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Original Research Article

The lipid content and fatty acid composition of four eastern central Pacific native fish species

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ABSTRACT

Fish is an important source of nutritious n-3 fatty acids, which are necessary for the prevention of cardiovascular and neurological diseases. The lipid content and fatty acid composition of economically important fishes from the eastern central Pacific, namely, *Caranx caballus*, *Cynoscion phoxocephalus*, *Lutjanus guttatus* and *Scomberomorus sierra*, were determined. Seasonal variations in their n-3 fatty acid composition were investigated as well. The lipid content of all these fish species was less than 4% by weight. In general, the studied species have moderate proportions of n-3 fatty acids. *C. caballus* was the fish species with the highest concentration of eicosapentaenoic acid (EPA) plus docosahexaenoic acid (DHA) (898 mg/100 g) followed by *S. sierra* (596 mg/100 g), *C. phoxocephalus* (421 mg/100 g) and *L. guttatus* (342 mg/100 g). The n-3/n-6 ratio of all the species studied ranged from 4.86 to 8.12. Results of this study indicate that all these fish species are highly recommended as a source of low calorie food that can meet the n-3 fatty acid dietary requirements of the Panamanian population.

1. Introduction

According to the Food and Agriculture Organization (FAO), it is estimated that 3 billion people around the world consume fish and other marine organisms as a source of proteins (Tveteras et al., 2012). In addition to providing people with high-quality proteins, fish consumption satisfies nutritional requirements for essential n-3 fatty acids, primarily eicosapentaenoic (EPA; 20:5 n-3) and docosahexaenoic (DHA; 22:6 n-3) acids, which are two long chain polyunsaturated fatty acids (LC-PUFAs) mainly present in fish (Connor, 2000). Surveys aimed at establishing the influence of n-3 fatty acids on various health conditions have shown their positive effects, both in disease prevention and health status improvement.

The human brain consists of 60% lipids, of which 33% are n-3 fatty acids (Bourre and Dumont, 1991). These fatty acids mediate the function of neuronal cells by regulating receptors and enzymes (Yehuda et al., 1994). DHA is essential for normal fetal brain and cognitive development as the formation of neuron synapses in the brain depends strongly on the integration of this fatty acid into growing neurons (Jensen, 2006). Research trials conducted on infants have suggested that it is necessary to incorporate an adequate quantity of DHA into their diets for correct maturation of the visual cortex and retina (Uauy et al., 2003).

Clinical studies indicated a direct relationship between a decline in cognitive function and memory loss with a deficiency in dietary n-3 fatty acids (Bourre, 2004; Fontani et al., 2005; Yurko-Mauro et al., 2010). Human studies and experimental models suggest that ingestion of n-3 fatty acids prevents and ameliorates Alzheimer's disease by inhibition of inflammatory cytokine secretion, downregulation of proapoptotic proteins, and upregulation of anti-apoptotic proteins secretion (Uauy and Dangour, 2006; Calviello et al., 2008; Boudrault et al., 2009). Gu et al. (2012) reported an association between a higher intake of n-3 PUFAs and lower levels of β-amyloid peptide in plasma, which is associated with a reduced risk of Alzheimer's disease. Mamalakis et al. (2002, 2006) found negative relationships between adipose tissue n-3 fatty acids and depression in adolescents, adults and the elderly, which may be due to the suppression on the production of cytokines, interleukin (IL) 2, IL-6 and tumor necrosis factor alpha (TNF-α) by monocytes.

Increasing n-3 fatty acids intake significantly reduces the incidence of cardiovascular disease. They reduce total cholesterol,

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Table 1
Taxonomic information, feeding habits, environment, common name and total lipid content of the fishes investigated.

Genus	Species	Family	Feeding	Environment	Common name	Lipid content
Caranx	*caballus*	Carangidae	Carnivore	Pelagic	Green jack/Cojinua	3.74 ± 0.41
Cynoscion	*phoxocephalus*	Sciaenidae	Carnivore	Demersal	Cachema weakfish/Corvina	2.75 ± 0.35
Lutjanus	*guttatus*	Lutjanidae	Carnivore	Reef associated	Spotted rose snapper/Pargo de la mancha	1.81 ± 0.12
Scomberomorus	*sierra*	Scombridae	Carnivore	Pelagic	Pacific sierra/Sierra	3.09 ± 0.23

Values are expressed as g/100 g wet weight and are means ± SD ($n = 50$).

and thus minimize significantly the risk of myocardial infarction (Lox, 1990; Zyriax and Windler, 2000). Furthermore, n-3 fatty acids reduce serum triglycerides level (Dasgupta and Bhattacharyya, 2007), lower blood pressure in hypertensive persons (Ueshima et al., 2007), and diminish the occurrence of sudden cardiac death (Villa et al., 2002). n-3 PUFAs, especially EPA and DHA, have proven to be beneficial in autoimmune diseases such as Crohn's disease, multiple sclerosis, lupus erythematosus and psoriasis (Simopoulos, 2002a). These n-3 fatty acids have been reported to have a lower risk and suppressing effects in prostate (Demark-Wahnefried et al., 2001) and colorectal cancers (Theodoratou et al., 2007).

Much research on the fatty acid composition of fish from different marine ecosystems has been conducted, e.g., fish from the Mediterranean Sea, the northeastern coast of Australia, the Adriatic Sea, Malaysian and Turkish waters (Belling et al., 1997; Osman et al., 2001; Zlatanos and Laskaridis, 2007; Pacetti et al., 2010; Chuang et al., 2012), but information concerning the nutritional value of certain fish species is still scarce. There is a lack of data on the n-3 fatty acid composition of fishes from the eastern central Pacific region, which is one of the major fishing areas of the FAO and includes part of the Pacific coast of the United States and the Central American Pacific coastline from Mexico to Panama. Fish is the main source of EPA and DHA for the population in this area. Our current research on Alzheimer's disease involves the study of the molecular mechanisms by which compounds present in food, such as the n-3 PUFAs fatty acids, in particular EPA and DHA, can prevent and/or mitigate the effect of the disease.

We therefore aimed to investigate the lipid content, fatty acid composition, and amount of essential n-3 fatty acids in four fish species of important commercial value that are highly consumed by the local population of Central America. Seasonal variations in the lipid content and n-3 fatty acid composition were also studied. Uncovering trustworthy information on these topics is required for designing health-related policies and programs intended for improving the nutritional status and health conditions of local inhabitants, not only from Panama, but from the rest of the Central American region. Furthermore, these data are of significant interest to the fishing and nutraceutical industries and for the establishment of conservation strategies to support the sustainable development of these marine species.

2. Materials and methods

2.1. Materials

Analytical grade hexane, chloroform, and methanol were purchased from Merck (Darmstadt, Germany). Butylated hydroxytoluene (BHT) was obtained from Sigma–Aldrich (St. Louis, MO, USA). Menhaden fish oil and fatty acid methyl esters (FAME) mixture (analytical standard) were purchased from Supelco (Bellefonte, PA, USA). All other reagents were of analytical grade.

2.2. Fish samples and lipid extraction

Fresh samples of 4 fish species (*Caranx caballus*, *Cynoscion phoxocephalus*, *Lutjanus guttatus*, and *Scomberomorus sierra*), were collected from the Pacific coast of Panama, Panama City, in February, April, June, September and November of 2011. Ten individuals from each species were sampled. Specimens on crushed ice were brought to the laboratory, and subjected to lipid extraction immediately. Each fish was beheaded and eviscerated, and the muscle below the dorsal fin, including the skin, was subsequently analyzed. A sample of 25 g of muscle was homogenized, and lipids were extracted according to the method of Folch et al. (1957) using a chloroform/methanol mixture (2:1, v/v) containing 0.01% butylated hydroxytoluene (BHT) to prevent oxidation. The lipid content was determined gravimetrically.

Table 1 provides taxonomic and environmental information about the fish species. The English and local names of the fishes are also provided.

2.3. Determination of fatty acid compositions

Aliquots of the lipids extracted were used to prepare the FAME according to the procedure described by Christie (1993). In brief, the sample was mixed with acidic-methanol solution (5% anhydrous hydrogen chloride in methanol), heated at 70 °C for 1 h, cooled and extracted with hexane. FAMEs were separated and identified on an Agilent/HP 6890 gas chromatograph with flame ionization detector (FID) equipped with an HP-Innowax capillary column (25 m × 0.20 mm i.d., 0.20 μm film thickness) (Agilent, Palo Alto, USA), using helium as the carrier gas at a flow rate of 1.2 mL min^{-1}. The oven temperature was initially set at 170 °C for 3 min, and then increased to 230 °C at 4 °C/min with a final hold time of 3 min. The injector and detector temperatures were set at 230 °C and 270 °C, respectively. The FAME chromatographic peaks were identified by comparison of their retention times with those from a known FAME standard mixture, and characterized menhaden fish oil sample. The results are expressed as the percentage of total area of identified fatty acids, or as the amount of fatty acids in mg/100 g wet weight of the edible part of the fish by transforming each percentage to mg/100 g of wet tissue, using the fish conversion factor proposed by Exler, Kinsella and Watt (Greenfield and Southgate, 2003).

2.4. Statistical analysis

The results of the analyses are presented as mean values ± standard deviation (SD). The data were subjected to a one-way analysis of variance (ANOVA) to determine the differences between the fatty acid contents and the n-3 to n-6 fatty acid ratio among the samples studied. Fisher's least significant difference test was applied to discriminate among the means. Differences were accepted as statistically significant at a probability of $p < 0.05$. Statistical evaluations were carried out with the Statgraphics Centurion system (Warrenton, VA, USA).

3. Results and discussion

Although plants and plant-derived food products, such as seeds, nuts, soybeans and vegetable oils, provide humans with essential linolenic acid (18:3 n-3), fish is the principal source of other n-3 fatty acids which are important in human clinical nutrition, specifically as a source of EPA and DHA. *C. caballus*, *C. phoxocephalus*, *L. guttatus* and *S. sierra* are important commercial fish species of the eastern central Pacific region, and they are widely consumed not only by the Panamanian population but also by a large number of inhabitants of Central America. Consequently, these species are the main dietary source of these bioactive n-3 fatty acids for this population. To the best of our knowledge, this is the first report to investigate the lipid content and fatty acid composition of these fish species from the eastern central Pacific region of Panama.

3.1. Lipid content

The study revealed that the four fish species have a moderate to low lipid content (Table 1). *C. caballus* muscle tissue had the highest total lipid content (3.74 g/100 g), while *L. guttatus* presented the lowest (1.81 g/100 g). According to its lipid content, *L. guttatus* can be classified as a lean fish (the fish lipid content lower than 2%), whereas *C. caballus*, *C. phoxocephalus* and *S. sierra* can be classified as low fat fish (lipid content between 2% and 4%) (Ackman, 1990). It is known that lean and low fat species tend to accumulate most of their lipid energetic reserves in the liver (more than 50%) (Jacquot, 1961). Although fat content differences can be mainly attributable to differences among the species, the fat content may be influenced by multiple factors, such as feed the composition, geographic origin, age variation, reproductive stage and catch season (Tsuchiya, 1961; Bandarra et al., 1997; Osman et al., 2001; Turkmen, 2003; Çelik, 2008).

3.2. Fatty acid composition

A detailed fatty acid composition of the total lipids extracted from the muscle of these marine species is presented in Table 2. More than 37% of the fatty acids identified in all examined species corresponded to SFAs (saturated fatty acids). Palmitic acid (16:0) was the most abundant SFA in all species under study, ranging from 22.69% to 25.78%. Other studies also reported this fatty acid as the most abundant SFA in fishes caught in the northern and southern Pacific regions (Belling et al., 1997; Huynh and Kitts, 2009). Stearic acid (18:0) was the second most abundant fatty acid identified in all the fishes (between 8.35% and 10.13%).

Oleic acid (18:1 n-9) was the principal monounsaturated fatty acid (MUFA) in all species. No difference was observed among the fishes in the oleic acid content. Prato and Biandolino (2012) also reported oleic acid as the most abundant of the MUFAs in most marine fishes. The second most abundant MUFA in the different fish species was palmitoleic acid (16:1 n-7), which varied from 8.23% to 14.06%. In the present study, the low fat fish *C. phoxocephalus* contained the highest amount of this fatty acid.

The proportion of polyunsaturated fatty acids (PUFAs) found in the eastern central Pacific fishes selected for this investigation ranged between 23.59% and 33.66%. The highest proportion of PUFAs was found in *C. caballus*. PUFAs are required to maintain cell membrane fluidity and membrane protein function; hence, they regulate such processes as gene expression and cell signaling (Das, 2006). Furthermore, linoleic acid (18:2 n-6) and linolenic acid (18:3 n-3) PUFAs are essential nutrients that must be obtained from food (Das, 2006).

In terms of the absolute amounts of fatty acids, all analyzed fishes contained higher amounts of n-3 PUFAs (ranging from 388 to 1007 mg/100 g) than n-6 PUFAs (ranging from 67 to 124 mg/100 g) (Table 3). Linoleic acid was the most representative n-6 fatty acid in all the species. No significant variation was seen in the proportion of this compound between the specimens ($p < 0.05$). Osman et al. (2001) also reported high linoleic acid values in comparison with other n-6 fatty acids for fish species with low fat contents from tropical marine waters.

A significantly ($p < 0.05$) higher amount of n-3 PUFAs was found in the pelagic fishes when compared to demersal and reef associated species. *C. caballus* and *S. sierra* contained the major concentration of n-3 fatty acids (1007 and 663 mg/100 g, respectively). This trend could be explained by the fact that pelagic fishes feed predominantly on species for which phytoplankton is the main food source. Phytoplankton is rich in n-3 fatty acids (EPA and DHA) and poor in n-6 PUFAs such as linoleic and arachidonic acid (Dunstan et al., 1988).

In general, the amount of n-3 PUFAs (%) tends to decrease in the muscle of the fish species studied as the percentage of SFAs and MUFAs increases in this tissue. This suggests that SFAs and MUFAs

Table 2
Fatty acid composition (% of total fatty acids) in the lipids of four eastern central Pacific native fishes.

Fatty acids	*C. caballus*	*C. phoxocephalus*	*L. guttatus*	*S. sierra*
14:0	4.95 ± 0.62a	8.37 ± 0.74b	5.91 ± 0.89ac	6.27 ± 1.00c
16:0	22.69 ± 1.66a	25.78 ± 1.39b	24.54 ± 1.32bc	23.62 ± 0.64ac
18:0	10.13 ± 0.73a	8.35 ± 0.49b	9.34 ± 0.34c	9.11 ± 0.34c
∑SFAs	37.77 ± 3.01a	42.50 ± 2.62b	39.79 ± 2.55c	39.11 ± 1.98ac
16:1 n-7	8.77 ± 1.14a	14.06 ± 3.30b	8.23 ± 1.36a	10.55 ± 1.99a
18:1 n-9	16.40 ± 2.51a	14.97 ± 1.53a	18.70 ± 3.44a	18.06 ± 1.47a
22:1 n-9	2.79 ± 0.80a	3.71 ± 1.54a	4.38 ± 1.28a	3.31 ± 1.11a
24:1 n-9	0.60 ± 0.15a	0.73 ± 0.12a	1.17 ± 0.20a	0.72 ± 0.16a
∑MUFAs	28.66 ± 4.60a	33.47 ± 6.49a	32.48 ± 6.28a	32.64 ± 3.73a
18:2 n-6	1.95 ± 0.21a	2.22 ± 0.56a	2.00 ± 0.41a	2.31 ± 0.53a
20:2 n-6	0.58 ± 0.13a	0.74 ± 0.12a	0.63 ± 0.11a	0.74 ± 0.08a
22:4 n-6	1.17 ± 0.26a	1.15 ± 0.13a	1.47 ± 0.09a	1.22 ± 0.22a
18:3 n-3	1.28 ± 0.08a	0.93 ± 0.08a	1.11 ± 0.15a	1.07 ± 0.10a
20:3 n-3	0.11 ± 0.05a	0.12 ± 0.05a	0.30 ± 0.09a	0.15 ± 0.08a
20:5 n-3	7.09 ± 1.59a	6.24 ± 1.83a	4.84 ± 1.12a	6.80 ± 1.60a
22:5 n-3	1.83 ± 0.34a	1.37 ± 0.17b	1.44 ± 0.31b	1.20 ± 0.03b
22:6 n-3	19.65 ± 4.00a	10.82 ± 5.84a	16.11 ± 5.60a	14.64 ± 3.36a
∑PUFAs	33.66 ± 6.66a	23.59 ± 8.78b	27.90 ± 7.88b	28.13 ± 6.00b

SFAs, saturated fatty acids; MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids.
Results are the means ± S.D ($n = 50$).
Values with different letters are significantly different ($p < 0.05$).

Table 3
Comparison of EPA, DHA, total n-3, total n6, and n-3/n-6 ratio.

Species	EPA	DHA	∑n-3	∑n-6	∑n-3/∑n-6
C. caballus	238 ± 50a	660 ± 130a	1007 ± 80a	124 ± 10a	8.12 ± 0.52a
C. phoxocephalus	154 ± 50b	267 ± 140b	483 ± 100b	101 ± 10b	4.86 ± 1.40b
L. guttatus	79 ± 30c	263 ± 90b	388 ± 60b	67 ± 10c	5.90 ± 1.07b
S. sierra	189 ± 40ab	407 ± 120b	663 ± 80c	120 ± 10a	5.62 ± 1.04b

EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.
Values of EPA, DHA, ∑n-3, and ∑n-6 are expressed as mg/100 g wet weight and are means ± SD ($n = 50$).
Values with different letters are significantly different ($p < 0.05$).

are used as metabolic sources of energy for these species, and long chain n-3 fatty acids are required mainly for structural purposes, i.e., as constituents of membrane phospholipids. The major contributors to the n-3 PUFA composition in all specimens studied here were DHA and EPA (Table 2), with low concentrations of linolenic acid (<2.0%). In terms of the absolute amount of DHA, the highest DHA content was found in *C. caballus* (660 mg/100 g). The concentration of EPA in the selected fishes ranged between 79 and 238 mg/100 g. DHA absolute amount was higher than EPA among fish species (Table 3). The same trend has been observed in other fishes from the Pacific Ocean, such as Pacific hake, walleye pollock and canary rockfish (Huynh and Kitts, 2009). The accumulation of fatty acids in fish muscle is influenced by several factors besides diet and genetics, such as sexual maturity, geographic location and the season of the catch. One relevant aspect of the present research was the nutritional quality of the fish species in terms of their contribution to the daily dietary intake of bioactive EPA + DHA acids and n-3/n-6 ratio. The US Department of Agriculture (USDA) (2010) proposed a daily intake of EPA + DHA of 250 mg. Thus, to meet this daily recommendation, it would be necessary to consume approximately 28 g of *C. caballus*, 42 g of *S. sierra*, 59 g of *C. phoxocephallus*, and 73 g of *L. guttatus*.

Western diets tend to incorporate lower amounts of n-3 fatty acids when compared withn-6 fatty acids intake. Nevertheless, it is desirable to lower the amount of n-6 PUFAs in the diet and increase the dietary intake of n-3 fatty acids to reduce the risk of chronic diseases (Simopoulos, 2002b). The n-3/n-6 ratio index has been suggested for assessing the nutritional value of fish oils, and an increase in human dietary n-3/n-6 fatty acids helps in reducing cancer and cardiovascular risks (Kinsella et al., 1990; Piggott and Tucker, 1990). The n-3/n-6 ratio index of all eastern central Pacific species determined in this study ranged from 4.86 to 8.12 (Table 3). The notably cheap *C. caballus* fish had the highest nutritional value in terms of the n-3/n-6 ratio. In general, all fish species investigated in this study can be considered beneficial to health in terms of their n-3/n-6 ratio.

3.3. Seasonal changes in lipids and nutritionally important fatty acid contents

Panama has a tropical climate with two main seasons in the Pacific region, that is, wet and dry seasons. Generally, the dry season begins around mid-December and extends to the end of April, and is characterized by northeasterly winds and almost no rainfall. On the other hand, the wet season begins around May and ends around December and is differentiated by high rainfall. The influence of seasonal variation on the lipid content and nutritionally important n-3 fatty acids was investigated for each fish species (Table 4) to determine the time of year with the optimum content of these bioactive fatty acids. Samples were collected during the dry season (February and April) and the wet season (June, September and November). An increment in the fat content was observed during the dry season months, reaching a peak in June (wet season) for *C. caballus*, *C. phoxocephalus* and *L. guttatus* (7.72 g/100 g, 5.03 g/100 g and 3.63 g/100 g, respectively). Afterward, the fat content of the edible parts of these fish species tends to be lower during September and November. In the case of *S. sierra*, the lipid content tends to increase during the dry season until June, and then

Table 4
Seasonal variation in the lipid content, DHA, EPA, EPA + DHA, and ∑n-3 fatty acid composition of the Pacific fish species.

Species	Month	Lipid	∑n-3	DHA	EPA	EPA + DHA
Caranx caballus	February	2.37 ± 0.14	30.62 ± 1.21	18.96 ± 0.42	8.68 ± 0.48	27.64 ± 0.90
	April	4.66 ± 0.79	28.22 ± 2.23	17.86 ± 0.75	7.24 ± 0.63	25.10 ± 1.38
	June	7.72 ± 1.80	26.84 ± 3.48	14.66 ± 1.72	8.51 ± 0.80	23.17 ± 2.52
	September	1.56 ± 0.18	32.93 ± 2.45	25.30 ± 1.04	4.99 ± 0.48	30.29 ± 1.84
	November	2.38 ± 0.19	31.20 ± 3.49	21.48 ± 2.59	6.03 ± 0.06	27.51 ± 2.65
Cynoscion phoxocephalus	February	1.03 ± 0.11	21.87 ± 2.41	16.14 ± 2.17	3.80 ± 0.17	19.94 ± 2.34
	April	1.43 ± 0.56	25.86 ± 4.57	17.88 ± 3.32	6.08 ± 0.84	23.96 ± 4.16
	June	5.03 ± 0.99	16.36 ± 1.26	4.51 ± 0.21	9.20 ± 0.66	13.71 ± 0.87
	September	3.74 ± 0.77	17.19 ± 4.15	7.88 ± 1.82	6.25 ± 0.52	14.13 ± 2.34
	November	2.51 ± 0.70	16.48 ± 1.23	7.71 ± 0.77	5.87 ± 0.96	13.58 ± 0.97
Lutjanus guttatus	February	1.14 ± 0.22	29.05 ± 3.58	22.88 ± 2.69	4.17 ± 0.52	27.05 ± 3.21
	April	2.02 ± 0.32	22.17 ± 3.18	11.69 ± 1.38	7.17 ± 1.36	18.86 ± 2.74
	June	3.63 ± 0.61	18.98 ± 1.52	9.53 ± 0.61	6.36 ± 0.56	15.89 ± 1.17
	September	1.06 ± 0.10	22.63 ± 4.89	15.48 ± 2.77	4.14 ± 0.59	19.62 ± 4.36
	November	1.21 ± 0.22	26.17 ± 4.97	20.98 ± 4.57	2.38 ± 0.55	23.36 ± 4.62
Scomberomorus sierra	February	1.86 ± 0.24	26.07 ± 3.61	17.78 ± 2.39	6.63 ± 0.92	24.41 ± 3.31
	April	2.17 ± 0.43	23.76 ± 4.21	13.35 ± 1.99	7.82 ± 0.89	21.17 ± 2.88
	June	3.97 ± 0.68	19.92 ± 2.65	8.27 ± 0.94	8.86 ± 0.76	17.13 ± 1.70
	September	2.12 ± 0.31	26.85 ± 4.33	19.57 ± 2.04	4.72 ± 0.61	24.29 ± 2.65
	November	5.31 ± 0.83	22.67 ± 2.82	14.21 ± 1.77	5.98 ± 0.62	20.19 ± 2.39

EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.
Values of EPA, DHA, EPA + DHA, and ∑n-3 are expressed as % of total fatty acids and are means ± SD ($n = 10$).
Values of lipid content are expressed as g/100 g wet weight and are means ± SD ($n = 10$).

it decreases in September, achieving its maximum value in November (5.31 g/100 g). The maximum proportion of lipids found in these fish species may be due to an increasing growth rate and food intake (Gökçe et al., 2004).

Throughout the entire year, *C. caballus* and *S. sierra* had the most stable n-3 fatty acid composition. However, *L. guttatus* and *S. sierra* presented the greatest annual variations. *C. caballus* exhibited the highest n-3 fatty acid composition in September (32.93%); *S. sierra* showed the largest amount during this same month and in February (26.85% and 26.07%, respectively). The highest n-3 fatty acid proportion was observed during the dry season months for *C. phoxocephalus* (25.86%) and *L. guttatus* (29.05%). Furthermore, the combined EPA + DHA content followed the same trend observed for the total n-3 fatty acid content in the edible portion.

A negative correlation was found between the lipid content and the n-3 fatty acid content for the four species studied, indicating that these fatty acids are not used mainly for energy storage. Zlatanos and Laskaridis (2007) found the same correlation for sardines and anchovies from the Mediterranean Sea.

4. Conclusions

The data obtained from this work represents the first step toward knowledge about the biochemical composition and nutritional value of some important fish species from the East Central Pacific. The evaluated fishes are characterized by their low fat content and moderate levels of n-3 fatty acids, namely, EPA and DHA. There was no seasonal variation in the content of EPA + DHA fatty acids in the edible portion as the contents of the bioactive compounds remained practically unchanged for all the species studied.

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