Effect of a fishing closure on *Chamelea gallina* stocks along the Turkish coast

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Abstract

The striped venus clam *Chamelea gallina* (SVE), plays an important role as an infaunal filter-feeder in the ecosystem, besides an important economic role in the Black Sea coasts of Turkey. It is caught using hydraulic dredge boats, then processed, and the final product (frozen meat) is exported to EU countries. SVE fishing requires a special licence and regulations. Also, SVE beds were closed to fisheries for the recovery of stocks for 2 years. In the study, SVE beds were investigated during the closed season over two years to assess stock density. Additionally, the number of macrobenthic species that share the same habitat as the SVE was determined. The sampling area was divided into five sub-areas and four strata by depth and then stratified random sampling was applied to collect data. In 2011, SVE stock sizes in the sub-areas were $11,723.58 \pm 5167.262$ tons (Cide), $35,082.94 \pm 27,510.95$ tons (İnebolu), $10,077.05 \pm 4970.68$ tons (Türkeli), 3304.36 ± 3215.1 tons (Ayancık) and 1431.3 ± 1703.5 tons (Sarıkum). In 2012, these estimated stocks were $13,820.41 \pm 6977.86$ tons, $34,841.94 \pm 14,623.71$ tons, 8148.27 ± 5006.74 tons, 3420.72 ± 3093.67 tons and 2023.74 ± 2832.63 tons, respectively. However, the estimated SVE total biomass did not change significantly during the period when the fields were closed ($P > 0.05$). The results indicate that length-weight relationship parameters varied of b from 2.9011–2.9072 in two years. Shell damage during fishing, environmental factors, food competition and consumption by the main predator all have a significant impact on stock densities, and changes occurring in these conditions should be considered in fisheries management.

Introduction

Striped venus clam (SVE), *Chamelea gallina* (Linnaeus, 1758), is a commercially important species of the Veneridae family (Froglia, 1989). *Chamelea gallina* is distributed in the Black Sea, Aegean coasts and in the north of the Sea of Marmara around the Turkish coasts (Deval, 1991; Deval & Oray, 1992). It is also commercially exploited in other areas such as the Mediterranean and the eastern Atlantic (Baeta *et al.*, 2021). *Chamelea gallina* is found in large populations, especially in the Black Sea and around the Sea of Marmara, with sandy substratum and at depths of 1–20 m (Bilecik, 1986; Deval, 1995). Catches of SVE in Italy and Turkey account for a large proportion of the total catch, with Turkey ranking first (69.45%) in the world at 52,717 tons of production in 2019 (FAO, 2022). In Italy, the rapid increase in *C. gallina* production by hydraulic dredges reached a maximum level of about 105,000 tons in 1984 (Froglia, 1989) but unplanned overfishing for many years led to a strong decline in landings. Following this destruction, fleet regulation was introduced and quotas were applied. In Italy in 1974, a fleet of 383 boats operated in the SVE fishery, whereas in 1993, the fleet had increased to 778 boats. Ultimately, the European Union (EU) introduced a fleet restriction in 2002 fixed at 585 boats (Scarcella & Cabanelas, 2016).

The decrease in Italian production has led the *C. gallina* processing sector to alternative sources, most importantly to the Turkish coast, resulting in various investments in Turkey by Italian companies. A boat equipped with 'turbo blower hydraulic dredge' equipment, brought from Italy, was first used to catch *C. gallina* for the first time in August 1986 at Tekirdağ on the Turkish coast. As a result, intensive *C. gallina* fishing began using 'mechanical dredges' in addition to 4–5 turbo blower hydraulic dredge boats brought in by Italian collaborators. *Chamelea gallina* has been exported as live, frozen, and later as a canned product following the establishment of processing plants (Bilecik, 1986; Deval, 1995; Dalgıç *et al.*, 2006). This practice was carried out in the Sea of Marmara until the end of the 1990s. From that date, fishers in the Sea of Marmara were banned until the start of the Black Sea fishing season. Although the Black Sea fleet was open to catching in all regions in the first period, the system was switched to a turn-off (fallow) management system for two years, starting from 2004.

Notifications are prepared by the authorities and in this way, place, time, shell height, etc. prohibitions apply. The minimum conservation reference size is determined according to the shell height (≥ 17 mm), (DGFA, 2020). Sparre & Venema (1992) stated that necessary

precautions should be taken by defining the conditions of existing stocks in the area so that the natural living resources can be continuously utilized at the highest production level through renewable management methods. However, benthic organisms play a vital role in the continuity of marine ecosystems. Benthic organisms are integral to the remineralization of nutrients supporting pelagic primary production and in the storage of organic matter (Thrush *et al.*, 2006). At the same time, benthic organisms constitute most of the nutrients in the marine ecosystem and play an active role in the energy cycle (Bagher *et al.*, 2007). Thus, it is important to understand the natural history of *C. gallina*, one of the dominant species in the benthic ecosystem of the Black Sea, as well as being commercially important. This study was carried out to investigate the population dynamics of SVE for the first time off the Turkish coast.

Materials and methods

Sampling design and survey area

The data for the analysis were collected from hydraulic dredge experimental surveys, using the swept area method (Sparre & Venema, 1992). Station selection followed a stratified-random sampling design, where the number of stations allocated to a depth stratum is proportional to its area. Investigation of biomass surveys was conducted annually, in summer (July) in 2011 and again in 2012. In addition, seasonal sampling was done to determine the growth parameters.

The study covered the areas between Sinop and Cide in the western Black Sea. The survey area was divided into five sub-areas, based on the region's structure. The sub-regions are Sinop-Sarıkum, Sinop-Ayancık, Sinop-Türkeli, Kastamonu-İnebolu and Kastamonu-Cide. The coastal length between these areas is ∼90 nautical miles. The study area extended from the coastline to 20 m depth. The research area was divided into four strata, according to depth: Stratum 1 (0–5 m), Stratum 2 (5–10 m), Stratum 3 (10–15 m) and Stratum 4 (15–20 m) (Figure 1).

A turbo blower hydraulic dredge was used for the sampling. The mouth opening of the hydraulic dredge was 350 cm and the length was 300 cm. Samples collected from the turbo blower hydraulic dredge were placed directly into the collection box without sieving (Figure 2). Once the dredge was lowered into the sea and reached the bottom, the boat moved at a speed of ∼2.0 knots (nautical miles per hour) and another engine started to inject water (up to 3 bar pressure) into the dredge with the help of a hose. Each operation took 2 min.

Following hydraulic dredge sampling at sea, 10 kg sub-samples were obtained. The catch composition was categorized as *C. gallina*, bycatch and discard species for each tow, and all the samples were identified and weighed (0.1 g). Lengths of the SVE samples and height frequency were measured. The height frequency distribution was constructed according to sub-samples of 600 g and over, depending on the condition of the population. In a sample with excess recruitment, 300 g subsamples were taken (Froglia, 1989). Shell height frequency was measured for 33,570 individuals (Figure 2). Length, height, width and weight parameters were obtained for all depth layers (Strata 1–4) representing each sub-area (Cide, İnebolu, Türkeli, Ayancık and Sarıkum). The length, height and width of the SVE specimens were measured with digital callipers (0.01 mm). Total wet weight was measured using a digital balance with a precision of 0.1 g. Seasonal sampling was done to calculate the growth parameters. Samples were collected by dredge at seasonal intervals between February, May, July, December 2011 and 2012 years. Tows were performed parallel to the shoreline for 10 min at depths of 0–20 m. Sampling was carried out İnebolu, Türkeli, Ayancık and Sarıkum regions to represent the sub-areas.

Estimation of C. gallina biomass

SVE catch per unit area (km^2) was calculated by taking standard draft shots. Total stock size for the entire study area, catch per unit area and biomass were calculated. The formula proposed by Sparre & Venema (1992) was used to determine the area covered by the hydraulic dredge in 1 h towards the calculation of the size of the swept area. The formulas for average biomass and total biomass per unit area are given below.

$$C_a = \frac{C_w}{a} \quad \bar{b} = \frac{\overline{C_w/a}}{X_1}$$

where C_w is the weight of *C. gallina* in one sampling, a = area scanned in one haul (km^2), C_a is the catch per unit area (kg km^{-2}) in one haul, b = biomass per unit area (kg km^{-2}) and X_1 is the coefficient of catch. The hydraulic dredge coefficient of fishing has been accepted as '1'. The biomass formula could be written more clearly as follows:

$$B_i = \frac{A_i}{X_1} \times \frac{1}{n} \times \sum_{i=1}^{n} C_a(i) = \frac{A_i}{X_1} \times \overline{C_a}$$

The stock size was estimated according to the distributed areas of *C. gallina* (Table 1).

$$a = D \times hr \times X_2$$

where a = swept area, X_2 is a fraction expressing the width of the area swept by the net divided by the length of the head rope, D = distance covered, and hr is the length of the head-rope. The towing distance was estimated in units of km^2 (1 nautical mile = 1.852 km), by:

$$D = \frac{}{60 \times \sqrt{(Lat1 - Lat2)^2 + (Lon1 - Lon2)^2} \times \cos^2(0.5 \times (Lat1 + Lat2))}$$

Lat1 is the latitude at the start of haul (degrees) and Lat2 is the latitude at end of haul (degrees). Similarly, Lon1 is the longitude at the start of haul (degrees) and Lon2 is the longitude at end of haul (degrees).

The stock size was estimated according to the area distribution of *C. gallina* (Table 1). In this study, data were collected annually from the same 174 stations selected to represent the continental shelf of the western region of Turkey (Table 1). *C. gallina* distribution biomass was created using ESRI ArcGIS Desktop 10.1 software. Data were analysed in R (R Core Team, 2020).

Growth

Length-weight relationships of *C. gallina* were examined using the equation below (Le Cren, 1951).

$$W = aSL^b \quad \text{or} \quad \log W = \log(a) + b(\log SL)$$

where a and b are regression constants, a = intercept, b = slope, W = total body weight (g) and SL = shell length (mm). To determine the growth pattern, a and b values were found by subjecting the length and weight to regression analysis. With the resulting 'b' value, it was found that the growth was isometric (H_0, $b = 3$) or allometric with the formula $ts = (b-3)/S_b$ (Sokal & Rohlf, 1987) where ts denotes the Student's t-test value, b represents slope and S_b signifies the standard error of 'b' value. For the calculation
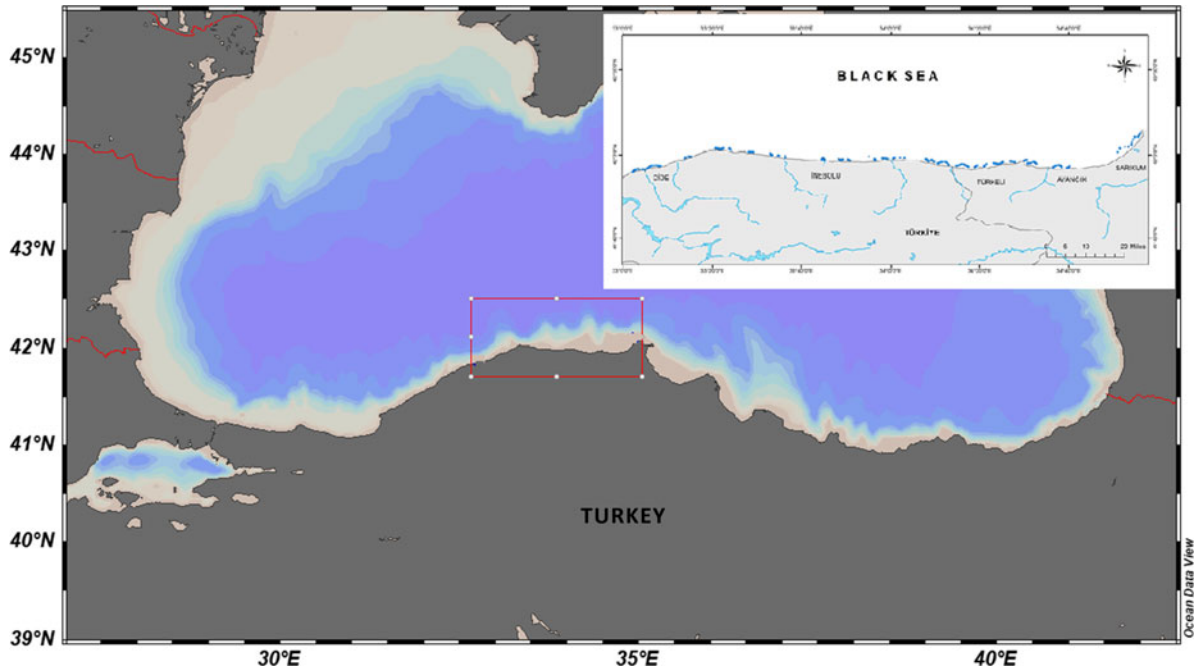
Fig. 1. Map showing the study areas and sampling stations in the Western Black Sea.

Fig. 2. Sampling procedure during the SVE survey.

of shell length-height and height-width relationships, the formula of Arneri *et al.* (1998) was used:

$$H(W) = a + b(\text{SL})$$

where $H =$ height (mm), $W =$ width (mm) and SL = shell length (mm). A three-way analysis of variance was performed using the STATISTICA software package (version 10) to detect differences between years, sub-areas and depths. A *P* value of <0.05 was accepted to indicate significance for all statistical analyses (Zar, 1984).

The growth parameters of von Bertalanffy were estimated according to Beverton & Holt (1959):

$$Lt = L_\infty(1 - e^{-K(t-t_0)})$$

where L_t is the length at time t, L_∞ is the theoretical asymptotic length, K is the growth coefficient and t_0 is the theoretical age at length zero. The values of L_∞ and K were calculated using ELEFAN in the TropFishR version 1.6.3 (SDG 14.4.1., 2022). The value of t_0 was calculated using the empirical equation of Pauly (1983) as follows:

$$\log(-t_0) = -0.3922 - 0.2752 \log(L_\infty) - 1.038 \log(K)$$

The growth performance index was compared using different growth values reported in the literature according to the Pauly & Munro (1984) formula:

$$\phi = 2 \log(L_\infty) + \log(K)$$

Table 1. Striped venus clam (*Chamelea gallina*) bed areas (km²) and number of hauls by subarea

Sub-area	Stratum (m)	Number of hauls	Area (km²)
Cide	15–20	13	13.75
	10–15	13	13.09
	5–10	12	17.29
	0–5	11	8.94
İnebolu	15–20	15	24.24
	10–15	12	25.42
	5–10	9	56.65
	0–5	5	21.5
Türkeli	15–20	12	35.44
	10–15	13	28.26
	5–10	10	16.15
	0–5	11	12.97
Ayancık	15–20	6	15.44
	10–15	6	10.96
	5–10	8	7.22
	0–5	6	6.62
Sarıkum	15–20	3	2.25
	10–15	3	1.91
	5–10	3	1.16
	0–5	3	0.82

Natural mortality (M) was calculated by Pauly's (1980) empirical equation:

$$Log(M) = -0.0066 - 0.279 \, \log(L_\infty) + 0.6543 \, \log(K) + 0.4634 \, \log(T)$$

where M = natural mortality, L_∞ and k are parameters of the von Bertalanffy equation, T is the mean annual temperature (°C) which is assumed to reflect the local temperature and set $T = 16$°C (Pauly, 1980). Commercial fisheries of *C. gallina* were not carried out in the research areas during the survey years. For this reason, the fishery mortality (F) was evaluated as zero. Since $F = 0$ in the $Z = M + F$ equation, it is taken as $Z = M$.

Results

In 2011, total SVE stock biomass in the sub-area of Cide was estimated as 11,723.58 ± 5167.26 tons and this figure increased to 13,820.41 ± 6977.86 tons in 2012. While total stocks in the İnebolu sub-area were 35,082.94 ± 27,510.95 tons in 2011, this figure decreased to 34,841.94 ± 14,623.71 tons in 2012 (Figures 3 & 4). The Türkeli sub-area is subject to year-round fishing for SVE. This sub-area stock was estimated at 10,077.05 ± 4970.68 tons in 2011 and 8148.27 ± 5006.74 tons in 2012 (Figures 3 and 4). In 2012, a flood event occurred in the Türkeli sub-area which coincided with the study conducted in July 2012. At this time it was observed that there was a die-off amongst *C. gallina* due to lack of oxygen, especially at depths from 0–10 m. The Ayancık sub-area is also subject to year-round fishing for SVE. The stock was estimated as 3304.36 ± 3215.10 tons in 2011 and 3420.72 ± 3093.67 tons in 2012 (Figures 3 and 4). Finally, the Sarıkum sub-area is again subject to year-round fishing for SVE. Here, the stock was estimated as 3304.361 ± 3215.101 tons in 2011 and 3420.716 ± 3093.67 tons in 2012 (Figures 3 and 4).

Biomass according to sub-regions is summarized in Figure 5 and Tables 2 and 3. The total stock estimations for the study area were 61,619.23 tons in 2011 and 62,255.07 tons in 2012. A decrease in stock biomass was observed in the İnebolu and Türkeli sub-areas. The biomass of *C. gallina* according to sub-area and depth in the sampling area had a significant difference ($P < 0.05$). However, overall there was no difference in total stock estimates for the five sub-areas between 2011 and 2012 ($P > 0.05$) (Table 4).

Size–frequency distribution, length–weight relationships, growth and mortality

The proportion of individuals under commercial shell height (<17 mm) in the population was relatively high in the Cide sub-area. The ratio of individuals under commercial size was 43.1% in 2011, which increased to 56.1% in 2012 year. In the other sub-regions juvenile rates were found to be below 35% (Figure 6). An overall evaluation of height distribution was 16.77 and 16.26 mm by year (Figure 7). The length-weight, height-weight and width-weight relationships of *C. gallina* sampled in the research area in 2011 and 2012 were examined (Table 5).

L_∞ of VBG parameters was 33.78 mm, K:0.31 (year⁻¹), and t_0 was −0.24 (year) respectively. The von Bertalanffy growth (VBG) curves fitted by ELEFAN with genetic algorithm were given in Figure 8. The estimated natural mortality rate (M) and total mortality (Z) was 0.57 year⁻¹.

The abundance of by-catch species

Within the samples, 32 bycatch species comprised. Within the catches, 32 of the commercial bycatch species comprised 15 Osteichthyes, five gastropods, six crustacea and six bivalves. The number of commercial species other than *C. gallina* was very low. The dominant species were founded in *A. kagoshimensis* and *R. venosa* (Table 6). *Rapana venosa*, of these species, which are both invasive species, is also a commercial species. The density of *Pitar rudis* and *Spisula subtruncata* bivalvia species, which share the same habitat with *C. gallina* and compete for food, was low (Table 6).

Discussion

The Cide area undergoes intermittent hauling for SVE. The region has a habitat with a dense, soft substrate, a very suitable environment for *C. gallina* to thrive, and unsurprisingly, this area has an abundance of stocks of SVE. The Inebolu sub-area includes Doğanyurt and Çatalzeytin, where intensive SVE hauling is carried out. Due to the negative effects of the hydraulic dredge, in some regions, there are pressures by both fishermen and by residents to prohibit fishing (Dağtekin, 2016). Although this perception has good justifications, it is understood that it is not always true. In consequence, the centre of the İnebolu sub-area has been permanently closed to fishing. However, at times illegal fishing may occur. Therefore it is rash to presume that stocks are not exploited in the areas closed to fishing. A significant flood event in 2012 adversely affected the Türkeli and İnebolu sub-regions. The widespread die-off of *C. gallina* occurred in estuarine areas. It is therefore thought that this flood event was the most important factor in the stock decrease in these regions. Undoubtedly, it is known that such disasters do not happen every year. However, these disasters are repeated in certain years in these regions.
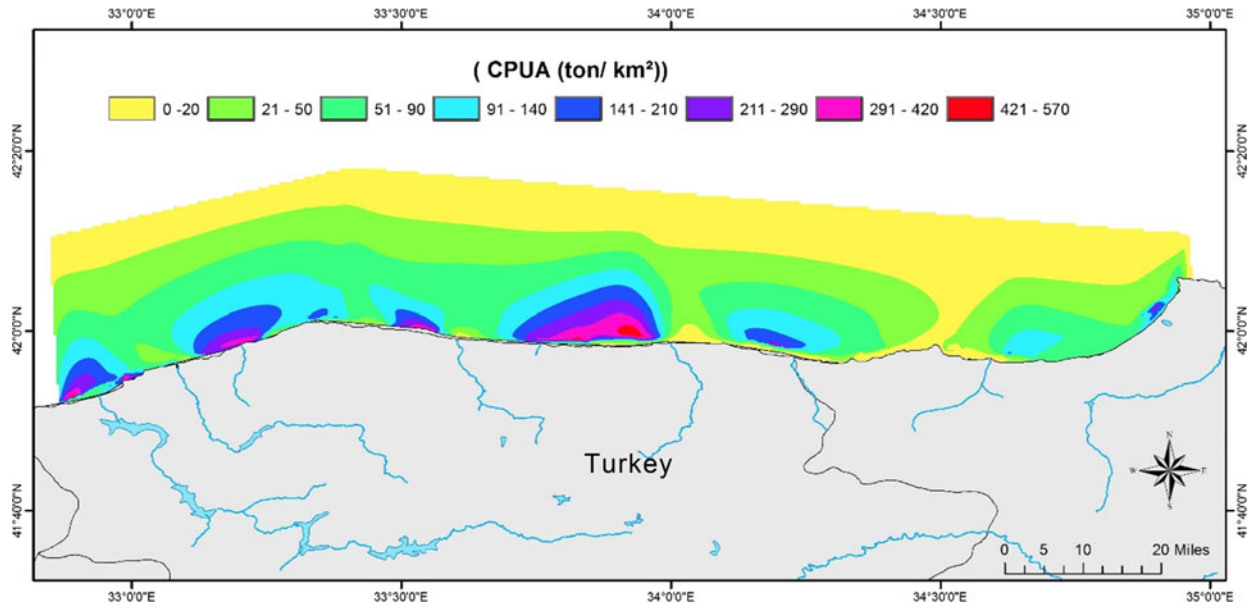
Fig. 3. Distribution of biomass of striped venus clam (*Chamelea gallina*) CPUA (tons km^{-2}) in 2011.

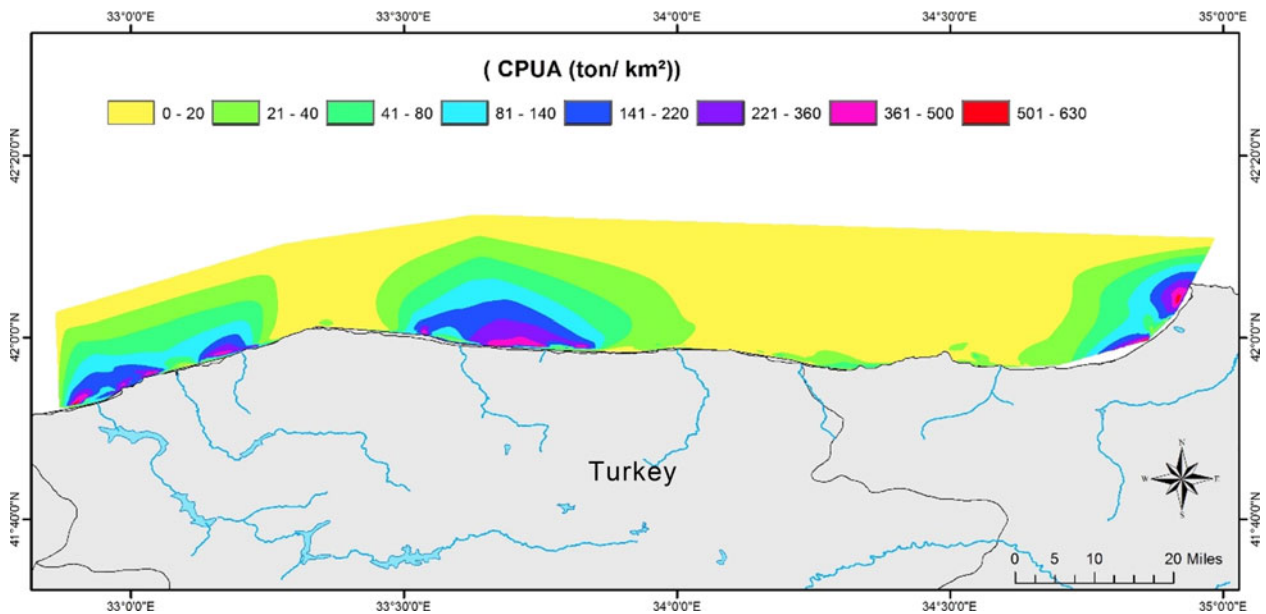
Fig. 4. Distribution of biomass of striped venus clam (*Chamelea gallina*) CPUA (tons km^{-2}) in 2012.
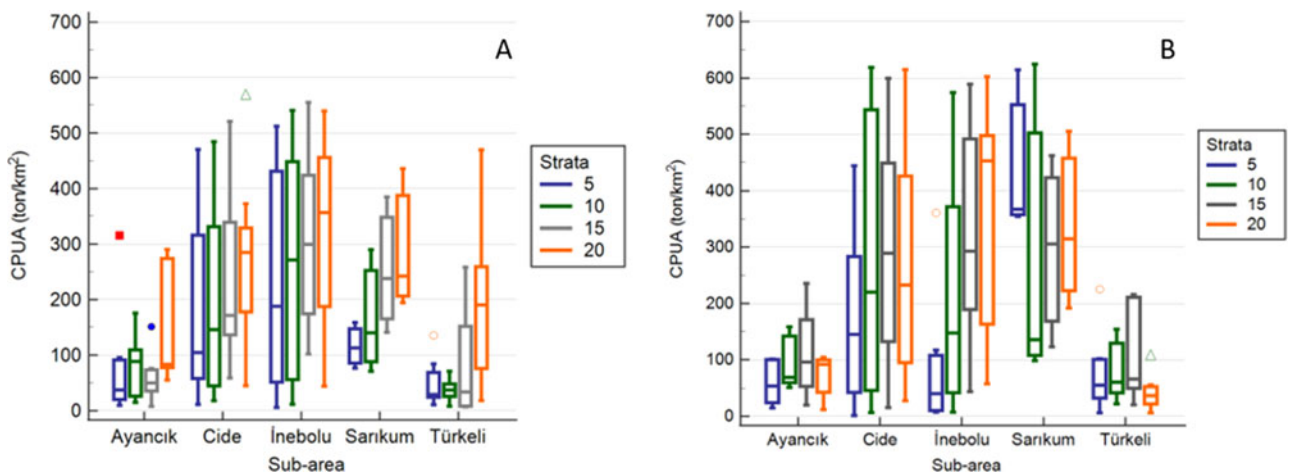

Fig. 5. Average CPUA (tons km^{-2}) distribution by region in 2011 (A) and 2012 (B) of striped venus clam (*Chamelea gallina*).

Table 2. Estimated biomass of striped venus clam (*Chamelea gallina*) according to sub-areas

Sub-area	Stratum	2011				2012			
		CPUA (tons km^{-2})	Estimated stock (tons)	(95% CI) (tons)	V.C. (%)	CPUA (tons km^{-2})	Estimated stock (tons)	(95% CI) (tons)	V.C. (%)
Cide	4	266.373	3662.635	1099.317	49.66	267.151	3673.333	1696.41	76.42
Cide	3	234.567	3070.486	1163.774	62.72	292.785	3832.562	1606.282	69.36
Cide	2	196.514	3397.732	1973.377	91.41	272.472	4711.034	2638.01	92.66
Cide	1	178.158	1592.729	930.793	86.98	179.36	1603.479	1037.155	90.42
İnebolu	4	323.590	7843.841	2097.788	48.29	353.93	8579.262	2908.567	58.72
İnebolu	3	308.471	7841.339	2506.683	50.31	331.125	8417.186	2839.573	55.83
İnebolu	2	253.041	14,334.768	9200.807	83.5	221.933	12,572.52	5701.152	85.1
İnebolu	1	235.488	5062.995	13,705.669	108.97	245.255	5272.974	3174.415	162.79
Türkeli	4	184.263	6530.284	2894.976	69.77	42.654	1511.664	1093.678	78.23
Türkeli	3	81.811	2311.987	1529.822	109.5	104.801	2961.684	2547.271	81.96
Türkeli	2	38.055	614.583	222.598	50.63	77.98	1259.378	658.277	66.75
Türkeli	1	47.818	620.202	323.287	77.59	79.74	1034.227	707.511	81.7
Ayancık	4	144.241	2227.081	1745.506	74.68	71.877	1109.781	751.037	54.5
Ayancık	3	60.865	667.08	464.018	75.21	112.04	1227.958	1575.398	80.63
Ayancık	2	23.95	172.919	444.496	69.75	95.469	689.286	436.245	50.97
Ayancık	1	35.843	237.281	561.081	129.89	59.47	393.691	330.99	67.71
Sarıkum	4	291.139	655.063	714.294	43.9	337.386	759.119	882.983	46.82
Sarıkum	3	254.895	486.849	582.467	48.16	296.992	567.254	805.291	57.15
Sarıkum	2	167.219	193.974	322.674	66.96	286.391	332.214	845.68	102.47
Sarıkum	1	116.354	95.41	84.069	35.47	445.312	365.156	298.676	32.93

Table 3. Estimated biomass of striped venus clam (*Chamelea gallina*) in sub-regions within the study area

Year	Sub-area	Biomass (tons)	CI (tons)
2011	Cide	11,723.58	±5167.262
2011	İnebolu	35,082.943	±27,510.947
2011	Türkeli	10,077.05	±4970.683
2011	Ayancık	3304.361	±3215.101
2011	Sarıkum	1431.296	±1703.504
TOTAL		61,619.23	±42,567.497
2012	Cide	13,820.408	±6977.857
2012	İnebolu	34,841.937	±14,623.708
2012	Türkeli	8148.269	±5006.737
2012	Ayancık	3420.716	±3093.67
2012	Sarıkum	2023.743	±2832.63
TOTAL		62,255.07	±32,534.602

The Catch Per Unit Effort (CPUE) of *C. gallina* was calculated as 125.1 kg h^{-1} by Köseoğlu (2005) at depths of 3–10 m in the west Marmara Sea. This figure is relatively low when compared with the densities in the sub-regions of our study area. It seems that in a study conducted in Italy (Morello, 2002), total biomass experienced very sharp declines over the years, where high stock biomass occurred in the years immediately after 1994, 1998 and 1999, when juveniles were present. This confirms that the abundance of stock is directly related to new stock recruitment. It is known that in animals feeding on planktonic organisms, natural mortality is high and the probability of survival is low at the larval stage (Rumrill, 1990). As widely recognized, recruitment itself is a very complex and little-known process. Recruitment is related to climate and weather conditions, constant changes immediately after the breeding period in the hydrodynamics of the region, reproductive potential, suitability of substrate, natural predations on adult and juvenile individuals, and competition with other species in the food chain (Osman & Whitlatch, 1995; Eckman, 1996; Apte *et al.*, 2010). To be able to assess this process successfully, it is necessary to understand and analyse all the elements in this complex system. Results obtained from many studies show that commercial fishing activity, as well as environmental factors, causes important changes in stocks. It is notable that the stock density of our study area, where fishing for *C. gallina* is regulated, was higher than for the Italian coasts, except for 1998 and 1999 (Morello, 2002). Following a comparison of our results with studies in Italy, one of the most important countries for SVE fishing in addition to Turkey, it was found that the ratio of individuals of commercial size in both stocks was high. Although there was no clam fishing in the Turkish region during our research, it is apparent that stock abundance was high compared with the coasts of Italy. Nevertheless, SVE stock levels have decreased in some regions. Kosyan & Divinsky (2019) reported that the SVE population biomass for 2010 was nearly the same as the highest values observed for 50 years. The biomass of *C. gallina* was 12.23 g/0.50 m^2 at 0.5 m depth, 54.025 g/0.50 m^2 at 1 m and 181.335 g/0.50 m^2 at 2 m in the study conducted at 0–2 m depths on the Adriatic coast

Table 4. Results of three-way ANOVA testing for biomass (tons km^{-2}) of striped venus clam (*Chamelea gallina*) with years, sub-area and depth as fixed factors. df, degrees of freedom; SS, sum of squares; MS, mean square; F, F value; significance levels *$P < 0.05$, **$P < 0.01$.

	df	SS	MS	F	Significance level
Intercept	1	8,546,252	8,546,252	364.3810	**
Years	1	31,242	31,242	1.3320	
Sub-area	4	1,966,996	491,749	20.9664	**
Depth	3	227,713	75,904	3.2363	*
Year × Sub-area	4	153,277	38,319	1.6338	
Year × depth	3	52,906	17,635	0.7519	
Sub-area × depth	12	161,970	13,498	0.5755	
Year × Sub-area × depth	12	251,737	20,978	0.8944	
Error	291	6,825,162	23,454		

(Vaccarella *et al*., 1996). In a study of *C. gallina* populations at a depth of 5.5–30 m in the north-west region of the Black Sea, the total biomass was estimated as 6948 g m^{-2} (Stadnichenko & Zolotarev, 2001). In a study by Morello *et al*. (2005a) conducted in the Adriatic Sea, the biomass of *C. gallina* was found to be 1666.19 g m^{-2} at 3–6 m and 3962.22 g m^{-2} at 7–12 m (Morello *et al*., 2005a). These earlier estimated biomass values are quite low compared with our study. In a study carried out on the southern coasts of Portugal, biomass at a depth of 3–15 m was estimated at 35,403 g m^{-2} (Rufino *et al*., 2010). These estimated amounts are also quite low compared to our study.

In another study performed in the Marmara Sea, which has been closed to SVE fishing since 1998, seasonal changes in biomass were estimated to be 86,281, 55,070, 27,118 and 34,849 kg km^{-2}, in spring, summer, autumn and winter, respectively. It was reported that no individuals were encountered for both the autumn and winter months in Şevketiye and Kemer sub-regions while the season with the greatest abundance was spring. Biomass was found to be relatively lower in the autumn and winter months. Finally, this study showed that biomass was densest at a depth of 5–10 m (Çolakoğlu, 2011). According to this study, the biomass (CPUA (kg km^{-2})) of SVE was higher in the Black Sea. Considering that bottom trawling and hydraulic dredge fishing are prohibited in the Marmara Sea, it was thought that the low CPUA in the Marmara Sea compared with the Black Sea was because the Black Sea is rich in primary production compared with many seas (Ağırbaş *et al*., 2014). Although individuals of legal size make up a larger proportion in the region, it is assumed that either natural mortality of *C. gallina* is high or recruitment is low. In a study of SVE from Italy between 2010 and 2012, abundance was estimated as 3.3–60.9 kg km^{-2} in the Trigno region, 1.6–22.2 kg km^{-2} in the Sinarca region, 6.9–58 kg km^{-2} in the Rio Vivo region and 0.1–32.6 kg km^{-2} in the Saccione region. Biomass of commercial-sized individuals in all regions were 1.5–25.8, 2.7–13.3, 4.0–39.6, 0.04–9.8 kg km^{-2}, respectively. The density of *C. gallina* in our research area was quite high when comparing CPUA ranges. A study performed off the coasts of Bulgaria (Petrova & Stoykov, 2011), reported that *C. gallina* individuals were in the 18–22 mm length range, total biomass was found to be 563 tons and 70% (411 tons) of the stock were of commercial size. While stocks of SVE in Bulgaria are very low compared with our study area, the average size was higher. It is thought that more intensive fishing activity off the Turkish coast impacted average length size. In a study carried out off the Mediterranean coasts of Egypt, *C. gallina* stocks were investigated in an area of 180 km^2. The biomass was estimated at three depth ranges (0–3, 3–6 and 6–9 m) as 668 ± 810, 571 ± 676 and 164 ± 454 kg km^{-2}, respectively, with total stock biomass in the

study area estimated at 136 tons (FAO EastMed, 2014). Compared with our findings, Egyptian biomass values were low. Many studies have reported that large waves and, in particular, winter storms damage the mussel stocks (Harger & Landenberger, 1971; Paine & Levin, 1981). For example, in a study performed on *Mytilus californianus*, environmental disasters had caused a collapse in mussel stocks of around 65% (O'Connor *et al*., 2006). Similarly, events such as El Niño cause negative effects on bivalve species in various regions of the world. One example of the severe environmental effects on commercial fisheries concerns *Mesodesma donacium* off the coast of Peru. This species lived in the soft substrate of the coast of Peru and experienced a massive amount of natural mortality causing stocks to collapse. In response, catching this species was prohibited in Peru in 1999. However, despite these measures, stocks did not recover to their pre-die-off levels. Natural disasters also cause harmful algae blooms and super-blooms, rising water temperature, and increased parasite populations. Environmental factors are widely known to have a great influence on benthic organisms (Defeo & Castilla, 2012).

Chamelea gallina feeds on phytoplankton and other suspended solids (Scopa *et al*., 2014). Its growth is related to the phosphorus to nitrogen ratio. When the seawater temperature is below 10°C, the growth rate of *C. gallina* decreases or ceases completely (Froglia, 2000). In addition to biotic and abiotic factors, stock density affects the development of *C. gallina*. If stock levels are above the carrying capacity or there is an increase in competing species, there can be a reduction in nutrient availability for all individuals in a population (Scopa *et al*., 2014). Among the abiotic factors affecting mussel species, dissolved oxygen is one of the most important parameters. In summer, when water temperatures increase, the corresponding decrease in oxygen concentration causes an increase in ammonium levels which may reduce growth. In a previous study (Brooks *et al*., 1991) where tolerance to varying oxygen levels, similar to those in the Black Sea habitat, of two bivalve species *C. gallina* and *Anadara kagoshimensis* were measured, the tolerance of *C. gallina* was reported to be relatively low. This suggests that natural mortality in *C. gallina* could be high in response to changes in abiotic factors. Shell deformation in *C. gallina* individuals under the minimum size, that are returned during hydraulic dredging may occur due to the effects of both water pressure and the size-based sieve system. In stressed individuals, a range of problems have been reported (Moschino *et al*., 2003). Although there had been no SVE fishing in the research area for two years, it is thought that such activities will have caused negative impacts on stocks. The average biomass of whiting, one of the predators of *C. gallina* along the Black Sea coast of Turkey, was estimated in 2012 to be 64.73 ± 66.60 kg
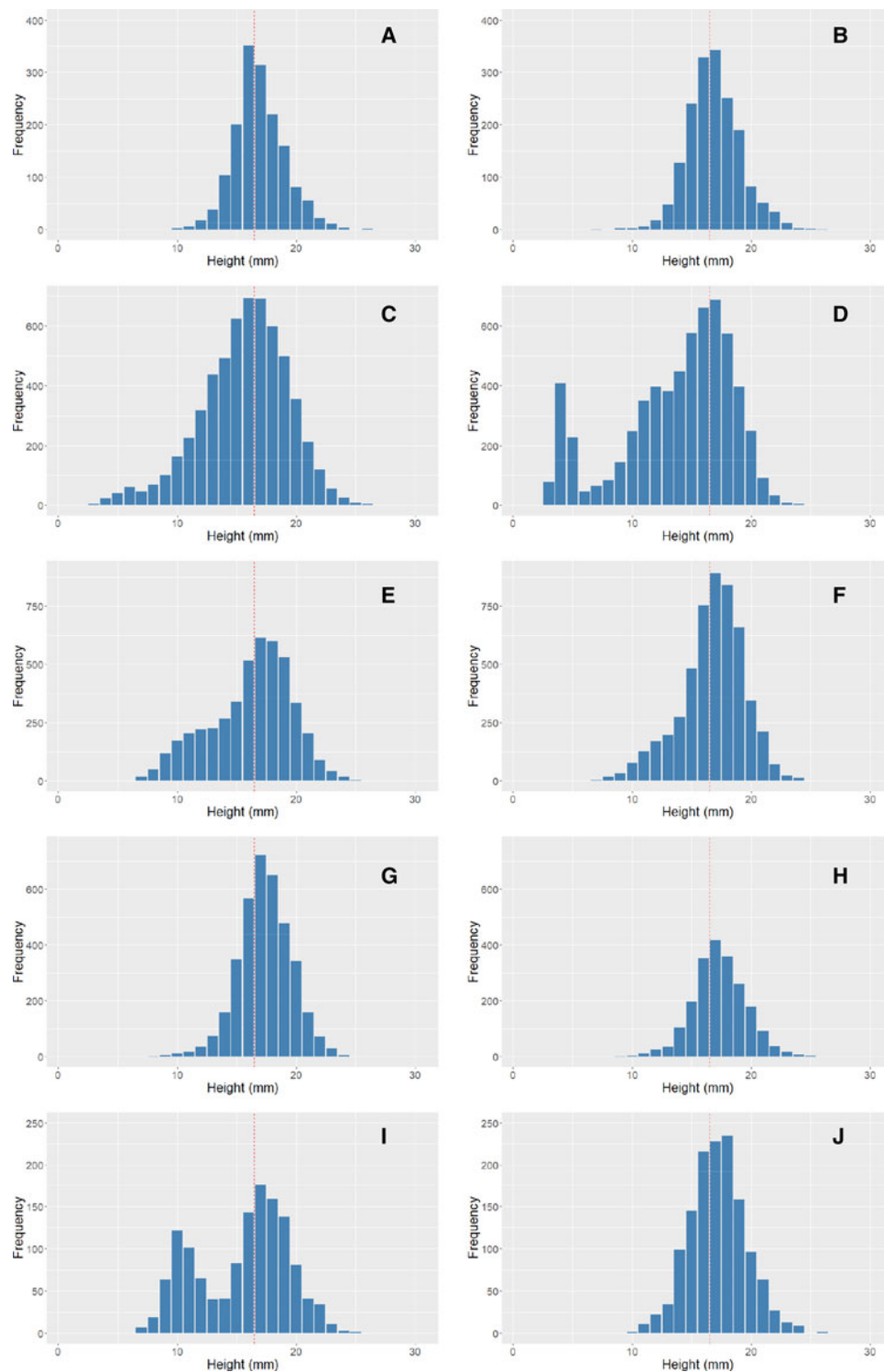
Fig. 6. Shell height (mm) frequency distribution (number of individuals) of striped venus clam (*Chamelea gallina*) at five different habitats: Habitats a and b – Ayancık 2011 and 2012, Habitats c and d – Cide 2011 and 2012, Habitats e and f – İnebolu 2011 and 2012, Habitats g and h – Türkeli 2011 and 2012, Habitats i and j – Sarıkum 2011 and 2012.

km^{-2}. Whiting biomass in 2012 in the Western Black Sea region (Zengin *et al*., 2020), where our study was conducted, was relatively higher than the mean at 67.35 ± 62.87 kg km^{-2} but estimated as 62.91 ± 69.55 kg km^{-2} in the Eastern Black Sea (Dağtekin *et al*., 2020). The biomass of *R. venosa*, a voracious predator in the benthic habitat, was found to be 10.1 tons km^{-2} (Sampson *et al*., 2014). *Chamelea gallina* is reported to be one of the prey species of *R. venosa* (Savini & Occhipinti-Ambrogi, 2006; Kosyan, 2016). Predator pressure on *C. gallina* will increase,

especially if species such as *Mytilus galloprovincialis*, which constitute the most important prey of *R. venosa*, decrease in the habitat.

In the present study (2011–2012) a negative allometric relationship was found between the length-weight parameters of *C. gallina*. In previous studies of *C. gallina* from different regions of the Black Sea, growth was reported to be negative allometric (Dalgıç, 2006; Gözler *et al*., 2006). The results reported by various researchers from different regions (Gaspar *et al*., 2001; Tunçer &
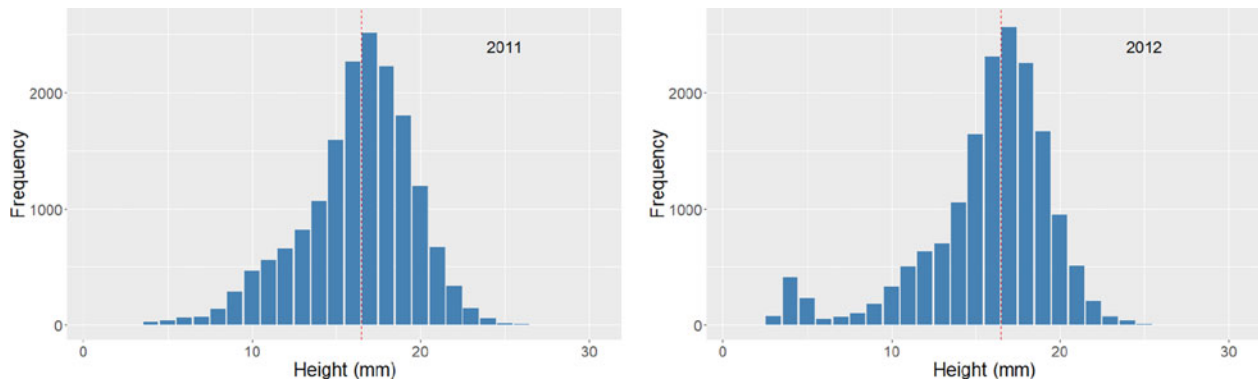
Fig. 7. Shell height-frequency distribution of striped venus clam (*Chamelea gallina*) (2011–2012).

Table 5. Relationships of length, height, width and weight parameters of striped venus clam (*Chamelea gallina*)

Year	Parameter	n	Equation	a	b	R^2
2011	Length-weight	5370	$W = 0.0004SL^{2.9011}$	0.0004	2.9011	0.96
2011	Height-weight	5370	$W = 0.0006SH^{2.8331}$	0.0006	2.8331	0.96
2011	Width-weight	5370	$W = 0.0036SW^{2.4167}$	0.0036	2.4167	0.95
2011	Length-height	5370	$SH = 0.9341SL + 0.0068$	0.9341	0.0068	0.96
2011	Length-width	5370	$SW = 0.4713SL + 0.4028$	0.4713	0.4028	0.90
2011	Height-width	5370	$SW = 0.496SH + 0.5394$	0.496	0.5394	0.91
2012	Length-weight	2702	$SH = 0.0004SL^{2.9072}$	0.0004	2.9072	0.97
2012	Height-weight	2702	$SW = 0.0006SL^{2.8295}$	0.0006	2.8295	0.97
2012	Width-weight	2702	$SW = 0.0032SH^{2.8966}$	0.0032	2.8966	0.96
2012	Length-height	2702	$SH = 0.9642SL + 0.3179$	0.9642	0.3179	0.98
2012	Length-width	2702	$SH = 0.4787SL + 0.2829$	0.4787	0.2829	0.93
2012	Height-width	2702	$SW = 0.4929SH + 0.5004$	0.4929	0.5004	0.94

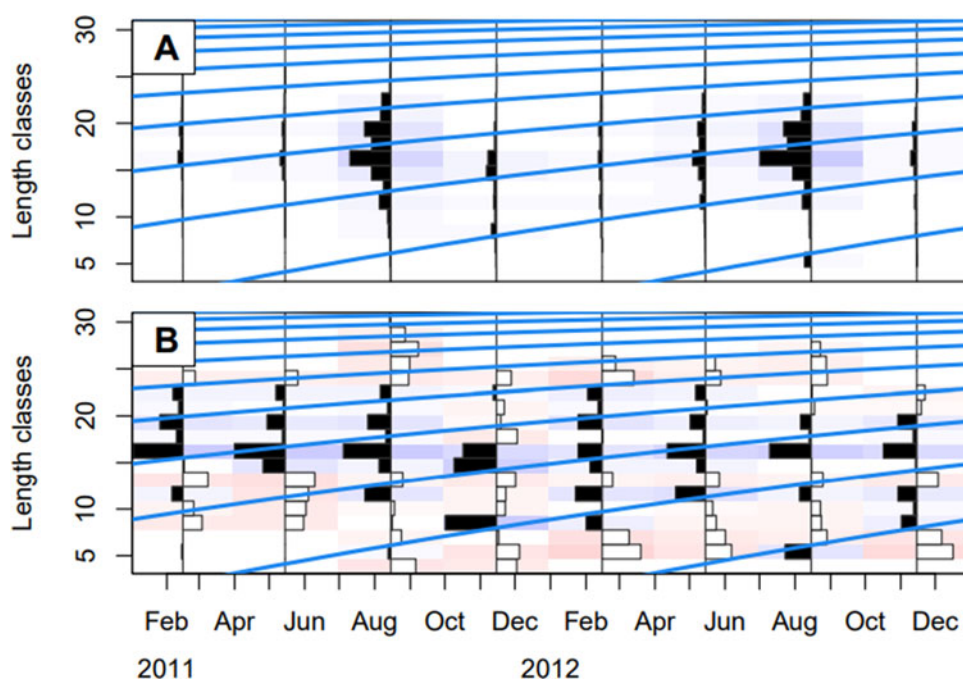W, weight; SL, Shell length; SH, Shell height; SW, Shell width.

Fig. 8. Uploaded raw (A) and restructured (B) length-frequency data of striped venus clam (*Chamelea gallina*) with overlaid von Bertalanffy growth (VBG) curves fitted by ELEFAN with genetic algorithm.

Table 6. Yearly distribution of other species identified in striped venus clam (*Chamelea gallina*) experimental survey, mean CPUA (kg km^{-2} ± SD)

Species	Ayancık (kg km^{-2}) ± SD		Cide (kg km^{-2}) ± SD		İnebolu (kg km^{-2}) ± SD		Sarıkum (kg km^{-2}) ± SD		Türkeli (kg km^{-2}) ± SD	
Bivalvia	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Anadara kagoshimensis (Tokunaga, 1906)	280.82 ± 319.51	5708.25 ± 5330.26	8829.84 ± 11,082.78	30,064.06 ± 13,501.61	8532.98 ± 6523.95	24,176.51 ± 14,661.83	928.34 ± 2027.52	21,400.65 ± 37,725.19	4187.68 ± 3406.31	8123.25 ± 4754.1
Acanthocardia deshayesii (Payraudeau, 1826)	–		0.001 ± 0.006		0.02 ± 0.12		–		–	
Donax trunculus Linnaeus, 1758	–	0.01 ± 0.05	0.02 ± 0.09	0.06 ± 0.25	0.01 ± 0.06	0.45 ± 3.06	–	0.001 ± 0.02	–	0.007 ± 0.02
Mytilus galloprovincialis (Lamark, 1819)	–	2.5 ± 8.61	0.48 ± 1.78	0.035 ± 0.10	0.003 ± 0.018	0.03 ± 0.12	–	0.04 ± 0.14	0.013 ± 0.06	0.83 ± 0.83
Pitar rudis (Poli, 1795)	0.19 ± 0.44	0.24 ± 0.66	0.29 ± 0.47	3.18 ± 12.25	2.25 ± 4.60	1.02 ± 2.53	0.22 ± 0.51	0.25 ± 0.35	0.64 ± 1.69	0.08 ± 0.22
Spisula subtruncata (da Costa, 1778)	0.047 ± 0.14	0.01 ± 0.04	1.16 ± 3.44	1.40 ± 5.83	0.81 ± 2.46	0.05 ± 0.19	0.37 ± 1.19	0.01 ± 0.03	0.27 ± 1.39	0.02 ± 0.08
Crustacea										
Crangon crangon (Linnaeus, 1758)	–	–	–	0.001 ± 0.02	–		–		–	0.007 ± 0.04
Diogenes pugilator (Roux, 1829)	0.08 ± 0.18	–	0.8 ± 2.17	–	0.24 ± 0.60		0.57 ± 0.92	0.05 ± 0.19	0.19 ± 0.36	
Liocarcinus depurator (Linnaeus, 1758)	0.13 ± 0.27	3.15 ± 3.17	0.80 ± 1.54	5.58 ± 24.05	0.66 ± 1.64	1.48 ± 2.6	0.051 ± 0.10	0.88 ± 1.52	0.13 ± 0.36	2.49 ± 2.77
Liocarcinus navigator (Herbst, 1794)	–	0.001 ± 0.005	0.10 ± 0.33	0.089 ± 0.45	0 ± 0	0.15 ± 0.57	0 ± 0		0 ± 0	0.02 ± 0.04
Eriphia verrucosa (Forskål, 1775)	–	–	–	–	–		–		–	0.01 ± 0.06
Upogebia pusilla (Petagna, 1792)	0.01 ± 0.02	0.77 ± 0.89	0.21 ± 0.84	0.92 ± 6.37	0.70 ± 1.72	0.70 ± 1.73	22.91 ± 75.95	0.94 ± 1.00	0.035 ± 0.08	2.17 ± 2.63
Gastropoda										
Rapana venosa (Valenciennes, 1846)	785.32 ± 1066.47	7500.81 ± 10,736.48	1781.1 ± 4811.69	6261.42 ± 9780.83	1319.98 ± 2278.86	931.95 ± 1356.81	2320.5 ± 2721.31	3062.31 ± 2695.27	814.83 ± 1130.85	2628.38 ± 4441.57
Tritia reticulata (Linnaeus, 1758)	0.77 ± 1.58	0.88 ± 1.21	0.61 ± 1.09	19.21 ± 113.3	1.67 ± 2.55	1.87 ± 2.83	0.54 ± 0.76	1.40 ± 1.018	0.65 ± 0.89	
Patella depressa Pennant, 1777	–	–	0.01 ± 0.01		–		–		–	
Cerithium vulgatum (Bruguière, 1792)	–		0.01 ± 0.05	0.01 ± 0.04	–		–		0.007 ± 0.048	
Gibbula sp.	0.02 ± 0.05	0.02 ± 0.041	0.46 ± 0.51	1.06 ± 3.28	0.42 ± 1.07	0.21 ± 1.2	0.34 ± 0.55	0.14 ± 0.20	0.038 ± 0.11	0.04 ± 0.08
Osteichthyes										
Arnoglossus laterna (Walbaum, 1792)	–		0.001 ± 0.007		–		–		–	
Callionymus lyra Linnaeus, 1758	–	0.002 ± 0.01	0.009 ± 0.042	0.0237 ± 0.0801	–	0.03 ± 0.14	–		0.01 ± 0.04	0.003 ± 0.01
Gobius niger Linnaeus, 1758	0.01 ± 0.02	0.13 ± 0.33	0.051 ± 0.007	0.0066 ± 0.0338	0.008 ± 0.01	0.11 ± 0.32	0.017 ± 0.03	0.06 ± 0.22	–	0.32 ± 0.52
Mesogobius batrachocephalus (Pallas, 1814)		0.11 ± 0.42							–	0.003 ± 0.01
Merlangius merlangus euxinus L., 1758	–		0.02 ± 0.07		–		–		0.02 ± 0.05	–
Neogobius melanostomus (Pallas, 1814)	–		–		0.001 ± 0.005		–		0.23 ± 0.28	–
Parablennius tentacularis (Brünnich, 1768)	0.10 ± 0.35	0.10 ± 0.35	–		–		0.02 ± 0.05	0.02 ± 0.05	–	–
Uranoscopus scaber Linnaeus, 1758	0.25 ± 0.22	1.88 ± 2.91	0.28 ± 0.35	1.12 ± 4.34	0.36 ± 0.32	0.26 ± 0.68	0.23 ± 0.28	2.37 ± 8.03	–	0.49 ± 1.30
Scorpaena porcus Linnaeus, 1758	–	–	0.004 ± 0.03	0.001 ± 0.03	0.026 ± 0.19	0.02 ± 0.19	–		–	–

Spicara smaris Linnaeus, 1758	–	0.001 ± 0.007	–	–	0.003 ± 0.01
Solea nasuta (Pallas, 1814)	0.02 ± 0.10	0.007 ± 0.05	0.023 ± 0.10	0.007 ± 0.05	0.06 ± 0.31
Hippocampus guttulatus Cuvier, 1829	–	–	–	0.001 ± 0.001	0.001 ± 0.001
Chelidonichthys lucerna Linnaeus, 1758	–	–	0.006 ± 0.037	–	–
Trachinus draco (Linnaeus, 1758)	0.01 ± 0.06	0.01 ± 0.06	0.01 ± 0.06	–	–
Symphodus tinca Linnaeus, 1758	–	–	–	–	0.009 ± 0.02
Syngnathus sp.	–	0.001 ± 0.004	0.001 ± 0.004	–	–

Erdemir, 2002; Dalgıç, 2006; Çolakoğlu, 2011) are also consistent with our findings. However, in contrast to most other research, Dalgıç (2006) reported an isometric distribution for samples from Samsun on the Turkish Black Sea coast, whereas most other sources report negative allometry for the length-weight relationship (Table 7).

Sparre & Venema (1992) reported that growth parameters varied between species and within stocks within the same species, owing to various environmental conditions. In this study, L_∞ (33.78 mm SL) differed from that of previous studies (Table 8). The highest reported L_∞ (52.2 mm) was observed in the Middle Adriatic Italy (Polenta, 1993), whereas the lowest reported L_∞ (15.78 mm) was obtained from the Eastern Black Sea, Turkey (Gözler et al., 2006). In this study, C. gallina exhibited a slower growth rate ($K = 0.276$ year^{-1}) compared with $K = 0.79$ year^{-1} from South Adriatic Italy (Vaccarella et al., 1996). Growth performance index according to our study findings, Costa et al. (1987), Ramón & Richardson (1992), Arneri et al. (1995), Vaccarella et al. (1996), Polenta (1993), Gaspar et al. (2004), FAO EastMed (2014), Boltacheva & Mazlumyan (2003), Deval (1995), Deval & Oray (1998), Çolakoğlu, (2011). It is higher than the results of the studies conducted by Dalgıç (2006) and Gözler et al. (2006) in the Black Sea (Table 8). However, there were no statistically significant differences in these investigations ($P > 0.05$).

The average natural mortality rate found by Çolakoğlu & Tokaç (2010) was 0.65 years^{-1}, and Deval's (2009) was 0.6031 year^{-1}in a study of the North Marmara. In this study it was found to be M: 0.57 year^{-1}. This shows that natural mortality rates at seas close to the regions where the present study was conducted were close to each other.

Conclusion

Chamelea gallina is one of the most important species in the benthic marine biocenosis of the Black Sea. Thus, the significance of this species in fisheries management must be considered. In this study, the total stock biomasses of C. gallina were estimated as 61,619.23 and 62,255.07 tons in 2011 and 2012, respectively. In 2012, stock levels decreased in the area of Ayancık, probably due to unusual environmental factors which are known to have a major impact on C. gallina. For this reason, we suggest that the present system of management of the fisheries, using a fallow period, should be reviewed. It appears that the 2-year closure period may not be sufficient for population recovery in some regions. The landings of SVE were 24,500 tons before the closure to fishing (TURKSTAT, 2022). If the regions are to be re-opened to fishing after the 2-year closed period, it will be useful to carry out stock assessments in the summer season to make more informed decisions. Considering the stock studies and the structure of the stocks, it will be beneficial to establish a quota system within the framework of these guidelines. It has been shown that large-sized individuals (25–30 mm) do not show even distribution within the population and that the proportion of individuals older than 4 years in the population was low. Fisheries will probably have an impact on this situation. The main causes of natural mortality, other than anthropogenic factors in clams, are related to phytoplankton explosions and anoxic layer changes in summer (Morello et al., 2005a, 2005b). Thus, opening and closing the region to fishing activity for specified periods may not be an effective strategy for the full recovery of stocks. During the planning of fisheries management regulations for SVE fishing, these factors should be considered. It is accepted that datasets based on long-term studies are needed to make evaluations in fisheries. Turkey plays an important role in terms of commercial fishing for the management of the Black Sea SVE stocks. Continuous

Table 7. Length-weight relationship of striped venus clam (*Chamelea gallina*) reported by various researchers

Region	N	Mean ± SD (Lmin-Lmak)	LWR	R^2	b SE (CI)	Growth type	References
Marmara Sea		25.20 ± 1.09 (18.1–35)	$W = 0.0004L^{2.9669}$	0.90	–	−A	Tunçer & Erdemir (2002)
Portugal	695	23.45 ± 5.84 (8.10–40)	$W = 0.0007L^{2.801}$	0.99	0.024 (2.752–2.850)	−A	Gaspar *et al.* (2001)
Marmara Sea	2462	−(7–39)	$W = 0.3539L^{2.8908}$	0.98	–	−A	Çolakoğlu (2011)
Black Sea Sinop	1432	–	$W = 0.3539L^{2.914}$	0.98	(2.887–2.942)	−A	Dalgıç (2006)
Black Sea Samsun	596	–	$W = 0.003L^{3.034}$	0.98	(2.986–3.082)	I	Dalgıç (2006)
Black Sea Kastamonu	424	–	$W = 0.0004L^{2.910}$	0.98	(2.8503–2.9692)	−A	Dalgıç (2006)
Sinop-Cide	5370	16.15 ± 0.72 (3.56–28.3)	$W = 0.0004L^{2.9011}$	0.96	0.0086 (2.884–2.918)	−A	Present study
Sinop-Cide	2702	16.22 ± 0.77 (2.50–30.34)	$W = 0.0004L^{2.9072}$	0.97	0.01 (2.887–2.928)	−A	Present study

SD, Standard deviation; SE, Standard error; −A, Negative allometric; I, Isometric; CI, Confidence interval.

Table 8. Von Bertalanffy growth parameters of striped venus clam (*Chamelea gallina*) in different areas

Region	Methods	Linf	K	t_0	ϕ'	R_n	Source
Tiran Sea	External rings	39.11	0.5	−0.30	2.88		Costa *et al.* (1987)
Middle Adriatic Italy	Inner rings	52.20	0.21	−0.97	2.76		Polenta (1993)
Middle Adriatic Italy	Inner rings	41.60	0.48	−0.01	2.92		Arneri *et al.* (1995)
South Adriatic Italy	Inner rings	42.82	0.79	−0.03	3.16		Vaccarella *et al.* (1996)
Portugal Atlantic Coast	External rings	38.95	0.47	−0.24	2.85		Gaspar *et al.* (2004)
Portugal Atlantic Coast	Inner rings	42.15	0.32		2.75		Gaspar *et al.* (2004)
Western Mediterranean Sea (Valencia)	Inner rings	36.12	0.35		2.66		Ramón & Rıchardson (1992)
Mediterranean Sea (Valencia)	Length-Frequency	40.05	0.40		2.81		Ramón & Rıchardson (1992)
Mediterranean Sea (Egypt)	Length-Frequency	38.84	0.737	−0.26	3.05		FAO Eastmed (2014)
North Black Sea (Ukraine)	Inner rings	27.50	0.61	−0.14	2.66		Boltacheva and Mazlumyan (2003)
Sea of Marmara	External rings	34.17	0.43	−0.37	2.7		Deval and Oray (1998)
Sea of Marmara	Inner rings	33.46	0.37	−0.69	2.62		Deval (1995)
Sea of Marmara	Length-Frequency	33.04	0.39	−0.43	2.63		Çolakoğlu (2011)
South Black Sea	Inner rings	28.88	0.21	−1.29	2.24		Dalgıç (2006)
South Black Sea	Inner rings	26.0	0.16	−1.96	2.03		Dalgıç (2006)
South Black Sea	Inner rings	26.6	0.22	−1.21	2.19		Dalgıç (2006)
Eastern Black Sea	Inner rings	15.78	0.69	−0.77	2.24		Gözler *et al.* (2006)
South Black Sea	Inner rings	32.28	0.249	−0.262	2.41		Dağtekin (2016)
South Black Sea	ELEFAN	33.78	0.276	−0.24	2.50	0.31	Present study

population monitoring studies would be extremely useful as stocks of *R. venosa*, the main predator of *C. gallina* (Saglam & Duzguneş, 2014; Kosyan, 2016), have increased three-fold in one year (Table 6). Increased commercial fishing for *R. venosa* in the affected regions will reduce predator pressure. Finally, it should be highlighted that commercial fishing should use methods that do no harm, or cause the minimum possible damage, to the benthic habitat (Morello *et al.*, 2005*a*, 2005*b*; Reine *et al.*, 2014).

References

Ağırbaş E, Feyzioğlu AMJ and Kopuz JU (2014) Seasonal changes of phytoplankton chlorophyll a, primary production and their relation in the continental shelf area of the south eastern Black Sea. *Turkish Journal of Fisheries and Aquatic Sciences* **14**, 713–726.

Apte D, Dutta SJ and Babu I (2010) Monitoring densities of the giant clam *Tridacna maxima* in the Lakshadweep archipelago. *Marine Biodiversity* **3**, 1–9.

Arneri E, Giannetti G and Antolini B (1998) Age determination and growth of *Venus verrucosa* L. (Bivalvia: Veneridae) in the southern Adriatic and the Aegean Sea. *Fisheries Research* **38**, 193–198.

Arneri E, Giannetti G, Polenta R and Antolini B (1995) Age and growth of *Chamelea gallina* (Bivalvia: Veneridae) in the Central Adriatic Sea obtained by thin sections. *Rapport du Congrès de la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée* **34**, 17.

Baeta M, Solís MA, Ballesteros M and Defeo O (2021) Long-term trends in striped venus clam (*Chamelea gallina*) fisheries in the western Mediterranean Sea: the case of Ebro Delta (NE Spain). *Marine Policy* **134**, 104798.

Bagher NSM, Negar G, Preetha KJ and Simin D (2007) Population growth of the venerid bivalve *Circenita callipyga* in the Hendijan coast, Persian Gulf. *Pakistan Journal of Biological Sciences* **1018**, 3185–3189.

Beverton RJH and Holt SJ (1959) A review of the lifespans and mortality rates of fish in nature, and their relationship to growth and other physiological characteristics. *Ciba Foundation Colloquia on Ageing* **5**, 142.

Bilecik N (1986) *Kum Midyesi'nin V.gallina L. Avlanması Amacıyla Marmara Denizi'nde Yapılan Deneme Çalışmalarına Ait Rapor*. Tarım Orman ve Köyişleri Bakanlığı, İstanbul İl Müdürlüğü. İstanbul, Türkiye.

Boltacheva NA and Mazlumyan SA (2003) The growth and longevity of *Chamelea gallina* (Mollusca, Veneridae) in the Black Sea. *Vestnik Zoologii* **37**, 71–74.

Brooks SPJ, De Zwaan A, Van Den Thıllart G, Cattanı O, Cortesı PJ and Storey KB (1991) Differential survival of *Venus gallina* and *Scapharca inaequivalvis* during anoxic stress: covalent modification of phosphofructokinase and glycogen phosphorylase during anoxia. *Journal of Comparative Physiology. B, Biochemical, Systemic, and Environmental Physiology* **1612**, 207–212.

Çolakoğlu S (2011) *Çanakkale Boğazı İle Batı Marmara'da Kum Midyesi Chamelea gallina, L., 1758 ve Kum Şırlanının Donax trunculus, L., 1758 Stok Tahmini, Ege Üniversitesi Fen Bilimleri Enstitüsü (Doktora Tezi)*. Su Ürünleri Avlama ve İşleme Anabilim Dalı, İzmir.

Çolakoğlu S and Tokaç A (2010) Batı Marmara'da Beyaz Kum Midyesinin (*Chamelea gallina* L., 1758) Bazı Populasyon Parametreleri. *Ege Journal of Fisheries and Aquatic Sciences* **27**, 65–71.

Costa C, Bınachını M, Ceccarellı P, Orecchıa P, Rambaldı E and Volterra L (1987) *Indagine sui molluschi bivalvi di interesse commerciale (telline, cannolicchi e vongole) delle coste della Toscana, del Lazio e della Campania. 1985–1987*. Quaderni Istituto Idrobiologia Acquacoltura Brunelli, 7 n. doppio:3–58; I-LXXVII.

Dağtekin M (2016) Abundance of Striped Venus (*Chamelea gallina* L., 1758) Stocks in Different Regions (Sinop-Kastamonu) with Seasonal Growth, and Socio-Economic Analysis of Fishing Boats. PhD thesis, Çukurova University Institute Of Natural And Applied Sciences Department Of Fishing And Fishing Processing, Adana, 173 pp.

Dağtekin M, Genç Y, Mısır DS, Erik G, Ok M and Altuntaş C (2020) *Monitoring Demersal Trawl Survey in the Eastern Black Sea*. Project No: TAGEM/HAYSUD/2017/A11/P-02/4. Final Report, Trabzon, Turkey, 142 pp.

Dalgıç G (2006) *Karadeniz Kum Midyesi Chamelea gallina L.,1758 Popülasyonun Üreme Periyodu ve Büyüme Performansının İncelenmesi (Doktora Tezi)*. KTÜ, Fen Bilimleri Enstitüsü, Trabzon, 99s.

Dalgıç G, Okumuş IJ and Karayücel S (2006) Türkiye'de Beyaz Kum Midyesi *Chamelea gallina* L., 1753 İşleme Endüstrisinin Durumuna Bir Bakış, E.U. *Journal of Fisheries, Aquatic Sciences* **23**(Suppl. 1/3), 397–400.

Defeo OJ and Castilla JC (2012) Governance and governability of coastal shellfisheries in Latin America and the Caribbean: multi-scale emerging models and effects of globalization and climate change. *Current Opinion in Environmental Sustainability* **43**, 344–350.

Deval MC (1991) *1990 Yılında Marmara Denizinin Kuzeybatısında ve Batı Karadeniz'in Bazı Bölgelerinde Beyaz Kum Midyesi Chamelea gallina Linneaus, 1758'nin Yumurta Bırakma Süresinin Tespiti (Yüksek Lisans Tezi)*. İstanbul Üniversitesi, Fen Bilimleri Enstitüsü Su Ürünleri Anabilim Dalı, İstanbul, 49s.

Deval MC (1995) *Kuzey Marmara Denizi'nde Chamelea gallina Linneaus, 1758'nın Yaş ve Kabuk Gelişimi (Doktora Tezi)*. İstanbul Üniversitesi, Fen Bilimleri Enstitüsü Su Ürünleri Anabilim Dalı, İstanbul, 100s.

Deval MC (2009) *Population Structure and Dynamic of the Striped Venus (Chamelea gallina L., 1758) After the 10 Year Fishing Ban in the Northern Sea of Marmara (in Turkish). 15*. Rize: Ulusal Su Ürünleri Sempozyumu, 137p.

Deval MC and Oray IK (1992) Marmara Denizi ve Karadeniz'de *C. gallina* L'nın Yumurtlama Dönemi ve Biyometrisi, İ.Ü. *Su Ürünleri Dergisi* **6**, 127–142.

Deval MC and Oray IK (1998) The annual shell increments of Bivalvia *Chamelea gallina* L. 1758 in the Northern Sea of Marmara. *Oebalia* **24**, 93–109.

DGFA (2020) Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Fisheries and Aquaculture, Visual Archive. Available at https://www.mevzuat.gov.tr/anasayfa/MevzuatFihristDetayIframe?MevzuatTur=9,MevzuatNo=34823,MevzuatTertip=5 (Accessed 1 May 2022).

Eckman JE (1996) Closing the larval loop: linking larval ecology to the population dynamics of marine benthic invertebrates. *Journal of Experimental Marine Biology and Ecology* **200**, 207–237.

FAO (2022) https://www.fao.org/gfcm/data/capture-production (Accessed 9 May 2022).

FAO EastMed (2014) *A Study to Investigate the Potential Exploitation of the Venus Clam* Chamelea gallina *in Egypt*. GCP/INT/041/EC – GRE – ITA/TD-20. Athens: FAO EastMed, 83pp.

Froglia C (1989) Clam fisheries with hydraulic dredges in the Adriatic Sea. In Caddy JF (ed.), *Marine Invertebrate Fisheries: Their Assessment and Management*. New York, NY: Wiley Interscience, pp. 507–524.

Froglia C (2000) Il contributo della ricerca scientifica alla gestione della pesca dei molluschi bivalvi con draghe idrauliche. *Biologia Marina Mediterranea*, **7**, 71–82.

Gaspar MB, Pereıra AM, Vasconcelos P and Monteıro CC (2004) Age and growth of *Chamelea gallina* from the Algarve coast (southern Portugal): influence of seawater temperature and gametogenic cycle on growth rate. *Journal of Molluscan Studies* **70**, 371–377.

Gaspar MB, Santos MNJ and Vasconcelos P (2001) Weight–length relationships of 25 bivalve species Mollusca: Bivalvia from the Algarve coast in southern Portugal. *Journal of the Marine Biological Association of the United Kingdom* **8105**, 805–807.

Gözler AM, Şahin C, Dalgıç G and Engin S (2006) *Doğu Karadeniz'de Beyaz Kum Midyesi Chamelea gallina'nın Yaş, Kabuk Gelişimi ve Üreme Periyodunun Tespiti*. Rize: TUBİTAK TOVAG 106O256.

Harger JRJ and Landenberger DE (1971) The effect of storms as a density dependent mortality factor on populations of sea mussels. *Veliger* **142**, 195–201.

Köseoğlu (2005) *Batı Marmara'da Kum Midyesinin Chamelea gallina Linnaeus 1758 Büyümesi, Üremesi ve Stok Tahmini Üzerine Bir Çalışma*. Çanakkale: Çanakkale Onsekiz Mart Üniversitesi, Fen Bilimleri Enstitüsü, Su Ürünleri Anabilim Dalı, 55s.

Kosyan A (2016) Predation mechanisms of *Rapana venosa* Gastropoda: Muricidae in different biotopes along the Black Sea coast. *Marine Pollution Bulletin* **1022**, 265–270.

Kosyan AR and Divinsky BV (2019) *Chamelea gallina* in the coastal waters of the Anapa bay bar (the Black Sea) as a carbonate sediment producer. *Oceanologia* **614**, 471–483.

Le Cren ED (1951) The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology*, 20, 201–219.

Morello EB (2002) Hydraulic Dredge Surveys for the Assessment of Clam Resources in the Maritime Districts of Ancona and San Benedetto del Tronto, central Adriatic Sea, Italy. Available at http://www.cmima.csic.es/pub/scsa/WS%202007%20Trawl%20Surveys/Selected%20documents/Morello%20Presentation.pdf (accessed 10 June 2016).

Morello EB, Froglia C, Atkinson RJA and Moore PG (2005a) Hydraulic dredge discards of the clam *Chamelea gallina* fishery in the western Adriatic Sea, Italy. *Fisheries Research* **763**, 430–444.

Morello EB, Froglia C, Atkinson RJ and Moore PG (2005b) Impacts of hydraulic dredging on a macrobenthic community of the Adriatic Sea, Italy. *Canadian Journal of Fisheries and Aquatic Sciences* **62**, 2076–2087.

Moschino V, Deppieri MJ and Marin MG (2003) Evaluation of shell damage to the clam *Chamelea gallina* captured by hydraulic dredging in the

northern Adriatic Sea. *ICES Journal of Marine Science: Journal du Conseil* **602**, 393–401.

O'Connor NE, Crowe TPJ and McGrath D (2006) Effects of epibiotic algae on the survival, biomass and recruitment of mussels, *Mytilus* L. Bivalvia: Mollusca. *Journal of Experimental Marine Biology and Ecology* **3282**, 265–276.

Osman RWJ and Whitlatch RB (1995) The influence of resident adults on larval settlement: experiments with four species of ascidians. *Journal of Experimental Marine Biology and Ecology* **190**, 199–220.

Paine RT and Levin SA (1981) Intertidal landscapes: disturbance and the dynamics of pattern. *Ecological Monographs* **512**, 145–178.

Pauly D (1980) On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *ICES Journal of Marine Science* **39**, 175–192.

Pauly D (1983) *Some Simple Methods for the Assessment of Tropical Fish Stocks*. FAO Fisheries Technical Paper 234. Rome: FAO, 52 pp.

Pauly D and Munro JL (1984) Once more on the comparison of growth in fish and invertebrates. *Fishbyte* **2**, 1–21.

Petrova E and Stoykov S (2011) Investigations of some bivalve mollusks in Burgas Bay, Bulgarian Black Sea coast. *Macedonian Journal of Animal Science* **11**, 223–226.

Polenta R (1993) *Osservazioni sull' acrescimento della vongola Chamelea gallinaL. nel Medio adriatico*. Tezi di Laurea in Scienze Biologiche. Università degli studi di Bologna, Italy, 61 pp.

Ramón M and Rıchardson CA (1992) Age determination and shell growth of *Chamelea gallina* (Bivalvia: Veneridae) in the western Mediterranean. *Marine Ecology Progress Series* **89**, 15–23.

R Core Team (2020) *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing. Available at https://www.R-project.org/.

Reine KJ, Clarke D and Dickerson C (2014) Characterization of underwater sounds produced by hydraulic and mechanical dredging operations. *Journal of the Acoustical Society of America* **135**, 3280–3294.

Rufino MM, Gaspar MB, Pereira AM, Maynou FJ and Monteiro CC (2010) Ecology of megabenthic bivalve communities from sandy beaches on the south coast of Portugal. *Scıentia Marına* **74**, 163–178.

Rumrill SS (1990) Natural mortality of marine invertebrate larvae. *Ophelia* **321–2**, 163–198.

Saglam H and Duzgunes E (2014) Biological parameters and feeding behaviour of invasive whelk *Rapana venosa* Valenciennes, 1846 in the southeastern Black Sea of Turkey. *Journal of Coastal Life Medicine* **2**, 442–446.

Sampson D, Ak O, Cardinale M, Chashchyn O, Damalas D, Dagtekin M, Daskalov G, Duzgunes E, Genç Y, Gücü AC, Gümüş A, Maximov V, Osio GC, Panayotova M, Radu G, Raykov V, Yankova M, and Zengin M (2014) Black Sea Stock assessments. Luxembourg: Publications Office of the European Union, EUR – Scientific and Technical Research series. doi: 10.2788/19168.

Savini D and Occhipinti-Ambrogi A (2006) Consumption rates and prey preference of the invasive gastropod *Rapana venosa* in the northern Adriatic Sea. *Helgoland Marine Research* **602**, 153–159.

Scarcella GJ and Cabanelas AM (2016) The clam fisheries sector in The EU – The Adriatic Sea case. Directorate-general for internal policies, policy department B: structural and cohesion policies *fisheries*, Brussels 60 pp. doi: 10.2861/401646.

Scopa EN, Recchi SJ and Nadia Beatrice Barile M (2014) Trends in the *Chamelea gallina* production from Molise region, Adriatic Sea, Italy: a ten-year survey. *Global Journal of Science Frontier Research* **14**, 1–17.

SDG 14.4.1. (2022) https://i-marine.d4science.org/group/sdg-indicator14.4.1/stock-monitoring-tools-v0.5 (Accessed 30 April 2022).

Sokal RR and Rohlf FJ (1987) *Introduction to Biostatistics*, 2nd edn. New York, NY: W. H. Freeman and Co.

Sparre PJ and Venema SC (1992) *Introduction to Tropical Fish Stock Assessment. Part 1. Manual*. FAO Technical Paper 306/1, 337 pp.

Stadnichenko SVJ and Zolotarev VN (2001) Estimating the productivity of the Black Sea bivalve *Chamelea gallina* from the size and biomass of its populations. *Russian Journal of Marine Biology* **273**, 130–134.

Thrush SF, Gray JS, Hewitt JEJ and Ugland KI (2006) Predicting the effects of habitat homogenization on marine biodiversity. *Ecological Applications* **165**, 1636–1642.

Tunçer SJ and Erdemir C (2002) A preliminary study on some properties for *Chamelea gallina* L., Bivalvia: Veneridae from Karabiga-Çanakkale. *Turkish Journal of Fisheries and Aquatic Sciences* **2**, 117–120.

TURKSTAT (2022) https://biruni.tuik.gov.tr/medas/?kn=97&locale=tr (Accessed 3 May 2022).

Vaccarella R, Pastorelli AM, De Zio V, Rositani LJ and Paparella P (1996) Valutazione della biomassa dei Molluschi Bivalvi Commerciabili Presenti nel Golfo di Manfredonia. *Biologia Marina Mediterranea* **31**, 237–241.

Zar JH (1984) Simple linear regression. *Biostatistical Analysis* **4**, 324–359.

Zengin M, Karakulak FS, Yıldız T, Uzer U, Akpınar İÖ and Gümüş A (2020) *Monitoring Demersal Trawl Survey in the Western Black Sea*. Project No. TAGEM/HAYSÜD/2011/09/02/06. TAGEM Final Report, Trabzon, Türkiye, 204 pp.