fishes

MDPI

Article

Biogeographic Variation Analysis of Phenotypic and Nutritional Quality Traits of Cultured *Conger myriaster* Along the Yellow Sea Coast of China

Yan Chen [1,2,3,†], Meijun Tao [1,2,4,†], Bao Shi [1,2,*], Shenglei Han [1,2], Binghua Liu [1,2], Lianshun Wang [3], Kewen Yan [1,2], Xinyu Zhao [1,2] and Mingze Liu [1,2]

[1] State Key Laboratory of Mariculture Biobreeding and Sustainable Goods, Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Qingdao 266071, China; cycy0519@126.com (Y.C.); taomeijun0725@163.com (M.T.); 17860712133@163.com (S.H.); liubh@ysfri.ac.cn (B.L.); yankewen1201@126.com (K.Y.); zhaoxinyu@hrfri.ac.cn (X.Z.); 15032660738@163.com (M.L.)
[2] Laboratory for Marine Fisheries Science and Food Production Processes, Qingdao Marine Science and Technology Center, Qingdao 266237, China
[3] College of Fisheries and Life Science, Dalian Ocean University, Dalian 116023, China; wanglianshun@dlou.edu.cn
[4] School of Marine Science and Fisheries, Jiangsu Ocean University, Lianyungang 222005, China
* Correspondence: shibao@ysfri.ac.cn
† These authors contributed equally to this work.

Abstract: Aquaculture has become increasingly important as a source of high-quality animal protein and fatty acids for humans. This study investigated the morphological traits, general nutritional component, amino acid composition, fatty acid composition, and antioxidant enzyme activity of artificially cultured whitespotted conger *Conger myriaster* from three different suppliers, Haiyang Yellow Sea Fisheries Co., Ltd. (YT), Rizhao Rongwang aquatic science and technology Co., Ltd. (RZ), and Weihai Shenghang aquatic science and technology Co., Ltd. (WH), based on the Yellow Sea coast in China. Of the 19 morphological traits, total length, body length, and vertical eye diameter were significantly different in the *C. myriaster* of YT, RZ, and WH ($p < 0.05$). The hepatosomatic index (HSI) of YT was significantly lower than that of RZ and WH ($p < 0.05$), and the gonadosomatic index (GSI) was not significantly different. The moisture, crude lipid, and crude ash contents in YT were significantly different from those in RZ and WH ($p < 0.05$). The methionine (Met) of RZ was significantly higher than that of YT and WH ($p < 0.05$). *C. myriaster* from YT, RZ, and WH were detected to have 26, 27, and 26 fatty acids, respectively. The docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) contents of YT were significantly higher than those of RZ and WH ($p < 0.05$). There were no significant differences in the antioxidant enzyme activities of *C. myriaster* from YT, RZ and WH ($p > 0.05$). The results showed that there are differences in the morphological traits, general nutritional component proximate composition, and amino acid and fatty acid compositions of cultured *C. myriaster* from different regions.

Keywords: *Conger myriaster*; captive population; quantitative and qualitative traits; various regions

Key Contribution: This study provides a basis for further identifying the specific factors affecting the traits of *C. myriaster* in different geographic locations and provides theoretical ideas for the influence of geographic location on alteration in the genetic factors of farmed *C. myriaster*.

check for updates

Academic Editor: Weijie Mu

Received: 2 May 2025
Revised: 14 May 2025
Accepted: 27 May 2025
Published: 3 June 2025

Citation: Chen, Y.; Tao, M.; Shi, B.; Han, S.; Liu, B.; Wang, L.; Yan, K.; Zhao, X.; Liu, M. Biogeographic Variation Analysis of Phenotypic and Nutritional Quality Traits of Cultured *Conger myriaster* Along the Yellow Sea Coast of China. *Fishes* **2025**, *10*, 266. https://doi.org/10.3390/fishes10060266

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Fish is a key source of animal protein and an essential part of a balanced human diet. It has been widely accepted as a nutritious source of protein which can help support a healthy body [1,2]. Amino acids in fish proteins are critical to determining protein nutritional quality. They serve as precursors for the synthesis of important biological substances such as peptide hormones and neurotransmitters. Additionally, they are vital for cell signaling, nutrient transport, metabolic disease prevention and treatment, cellular metabolism, and innate and cell-mediated immune responses [3–5]. Fish is also recognized as an important source of essential polyunsaturated fatty acids [6,7]. DHA and EPA are crucial indicators for evaluating nutritional quality, given their substantial role in preventing diverse diseases including diabetes, chronic cardiovascular disease, cancer, and age-related degenerative diseases. A high Σn-3/Σn-6 polyunsaturated fatty acids (∑n-3/∑n-6 PUFA) ratio is crucial for human health, as n-3 PUFAs are known for their anti-inflammatory effects, while n-6 PUFAs promote inflammation [8–12]. Moreover, a high ∑n-3/∑n-6 PUFAs ratio helps prevent the onset of cardiogenic diseases, and the recommended ratio in the diet is higher than 0.25. The demand for high-quality seafood is surging with the rapid socioeconomic development.

Aquaculture systems have emerged as a critical component of sustainable food production, serving as a sustainable mechanism to supply bioavailable animal-derived proteins that are fundamental for optimal ontogenetic development, neurocognitive function, and cardiovascular health maintenance in human populations. The *C. myriaster* is an economically important eel species and an important marine resource for the fish processing industry in East Asian countries, which is mainly distributed in the Bohai, Yellow, and East China Seas, the coastal waters of the Korean Peninsula, and the coast of Japan from southern Hokkaido to northern Okinawa [13,14]. In recent years, *C. myriaster* populations have declined drastically due to intensive fishing, so it has become important to protect this species [15,16]. As a result, many countries are regulating *C. myriaster* fishing in order to manage this resource [17,18]. Despite the implementation of robust conservation strategies aimed at enhancing *C. myriaster* population recovery, persistent demographic monitoring indicates that additional adaptive management interventions are required to effectively mitigate ongoing population declines. Presently, the practice of captive breeding *C. myriaster* is emerging along the Yellow Sea coast of China [19–21]. Moreover, high-quality genome assembly provides a robust foundation for developing molecular markers and advancing conservation and aquaculture efforts for *C. myriaster* [22]. The experimental aquaculture techniques for *C. myriaster* include pond culture, industrialized open-flowing water culture, and industrialized recirculating aquaculture [13]. In recent years, a number of studies have been conducted to investigate the relationship between morphological traits, proximate composition, amino acid and fatty acid contents, and antioxidant enzyme activity [23–27]. However, comparisons of the differences between different regions of *C. myriaster* from different regions have not been reported.

The growth performance of eels is species-specific and related to the growing environment [28]. In recent years, there has been a lot of attention on *C. myriaster* due to its significant nutritional value, including its rich protein content and substantial quantities of unsaturated fatty acids [29]. It has been shown that the farmed *C. myriaster* has higher contents of lipids, total amino acids, essential amino acids (EAAs), DHA, EPA, n-3 PUFAs, and total polyunsaturated fatty acids (total PUFAs) compared to wild fish [3]. However, comparisons of artificially cultured *C. myriaster* among the different regions have not been reported. Since all artificially cultured *C. myriaster* require wild fry captured from offshore waters, artificially cultured *C. myriaster* from different regions may also exhibit differentiation due to genetic factors. Therefore, a comparative evaluation can help us

to better understand the overall quality and characteristics of farmed *C. myriaster* from different regions. In view of this, in this study, *C. myriaster* produced under the same culture environments were selected to determine the differences in morphology and quality of farmed *C. myriaster* from different regions in China (namely Yantai, Shandong province (YT, 121.758 E, 36.411 N), Rizhao, Shandong province (RZ, 119.272 E, 35.253 N), and Weihai, Shandong province (WH, 122.754 E, 37.302 N)). By comparing their morphological traits, hepatosomatic index, gonadosomatic index, condition factor, proximate composition, amino acid composition, fatty acid composition, and antioxidant capacity, we can obtain important information for further investigating the genetic variations in populations of *C. myriaster* in different regions.

2. Materials and Methods

2.1. Samples

A total of 90 *C. myriaster* fish were collected from three aquaculture companies along the coast of the Yellow Sea in Shandong province, China. A total of 30 *C. myriaster* individuals were collected from each company, namely, Haiyang Yellow Sea Fisheries Co., Ltd. (YT) Yantai, China, Rizhao Rongwang aquatic science and technology Co., Ltd. (RZ) Rizhao, China, and Weihai Shenghang aquatic science and technology Co., Ltd. (WH) Weihai, China (Figure 1). The fish were one year old and have been cultured in similar industrial aquaculture environments. The relevant environment parameters were as follows: temperature 21.5–23.6 °C; ammonia nitrogen < 0.45 mg/L; nitrite nitrogen < 0.06 mg/L; pH 7.8–8.2, salinity 28–32; and DO ≥ 6.0 mg/L. The *C. myriaster* were fed once every day with commercial feed (Table 1), and the feed amount was approximately 1–2% of total body weight. The commercial feed was produced by Qingdao Saigelin Biotechnology Co., Ltd. (Qingdao, China). The final average body weights were 359.59 ± 53.07 g, 339.90 ± 45.91 g, and 373.17 ± 48.68 g for fish from the YT, RZ, and WH, respectively. The *C. myriaster* fish were anesthetized with 0.02% tricaine methanesulfonate (MS-222). Three fish were randomly collected from each region and frozen at −20 °C to determine whole-body proximate composition. For biochemical analyses, slices of muscles weighing approximately 1.5–2.0 g were cut from each specimen. The dissected tissues were immediately immersed in liquid nitrogen and then stored in a −80 °C freezer until laboratory analysis.

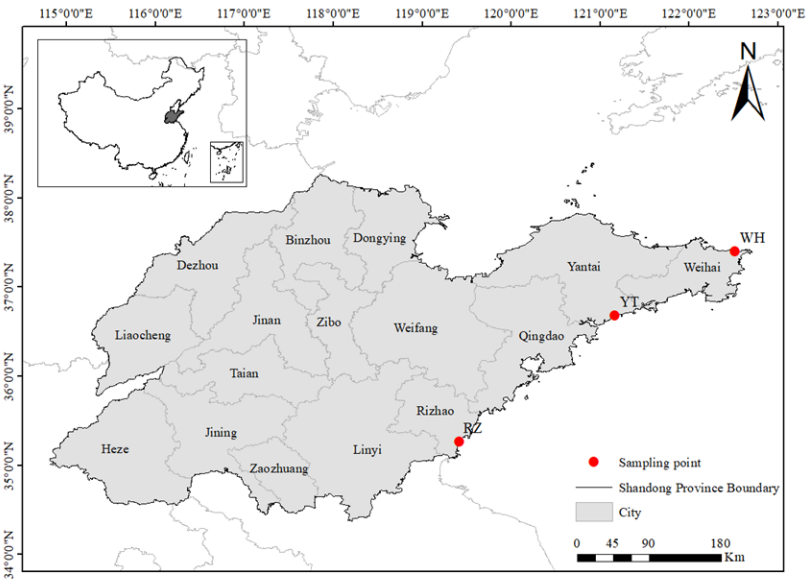


Figure 1. Map of three major cities in China where samples were collected. The three locations (YT: Haiyang Yellow Sea Fisheries Co., Ltd., RZ: Rizhao Rongwang aquatic science and technology Co., Ltd., WH: Weihai Shenghang aquatic science and technology Co., Ltd.) along the Yellow Sea coast of China.

Table 1. The approximate composition of the feed (%).

Nutritional Component	Proportion
Crude protein	47.60
Crude fat	11.71
Moisture	7.60
Crude ash	9.66
Crude fiber	2.74
Carbohydrate	17.60

2.2. Morphological Trait Analysis

The initial and net body weights of *C. myriaster* were weighed using a weighing scale (accuracy of 0.1 g). The total length, body length, and trunk length were measured using a ruler (accurate of 0.1 cm), while the body width, body height, head length, head height, head width, proboscis length, eye diameter, distance between eyes, vertical eye diameter, proboscis width, depth of rima oris, the vertical dimension from rostral side to orbit trailing edge, orbit trailing edge width, and pectoral fin length were measured using a vernier caliper (accurate of 0.1 mm). The HSI, GSI, and condition factor (CF) of the *C. myriaster* were calculated using the following formula [30]:

$$\text{HSI} = \text{hepatopancreas wet weight (g)}/\text{body weight (g)} \times 100 \quad (1)$$

$$\text{GSI} = \text{gonad wet weight (g)}/\text{body weight (g)} \times 100 \quad (2)$$

$$\text{CF} = \text{body weight (g)}/\text{total length}^3\ \text{(cm)} \times 100 \quad (3)$$

2.3. Proximate Composition Analysis

Proximate compositions such as moisture, crude protein, crude lipid, and ash were determined according to the standard methods of the Association of Official Analytical Chemists [31]. The moisture content of fish muscle samples was determined using the direct drying method under 105 °C until an unchanged weight was recorded. The crude protein content of fish muscle samples was determined by the Kjeldahl method (N × 6.25). The crude lipid content of fish muscle samples was determined using the Soxhlet method. The ash content of fish muscle samples was determined by placing the sample in a muffle furnace at 550 °C until it completely turned to ash. The total sugar content of fish muscle samples was determined using the spectrophotometry method. The YT, RZ, and WH groups consisted of three pooled samples with 10 fish in each, respectively. All experiments were performed in triplicate.

2.4. Amino Acid Analysis

Amino acids were analyzed by high-performance liquid chromatography (HPLC), following an alkaline hydrolysis for tryptophan and other amino acids performed by using the guidelines of Noman et al. with some modifications [32]. A total of 300 milligrams of the solid sample was digested with 10 mL of 6 M HCl at 110 °C for 22 h under a nitrogen atmosphere. After cooling, 4.8 mL of 10 M NaOH was added. The volume was brought up to 25 mL with distilled water; then, the sample was filtered through two layers of 0.22 µm filter paper and finally centrifuged at 10,000× *g* for 10 min. Amino acids were analyzed by using the reverse-phase HPLC (LA8080, Hitachi Limited, Tokyo, Japan). Each sample (1 µL) was injected into a Zorbax 80 A C-18 column (column size: 4.0 × 250 mm, 5 µm particle size; Agilent, Santa Clara, CA, USA) at 40 °C with detection at 338 nm. The mobile phase A was 7.35 mM/L of sodium acetate/triethylamine/tetrahydrofuran (500:0.12:2.5, *v*/*v*/*v*), adjusted to pH 7.2 using acetic acid, while the mobile phase B (pH 7.2) was 7.35 mM/L of

sodium acetate/methanol/acetonitrile (1:2:2, *v*/*v*/*v*). All determinations were performed in triplicate. The amino acid composition was expressed as grams of amino acids per 100 g of protein. Classification of amino acids in the *C. myriaster* samples was conducted according to relevant studies [5].

2.5. Fatty Acid Analysis

Fatty acids were extracted according to GB 5009.168–2016 in China [33]. Fat was extracted from the samples, and the fat extracts were saponified and methylated to obtain fatty acid methyl esters (FAMEs) [34]. FAMEs were analyzed by using a gas chromatography (GC) (7890A, Agilent, USA), equipped with a flame ionization detector and a fused-silica capillary column (HP-88, 100 m × 0.25 mm × 0.20 μm). The column was initially held at 100 °C for 13 min, followed by temperature programming to 180 °C at the rate of 10 °C/min, then held at 180 °C for 6 min and increased to 192 °C at the rate of 1 °C/min, then held at 192 °C for 6 min and increased to 230 °C at the rate of 3 °C/min, then held at 230 °C for 6 min. The temperatures of the injector and detector were set at 240 °C. GC peaks were identified by comparing their retention times with the reference standards and expressed as percentages. The analysis was carried out in triplicate, and mean values are reported.

2.6. Antioxidant Enzyme Activity Detection

The total antioxidant capacity (T-AOC) was measured via colorimetry. Superoxide dismutase (SOD) activity was measured using the xanthine oxidase method. Catalase (CAT) rapidly stops the decomposition of H_2O_2 by the addition of ammonium molybdate, and the remaining H_2O_2 with ammonium molybdate produces a pale-yellow complex. The change in absorbance at 405 nm was measured to calculate the activity of CAT. A total of 30 fish each from YT, RZ, and WH were selected; then, 2 g of muscle was collected from each fish. To quantify the antioxidant enzyme activity, the muscle was homogenized according to the manufacturer's instructions. Enzyme activities quantified in this study include T-AOC (A015-1-2, Nanjing Jiancheng Bioengineering Institute, Nanjing, China), SOD activity (A001-1-1, Nanjing Jiancheng Bioengineering Institute, Nanjing, China), and CAT activity (A007-1-1, Nanjing Jiancheng Bioengineering Institute, Nanjing, China). The samples were processed as instructed. Analyses were performed in triplicate.

2.7. Statistical Analysis

One-way analysis of variance (ANOVA) was performed to compare sample means and identify significant differences in morphological traits, general nutritional component, amino acid composition, fatty acid composition, and antioxidant enzyme activity between *C. myriaster* from YT, RZ, and WH. All assumptions of data normality and homogeneity of variance, required to perform ANOVA, were first checked by Kolmogorov–Smirnov and Levene tests, respectively. The analysis data were statistically analyzed by SPSS 26.0 (IBM, Chicago, IL, USA). Significant differences between means were determined by one-way ANOVA and Duncan's multiple comparisons (p value less than 0.05).

3. Results

3.1. Analysis of Measurable Character

The net body weight, head height, and orbit trailing edge width of WH were significantly higher than those of RZ ($p < 0.05$) (Table 2), while the total length, body length, eye diameter, vertical eye diameter, and pectoral fin length of WH were significantly higher that of YT and RZ ($p < 0.05$). The body width of YT was significantly higher that of RZ ($p < 0.05$), and the depth of rima oris and the vertical dimension from rostral side to orbit trailing edge of RZ were significantly higher than those of YT and WH ($p < 0.05$). The proboscis length

of YT was significantly lower than that of RZ and WH, while the trunk lengths of RZ and WH were significantly higher than that of YT ($p < 0.05$). The six measurable traits of body weight, body height, head length, head width, distance between eyes, and proboscis width were not significant differences ($p > 0.05$). The HSI of RZ and WH was significantly higher than that of YT ($p < 0.05$) (Table 3). The GSI of YT, RZ, and WH did not show significant differences, while the CF of YT was significantly higher than that of RZ and WH ($p < 0.05$).

Table 2. One-way ANOVA of measurable traits of *C. myriaster* in three different regions.

Trait	YT	RZ	WH
Body weight/g	359.59 ± 53.07 ^{a}	339.90 ± 45.91 ^{a}	373.17 ± 48.68 ^{a}
Net body weight/g	327.70 ± 37.57 ^{ab}	303.70 ± 44.97 ^{a}	343.90 ± 44.02 ^{b}
Total length/mm	583.26 ± 20.34 ^{a}	611.37 ± 32.17 ^{b}	637.97 ± 43.32 ^{c}
Body length/mm	580.59 ± 20.20 ^{a}	606.30 ± 32.01 ^{b}	631.07 ± 42.66 ^{c}
Body width/mm	29.47 ± 3.58 ^{b}	26.79 ± 2.37 ^{a}	27.48 ± 2.72 ^{ab}
Body height/mm	31.02 ± 3.42 ^{a}	30.49 ± 2.43 ^{a}	31.27 ± 3.97 ^{a}
Head length/mm	58.23 ± 4.80 ^{a}	72.76 ± 9.47 ^{a}	68.61 ± 7.57 ^{a}
Head height/mm	25.36 ± 3.25 ^{ab}	24.10 ± 1.98 ^{a}	26.48 ± 2.85 ^{b}
Head width/mm	27.24 ± 2.53 ^{a}	27.06 ± 1.40 ^{a}	27.92 ± 1.88 ^{a}
Proboscis length/mm	22.91 ± 1.99 ^{a}	28.09 ± 2.02 ^{b}	27.30 ± 5.51 ^{b}
Eye diameter/mm	9.14 ± 1.63 ^{a}	8.67 ± 0.69 ^{a}	10.11 ± 0.94 ^{b}
Distance between eyes/mm	19.73 ± 2.28 ^{a}	19.06 ± 2.64 ^{a}	20.76 ± 2.31 ^{a}
Trunk length/mm	215.63 ± 13.93 ^{a}	234.97 ± 14.71 ^{b}	236.24 ± 22.71 ^{b}
Vertical eye diameter/mm	8.93 ± 1.71 ^{b}	8.08 ± 0.49 ^{a}	10.00 ± 0.75 ^{c}
Proboscis width/mm	20.26 ± 2.67 ^{a}	19.20 ± 1.88 ^{a}	20.31 ± 1.84 ^{a}
Depth of rima oris/mm	21.62 ± 2.19 ^{a}	25.58 ± 2.07 ^{b}	22.68 ± 2.80 ^{a}
Vertical dimension from rostral side to orbit trailing edge/mm	22.72 ± 2.02 ^{a}	27.30 ± 1.81 ^{c}	25.64 ± 3.07 ^{b}
Orbit trailing edge width/mm	2.66 ± 0.41 ^{b}	2.38 ± 0.39 ^{b}	2.97 ± 0.48 ^{a}
Pectoral fin length/mm	37.42 ± 4.10 ^{b}	33.47 ± 2.60 ^{a}	40.68 ± 4.61 ^{c}

YT: Haiyang Yellow Sea Fisheries Co., Ltd.; RZ: Rizhao Rongwang aquatic science and technology Co., Ltd.; WH: Weihai Shenghang aquatic science and technology Co., Ltd.; Data are expressed as mean ± S.D; ^{a,b,c} Numbers within a row with different superscripts differ statistically at $p < 0.05$.

Table 3. The HSI, GSI, CF of *C. myriaster* from three different regions ($p < 0.05$).

	YT	RZ	WH
HSI/%	0.47 ± 0.95 ^{a}	1.99 ± 2.41 ^{b}	1.73 ± 1.93 ^{b}
GSI/%	1.42 ± 0.26 ^{a}	2.13 ± 2.10 ^{a}	1.41 ± 1.17 ^{a}
CF (g/cm^3)	0.18 ± 0.02 ^{b}	0.14 ± 0.02 ^{a}	0.15 ± 0.02 ^{a}

^{a,b} Numbers within a row with different superscripts differ statistically at $p < 0.05$.

3.2. Analysis of General Nutritional Components in Muscle

One-way ANOVA was used to analyze the general nutritional components in the muscle of *C. myriaster* from three different regions (Table 4). The moisture content of RZ and WH was similar, significantly higher than that of YT ($p < 0.05$). The crude protein contents of YT and RZ were significantly higher than that of WH ($p < 0.05$), and the crude lipid content of YT was significantly higher than that of RZ and WH ($p < 0.05$), while the crude ash content of RZ was significantly higher than that of YT ($p < 0.05$). There were no significant differences in the total sugar contents of YT, RZ, and WH.

Table 4. The analysis of general nutritional components in muscle of *C. myriaster*.

Nutritional Components	YT	RZ	WH
Moisture content/%	60.67 ± 1.44 ^{a}	68.77 ± 0.60 ^{b}	68.40 ± 1.14 ^{b}
Crude protein content/%	14.53 ± 0.31 ^{b}	14.77 ± 0.40 ^{b}	13.40 ± 0.36 ^{a}
Crude lipid content/%	21.93 ± 1.50 ^{b}	13.77 ± 0.85 ^{a}	16.37 ± 0.98 ^{a}
Crude ash content/%	1.00 ± 0.00 ^{a}	1.17 ± 0.06 ^{b}	1.10 ± 0.00 ^{ab}
Total sugar content/%	0.30 ± 0.00 ^{a}	0.17 ± 0.06 ^{a}	0.23 ± 0.06 ^{a}

^{a,b} Numbers within a row with different superscripts differ statistically at $p < 0.05$.

3.3. Amino Acid Composition Analysis and Nutritional Evaluation

In this study, 17 amino acids were measured. Trp could not be detected in the acid hydrolysis. The muscle samples of the *C. myriaster* were found to contain twelve essential amino acids (EAAs), three nonessential amino acids (NEAAs), and two conditionally essential amino acids (CEAAs). Asp, Glu, Gly, and Ala are palatable amino acids. One-way ANOVA was used to analyze the amino acid content in the muscle of *C. myriaster* from three different regions (Table 5). The amino acid with the highest content in the three regions was Lys, followed by Glu, Leu, and Asp. Additionally, that with the lowest content was Cys. Only Met showed a significant difference: its content in RZ was significantly higher than that in YT and WH ($p < 0.05$). The ΣEAA/ΣTAA was 0.64, 0.64, and 0.63 in YT, RZ, and WH, respectively; ΣEAA/ΣNEAA was 3.22, 3.29, and 3.10 in YT, RZ, and WH, respectively; and ΣDAA/ΣTAA was 0.33, 0.33, and 0.35 in YT, RZ, and WH, respectively.

Table 5. Amino acids composition in muscle of *C. myriaster*.

Amino Acid	YT (g/100 g)	RZ (g/100 g)	WH (g/100 g)
Asp △	0.81 ± 0.15 ^{a}	0.94 ± 0.03 ^{a}	0.77 ± 0.12 ^{a}
Thr *	0.42 ± 0.07 ^{a}	0.46 ± 0.01 ^{a}	0.39 ± 0.06 ^{a}
Ser	0.28 ± 0.05 ^{a}	0.27 ± 0.01 ^{a}	0.24 ± 0.06 ^{a}
Glu △#	0.92 ± 0.22 ^{a}	1.03 ± 0.04 ^{a}	0.86 ± 0.17 ^{a}
Gly △#	0.51 ± 0.07 ^{a}	0.56 ± 0.03 ^{a}	0.58 ± 0.14 ^{a}
Ala △	0.63 ± 0.09 ^{a}	0.72 ± 0.04 ^{a}	0.66 ± 0.12 ^{a}
Cys *	0.07 ± 0.02 ^{a}	0.09 ± 0.00 ^{a}	0.07 ± 0.03 ^{a}
Val *	0.54 ± 0.10 ^{a}	0.62 ± 0.02 ^{a}	0.51 ± 0.02 ^{a}
Met *	0.09 ± 0.01 ^{a}	0.25 ± 0.01 ^{b}	0.12 ± 0.03 ^{a}
Iie *	0.50 ± 0.12 ^{a}	0.58 ± 0.01 ^{a}	0.46 ± 0.02 ^{a}
Leu *	0.85 ± 0.15 ^{a}	0.98 ± 0.01 ^{a}	0.81 ± 0.10 ^{a}
Tyr *	0.38 ± 0.06 ^{a}	0.40 ± 0.02 ^{a}	0.30 ± 0.09 ^{a}
Phe *	0.43 ± 0.08 ^{a}	0.49 ± 0.02 ^{a}	0.40 ± 0.05 ^{a}
Lys *	0.97 ± 0.18 ^{a}	1.09 ± 0.02 ^{a}	0.92 ± 0.10 ^{a}
His *	0.33 ± 0.03 ^{a}	0.34 ± 0.03 ^{a}	0.26 ± 0.05 ^{a}
Arg *	0.58 ± 0.10 ^{a}	0.67 ± 0.02 ^{a}	0.59 ± 0.10 ^{a}
Pro *	0.35 ± 0.03 ^{a}	0.37 ± 0.02 ^{a}	0.32 ± 0.06 ^{a}
ΣTAA	8.65 ± 1.38 ^{a}	9.85 ± 0.07 ^{a}	8.27 ± 1.24 ^{a}
ΣEAA	5.51 ± 0.80 ^{a}	6.34 ± 0.06 ^{a}	5.15 ± 0.64 ^{a}
ΣDAA	1.73 ± 0.37 ^{a}	1.96 ± 0.07 ^{a}	1.63 ± 0.30 ^{a}
ΣNEAA	1.72 ± 0.29 ^{a}	1.93 ± 0.02 ^{a}	1.67 ± 0.30 ^{a}
ΣCEAA	1.43 ± 0.28 ^{a}	1.58 ± 0.01 ^{a}	1.44 ± 0.31 ^{a}
ΣEAA/ΣTAA	0.64 ± 0.01 ^{a}	0.64 ± 0.00 ^{a}	0.63 ± 0.02 ^{a}
ΣEAA/ΣNEAA	3.22 ± 0.07 ^{a}	3.29 ± 0.03 ^{a}	3.10 ± 0.17 ^{a}
ΣDAA/ΣTAA	0.33 ± 0.01 ^{a}	0.33 ± 0.00 ^{a}	0.35 ± 0.01 ^{a}

* indicates essential amino acids, △ indicates palatable amino acids, # indicates conditionally essential amino acids, ΣTAA indicates total amino acids, ΣEAA indicates total amount of essential amino acids, ΣDAA indicates total amount of palatable amino acid, ΣNEAA indicates total nonessential amino acids, and ΣCEAA indicates total conditionally essential amino acids. ^{a,b} Numbers within a row with different superscripts differ statistically at $p < 0.05$.

3.4. Fatty Acid Composition Analysis

The fatty acid contents expressed as a percentage of total fatty acids and as g/100 g of fish sample are shown in Table 6. A total of 26 fatty acids were detected in the muscle of *C. myriaster* from YT and WH, including ten SFAs, six MUFAs, and ten PUFAs. A total of 27 fatty acids were detected in the muscle of *C. myriaster* samples from RZ, including eleven SFAs, six MUFAs, and ten PUFAs. One-way ANOVA was used to analyze the fatty acid content in the muscle of *C. myriaster* in the three regions. The C12:0, C16:1, C18:2n6c, C20:1, and C20:2 contents in YT, RZ, and WH showed significant differences ($p < 0.05$), as did the

C10:0 and C22:2 contents in YT and WH ($p < 0.05$). The C14:0 and C16:0 contents in YT and RZ were significantly different ($p < 0.05$), while the C14:1, C15:0, C17:0, C20:3n3, C22:1n9, and C24:1 contents in YT and WH were significantly higher than those in RZ ($p < 0.05$). The C18:0, C20:5n3, and C22:6n3 contents in YT were significantly higher than those in RZ and WH ($p < 0.05$), while the C21:0 and C20:3n6 contents in RZ were significantly higher than those in YT and WH ($p < 0.05$). The contents of other fatty acids were not significantly different in YT, RZ, and WH. The total content of fatty acids in YT was significantly higher than that in RZ and WH ($p < 0.05$). Through comparison, the following trend was found in each region: MUFA content > SFA content > PUFA content. The DHA + EPA content in YT was significantly higher than that in RZ and WH ($p < 0.05$). Finally, the n-3 ΣPUFA content was highest in YT, but the n-6 ΣPUFA content was highest in RZ.

Table 6. Fatty acid composition (mg/100 g of total fatty acids) in muscle of *C. myriaster*.

Fatty Acid	YT	RZ	WH
C10:0	21.47 ± 0.00 ^{ab}	16.43 ± 0.00 ^{a}	25.63 ± 0.00 ^{c}
C12:0	10.97 ± 0.00 ^{b}	7.33 ± 0.00 ^{a}	13.07 ± 0.00 ^{c}
C14:0	628.33 ± 0.05 ^{b}	413.90 ± 0.05 ^{a}	527.80 ± 0.04 ^{ab}
C14:1	21.37 ± 0.00 ^{b}	12.83 ± 0.00 ^{a}	17.73 ± 0.00 ^{b}
C15:0	66.47 ± 0.01 ^{b}	29.80 ± 0.01 ^{a}	52.13 ± 0.00 ^{b}
C16:0	3248.83 ± 0.20 ^{b}	2236.53 ± 0.18 ^{a}	2722.50 ± 0.19 ^{ab}
C16:1	1417.23 ± 0.13 ^{c}	708.37 ± 0.08 ^{a}	1076.03 ± 0.07 ^{b}
C17:0	47.93 ± 0.00 ^{b}	30.67 ± 0.00 ^{a}	45.50 ± 0.00 ^{b}
C18:0	646.70 ± 0.04 ^{b}	466.20 ± 0.02 ^{a}	502.27 ± 0.04 ^{a}
C18:1n9c	5000.30 ± 0.33 ^{a}	4399.20 ± 0.32 ^{a}	4156.20 ± 0.31 ^{a}
C18:2n6c	222.20 ± 0.01 ^{b}	647.80 ± 0.01 ^{c}	166.73 ± 0.01 ^{a}
C20:0	43.13 ± 0.01 ^{a}	35.43 ± 0.00 ^{a}	39.87 ± 0.00 ^{a}
C18:3n6	9.27 ± 0.00 ^{a}	15.97 ± 0.00 ^{a}	9.23 ± 0.00 ^{a}
C18:3n3	127.83 ± 0.01 ^{a}	120.00 ± 0.01 ^{a}	127.37 ± 0.01 ^{a}
C20:1	713.57 ± 0.07 ^{c}	251.13 ± 0.04 ^{a}	527.30 ± 0.02 ^{b}
C21:0	0.00 ± 0.00 ^{a}	6.00 ± 0.00 ^{b}	0.00 ± 0.00 ^{a}
C20:2	81.07 ± 0.00 ^{c}	69.67 ± 0.00 ^{b}	57.17 ± 0.01 ^{a}
C22:0	18.00 ± 0.00 ^{a}	14.67 ± 0.00 ^{a}	16.93 ± 0.00 ^{a}
C20:3n3	32.33 ± 0.00 ^{b}	18.90 ± 0.00 ^{a}	26.50 ± 0.00 ^{b}
C20:3n6	25.13 ± 0.00 ^{a}	40.07 ± 0.01 ^{b}	17.07 ± 0.00 ^{a}
C20:4n6	64.70 ± 0.00 ^{a}	60.53 ± 0.01 ^{a}	50.20 ± 0.00 ^{a}
C22:1n9	91.03 ± 0.01 ^{b}	51.03 ± 0.00 ^{a}	82.53 ± 0.00 ^{b}
C22:2	24.27 ± 0.01 ^{b}	18.17 ± 0.00 ^{ab}	12.70 ± 0.00 ^{a}
C23:0	10.20 ± 0.00 ^{a}	6.93 ± 0.00 ^{a}	9.63 ± 0.00 ^{a}
C20:5n3 (EPA)	1060.83 ± 0.09 ^{b}	379.73 ± 0.04 ^{a}	578.37 ± 0.06 ^{a}
C24:1	98.87 ± 0.01 ^{b}	51.33 ± 0.00 ^{a}	89.33 ± 0.01 ^{b}
C22:6n3 (DHA)	1626.73 ± 0.13 ^{b}	718.67 ± 0.07 ^{a}	1044.63 ± 0.15 ^{a}
Total	15,356.67 ± 1.05 ^{b}	10,826.67 ± 0.83 ^{a}	11,996.67 ± 0.91 ^{a}
ΣSFA	4742.03 ± 0.30 ^{b}	3263.90 ± 0.26 ^{a}	3955.33 ± 0.27 ^{ab}
ΣMUFA	7342.37 ± 0.53 ^{b}	5473.90 ± 0.44 ^{a}	5949.13 ± 0.40 ^{a}
ΣPUFA	3274.37 ± 0.23 ^{b}	2089.50 ± 0.13 ^{a}	2089.97 ± 0.24 ^{a}
DHA + EPA	2687.57 ± 0.22 ^{b}	1098.40 ± 0.11 ^{a}	1623.00 ± 0.22 ^{a}
n-3 ΣPUFA	2847.73 ± 0.23 ^{b}	1237.30 ± 0.12 ^{a}	1776.87 ± 0.22 ^{a}
n-6 ΣPUFA	321.30 ± 0.01 ^{b}	764.37 ± 0.01 ^{c}	243.23 ± 0.02 ^{a}

ΣSFA indicates total amount of total saturated fatty acid. ΣMUFA indicates total amount of monoun-saturated fatty acid. ΣPUFA indicates total amount of polyunsaturated fatty acid. DHA + EPA indicates total amount of DHA and EPA. n-3 ΣPUFA indicates total amount of n-3 polyunsaturated fatty acid. n-6 ΣPUFA indicates total amount of n-6 polyunsaturated fatty acid. ^{a,b,c} Numbers within a row with different superscripts differ statistically at $p < 0.05$.

3.5. Antioxidant Enzyme Activity Analysis

The physiological and biochemical indexes of *C. myriaster* are presented in Table 7. The T-AOC is 2.67~2.70 μmol/g and the SOD activity is 52.75~56.64 U/g for the three different regions. The CAT activity is 834.90~858.78 μmol/(min·g). There were no significant differences in T-AOC, SOD, and CAT activities among the three different regions of YT, RZ, and WH ($p > 0.05$).

Table 7. Physiological and biochemical indexes of *C. myriaster*.

Indexes	YT	RZ	WH
T-AOC (μmol/g)	2.68 ± 0.14 [a]	2.70 ± 0.09 [a]	2.67 ± 0.10 [a]
SOD (U/g)	52.75 ± 12.59 [a]	55.77 ± 11.62 [a]	56.64 ± 15.35 [a]
CAT [μmol/(min·g)]	834.90 ± 144.78 [a]	848.13 ± 151.36 [a]	858.78 ± 123.63 [a]

T-AOC, total antioxidant capacity; SOD, superoxide dismutase; CAT, catalase. [a] Numbers within a row with different superscripts differ statistically at $p < 0.05$.

4. Discussion

Length and weight are two critical morphometric traits strongly affected by species, ontogenetic changes, and environmental conditions [35]. The relationship between weight and length was used to develop CF [36]. In fish, CF serves as an indicator of the physiological and health status of fish and can be used to compare their relative health, with larger values indicating increased fat mass [37,38]. This study found that there were no significant differences in the body weights of samples from YT, RZ, and WH. The body length of WH was significantly higher than that of YT and RZ, and the body length of RZ was significantly higher than that of YT. Comparison of CF revealed that it was significantly higher in YT than in WH and RZ. In addition, the crude fat content of YT was significantly higher than that of RZ and WH. In a related study on European eel *Anguilla anguilla*, it was noted that higher CF and fat contents indicated a better fish condition [39]. The liver is an important organ for storing energy and is often the first site for lipid storage in many fish species. Therefore, HSI is used as an indirect measure of body condition to assess energy reserves and metabolic activity [40]. A high-fat diet (HFD) has been widely used in modern aquaculture because of its low cost, reduced nitrogen emissions, and protein-saving effects [41]. It has been observed that the intake of an HFD in the rice field eel *Monopterus albus* caused the deposition of fat in the liver, which increased the HSI [42]. In this study, all the collected *C. myriaster* samples were fed with an HFD; however, the HSIs of RZ and WH were higher than that of YT. This may be related to the level of lipid metabolism in the liver. This suggests that the *C. myriaster* population of YT might have been in a better health condition and made good use of diet resources in terms of energy acquisition. In summary, the *C. myriaster* population of YT was in a better condition and able to access energy resources in their diet more effectively, with less lipid deposition and higher metabolic levels in the liver. The AMPK/PPAR signaling pathway is a major regulatory pathway of lipid catabolism [43], and the expression characteristics of key genes affecting this pathway in *C. myriaster* from different regions still need to be further investigated. Future work is expected to explore the differences caused by genetic variation in *C. myriaster* among geographically distinct populations.

Fish muscles are a major source of nutrition in the human diet and contain fats, proteins, and minerals that are of great value to human health [44]. The proximate composition of fish muscles can provide information about its physiological condition, energetic adaptation, habits, nutritional value, and commercial applications [45]. In this study, we determined the moisture, crude protein, crude lipid, crude ash, and total sugar contents in the muscle of *C. myriaster*. There was no significant difference in the moisture contents

of RZ and WH ($p > 0.05$), but they were significantly higher than that in YT ($p < 0.05$). On the contrary, YT had a significantly higher lipid content than RZ and WH ($p < 0.05$). In fish, the lipid content is usually inversely proportional to the moisture content [46]. The results of the present study show that there may be a negative correlation between lipid and moisture content in *C. myriaster*. There is a higher intake of protein and lipid from fish muscle, as these macronutrients are important sources of energy and play a vital role in bodily functions [47]. The results of this study showed that the crude protein contents of YT and RZ were significantly higher than that of WH ($p < 0.05$). Moreover, a higher crude lipid content was observed in the muscles of *C. myriaster* from YT compared to those from RZ and WH. Therefore, *C. myriaster* from YT may have a superior nutritional quality and value. Interestingly, the crude ash content of YT was significantly lower than that of RZ and WH ($p < 0.05$); this suggests that *C. myriaster* from RZ and WH may contain a higher mineral content compared to YT. The reasons for these differences can be explored in depth by testing the elemental content of *C. myriaster* in each region, with the aim of analyzing the intrinsic mechanisms between proximate composition.

High-quality proteins have a high utilization rate and contain EAAs in quantities that correspond to human requirements [48]. This study indicated that the 12 kinds of EAAs were found in the muscle samples from the three regions, with abundant lysine acid, leucine acid, arginine acid, and valine acid, which is consistent with the findings reported by Zhang et al. [3]. Met has a growth-promoting effect, which can improve protein synthesis and enhance antioxidant capacity [49]. In this study, the Met content of RZ was significantly higher than that of YT and WH. However, there were no significant differences in T-AOC, SOD, and CAT of YT, RZ, and WH in this study. In addition, according to the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) criteria, good-quality proteins not only contain the complete range of essential amino acids but also have an appropriate essential amino acid-to-total amino acid ratio [50]. The ratios of essential amino acids to total amino acids for YT, RZ, and WH were 43.9%, 45.4%, and 43.9%, which were in accordance with the FAO/WHO ideal model standard (40%). The ratios of essential amino acids to non-essential amino acids were 96.2%, 102.3%, and 96.0%, respectively, which far exceed FAO/WHO standards (60%). This demonstrates that the proteins in *C. myriaster* muscle in YT, RZ, and WH exhibit a well-balanced essential amino acid composition and were all of a high quality. Lys is the most abundant free amino acid in *C. myriaster* from YT, RZ, and WH; it crucially regulates metabolism and growth in fish [51]. The proteins in *C. myriaster* protein from YT, RZ, and WH heavily feature Glu, which plays important physiological roles in protein synthesis and muscle flesh quality [52]. Glu is the most abundant free amino acid in artificially cultured yellow croaker *Larimichthys crocea*, as well as in African catfish *Clarias gariepinus* [53,54], while Lys is the most abundant free amino acid in Japanese eel *Anguilla japonica* [55]. The amino acid content of crayfish *Procambarus clarkii* from different regions has been determined, and it was found that the most common component was Glu [29]. Comparison of the amino acid content of male Chinese mitten crab *Eriocheir sinensis* cultured in different regions showed that there were fewer individual differences between regions [30]. It can be concluded that the differences in free amino acid content in artificially farmed fish from different regions were minor, indicating that geographical differences are not an important factor in determining the amino acid content in fish. On the other hand, the differences in free amino acids between different fish were substantial, which may be related to genetic factors.

The fatty acid composition of fish muscle is an important indicator for assessing nutritional value [56]. The Σn-3 and Σn-6 can serve as important indicators for assessing the nutritional quality because n-3 polyunsaturated fatty acids have an anti-inflammatory effect, whereas n-6 polyunsaturated fatty acids are pro-inflammatory [8–12]. In this study,

the Σn-3 of *C. myriaster* from YT was significantly higher than that from WH and RZ, and the Σn-6 of *C. myriaster* from RZ was significantly higher than that from YT and WH. It has been shown that the amounts and types of fatty acids in tissues were often affected by the maturity period, different seasons, geographical locations, and size and age of the fish [57]. The ΣMUFA and ΣPUFA of *C. myriaster* were significantly higher in YT than in RZ and WH, and this difference may be related to geographical location. DHA and EPA are dominant unsaturated fatty acids in fish oil which have potential therapeutic benefits in the treatment of a variety of human diseases including autoimmune disorders, inflammatory diseases, cardiovascular disease, and diabetes mellitus [58]. In addition, DHA and EPA are essential for fish reproduction and gonadal development [59]. In this study, DHA and EPA in *C. myriaster* from YT were significantly higher than in samples from RZ and WH. As a result, the *C. myriaster* of YT may be healthier and have a higher nutritional value.

5. Conclusions

In this study, the morphological traits, body composition, amino acid composition, fatty acid composition, and antioxidant enzyme activity of artificially cultured *C. myriaster* from YT, RZ, and WH were comparatively analyzed. Significant differences were found in total length, body length, vertical eye diameter, the vertical dimension from rostral side to orbit trailing edge, and fatty acid C12:0, C16:1, C18:2n6c, C20:1, C20:2 contents between fish from among the three regions. Preliminary evidence suggests that the *C. myriaster* population of YT is able to access energy resources in their diet more effectively and may have superior nutritional quality and value. This suggests that differences in geographic location may affect the growth and development level, as well as the nutritional value, of artificially cultured *C. myriaster*. Further studies can be carried out on the ultrastructure of muscle fibers, muscle mineral elements, and taste substances. However, *C. myriaster* from YT, RZ, and WH differed significantly only in Met content, suggesting that geographical differences are not a critical factor in determining the amino acid content, but it can may be determined genetically. In the future, genetic factors will be explored by combining data from genomic resources such as whole-genome sequencing (WGS) and 10 × Genomics analysis from the *C. myriaster* populations of various regions. Our study provides a foundation for the subsequent identification of the specific factors affecting *C. myriaster* in different geographic locations and provides theoretical ideas for how geographic location variations cause alterations in the genetic factors of farmed *C. myriaster*.

Author Contributions: Conceptualization, Y.C., M.T. and B.S.; methodology, S.H. and B.L.; software, L.W. and M.L.; validation, K.Y.; formal analysis, X.Z.; investigation, Y.C., M.T. and K.Y.; resources, B.S.; data curation, Y.C. and B.S.; writing—original draft preparation, Y.C. and M.T.; writing—review and editing, B.S.; supervision, B.S.; project administration, B.S.; funding acquisition, B.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by National Key Research and Development Program of China, grant number 2024YFD2401002; Central Public-Interest Scientific Institution Basal Research Fund, YSFRI, CAFS, grant number 20603022023023 and 2023TD51; and the China Agriculture Research System, grant number CARS-47.

Institutional Review Board Statement: All experimental procedures were conducted strictly in accordance with the research protocols approved by the Institutional Animal Ethics Committee of Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments: We thank the Haiyang yellow sea Fisheries Co., Ltd., Rizhao Rongwang aquatic science and technology Co., Ltd., and Weihai Shenghang aquatic science and technology Co., Ltd.

for providing the *C. myriaster*. We also thank the assistance of Chenbai Wang (Qingdao Hongdao People's Hospital) in fatty acid composition analysis.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Indur, B.; Vishwajit, D.; Prashant, V.; Ambrish, V. Evaluation of muscle proximate composition and nutritional value of six freshwater fish species. *Int. J. Environ. Clim. Chang.* **2023**, *13*, 156–168. [CrossRef]
2. Noreen, S.; Hashmi, B.; Aja, P.M.; Atoki, A.V. Health benefits of fish and fish by-products-a nutritional and functional perspective. *Front. Nutr.* **2025**, *12*, 1564315. [CrossRef] [PubMed]
3. Zhang, Y.M.; Wang, Y.Y.; Jia, J.; Zhang, S.H.; Guo, X.H.; Sun, A.H.; Dong, H.; He, P.Q.; Song, X.F. Comparative study of the nutritional composition of wild and farmed White-Spotted Conger, *Conger myriaster*. *Pakistan J. Zool.* **2023**, *55*, 2607–2615. [CrossRef]
4. Mohanty, B.; Mahanty, A.; Ganguly, S.; Sankar, T.V.; Chakraborty, K.; Rangasamy, A.; Paul, B.; Sarma, D.; Mathew, S.; Asha, K.K.; et al. Amino acid compositions of 27 food fishes and their importance in clinical nutrition. *J. Amino Acids* **2014**, *2014*, 269797. [CrossRef]
5. Wu, G.Y. Functional amino acids in nutrition and health. *Amino Acids* **2013**, *45*, 407–411. [CrossRef]
6. Guérin, T.; Chekri, R.; Vastel, C.; Sirot, V.; Volatier, J.; Leblanc, J.; Noël, L. Determination of 20 trace elements in fish and other seafood from the French market. *Food Chem.* **2011**, *127*, 934–942. [CrossRef]
7. Mohanty, B.P.; Mahanty, A.; Ganguly, S.; Mitra, T.; Karunakaran, D.; Anandan, R. Nutritional composition of food fishes and their importance in providing food and nutritional security. *Food Chem.* **2019**, *293*, 561–570. [CrossRef]
8. Fabrikov, D.; Barroso, F.G.; José Sánchez-Muros, M.; Carmen Hidalgo, M.; Cardenete, G.; Tomás-Almenar, C.; Melenchón, F.; Guil-Guerrero, J.L. Effect of feeding with insect meal diet on the fatty acid compositions of sea bream (*Sparus aurata*), tench (*Tincatinca*) and rainbow trout (*Oncorhynchus mykiss*) fillets. *Aquaculture* **2021**, *545*, 737170. [CrossRef]
9. Gebauer, S.K.; Psota, T.L.; Harris, W.S.; Kris-Etherton, P.M. n-3 fatty acid dietary recommendations and food sources to achieve essentiality and cardiovascular benefits. *Am. J. Clin. Nutr.* **2006**, *83*, 1526s–1535s. [CrossRef]
10. Robinson, J.G.; Stone, N.J. Antiatherosclerotic and antithrombotic effects of omega-3 fatty acids. *Am. J. Cardiol.* **2006**, *98*, 39–49. [CrossRef]
11. Simopoulos, A.P. Omega-6/omega-3 essential fatty acids: Biological effects. *World Rev. Nutr. Diet.* **2009**, *99*, 1–16. [PubMed]
12. Trautwein, E. n-3 fatty acids-physiological and technical aspects for their use in food. *Eur. J. Lipid Sci. Technol.* **2001**, *103*, 45–55. [CrossRef]
13. Zhao, X.Y.; Shi, B.; Wang, C.B.; Cheng, H.L.; Wang, C.G.; Ma, X.D.; Yan, K.W.; Chen, Y. Effects of dietary supplementation of compound probiotics on growth, non-specific immunity, intestinal digestive enzyme, and microbiota of whitespotted conger (*Conger myriaster*) in recirculating aquaculture system. *Aquac. Int.* **2024**, *32*, 2713–2738. [CrossRef]
14. Tokimura, M. Fisheries and their resources in the East China Sea. *Nippon Suisan Gakk.* **2011**, *77*, 919–923. [CrossRef]
15. Mu, X.X.; Zhang, C.; Zhang, C.L.; Yang, J.; Ren, Y.P. Age-structured otolith chemistry profiles revealing the migration of *Conger myriaster* in China seas. *Fish. Res.* **2021**, *239*, 105938. [CrossRef]
16. Gorie, S.; Tanda, M.; Katayama, S. Age and growth of white-spotted conger *Conger myriaster* collected in northeast Harima Nada, Seto Inland Sea. *J. Aquac. Feed. Sci. Nutr.* **2004**, *52*, 407–411.
17. Hori, T.; Noda, T.; Wada, T.; Iwasaki, T.; Arai, N.; Mitamura, H. Effects of water temperature on white-spotted conger *Conger myriaster* activity levels determined by accelerometer transmitters. *Fish. Sci.* **2019**, *85*, 295–302. [CrossRef]
18. Nemoto, Y.; Yamada, M.; Ishida, T. Fishery and resource management of white-spotted conger in Fukushima Prefecture. *Tohoku Sokouo Kenkyu.* **2006**, *26*, 92–97.
19. Chen, Y.; Shi, B.; Wang, C.G.; Bo, W.J.; Yan, K.W.; Tao, M.J.; Zhao, X.Y.; Ma, X.D. *LH* gene cloning, sequence feature analysis and prokaryotic expression in *Conger myriaster*. *Prog. Fish. Sci.* **2025**, *46*, 40–52.
20. Shi, B.; Wang, C.G.; Tang, X.H.; Zhao, X.Y.; Yan, K.W.; Ma, X.D. A study on sperm ultrastructure in the whitespotted conger, *Conger myriaster*. *Mar. Sci.* **2023**, *44*, 112–120.
21. Zhao, X.Y.; Shi, B.; Wang, C.G.; Cheng, H.L.; Ma, X.D. Effects of feeding frequency on the growth, physiological indices and water quality of *Conger myriaster* reared in industrial recirculating aquaculture systems. *Prog. Fish. Sci.* **2024**, *45*, 233–244.
22. Han, S.L.; Li, C.; Li, S.; Chen, Y.; Wang, C.G.; Liu, K.Q.; Liu, Y.Y.; Wang, H.Y.; Wang, Q.; Cao, X.W.; et al. High-quality chromosome-level genome assembly of the whitespotted conger (*Conger myriaster*). *Sci. Data* **2025**, *12*, 626. [CrossRef] [PubMed]
23. Asaduzzaman, M.; Iqbal, M.Z.; Chamily, F.A.; Akter, S.; Khan, M.S.R.; Wong, L.L.; Rahman, S.M.; Rahman, M.M. Body shape divergence of paradise thread fish (*Polynemus paradiseus*) collected from different coastal habitats of southern Bangladesh: A multivariate approach for population discrimination. *Aquac. Fish.* 2024, 1–16, *in press*.

24. Gladyshev, M.I.; Makhrov, A.A.; Sushchik, N.N.; Makhutova, O.N.; Rudchenko, A.E.; Balashov, D.A.; Vinogradov, E.V.; Artamonova, V.S. Differences in composition and fatty acid contents of different rainbow trout (*Oncorhynchus mykiss*) strains in similar and contrasting rearing conditions. *Aquaculture* **2022**, *556*, 738265. [CrossRef]
25. Peng, J.L.; Larondelle, Y.; Pham, D.; Ackman, G.; Rollin, X. Polyunsaturated fatty acid profiles of whole body phospholipids and triacylglycerols in anadromous and landlocked Atlantic salmon (*Salmo salar* L.) fry. *CBPC* **2003**, *134*, 335–348. [CrossRef]
26. Yang, S.Y.; Wang, M.M.; Chen, H.G. Comparative study of amino acid content and volatile odor compound composition of crayfish from different areas. *Mod. Agric. Sci. Technol.* **2024**, *8*, 129–133.
27. Chen, Q.Q.; Liu, J.Q.; Wang, Y.Z.; Sun, Y.F.; Cheng, Y.X. Analysis of the difference of conventional nutrients and free amino acids in edible tissues of male *Eriocheir sinensis* cultured in Yangtze River Delta. *Chin. Fish. Qual. Stand.* **2023**, *13*, 1–9.
28. Hagihara, S.; Aoyama, J.; Limbong, D.; Tsukamoto, K. Age and growth of migrating tropical eels, *Anguilla celebesensis* and *Anguilla marmorata*. *J. Fish Biol.* **2018**, *92*, 1526–1544. [CrossRef]
29. Chen, H.; Ge, Y.G.; Yang, T.; Wang, S.S.; Liu, N.; Sun, Y.; Zhou, D.Q.; Xi, R.; Sun, G.H. Quality changes of whitespotted conger (*Conger myriaster*) based physicochemical changes and label-free proteomics analysis during frozen storage. *Curr. Res. Food Sci.* **2024**, *8*, 100779. [CrossRef]
30. Zheng, J.C.; Zhang, W.C.; Dan, Z.J.; Cao, X.F.; Cui, K.; Zhu, S.; Zhuang, Y.W.; Mai, K.S.; Ai, Q.H. Effects of fish meal replaced by methanotroph bacteria meal (*Methylococcus capsulatus*) on growth, body composition, antioxidant capacity, amino acids transporters and protein metabolism of turbot juveniles (*Scophthalmus maximus* L.). *Aquaculture* **2023**, *562*, 738782. [CrossRef]
31. Association of Official Analytical Chemists (AOAC). *Official Methods of Analysis of Official Analytical Chemists International*, 20th ed.; Association of Official Analytical Chemists: Arlington, TX, USA, 2016.
32. Noman, A.; Xu, Y.S.; AL-Bukhaiti, W.Q.; Abed, S.M.; Ali, A.H.; Ramadhan, A.H.; Xia, W.S. Influence of enzymatic hydrolysis conditions on the degree of hydrolysis and functional properties of protein hydrolysate obtained from Chinese sturgeon (*Acipenser sinensis*) by using papain enzyme. *Process Biochem.* **2018**, *67*, 19–28. [CrossRef]
33. *GB 5009.168-2016*; Method for Determination of Fatty acids in Foods. Standards Press of China: Beijing, China, 2016.
34. Tola, S.; Adepoju, M.K.; Yuangsoi, B.; Charoenwattanasak, S.; Jatuwong, K.; Seel-audom, M. Effects of partial and complete replacement of fish oil with perilla oil on growth performance, feed efficiency, health status, and fatty acid accumulation in flesh of Asian seabass (*Lates calcarifer*) reared in freshwater. *Anim. Feed Sci. Technol.* **2025**, *323*, 116277. [CrossRef]
35. Arnillas, C.A.; Abedi, R.; Parzanini, C.; Strandberg, U.; Arts, M.T.; Bhavsar, S.P.; Arhonditsis, G.B. Intra-specific correlations between fatty acids and morphological traits are consistent across fish species. *J. Great Lakes Res.* **2023**, *49*, 821–835. [CrossRef]
36. Froese, R. Cube law, condition factor and weight–length relationships: History, meta-analysis and recommendations. *J. Appl. Ichthyol.* **2006**, *22*, 241–253. [CrossRef]
37. Ighwela, K.A.; Ahmed, A.B.; Abol-Munafi, A.B. Condition factor as an indicator of growth and feeding intensity of Nile tilapia fingerlings (*Oreochromis niloticus*) feed on different levels of maltose. *Am.-Eurasian J. Agric. Environ. Sci.* **2011**, *11*, 559–563.
38. Furuya, V.R.B.; Michelato, M.; da Cruz, T.P.; Furuya, W.M. Length-weight relationships and prediction equations of body composition of farm raised *Astyanax* aff. *Fasciatus* (Actinopterygii: Characiformes: Characidae). *Zoologia* **2014**, *31*, 521–524. [CrossRef]
39. Denis, J.; Mahé, K.; Tabouret, K.; Rabhi, K.; Boutin, K.; Boutin, K.; Diop, M.; Amara, R. Relationship between habitat use and individual condition of European eel (*Anguilla anguilla*) in six estuaries of the eastern English channel (North-eastern Atlantic ocean). *Estuar Coast Shelf S.* **2023**, *291*, 108446. [CrossRef]
40. Costa, E.F.S.; Teixeira, G.M.; Freire, F.A.M.; Dias, J.F.; Fransozo, A. Effects of biological and environmental factors on the variability of *Paralonchurus brasiliensis* (Sciaenidae) density: An GAMLSS application. *J. Sea Res.* **2022**, *183*, 102203. [CrossRef]
41. Kong, W.; Huang, S.; Yang, Z.; Shi, F.; Feng, Y.; Khatoon, Z. Fish feed quality is a key factor in impacting aquaculture water environment: Evidence from incubator experiments. *Sci. Rep.* **2020**, *10*, 187. [CrossRef]
42. Xie, K.; Tang, Z.; Shi, Y.; Deng, Z.T.; Cai, M.L.; Dai, J.H.; Shao, C.; Zhang, J.Z.; Hu, Y.; Li, D.L. Effects of *Corbicula fluminea* meal in high-fat diet on growth, lipid metabolism and intestinal microbiota of juvenile rice field eel *Monopterus albus*. *Aquaculture* **2024**, *590*, 741064. [CrossRef]
43. Zhou, W.H.; Limbu, S.M.; Li, R.X.; Luo, Y.; Ren, J.; Qiao, F.; Du, Z.Y. Dietary sodium acetate improves high-fat diet utilization through promoting differential nutrients metabolism between liver and muscle in Nile tilapia (*Oreochromis niloticus*). *Aquaculture* **2023**, *565*, 739142. [CrossRef]
44. Polak-Juszczak, L.; Podolska, M. Mineral and toxic metal composition in three commercial species of *Gadidae*. *J. Food Compos. Anal.* **2021**, *95*, 103658. [CrossRef]
45. Gomez-Limia, L.; Cobas, N.; Martinez-Suarez, S. Proximate composition, fatty acid profile and total amino acid contents in samples of the European eel (*Anguilla anguilla*) of different weights. *Int. J. Gastron. Food Sci.* **2021**, *25*, 100364. [CrossRef]
46. Gomez-Limia, L.; Cobas, N.; Franco, I.; Martinez-Suarez, S. Fatty acid profiles and lipid quality indices in canned European eels: Effects of processing steps, filling medium and storage. *Food Res. Int.* **2020**, *136*, 109601. [CrossRef] [PubMed]

47. Liu, M.J.; Gao, J.; Guo, H.Y.; Zhu, K.C.; Liu, B.S.; Zhang, N.; Zhu, T.F.; Zhang, D.C. Influence of aquaculture environments on the muscle quality of Golden Pompano (*Trachinotus ovatus*) in the Beibu Gulf: A multifaceted analysis of nutritional, textural, and flavor profiles. *LWT-Food Sci. Technol.* **2024**, *212*, 116957. [CrossRef]
48. Moughan, P.J.; Fulgoni, V.L.; Wolfe, R.R. The importance of dietary protein quality in mid- to high-income countries. *J. Nutr.* **2024**, *154*, 804–814. [CrossRef]
49. Wang, L.; Gao, C.; Wang, B.; Wang, C.Y.; Sagada, G.; Yan, Y.Z. Methionine in fish health and nutrition: Potential mechanisms, affecting factors, and future perspectives. *Aquaculture* **2023**, *568*, 739310. [CrossRef]
50. Joint FAO/WHO. Protein quality evaluation. *FAO Food Nutr. Pap.* **1991**, *51*, 1–66.
51. Zhang, S.Z.; Wang, C.A.; Liu, S.Y.; Wang, Y.L.; Lu, S.X.; Han, S.C.; Jiang, H.B.; Liu, H.B.; Yang, Y.H. Impact of dietary lysine on growth, nutrient utilization, and intestinal health in triploid rainbow trout (*Oncorhynchus mykiss*) fed low fish meal diets. *Aquac. Rep.* **2024**, *39*, 102402. [CrossRef]
52. Dong, B.; Wu, L.Y.; Wang, Y.; Han, D.; Liu, H.K.; Zhu, X.M.; Yang, Y.X.; Xie, S.Q.; Liu, Z.; Jin, J.Y. Glutamate improves flesh quality and muscle growth of triploid crucian carp. *Aquac. Rep.* **2023**, *33*, 101832. [CrossRef]
53. Zheng, J.L.; Wan, F.G.; Chen, Y.L.; Jiang, L.H.; Zhan, Q.H.; Chen, T.H.; Chen, S.; Zhu, Q.L.; Li, W.Y.; Liu, Y.F.; et al. Comparative study on the morphological characteristics, nutritional quality, and tastes of large yellow croaker from five cage culture areas: Relay farming improved fish quality. *Aquaculture* **2024**, *590*, 741030. [CrossRef]
54. Kari, Z.A.; Kabir, M.A.; Dawood, M.A.; Razab, M.K.A.A.; Ariff, N.S.N.A.; Sarkar, T.; Pati, S.; Edinur, H.A.; Mat, K.; Ismail, T.A.; et al. Effect of fish meal substitution with fermented soy pulp on growth performance, digestive enzyme, amino acid profile, and immune-related gene expression of African catfish (*Clarias gariepinus*). *Aquaculture* **2022**, *546*, 737418. [CrossRef]
55. Damusaru, J.H.; Moniruzzaman, M.; Park, Y.; Seong, M.; Jung, J.; Kim, D.J.; Bai, C.S. Evaluation of fish meal analogue as partial fish meal replacement in the diet of growing Japanese eel *Anguilla japonica*. *Anim. Feed Sci. Technol.* **2019**, *247*, 41–52. [CrossRef]
56. Bao, S.M.; Zhuo, L.Y.; Qi, D.L.; Tian, H.N.; Wang, D.Y.; Zhu, B.; Meng, Y.Q.; Ma, R. Comparative study on the fillet nutritional quality of diploid and triploid rainbow trout (*Oncorhynchus mykiss*). *Aquac. Rep.* **2023**, *28*, 101431. [CrossRef]
57. Ning, J.H.; Pan, H.; Li, B.Y.; Jiang, C. Nutritional comparison in muscle of wild, pond and factory cultured Japanese flounder (*Paralichthys olivaceus*) adults. *Aquac. Res.* **2018**, *49*, 2572–2578.
58. Gao, Y.; Liu, C.D.; Wang, X.; Zhou, H.H.; Mai, K.S. EPA and DHA promote cell proliferation and enhance activity of the Akt-TOR-S6K anabolic signaling pathway in primary muscle cells of turbot (*Scophthalmus maximus* L.). *Fish Physiol. Biochem.* **2024**, *50*, 1483–1494. [CrossRef]
59. Thiruvasagam, T.; Chidambaram, P.; Ranjan, A.; Komuhi, N.B. Significance of fatty acids in fish broodstock nutrition. *Anim. Reprod. Sci.* **2024**, *268*, 107573. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.