute to ≥25% of daily RNIs for PLW and/or infants for 3 or more nutrients of public health significance, if provided in a 50 g or 25 g serve, respectively.

exceeding that in fish species, with 0.49 and 1.2 mg/100 g found in Harina Chingri and Najari Icha, respectively; although largely consistent with results reported for fish and seafood elsewhere (FAO/INFOODS, 2013). Chromium was undetectable in almost all species, with the exception of cultured Mola and Najari Icha which had very low concentrations of 0.027 and 0.022 mg/100 g, respectively, also consistent with data reported elsewhere (FAO/INFOODS, 2013).

3.3. Vitamin composition

The vitamin A, B12, D, E and folate composition of fish and shrimp species is shown in Table 6.

3.3.1. Vitamin A

In addition to vitamin A content of 20 species originally presented by Roos (2001), data on a further 28 species (and cultured Mola) are presented in Table 6. Total vitamin A was undetected in 11 species and ranged up to 2503 μg RAE/100 g. As expected, cultured Mola fish had significant concentrations of retinol and dehydroretinol as had been identified previously in capture Mola (Roos, 2001). Three species (all SIS): Mola, Dhela and Darkina were identified that could potentially contribute ≥25% of RNI for PLW and infants in a standard portion. The data presented here support previous studies in Bangladesh which have identified that some SIS such as Mola have potential to play a significant role in food-based strategies to address vitamin A deficiency (Roos et al., 2007a).

3.3.2. Vitamin B12

The vitamin B12 content in fish species ranged from 0.50 to 14 μg/100 g (n = 49). The highest concentration, 14 μg/100 g, was found in Majhari Thai Pangas (juvenile Thai Pangas), however, this was not maintained in the adult Thai Pangas with a concentration of only 1.5 μg/100 g. Very limited data on vitamin B12 in fish and seafood are available for comparison in the literature. In the Australian food composition database, vitamin B12 content of fish and seafood ranges from 0.2 to 15.2 μg/100 g which is consistent with results reported here (FSANZ, 2010). For PLW and infants, 13 and 21 species respectively, were identified that would potentially contribute ≥100% of the daily RNI in a standard portion. Care should be taken however, when comparing results of vitamin B12 in species analysed by different laboratories due to differences in analytical methods. This is the first analysis of vitamin B12 composition of fish species in Bangladesh, and is of particular public health significance given the recent estimate of a national prevalence of vitamin B12 deficiency in 22% of adult women and the clear negative implications of deficiency on cognitive development and function (de Benoist, 2008). As dietary sources of vitamin B12 are exclusively animal-source foods, of which, in Bangladesh, fish is the most significant, increased consumption of fish is likely to be an appropriate food-based strategy to prevent and fight vitamin B12 deficiency.

3.3.3. Vitamin D

Vitamin D3 was undetected in five species and ranged up to 34 μg/100 g (n = 49). Very limited data on vitamin D in fish and seafood are available for comparison in the literature. The range reported here is greater than the range of Vitamin D3 in Australian fish and seafood at 0–20 μg/100 g (FSANZ, 2010), and similar to the range of vitamin D3 reported for selected fish and seafood in the United States at 0–33 μg/100 g (Byrdwell et al., 2013). Considering that the RNI of total vitamin D is 5 μg/day for PLW and infants, it is likely that several species could contribute significantly to dietary vitamin D intakes. Although the same analytical methods were used, comparisons between species of low vitamin D3 content (<0.1 μg/100 g) analysed in different laboratories should be made with caution due to differences in the LOQ in analysis by the two laboratories. For example, 14 species were identified with concentrations of vitamin D3 by analysis at *DTU* which would not have returned detectable concentrations by analysis at *AsureQuality* (LOQ of 0.05 μg/100 g at *DTU* compared to 0.5 μg/100 g at *AsureQuality*). Of the species analysed for vitamin D2 (n = 20) only five species were found to have detectable concentrations ranging from 0.39 to 2.9 μg/100 g. Vitamin D2 is however, generally only considered to be found in plant-source foods, specifically yeasts and fungi. There is evidence, however, that it is found in microalgae and zooplankton, and if this forms part of the diet of fish, may account for its presence (Rao and Raghuramulu, 1996). No species were found to have detectable concentrations of 25-hydroxyvitamin D3 (n = 29). This is the first time that vitamin D content in fish in Bangladesh has been evaluated. The data presented here indicate that some species may contribute significantly to dietary vitamin D intakes in Bangladesh and it is recommended that further analysis of both vitamin D2 and D3, using standard analytical methods be conducted.

3.3.4. Vitamin E

Vitamin E in the form of α-tocopherol, δ-tocopherol and γ-tocopherol was analysed in 20 species at *AsureQuality*. The form of vitamin E with highest biological activity, α-tocopherol, was analysed in an additional 25 species at *DTU* (Table 6). Across all 45 species, α-tocopherol was undetected in four species and ranged up to 1.9 mg/100 g. Very limited data on α-tocopherol in fish and seafood are available for comparison in the literature. In the Australian food composition database, α-tocopherol content of fish and seafood ranges from 0.1 to 4.2 μg/100 g which is broadly consistent with results reported here (FSANZ, 2010). It is worth pointing out, however, that although the same method of analysis was used by the two laboratories, differences in the LOQ mean that samples tested at *AsureQuality* were less likely to return detectable concentrations of α-tocopherol compared to those tested at *DTU* (LOQ of 0.07 and 0.02 mg/100 g at *AsureQuality* and *DTU*, respectively). No species analysed for other vitamin E components were found to have detectable concentrations of δ-tocopherol and only two species were found to have detectable concentrations of γ-tocopherol which were Tara Baim and Shing with 0.01 and 0.04 IU/100 g, respectively (0.007 and 0.03 mg/100 g, respectively). This is the first time the vitamin E content of fish species in Bangladesh has been analysed. Considering that the daily RNI for infants ranges from 2.7 to 5.0 mg α-tocopherol equivalents/day, (no recommendation for PLW), the data presented here indicate that some fish are a potentially important source of vitamin E, particularly in the form of α-tocopherol and it is therefore recommended that further analysis, using standard methods be conducted.

3.3.5. Folate

Folate content was analysed in 49 species and is shown in Table 6. Folate content was below detectable limits in 17 species and ranged up to 18 μg/100 g, consistent with results reported elsewhere (FSANZ, 2010). Comparisons between species of low folate content (<8 μg/100 g) analysed in different laboratories should be made with caution due to differences in analytical methods and LOQs (LOQ of 8 and 0.2 μg/100 g at *AsureQuality* and *DTU*, respectively). For example, 20 species were identified by analysis at *DTU* with concentrations of folate that would not have returned detectable concentrations had they been analysed at *AsureQuality*. This is the first time folate has been analysed in fish species in Bangladesh. Considering that the RNI for PLW ranges from 500 to 600 μg dietary folate equivalents (DFE)/day and for infants, 80–150 μg DFE/day, the results indicate that all species

Table 6
Vitamin A, B12, D, E and folate composition in fish and shrimp species.

	Nutrient content per 100 g raw edible parts										
	Vitamin B12	Vitamin D3	Vitamin D2	Vitamin E (α-tocopherol)	Folate	Vitamin A					
						β-carotene	13-*cis*-retinol	13-*cis*-dehydroretinol	All-*trans*-retinol	All-*trans*-dehydroretinol	Total Vitamin A
	μg	μg	μg	mg	μg	μg	μg	μg	μg	μg	μg RAE[c]
Inland capture											
Small indigenous fish species (SIS)											
Baim	1.72	1.30	0.76	nd	nd	5[a]	1[a]	5[a]	1[a]	51[a]	27
Bele, Bailla[b]	2.1	1.6	–	0.17	6.7	–	nd	nd	18	nd	18
Boro Kholisha	5.55	3.13	2.1	0.12	nd	11[a]	5[a]	5[a]	34[a]	14[a]	46
Chanda	6.42	11.9	nd	0.18	nd	43[a]	14[a]	51[a]	128[a]	433[a]	336
Chapila	6.99	4.92	nd	nd	nd	nd[a]	1[a]	21[a]	9[a]	136[a]	73
Chela	5.64	4.00	nd	0.11	nd	21[a]	25[a]	9[a]	90[a]	45[a]	132
Darkina	12.5	6.31	nd	0.84	nd	100[a]	63[a]	48[a]	433[a]	381[a]	660
Dhela[b]	4.7	0.14	–	0.24	6.6	–	15	68	28	2130	918
Ekthute[b]	3.0	2.4	–	0.65	11	–	18	nd	84	nd	98
Foli[b]	2.0	0.70	–	0.64	18	–	nd	nd	nd	nd	nd
Guchi	2.47	2.29	nd	0.11	nd	110[a]	1[a]	14[a]	9[a]	133[a]	78
Gutum	8.75	nd	nd	0.19	nd	25[a]	1[a]	9[a]	17[a]	131[a]	76
Jat Punti	4.01	1.29	nd	0.15	nd	13[a]	4[a]	9[a]	27[a]	49[a]	54
Kachki	3.55	1.5	nd	0.09	nd	15[a]	2[a]	30[a]	14[a]	122[a]	78
Kajuli, Bashpata[b]	4.1	0.091	–	0.28	2.9	–	nd	nd	37	nd	37
Kakila	2.89	1.4	0.66	0.40	9.2	56[a]	9[a]	12[a]	54[a]	53[a]	91
Koi	2.38	1.19	nd	nd	11.4	74[a]	61[a]	30[a]	163[a]	171[a]	295
Kuli, Bhut Bailla[b]	1.4	22	–	0.55	3.7	–	nd	nd	37	nd	37
Magur	4.83	nd	nd	0.13	9.4	64[a]	4[a]	8[a]	7[a]	15[a]	25
Meni, Bheda[b]	0.90	0.78	–	0.36	3.5	–	nd	nd	36	61	60
Mola	7.98	2.03	2.9	0.27	nd	nd[a]	nd[a]	460[a]	323[a]	4990[a]	2503
Mola (cultured)[b]	5.9	3.0	–	0.91	4.3	–	44	42	340	4590	2226
Rani, Bou[b]	6.4	0.12	–	0.63	3.2	–	nd	nd	nd	60	24
Shing	12.8	nd	nd	0.34	nd	45[a]	5[a]	11[a]	11[a]	22[a]	32
Taki	1.60	nd	nd	0.14	nd	22[a]	9[a]	13[a]	84[a]	104[a]	139
Tara Baim	5.20	nd	nd	0.17	nd	135[a]	2[a]	15[a]	16[a]	120[a]	83
Tengra[b]	3.5	0.19	–	0.23	10	–	nd	nd	nd	29	12
Tit Punti	6.74	0.995	nd	0.16	nd	25[a]	4[a]	5[a]	11[a]	8[a]	21
Large fish species											
Gojar[b]	0.55	0.42	–	0.28	2.0	–	nd	nd	nd	nd	nd
Ilish[b]	2.3	18	–	1.7	1.5	–	nd	nd	nd	49	20
Jatka Ilish[b]	2.0	9.0	–	1.9	3.2	–	nd	nd	nd	36	14
Shol[b]	1.2	0.18	–	0.52	2.4	–	nd	nd	nd	nd	nd
Shrimp/prawn											
Harina Chingri[b]	1.4	0.055	–	1.6	14	–	nd	nd	nd	nd	nd
Inland aquaculture											
Indigenous major carps											
Catla[b]	1.3	0.28	–	0.23	4.4	–	nd	nd	22	nd	22
Mrigal	5.57	0.616	0.39	nd	nd	nd[a]	2[a]	2[a]	9[b]	9[a]	15
Rui	5.05	1.17	nd	0.12	nd	6[a]	2[a]	1[a]	9[b]	4[a]	13
Introduced fish species											
Silver Carp[b]	0.55	0.24	–	0.49	7.7	–	nd	nd	nd	nd	nd
Thai Pangas[b]	1.5	0.13	–	0.32	9.0	–	nd	nd	nd	78	31
Majhari Thai Pangas [b]	14	0.12	–	0.10	15	–	nd	nd	nd	31	12
Thai Sharpunti[b]	2.2	23	–	0.32	2.2	–	nd	nd	12	nd	12
Tilapia[b]	0.70	6.3	–	0.40	7.6	–	nd	nd	10	nd	10
Majhari Tilapia[b]	2.5	34	–	1.5	8.0	–	nd	nd	10	27	21
Marine capture											
Foli Chanda[b]	1.5	0.097	–	0.19	4.8	–	nd	nd	nd	nd	nd
Kata Phasa[b]	1.3	3.8	–	0.37	8.6	–	nd	nd	nd	nd	nd
Lal Poa[b]	2.0	1.3	–	0.38	7.7	–	nd	nd	nd	nd	nd
Maita[b]	1.6	1.7	–	0.50	2.5	–	nd	nd	nd	nd	nd
Murbaila[b]	0.50	0.20	–	0.09	2.2	–	nd	nd	nd	nd	nd
Tailla[b]	0.85	13	–	0.44	3.1	–	nd	nd	nd	nd	nd
Tular Dandi[b]	1.7	0.28	–	0.26	8.7	–	nd	nd	20	nd	20

[a] Data on vitamin A components previously published by Roos (2001).
[b] Data on all vitamin components analysed at *DTU*, Denmark.
[c] μg RAE, retinol activity equivalent.
–, no data available.
nd, not detected. Limit of detection: vitamin A components, 10 μg/100 g; vitamin D2, 0.1 μg/100 g; vitamin D3, 0.1 μg/100 g; vitamin E, 0.11 IU/100 g (equivalent to 0.074 mg/100 g using conversion factor vitamin $E_{(tocopherol)}$ (mg/100 g) = vitamin $E_{(tocopherol)}$ (IU/100 g) × 0.67; (FAO/INFOODS, 2012).
$n = 1$ pooled sample.

analysed would generally be considered low dietary sources of folate, and therefore unlikely to contribute significantly to dietary folate intake in Bangladesh.

3.4. Fatty acid composition

All samples with a total fat content of >6 g/100 g were analysed further for composition of 38 fatty acids and the results are shown in Table 7 (in addition to juvenile Thai Pangas which had a total fat content of 1.4 g/100 g but was analysed for the purpose of comparison with its adult counterpart). Although it is recognised that fish species with fat content <6 g/100 g may well be good sources of fatty acids, due to resource constraints in this study, species with higher total fat content were prioritised for analyses. Total PUFA, monounsaturated fatty acid (MUFA) and saturated fatty acid (SFA) contents ranged from 0.5 to 3.6 g/100 g, 0.4–7.7 g/100 g and 0.5–8.9 g/100 g, respectively. Ilish was the most significant source of PUFA and SFA, whereas Thai Pangas was the most significant source of MUFA. The total n-3 PUFA content ranged from 211 to 2034 mg/100 g, with the most significant sources being Ilish and Parse. Total n-6 PUFA content ranged from 178 to 2157 mg/100 g, with the most significant sources being Thai Pangas and Jat Punti. The ratio of n-6:n-3 PUFA was highest in Thai Pangas, which is also the only farmed and omnivorous fish analysed here (except for its juvenile counterpart). This may reflect differences in the diet and or environmental conditions of farmed versus capture fish among other factors (Li et al., 2011), although this would require further investigation. A more balanced n-6:n-3 PUFA ratio is more desirable in prevention of cardiovascular and other chronic diseases (Simopoulos, 2008), however this evidence relates to higher disease risk with low n-3 intake, rather than high n-6 intake or a high n-6:n-3 PUFA ratio and as such, no dietary recommendation for such a ratio exists (FAO, 2010). The percentage contribution to daily average nutrient requirement of docosahexaenoic acid (DHA) for PLW and infants (7–23 months) from a standard portion of fish is shown in Fig. 2, and clearly

Table 7
Fatty acid composition of fish species.

Nutrient[a]	Unit	Nutrient content per 100 g raw edible parts									
		Ilish	Jatka Ilish	Jat Punti	Kajuli, Bashpata	Koi	Modhu Pabda	Parse	Rani, Bou	Thai Pangas	Majhari Thai Pangas
Total fat (mean)	g	18.3	7.7	7.2	12.6	12.8	9.5	14.3	10.6	17.7	1.4
Total SFA	g	8.9	3.8	2.2	5.4	4.8	3.6	7.4	4	7.5	0.5
Total MUFA	g	6.9	2.5	2.4	5.2	5.7	4.2	4.5	4	7.7	0.4
Total PUFA	g	3.6	1.6	2.5	2.1	1.9	1.7	2.7	2.7	2.6	0.5
C12:0	mg	13	32	30	65	11	20	12	180	nd	nd
C13:0	mg	nd	nd	nd	nd	nd	10	nd	35	nd	nd
C14:0	mg	1550	710	100	580	270	150	630	430	620	52
C15:0	mg	64	36	56	100	36	98	310	160	29	nd
C16:0	mg	5780	2310	1290	3270	3270	2270	5530	2690	5180	310
C17:0	mg	36	28	88	180	55	120	160	230	31	22
C18:0	mg	1320	620	570	1120	1050	750	610	100	1560	130
C20:0	mg	25	16	28	41	39	43	26	36	35	nd
C22:0	mg	19	18	16	17	11	27	18	19	19	nd
C24:0	mg	20	22	19	42	28	41	21	42	nd	nd
C14:1	mg	11	nd	28	100	14	98	63	71	11	18
C15:1	mg	nd	nd	15	38	nd	39	21	38	nd	nd
C16:1	mg	2110	820	190	580	390	490	1930	760	160	51
C17:1	mg	10	nd	22	72	27	62	150	92	16	nd
C18:1n-6	mg	nd	nd	nd	nd	16	13	53	12	nd	nd
C18:1n-7	mg	700	280	130	310	230	270	470	370	210	48
C18:1n-9	mg	3730	1240	1790	3680	4890	2850	1490	2040	7010	180
C20:1n-9	mg	250	65	32	52	120	83	30	61	210	nd
C20:1n-11,13	mg	nd	nd	34	15	11	41	22	120	14	nd
C22:1n-9	mg	24	nd	nd	nd	47	nd	nd	nd	23	nd
C22:1n-11,13	mg	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
C24:1	mg	25	15	nd	nd	10	nd	12	nd	nd	nd
C18:2n-6 (LA)	mg	120	88	1710	410	1100	760	220	440	1820	77
C18:3n-6	mg	47	16	43	33	80	25	91	31	42	nd
C20:2n-6	mg	nd	nd	nd	25	nd	71	nd	nd	77	nd
C20:3n-6	mg	57	21	46	46	65	55	27	61	110	15
C20:4n-6	mg	170	110	140	260	57	200	165	230	70	57
C22:4n-6	mg	34	20	35	53	22	32	34	56	38	29
C22:5n-6	mg	58	21	nd	nd	nd	nd	13	nd	nd	nd
Total n-6 PUFA	mg	486	276	1974	827	1324	1143	550	818	2157	178
C18:3n-3 (ALA)	mg	24	27	150	430	81	140	370	300	140	69
C18:4n-3	mg	110	50	19	nd	18	nd	300	16	nd	nd
C20:3n-3	mg	nd	nd	nd	25	nd	28	26	55	13	nd
C20:4n-3	mg	120	44	10	81	19	13	99	48	11	20
C20:5n-3 (EPA)	mg	1200	430	40	160	30	68	400	96	13	38
C21:5n-3	mg	nd	nd	nd	nd	nd	nd	nd	nd	11	nd
C22:5n-3	mg	270	94	24	120	59	53	120	84	19	24
C22:6n-3 (DHA)	mg	310	230	86	190	170	100	120	120	37	60
Total n-3 PUFA	mg	2034	875	329	1006	377	402	1435	719	244	211
n-6: n-3 PUFA	–	0.2:1	0.3:1	6:1	0.8:1	3.5:1	2.8:1	0.4:1	1.1:1	8.8:1	0.8:1

[a] SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; LA, linoleic acid; ALA, α-linolenic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.
nd, not detected. Limit of detection for all fatty acids: 6 mg/100 g.
n = 1 pooled sample.

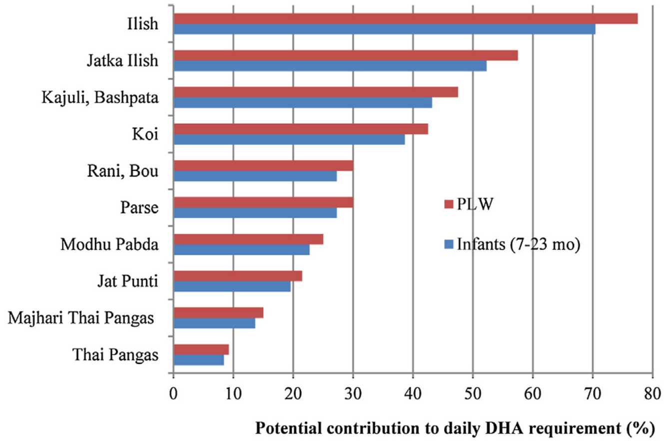

Fig. 2. Potential contribution to daily nutrient requirement[a] of docosahexaenoic acid (DHA) from a standard serve[b] of fish for PLW[c] and infants (7–23 months).
(a) Daily average nutrient requirement of DHA for PLW is 200 mg/day and the adequate intake for infants is 10–12 mg/kg/day (FAO, 2010). For infants an average figure of 110 mg/day is used. This was calculated by taking the midpoint within the maximum range of adequate intakes throughout the age period (10 mg/kg/day for a 7 month old of 7.6 kg and 12 mg/kg/day for a 23 month old of 12.0 kg) where weight is estimated at the 50th percentile according to WHO growth standards (WHO, 2006).
(b) Standard serve of fish for PLW is 50 g/day and for infants is 25 g/day.
(c) PLW, pregnant and lactating women.

demonstrates that all species, except adult and juvenile Thai Pangas would contribute ≥20% of daily requirements of DHA for both PLW and infants. This is of particular interest given the growing body of literature on the role of fatty acids in growth and development during the first 1000 days, and specifically, the role of DHA in normal retinal and brain development (FAO, 2010). The data presented here indicate that important fish species in Bangladesh, particularly indigenous species are a good dietary source of fatty acids and should be considered in food-based approaches to optimise growth and development during the first 1000 days. It is also recommended that the fatty acid composition of further species be analysed.

3.5. Species size, edible parts and biodiversity

When making comparisons between species on their overall nutritional value, it is important to consider the size of the fish, and implications for what is typically considered 'edible' parts. SIS are typically consumed whole with head, bones and in some cases, viscera, in stark contrast to large species, where edible parts typically include body tissue only. The nutritional consequences of this can be seen when anatomical components of fish are analysed separately. For example, in Mola, the eyes and viscera have an extremely high concentration of vitamin A compared to the body tissue (Roos et al., 2002). Although separate anatomical parts have not been analysed here, this trend can be seen when considering the edible parts of SIS compared to that of large indigenous and aquaculture species (Table 1), and potential contributions to RNIs (Table 5). When considering iron, zinc, calcium, vitamin A and vitamin B12 requirements, there are seven species that would contribute to ≥25% of RNI for PLW and six species that would contribute to ≥25% of RNI for infants, for three or more micronutrients simultaneously, when consumed in a 50 g or 25 g portion, respectively. These species are all SIS (except for Najara Icha which is a prawn) and edible parts include head and bones. This underlines the importance of considering typical consumption patterns, often related to size of the individual fish, shrimp or prawn, in design of programmes that aim to influence production and or consumption of fish. One promising example of this, now gaining momentum, is the inclusion of nutrient-rich Mola in pond polyculture systems with carps, which is being promoted throughout rural Bangladesh (Thilsted and Wahab, 2014b,c).

Table 5 also calls attention to the variation in potential nutrient contributions of different species. For example, some species contribute significantly to iron and calcium RNIs and less so to vitamin A, whereas, others contribute more to zinc and vitamin A RNIs and less so to iron RNIs. No single species is of resounding superior nutritional value than any other single species, across all nutrients, which emphasises the importance of biodiversity in fish consumption for meeting population nutrient needs.

3.6. Limitations

Nutrient composition of foods, including fish, is known to vary seasonally, depending on the stage of the life cycle, food availability, and changes in the wider environment. It was however, outside the scope of this study to attempt to sample to account for these variations. Furthermore, a relatively small size of pooled samples was used, and in the case of analysis of fatty acids, the use of single replicates. In the local context and considering resource constraints, it was also not possible to obtain larger more representative sample sizes. Another limitation of this study is the use of different methods for analysis of vitamin B12 and folate between species analysed by different laboratories, although the methods are generally considered similar (Indyk and Woollard, 2013; Indyke et al., 2002). Therefore, while it is recognised that these are limitations of the study, given the lack of existing data on nutrient composition of fish species in Bangladesh, the results are still of significant value, providing time and location specific estimates for comparison with future analyses.

4. Conclusions

Several species have been identified that would contribute significantly to the RNIs of multiple nutrients of public health significance. When considering the role of fish in food and nutrition security in recent decades, research, funding and interventions have largely focused on the development of aquaculture, particularly of large carps and introduced species, with an assumed benefit for nutrition-related outcomes, although this linkage is dubious. The data presented here show that from a nutritional perspective, species from inland capture fisheries, particularly small indigenous species (SIS), hold the potential to provide a much greater contribution to micronutrient intakes of vulnerable groups in the population compared to common aquaculture species. This is likely partially due to the way in which small fish are consumed, namely, whole with head and bones. Further still, given the large range in nutrient composition of the different species reported here, diversity in fish consumption, particularly of SIS, is likely to promote a more all-inclusive nutrient intake. This supports the compelling argument that to effectively target malnutrition, resources should be directed towards ensuring a more balanced approach of both sustainable capture fisheries management and aquaculture, including the development of innovative aquaculture technologies which include nutrient-rich species, in particular SIS. This paper significantly expands the current knowledge on the nutritional value of the large diversity of fish species in Bangladesh, and demonstrates that many species, particularly SIS and those from inland capture fisheries, have the *potential* to contribute significantly to RNIs for a variety of nutrients. In future studies, it would be useful to determine the *real* contribution of different species to nutrient intakes of vulnerable groups based on consumption, to better inform programmes targeting improved access, availability and consumption of nutritious foods.

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