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ARTICLE

Reproductive and Growth Parameters of the Razor Clam, *Cultellus maximus* (Gmelin, 1791), in Southern Vietnam

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Abstract
This study aimed to analyze the sex ratio, spawning seasons, length at first maturity, length distribution, length–weight relationship, and relative condition factor of *Cultellus maximus* (Gmelin, 1791) in Southern Vietnam. A total of 1037 individuals of *C. maximus* were collected at 3 sampling sites from June, 2019 to June, 2020. The sex ratio was found to be female biased in Can Gio and male biased in Phu Tan and Ngoc Hien. The clam spawns throughout the year, peaking at Q2 and Q3 during the rainy season. Pooled length at first maturity was 10.12 cm (9.65–10.49 cm CI 95%, P-value < $2.2 \cdot 10^{-16}$). The length–weight relationship indicates positive allometric growth. This study suggests that imposing a minimum harvest size limit on *C. maximus* using the length at first maturity as reference and with harvest seasons in Q1 in Ngoc Hien and Can Gio and Q2 or Q3 in Phu Tan would be ideal for consumption of this species.

Keywords Clam spawning season · Can Gio · Ca Mau · Length at first maturity · Length weight · Sex ratio

1 Introduction

Marine and estuarine mollusc biological parameters are often used as indicators to assess coastal health due to the high sensitivity of these organisms to environmental change (Pearson and Rosenberg 1978; Negri et al. 2014). Such indicators include temperature, salinity, suspended and deposited particle composition, and so on.

As active suspension filter feeders, molluscs can filter excess nutrients from seawater, serving a critical ecological function. Many marine and estuarine molluscs are also important food items throughout different parts of the world. However, marine and estuarine mollusc fisheries face myriad threats including climate change, pollution, and overexploitation, among others (Johnson and Welch 2009). In response to these challenges, fisheries industries have few options, including imposing stricter fishing regulation and sustainable harvest practices, exploring marine aquaculture, or sometimes shifting the target species to a novel one. These strategies are aimed at protecting the existing stocks that face continued decline, while meeting the demand of growing populations.

Vietnam has a long costal line with a high potential for bivalve aquaculture. However, Vietnam's bivalve aquaculture production per km of coastline is just about 8% of China's (O'Connor et al. 2012). In recent years, the Vietnamese government has enacted policies to encourage expanded, sustainable marine aquaculture growth (Nguyen 2016; Gentry et al. 2017). Still, the expansion of bivalve aquaculture in Vietnam is hindered by the reliance on the collection of wild seed which are overly exploited (O'Connor et al. 2012). For example, this is true for White clams (*Meretrix lyrata* [Sowerby, 1851]), the predominant species of bivalve in Vietnamese aquaculture. Diversification of culture species is an option to explore in an effort to ease pressures on existing bivalve culture.

The razor clam, *Cultellus maximus* (Gmelin, 1791), is a near shore marine bivalve known locally in Vietnam as Nghêu

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Móng Tay Chúa. This razor clam species occurs in Asian pacific coastal waters and lives buried in the relatively flat sandy bottom between depths of 2.5 and 10 m (Nguyen 2016). There are several known species of allied genus *Solen* Linnaeus, 1758, but to date, *C. maximus* is the only *Cutellus* to have been recorded in Vietnam (Hylleberg and Kilburn 2003), which is often misidentified as *Sinonovacula sp*. (Nguyen 2016). *C. maximus* is among the most important commercial bivalves to be considered for aquaculture recently (Nguyen 1996) due to its potential economic value but its natural production continues to decline (Vu 2021). However, little information is known about the life history and reproductive biology of this species, precluding an informed and sustainable harvest program.

Life history information of the razor clam is requisite information for aquaculture activities and could be used in fishery models for stock management. Information about the clam's populations from different habitats is useful to understand growth rate patterns as a function of environmental conditions and provides insight into the dynamics of the population in nature (Walters and Martell 2020; Lai et al. 2020a). If interpopulation differences in reproductive and growth parameters are detected, fisheries programs can be tailored to each population for appropriate, sustainable harvest practices.

In Southeast Asia, and Vietnam in particular, fishing regulations such as harvest season and size limit are rarely applied and the regulations are limited to banning some gear types along with destructive methods. Consequently, many stocks have declined or have been overexploited especially near shore fisheries (Rosenberg 2008). Over exploitation happens when too many small individuals are caught, or not enough time is allowed for small individuals to grow and spawn at least once to sustain viable populations (Walters and Martell 2020). Size of fisheries species at which 50% of individuals are mature and able to spawn, or size at first maturity, has been used as the reference for minimum harvest size limit in many different parts of the world to prevent stock decline (Walters and Martell 2020).

However, there is no information on the life history and size at first maturity of *Cultellus maximus* in Vietnam nor in other parts of world. This study aims to present the first data on sex ratio, maturation size, length–weight, width-weight and thickness-weight relationships, and spawning season of *Cultellus maximus* to better understand the species' biology and serve as a basis for the proper resource management and conservation of the clam's stocks in Southern Vietnam.

2 Materials and Methods

2.1 Study Area and Sampling Time

The first study area is in the Long Hoa commune, Can Gio district (Can Gio), south of Ho Chi Minh City. The hydrologic regime in Can Gio is regulated by the combination of flow from the Saigon and Dong Nai Rivers and tidal effects of the South China Sea. The area demonstrates a predominantly semi-diurnal tidal regime (Van Loon et al. 2007). The second and third study areas are in the Dat Mui commune, Ngoc Hien district (Ngoc Hien) and in the Viet Khai commune, Phu Tan district (Phu Tan), respectively, in the Ca Mau Peninsula, Vietnam. The hydrological regime in the Ca Mau Peninsula is complex and influenced by the tidal regime in the South China Sea, the Gulf of Thai Lan, and flow from the Mekong River (Tinh 2019) (Fig. 1). Samplings were carried out from June 2019 to June 2020 at the three sampling sites and were replicated 4 times starting in May/June 2019 (Q2), September/October 2019 (Q3), November/December 2019 (Q4) and March/April 2020 (Q1). Q1 and Q4 are the dry season and Q2 and Q3 are the rainy season.

2.2 Water and Sediment Sample

Water samples were collected near the substrate, stored in 5 L water jars and brought to the shore for measuring general water chemistry including temperature (°C), dissolved oxygen (DO, mg/l), salinity (g/L), pH and alkalinity (mg/l). Water samples were also sealed in 1 L bottles and transported in coolers to the lab of the Nam Song Hau Sub-Institute for Fisheries Research to analyze chemical oxygen demand (COD, mg/l) and biological oxygen demand (BOD_5, mg/l).

Sediment samples were collected from sampling sites using plastic cores (6.03 cm diameter by 40 cm depth) from the sediment surface where the clams reside. Sediment samples were individually stored in 2 kg plastic bags within coolers and brought to the lab to analyze the percentage of mud and sand. Percentages of mud and sand were analyzed following the method to determine the content of soil quality—pretreatment of samples for physico-chemical analysis TCVN 6647:2007 protocol.

2.3 Razor Clam Sampling

All samples were collected by hand by local divers at the depth of 5–10 m from the surface. All specimens were individually tagged and labeled in the field and measured for total length (TL), width (W_{idth}), thickness (TN) by electronic caliper to the nearest 0.01 cm and weighed by digital scale for total wet weight (W) to the nearest 0.001 g. Clams were

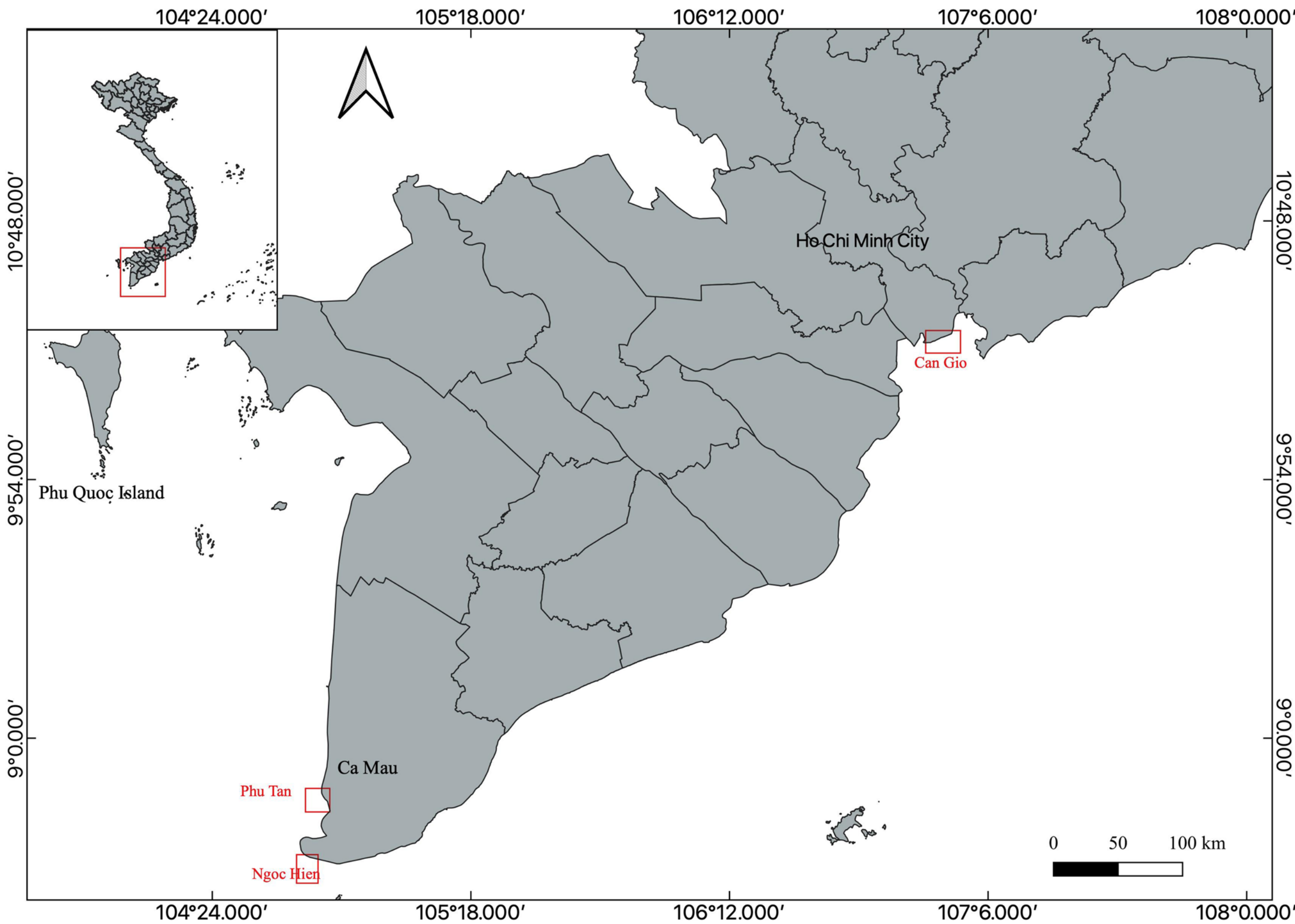

Fig. 1 Location of sampling sites in Southern Vietnam. Red rectangles are sampling sites

kept in coolers and brought back to the lab for further analysis. In the lab, the razor clams were identified based on the morphological identification described by Hylleberg and Kilburn (2003) and Nguyen (2016). Clams were then dissected to separate shells, flesh and gonads. Gonads were then fixed in a 10% formalin solution for 24 h and preserved in ethanol 70% for gonad histological analysis. Voucher specimens were deposited in the Nam Song Hau Sub-Institute for Fisheries Research—Research Institute for Aquaculture II.

2.4 Sex Ratio and Maturity Stages

Sex was initially identified based on the gonad color and morphological appearance. Testis are generally milky white, whereas and ovaries are commonly from light yellow to orange in color (Hoang and Tuyen 2016). The color of the sex was later confirmed by histological analysis and reported for both male and female.

Maturity stages were characterized using histological analysis of male and female gonad samples. The gonad samples were embedded in paraffin and then cut into slides and stained with Hematoxyline and Eosine for microscopic analysis (Kiernan 1990). Following Gervis and Sims (1992) and Quayle and Newkirk (1989), maturity was divided into 5 stages numbered from 0 to 4. Stages are defined as follows: stage 0 indicates indeterminate sex; stage 1 is characterized by the beginning of gametogenesis with the appearance of follicles; stage 2 is characterized by enlarged follicles with well-formed but unripe gametes; stage 3 is characterized by the presence of sexually matured ova capable of fertilization and active sperm; stage 4 is characterized as organisms having recently spawned with follicles spatially collapsed and none or only few relict ova or sperm.

2.5 Data Analysis

The clams were considered immature when their maturation was in stages 0, 1 or 2. Clams were considered as mature when their maturation was stage 3 or 4 (Galimany et al. 2015). The relation between total length and predicted probability of clam being mature at a given length was determined using the logistic regression equation: $p = \frac{e^{a1+b1*\mathrm{TL}}}{1+e^{a1+b1*\mathrm{TL}}}$, where p is probability (%) of clam being mature at a given length, TL is total length (cm), and *a1* and *b1* are parameters of the logistic regression equation. The lengths at which 50% of clams matured (Lm_{50}) were reported for each males, females and for combined samples of the three sampling sites.

Weight-related relationships including length–weight, width-weight and thickness-weight relationships were determined using the equation $W = a2 \times TL^{b2}$ (Le Cren 1951), where *W* is body mass (including shell weight, g), TL is total length or Width (W_{idth}) or Thickness (TN) measured in cm, and *a2* and *b2* are parameters of the weight-related relationship equation.

Length-related relationships including length–width, length-thickness and width-thickness relationships were estimated using regression analysis (Chowdhury et al. 2021) $W_{idth} = a3 + b3 \cdot TL$, where W_{idth} is body width (cm) or thickness (TN, cm), and *a3* and *b3* are regression parameters of the length related relationship equation.

Relative condition factor (K_n) was calculated using the equation $K_n = \frac{W}{a \times TL^b}$ (Le Cren 1951) for each sampling site. ANOVA analysis followed by Tukey post hoc test were used to compare the difference of K_n between sampling sites. All analyses were performed using R (R Core Team 2013).

3 Results

3.1 Physiochemistry

Summary physiochemical parameters of sediment and water samples during the field are presented in Table 1. In the sediment, the percentage of mud ranged from 58.4 to 85.7% and water temperature ranged from 24.5 to 32.8 °C. The highest salinity during our sampling period in Q1 and Q2 was about 30 g/L and the lowest in Q3 and Q4 was 25 g/L, 20 g/L and 15 g/L in Ngoc Hien, Phu Tan and Can Gio, respectively. The highest COD and BOD was recorded in Can Gio. On average, the lowest DO was recorded in Can Gio and the highest was in Phu Tan. Alkalinity and pH are similar between all three sampling sites. Detailed physiochemical parameters of each sampling sites and seasons are presented in the Supplementary Material.

3.2 Samples and Sex Ratio

A total of 1037 samples of razor clam were collected across the 3 sampling sites throughout the sampling periods. There were 454 males and 415 females identified, with the sex of 168 (16.2%) samples unidentifiable. Female gonads were bright orange with a milky texture and male gonads were creamy colored and granular (Fig. 2). We found no evidence of hermaphroditism in the razor clam. The sex ratio fluctuated by sampling time and sites. Sex ratios were male biased in Ngoc Hien and Phu Tan in Ca Mau, but reversely female biased in Can Gio in Ho Chi Minh City. The overall sex ratio was roughly normal at 1.09. (Table 2).

3.3 Maturation and Spawning Phenology

The razor clam spawned throughout the year and peaked at Q2 and Q3 during the rainy season. Spawning was relatively steady in Phu Tan with the percentage of observed mature clams in stage 3 at about 65% for all quarters. Spawning gradually increased from Q1 to Q3 and decreased in Q4 in Ngoc Hien, whereas spawning in Can Gio occurred predominantly in Q2 and Q3 with 82% of samples observed in stage 3 (Fig. 3).

3.4 Length at Maturity

The smallest mature male occurred at length 7.7 cm and the smallest mature female at length 7.8 cm. The length at which 50% of male clams are mature is 10.39 cm (9.80–10.81 cm CI 95%) and 50% of female clams mature at 9.84 cm (8.76–10.45 cm CI 95%). The function of predicted probability of being matured at a given length value of combined sexes in the form $p = \frac{e^{-4.73+0.47*TL}}{1+e^{-4.73+0.47*TL}}$, where the proportion of 50% clams are mature, is at the length of 10.12 cm (9.65–10.49 cm CI 95%, *P*-value $< 2.2 \cdot 10^{-16}$; Fig. 4).

3.5 Length Frequency Distribution

Length distribution was normally distributed in Phu Tan, while left skewed in Ngoc Hien and Can Gio. The razor clam with spawning potential (TL > 10 cm) dominated in all sampling sites (Fig. 5) and the highest frequency occurred in

Table 1 Physiochemical parameters of sediment and water at the sampling sites

Sampling sites	Mud (%)	Temperature (°C)	Salinity (g/L)	COD (mg/l)	BOD (mg/l)	DO (mg/l)	Alkalinity (mg/l)	pH
Ngoc Hien	58.4–85.7	24.5–32.8	25–30	6.6–12.4	6.1–9.6	4.8–8.1	80–130	7.5–8.5
Phu Tan	62.0–86.3	24.7–31.3	20–30	6.8–15	5.7–10.6	4.9–9	89.5–130	7.5–8.5
Can Gio	64.2–85.3	27.9–31.5	15–29	6.7–15.6	5.6–10.8	5.1–6.8	80–125	6–8.5

Fig. 2 Gonad histology of *Cultellus maximus.* Number 0–4 correspond to Stage 0–4. Stage 0 is indeterminate sex. Letters a and b correspond to female and male accordingly. Scale bar: 100 µm (**2a**, **3a**), 50 µm (**1a**, **4a**, **2b**, **3b**) and 25 µm (**2b**, **3b**)

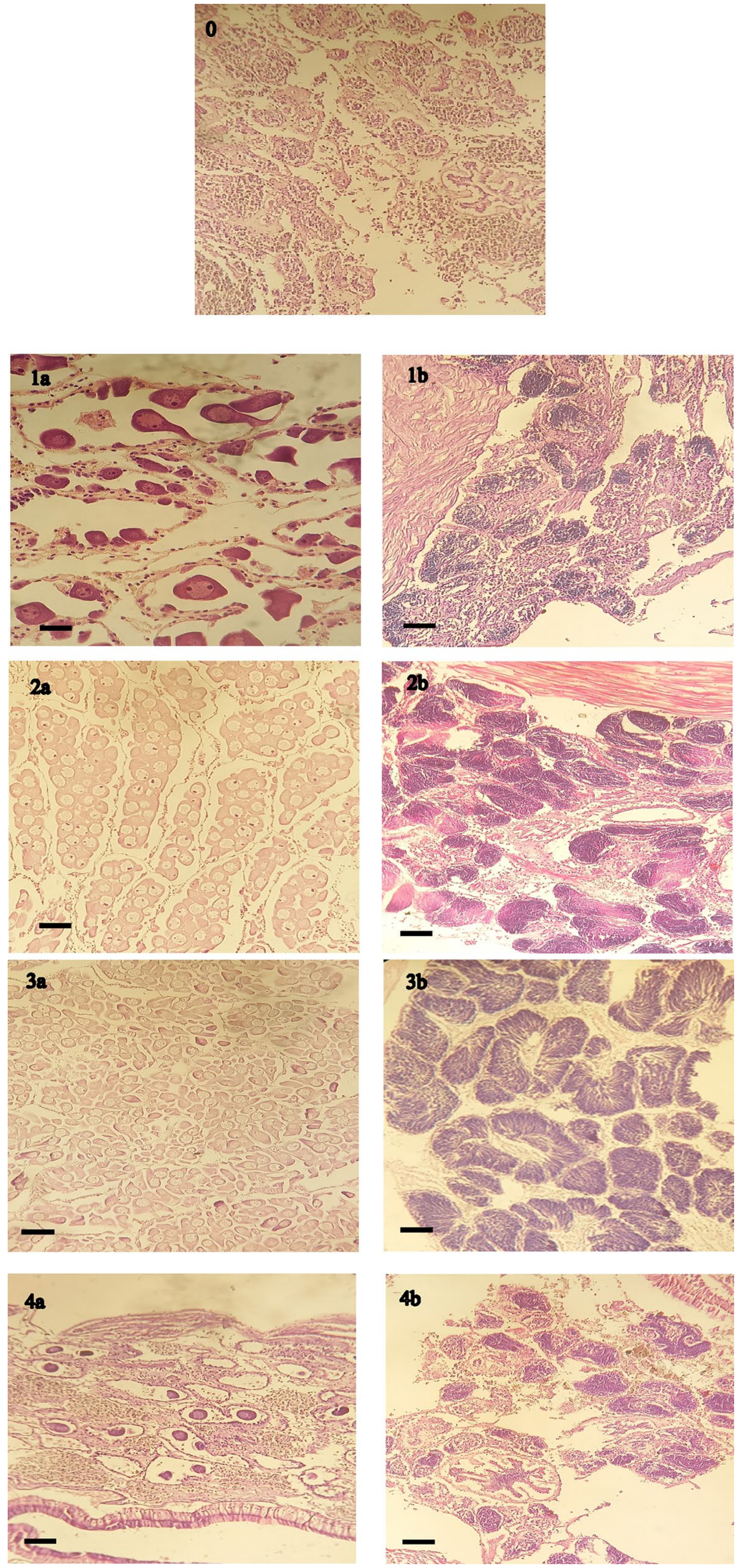

Table 2 Razor clam samples and sex ratio across sampling sites

Sampling sites/time	Male	Female	Sexually undifferentiated	Sex ratio (male/female)
Ngoc Hien	144	127	81	1.13
Q1	35	48	2	0.73
Q2	37	33	18	1.12
Q3	42	29	18	1.45
Q4	30	17	43	1.76
Phu Tan	168	140	22	1.20
Q1	46	44	0	1.05
Q2	31	38	2	1.11
Q3	41	32	16	1.28
Q4	50	36	4	1.39
Can Gio	142	148	65	0.96
Q1	31	35	24	0.89
Q2	35	50	0	0.66
Q3	43	43	2	1.00
Q4	33	17	39	1.94
Total	454	415	168	1.09

length group of ~ 11.5 cm. Clams reach ~ 16 cm in maximum length in all areas.

3.6 Weight-Related Relationships

Total wet weight (W,g) of the clam ranged from 9.3 to 189.3 g, while total length (TL, cm) ranged from 6.0 to 15.7 cm. A relationship between total length and total wet weight is described in the form $W = 0.032 \times TL^{3.12}$ ($r^2 = 0.92$, P-value $< 2.2 \cdot 10^{-16}$, Fig. 6).

Width (W_{idth}, cm) of the clam ranged from 1.8 to 5.1 cm. A relationship between width and total wet weight is described in the form $W = 1.869 \times W_{idth}^{2.78}$ ($r^2 = 0.85$, P-value $< 2.2 \cdot 10^{-16}$) (Fig. 7; Table 3).

Thickness (TN, cm) of the clam ranged from 0.8 to 3.8 cm. A relationship between thickness and total wet weight is described in the form $W = 9.91 \times W_{idth}^{2.25}$ ($r^2 = 0.848$, P-value $< 2.2 \cdot 10^{-16}$).

3.7 Length-Related Relationships

A relationship between total length and width is described in the form $W_{idth} = -\ 0.065 + 0.312 \cdot TL$ ($r^2 = 0.89$, P-value $< 2.2 \cdot 10^{-16}$).

A relationship between total length and thickness is described in the form $TN = -\ 0.429 + 0.240 \cdot TL$ ($r^2 = 0.813$, P-value $< 2.2 \cdot 10^{-16}$).

A relationship between width and thickness is described in the form $TN = -\ 0.252 + 0.714 \cdot W_{idth}$ ($r^2 = 0.83$, P-value $< 2.2 \cdot 10^{-16}$).

3.8 Relative Condition Factor (K_n)

Relative conditional factor (K_n) ranged from 0.49 to 1.95 with a mean of 1.014 (Fig. 8). Generally, K_n was the highest in Can Gio and the lowest in Phu Tan and showed significant difference between pairwise comparisons (P-value $< 2.2 \cdot 10^{-16}$, Table 4). In Ngoc Hien and Can Gio, mean K_n is the highest in Q1, while K_n is highest in Q2 and Q3 in Phu Tan (Fig. 9).

4 Discussion

This study documents the sex ratio, spawning seasons, length at first maturity, length-frequency distribution, length–weight relationship and relative condition factor of *Cultellus maximus* in Southern Vietnam. Not only is this

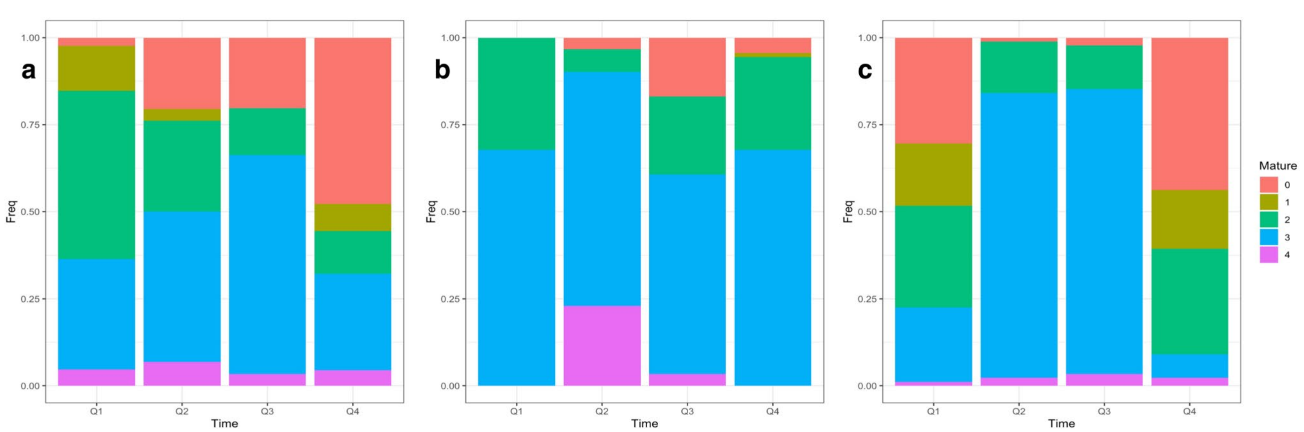

Fig. 3 Maturity stages by sampling times. Q1, Q2, Q3 and Q4 are quarters 1 to 4, respectively. Left to right graphs (**a**) Ngoc Hien; (**b**) Phu Tan; and (**c**) Can Gio sampling sites

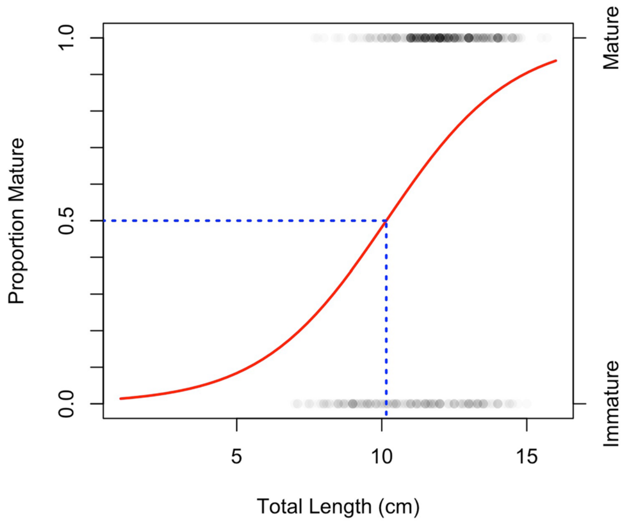

Fig. 4 Fitted logistic regression for proportion of razor clam maturation by total length (red line), with blue dash line as the length at which 50% of clams are mature. Gray-shaded dots are individual data, where the darker the dot the more individuals are plotted at that point

species a bioindicator of unique intertidal biofacies and useful in benthic geological and ecological studies (Negri et al. 2014), but its potential as a food commodity appears to be high. The study provides potentially useful information for razor clam aquaculture and also for managing and conserving this important marine resource in Vietnam.

Bivalves often exhibit roughly equal numbers of males and females within a population (Gosling 2015). However, the sex ratio imbalance observed here is indicative of the unique geophysical location and environmental conditions such as temperature and food availability, or sampling bias (Rinyod and Rahim 2011; Hoang and Tuyen 2016; Trisyani et al. 2019). Individuals' sex at birth is determined by environmental conditions and genetic variation, or the combination thereof (Yusa 2007). The temporal sex ratio variation has been observed in razor clam populations such as in a *Solen regularis* Dunker, 1862 population in Malaysia (Rinyod and Rahim 2011), in a *Solen* sp. population in Indonesia (Trisyani et al. 2019), and in a *Solen thachi* Cosel, 2002 population in the central coast of Vietnam (Hoang and

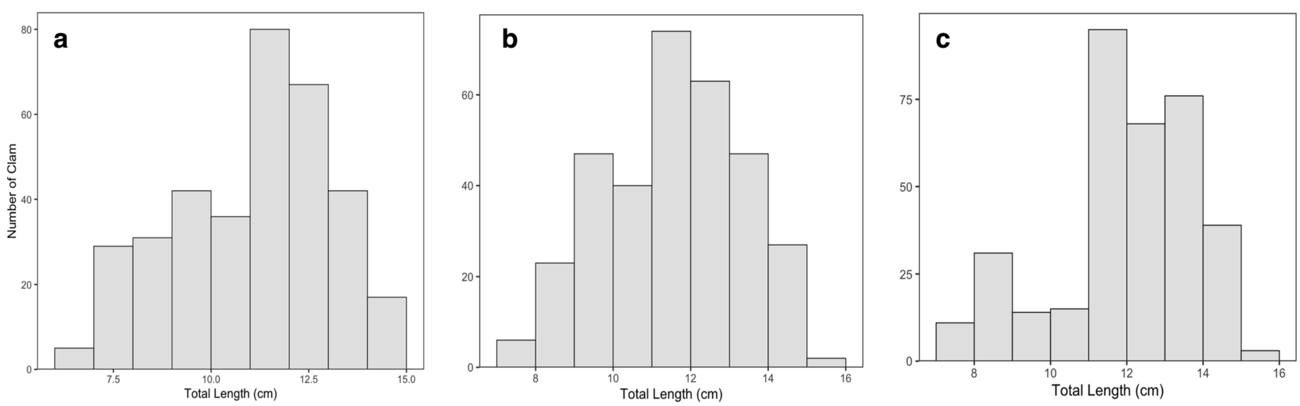

Fig. 5 Length frequency distribution of all samples. Left to right graphs (**a**) Ngoc Hien; (**b**) Phu Tan; and (**c**) Can Gio sampling sites

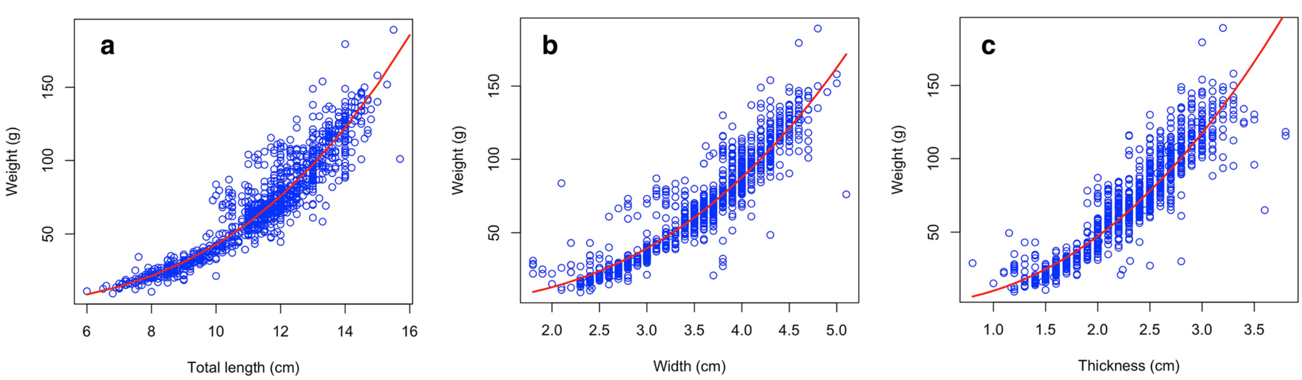

Fig. 6 Weight-related relationships of razor clam in the sampling sites. From **a** to **c** are the relationship of weight with length, width and thickness, respectively

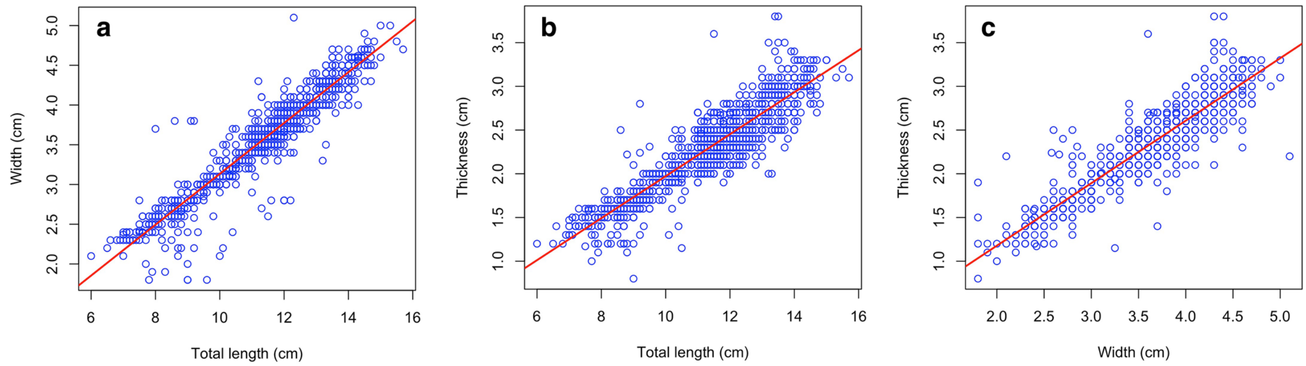

Fig. 7 Length-related relationships of razor clam in the sampling sites. From **a** to **b** are the relationship of length with width and thickness, respectively. **c** The relationship of width and thickness

Table 3 Summary of equations of length and weight-related relationship

	Weight (W)	Width (W_{idth})	Thickness (TN)
Length (TL)	$W = 0.032 \times TL^{3.12}$	$W_{idth} = -0.065 + 0.312 \cdot TL$	$TN = -0.429 + 0.240 \cdot TL$
Weight (W)		$W = 1.869 \times W_{idth}^{2.775}$	$W = 9.91 \times W_{idth}^{2.25}$
Width (W_{idth})			$TN = -0.252 + 0.714 \cdot W_{idth}$

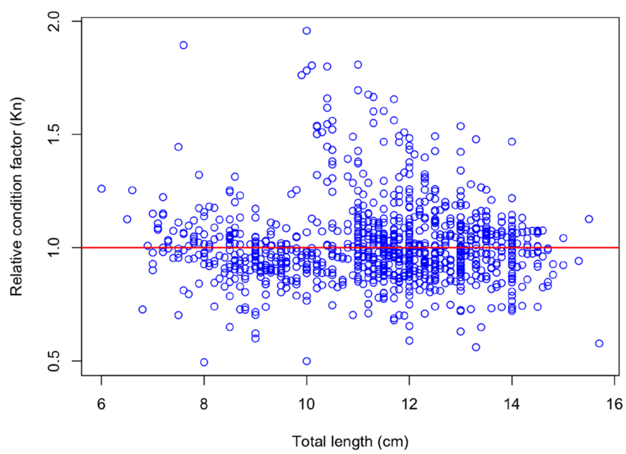

Fig. 8 Relative condition factor (K_n) of razor clam at given length

Tuyen 2016). Trisyani et al. (2019) hypothesized that the sex imbalance could result from the impact of excessive exploitation on one of the sexes of the *Solen* sp. populations in Indonesia. However, we did not believe this is the case regarding the *Cultellus maximus* in Southern Vietnam, and may instead be due to sampling bias by individual divers in this study, which also resulted in skewed length distribution.

Gosling (2015) suggested that different types of environmental cues such as storms, salinity change, lunar phase and tidal fluctuations could stimulate spawning of bivalves. In Ngoc Hien and Can Gio, the spawning peaks in Q2 and Q3 coincide with the rainy season in the area and also when there is the highest tidal amplitude (Tri et al. 2019), thereby perhaps enhancing the chances of fertilization in light of increased gamete movement in the water column. Steady spawning was observed year round in Phu Tan, where the tidal regime is complex and influenced by both the tidal regime from the South China Sea and the Gulf of Thailand. The interaction between the two seas on the spawning potential of *Cultellus maximus* should be a subject of future study.

The length at first maturity in this study (10.12 cm, 9.65–10.49 cm CI 95%) is longer than the *Solen thachi* population in the central coast of Vietnam (i.e., 7 cm; Hoang and Tuyen 2016). Kim and Lee (2008) reported

Table 4 Relative condition factor (K_n) of the clams sampled at sites

Sampling sites	No. individuals	$A \pm$ CI 95%	$B \pm$ CI 95%	r^2	$K_n \pm$ SE
Ngoc Hien	353	0.038 ± 0.008	3.08 ± 0.097	0.92	1.033 ± 0.010*
Phu Tan	330	0.029 ± 0.006	3.12 ± 0.087	0.94	0.914 ± 0.006*
Can Gio	354	0.038 ± 0.01	3.08 ± 0.097	0.92	1.088 ± 0.008*
All samples	1037	0.032 ± 0.005	3.12 ± 0.057	0.92	1.014 ± 0.005

*Significant difference at p-value < 0.05

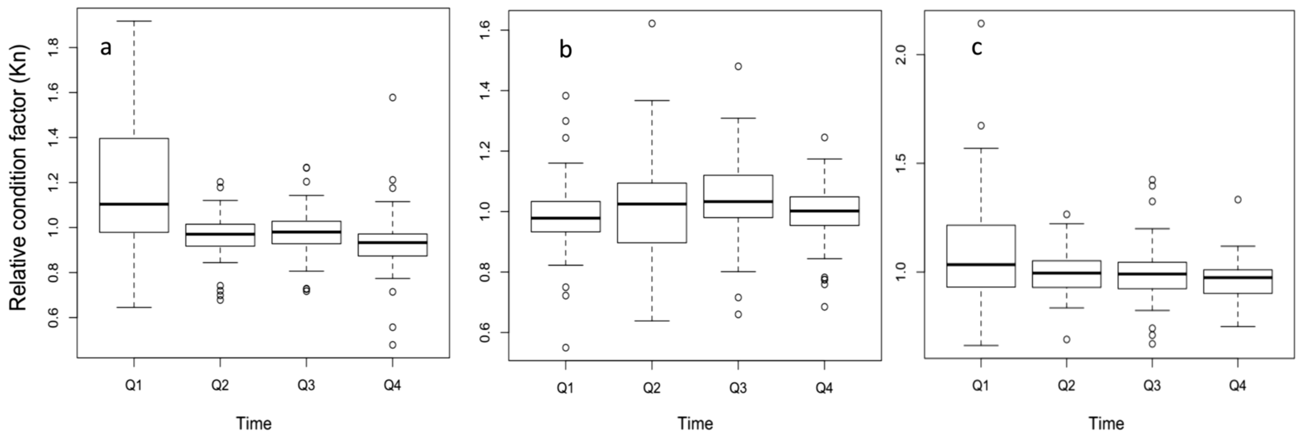

Fig. 9 Relative condition factor of *Cultellus maximus* per sampling time and site. Q1, Q2, Q3 and Q4 are quarters 1–4, respectively. Left to right graphs (**a**) Ngoc Hien; (**b**) Phu Tan; and (**c**) Can Gio sampling sites

that the length at first maturity of *Sinonovacula constricta* (Lamarck, 1818) in western South Korea was 5–6.1 cm. However, they described the maturity stage as from the late active stage which is in between stage 2 and stage 3 outlined in this paper. Therefore, the report of the length at first maturity should correspond to or match the definition of reproductive or non-reproductive stage.

Trisyani et al. (2019) observed that in *Solen sp*. and *Ensis sp*. populations there is positive correlation between the maximum length and the length at first maturity, whereas the length at first maturity of *Cultellus maximus* in this study is similar with *Ensis macha* (Molina, 1782) in Argentina, where maximum length and the length at first maturity of *Ensis macha* is 15.4 cm and 11.2 cm, respectively (Barón et al. 2004). In addition, Ridgway et al. (2011) found that the longer time a bivalve takes to attain maturity, the longer the lifespan it might exhibit, and vice versa. The time to reach maturity in bivalves could also result from an adaptation to local environmental conditions, particularly food availability (Gosling 2015).

It was determined at the three sampling sites in this study that the species' allometry (b) is higher than the cubic value of three, demonstrating that the razor clam grows faster in weight than in length. However, growth patterns could vary differently between life stages, size class (Froese 2006) and even within the year (Ngor et al. 2018), especially in bivalves population.

Relative condition factor (K_n) evaluates the physical condition while simultaneously compensating for changes in physiological well-being associated with an increase in length (Froese 2006). Many environmental factors affect the growth condition and physiological well-being of bivalves including temperature, salinity and suspended solids that regulate bivalves' filtration rate, as well as availability of food in the water column (Lai et al. 2020b). $K_n > 1$ signifies excellent physiological condition (Le Cren 1951). In addition, the variation of K_n may be associated with the reproductive cycle, and marine organisms often decrease their feeding activity during spawning which results in a decrease in condition (Lizama and Ambrosio 2002). The analysis of relative condition factor (K_n) coupled with the analysis of maturity stages (Fig. 3) suggests that the harvest could be economical and sustainability possible if executed in Q1 in Ngoc Hien and Can Gio and Q2 or Q3 in Phu Tan and when the condition of minimum size limit at the length at first maturity is met.

In Vietnam and in other Southeast Asian countries, fishing regulations in fresh water and marine environments have not often been put in place due to the lack of systematic scientific information about animals' biology, ecology and monitoring of stock status. The work here provides preliminary information of *Cultellus maximus* populations in Southern Vietnam. The data can be used to implement fishing regulations such as harvesting season and size limit of *Cultellus maximus* in Southern Vietnam.

5 Conclusions

This study is the first to document the life history information of *Cultellus maximus* based on the sampling of 1037 individuals in three sampling sites in Southern Vietnam. *Cultellus maximus* was generally male biased but the sex ratio was varied spatially and temporally. The length at first maturity (Lm_{50}) and spawning season reported in this study could be used as references to impose a minimum harvest size limit and harvest season of this clam in Southern Vietnam so as to conserve this important commercial species and ensure a sustainable and economically beneficial harvest.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12601-022-00089-5.

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