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METAL VARIATIONS IN NOTCHED THREADFIN BREAM FROM NEARSHORE AND OPEN WATER AREAS OF TERENGGANU

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Abstract: The notched threadfin bream, *Nemipterus peronii,* is captured using a gill net or trap (*bubu*) in Malaysia. Accessibility to 5 locations and 42 samples enabled the present investigation. Samples originating from nearshore environments accumulated Cr, Cu, Fe, and Se in lesser quantities than open water samples. For size-to-weight evaluations, fish caught using *bubu* weighed less than those captured using gill nets. Although the correlation was poor for samples and their location ($p = 0.066$), the data was better correlated ($p = \sim 0.30-0.60$) for the accumulation of Cr, Cu, and Fe in fish organs. The fish from open water environments were relatively larger in size compared to nearshore environments ($p = 0.916$). These fish were detected with Cr, Cu, Fe, and Se in the cumulative range of 400-500 mg/kg per fish; its flesh contained ~10-20% of the detected metals. This study has novelty in awareness raising. It is not a given that nearshore fish endure more elasticity than fish in open water. In addition, aside from small sizes, the nearshore *N. peronii* could be claimed with lower body burden risk. Overall, the nearshore fish posed fewer health concerns when consumed compared to the open-water fish caught using gill nets.

Keywords: *Nemipterus*, South China Sea, fisheries, food, health.

Introduction

In recent years, topics concerning persistent and non-biodegradable contaminants in aquatic ecosystems has gained research attention. Economic practices such as aquaculture, agriculture and fishing were identified as routes for the introduction of persistent contaminants, especially metals (Haris & Aris, 2015). From this, copper (Cu), iron (Fe) and selenium (Se) were described as essential metals (Gu *et al.*, 2018) whereas chromium (Cr) is non-essential but, classified as a trace metal (Vardhan *et al.*, 2019). In Malaysia, various studies have reported on persistent metals being naturally present in aquatic species (Sobihah *et al.*, 2018; Azmi *et al.*, 2019), plants (Nazli & Hashim, 2010; Sidi *et al.*, 2018) and terrestrial habitats (Looi *et al.*, 2019; Razak *et al.*, 2021). All these studies highlighted risks either, from exposure or consumption. This concern about contaminants in aquatic species includes the Notched threadfin bream or *Nemipterus peronii*, a fish species that support the global demand for marine-based protein.

Being widespread in the South China Sea, *N. peronii* is integral to the fisheries economy of Terengganu, a state on the East Coast of Peninsular Malaysia (Mazhar *et al.*, 2014; Abdul-Kadir *et al.*, 2018). Living in the demersal column, *N. peronii* is a voracious predator that feeds on small fishes, crustaceans, molluscs, polychaetes, and echinoderms (Said *et al.*, 1994). This feeding strategy supports its long reproduction season that spans between February to July; peaking in April-May annually (Tonnie *et al.*, 2018). However, despite year-round availability, *N. peronii* has competitive pricing from USD 2.5 (MYR 10.50) to USD 3.5 (~MYR 15.00) per kilogram. With the disparity in sex ratio (or 0.59) where a male fish measures < 100 mm in fork length (Wu *et al.*, 2008), it implies that sizing and quantity per kilogram are determinants in potentially consuming either, a male or female fish. Moreover, it is possible to haul in mostly female *N. peronii* in a single net catch.

N. peronii could be caught using either, a 4 to 4.5-inch gill net or rattan and netted-steel traps called *bubu* (Malay language). Fishermen usually anchor *bubu* against the inflow of seawater in shallow nearshore areas adjacent to a river inlet or estuary (Kongprom *et al.*, 2003). Otherwise, gill nets are cast in open water sections where the water depth is greater than the nearshore. Gill nets provide better efficiencies in the catch-per-unit effort. There is a possibility of gear overlap but it depends on the intended catch.

In this era, being able to purchase a higher number of fish at a cheaper cost is an economical way to feed a large family (Prompatanapak & Lopetcharat, 2020). This is probably the case for Terengganu, where families tend to be large and fresh fish is the preferred source of protein. Since the use of *bubu* is practical and offers fast resource acquisition, daily catching of *N. peronii* is possible. Yet, the size and appearance of nearshore fish seems disadvantageous (c.f. Mazhar *et al*., 2014), as fish caught using bubu are usually priced lower on the market.

Quality of the catch is determined by age-to-size and the appearance. Fish with less vibrant colour or odd appearances (swelled eyes or dull-coloured gills) imply a stressed stock. In this sense, metals are not visible to the naked eye and excessive intake is known to adversely affect the body. Like all organisms, fish can depurate metals by urine and faeces, but, the constant exposure to free ionic metals could force deposition into hard structures, such as bones, scales, and fins (Sueiro *et al.*, 2020). The aim of this study is to examine if the origin of *N. peronii* from either nearshore or open water environments has different heavy metal content. Then, metal composition in soft and hard tissues was used to determine consumerism risks. This is particularly important because *N. peronii* has commercial value and is regarded as one of the primary sources of marine-based protein, particularly in Terengganu.

Materials and Methods

Collection and Preparations

All fish were sourced from the fishermen's wet markets in Kuala Besut (N 5° 33' 52.1928", E 102° 34' 2.2692"; a focal point of 0 km), Setiu (N 5.678569, E 102.711549; 59.8 km South), Batu Rakit (N 5° 26' 6.0324", E 103° 3' 48.8448"; 89.2 km South-southeast), Pulau Kambing (N 5° 19' 18.9624", E 103° 7' 41.5344"; 106.1 km South) and Chendering (N 5° 17' 55.7952", E 103° 7' 17.7672"; 115.6 km South-southwest) which are along the coast. The distance between the sites is for spatial separation for the acquisition of fish samples and assurance of sourcing isolated fish populations. We insisted on fresh samples, where fish death is no longer than 24 hours, which means the fish were landed and distributed on the same purchase day. An additional criterion was that fish must be caught by either, 4.0 to 4.5-inch mesh gill nets or steel or wood *bubu* bounded by 1.5 to 2.0-inch mesh nets. All fishmongers volunteered for the study, agreed to both criteria of fish samples, and no personal information. There was informed consent before the informal inquiry on the fish source and catch method before the purchasing of *N. peronii* from the wet market (Figure 1). A total of 4 kg of fish were purchased from each market, per locality for a period of three months apart (February, May, and August). At the laboratory, all fish were firstly categorised

Figure 1: The Notched threadfin bream, *Nemipterus peronii*
Photo credit Zaki, M.R.M.

by capture method; net and trap before being measured for their weight (g), fork (cm) and total length (cm). Later, the fish were divided by their flesh, gills bones, scales, and fins. All samples were stored in yellow-cap urine containers (40 ml) and oven dried for up to three days or until constant weight is reached. These fish components were then ground up using a pestle and mortar before long-term storing in a top-loader freezer (-20°C).

Sample Analysis

A total of ± 0.1 g sample was transferred into a Teflon jacket before being added with 2 ml nitric acid and 1 ml hydrogen peroxide (2:1; v/v). Samples, prepared in triplicate, were heated in an oven for 5 hours at 160°C before cooling down to 90°C for 2 hours and left to stand overnight at room temperature (modified from Nelson *et al.*, 2016). Filtrate (if present) was removed by running the sample through a filter paper (Whatman Grade 1), into a 10 ml centrifuge tube before adding deionized water to maximum volume. The multi-element standard solution was used to develop the standard curve in ICP-OES (Agilent Technologies, Malaysia) using the logarithmic scale of 0.001, 0.01, 0.1, 1, and 10 ppm. The samples were quantified for chromium (Cr; λ = 267.716), copper (Cu; λ = 324.754), iron (Fe; λ = 238.204) and selenium (Se; λ = 185.457). NRCC-certified reference material dogfish liver (DOLT-4) was used to validate the digestion procedure applied in this study.

Data Analysis

Dogfish liver (or DOLT-4) and fish samples were corrected to the mg/kg w/w ratio before tabulation in Microsoft Excel. The data was processed using log transformation before Bray-Curtis Resemblance and Kendall's Correlation, which is amalgamated in the Stepwise Analysis in Primer v.7 (modified from Nelson *et al.*, 2015). Additional relationships were indicated using the Principal Component Analysis (PCA) within the same software.

Results

Fish Samples

The 4 kg purchases from each site in Terengganu 2 kg for gill net and 2 kg for traps - resulted in three batches of analysis and 42 fish samples. Briefly, fish caught using gill nets had fork lengths of 15.4 - 21.8 cm, 17.2 - 24.5 cm in total length and weighed 168.6 - 239.2 g. Trapped fish had a fork length of 10.8 - 14.0 cm, 12.1 - 15.6 cm in total length and weighed 119.6 - 153.9 g. Relatively, the trapped fish (in bubu) were 67.2% smaller than those caught using nets (Table 1). However, all fish were within the normal 0.89 ± 0.004 indices for fork length-to-total length measurements (Kendall's correlation, p = 0.916). This assurance corroborated the reliability of assessing size-metal accumulations by using fork length. Fish weight had deviations of ± 9.6 g and ± 19.2 g respectively for the gill net and trapped fish (Table 2). Over 7 months, the netted fish (or captured using gill nets) increased in weight and size by 1.1 - 1.5%. A 1.9 - 4.3% variation in weight and size measurements was recorded for the trapped (or captured using *bubu*) fish.

Naturalisation of Metals

Validation of ICP-OES was demonstrated using the certified reference material DOLT-4; dogfish liver with satisfying results. The recoveries of 91.12 - 103.6% for Cr, 94.36 - 108.25% for Cu, 88.73 - 101.2% for Fe, and 90.74 - 104.83% for Se were found within the acceptable level of ± 10% except for Cu (11%). In general, *N. peronii* captured using traps had 14% fewer metals than netted fish (Table 1). Site-wise, the fish from Kuala Besut and Batu Rakit 146 - 184% more metals. For all the sites, the degree of metals accumulated was Fe > Cr > Cu > Se with average values in the range of 76 - 82 mg/kg for Fe, 13 - 19 mg/kg for Cr, 5 - 8 mg/kg for Cu and < 1.0 mg/kg for Se, depending on the fishing method used. Meanwhile, for fish organs, Cr was detected in scales (5.7 - 41.8 mg/kg; p = 0.379) and bones (7.5-29.6 mg/kg; p = 0.620); Cu in gills (6.1 - 9.8 mg/kg; p = 0.514) and flesh (4.3 - 11.0 mg/kg; p = 0.464); Fe in gills (76.3 - 110.4 mg/kg; p = 0.566), bones (41.0 - 84.1 mg/kg; p = 0.622) and scales (21.6 - 79.5 mg/kg; p = 0.435) and; Se in gills (0.06 - 0.11 mg/kg; p = 0.576) and bones (0.06 - 0.09 mg/kg; p = 0.503).

Interestingly, Cr was observed to be excessively accumulated in the bones (26.0 - 35.6 mg/kg; p = 0.621) and fins (18.4 - 23.9 mg/kg; p = 0.417) while high concentrations of Fe were present in the gills (94.9 - 124.2 mg/kg; p = 0.257) and bones (74.4 - 99.0 mg/kg; p = 0.619). Comparatively, fish caught using traps had scales and fins with higher Cr content, while their bones and gills accumulated Fe excessively (Table 2). Trends in size-to-metal accumulations were weak (p = 0.066) but, stronger relationships were established for flesh (p = 0.228), gills (*p* = 0.292) and bones (0.233) over a period of 7 months. In principal component analysis constructed using fork length-metal values, *N. peronii* indicated an affinity for Cr in fins and bones (for netted fish), Cu in gills and flesh (trapped > netted fish), Fe in gills (for netted fish), scales and fins (for trapped fish) and Se in flesh, scales, and gills (for netted fish; Figure 2). In addition, netted and trapped fish accumulated Se with overall values < 0.1 mg/kg. Overall, the trapped fish from Chendering had 10% less metal content than the netted fish, while netted fish from Kuala Besut had 84% more metal content than the trapped fish. In fact, through principal component analysis on trapped fish (Figure 3), the fishing gear (or method) used provided insights into the environmental conditions and variations in metal accumulations within the fish. For instance, netted fish from Batu Rakit, Pulau Kambing and Chendering tend to accumulate Cu in gills; trapped fish from all sites except Batu Rakit accumulated Cu in flesh; Se was prevalent in bones of trapped fish from all sites; Se accumulated in the fins of fish from Pulau Kambing, Batu Rakit and Chendering and trapped fish from all sites accumulated Cu and Fe in their scales (Figure 3).

Table 1: Raw data for size, weight and metals accumulated in *Nemipterus peronii* caught using the gill net

	Criteria	Batch 1 (Net; n = 6)						Batch 2 (Net; n = 6)						Batch 3 (Net; n = 6)					
	Fork (cm)	16.7	17.1	19.0	17.5	16.6	17.0	17.9	18.3	20.3	16.8	16.0	16.3	19.3	19.7	21.9	16.2	15.4	15.7
	Total (cm)	18.7	19.1	21.2	19.5	18.6	19.0	20.1	20.5	22.8	18.9	17.9	18.3	21.6	22.1	24.5	18.2	17.3	17.7
	Weight (g)	182.4	186.1	206.8	190.6	181.1	185.0	196.2	200.1	222.4	183.9	174.8	178.5	211.0	215.2	239.2	177.5	168.7	172.2
	Gills (Cr)	5.4	5.6	6.2	5.7	5.4	5.5	5.9	6.0	6.6	5.5	5.2	5.3	6.3	6.4	7.1	5.3	5.0	5.1
	Flesh (Cr)	12.4	12.6	14.0	12.9	12.3	12.5	13.3	13.6	15.1	12.5	11.8	12.1	14.3	14.6	16.2	12.0	11.4	11.7
	Bone (Cr)	27.1	27.7	30.8	28.4	26.9	27.5	29.2	29.8	33.1	27.4	26.0	26.5	31.4	32.0	35.6	26.4	25.1	25.6
	Scale (Cr)	18.4	18.8	20.9	19.3	18.3	18.7	19.8	20.2	22.5	18.6	17.7	18.0	21.3	21.8	24.2	17.9	17.1	17.4
	Fin (Cr)	19.9	20.3	22.6	20.8	19.8	20.2	21.4	21.8	24.3	20.1	19.1	19.5	23.0	23.5	26.1	19.4	18.4	18.8
	Gills (Cu)	8.8	9.0	10.0	9.2	8.7	8.9	9.5	9.7	10.7	8.9	8.4	8.6	10.2	10.4	11.6	8.6	8.1	8.3
	Flesh (Cu)	9.8	10.0	11.1	10.3	9.8	10.0	10.6	10.8	12.0	9.9	9.4	9.6	11.4	11.6	12.9	9.6	9.1	9.3
	Bone (Cu)	4.2	4.2	4.7	4.3	4.1	4.2	4.5	4.6	5.1	4.2	4.0	4.1	4.8	4.9	5.5	4.1	3.8	3.9
Kuala Besut	Scale (Cu)	5.2	5.4	6.0	5.5	5.2	5.3	5.6	5.8	6.4	5.3	5.0	5.1	6.1	6.2	6.9	5.1	4.9	5.0
	Fin (Cu)	5.6	5.7	6.3	5.8	5.5	5.6	6.0	6.1	6.8	5.6	5.3	5.5	6.4	6.6	7.3	5.4	5.2	5.3
	Gills (Fe)	99.0	101.0	112.3	103.5	98.3	100.4	106.5	108.6	120.7	99.8	94.9	96.9	114.5	116.8	129.8	96.3	91.5	93.5
	Flesh (Fe)	62.1	63.4	70.5	64.9	61.7	63.0	66.8	68.2	75.8	62.7	59.6	60.8	71.9	73.3	81.5	60.5	57.5	58.7
	Bone (Fe)	75.5	77.0	85.6	78.9	74.9	76.5	81.2	82.8	92.0	76.1	72.3	73.8	87.3	89.0	99.0	73.4	69.8	71.3
	Scale (Fe)	71.3	72.7	80.9	74.5	70.8	72.3	76.7	78.2	87.0	71.9	68.3	69.8	82.5	84.1	93.5	69.4	65.9	67.3
	Fin (Fe)	55.8	56.9	63.2	58.3	55.4	56.6	60.0	61.2	68.0	56.2	53.4	54.6	64.5	65.8	73.1	54.3	51.6	52.7
	Gills (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Flesh (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Bone (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Scale (Se)	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1
	Fin (Se)	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0

Setiu	Fork (cm)	17.3	17.7	19.7	18.1	17.2	17.6	17.7	18.0	20.0	18.3	17.4	17.8	18.1	18.4	20.5	18.6	17.7	18.0
	Total (cm)	19.4	19.8	22.0	20.3	19.3	19.7	19.8	20.2	22.5	20.6	19.5	20.0	20.3	20.7	23.0	20.9	19.8	20.2
	Weight (g)	193.0	196.9	218.9	201.7	191.7	195.7	197.4	201.3	223.8	204.6	194.4	198.5	201.8	205.8	228.9	207.5	197.2	201.4
	Gills (Cr)	5.8	5.9	6.5	6.0	5.7	5.8	5.9	6.0	6.7	6.1	5.8	5.9	6.0	6.1	6.8	6.2	5.9	6.0
	Flesh (Cr)	13.1	13.3	14.8	13.7	13.0	13.3	13.4	13.6	15.2	13.9	13.2	13.5	13.7	14.0	15.5	14.1	13.4	13.7
	Bone (Cr)	28.7	29.3	32.6	30.0	28.5	29.1	29.4	29.9	33.3	30.4	28.9	29.5	30.0	30.6	34.0	30.9	29.3	30.0
	Scale (Cr)	19.5	19.9	22.1	20.4	19.4	19.8	20.0	20.4	22.6	20.7	19.7	20.1	20.4	20.8	23.1	21.0	19.9	20.4
	Fin (Cr)	21.1	21.5	23.9	22.0	20.9	21.4	21.5	22.0	24.4	22.3	21.2	21.7	22.0	22.5	25.0	22.6	21.5	22.0
	Gills (Cu)	9.3	9.5	10.6	9.7	9.3	9.5	9.5	9.7	10.8	9.9	9.4	9.6	9.7	9.9	11.1	10.0	9.5	9.7
	Flesh (Cu)	10.4	10.6	11.8	10.9	10.3	10.6	10.6	10.9	12.1	11.0	10.5	10.7	10.9	11.1	12.3	11.2	10.6	10.9
	Bone (Cu)	4.4	4.5	5.0	4.6	4.4	4.5	4.5	4.6	5.1	4.7	4.4	4.5	4.6	4.7	5.2	4.7	4.5	4.6
	Scale (Cu)	5.6	5.7	6.3	5.8	5.5	5.6	5.7	5.8	6.4	5.9	5.6	5.7	5.8	5.9	6.6	6.0	5.7	5.8
	Fin (Cu)	5.9	6.0	6.7	6.2	5.9	6.0	6.0	6.1	6.8	6.2	5.9	6.1	6.2	6.3	7.0	6.3	6.0	6.1
	Gills (Fe)	104.8	106.9	118.8	109.5	104.0	106.2	107.1	109.3	121.5	111.1	105.5	107.8	109.5	111.7	124.2	112.6	107.0	109.3
	Flesh (Fe)	65.8	67.1	74.6	68.7	65.3	66.7	67.3	68.6	76.3	69.7	66.2	67.6	68.8	70.1	78.0	70.7	67.2	68.6
	Bone (Fe)	79.9	81.5	90.6	83.5	79.3	81.0	81.7	83.3	92.6	84.7	80.4	82.1	83.5	85.2	94.7	85.9	81.6	83.3
	Scale (Fe)	75.5	77.0	85.6	78.9	74.9	76.5	77.2	78.7	87.5	80.0	76.0	77.6	78.9	80.5	89.5	81.1	77.1	78.7
	Fin (Fe)	59.0	60.2	66.9	61.7	58.6	59.9	60.3	61.6	68.4	62.6	59.4	60.7	61.7	62.9	70.0	63.5	60.3	61.6
	Gills (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Flesh (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Bone (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Scale (Se)	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0
	Fin (Se)	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1

	Fork (cm)	16.4	16.7	18.6	17.1	16.3	16.6	16.5	16.9	18.7	16.6	15.8	16.1	16.8	17.1	19.0	16.2	15.4	15.7
	Total (cm)	18.3	18.7	20.8	19.1	18.2	18.6	18.6	18.9	21.0	18.7	17.7	18.1	18.8	19.2	21.3	18.2	17.3	17.6
	Weight (g)	185.6	189.4	210.5	194.0	184.3	188.2	188.1	191.9	213.3	189.1	179.7	183.5	190.7	194.5	216.2	184.4	175.2	178.9
	Gills (Cr)	5.5	5.7	6.3	5.8	5.5	5.6	5.6	5.7	6.4	5.6	5.4	5.5	5.7	5.8	6.5	5.5	5.2	5.3
	Flesh (Cr)	12.6	12.8	14.3	13.1	12.5	12.8	12.8	13.0	14.5	12.8	12.2	12.4	12.9	13.2	14.7	12.5	11.9	12.1
	Bone (Cr)	27.6	28.2	31.3	28.9	27.4	28.0	28.0	28.5	31.7	28.1	26.7	27.3	28.4	28.9	32.2	27.4	26.1	26.6
	Scale (Cr)	18.8	19.1	21.3	19.6	18.6	19.0	19.0	19.4	21.6	19.1	18.2	18.6	19.3	19.7	21.9	18.6	17.7	18.1
	Fin (Cr)	20.3	20.7	23.0	21.2	20.1	20.5	20.5	20.9	23.3	20.6	19.6	20.0	20.8	21.2	23.6	20.1	19.1	19.5
	Gills (Cu)	9.0	9.1	10.2	9.4	8.9	9.1	9.1	9.3	10.3	9.1	8.7	8.9	9.2	9.4	10.4	8.9	8.5	8.6
	Flesh (Cu)	10.0	10.2	11.3	10.5	9.9	10.1	10.1	10.3	11.5	10.2	9.7	9.9	10.3	10.5	11.7	9.9	9.4	9.6
	Bone (Cu)	4.2	4.3	4.8	4.4	4.2	4.3	4.3	4.4	4.9	4.3	4.1	4.2	4.4	4.4	4.9	4.2	4.0	4.1
Batu Rakit	Scale (Cu)	5.3	5.4	6.1	5.6	5.3	5.4	5.4	5.5	6.1	5.4	5.2	5.3	5.5	5.6	6.2	5.3	5.0	5.1
	Fin (Cu)	5.7	5.8	6.4	5.9	5.6	5.7	5.7	5.9	6.5	5.8	5.5	5.6	5.8	5.9	6.6	5.6	5.4	5.5
	Gills (Fe)	100.8	102.8	114.3	105.3	100.1	102.2	102.1	104.2	115.8	102.7	97.6	99.6	103.5	105.5	117.3	100.1	95.1	97.1
	Flesh (Fe)	63.3	64.5	71.7	66.1	62.8	64.1	64.1	65.4	72.7	64.4	61.2	62.5	65.0	66.3	73.7	62.8	59.7	61.0
	Bone (Fe)	76.8	78.3	87.1	80.3	76.3	77.9	77.8	79.4	88.3	78.3	74.4	75.9	78.9	80.5	89.4	76.3	72.5	74.0
	Scale (Fe)	72.6	74.0	82.3	75.8	72.1	73.6	73.6	75.0	83.4	74.0	70.3	71.8	74.5	76.0	84.5	72.1	68.5	70.0
	Fin (Fe)	56.8	57.9	64.4	59.3	56.4	57.6	57.5	58.7	65.2	57.8	55.0	56.1	58.3	59.5	66.1	56.4	53.6	54.7
	Gills (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Flesh (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Bone (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Scale (Se)	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1
	Fin (Se)	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1

Pulau Kambing	Fork (cm)	17.2	17.5	17.8	17.9	17.3	17.4	16.0	16.3	16.5	18.3	17.6	17.7	14.9	15.2	15.4	18.7	18.0	18.1
	Total (cm)	19.2	19.6	19.9	20.1	19.4	19.5	17.9	18.3	18.5	20.5	19.8	19.9	16.8	17.1	17.3	21.0	20.2	20.3
	Weight (g)	195.4	199.3	202.0	204.2	197.2	198.1	182.5	186.2	188.7	208.7	201.5	202.5	170.5	173.9	176.3	213.3	205.9	207.0
	Gills (Cr)	5.8	6.0	6.0	6.1	5.9	5.9	5.5	5.6	5.6	6.2	6.0	6.0	5.1	5.2	5.3	6.4	6.1	6.2
	Flesh (Cr)	13.2	13.5	13.7	13.8	13.4	13.4	12.4	12.6	12.8	14.1	13.7	13.7	11.6	11.8	11.9	14.5	14.0	14.0
	Bone (Cr)	29.1	29.6	30.1	30.4	29.3	29.5	27.1	27.7	28.1	31.0	30.0	30.1	25.4	25.9	26.2	31.7	30.6	30.8
	Scale (Cr)	19.8	20.1	20.4	20.6	19.9	20.0	18.5	18.8	19.1	21.1	20.4	20.5	17.2	17.6	17.8	21.6	20.8	20.9
	Fin (Cr)	21.3	21.7	22.0	22.3	21.5	21.6	19.9	20.3	20.6	22.8	22.0	22.1	18.6	19.0	19.2	23.3	22.5	22.6
	Gills (Cu)	9.4	9.6	9.8	9.9	9.5	9.6	8.8	9.0	9.1	10.1	9.7	9.8	8.2	8.4	8.5	10.3	9.9	10.0
	Flesh (Cu)	10.5	10.7	10.9	11.0	10.6	10.7	9.8	10.0	10.2	11.2	10.9	10.9	9.2	9.4	9.5	11.5	11.1	11.2
	Bone (Cu)	4.5	4.5	4.6	4.7	4.5	4.5	4.2	4.2	4.3	4.8	4.6	4.6	3.9	4.0	4.0	4.9	4.7	4.7
	Scale (Cu)	5.6	5.7	5.8	5.9	5.7	5.7	5.3	5.4	5.4	6.0	5.8	5.8	4.9	5.0	5.1	6.1	5.9	6.0
	Fin (Cu)	6.0	6.1	6.2	6.2	6.0	6.1	5.6	5.7	5.8	6.4	6.2	6.2	5.2	5.3	5.4	6.5	6.3	6.3
	Gills (Fe)	106.1	108.2	109.7	110.8	107.0	107.5	99.1	101.0	102.4	113.3	109.4	109.9	92.5	94.4	95.7	115.8	111.8	112.3
	Flesh (Fe)	66.6	67.9	68.8	69.6	67.2	67.5	62.2	63.4	64.3	71.1	68.7	69.0	58.1	59.2	60.1	72.7	70.2	70.5
	Bone (Fe)	80.8	82.5	83.6	84.5	81.6	82.0	75.5	77.0	78.1	86.3	83.4	83.8	70.5	71.9	72.9	88.2	85.2	85.6
	Scale (Fe)	76.4	77.9	79.0	79.8	77.1	77.5	71.4	72.8	73.8	81.6	78.8	79.2	66.6	68.0	68.9	83.4	80.5	80.9
	Fin (Fe)	59.7	60.9	61.8	62.4	60.3	60.6	55.8	56.9	57.7	63.8	61.6	61.9	52.1	53.2	53.9	65.2	63.0	63.3
	Gills (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Flesh (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Bone (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Scale (Se)	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0
	Fin (Se)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0

	Fork (cm)	17.3	17.6	17.8	18.0	17.1	17.5	17.5	17.8	18.1	18.3	17.4	17.7	17.8	18.1	18.4	18.6	17.7	18.0
	Total (cm)	19.3	19.7	20.0	20.2	19.2	19.6	19.6	20.0	20.3	20.5	19.5	19.9	20.0	20.4	20.6	20.9	19.8	20.2
	Weight (g)	192.1	195.9	198.6	200.7	190.8	194.8	195.3	199.2	202.0	204.1	193.9	198.0	198.6	202.5	205.3	207.5	197.2	201.4
	Gills (Cr)	5.7	5.9	5.9	6.0	5.7	5.8	5.8	5.9	6.0	6.1	5.8	5.9	5.9	6.0	6.1	6.2	5.9	6.0
	Flesh (Cr)	13.0	13.3	13.5	13.6	12.9	13.2	13.2	13.5	13.7	13.8	13.1	13.4	13.5	13.7	13.9	14.1	13.4	13.6
	Bone (Cr)	28.6	29.1	29.5	29.9	28.4	29.0	29.1	29.6	30.0	30.4	28.8	29.5	29.5	30.1	30.5	30.9	29.3	30.0
	Scale (Cr)	19.4	19.8	20.1	20.3	19.3	19.7	19.7	20.1	20.4	20.6	19.6	20.0	20.1	20.5	20.8	21.0	19.9	20.4
	Fin (Cr)	21.0	21.4	21.7	21.9	20.8	21.3	21.3	21.7	22.0	22.3	21.2	21.6	21.7	22.1	22.4	22.6	21.5	22.0
	Gills (Cu)	9.3	9.5	9.6	9.7	9.2	9.4	9.4	9.6	9.8	9.9	9.4	9.6	9.6	9.8	9.9	10.0	9.5	9.7
	Flesh (Cu)	10.4	10.6	10.7	10.8	10.3	10.5	10.5	10.7	10.9	11.0	10.5	10.7	10.7	10.9	11.1	11.2	10.6	10.9
	Bone (Cu)	4.4	4.5	4.5	4.6	4.4	4.4	4.5	4.5	4.6	4.7	4.4	4.5	4.5	4.6	4.7	4.7	4.5	4.6
Chendering	Scale (Cu)	5.5	5.6	5.7	5.8	5.5	5.6	5.6	5.7	5.8	5.9	5.6	5.7	5.7	5.8	5.9	6.0	5.7	5.8
	Fin (Cu)	5.9	6.0	6.1	6.1	5.8	5.9	6.0	6.1	6.2	6.2	5.9	6.0	6.1	6.2	6.3	6.3	6.0	6.1
	Gills (Fe)	104.3	106.4	107.8	109.0	103.5	105.7	106.0	108.1	109.6	110.8	105.3	107.5	107.8	109.9	111.4	112.6	107.0	109.3
	Flesh (Fe)	65.5	66.8	67.7	68.4	65.0	66.4	66.5	67.9	68.8	69.5	66.1	67.5	67.7	69.0	70.0	70.7	67.2	68.6
	Bone (Fe)	79.5	81.1	82.2	83.1	78.9	80.6	80.8	82.4	83.6	84.4	80.2	81.9	82.2	83.8	84.9	85.8	81.6	83.3
	Scale (Fe)	75.1	76.6	77.7	78.5	74.6	76.2	76.4	77.9	79.0	79.8	75.8	77.4	77.6	79.2	80.3	81.1	77.1	78.7
	Fin (Fe)	58.7	59.9	60.7	61.4	58.3	59.6	59.7	60.9	61.7	62.4	59.3	60.6	60.7	61.9	62.8	63.4	60.3	61.6
	Gills (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Flesh (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Bone (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Scale (Se)	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1
	Fin (Se)	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0

Note: Size measurements, fork length and total length is centimetre (cm), weight in gram (g); metal values as mg/kg and batches 1-3 indicate samples from 3 months apart (February, May and August)

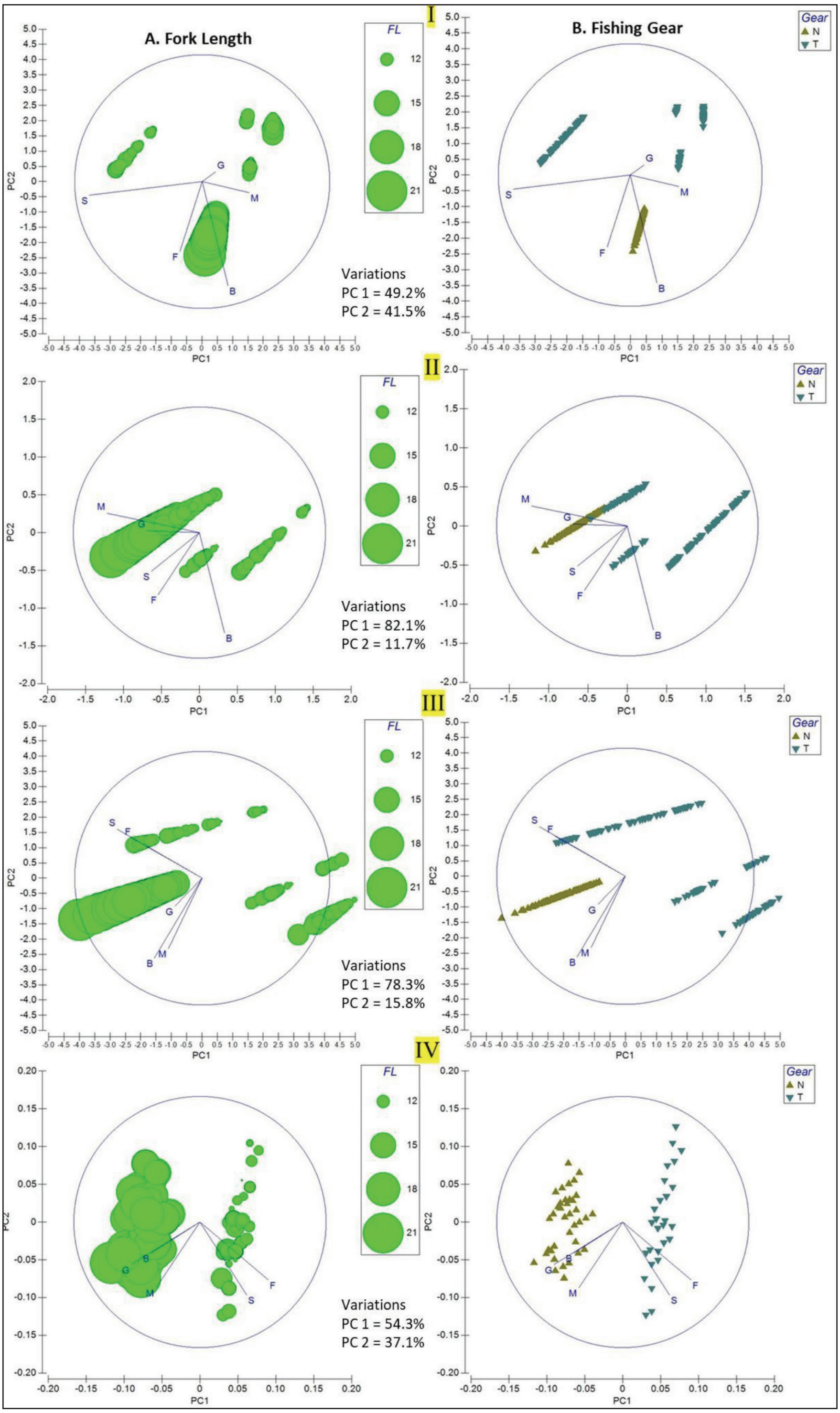

Figure 2: Principal component analysis for fish fork length and fishing gear used. The abbreviations I-IV indicate the metals Cr, Cu, Fe and Se; FL = fork length and gears, N = net and T = trap (or bubu)

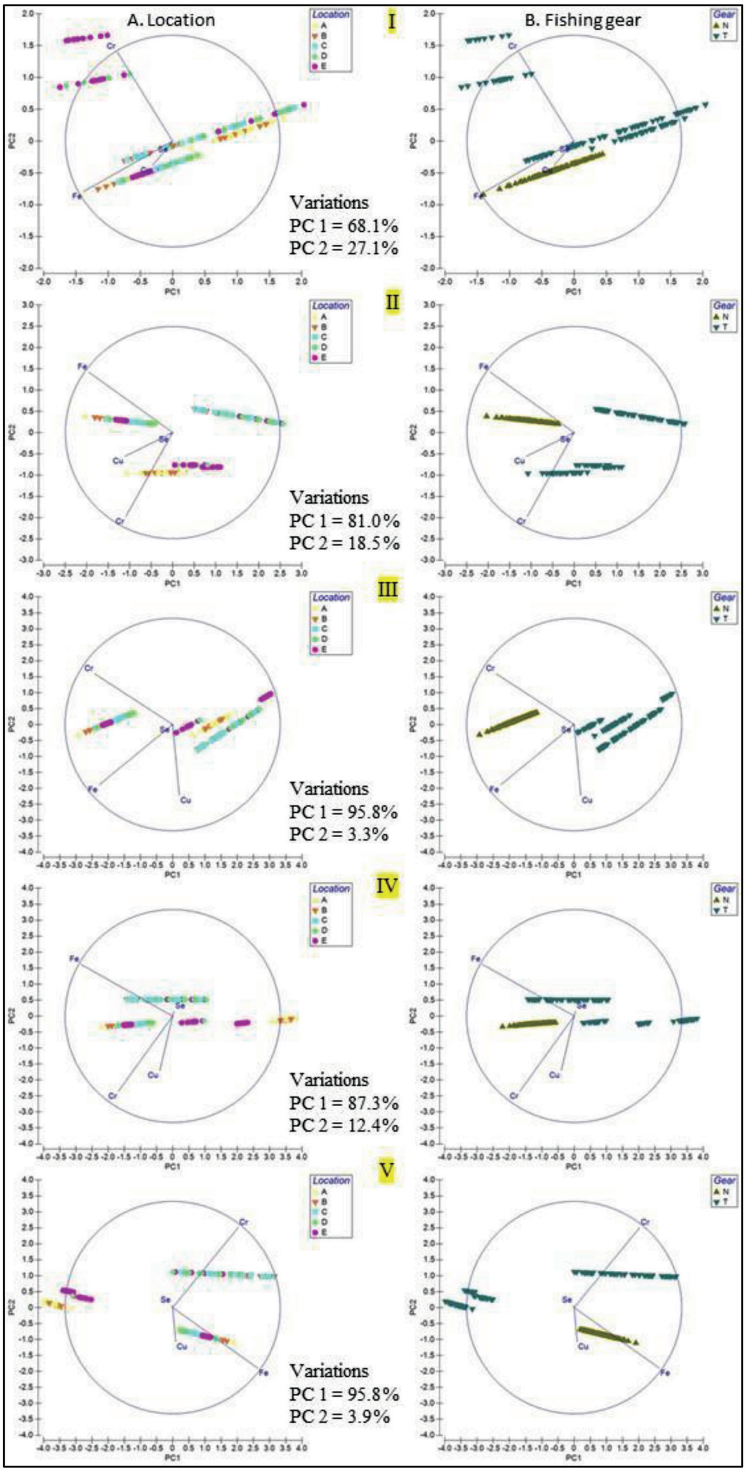

Figure 3: Principal component analysis for location and fishing gear used. The abbreviations I-V indicate fish organs = gills, flesh, bone, scales, and fins; Locations A-E = Kuala Besut, Setiu, Batu Rakit, Pulau Kambing

Table 2: Raw data for size, weight and metals accumulated in *Nemipterus peronii* caught using the trap (or *bubu*)

	Criteria	Batch 1 (Trap; n = 8)								Batch 2 (Trap; n = 8)								Batch 3 (Trap; n = 8)			
	Fork (cm)	11.7	11.8	12.1	11.7	12.0	12.1	11.6	12.0	13.6	13.7	14.0	10.9	11.2	11.2	13.5	11.2	12.6	12.7	13.0	11.3
	Total (cm)	13.1	13.2	13.5	13.0	13.4	13.5	13.0	13.4	15.2	15.3	15.6	12.1	12.5	12.6	15.0	12.5	14.1	14.2	14.5	12.6
	Weight (g)	129.2	130.5	133.1	128.5	132.2	133.1	128.2	132.1	149.4	150.9	153.9	119.7	123.1	123.9	148.2	123.0	139.0	140.3	143.1	124.0
	Gills (Cr)	4.6	5.2	4.7	5.1	4.7	5.3	4.5	5.2	5.3	6.0	5.4	4.7	4.4	4.9	5.2	4.9	4.9	5.5	5.1	4.9
	Flesh (Cr)	17.2	19.4	17.7	19.1	17.6	19.8	17.0	19.6	19.8	22.4	20.4	17.8	16.3	18.4	19.7	18.3	18.5	20.8	19.0	18.4
	Bone (Cr)	8.0	9.1	8.3	8.9	8.2	9.3	8.0	9.2	9.3	10.5	9.6	8.3	7.7	8.6	9.2	8.6	8.6	9.8	8.9	8.6
	Scale (Cr)	5.2	5.9	5.4	5.8	5.3	6.0	5.2	5.9	6.0	6.8	6.2	5.4	5.0	5.6	6.0	5.5	5.6	6.3	5.8	5.6
	Fin (Cr)	4.0	4.5	4.1	4.5	4.1	4.6	4.0	4.6	4.6	5.2	4.8	4.1	3.8	4.3	4.6	4.3	4.3	4.9	4.4	4.3
	Gills (Cu)	8.1	9.2	8.3	9.0	8.3	9.3	8.0	9.3	9.4	10.6	9.7	8.4	7.7	8.7	9.3	8.6	8.7	9.8	9.0	8.7
	Flesh (Cu)	8.5	9.6	8.8	9.5	8.7	9.8	8.4	9.7	9.8	11.1	10.1	8.8	8.1	9.1	9.8	9.0	9.1	10.3	9.4	9.1
	Bone (Cu)	4.4	4.9	4.5	4.9	4.5	5.0	4.3	5.0	5.1	5.7	5.2	4.5	4.2	4.7	5.0	4.7	4.7	5.3	4.8	4.7
Kuala Besut	Scale (Cu)	3.1	3.5	3.2	3.4	3.2	3.6	3.1	3.5	3.6	4.0	3.7	3.2	2.9	3.3	3.5	3.3	3.3	3.7	3.4	3.3
	Fin (Cu)	3.2	3.7	3.3	3.6	3.3	3.7	3.2	3.7	3.8	4.2	3.9	3.4	3.1	3.5	3.7	3.5	3.5	3.9	3.6	3.5
	Gills (Fe)	69.8	78.8	71.9	77.6	71.4	80.4	69.2	79.8	80.7	91.2	83.1	72.3	66.5	74.9	80.1	74.3	75.0	84.8	77.3	74.9
	Flesh (Fe)	43.6	49.3	44.9	48.5	44.6	50.3	43.3	49.9	50.5	57.0	52.0	45.2	41.6	46.8	50.1	46.5	46.9	53.0	48.3	46.8
	Bone (Fe)	44.7	50.5	46.1	49.8	45.8	51.5	44.4	51.2	51.7	58.5	53.3	46.4	42.6	48.0	51.3	47.6	48.1	54.4	49.6	48.0
	Scale (Fe)	19.8	22.3	20.4	22.0	20.2	22.8	19.6	22.6	22.9	25.8	23.6	20.5	18.8	21.2	22.7	21.1	21.3	24.0	21.9	21.2
	Fin (Fe)	13.0	14.7	13.4	14.5	13.3	15.0	12.9	14.9	15.0	17.0	15.5	13.5	12.4	13.9	14.9	13.8	14.0	15.8	14.4	14.0
	Gills (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Flesh (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Bone (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Scale (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Fin (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

	Fork (cm)	11.9	12.0	12.2	11.8	12.1	12.2	11.8	12.1	12.8	11.8	12.2	12.4	12.3	12.3	12.7	12.1	11.9	12.3	12.1	12.1
	Total (cm)	13.3	13.4	13.7	13.2	13.6	13.7	13.2	13.5	14.3	13.2	13.6	13.9	13.7	13.8	14.2	13.6	13.3	13.7	13.6	13.6
	Weight (g)	131.5	132.8	135.5	130.8	134.5	135.5	130.5	134.4	140.9	130.3	134.0	137.0	136.4	136.6	140.5	134.5	131.1	135.0	134.5	134.7
	Gills (Cr)	6.3	6.4	7.2	7.0	7.2	6.5	7.0	6.5	5.0	5.2	4.7	5.4	6.6	6.6	7.5	7.2	4.6	5.3	6.5	6.5
	Flesh (Cr)	6.7	6.8	7.7	7.4	7.6	6.9	7.4	6.9	18.7	19.4	17.8	20.3	7.0	7.0	8.0	7.6	17.4	20.1	6.9	6.9
	Bone (Cr)	8.0	8.0	9.1	8.8	9.0	8.2	8.7	8.1	8.8	9.1	8.3	9.5	8.3	8.3	9.4	9.0	8.1	9.4	8.1	8.2
	Scale (Cr)	44.5	44.9	50.7	48.9	50.4	45.8	48.8	45.5	5.7	5.9	5.4	6.2	46.1	46.2	52.6	50.4	5.3	6.1	45.5	45.6
	Fin (Cr)	14.1	14.3	16.1	15.6	16.0	14.6	15.5	14.4	4.4	4.5	4.2	4.7	14.7	14.7	16.7	16.0	4.1	4.7	14.4	14.5
	Gills (Cu)	6.5	6.5	7.4	7.1	7.3	6.7	7.1	6.6	8.8	9.1	8.4	9.6	6.7	6.7	7.7	7.3	8.2	9.5	6.6	6.6
	Flesh (Cu)	4.6	4.6	5.2	5.0	5.2	4.7	5.0	4.7	9.3	9.6	8.8	10.1	4.8	4.8	5.4	5.2	8.6	9.9	4.7	4.7
	Bone (Cu)	7.0	7.1	8.0	7.8	8.0	7.3	7.7	7.2	4.8	4.9	4.5	5.2	7.3	7.3	8.3	8.0	4.4	5.1	7.2	7.2
Setiu	Scale (Cu)	3.4	3.4	3.9	3.7	3.8	3.5	3.7	3.5	3.4	3.5	3.2	3.7	3.5	3.5	4.0	3.8	3.1	3.6	3.5	3.5
	Fin (Cu)	4.1	4.1	4.7	4.5	4.6	4.2	4.5	4.2	3.5	3.7	3.4	3.8	4.2	4.2	4.8	4.6	3.3	3.8	4.2	4.2
	Gills (Fe)	96.8	97.8	110.4	106.6	109.7	99.8	106.3	99.0	76.1	78.7	72.4	82.8	100.4	100.6	114.5	109.7	70.8	81.6	99.0	99.2
	Flesh (Fe)	43.5	43.9	49.6	47.8	49.2	44.8	47.7	44.4	47.6	49.2	45.2	51.7	45.1	45.2	51.4	49.2	44.3	51.0	44.4	44.5
	Bone (Fe)	49.8	50.3	56.8	54.9	56.4	51.3	54.7	50.9	48.8	50.5	46.4	53.1	51.7	51.8	58.9	56.4	45.4	52.3	51.0	51.1
	Scale (Fe)	75.7	76.4	86.3	83.3	85.7	77.9	83.1	77.3	21.6	22.3	20.5	23.5	78.5	78.6	89.5	85.7	20.1	23.1	77.4	77.5
	Fin (Fe)	58.3	58.9	66.5	64.2	66.0	60.0	64.0	59.6	14.2	14.7	13.5	15.4	60.4	60.6	68.9	66.0	13.2	15.2	59.6	59.7
	Gills (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Flesh (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Bone (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Scale (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Fin (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Batu Rakit	Fork (cm)	11.1	11.2	11.4	11.0	11.3	11.4	11.0	11.3	12.5	12.1	12.6	12.1	12.0	12.1	12.1	11.5	12.3	12.4	11.9	11.8
	Total (cm)	12.4	12.5	12.8	12.3	12.7	12.8	12.3	12.7	14.0	13.5	14.0	13.5	13.4	13.5	13.5	12.9	13.7	13.8	13.3	13.2
	Weight (g)	124.6	125.9	128.4	123.9	127.5	128.3	128.5	127.4	139.3	134.4	139.4	134.0	132.9	133.8	134.0	127.8	136.3	137.3	132.2	131.1
	Gills (Cr)	5.3	4.4	5.9	5.3	4.4	5.4	4.5	4.4	7.4	7.2	7.4	6.5	7.1	6.4	7.1	6.2	7.3	6.6	7.0	6.3
	Flesh (Cr)	5.7	4.7	6.3	5.6	4.6	5.7	4.7	4.7	7.9	7.6	7.9	6.9	7.5	6.9	7.6	6.5	7.7	7.0	7.5	6.7
	Bone (Cr)	6.7	5.5	7.4	6.6	5.5	6.8	5.6	5.5	9.3	9.0	9.3	8.1	8.9	8.1	9.0	7.7	9.1	8.3	8.9	7.9
	Scale (Cr)	37.5	30.9	41.5	37.1	30.6	37.9	31.3	30.9	52.1	50.3	52.2	45.3	49.7	45.3	50.1	43.2	51.0	46.4	49.5	44.3
	Fin (Cr)	11.9	9.8	13.2	11.8	9.7	12.0	9.9	9.8	16.6	16.0	16.6	14.4	15.8	14.4	15.9	13.7	16.2	14.7	15.7	14.1
	Gills (Cu)	5.5	4.5	6.0	5.4	4.5	5.5	4.5	4.5	7.6	7.3	7.6	6.6	7.2	6.6	7.3	6.3	7.4	6.8	7.2	6.4
	Flesh (Cu)	3.9	3.2	4.3	3.8	3.2	3.9	3.2	3.2	5.4	5.2	5.4	4.7	5.1	4.7	5.2	4.5	5.3	4.8	5.1	4.6
	Bone (Cu)	5.9	4.9	6.6	5.9	4.9	6.0	5.0	4.9	8.3	8.0	8.3	7.2	7.9	7.2	7.9	6.8	8.1	7.4	7.8	7.0
	Scale (Cu)	2.9	2.4	3.2	2.8	2.3	2.9	2.4	2.4	4.0	3.8	4.0	3.4	3.8	3.4	3.8	3.3	3.9	3.5	3.8	3.4
	Fin (Cu)	3.4	2.8	3.8	3.4	2.8	3.5	2.9	2.8	4.8	4.6	4.8	4.2	4.6	4.2	4.6	4.0	4.7	4.3	4.5	4.1
	Gills (Fe)	81.7	67.4	90.5	80.9	66.7	82.5	68.1	67.4	113.5	109.6	113.6	98.7	108.3	98.6	109.2	94.1	111.1	101.1	107.8	96.5
	Flesh (Fe)	36.6	30.2	40.6	36.3	29.9	37.0	30.5	30.2	50.9	49.2	51.0	44.3	48.6	44.2	49.0	42.2	49.9	45.4	48.4	43.3
	Bone (Fe)	42.0	34.7	46.6	41.6	34.3	42.5	35.0	34.7	58.4	56.4	58.5	50.8	55.8	50.7	56.2	48.4	57.2	52.0	55.5	49.7
	Scale (Fe)	63.8	52.6	70.7	63.2	52.1	64.5	53.2	52.6	88.7	85.6	88.8	77.1	84.6	77.0	85.3	73.5	86.8	79.0	84.2	75.4
	Fin (Fe)	49.2	40.6	54.4	48.7	40.2	49.7	41.0	40.6	68.3	65.9	68.4	59.4	65.2	59.3	65.7	56.6	66.9	60.8	64.9	58.1
	Gills (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Flesh (Se)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Bone (Se)	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Scale (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Fin (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Pulau Kambing	Fork (cm)	11.8	11.9	12.1	11.7	12.0	12.1	11.7	12.0	11.1	11.0	10.1	11.2	11.8	11.0	10.9	9.6	10.7	10.3	10.6	11.7
	Total (cm)	13.2	13.3	13.6	13.1	13.5	13.6	13.1	13.5	12.4	12.3	11.3	12.5	13.2	12.3	12.2	10.8	11.9	11.5	11.8	13.0
	Weight (g)	132.7	134.0	136.7	132.0	135.8	136.7	136.8	135.6	123.5	122.4	113.5	125.4	132.9	123.5	122.5	108.1	119.9	115.7	119.1	131.2
	Gills (Cr)	15.9	16.0	16.4	17.9	17.0	16.4	16.4	16.2	6.6	5.9	4.9	4.4	6.1	5.3	5.6	4.6	5.5	4.9	4.1	5.5
	Flesh (Cr)	13.8	13.9	14.2	15.5	14.7	14.2	14.2	14.1	7.0	6.3	5.2	4.7	6.5	5.6	6.0	4.9	5.9	5.3	4.3	5.9
	Bone (Cr)	14.2	14.3	14.6	16.0	15.2	14.6	14.6	14.5	8.3	7.4	6.1	5.5	7.7	6.6	7.1	5.8	6.9	6.2	5.1	6.9
	Scale (Cr)	9.4	9.5	9.7	10.6	10.1	9.7	9.7	9.6	46.2	41.4	34.2	30.8	43.0	37.0	39.7	32.4	38.8	34.7	28.6	38.7
	Fin (Cr)	12.4	12.5	12.7	13.9	13.3	12.7	12.8	12.6	14.7	13.2	10.9	9.8	13.7	11.8	12.6	10.3	12.3	11.0	9.1	12.3
	Gills (Cu)	7.4	7.4	7.6	8.3	7.9	7.6	7.6	7.5	6.7	6.0	5.0	4.5	6.3	5.4	5.8	4.7	5.6	5.0	4.2	5.6
	Flesh (Cu)	8.0	8.1	8.3	9.0	8.6	8.3	8.3	8.2	4.8	4.3	3.5	3.2	4.4	3.8	4.1	3.3	4.0	3.6	3.0	4.0
	Bone (Cu)	7.0	7.1	7.2	7.9	7.5	7.2	7.2	7.2	7.3	6.6	5.4	4.9	6.8	5.9	6.3	5.1	6.1	5.5	4.5	6.1
	Scale (Cu)	4.3	4.3	4.4	4.8	4.6	4.4	4.4	4.4	3.5	3.1	2.6	2.3	3.3	2.8	3.0	2.5	3.0	2.6	2.2	2.9
	Fin (Cu)	4.9	4.9	5.0	5.5	5.2	5.0	5.0	5.0	4.2	3.8	3.1	2.8	3.9	3.4	3.6	3.0	3.6	3.2	2.6	3.6
	Gills (Fe)	104.4	105.4	107.5	117.3	111.8	107.5	107.6	106.7	100.7	90.1	74.4	67.1	93.7	80.6	86.4	70.6	84.5	75.5	62.3	84.3
	Flesh (Fe)	39.4	39.8	40.6	44.3	42.2	40.6	40.7	40.3	45.2	40.5	33.4	30.1	42.0	36.2	38.8	31.7	37.9	33.9	28.0	37.8
	Bone (Fe)	50.7	51.2	52.2	56.9	54.3	52.2	52.2	51.8	51.8	46.4	38.3	34.6	48.2	41.5	44.4	36.3	43.5	38.9	32.1	43.4
	Scale (Fe)	25.0	25.3	25.8	28.1	26.8	25.8	25.8	25.6	78.6	70.4	58.1	52.5	73.2	63.0	67.5	55.1	66.0	59.0	48.7	65.9
	Fin (Fe)	36.8	37.2	37.9	41.4	39.4	37.9	38.0	37.6	60.6	54.3	44.8	40.4	56.4	48.5	52.0	42.5	50.9	45.5	37.5	50.7
	Gills (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1
	Flesh (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Bone (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.1
	Scale (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1
	Fin (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

	Fork (cm)	11.9	12.0	12.2	11.8	12.2	12.2	11.8	12.1	10.8	10.5	10.8	11.9	11.4	11.8	12.2	11.3	12.0	12.1	12.3	11.9
	Total (cm)	13.3	13.4	13.7	13.2	13.6	13.7	13.2	13.6	12.1	11.7	12.0	13.3	12.8	13.2	13.7	12.6	13.4	13.5	13.8	13.3
	Weight (g)	133.1	134.4	137.1	132.4	136.2	137.1	132.1	136.0	121.9	117.7	121.0	133.4	133.5	132.3	137.9	127.3	134.9	136.3	139.0	134.2
	Gills (Cr)	23.0	23.3	23.7	21.7	22.3	23.6	22.7	21.3	5.6	5.0	4.1	5.6	4.6	4.6	16.5	15.2	16.2	16.3	16.6	18.2
	Flesh (Cr)	13.4	13.6	13.8	12.6	13.0	13.8	13.3	12.4	6.0	5.3	4.4	6.0	4.9	4.9	14.3	13.2	14.0	14.1	14.4	15.7
	Bone (Cr)	5.8	5.9	6.0	5.5	5.6	6.0	5.8	5.4	7.1	6.3	5.2	7.0	5.8	5.8	14.8	13.6	14.4	14.6	14.9	16.2
	Scale (Cr)	9.4	9.5	9.7	8.8	9.1	9.6	9.2	8.7	39.4	35.3	29.1	39.4	32.5	32.1	9.8	9.0	9.6	9.7	9.9	10.8
	Fin (Cr)	9.3	9.4	9.6	8.8	9.0	9.6	9.2	8.6	12.5	11.2	9.2	12.5	10.3	10.2	12.9	11.9	12.6	12.7	13.0	14.1
	Gills (Cu)	9.5	9.6	9.8	8.9	9.2	9.7	9.4	8.8	5.7	5.1	4.2	5.7	4.7	4.7	7.7	7.1	7.5	7.6	7.7	8.4
	Flesh (Cu)	7.4	7.5	7.6	7.0	7.2	7.6	7.3	6.8	4.1	3.6	3.0	4.1	3.4	3.3	8.3	7.7	8.2	8.2	8.4	9.2
	Bone (Cu)	4.1	4.1	4.2	3.9	4.0	4.2	4.0	3.8	6.2	5.6	4.6	6.2	5.1	5.1	7.3	6.7	7.1	7.2	7.4	8.0
Chendering	Scale (Cu)	4.2	4.3	4.4	4.0	4.1	4.3	4.2	3.9	3.0	2.7	2.2	3.0	2.5	2.4	4.5	4.1	4.4	4.4	4.5	4.9
	Fin (Cu)	3.3	3.3	3.4	3.1	3.2	3.4	3.3	3.1	3.6	3.2	2.7	3.6	3.0	3.0	5.0	4.7	4.9	5.0	5.1	5.6
	Gills (Fe)	104.4	105.4	107.5	98.0	100.9	106.8	102.9	96.2	85.9	76.8	63.4	85.7	70.7	70.0	108.5	100.1	106.1	107.2	109.3	119.3
	Flesh (Fe)	37.1	37.5	38.2	34.9	35.9	38.0	36.6	34.2	38.6	34.5	28.4	38.5	31.7	31.4	41.0	37.8	40.1	40.5	41.3	45.1
	Bone (Fe)	28.0	28.3	28.8	26.3	27.1	28.7	27.6	25.8	44.2	39.5	32.6	44.1	36.4	36.0	52.6	48.6	51.5	52.0	53.1	57.9
	Scale (Fe)	22.3	22.5	22.9	20.9	21.5	22.8	21.9	20.5	67.1	60.0	49.5	67.0	55.3	54.7	26.0	24.0	25.5	25.7	26.2	28.6
	Fin (Fe)	23.7	23.9	24.4	22.3	22.9	24.3	23.4	21.9	51.7	46.2	38.1	51.6	42.6	42.1	38.2	35.3	37.4	37.8	38.5	42.1
	Gills (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Flesh (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
	Bone (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
	Scale (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Fin (Se)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Note: Size measurements, fork length and total length is centimetre (cm), weight in gram (g); metal values as mg/kg and batches 1-3 indicate samples from 3 months apart (February, May and August)

Discussion

Nemipterus peronii is important to coastal assemblages in Australia and China (Hung *et al.*, 2017). In Malaysia, this fish is part of the capture economy. It also means that *N. peronii* is a sub-dietary component, especially in the coastal communities of Terengganu. In this study, the catch method, either by *bubu* or fishing net was used to demarcate the origin of *N. peronii* samples. Although samples from shallow water (nearshore) environments possessed shorter fork lengths, all 42 samples regardless of nearshore or open water had a 0.892:1 ratio for their fork-to-total length. It means that all *N. peronii* fall within the adult-size class. Altogether, this finding shows that the *N. peronii* samples have satisfactory morphology (Sainsbury & Whitelaw, 1984; Wu *et al.*, 2008) and rule out assumptions of stress or poor health. A total of 6 netted and 8 trapped fishes were needed to reach a cumulative weight of 1 kg and the trapped fish (by using *bubu*) were sold cheaper at ± USD 1 less per kg fish.

A single fish caught using *bubu* contains 281.6 - 419.1 mg/kg of Cr, Cu, Fe and Se whereas for netted fish it was 503.5 - 536.2 mg/kg. However, since only the flesh is edible, the cumulative total of metals for trapped fish was 51.5 - 75.8 mg/kg and 88.3 - 94.1 mg/kg for the netted fish. In addition, the Fe detected in flesh and bones were at higher concentrations, in the range of 72 - 86 mg/kg. This concentration is particularly high, exceeding the 4 - 5 mg/kg range found in other marine fish (Silva *et al.*, 2023). While some of the Fe may have originated from haemoglobin, there is the possibility that free ionic Fe is circulating within the trophic network of nearshore and offshore areas. Terengganu has had a history of land reclamation and sea sand mining since 2010. Thus, possible sources for free ionic metals may include surfaced earthen metals and seawater weathering of steel structures.

Offshore baited videos revealed that *N. peronii* constitutes approximately 5.9% of the total benthic fish populations (Baletaud *et al.*, 2022). This richness of *N. peronii* corroborates with the stock replenishing rate and the voracious carnivore habits of a generalist feeder. Considering its behaviour of predating fish and crustaceans (Saraswati & Perdhana, 2020), the relatively high Cr, Cu, Se, and Fe N. peronii could be due to tier-1 carnivore biomagnification. Also, calcium-analogue affinity has enabled fish to withstand metal toxicity naturally. Small quantities of calcium could be replaced with metals of higher affinity (Wood, 2011). This metal-storing process is possible through sequestration where the bony structures of fish could uptake metals (Tabinda & Muhammad, 2013). Perhaps this accounts for the presence of Cr, Cu, Fe, and Se in bones, fins, scales and (hard parts of) gills for the *N. peronii* samples.

On the contrary, Abd-Kadir *et al.* (2018) reported that *N. peronii* flesh samples from Pulau Kambing and Kuala Besut contained 4.2 - 5.3 mg/kg of Cr, which was below the 6.3 - 18.8 mg/kg range detected in the present study. Although Abd-Kadir *et al.* (2018) did not report the catch method (or source), comparatively, there is agreement that high concentrations of Cr could be present in the flesh of *N. peronii*. In addition, the fish from open water contained more Cr than those from nearshore. This peculiarity relates to shallow-to-deep water sediment drifts (Pati *et al.*, 2021) as a response to unsettling metals in shallow benthic environments (Nelson *et al.*, 2015). As mentioned, biomagnification corresponds to prey-predator relationships and it is prominent with the larger *N. peronii from* open water, which could be associated with deeper water columns than the nearshore environments.

In the shallow nearshore of Terengganu, seawalls have created a zone where sediments remain unsettled. The diversity of marine species becomes selective and limited. Resource competition reduces the size of prey,which negatively affects the size of *N. peronii*. On the contrary, areas with poor productivity have low organic material (*i.e.*, faeces, remnants, and debris) circulation and in return, the chances of metals becoming partitioned also decreases (Talukder *et al.*, 2012). It accounts for the reduced uptake of free metals along the trophic network and the resultant poorer biomagnification of Cr, Cu, Fe, and Se in organs of nearshore *N. peronii*. For this comparison, it is agreed that magnitude of biomagnification relates to the quantity of food uptake (Niu *et al.*, 2021) and the relative size of prey (Biswas *et al.*, 2021). Overall, the *bubu* deployed in the shallow nearshore environments captured *N. peronii* with lower concentrations of Cr, Cu, Fe, and Se in their organs. It means these fish were less subject to biomagnification and could be regarded safe-to-consume despite mature fish having a smaller size range.

Conclusion

Demersal fish like *N. peronii* usually have a set of prey. In the first assumption, metal uptake occurs from biomagnification which is prominent in open-water environments due to the availability of metals from sediment drifts. This accounts for the higher concentration of Cr, Cu, Fe, and Se in the net-caught fish in open water areas off the coast of Terengganu. In the second assumption, smaller sized *N. peronii* within nearshore environments endure less biomagnification because food sources were limited or the prey was smaller in size. In return, the fish appears to have less concentration of Cr, Cu, Fe, and Se in their organs. The comparative catch method used in this study is indicative of fish origin. Overall, fish from nearshore environments though smaller in sizes were thought to be much safer to consume due to lower metal concentrations than the larger fish from open water.

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