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ORIGINAL ARTICLE

Some population parameters of *Ruditapes philippinarum* (Bivalvia, Veneridae) on the southern coast of the Marmara Sea, Turkey

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Abstract *Ruditapes philippinarum*, a venerid clam, is a dominant species in the sandy and muddy areas in the coastal waters of the Marmara Sea. Intensive commercial harvesting of this species is conducted in these regions. We studied the population dynamics of *R. philippinarum* on the southern coast of the Marmara Sea (Bandırma). Samples were collected on a monthly basis between September 2012 and August 2013. Seasonal von Bertalanffy growth parameters using the length–frequency distribution of *R. philippinarum* were estimated at $L_\infty = 67.50$ mm and $K = 0.33$ year^{-1}, and the seasonal oscillation in growth rate was 0.53. The slowest growth period was in January. The growth performance index and potential lifespan were 3.182 and 8.06 years, respectively. The growth relationship was confirmed to have a positive allometric pattern. The average total mortality rate was estimated to be 0.777 year^{-1}, whereas the natural and fishing mortality rates were 0.539 and 0.238 year^{-1}, respectively. The current exploitation rate of *R. philippinarum* was 0.306. The recruitment pattern peaked during June–August, and spawning occurred between May and August. The results of this study provide valuable information on the status of *R. philippinarum* stocks.

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Introduction

The venerid clam *Ruditapes philippinarum* inhabits sandy and muddy bottoms of seas and is usually found buried 2–3 cm below the surface in the intertidal zone. Natural populations of this species are distributed along the coast of the Pacific and Atlantic Oceans, as well as the coastlines of the Adriatic and Aegean Seas (Jensen et al. 2004), and along the coast of the Mediterranean and Marmara Seas (Albayrak 2005). Along the southern coast of the Marmara Sea, *R. philippinarum* is one of the most abundant bivalve species at depths between 1 and 10 m, and it is only collected by scuba diving. *R. philippinarum* was first introduced in this area by Albayrak (2005).

R. philippinarum is one of the most commercially exploited bivalve molluscs in the world, and its production comes from both fishing of natural stocks and cultivated grounds. The total catch of this species was reported to be approximately 40.000 tonnes in 2010 (FAO 2012). However, in Turkey, natural stocks are the only source of *Ruditapes* sp., and the annual catch was reported to be 14.9 tonnes in 2011 (Türkstat 2012).

The commercial harvesting of *R. philippinarum* in the Marmara Sea increased during the 2000s (Albayrak 2005) with the establishment of designated growing areas for intensive fishing. However, there have been no previous investigations of the population dynamics of this clam in the Marmara Sea. Several studies have analysed other aspects of this species such as stock assessment and management (Cho et al. 2008; Spillman et al. 2009; Dang et al. 2010; Choi et al. 2011), reproduction (Robert et al. 1993;

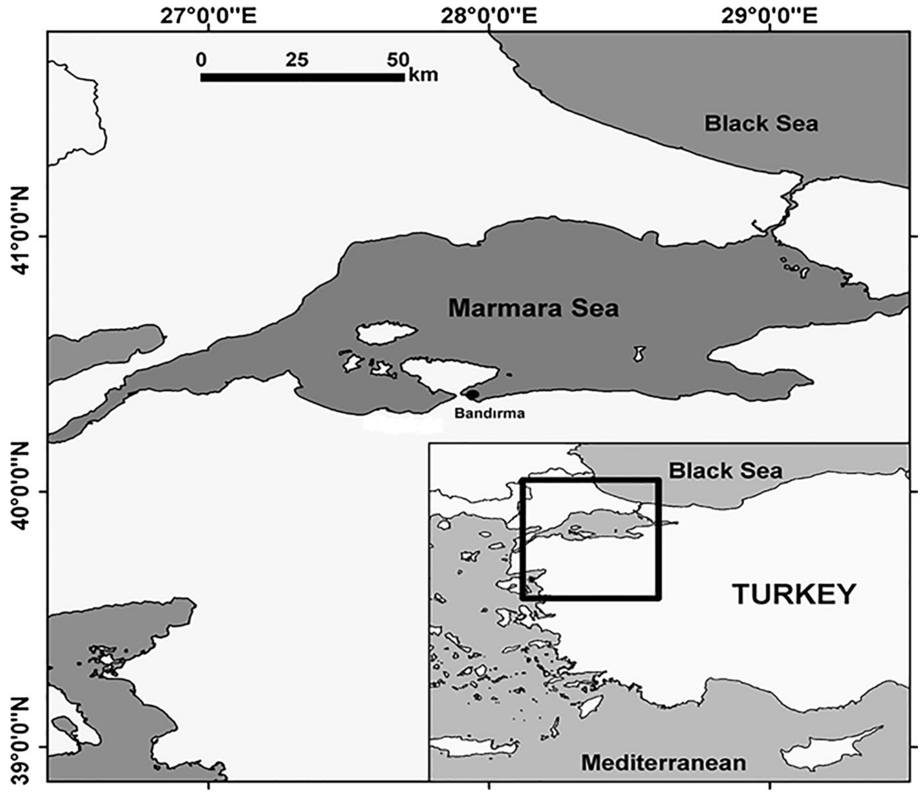

Fig. 1 Sampling location [Bandırma (40°24′25″N–27°55′33″E)]

Matozzo et al. 2003; Kang et al. 2007; Ren et al. 2008), recruitment (Toba et al. 2007; Komorita et al. 2009) and population structure (Yap 1977; Bourne 1982; Flye-Sainte-Marie et al. 2007; Ponurovsky 2008; Caill-Milly et al. 2012).

The objective of the present study was to examine the growth rates, mortality rates, reproduction and recruitment of *R. philippinarum* as well as to assess its stocks in the coastal regions of the Marmara Sea. This information will be important for the management and conservation of populations of this species in this region.

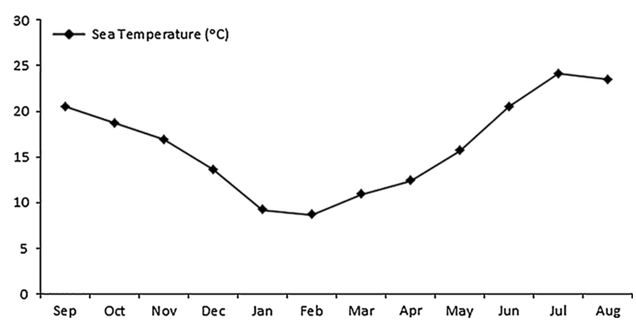

Fig. 2 Changes in seawater temperature during the study period

Materials and methods

Study area and sampling

This study was conducted on the Bandırma Bay coast, south of the Marmara Sea (40°24′25″N–27°55′33″E; Fig. 1) in intertidal and shallow sub-tidal areas with sandy bottoms. *R. philippinarum* samples were collected on a monthly basis between September 2012 and August 2013. Samples were collected by towing parallel to the shoreline during low tide for 10 min (length of dredge mouth and height: 55 and 30 cm, respectively; number of teeth and length: 25 and 16 cm, respectively; mesh size: 5 mm) at a depth of 3–8 m using a mechanical dredge. Shell length (SL) and total weight (TW) of individual bivalves were measured for a period of 1 year. Size measurements were used to estimate growth parameters. The sea surface temperature varied between 8.70 °C in winter (February) and 24.10 °C in summer (July), with a mean of 16.20 ± 1.55 °C (Fig. 2). Seawater temperature in the sampling area was measured using a mercury bulb thermometer.

Growth

In total, 10.626 *R. philippinarum* were sampled. Anterior–posterior length (SL) of individual specimens was measured using digital callipers (0.01-mm accuracy). Length–

frequency distributions were constructed with 1-mm intervals for each month. Total, shell and wet meat weight of each bivalve were measured using an electronic balance (0.01-mg accuracy).

The length–weight relationship was determined according to the allometric equation defined by Ricker (1973): $Y = aX^b$, where Y is TW, X is SL, a is the intercept and b is the slope. Parameters a and b were estimated by least squares linear regression using log–log transformed data:

$$\log \mathrm{TW} = \log a + b \log \mathrm{SL} \qquad (1)$$

The coefficient of determination (r^2) was used as an indicator of the linear regression quality. In addition, the 95 % confidence limit of b and the significance level of r^2 were also estimated. To confirm whether the value of b obtained by linear regression was significantly different from the isometric value ($b = 3$) and if they had negative ($b < 3$) or positive ($b > 3$) allometric relationships, a t test was applied with a confidence level of ±95 % ($\alpha = 0.05$; Sokal and Rohlf 1987).

On the basis of monthly sampling frequency in the study area, 12 time-series datasets (1-mm SL size classes) were estimated using the electronic length–frequency analysis (ELEFAN) procedure in the length–frequency distribution analysis (LFDA) program (Kirkwood et al. 2001). Length was predicted as a function of age according to the von Bertalanffy growth equation (VBG, Eq. 2). This equation is used when a non-seasonal growth pattern is observed

$$L_t = L_\infty \left(1 - e^{-K(t - t_{0)}}\right) \qquad (2)$$

A study conducted by Hoenig and Hanumara (1990) found the Hoenig and Hanumara (1982) model used in fisheries better fit seasonal growth data; this model represents a combination of features from other models. Therefore, seasonal growth was described using the Hoenig and Hanumara (1982) version of the VBG equation:

$$L_t = L_\infty \left[1 - e^{\left[-K(t - t_0) + \left(C\frac{K}{2\neq}\right)\sin 2\neq(t - t_s) - \left(C\frac{K}{2\neq}\right)\sin 2\neq(t_0 - t_s)\right]}\right] \qquad (3)$$

where L_t is the maximum anterior–posterior shell length (apSL; mm) at time t, L_∞ is the asymptotic apSL (mm), K (year^{-1}) is the growth curvature parameter, C is the relative amplitude ($0 \leq C \leq 1$) of seasonal oscillations, t_0 is the theoretical age when the SL is zero (years) and t_s is the phase of the seasonal oscillations ($-0.5 \leq t_s \leq 0.5$), which denotes the time of year that corresponds to the start of the convex segment of sinusoidal oscillation.

The time of the year when growth is slowest, known as the winter point (WP), was calculated as:

$$\mathrm{WP} = t_s + 0.5 \qquad (4)$$

Seasonal and non-seasonal VBG curves were fitted to length–frequency distributions after first specifying a range of values for L_∞ and K to maximize the goodness of fit (Rn) for each curve, thereby optimizing data. Rn was calculated as:

$$\mathrm{Rn} = \frac{10^{\mathrm{ESP/ASP}}}{10} \qquad (5)$$

where ASP is the available sum of peaks, computed by adding the best values of the available peaks, and ESP is the explained sum of peaks, computed by summing all the peaks and troughs hit by the VBG curve. In the area on the score grid that the best maximum is found, maximization has been done on the small area ($0.1 < K < 0.5$ year^{-1} and $60 < L_\infty < 70$ mm), in order to obtain the highest score function possible. Through the value of this score function, growth parameters were determined to be stable.

The growth performance index ($Ø'$, Eq. 6) was compared using different growth values reported in the literature, according to the following formula (Eq. 6; Pauly and Munro 1984). In addition, we constructed a 95 % confidence interval for $Ø'$ from the different combination estimates and from those in this study ($\alpha = 0.05$)

$$\emptyset' = 2\log_{10}(L_\infty) - \log_{10} K \qquad (6)$$

The maximum lifespan (A_{95}, Eq. 7) was calculated using the inverse of the VBG equation, where we considered the maximum SL as 95 % of the L_∞ (Taylor 1958):

$$A_{95} = t_0 + \frac{2.996}{K} \qquad (7)$$

Mortality

The instantaneous total mortality rate (Z, Eq. 8) was estimated using different methods. The Beverton and Holt (1956) equation for estimating Z was calculated as:

$$Z = K\left[\frac{L_\infty - \overline{L}}{\overline{L} - L'}\right] \qquad (8)$$

where L' is the length when *R. philippinarum* were first fully recruited and $\overline{L}$ is the mean length of all clams longer than L'.

The length-converted catch curve (LCCC; Pauly 1983, 1984a, b) was also used to estimate Z as follows:

$$\ln\left(\frac{N_i}{\Delta t_i}\right) = a + bt'_i \qquad (9)$$

where N_i is the frequency in length class i, Δt_i is the time required for a clam to grow and reach length class i, a is the intercept, t'_i is the relative age of individual clams that correspond to length class i and b is the slope that corresponds to Z with a sign change.

The natural instantaneous mortality rate (M, Eq. 10) was estimated using the empirical relationship defined by Pauly (1980):

$$\log M = -0.0066 + 0.279 \log \mathrm{TL}_{\infty} + 0.6543 \log K + 0.4634 \log T \quad (10)$$

where T is the mean annual seawater temperature and TL_{∞} is the asymptotic total length (cm) that *R. philippinarum* can reach. This empirical equation assumes that the length is measured as TL in cm (Gayanilo et al. 2005). Therefore, length–frequency analyses were reapplied to length composition data to obtain TL_{∞} (cm), TL and K for use in Pauly's empirical equation.

The fishing mortality rate (F) was calculated as:

$$Z = M + F \quad (11)$$

The exploitation rate (E; Sparre and Venema 1992) was calculated as:

$$E = \frac{F}{F + M} \quad (12)$$

Moreover, instantaneous mortality rates were then converted to annual mortality rates (A) as:

$$A = e^{-Z} \quad (13)$$

The Beverton–Holt and LCCC Z were calculated using length–frequency distribution analysis version 5.0 (Kirkwood et al. 2001). M was estimated using the FISAT II program (Gayanilo et al. 2005). Significant differences between the Beverton–Holt and LCCC mortality rates were analysed by one-way analysis of variance (ANOVA; F test), using Microsoft Excel 2010 (Zar 1984).

Reproduction

The reproductive activity of *R. philippinarum* was determined on the basis of the ash-free dry weight (AFDW)/dry shell weight (DSW) ratio. Each month, sub-samples of 35 clams were used to extract all their soft parts. The sub-sample used for condition index (CI, Eq. 14) analysis had an SL ranging from 20 to 50 mm. To determine the body mass cycle, all soft parts were removed and dried to a constant mass at 100 °C for 24 h to obtain DSW (g). AFDW (mg) was obtained by drying soft tissues in an oven at 550 °C for 7 h (Laudien et al. 2003). CI was calculated according to the following formula (Walne and Mann 1975):

$$\mathrm{CI} = (\mathrm{AFDW}/\mathrm{DSW}) \times 100 \quad (14)$$

The monthly gonado-somatic index (GSI, Eq. 15), which is defined as the volume of gonadal tissue (V_{gon}) relative to the total body volume (V_{body}), was estimated using a method based on linear measurements of the gonad region, which forms a sheath around the digestive gland (Urban and Riascos 2002; Riascos et al. 2007).

$$\mathrm{GSI} = V_{\mathrm{gon}}/V_{\mathrm{body}} \times 100 \quad (15)$$

A sub-sample of 35 specimens (SL = 40–50 mm) was used to study the reproductive cycle. The body mass cycle of individual bivalves was determined in the gonad stage on the basis of microscopic observations of fresh gonadal material. We used a semi-quantitative scale proposed by Guillou et al. (1990), which allowed us to classify males and females into four gonad stages: indifferent, ripe I, ripe II and spent.

Results

Size–frequency distribution, length–weight and shell morphometric relationships

Monthly length–frequency distributions of *R. philippinarum* are shown in Fig. 3. The length of individual bivalves ranged from 4 to 62 mm, and the weight ranged from 0.02 to 63.9 g ($N = 10{,}626$). Throughout the sampling period, we found 76.72 % smaller (<25 mm) and 23.28 % larger individuals (≥25 mm). The recruitment pattern peaked from June to August. Length–frequency distributions showed that recruitment continued during the summer and ended in August, where young clams that measured 4–10 mm were found at the beginning of the summer (June; Fig. 3). The calculated length–weight equation was log TW = −4 + 3.1384 log SL. In exponential form, the equation is $\mathrm{TW} = 0.0001\mathrm{SL}^{3.1384}$ ($r^2 = 0.87$; $N = 1{,}890$). Linear regression showed a significant relationship between TW ($P < 0.05$) and SL. The morphometric relationship between TW/SL ($b = 3.1384$) indicated consistent positive allometric growth. The 95 % confidence interval range for b was calculated as 3.7181–3.7296.

Growth

The maximum SL recorded in *R. philippinarum* was 62 mm; the predicted longest length was 63.31 mm. L_{∞} of seasonal and non-seasonal VBG parameters was 67.50 and 67.14 mm, respectively, and K was 0.33 year^{-1} (Fig. 4). Seasonal and non-seasonal VBG parameters obtained from LFDA are summarized in Table 1. The seasonal growth curve computed using these parameters is shown above the restructured length distribution in Fig. 5. The slowest growth rate was observed in January (0.02 × 12 = 0.24 months). $\text{Ø}'$ and A_{95} derived from seasonal VBG parameters were 3.182 and 8.06 years, respectively, with a 95 % confidence interval of 2.868–3.110 ($t_{0.05,10} = 2.228$).

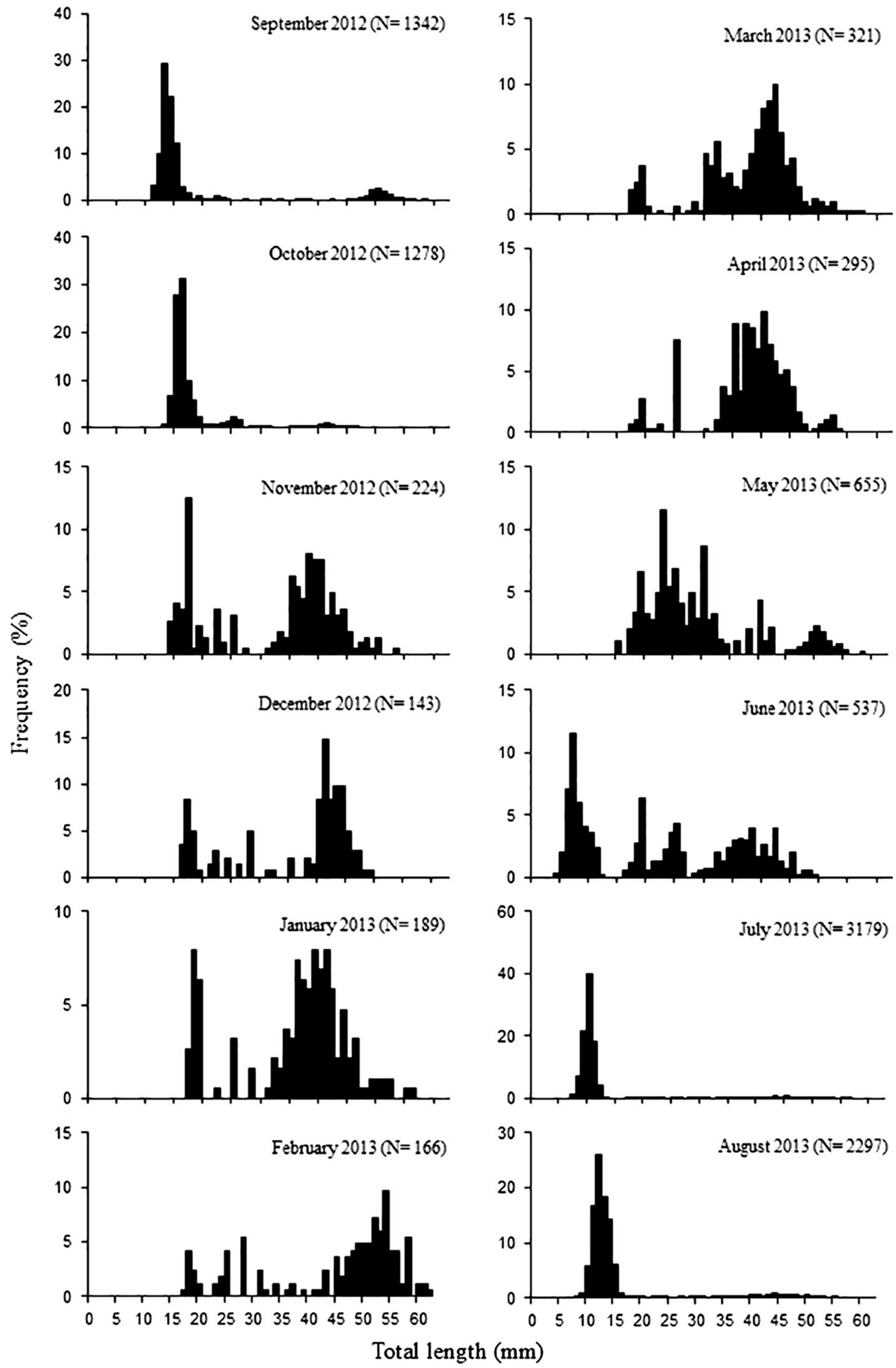

Fig. 3 Length–frequency data for *R. philippinarum* collected from the southern coast of the Marmara Sea (Bandırma) between September 2012 and August 2013

Mortality and exploitation rate

A estimated with different combinations of methods ranged between 0.512 (LCCC) and 0.413 (Beverton–Holt) year^{-1}. The Beverton–Holt *Z* estimates ranged between 0.287 and 1.436 year^{-1}, with a mean of 0.884 ± 0.107 year^{-1} (95 % confidence interval, 0.650–1.118). *Z* estimated with the LCCC method ranged between 0.19 and 1.56 year^{-1}, with a mean of 0.670 ± 0.031 year^{-1} (95 % confidence interval, 0.443–0.897). The highest mortalities were observed in October (LCCC, 1.56 year^{-1}) and June (Beverton–Holt, 1.436 year^{-1}), whereas the lowest was observed in February (LCCC, 0.19 year^{-1}; Beverton–Holt, 0.287 year^{-1}; Fig. 6). Compared with LCCC, mortality rates obtained using the Beverton–Holt method were similar with the input parameters from ELEFAN. No significant differences ($P < 0.05$) were observed between the mortality rates [LCCC/Beverton–Holt *F* test (1,

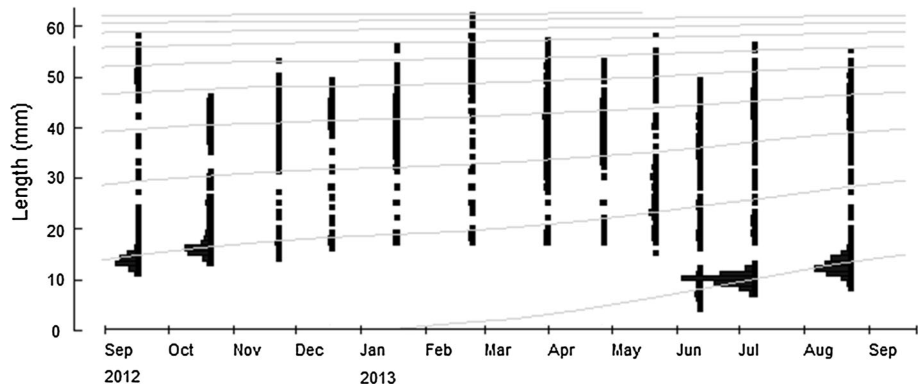

Fig. 4 Growth curves (*grey lines*) of *R. philippinarum* estimated from monthly length–frequency data (*black histograms*) for the periods of September 2012 to August 2013

Table 1 Seasonal and non-seasonal von Bertalanffy growth parameters estimated from length–frequency distribution analysis of *R. philippinarum*

Parameters	Seasonal	Non-seasonal
L_∞ (mm)	67.511	67.143
K (year^{-1})	0.334	0.330
t_0 (year)	−0.91	−0.99
WP	0.02	–
t_s	−0.48	–
C	0.53	–
$Ø'$	3.182	3.173
A_{95}	8.06	8.09
Rn	0.292	0.253

L_∞ The asymptotic total length (mm), K the growth curvature parameter (year^{-1}), t_0 the theoretical age at which the length is zero (year), t_s is the phase of the seasonal oscillations, C the relative amplitude of the seasonal oscillations, $Ø'$ the growth performance index, *WP* winter point, A_{95} the maximum lifespan, *Rn* goodness of fit index

22) = 2.085 ($Fcrit = 4.301$); $P = 0.163$]. M was 0.539 year^{-1}, whereas the average Z was estimated to be 0.777 year^{-1}. F was calculated as 0.238 year^{-1}, and E was estimated to be 0.306.

Reproduction

CI, GSI and the distribution of reproductive stages are shown in Fig. 7. *R. philippinarum* were continuously observed in the spent stage throughout the year. Spawning occurred between May and August based on declines in CI and GSI and increased microscopic observation of spent stages (Fig. 7). CI and GSI development started with increasing water temperatures in March and peaked with high water temperature in May. Moreover, spawning appeared to occur due to the major increase in the spent stages and decrease in ripe clams. In general, higher proportions of ripe individuals were observed between February and May.

Discussion

Our study represents the first analysis of the length–weight relationship in *R. philippinarum* specimens from the coastline of the Marmara Sea. The allometric coefficient b (3.138) was confirmed as having a positive allometric pattern. Similar exponential values were reported by

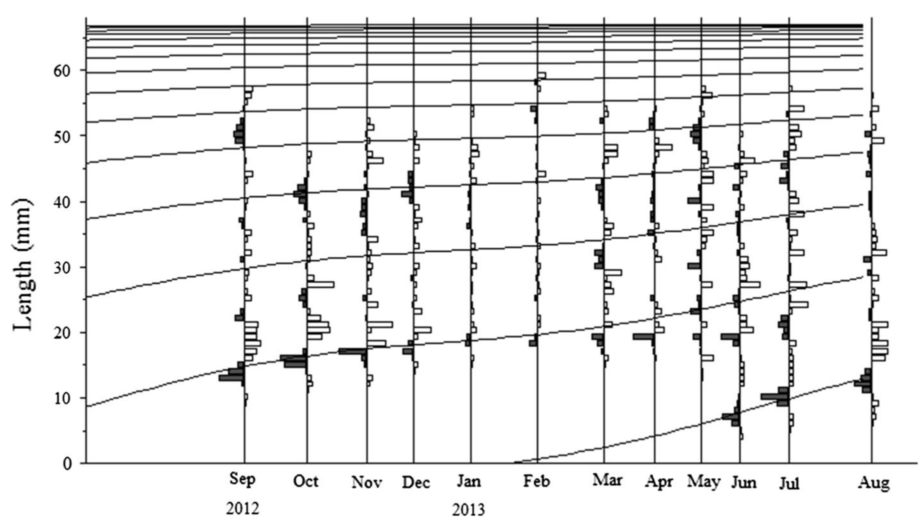

Fig. 5 Length–frequency distribution (*bars*) for *R. philippinarum*, where the seasonal von Bertalanffy growth curves (*lines*) are superimposed

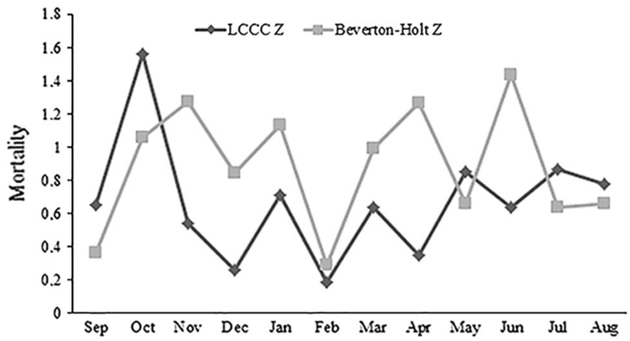

Fig. 6 Mortality rates (*Z*) in each month according to different methods

Mingyun et al. (1989; $b = 3.259$), Choi et al. (2011; $b = 3.036$) and Caill-Milly et al. (2012; $b > 3$). In contract, Yap (1977; $b = 2.862$), Cho et al. (2008; $b = 2.988$) and Ponurovsky (2008; $b = 2.954$) reported negative allometric patterns. Discrepancies in the value of *b* in length–weight relationships could have been affected by variations in environmental conditions, such as the density of substrata in the sediment, intensity of predation and variability in food availability (Gaspar et al. 2001).

Sparre and Venema (1992) reported that growth parameters differed among species and among stocks within the same species, which was attributed to different environmental conditions. In the present study, L_∞ (67.511 mm SL) differed from that of previous studies (Table 2). The highest reported L_∞ (75.53 mm) was observed on the central coast of British Columbia, Canada (Bourne 1982), whereas the lowest reported L_∞ (41.1 mm) was obtained from Arcachon Bay, France (Dang et al. 2010). In the present study, *R. philippinarum* exhibited a slower growth rate ($K = 0.33$ year^{-1}) compared with $K = 0.913$ year^{-1} from Kaneohe Bay, Hawaiian Islands (Yap 1977), $K = 0.697$ year^{-1} on the British coast, UK (Humphreys et al. 2007), $K = 0.72$ year^{-1} from Arcachon Bay (Dang et al. 2010) and $K = 0.341$ year^{-1} in the Taehwa River, Ulsan, South Korea (Choi et al. 2011). In contrast, the growth rate determined in the current report was higher than that reported by other studies conducted in British Columbia ($K = 0.273$ year^{-1} or $K = 0.303$ year^{-1}) (Bourne 1982) and Amurshy Bay, Sea of Japan ($K = 0.302$ year^{-1}; Ponurovsky 2008). We found that *R. philippinarum* exhibited seasonal growth ($C = 0.53$), with the slowest growth in January (WP = 0.02).

$\varnothing'$ is appropriate for comparing the growth performance of different populations of bivalve species. The $\varnothing'$ of *R. philippinarum* derived from VBG parameters was 3.182, which is higher than values obtained from other locales, like that obtained from Kaneohe Bay (3.399; Table 2; Yap

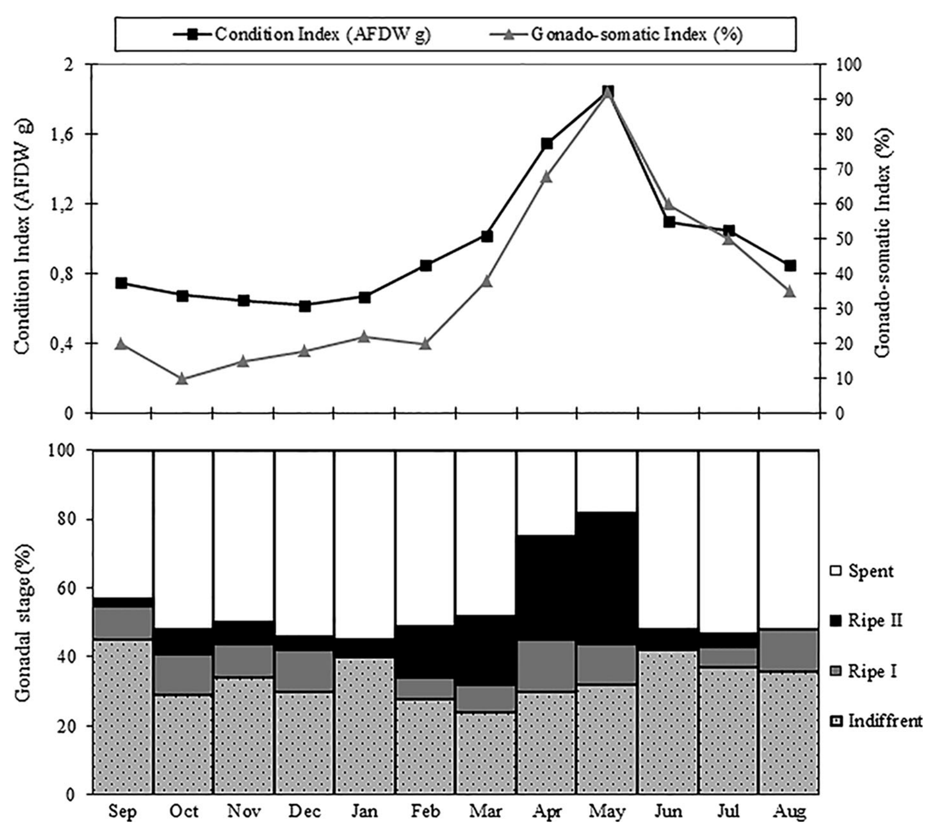

Fig. 7 Distributions of the condition index (CI), gonado-somatic index (GSI) and reproductive stages in successive months for *R. philippinarum*

Table 2 Von Bertalanffy growth parameters and mortality of *R. philippinarum* in different areas

Location	L_∞	K	$Ø'$	A_{95}	Z	Source
Kaneohe Bay, Hawaiian Islands	52.40	0.913	3.399	–	0.201	Yap (1977)
West Coast of Vancouver Island, British Columbia	57.08	0.273	2.949	4	–	Borne (1982)
Strait of Georgia, British Columbia	56.80	0.303	2.99	4	–	Borne (1982)
Central Coast, British Columbia	75.53	0.153	2.941	5	–	Borne (1982)
Allert Bay, British Columbia	68.80	0.140	2.821	5.5	–	Borne (1982)
British Coast, UK	43.32	0.697	3.117	–	–	Humphreys et al. (2007)
Amurshy Bay, Sea of Japan	56.60	0.302	2.986	7	–	Ponurovsky (2008)
The Coast of Yeongi at Tongyeong, Korea	68.08	0.145	2.827	10.55	0.991	Cho et al. (2008)
Arcachon Bay, France[a]	41.10	0.72	2.99	–	3.028	Dang et al. (2010)
Taehwa River, Ulsan	46.64	0.341	2.870	6	1.171	Choi et al. (2011)
Bandırma Bay, South Marmara Sea	67.51	0.334	3.182	8.06	0.777	This study
	67.14	0.330	3.173	8.09		

Z the instantaneous total mortality rate year^{-1}

[a] Data are means

1977). However, there were no significant differences in the $Ø'$ between these studies ($P < 0.05$). To determine the age of bivalve species, the most commonly used methods are based on analysis of external surface rings, internal growth lines and micro-growth bands in shells (Richardson 2001), including an analysis of length–frequency distributions (Peharda et al. 2013). In addition, the approximate lifespan of bivalve species can be estimated on the basis of VBG parameters (Taylor 1958). We determined that $A_{95} = 8.06$ years for *R. philippinarum*, which is higher than values reported from other areas outside the studied coast of Yeongi, Tongyeong, Korea (Table 2; Cho et al. 2008).

The wide range of Z estimates obtained using different methods made it difficult to decide a reliable single value for the mortality rate. However, Z and A of *R. philippinarum* were similar using LCCC ($Z = 0.670$ year^{-1}; $A = 0.512$ year^{-1}) and Beverton–Holt ($Z = 0.884$ year^{-1}; $A = 0.413$ year^{-1}) methods. The average Z (0.777 year^{-1}) in the present study was different from those estimated by other studies in different areas of the world (Table 2). In addition, F was lower (0.238 year^{-1}) than M (0.539 year^{-1}), indicating a balanced stock of *R. philippinarum* in our study area. The main approach used to evaluate stock status was based on an analysis of harvest rates from time-series datasets available from previous years and an estimate of the current E. Patterson (1992) recommends $E = 0.4$ as the limit management reference point, which is consistent with high long-term yields. Relative to this E reference point, we determined that the *R. philippinarum* stock on the southern coast of the Marmara Sea may be considered as being exploited in a sustainable manner ($E = 0.306$).

We observed continuous gametogenic activity in *R. philippinarum* throughout the year (Fig. 7). However, periods of increased gametogenic activity correlated with climatic variation (Riascos et al. 2007). In our study, the reproductive cycle of *R. philippinarum* had a seasonal spawning pattern based on the similarity between GSI/CI and the percentage of spent animals (Fig. 7). *R. philippinarum* is well known for asynchronous partial successive spawning and fast maturation of gametes. Some researchers point out the difficulty in estimating the peak reproductive weight and evolution of mean weight from observed data of individual clams when asynchronous partial spawning events occur in the studied population (Flye-Sainte-Marie et al. 2007). Therefore, in this study, it can only be said that clam gonads started to ripen when the average water temperatures reached 12 °C in the Bandırma Bay. Spawning period of *R. philippinarum* appeared to occur between May and August (summer). Different studies around the world have shown that *R. philippinarum* has various spawning periods, depending on location. In other studies, the spawning period was June–September in British Columbia (Bourne 1982), April–August and late summer in Ile Tudy, South Brittany, France (Beninger and Lucas 1984), autumn–summer in Arcachon Bay (Robert et al. 1993; Dang et al. 2010), June–November in Ria de Vigo, Spain (Rodriguez-Moscoso et al. 1992), summer in Vostok Bay, Russia (Ponurovsky and Yakovlev 1992), May–September in the Lagoon of Venice, Italy (Meneghetti et al. 2004) and summer–autumn in Tokyo Bay, Japan (Toba et al. 2007). These different spawning seasons are probably related to the seawater temperature (Dang et al. 2010) and variations in seasonal seawater temperature during the spawning season, especially in the neighbourhood of intertidal zone, which may also explain the high variability in spawning patterns.

Length–frequency distributions indicated a rapid increase in recruitment (individual clams with

SL < 17 mm) from June to October in 2013 (Fig. 3). The major recruitment peak of this bivalve occurred during June–August (summer). However, other studies of this species have reported different results. For example, the recruitment of *R. philippinarum* occurred twice each year in May (spring) and October (autumn) in Tokyo Bay (Toba et al. 2007), August (summer) and October (autumn) in Hokkaido, Japan (Komorita et al. 2009) and May–August and October–November in Arcachon Bay (Dang et al. 2010). Recruitment patterns of bivalves differ among species depending on the season, nutritional needs and environmental conditions (Rufino et al. 2010).

To the best of our knowledge, no other previous studies have investigated the population dynamics of *R. philippinarum* in the Marmara Sea. On the basis of our results, it was concluded that the stock of *R. philippinarum* analysed is currently at a sustainable level, with an existing fishing level. Exploitation is below the optimum exploitation level ($E = 0.4$). Results from this study also provide basic information that may facilitate conservation and stock management policies for *R. philippinarum* clam populations in the Bandırma Bay.

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