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Population dynamics of *Philocheras trispinosus* (Crangonidae) with abundance of other caridean shrimps (Crustacea: Decapoda) caught by beam trawl in the Southern Black Sea, Turkey

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ABSTRACT

Objective: To determine growth and reproduction biology of *Philocheras trispinosus* (*P. trispinosus*) with abundance of other caridean shrimps caught by beam trawl in the Southern Black Sea.

Methods: Samplings were carried out monthly with a beam trawl of 2 m length and 15 mm cod-end mesh size between December 2012 and November 2013. All individuals were sampled between 1 and 40+ m water depth from 146 hauls.

Results: A total of 550 *P. trispinosus*, 618 *Palaemon adspersus*, 12 *Palaemon serratus*, 11 *Philocheras fasciatus* and 10 *Crangon crangon* were sampled during the study period. The crangonid shrimps started appearing during the winter and spring and the number of individuals increased to reach their highest value in mid-winter and mid-spring. The seasonal von Bertalanffy growth parameters for *P. trispinosus* were estimated as L_∞ = 29.3 mm total length, K = 0.860/year, t_0 = –0.900 year, C = 0.180, and t_s = 0.010. The start of the slow growth period was at the beginning of July (*WP* = 0.510). Ovigerous females appeared in the sampling area between January and April. Size at sexual maturity was estimated as 25.69 mm total length.

Conclusions: The results supported the distribution and abundance of caridean shrimp species from the study area and the population dynamics of the most abundant shrimp species, *P. trispinosus*. The current study can be answered as baseline data prior to management strategies to ensure sustainable conservation of the shrimp species.

1. Introduction

There are 10 caridean shrimp species belonging to 4 families and 6 genera occurring in the Anatolian Black Sea Coast[1,2]. These species are *Athanas nitescens, Crangon crangon* (*C. crangon*), *Philocheras fasciatus* (*P. fasciatus*), *Philocheras trispinosus* (*P. trispinosus*), *Hippolyte leptocerus, Lysmata seticaudata, Palaemon adspersus* (*P. adspersus*), *Palaemon elegans* (*P. elegans*), *Palaemon serratus* (*P. serratus*) and *Palaemon longirostris*. Within these species, *C. crangon*, *P. adspersus* and *P. serratus* have been reported as commercial importance and others were described as ecological important species[3]. In the Black Sea, these species, especially *Palaemon* species inhabiting shallow waters, are used as fish feed to fish in the amateur or sports fishing activities such as fishing line (personal observation).

Spatial and temporal variation of caridean species such as *P. adspersus*, *P. elegans* and *C. crangon* were reported off Sinop in the Black Sea. Moreover, seasonal and non-seasonal growth pattern and reproduction biology such as reproduction time, size at sexual maturity and fecundity of these three species and embryonic and larval development were details studied in the Black Sea[4-7]. Growth and reproduction biology were also reported for *P. adspersus*[8] and *Palaemon xiphias* from Alfacs Bay (Ebro Delta), on the Spanish Mediterranean coast[9] for *C. crangon* in Port Erin Bay, Isle of Man, from Irish Sea[10,11]. Moreover, reproduction biology of *P. trispinosus* was reported from the Spanish Mediterranean coast[12] in Port Erin Bay, Isle of Man, from Irish Sea[13] and in the Banyuls-sur-Mer in the

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Northwestern Mediterranean[14]. However, no population dynamics information exists for unexploited *Philocheras* species inhabiting the Black Sea. The aim of this study was to investigate growth and reproduction biology of *P. trispinosus* with abundance of other caridean shrimps caught by beam trawl in the Southern Black Sea. In addition, seasonal growth pattern was investigated in details for the *P. trispinosus*.

2. Materials and methods

Shrimps were collected monthly during daylight between December 2012 and November 2013 on the Rize coast of the Black Sea where no shrimp fishery existed (Figure 1). All individuals were captured between 1 and 40+ m depth with a beam trawl of 2 m length and 15 mm cod-end mesh size. A total of 146 hauls were conducted during the study period. Depending on the bottom structure and meteorological sea conditions, sampling duration ranged between 8 and 25 min per haul with a towing speed between 2.0 and 2.5 knot.

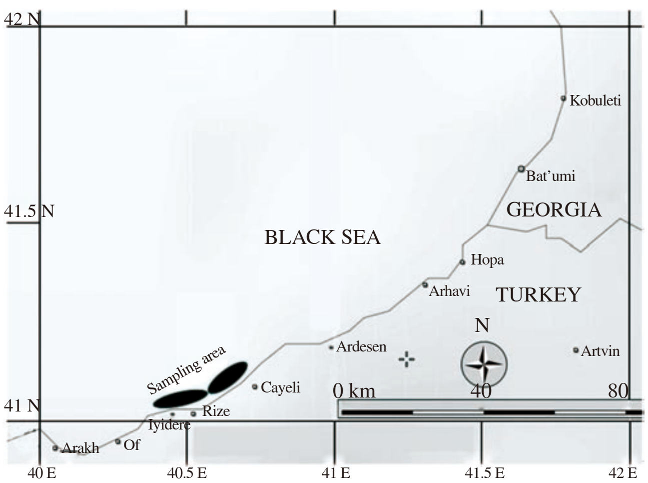

Figure 1. Sampling area.

Seasons were grouped as winter (between December and February; 29 hauls), spring (between March and May; 40 hauls), summer (between June and August; 44 hauls), and autumn (between September and November; 33 hauls). Water depth distribution of shrimp species was investigated between water depths of 1 and 40+ m. Since water depths varied during the trawl operation, water depths were grouped between 1 and 10 m (a total of 65 hauls), between 11 and 20 m (a total of 37 hauls), between 21 and 30 m (a total of 29 hauls), and between 31 and 40+ m (a total of 15 hauls). Catch per unit effort (CPUE) was calculated as the number of individuals and divided by the hauling time in hour. CPUE for shrimp species was used for the comparison of density distributions among seasons and depth groups.

The presence (males) or absence (females) of an appendix masculina (Figure 2) on the second pleopod was the criterion for sex determination[13,15]. The total body length of each specimen was measured from the tip of the rostrum to the posterior end of the telson (excluding spines) with an accuracy of 1 mm. Specimens were weighed (wet weight) on a balance with a sensitivity of 0.001 g.

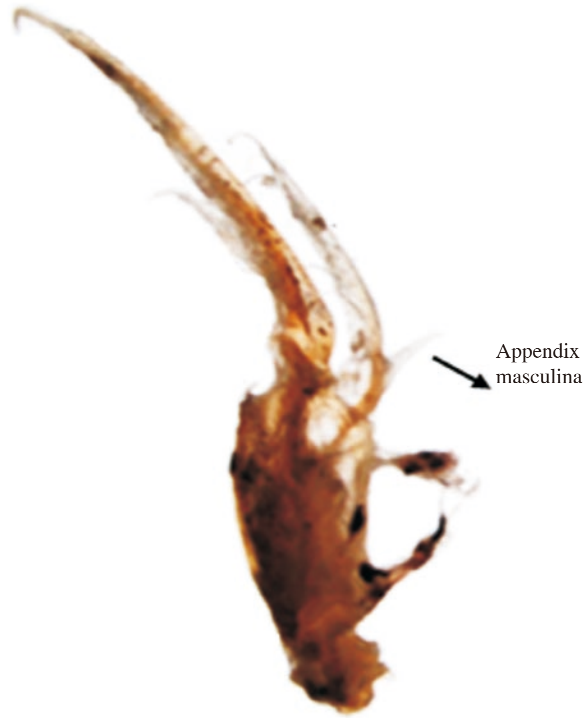

Figure 2. Appendix masculina on the second pleopod: secondary sexual character of *P. trispinosus* male.

The weight-length relationship was estimated as:

$$W = aTL^b$$

where W is the body weight (g), TL is the total length (mm), a is the intercept, and b is the slope of the regression line.

The standard von Bertalanffy growth (VBG) equation $L_t = L_\infty\ [1-e^{-K(t-t_0)}]$ predicts length as a function of age and is used when growth has a non-seasonal pattern. Seasonal growth was described using the Somers's[16] version of the VBG equation:

$$Lt = L_\infty \left[1-e^{\left[-k(t-t_0)-(\frac{CK}{2\pi})\sin 2\pi(t-t_s)+(\frac{CK}{2\pi})\sin 2\pi(t_0-t_s) \right]} \right]$$

where, L_t is length at age t, L_∞ is the asymptotic length to which the whiting grow, K is the growth-rate parameter, t_0 is the nominal age at which the length is zero, C is the relative amplitude ($0 \leqslant C \leqslant 1$) of the seasonal oscillations, t_s is the phase of the seasonal oscillations ($-0.5 \leqslant t_s \leqslant 0.5$) denoting the time between 0 and the start of the convex segment of the first sinusoidal oscillation.

The period of the lowest growth rate, known as the winter point (WP), was calculated as:

$$WP = t_s + 0.5$$

Seasonal and non-seasonal VBG curves were fitted to the length distributions after first displaying a range of values of K and L_∞ and decreasing iteratively the range to maximize the goodness of fit (Rn) of the VBG curves to the data. Rn values were calculated as:

$$Rn = \frac{10^{\frac{ESP}{ASP}}}{10}$$

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.

Growth performance comparisons were made using the growth performance index (Φ') which was preferred rather than using L_∞ and

K individually[17] and was computed as:

$\Phi' = \log(K) + 2\log(L_\infty)$

The maximum age of *P. trispinosus* was calculated using the empirical equation proposed by Taylor[18] as:

$$A_{95} = t_0 + \frac{2.996}{K}$$

where A_{95} is the life span to attain 95% of L_∞, calculated from the VBG equation.

Size at sexual maturity of *P. trispinosus* was determined from females by calculating the proportion of mature females in 1 mm size classes in the breeding period. Ovigerous females were considered to be mature. The proportion of mature females by size was fitted to the logistic equation:

$$P = \frac{1}{1 + e^{a+bTL}}$$

where P is the proportion of mature females, a and b are the coefficients of the equation, and TL is the total length. Size at sexual maturity (TL_{50}), corresponding to 50% sexually mature females, was calculated from $-(a/b)$.

3. Results

3.1. Population structure

A total of 550 *P. trispinosus* (446 females without ovigerous, 99 ovigerous females, 5 males), 618 *P. adspersus* (151 females without ovigerous, 174 ovigerous females, 293 males), 12 *P. serratus* (4 females without ovigerous, 2 ovigerous females, 6 males), 11 *P. fasciatus* (8 females without ovigerous, 3 ovigerous females) and 10 *C. crangon* (7 females without ovigerous, 2 ovigerous females, 1 male) were sampled from 146 hauls between December 2012 and November 2013. Total length ranged between 13.30 and 31.80 mm [mean: (22.30 ± 0.17) mm] for *P. trispinosus*, between 35.20 and 75.20 mm [mean: (52.40 ± 0.32) mm] for *P. adspersus*, between 24.30 and 68.70 mm [mean: (37.80 ± 3.48) mm] for *P. serratus*, between 18.50 and 30.70 mm [mean: (24.70 ± 1.22) mm] for *P. fasciatus*, and between 20.90 and 69.60 mm [mean: (43.70 ± 5.95) mm] for *C. crangon*.

P. trispinosus and *P. adspersus* were sampled mostly during the study period and the other shrimp species sampled least values. *P. adspersus* total length by sexes were measured as between 36.30 and 71.70 mm [mean: (53.4 ± 0.62) mm] for females, between 43.70 and 75.20 mm [mean: (59.90 ± 0.43) mm] for ovigerous females and between 35.20 and 62.50 mm [mean: (47.40 ± 0.28) mm] for males. Size-frequency distributions were not significantly different between females and males (Kolmogorov-Smirnov two-sample test, d = 0.6248, P = 9.11198E–54).

The mean total length of female was significantly greater than male mean total length (t-test: P = 2.40E–62). *P. trispinosus* total length by sexes were also measured as between 13.30 and 30.70 mm [mean: (21.30 ± 0.16) mm] for females, between 19.60 and 31.80 mm [mean: (26.90 ± 0.20) mm] for ovigerous females and between 17.10 and 30.30 mm [mean: (26.20 ± 2.46) mm] for males (Figure 3). Size-frequency distributions were significantly different between females and males (Kolmogorov-Smirnov two-sample test, d = 0.5743, P < 0.045). The mean total length of female was significantly greater than male mean total length (t-test: P = 0.0266).

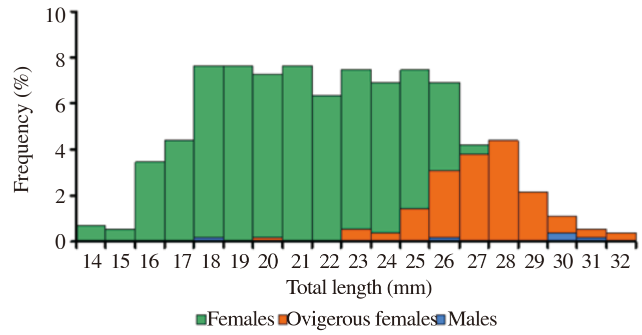

Figure 3. Length-frequency distribution of females, ovigerous females and males of *P. trispinosus* between December 2012 and November 2013 in the Black Sea.

Length-weight relationships of *P. trispinosus* were significantly different between sexes and each slope of the regression lines was significantly different than the isometric growth curve slope of 3 (P < 0.05). The relationships were as follows:

Females without ovigerous: W = 1E–05TL$^{3.1378}$ (r^2 = 0.9314, n = 446)

Ovigerous females: W = 1E–05TL$^{3.1043}$ (r^2 = 0.8715, n = 99)

Females with and without ovigerous: W = 7E–06TL$^{3.2602}$ (r^2 = 0.9472, n = 545)

Males: W = 8E–06TL$^{3.2207}$ (r^2 = 0.9979, n = 5).

3.2. CPUE (individuals/h)

The abundance of crangonid and palaemonid shrimps were seasonal (Table 1). The crangonid shrimps started appearing during the winter and spring and the number of individuals increased to reach their highest value in mid-winter and mid-spring. *C. crangon* and *P. fasciatus* were not observed in summer months and also *P. trispinosus* and *P. fasciautsu* in autumn months. *P. trispinosus* and *P. adspersus* were most abundant two species in the study area (Table 2). The other three shrimp species, *P. serratus*, *C. crangon* and *P. fasciatus*, were also sampled relatively small amounts of CPUE. Monthly CPUE of *P. adspersus* started increasing in spring months and reached their highest value in June (Figure 4). Seasonal CPUE of *P. trispinosus* decreased from winter to autumn. The CPUE was (29.70 ± 10.93) individual/h in winter (29 hauls), (26.00 ± 6.04) individual/h in spring (40 hauls), (0.20 ± 0.13) individual/h in summer (44 hauls) and (0.00 ± 0.00) individual/h in autumn (33 hauls) (Table 1). Monthly mean CPUE of *P. trispinosus* were highest in the mid-winter and mid-spring [*e.g.* (50.00 ± 28.70) individua/h in January and (43.20 ± 9.43) individual/h in April] (Figure 4). Bathymetrical distribution of *P. trispinosus* showed a clear tendency towards the shallower waters in the study area. Depth zone analyses from the complete data set collected over all seasons and depths revealed that the highest mean CPUE for *P. trispinosus* was observed up to 10 m water depth in all seasons especially winter and spring seasons (Table 3). Namely, the CPUE was (28.70 ± 6.06) individual/h in 0–10 m depth contour (65 hauls), (0.60 ± 0.31) individual/h in 10–20 m depth contour (37 hauls), (0.40 ± 0.23) individual/h in 20–30 m depth contour (29 hauls) and (0.50 ± 0.53) individual/h in 30–40+ m depth contour (15 hauls).

Table 1

Seasonal abundance [CPUE (individuals/h)] of crangonid and palaemonid shrimps.

Seasons	Hauls numbers	Palaemonid shrimps		Crangonid shrimps			All
		P. adspersus	*P. serratus*	*C. crangon*	*P. fasciatus*	*P. trispinosus*	
Winter	29		0.20 ± 0.17	0.20 ± 0.17	0.10 ± 0.14	29.70 ± 10.93	6.00 ± 2.37
Spring	40	21.30 ± 11.99	0.70 ± 0.47	0.70 ± 0.27	1.20 ± 0.77	26.00 ± 6.04	10.00 ± 2.78
Summer	44	52.20 ± 51.98	0.30 ± 0.34			0.20 ± 0.13	10.50 ± 10.40
Autumn	33	17.00 ± 13.09	0.40 ± 0.20	0.40 ± 0.36			3.50 ± 2.64
All	146	25.40 ± 16.22	0.40 ± 0.17	0.30 ± 0.12	0.40 ± 0.22	13.10 ± 2.93	7.90 ± 3.31

Table 2

Monthly CPUE with standard error of the five shrimp species between December 2012 and November 2013 in the South East Black Sea.

Months-years	*N*	CPUE (individuals/h)				
		C. crangon	*P. adspersus*	*P. serratus*	*P. fasciatus*	*P. trispinosus*
December 2012	5	1.00 ± 1.00 (*n* = 1)		1.00 ± 1.00 (*n* = 1)		18.60 ± 17.86 (*n* = 13)
January 2013	9				0.40 ± 0.44 (*n* = 1)	50.00 ± 28.70 (*n* = 165)
February 2013	15					21.30 ± 11.11 (*n* = 91)
March 2013	13	0.30 ± 0.27 (*n* = 1)	1.10 ± 1.09 (*n* = 4)	0.90 ± 0.92 (*n* = 3)		21.90 ± 11.78 (*n* = 62)
April 2013	17	1.40 ± 0.57 (*n* = 1)	37.10 ± 25.41 (*n* = 115)	0.90 ± 0.88 (*n* = 3)	2.80 ± 1.77 (*n* = 10)	43.20 ± 9.43 (*n* = 171)
May 2013	10		20.80 ± 20.80 (*n* = 52)			2.10 ± 1.25 (*n* = 6)
June 2013	22		104.30 ± 103.96 (*n* = 307)	0.70 ± 0.68 (*n* = 2)		0.20 ± 0.18 (*n* = 1)
July 2013	8					
August 2013	14					0.30 ± 0.29 (*n* = 1)
September 2013	8		18.00 ± 18.00 (*n* = 36)	0.50 ± 0.50 (*n* = 1)		
October 2013	15		27.70 ± 27.45 (*n* = 104)	0.30 ± 0.27 (*n* = 1)		
November 2013	10	1.20 ± 1.20 (*n* = 3)		0.40 ± 0.40 (*n* = 1)		
All	146	0.30 ± 0.12 (*n* = 10)	25.40 ± 16.22 (*n* = 618)	0.40 ± 0.17 (*n* = 12)	0.40 ± 0.22 (*n* = 11)	13.10 ± 2.93 (*n* = 510)

N: Number of sampling; *n*: Number of individuals of the species.

Table 3

Seasonal mean CPUE (individuals/h) of *P. trispinosus* at different depth groups.

Depth groups	Seasons				All
	Winter	Spring	Summer	Autumn	
1–10 m	70.60 ± 21.80 (12)	46.00 ± 8.98 (22)	0.40 ± 0.25 (22)	0.00 ± 0.00 (9)	28.70 ± 6.06 (65)
11–20 m	0.70 ± 0.67 (6)	1.70 ± 0.94 (11)	0.00 ± 0.00 (9)	0.00 ± 0.00 (11)	0.60 ± 0.31 (37)
21–30 m	0.50 ± 0.50 (6)	1.80 ± 1.09 (5)	0.00 ± 0.00 (9)	0.00 ± 0.00 (9)	0.40 ± 0.23 (29)
31–40+ m	1.60 ± 1.60 (5)	0.00 ± 0.00 (2)	0.00 ± 0.00 (4)	0.00 ± 0.00 (4)	0.50 ± 0.53 (15)
All	29.70 ± 10.93 (29)	26.00 ± 6.04 (40)	0.20 ± 0.13 (44)	0.00 ± 0.00 (33)	13.10 ± 2.93 (146)

Number of hauls are given in parenthesis.

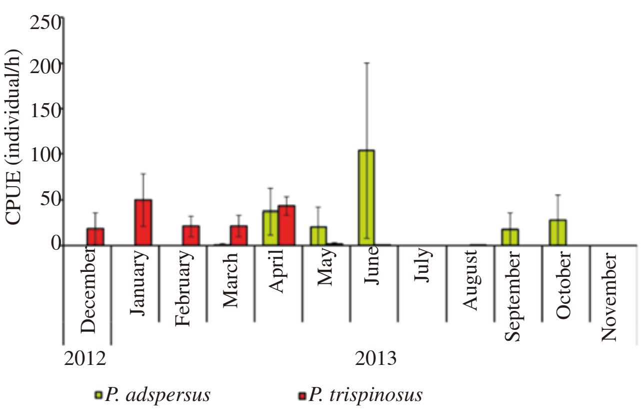

Figure 4. Monthly CPUE with standard error of the most sampled two shrimp species between December 2012 and November 2013 in the South East Black Sea.

3.3. Seasonal and non-seasonal VBG parameters

The seasonal and non-seasonal VBG parameters obtained from the length frequency distribution analysis for *P. trispinosus* were shown in Table 4. The seasonal VBG parameters were estimated as L_∞ = 29.286 mm total length, K = 0.860/year, t_0 = –0.900 year, C = 0.180, and t_s = 0.010. The length frequency distribution analysis showed that *Rn* value of the non-seasonal growth curve improved when a seasonal growth curve was fitted (Figure 5), suggesting that, at least for our data, *P. trispinosus* exhibited a seasonal growth pattern. The *Rn* value of the non-seasonal VBG curve improved by 4.13% after fitting a seasonal VBG curve (Table 4). Seasonal variation of growth was a bit stronger (C = 0.180). The start of the slow growth period was at the beginning of July (*WP* = 0.510). Growth performance indices and the maximum life span derived from seasonal VBG parameters were estimated as φ' = 2.867 8 and t_{max} = 31 months, respectively.

Table 4

Seasonal and non-seasonal VBG parameters estimated from length frequency distribution analysis for *P. trispinosus* in the Black Sea.

Parameters	Seasonal	Non-seasonal
L_∞ (mm)	29.286	28.466
K (per year)	0.860	0.929
t_0 (year)	–0.900	–0.880
WP	0.510	
t_s	0.010	
C	0.180	
Rn	0.533	0.511
φ'	2.867 8	2.876 7

L_∞: Asymptotic total length; K: Growth coefficient; t_0: Age at zero length; *WP*: Winter point; t_s: Phase of the seasonal oscillations; C: Amplitude of growth oscillation; *Rn*: Goodness of fit the index; φ': Growth performance index.

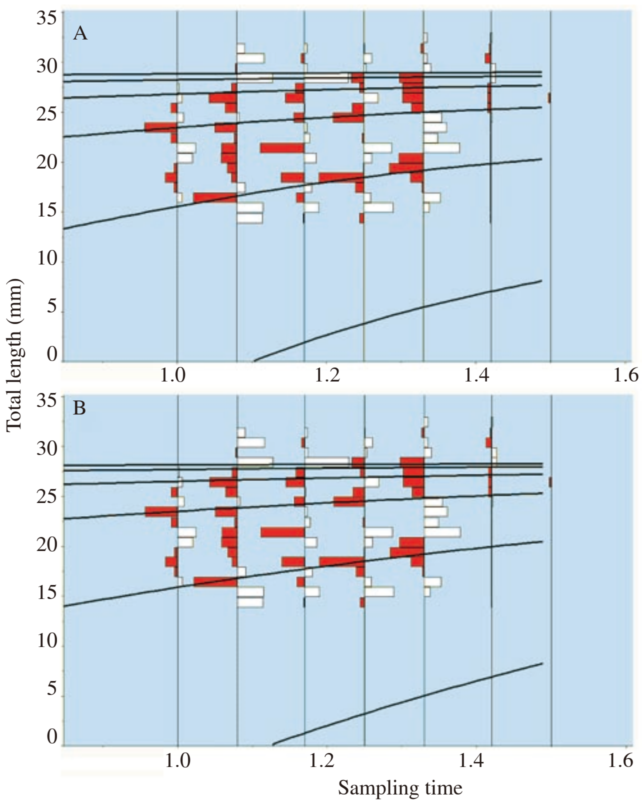

Figure 5. Length frequency distribution of *P. trispinosus* with non-seasonal (a) and seasonal (b) VBG curves (lines) superimposed.

3.4. Reproduction biology

Ovigerous females appeared in the sampling area from January to April (Figure 6). This time interval was determined as the spawning period of *P. trispinosus*. Size at sexual maturity was estimated from 529 females (sampled spawning period) of which 99 were ovigerous females considered as mature. The relationship between total length and proportion of mature females was calculated as:

$$P=\frac{1}{1+e^{10.081-0.3924*TL}}(R^2=0.723\,3,\ P<0.05)$$

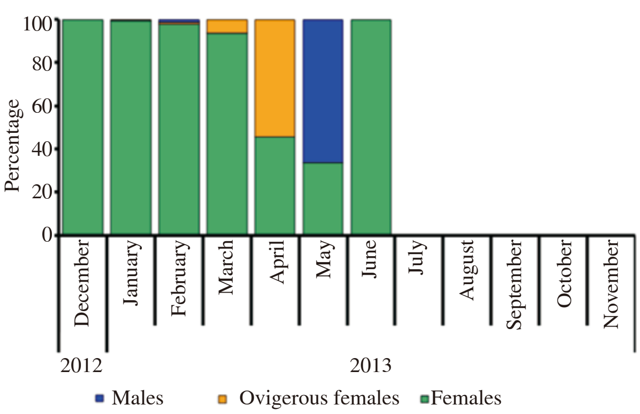

Figure 6. Monthly proportion of males, ovigerous females and females of *P. trispinosus* in the Black Sea

From this, the estimated size for 50% sexual maturity for females was 25.69 mm total length (Figure 7). The minimum length of an ovigerous female was 19.63 mm total length.

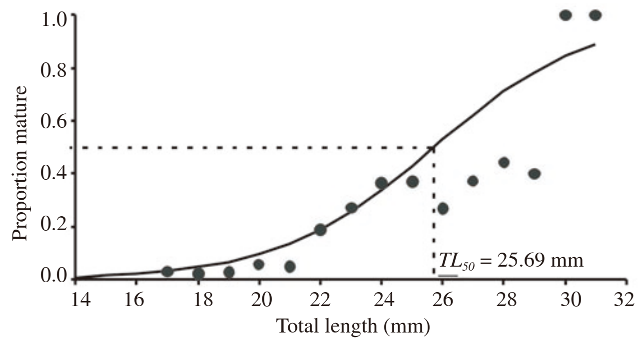

Figure 7. Logistic function fitting the proportion of mature females to total length.

TL_{50} corresponds to proportion of 50% of females that are mature.

4. Discussion

Seasonal and spatial distributions were elaborated for palaemonid and crangonid shrimps such as *C. crangon*, *P. adspersus* and *P. elegans* off Sinop coast in the Black Sea[5]. Growth and reproduction biology were also reported for *P. adspersus*[6] and *P. elegans*[7] in the Black Sea. This study provided the first information on distribution, growth and reproduction biology of *P. trispinosus* in water depth up to 40 m in the Black Sea. Previous studies that focused on reproduction biology of *P. trispinosus* studied subtidally from Port Erin Bay, Isle of Man relatively shallow water[13], Banyuls-sur-Mer in the Northwestern Mediterranean, Spain[14] and Vinaròs located on the Mediterranean Sea coast, 10 km south of the Ebro River Delta[12]. These three studies were conducted in relatively shallow water (*e.g.* < 6 m).

Spawning time in *P. trispinosus* was reported as throughout the most of the year with the highest proportions of ovigerous females between March and August in the Isle of Man by Oh and Hartnol[13]. On the Mediterranean coast of Spain, it was reported throughout the year in 2004 and in 2005, and between April and October in 2006 by Sanz-Brau *et al.*[12], and two separate spawning season, one in winter and one in summer in the Banyuls-sur-Mer in the Northwestern Mediterranean by Labat[14]. Our results showed that ovigerous females appeared in the sampling area between January and April, suggesting that spawning occurs mainly in winter and spring. At other times of the year, ovigerous females were not obtained in the sampling area. The differences of spawning time among the area may be due to latitudinal and water temperature differences[12]. In addition, the difference among the studies may also be due to sample strategies such as depth and bottom structures where shrimp prefer to live[5,19,20].

The distribution pattern of palaemonid and crangonid shrimps was affected by environmental factors such as temperature, habitat types (*e.g.* covered with sea grass, muddy *etc.*), different seasonal migration pattern. Presence or absence, distribution and abundance of the caridean shrimps on the different region (*e.g.* Sinop Peninsula and Rize coast) in the Black Sea were also primarily affected by habitat types, water depth and temperature. The effect of these features on spatial and temporal variations was reported for *P. adspersus*, *P. elegans* and *C. crangon* off Sinop coasts in the Black Sea[5]. The abundance of the shrimp species off Sinop were different from those in the Rize coast in the Black Sea (the distance between two area about 450 km). For example, *C. crangon*, *P. adspersus* and *P. elegans* were sampled throughout the year up to 30 m water depths in Sinop Region but, *P. trispinosus* specimens were not obtained in the Sinop Region[5].

Moreover, monthly abundance and distribution of shrimp species and diversity were different both area in the Black Sea. Namely, a total of 9 species belonging to 4 families and 6 genera occur in the Sinop coast of the Black Sea[1,2]. These species are *Athanas nitescens*, *C. crangon*, *P. trispinosus*, *Hippolyte leptocerus*, *Lysmata seticaudata*, *P. adspersus*, *P. elegans*, *P. serratus* and *Palaemon longirostris*. But, only 5 species studied in the present study were reported from the Rize coast in the Black Sea. This is most probably due to difference of habitat types in the sampling area and the negative impacts on coastal ecosystems of the Black Sea coastal road construction on Rize coast (personal observation). Sinop Peninsula is also a natural harbor, indented coast and the bottom structure have different habitat types which constitute the habitat of caridean shrimp such as mainly sandy bottoms, bare sandy bottoms, and muddy habitats with many patches of sea grass beds[5].

Size at sexual maturity (TL_{50}) of female *P. trispinosus* was estimated as 25.69 mm total length in the southeastern Black Sea. The size at which 50% of female was reported is 3.7 mm carapace length from Port Erin Bay, Isle of Man relatively shallow water[13]. This carapace length approximately corresponds to our total length result.

Seasonal growth pattern was reported for different palaemonid shrimp species such as *P. adspersus*[6], *P. elegans*[7], *Palaemon xiphias*[9] and crangonid shrimp species such as *C. crangon*[10]. However, no study investigated the seasonal growth oscillation and VBG parameters for *P. trispinosus*. Seasonal VBG analyses suggested that *P. trispinosus* exhibited seasonal growth pattern with a reduction in growth of 4.1% and the period of the slowest growth rate corresponded to July (WP = 0.510). However, no obvious conclusion can be made from our data about the main factors determining the period of the slowest growth time for Black Sea *P. trispinosus* population. Seasonal variations in the growth of aquatic animals are related to temporal changes in water temperature and seasonal variations in abundance and quality of food[21]. Moreover, the seasonal growth pattern could be attributed to the energy input into reproduction during the breeding season[22]. It was reported that slow growth of *P. adspersus* and *P. elegans* Black Sea population in the breeding season is probably due to the energy investment in reproduction[6,7].

Conflict of interest statement

We declare that we have no conflict of interest.

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References

[1] Bilgin S, Gönlügür Demirci G. [The shrimps of the Sinop coasts of the Black Sea]. *Sci Eng J Fırat Univ* 2005; **17**: 143-50. Turkish.

[2] Sezgin M, Aydemir E, Ateş AS, Katağan T, Özcan T. On the presence of the non-native estuarine shrimp, *Palaemon longirostris* H.Milne-Edwards, 1837 (Decapoda, Caridea), in the Black Sea. *Aquat Invasions* 2007; **2**: 464-5.

[3] Holthuis LB. *Shrimps and prawns of the world: an annotated catalogue of species ofinterest to fisheries*. Rome: Food and Agriculture Organization of the United Nations; 1980.

[4] Bilgin S, Samsun O. Fecundity and egg size of three shrimp species, *Crangon crangon*, *Palaemon adspersus*, and *Palaemon elegans* (Crustacea: Decapoda: Caridea), off Sinop Peninsula (Turkey) in the Black Sea. *Turk J Zool* 2006; **30**: 413-21.

[5] Bilgin S, Ozen O, Ates AS. Spatial and temporal variation of *Palaemon adspersus*, *Palaemon elegans*, and *Crangon crangon* (Decapoda: Caridea) in the southern Black Sea. *Estuar Coast Shelf Sci* 2008; **79**: 671-8.

[6] Bilgin S, Samsun O, Ozen O. Seasonal growth and reproduction biology of the Baltic prawn, *Palaemon adspersus* (Decapoda: Palaemonidae), in the southern Black Sea. *J Mar Biol Assoc U.K.* 2009; **89**(3): 509-19.

[7] Bilgin S, Ozen O, Samsun O. Sexual seasonal growth variation and reproduction biology of the rock pool prawn, *Palaemon elegans* (Decapoda: Palaemonidae) in the southern Black Sea. *Sci Mar* 2009; **73**(2): 239-47.

[8] Guerao G, Ribera C. Growth and reproductive ecology of *Palaemon adspersus* (Decapoda, Palaemonidae) in the western Mediterranean. *Ophelia* 1995; **43**: 205-13.

[9] Guerao G, Pérez-Baquera J, Ribera C. Growth and reproductive biology of *Palaemon xiphias* Risso, 1816 (Decapoda, Caridea, Palaemonidae). *J Crustacean Biol* 1994; **14**: 280-8.

[10] Oh CW, Hartnoll RG, Nash RDM. Population dynamics of the common shrimp, *Crangon crangon* (L.), in Port Erin Bay, Isle of Man, Irish Sea. *ICES J Mar Sci* 1999; **56**: 718-33.

[11] Oh CW, Hartnoll RG. Reproductive biology of the common shrimp *Crangon crangon* (Decapoda : Crangonidae) in the central Irish Sea. *Mar Biol* 2004; **144**: 303-16.

[12] Sanz-Brau A, Gil-Delgado JA, Mesquita-Joanes F. Seasonal variation of clutch size in the crangonid shrimp *Philocheras trispinosus* (Crustacea: Decapoda) in the western Mediterranean (Spain). *Vie et Milieu Life Environ* 2010; **60**(4): 283-9.

[13] Oh CW, Hartnoll RG. Size at sexual maturity, reproductive output, and seasonal reproduction of *Philocheras trispinosus* (Decapoda) in Port Erin Bay, Isle of Man. *J Crustacean Biol* 1999; **19**(2): 252-9.

[14] Labat JP. [Life cycle of *Philocheras trispinosus* (Hailstone) (Crangonidae: Decapoda) in the region of Banyuls-sur-Mer]. *Vie Millieu* 1984; **34**(1): 9-16. French.

[15] Berglund A. Sex dimorphism and skewed sex-ratios in the prawn species *Palaemon adspersus* and *Palaemon squilla*. *Oikos* 1981; **36**: 158-62.

[16] Somers IF. On a seasonally oscillating growth function. *Fishbyte* 1988; **6**(1): 8-11.

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

[18] Taylor CC. Cod growth and temperature. *J Cons Int Explor Mer* 1958; **23**: 366-70.

[19] Berglund A. Niche differentiation between two littoral prawns in Gullmar Fjord, Sweden: *Palaemon adspersus* and *P. squilla. Holarct Ecol* 1980; **3**: 111-5.

[20] Berglund A. Different reproductive success at low salinity determines the estuarine distribution of two *Palaemon* prawn species. *Holarct Ecol* 1985; **8**: 49-52.

[21] Cloern JE, Nichols FH. A von bertalanffy growth model with a seasonally varying coefficient. *J Fish Res Board Can* 1978; **35**(11): 1479-82.

[22] Hartnoll RG. Growth, sexual maturity and reproductive output. In: Wenner AM, editor. *Factors in adult growth*. Rotterdam: A. A. Balkema; 1985, p. 101-28.