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Research article

Spatiotemporal Variation in Fulton and Clark Indexes of *Mystus albolineatus* in the Vietnamese Mekong Delta

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Abstract

This study assessed the fluctuations of two key indexes - Fulton and Clark indexes - in evaluating the nutritional status and health of *Mystus albolineatus* at two different sampling sites within the Hau River basin, Mekong Delta. A total of 597 specimens comprising 307 females and 290 males were collected from Cai Rang (Can Tho) and Long Phu (Soc Trang) from January to December (2023). The results indicated that both indexes were not influenced by sex or sampling site but varied significantly according to season and month. The Fulton index was significantly higher during the dry season (1.53±0.03 SE) compared to the wet season (1.35±0.04 SE, $F=14.06$, $p<0.001$). Similarly, the Clark index was significantly higher during the dry season (0.84±0.02 SE) compared to the wet season (0.67±0.02 SE, $F=30.94$, $p<0.001$). This suggests a better nutritional status during the dry season for this species. The findings played important information regarding the nutritional status and health of *Mystus albolineatus*, contributing to managing and conserving fishery resources in the Mekong Delta.

Keywords: Clark, Fulton, seasonal variation, *Mystus albolineatus*, nutritional status.

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INTRODUCTION

Vietnam has two large delta regions: the Red River Delta (Northern Region) and the Mekong Delta (Southern Region). The Mekong Delta (Vietnamese Mekong Delta: VMD) is one of Southeast Asia's largest deltas and Vietnam's largest delta. The VMD is a complex network of tributaries with major rivers, such as the Tien River and the Hau River, among others, belonging to the lower Mekong River system. Therefore, the VMD is a region of diverse and abundant habitats despite only covering about 5% of the lower Mekong River basin area (Tang et al., 2020). The predominant water types are freshwater and brackish water, with fertile alluvial soils throughout the year, giving the VMD a decisive advantage in developing the agricultural economy, especially aquaculture. The VMD covers an area of approximately 40,922 km^2 (General Statistics Office, 2021) with a coastline of about 700 km, bordering the East Sea and the Gulf of Thailand, providing favorable conditions for developing the marine economy. Notably, the flood season in the VMD occurs from around August to November each year when water from the upper Mekong River flows down, creating a flood season with a large amount of sediment deposition and many economically valuable aquatic species (Dinh et al., 2022). The VMD region recorded by Tran et al. (2013) has about 322 species belonging to 77 families, including various habitats such as freshwater and brackish water, with 312 species, and the remaining 10 species recorded in the estuarine ecosystem. This number is showing a decreasing trend due to various factors, especially the sharp decline in annual water volume due to the construction of hydropower dams in the upper and middle reaches of the Mekong River (To et al., 2019). This also significantly affects the process of saltwater intrusion in the VMD.

The Bagridae family comprises 241 species of 21 genera primarily distributed in freshwater and brackish water habitats. Bagridae is also noted as one of the largest fish families, according to Froese & Pauly (2024). According to Tran et al. (2013) and Froese and Pauly (2024), this family has a wide distribution range extending from Africa to Asia, including Vietnam. The genus *Mystus* is recorded with 48 species; although relatively low in number, it holds economic value for many countries in general and specifically for Vietnam (Froese & Pauly, 2021; Nguyen et al., 2024). In Vietnam, specifically in the VMD, six species belonging to the genus *Mystus* have been recorded, with the most common species being *Mystus mysticetus*, *Mystus albolineatus*, and *Mystus atrifasciatus* (Tran et al., 2013).

Mystus albolineatus is a freshwater fish species belonging to the Bagridae family, first described by Roberts (1994), primarily distributed in Vietnam's Mekong Delta region (Nguyen et al., 2018), and also found in other areas such as the Chao Phraya and Bangpakong basins in Thailand as recorded by Froese and Pauly (2024). *Mystus albolineatus* is characterized by its silvery-gray body with a dark, broad white stripe running lengthwise along both sides of the body. Its elongated adipose fin distinguishes it. This species' maximum recorded body length is 35 cm (Baird et al., 1999). *Mystus albolineatus* inhabits diverse environments, from stagnant ponds to flowing waters (rivers). Along the research sites along the Hau River in the Mekong Delta region, *Mystus albolineatus* individuals have been observed to have larger females than males

and better development during the wet season. Morphological characteristics assessments indicate that this species is well adapted to freshwater and brackish water environments, according to Nguyen & Dinh (2023).

When studying the biological characteristics of *Mystus albolineatus*, it is noted that there are still limitations in understanding its nutritional aspects. Fulton's (F) and Clark's condition factors are among the critical indexes in shaping the dietary characteristics of each fish species. However, as seen in other studies on different species, these indexes can vary depending on the research area, season, or sex, as evidenced by studies on the nutritional aspects of *Glossogobius sparsipapillus* (Tran & Dinh, 2021), the biological characteristics of *Onychostoma laticeps* (Vo et al., 2019), *Butis koilomatodon* (Dinh et al., 2020), and *Periophthalmus variabilis* (Tran & Dinh, 2021), which show that these two indexes can vary according to location, season, or sex of the fish. Therefore, this study provides specific insights into the nutritional biology characteristics of *Mystus albolineatus* to serve artificial breeding applications and pave the way for further research endeavors.

MATERIALS AND METHODS

Sampling and analysis

The sample of *Mystus albolineatus* used in this study originated from two different sites within the Hau River basin, the Mekong Delta, namely Cai Rang (Can Tho City, CRCT) and Long Phu (Soc Trang Province, LPST) (Figure 1). These two sampling sites were approximately 60 km apart, with CRCT having freshwater conditions year-round and LPST experiencing saltwater intrusion and dry seasons (Vo, et al. 2022).

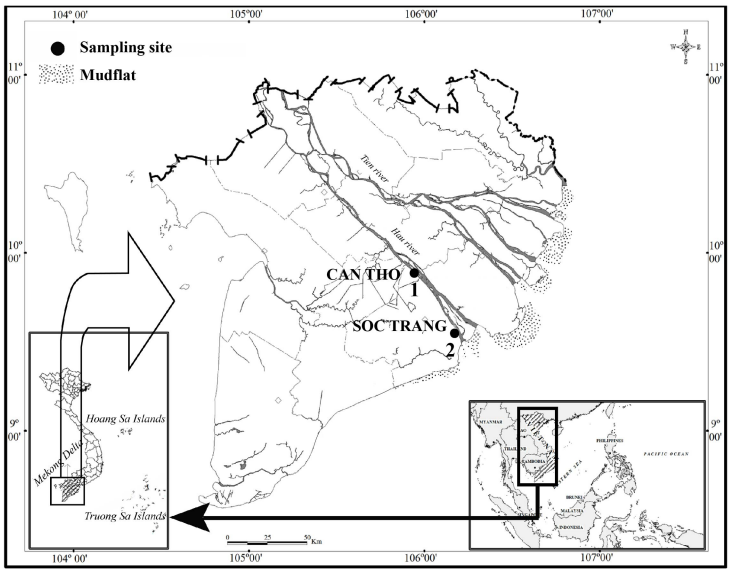

Figure 1 Sampling site map (●: Sampling sites; 1: Cai Rang District, Can Tho City; 2: Long Phu District, Soc Trang Province; this figure was modified from Dinh (2018))

A total of 597 specimens were used for this study, consisting of 307 female individuals and 290 male individuals. At the sampling sites, fish were caught monthly using trawl nets with a mesh size of 2a = 1.5 cm. There is no need to apply for animal ethics approval due to the use of dead fish in the present study.

Statistical Analysis

Through descriptions of external morphology and color described by Tran et al. (2013), the species were identified. Additionally, the fish samples were sexed based on the description of genital spines and gonads by Vo et al. (2023). After determining the sex characteristics, the fish were further assessed for specific morphometric parameters to facilitate the calculation of Clark and Fulton indexes, including total length (TL, measured from the mouth to the end of the tail), standard length (SL, measured from the mouth to the caudal peduncle), total weight (W, initial weight of the fish), and standard weight (W_o, weight of the fish after removing internal organs from the abdomen). TL and SL were measured accurately to 0.01 cm, while W and W_o were measured precisely to 0.01 gram.

From the two parameters of total weight (W, g) and standard length (SL, cm), the Fulton index (F) could be determined using the formula by Peig & Green (2010): $F=(W/SL^3)\times100$.

Meanwhile, standard weight (W_o, g) and total length (TL, cm) were used to estimate the Clark (Clark 1928): $Clark=(W_o/TL^3)\times100$.

Differences in Fulton and Clark indexes concerning sex, season, site, month, and interactions between these factors were analyzed using Jamovi v2.4.11 with the ANOVA procedure. Additionally, Principal Component Analysis (PCA) was employed to evaluate the relationship between sex, sampling location, and season regarding these two indexes. All tests were conducted at a significance level of 5%.

RESULTS

Fulton index

A total of 597 specimens were collected from two sampling sites to determine the Fulton index of *Mystus albolineatus*. This index plays a crucial role in assessing the fish population's health status, development, and quality. The results showed that this index did not significantly differ by sex (ANOVA, $F=0.05$, $p=0.83$). The specific values for males and females were 1.45±0.04 and 1.44±0.03 SE (mean ± standard error). However, this index had a significant variation between the dry and wet seasons ($F=14.06$, $p<0.001$). In the dry season, the Fulton index value for the fish was 1.53±0.03 SE. However, this value significantly decreased during the wet season compared to the dry season, reaching only 1.35±0.04 SE. Although there were significant differences in salinity and temperature between the sampling sites, this did not seem to affect the Fulton index value of this fish species. Both sampling sites, CRCT and LPST, recorded equivalent values of 1.44±0.03 and 1.44±0.04 SE, respectively ($F=0.01$, $p=0.97$). Since sampling was conducted monthly, fluctuations in the

Fulton index by month were also observed for this fish species. Similar to seasonal changes, a significant variation in the Fulton index by month was noted ($F=3.59$, $p<0.001$). Figure 2 illustrates that the highest value of this index was in January, and the lowest was in June (the wet season).

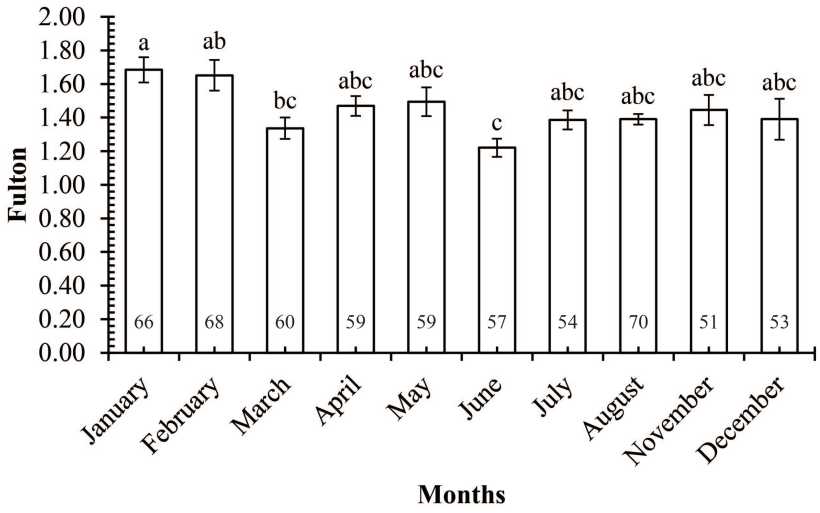

Figure 2 The changes in the Fulton index of *Mystus albolineatus* regarding month (Different letters a, b, and c indicate statistically significant differences; Numbers in the column indicate the number of samples collected each month; Vertical bars: standard error)

In some cases, interactions from factors like sex, season, and site may influence the Fulton index of fish. However, in *Mystus albolineatus*, no such variations were observed. Specifically, the factors of sex × season ($F=0.72$, $p=0.39$), sex × site ($F=0.68$, $p=0.41$), season × site ($F=1.74$, $p=0.19$), and sex × season × site ($F=0.38$, $p=0.54$) were not significantly affect the Fulton index. The PCA analysis results indicated no distinct grouping between males and females, CRCT and LPST, but rather a seasonal grouping (Figure 3). Specifically, salinity and temperature were identified as factors influencing this fish species' Fulton index.

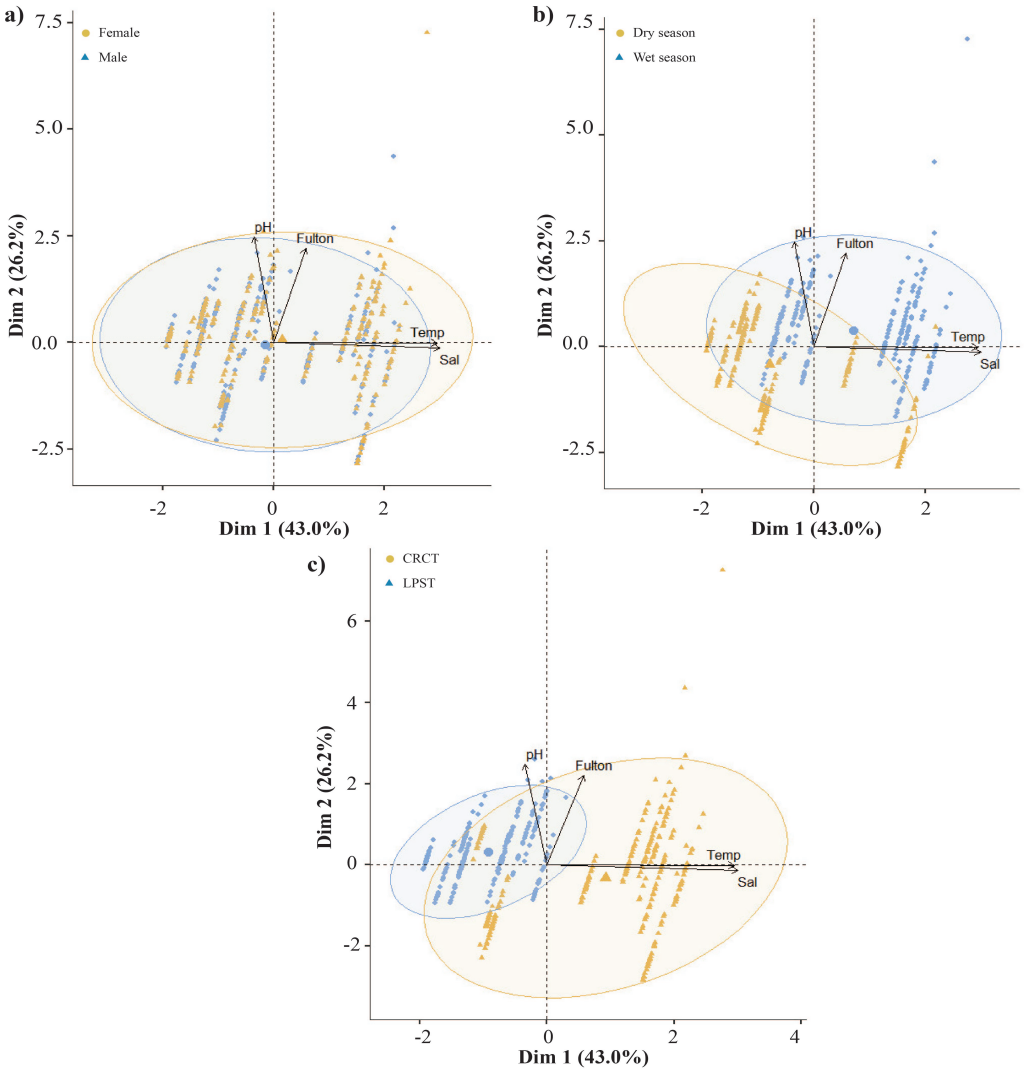

Figure 3 PCA plot of quantitative variables showing the relationship between environmental factors (Tem: temperature, pH, Sal: salinity) and Fulton index concerning sex (a), season (b), and site (c)

Clark index

Similarly, the Clark condition factor was essential for assessing fish's nutritional status and body condition. Additionally, this index provided crucial information about fish's health and reproductive capability in biological and fisheries management studies. The results determining the mean values of the Clark index in this fish species showed significant similarity with the Fulton index. Specifically, this index had a lower value in females (0.75±0.02) than in males (0.77±0.02 SE). However, this difference was not statistically significant ($F=0.49$, $p=0.48$). Similarly, this index had no significant difference between the two sampling sites ($F=2.62$, $p=0.11$), with values at CRCT and LPST being 0.73±0.02 and 0.77±0.02 SE, respectively. However, the factors of the season ($F=30.94$, $p<0.001$) and sampling month ($F=5.12$, $p<0.001$) significantly influenced the change in the Clark index of this fish species. Specifically, the dry season (0.84±0.02 SE) had a significantly higher value than the wet season (0.67±0.02 SE). This variation can be observed more clearly through the monthly fluctuations of this value in Figure 4.

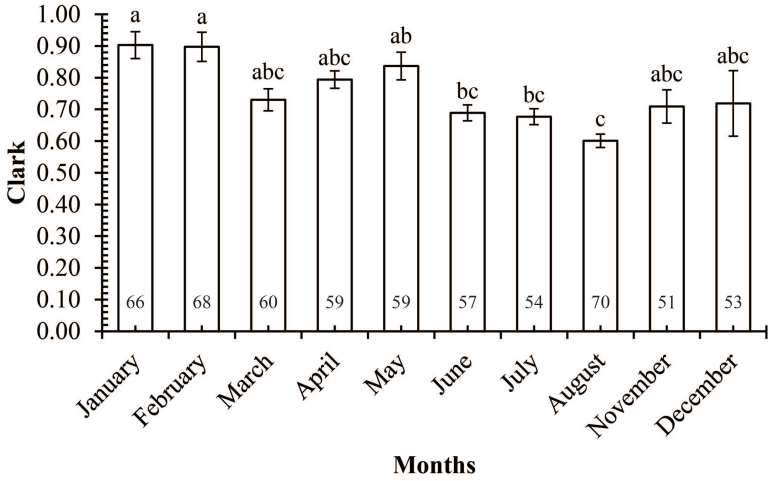

Figure 4 The changes in the Clark index of *Mystus albolineatus* by month (Different letters a, b, and c indicate statistically significant differences; Numbers in the column indicate the number of samples collected each month; Vertical bars: standard error)

Similarly, the interactions of sex × season (F=0.61, p=0.43), sex × site (F=1.02, p=0.31), and sex × season × site (F=0.17, p=0.68) did not show significant effects on the Clark index, similar to the Fulton index. However, unlike the Fulton index, the Clark index exhibited a substantial change due to the interaction of season × site (F=4.69, p=0.03; Figure 5). Specifically, during the wet season, this index had a significantly higher value at CRCT (0.72±0.03 SE) than LPST (0.63±0.03 SE). However, this difference was not observed during the dry season.

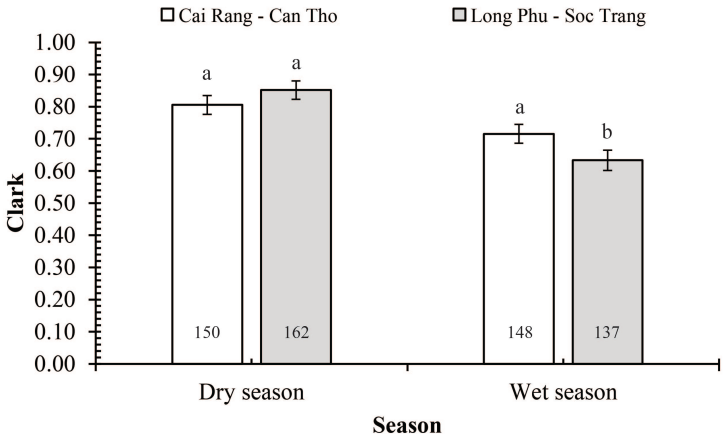

Figure 5 The changes in the Clark index of *Mystus albolineatus* by season × site (Different letters indicate statistically significant differences; Numbers in the column indicate the number of samples collected each month; Vertical bars: standard error)

Similarly, the Clark index only demonstrated distinct grouping results between the dry and wet seasons. Meanwhile, sex and sampling sites only comprised a single group. Salinity emerged as the primary factor influencing the Clark index in this fish species, followed by temperature and pH, which had lesser impacts (Figure 6).

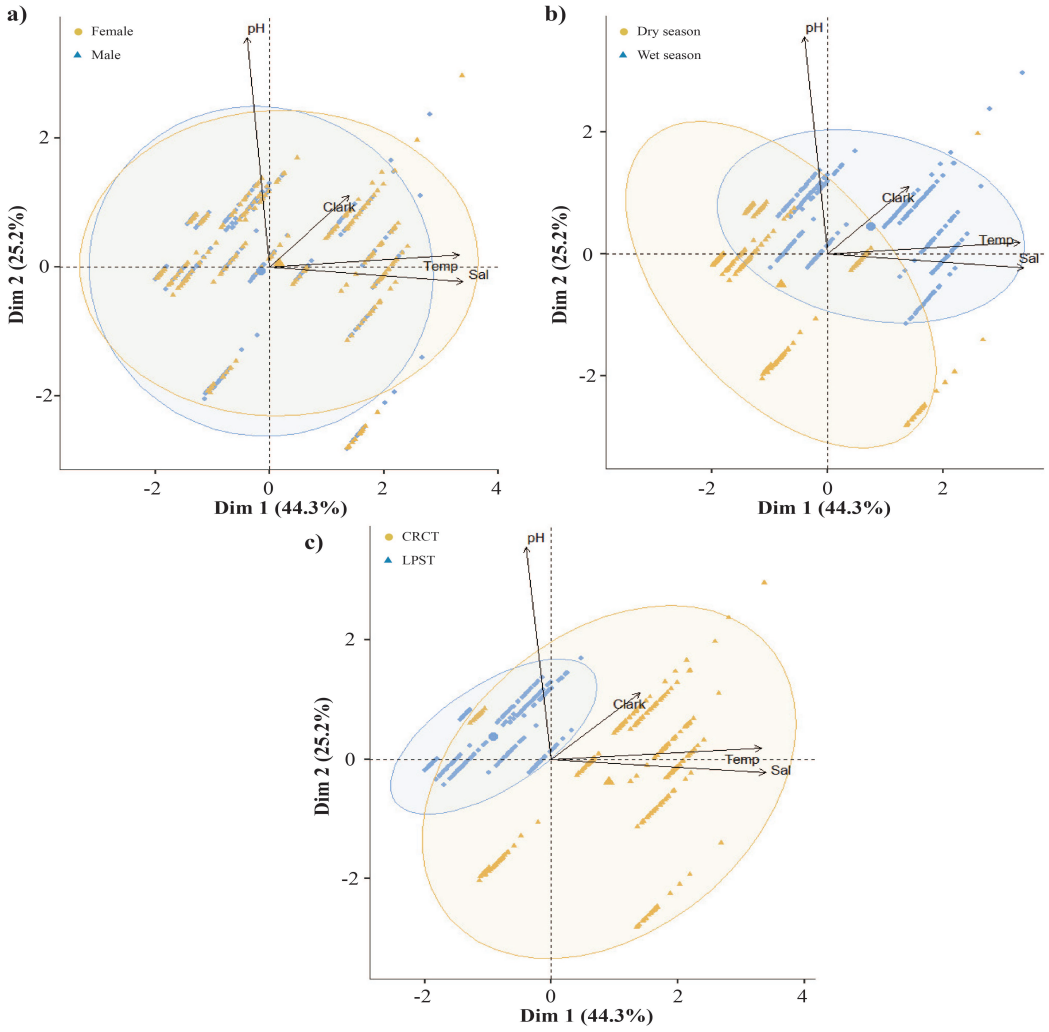

Figure 6 PCA plot of quantitative variables showing the relationship between environmental factors (Tem: temperature, pH, Sal: salinity) and Clark index concerning sex (a), season (b), and site (c)

DISCUSSION

The study of the Fulton and Clark indexes provided essential and comprehensive information about fish's nutritional status, body condition, and health. The Fulton index focuses on the flesh ratio and body development of fish (Peig & Green, 2010; Stavrescu-Bedivan et al., 2015; Santos et al., 2019), while the Clark index assesses the level of fatness and body condition (Clark, 1928; Tran & Dinh, 2021; Nguyen et al., 2022). Combining information from both these indexes helps researchers, fishery resource managers, and fish farmers gain a more holistic view of fish nutrition, making informed decisions and implementing rational management measures. Furthermore, studying these indexes together supported fish health and reproductive capability assessment. The Fulton index may be related to reproductive ability through the evaluation of development and flesh ratio (Jonsson et al., 2014; Tessema et al., 2019), while the Clark index provided information about body condition and fatness (Dinh et al., 2020; Tran & Dinh, 2021; Nguyen et al., 2022). Synthesizing information from these two indexes helps in determining the health status and reproductive ability of fish comprehensively and accurately.

Results regarding both the Fulton and Clark indexes showed similarity between these two indexes. Both indicated no significant differences based on sex and sampling sites but significant differences based on season and month. Although the environments in these two areas had been identified as significantly different in terms of salinity and temperature (Nguyen & Dinh, 2023; Phan et al., 2023), these changes did not seem to affect the adiposity indexes of the fish, suggesting that this fish species adapts well to different environments. Similarly, these indexes do not differ by sex, indicating that both males and females had equal energy accumulation capabilities. Similar findings had been observed in other fish species in the Mekong Delta, such as *Eleotris melanosoma* (Dinh et al., 2017a), *Stigmatogobius pleurostigma* (Dinh & Tran, 2018), *Periophthalmodon schlosseri* (Tran et al., 2019), *Glossogobius sparsipapillus* (Tran et al., 2021), *Butis koilomatodon* (Dinh et al., 2020), and *Ellochelon vaigiensis* (Nguyen et al., 2022).

On the other hand, environmental changes studied by month and season strongly influence the Fulton and Clark indexes of *Mystus albolinetus*. Significantly higher values for both these indexes during the dry months indicated considerable energy accumulation by the fish during these months. However, these coefficients showed a significant decrease during the wet season, especially from June to August. Initially, this was difficult to understand as the rainy months in the Mekong Delta were usually more favorable for fish species. Therefore, low adiposity index values during these months were not reasonable. However, according to some studies on *Mystus* species, these were primarily spawning months occurring during the wet season (Phan et al., 2023). This indicated that *Mystus albolinetus* primarily focuses energy on the reproductive process during these months. Hence, this led to a sudden decrease in these adiposity indexes during the wet season. This phenomenon had been demonstrated in many other fish species with spawning seasons during the wet season in the Mekong Delta such as *Parapocryptes serperaster* (Dinh et al., 2017b), *Stigmatogobius pleurostigma* (Dinh & Tran, 2018), *Periophthalmodon schlosseri* (Tran et al., 2019), *Glossogobius sparsipapillus* (Tran et al., 2021),

Periophthalmus variabilis (Tran & Dinh, 2021), and *Ellochelon vaigiensis* (Nguyen et al., 2022). These results demonstrated that the Fulton or Clark indexes not only help monitor the body condition of fish but can also be used to observe monthly fluctuations to predict fish reproductive capacity.

CONCLUSIONS

The Fulton and Clark indexes of this fish did not vary with sex, indicating equivalent development between the two sexes. Both indexes significantly varied by season, with higher values in the dry season compared to the wet season. This reflects better nutritional status and health of the fish during the dry season. There were no differences in the Fulton index between the two sampling sites, but the Clark index was higher at the CRCT point than at the LPST point during the wet season. Both indexes fluctuated monthly, with the highest values in January and the lowest in June (wet season). There was no significant interaction between sex, seasons, and sampling sites for the Fulton index. However, for the Clark index, there was an interaction between seasons and sampling sites. These results provide important information about the nutritional status, health, and development of *Mystus albolineatus* under different environmental conditions, supporting the management and conservation of this fishery resource.

AUTHOR CONTRIBUTIONS

This work was conducted with the contribution of all authors. **THDN, VVL, TTKN, and QMD** also carried out the investigation, methodology, formal analysis, and manuscript preparation. All authors read and approved the final manuscript.

CONFLICT OF INTEREST

We have no conflict of interest.

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