Pol. J. Environ. Stud. Vol. 28, No. 3 (2019), 1917-1924
DOI: *10.15244/pjoes/90621* ONLINE PUBLICATION DATE: 2018-12-12

Original Research

Determining Bioecological and Biometric Properties of Freshwater Mussels (*Unio crassus* Philipsson, 1788)

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Received: 25 March 2018
Accepted: 27 April 2018

Abstract

Population characteristics of *Unio crassus,* an endangered freshwater mussel in many countries, are very important. In this study, we have attempted to determine the environmental conditions of Aydın-Çine Creek and the biometric properties of *U.crassus*. The largest length during the study period was 92.50 mm in February, and the smallest length was 37.03 mm in April. In addition, the heaviest individual was found to be 124.15 g in February, while the smallest individual was 6.69 g in April. It was found that 141 individuals were found in a group of 70.0-79.99 mm at maximum in the distribution frequency of *U.crassus* in Çine Creek. The water temperature was measured at 9.8-24.0ºC, and oxygen value was 6.0-10.4 mg/L during the study. In the current environmental conditions in Çine Creek, various sizes and population development of *U.crassus* have been identified.

Keywords: *Unio crassus*, thick-shelled river mussel, biometric measurements, Çine Creek, Turkey

Introduction

Freshwater mussels have an important role in the ecological system because of their filter feeding organism and its interesting life cycle [1]. Some freshwater mussel species are economically important as they have potential for production, consumption, and processing. Mussels that have nacreous shell produce pearl and have a particularly high market value [2-3]. The numbers of some freshwater mussel species have decreased day by day and have even become in danger of extinction due to pollution, drought, coastal arrangements, insensible fishing, and a low number of host fish in the environment [4-5]. Despite the fact that *Unio crassus* has spread to many parts of the world and has produced a high population (over 700 individuals/m^2), the number of freshwater mussels in Europe has been greatly reduced in the last 40-50 years [6-8]. Only the population in the Baltic States and in the European side of Russia is in relatively good condition. However, the situation of the population in Greece and Turkey is not yet known [8]. *U.crassus* is a sensitive organism of unfavorable environmental conditions, closely related to the need for specific ecological requirements at different stages of life, and therefore the conditions of environment to be optimal is directly related with the ability to complete its life cycle [7]. It has been reported that *U. crassus* has lived up to 75 years and some shells even have 90 growth rings [9]. When the growth and survival ages of *U. crassus* are compared, it is reported that slow-growing

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individuals have longer lives than fast-growing individuals [10-11].

It is determined that more information is required due to lack of knowledge about the populations' structure of *Unio crassus* where it is distributed among other countries. Studies in Turkey have focused on growth and some biological properties of freshwater mussels such as *Unio pictorum* and *Unio tumidus* [12-13], there has been no study related to *U. crassus*'s population situation. For this reason, in order to determine the population status of *U. crassus* in Aydın Çine Creek, biometrics measurements of mussels were taken, length frequency was examined, and relations between biometric measurements and changes of environmental parameters were determined.

Materials and Methods

Study Area

Çine Creek is a branch of the Büyük Menderes River, which is one of the longest rivers of Western Anatolia. It is approximately 119 km long and is within the borders of Aydın [14]. Çine Creek (37°45'51"N, 27°49'59"E) was selected to study the population status of *Unio crassus* (thick-shelled river mussel). Samples were collected by hand from a maximum 70 cm depth and sandy bottom (Fig. 1).

Environmental Factors

Water samples were taken from the study area on a monthly basis and the water parameters in the area where the mussels were distributed were followed. The water temperature was measured during sampling with an alcohol thermometer (-10 to 100 0.5ºC). Water samples were taken to determine the amount of oxygen and were examined in laboratory according to the Winkler method. Water samples were taken to determine total particulate matter (TPM), particulate inorganic matter (PIM), particulate organic matter (POM), and chlorophyll-a, and were filtrated with GF/C filter paper in the laboratory. Analyses were made according to the method developed by Strickland and Parsons [15].

Sampling and Biometric Measurements

The study was conducted monthly between September 2012 and August 2013. In total, 30 live individuals of *U. crassus* were collected from Çine Creek every month and their biometric measurements were taken. In order not to measure the same mussels, those collected were taken away from the current station. Shell length, width, and thickness measurements were made with the aid of a digital caliper (IP 66-Mitutoyo Absolute) and weights were measured with digital scales (±0.01 g).

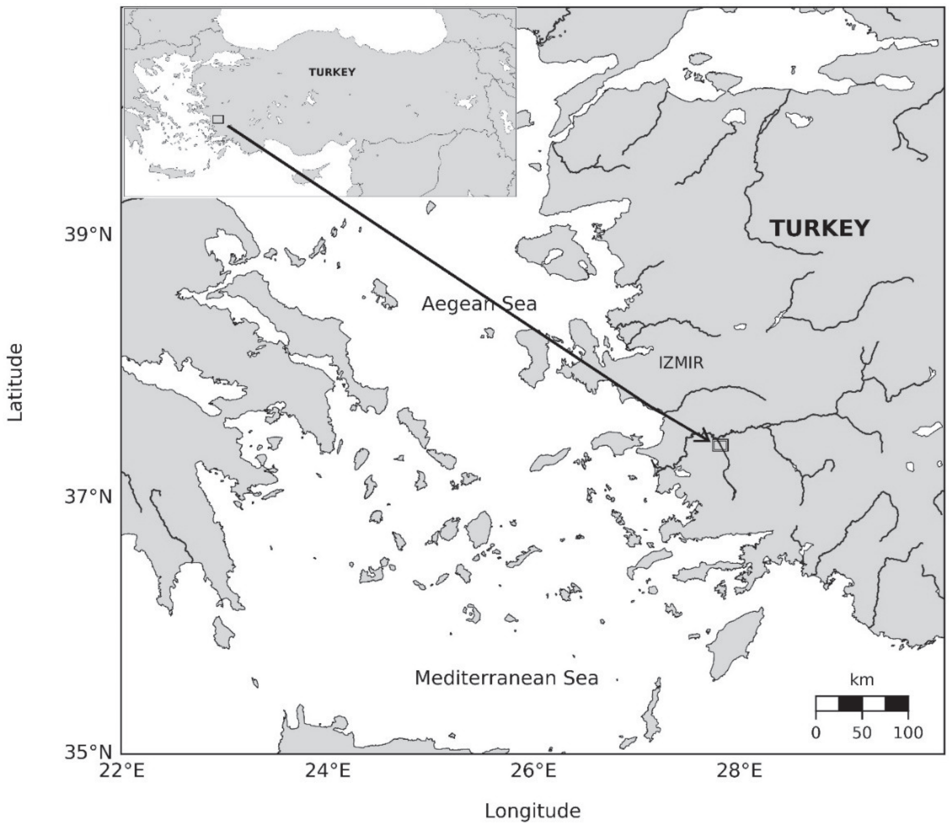

Fig. 1. Map of the study area.

Data Analysis

Shell length was measured from the widest point in the anterior-posterior axis line, and thickness is the measurement taken from the highest point when two shells come together.

The $W = aL^b$ equation was used to determine the relationship between shell length-weight, weight-width, weight-thickness, shell length-width, and shell length-thickness of freshwater mussels [16]. "W" represents total weight, "L" represents shell length (anterior-posterior axis), and "a" and "b" coefficients represent growth parameters. If the value of b is equal to 3, it is defined as isometry, and negative allometry is defined when $b<3$ and positive allometry is defined when $b>3$. Also, the value of "r" (correlation coefficient) is calculated to determine the force between the parameters. Microsoft Excel Office 2010 was used to examine the biometric measurements and to determine the relationships between the dimensions.

Results

Environmental Parameters

The water temperature ranged from 9.8ºC to 24.0ºC during the study, while the oxygen level was measured between 6.0 mg/L and 10.4 mg/L (Fig. 2). The highest amount of chlorophyll-a was detected in May (70.48 µg/L) and the lowest in July (1.58 µg/l). The highest and the lowest values of total particulate matter (TPM) were determined in October (123.2 mg/L) and August (7 mg/L). The highest and the lowest POM were found in February and August as 126.16 mg/L in and 5 mg/l, respectively. PIM concentration was highest in April (20.3 mg/L) and lowest in August (2 mg/L) (Fig. 3).

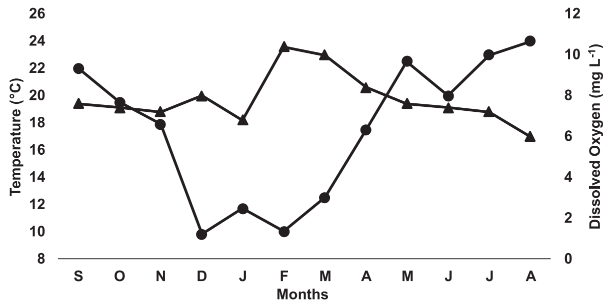

Fig. 2. Variation of water temperature and oxygen values.

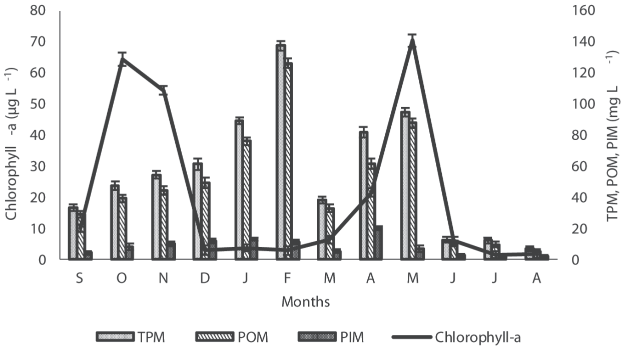

Fig. 3. Chlorophyll-a, TPM, POM, and PIM levels.

Biometric Properties

The largest average length of freshwater mussels was measured in September as 71.00±1.99 mm, and the smallest average length was measured in April as 62.51±2.10 (Table 1). The largest length during the study period was in February as 92.50 mm and the smallest length was in April as 37.03 mm (Table 1).

The highest average width was in September as 39.52±1.03mm, while the lowest average width was in April as 35.08±1.07 mm. During the study, the largest individual was measured in June as 51.18 mm, while the minimum width was measured in October as 21.28 mm (Table 1).

The largest average thickness was found in September as 26.48±0.77 mm, and the smallest average thickness was found in April as 22.99±0.76 mm. The thickest individual was measured in February as 36.23 mm and the minimum thickness was found in April as 13.37 mm (Table 1).

The highest average weight was in September as 48.82±3.41 g and the lowest average weight was in April as 33.73±2.86 g. The highest weight was found in February as 124.15 g, while the smallest individual was in April as 6.69 g (Table 1).

When the averages of the biometric measurements of the freshwater mussels collected throughout the year were calculated, the average shell length was 71.75±7.63 mm, average width 39.95±4.20 mm, average thickness 26.90±3.74 mm, and average weight 48.41±16.63 g (Table 1).

For the frequency distribution of the individuals measured, we found that the maximum number of individuals is in the group of 70.0-79.99 mm, with 141 individuals. Three individuals were found in the longest-length group (90.0-99.99 mm), and five individuals were found in the smallest length group (30.00-39.99 mm) (Fig. 4).

Relationship between Biometric Measures

When all biometric measurements were compared, we concluded that there was negative allometric relationship in all cases (Table 2). The lowest correlation coefficient (r) in the study was found to be between shell length and shell width (0.93). The highest r value (0.97) was calculated between shell length and weight, and shell length and width, and a strong correlation was found between these measures (Table 2).

Table 1. Biometric measurements of *U. crassus*.

		N	Mean X±SE	Min	Max
September	Shell Length (mm)	30	71.00±1.99	42.42	86.16
	Shell Width (mm)	30	39.52±1.03	25.46	46.75
	Shell Height (mm)	30	26.48±0.77	16.95	32.29
	Weight (g)	30	48.82±3.41	6.98	82.75
October	Shell Length (mm)	30	65.81±1,90	37.52	79.68
	Shell Width (mm)	30	36.84±1,05	21.28	43.5
	Shell Height (mm)	30	25.32±0.75	15.40	30.11
	Weight (g)	30	40.38±2.75	7.29	60.36
November	Shell Length (mm)	30	67.21±1.96	61.91	84.43
	Shell Width (mm)	30	37.73±1.08	34.57	48.19
	Shell Height (mm)	30	25.25±0.72	16.90	32.10
	Weight (g)	30	41.50±3.12	9.64	73.50
December	Shell Length (mm)	30	68.74±1.98	63.83	85.01
	Shell Width (mm)	30	38.31±1.16	21.38	47.12
	Shell Height (mm)	30	26.20±0.83	13.87	33.13
	Weight (g)	30	46.48±3.46	7.34	84.79
January	Shell Length (mm)	30	67.80±1.76	39.95	75.55
	Shell Width (mm)	30	37.85±0.92	22.87	42.30
	Shell Height (mm)	30	24.66±0.63	14.42	28.11
	Weight (g)	30	40.00±2.15	8.99	48.66
February	Shell Length (mm)	30	68.41±2.45	40.59	92.52
	Shell Width (mm)	30	38.25±1.30	22.89	50.53
	Shell Height (mm)	30	25.70±0.96	15.09	36.23
	Weight (g)	30	46.99±5.12	8.97	124.15
March	Shell Length (mm)	30	68.33±1.86	40.88	80.36
	Shell Width (mm)	30	36.03±1.00	24.58	43.91
	Shell Height (mm)	30	23.84±0.70	15.13	30.22
	Weight (g)	30	37.61±2.90	10.18	64.14
April	Shell Length (mm)	30	62.51±2.10	37.03	84.3
	Shell Width (mm)	30	35.08±1.07	21.34	45.80
	Shell Height (mm)	30	22.99±0.76	13.37	30.37
	Weight (g)	30	33.73±2.86	6.69	69.09
May	Shell Length (mm)	30	68.35±2.26	41.30	85.38
	Shell Width (mm)	30	37.96±1.25	23.03	49.18
	Shell Height (mm)	30	25.67±0.90	14.52	32.92
	Weight (g)	30	43.40±3.81	8.73	79.7
June	Shell Length (mm)	30	69.13±2.14	41.61	91.28
	Shell Width (mm)	30	38.05±1.15	23.10	51.18
	Shell Height (mm)	30	25.36±0.75	14.98	33.5
	Weight (g)	30	43.68±3.69	9.08	93.62

Table 1. Continued

July	Shell Length (mm)	30	69.78±1.93	41.93	81.38
	Shell Width (mm)	30	39.40±1.01	27.07	46.19
	Shell Height (mm)	30	26.15±0.77	16.58	32.42
	Weight (g)	30	46.29±3.19	10.80	73.38
August	Shell Length (mm)	30	70.28±2.06	42.31	86.45
	Shell Width (mm)	30	39.11±1.17	23.63	50.00
	Shell Height (mm)	30	25.80±0.86	15.06	33.28
	Weight (g)	30	45.27±3.52	9.08	76.38
All year	Shell Length (mm)	360	71.75±7.63	37.03	92.50
	Shell Width (mm)	360	39.95±4.20	21.28	51.18
	Shell Height (mm)	360	26.90±3.74	13.37	36.23
	Weight (g)	360	48.41±16.63	6.69	124.15

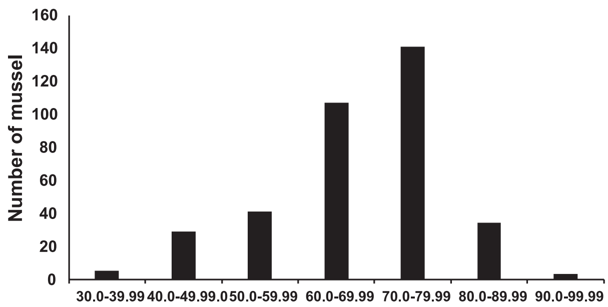

Fig. 4. Frequency distribution of *U. crassus* shell length.

Discussion

Freshwater mussel species are extremely important organisms for the conservation of freshwater ecological balance. The environmental factors are very important in the areas where these populations are distributed for sustainability of the species [17-18]. Although *U. crassus* is resistant to undesirable environmental conditions, the population of this species was reduced in many European countries and it became endangered [10, 19]. Biological activities of *U. crassus* could be affected by factors such as water temperature, turbidity, or availability of nutrition, and at the same time, water acidity may be effective on shell growth [18, 20-21]. During the study period, *U.crassus* was distributed between 9.8 and 24ºC temperature in Çine Creek, therefore this species can live commonly in such temperature ranges. There is a positive effect of water temperature on the body growth rate [10], while water temperature is one of the most important factors in releasing the glochidia larvae [21], thus it affects reproduction and the condition of the population in the environment [22-24].

The dissolved oxygen level, pH, and water temperatures were highly correlated among themselves [25-26]. *U. crassus* individuals need high dissolved oxygen levels, so the oxygen value of the environment is very important [27]. While the oxygen level in Çine Creek ranged from 6-10.4 mg/L, the oxygen level was reported to be between 8-11 mg/L in Lužnice River (Czech Republic) where *U. crassus* was distributed [27], and in Malopolska (Poland) it ranged between 10.0 and 11.3 mg/L [28]. When the negative effects of a low amount of oxygen on *U. crassus* are examined, it is noteworthy that this species is not found in still water, especially where the change in oxygen content is more important [27]. The oxygen level in Çine Creek was

Table 2. Relationships of biometrical measurements on *U.crassus*.

	N	Equation	Correlation Coefficient (r)	Growth Type
Shell length-Weight	360	$W = 0{,}0002L^{2{,}8874}$	0.97	Allometric (-)
Shell length-Shell height	360	$W = 0{,}4120L^{0{,}9759}$	0.94	Allometric (-)
Shell length-Shell width	360	$W = 0{,}7278L^{0{,}9369}$	0.96	Allometric (-)
Shell height -Shell width	360	$W = 0{,}6675L^{0{,}9997}$	0.93	Allometric (-)
Shell height -Weight	360	$W = 0{,}0051L^{2{,}7752}$	0.96	Allometric (-)
Shell width -Weight	360	$W = 0{,}0008L^{2{,}9785}$	0.97	Allometric (-)

determined at 6 mg/L only in August, but it is thought that this value is not adversely affected since water is not still in observations made in this environment.

In this study, it was determined that the level of nutrition was high in Çine Creek during the year. The amount of TPM is high when the amount of chlorophyll is low, and the amount of chlorophyll is high when the amount of TPM is low. Hochwald [10] reported that even if the temperature is low, as long as the nutrients are abundant in the areas where *U. crassus* is distributed, the metabolism slows down and the growth continues with a low pace, thus these individuals live long and spawn many times. In our study area it is thought that even if the temperature decreases, the process of feed intake continues at a slow pace. Douda [27] reported that the *U.crassus* individuals in Luznice and Nezarka Rivers show very rapid growth and short life spans, and that the metabolic rates of these individuals are high. This suggests that metabolic changes of *U. crassus* populations in different regions may be different according to environmental conditions.

The shell measurements and population dynamics of *U. crassus* are related to the water conditions and the region [10, 29-30]. In studies on *U. crassus*, the maximum shell length was reported as 66.9 mm in the Wkra River (Poland) [31]), 67.4 mm in the Palakaria River (Bulgaria) [32], 81 mm in Bohemia (Czech Republic) [30], 83 mm in Estonia [9], 85.4 mm in the Vantaa River (Finland) [33], and 95 mm in the Susa River (Denmark) [34]. During this study, which was done in Çine Creek, the largest length was measured as 92.50 mm, while another study conducted in Sapanca Lake on the west coast of Turkey reported that *U. crassus* were found with lengths of 74 mm [35]. When all these studies are taken into consideration, it is seen that the mussel measured in Çine Creek has the longest length except for the Susa River. Helama et al. [33] reported that the average age of death for *U. crassus* individuals in the Vantana River (Finland) was 12.5 years and the longest living individual has a lifespan of 38 years, and that these individuals weighed 58.7 mm on average and weighed 14.9 g on average. The largest individual measured 85.4 mm and weighed 44.4 g and this individual was 15 years old. It is estimated that the major part of the population in Çine Creek is over 15 years old, as most individuals distributed in Çine Creek are larger than the individuals in the Vantana River [33]. This shows that the *U. crassus* species in this region can live for a long time. On the other hand, Nagel et al. [36] indicated that there was a large degree of plasticity in growth, for example individuals measuring 40 mm may be between 2 and 14 years old.

It is difficult to find juvenile individuals due to the fact that *U. crassus* species live completely buried in substratum [10]. In this study, the smallest size among the individuals taken from Çine Creek was measured as 37.03 mm. Lamand and Beisel [37] reported that juveniles of *U. crassus* were only observed during sediment excavation and sieving. In total, 36 juveniles (length < 30 mm) were found in five rivers in France and the smallest individual (12 mm) was measured in the Esch River. Douda [27] reported that the smallest group of *U. crassus* was 5-10 mm in his work about the Luznive River. Differences between the sampling methods of these two studies and the method of manual collection in Çine Creek have reduced the possibility of obtaining smaller juveniles. In addition, Douda [27] found that the most frequent group in the Luznive River was the 50-55 mm length group, whereas in our study the most frequent group was the 70.0-79.99 mm length group. This shows that *U. crassus* individuals in this region may have had more reproductive seasons.

The relationship between absolute and relative shell growth is very important due to the use of shape indexes in shellfish systematics. The form of a shell, described by shape indexes, is one of the taxonomic characters used both in describing the species and in taxonomic diagnostics of individuals [38]. There was a negative allometric relationship in all biometric measurements in Çine Creek. Besides, a strong correlation was found between these measures. Rizhinashvili [38] reported that both negative allometry and positive allometry were detected in biometric measurements in the Valdai water system and the Plyussa River (Russia). While the coefficient b is evaluated as 1 in the study of Rizhinashvili [38], in our study, the calculation is made according to 3, therefore the negative/positive differences found in allometry are due to the coefficient.

Conclusions

Freshwater mussel *U. crassus* species is listed among endangered species in many parts of Europe. There is not enough data about the status of this species in Turkey. With this study, it was determined that juvenile and mature individuals of *U. crassus* exist in Çine Creek, and the presence of individuals in various length groups indicates that the life cycle for this species is being completed under the present environmental conditions in this region. Undoubtedly, the histological studies that will be carried out should reveal the gonad developmental stages and the time of reproduction in this region. In addition, it is necessary to allow more species to reproduce and grow larvae in sheltered areas that can be formed in Çine Creek and also to allow the growth of the larvae of glochidia, the host fishes should be protected. After the detailed population studies are done, Çine Creek can be determined as a potential stock region for producing species of *U. crassus* manually and to transplant offspring to areas that have low population by providing optimal conditions.

Acknowledgements

This study was partly supported by the Scientific and Technological Research Council of Turkey under the University Student Scholarship Program. The authors would like to thank Ünsal Orhan for help in field observations.

Conflict of Interest

The authors declare no conflict of interest.

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