

Distribution and population structure of the red shrimp (*Aristeus antennatus*) on an unexploited fishing ground in the Greek Ionian Sea

Costas Papaconstantinou*, Konstantinos Kapiris

National Centre for Marine Research, Agios Kosmas, 166 04, Hellinikon, Greece

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Abstract – The distribution and population structure of the red shrimp, *Aristeus antennatus*, were investigated for an unexploited fishing ground in the Greek Ionian Sea (middle-eastern Mediterranean). A total of 8 618 specimens, 7 273 females and 1 345 males was caught during a 12-month survey, from January to December 1997, at depths ranging from 400 to 800 m. Monthly size frequency distributions were analysed using different techniques, resulting in estimates of growth and mortality. Carapace lengths (cephalothoracic lengths, CL) ranged between 12 and 62 mm for females and 9 and 45 mm for males. The mean size of specimens exhibited statistically significant differences in relation to sex and months. Recruitment of both sexes occurred in mid-winter (January). Only the mean size of females seemed to increase with depth. Estimation of the von Bertalanffy growth parameters revealed high k values and a life expectancy of 4 and 5 years for males and females, respectively. A high percentage of specimens bore spermatophores during May and August, indicating that these months were peak breeding periods. Natural mortality rates ranged from 0.55 to 0.70 for females and from 0.62 to 0.79 for males, depending on the method used. Based on its biology and population dynamics, it appears that the red shrimp population in the study area has the potential to support a viable fishery.

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growth / mortality / population structure / *Aristeus antennatus* / Ionian Sea / Mediterranean

Résumé – Distribution et structure de la population de la crevette *Aristeus antennatus* d'une zone inexploitée de la mer Ionienne grecque. La distribution et la structure de la population de la crevette, *Aristeus antennatus*, ont été étudiées dans une zone de pêche inexploitée de la mer Ionienne (est Méditerranée). Un total de 8 618 spécimens, 7 273 femelles et 1 345 mâles, ont été capturés durant une campagne de janvier à décembre 1997, à des profondeurs situées entre 400 et 800 m. Les répartitions en fréquence de taille ont été analysées chaque mois selon diverses méthodes, ainsi que les estimations de la croissance et de la mortalité. La taille des carapaces (longueur céphalothoracique, CL) s'étend de 12 à 62 mm pour les femelles et de 9 à 45 mm pour les mâles. La taille moyenne des individus montre une différence significative entre les sexes et entre chaque mois. Le recrutement des deux sexes se déroule en janvier en milieu d'hiver. Seule, la taille moyenne des femelles semble augmenter avec la profondeur. L'évaluation des paramètres de croissance de von Bertalanffy montrent des valeurs de k importantes et une espérance de vie de 4 et 5 ans respectivement pour les mâles et les femelles. Un fort pourcentage d'individus porte des spermatophores durant les mois de mai et août, indiquant que ces mois sont des pics de périodes de ponte. Les taux de mortalité naturelle varient de 0,55 à 0,70 pour les femelles, et de 0,62 à 0,79 pour les mâles, selon la méthode utilisée. D'après la biologie et la dynamique des populations, il semble que dans cette zone, cette espèce peut supporter une exploitation. © 2001 Ifremer/CNRS/Inra/IRD/Cemagref/Éditions scientifiques et médicales Elsevier SAS

croissance / mortalité / structure des populations / *Aristeus antennatus* / mer Ionienne / Méditerranée

1. INTRODUCTION

The red shrimp, *Aristeus antennatus* (Risso, 1816), is found in the East Atlantic, along the south coast of Portugal to the Cape Verde islands and the Mediterranean, with the exception of the Adriatic Sea (Holthuis, 1980; Ribeiro-Cascalho and Arrobas, 1982). It repre-

sents an important traditional commercial resource in the western and central Mediterranean and is caught exclusively by trawlers on muddy bottoms, near submarine trenches and canyons (Yahiaoui et al., 1986; Relini and Orsi-Relini, 1987; Arculeo et al., 1992; Matarrese et al., 1992; Demestre and Lleonart, 1993; Demestre and Martin, 1993; Vacchi et al., 1994; Ragonese and Bianchini, 1996).

*Correspondence and reprints.

E-mail address: pap@ncmr.gr (C. Papaconstantinou).

The red shrimp was known to be a scarce resource in the eastern Mediterranean (Thessalou-Legaki, 1994). However, recent studies in the Aegean Sea (Mytilineou and Politou, 1997; Anonymous, 1998) indicate the existence of populations suitable for exploitation. The presence of a commercially important stock was reported by Petrakis and Papaconstantinou (1998) along the coasts of the Greek Ionian Sea. Kapiris et al. (2000) described the diet as well as some biological parameters of this species in the Greek Ionian Sea.

The purpose of this paper is to provide information on the size composition, depth distribution, growth, sex ratio and mortality rates of the red shrimp population in the Greek Ionian Sea, and to compare its biology with findings on other red shrimp populations in exploited areas of the Mediterranean sea. This information will be used to manage the resource locally, and will provide a benchmark against which the effects of fishing on this still unexploited population can be measured, taking into account the consideration that in the study area, commercial fishing does not take place in depths greater than 400–450 m, where the greatest abundance of red shrimp appears.

2. MATERIALS AND METHODS

Samples were collected by the commercial trawler *Panagia Faneromeni II* (26 m in length, 450 HP) using a net with a cod-end mesh size of 14 mm from knot to knot. Sampling took place along the south coast of the Greek Ionian Sea (figure 1), on a monthly basis from January to December 1997. The sampling area covers about 1 500 km² suitable for bottom trawling, 300 km² of which is between 400–800 m depth. Sampling was carried out at depths between 250 and 800 m (94 stations) during daylight hours (07h00 and 19h00). The species was found at 47 of the 85 stations which were in waters deeper than 400 m. Based on our data and literature, the red shrimp in the Mediterranean occur mainly between 450 and 750 m (Ragonese and Bianchini, 1996; D'Onghia et al., 1997), so the study area was divided into two depth zones: < 550 m and > 550 m depth. This way the relationship between depth and carapace length could be assessed. The depth of 550 m is the midpoint of the depth range 450–750 m and differences in the biology and ecology from a preliminary elaboration were found. A random depth-stratified sampling strategy was employed, with stations positioned either deeper or shallower than 550 m. The duration of the tows was 60 min, and the trawling speed fluctuated from 2.5 to 3.0 knots, depending on the depth and the nature of the substrate at the station.

Carapace length (CL) was measured to the nearest 0.01 mm, from the posterior margin of orbit to the posterior hind edge of the cephalothorax, using electronic calipers. In a representative sub-sample, the weight of each specimen was measured to the nearest 0.01 g. All specimens captured were sexed and the

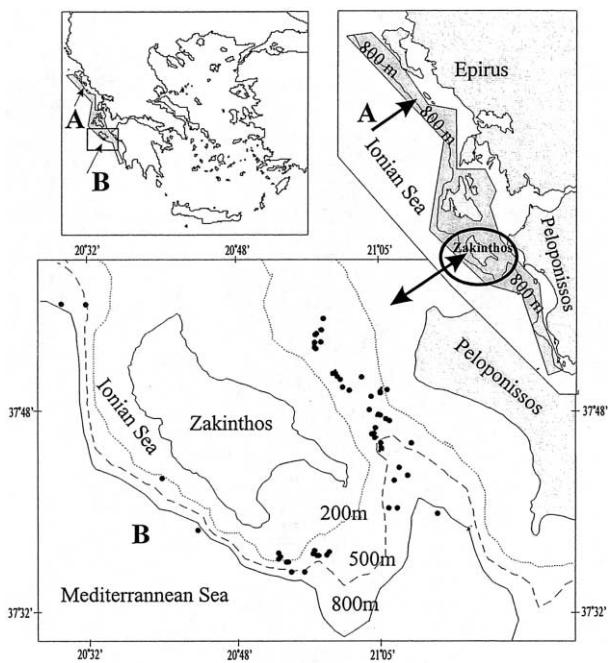


Figure 1. Map of the area showing the red shrimp distribution in the Greek Ionian Sea (A), and the sampled stations (•) for the needs of the present study (B).

presence of spermatophore in the thelycum of the female was recorded. Immature male and female shrimp smaller than 24 mm CL were classified as young-of-the-year (Sardà and Demestre, 1987). The carapace length-weight relationships were based on the regression $W = aL^b$, where W is the weight in grams, CL the carapace length in millimetres, a the constant, b the slope or allometric parameter. Size-frequency distributions (LFD) of males and females, in 2-mm intervals, were plotted for each month from January to December 1997.

Bhattacharya's method, implemented from the package FiSAT (Gayaniilo et al., 1996), was used to identify the modes in the polymodal length-frequency distributions of male and female red shrimp. All the identified in size/age groups were derived from at least three consecutive points, and selection of the best results was based on the following criteria: (a) the values of separation index (SI) for the different age groups; (b) the number of the identified age groups and (c) the standard deviation (SD) (Gayaniilo et al., 1988).

The relationship between carapace length and age was modelled using the von Bertalanffy growth function (VBGF), as this model adequately describes the average deterministic growth of penaeid shrimps, especially if a term to allow a seasonal oscillation is included (Dall et al., 1990). The estimation of the von Bertalanffy growth parameters: L_∞ (asymptotic carapace length in millimetres), k (curvature parameter of VBGF in year⁻¹), t_0 (age at length zero in year), and W_∞ (asymptotic weight in grams) was based on the

overall size distribution for each sex using the length-based fish stock assessment program: FISAT (Sparre, 1987). The ELEFAN I package (Gayanilo et al., 1988) was also used to obtain the index of goodness-of-fit (R_n), indicating the fitting of the data to the growth model. The 'best curve' was chosen on the basis of this index using the L_∞ , k , and the LFD of the pooled data from all round the study period. The growth performance index ϕ' (Pauly and Munro, 1984) of the red shrimp in the study area, was estimated using the equation $\phi' = \log_{10}k + \log_{10}L_\infty$.

The total instantaneous mortality rates (Z) per sex were calculated from the length-converted catch curve (Pauly, 1983), while natural mortality rates (M) were calculated by the empirical formula of Pauly [$\log_{10}M = -0.0066 - 0.279 \log_{10}L_\infty + 0.6543 \log_{10}K + 0.463 \log_{10}T$, where M is the natural mortality of a given stock, L_∞ the asymptotic length, K refers to the curvature parameters of the VBGF and the value of T is the annual mean habitat temperature of the water in which the stock lives (Pauly, 1980)]. Natural mortality was also estimated using the empirical formula of Hoening (1983), which relates total instantaneous mortality to the maximum observed age t_{\max} : $\ln(Z) = 1.46 - 1.01 \times \ln(t_{\max})$. Even though the method has been based on data derived from a wide variety of marine groups (fish, mollusks and cetaceans), certain authors have used this method for *A. antennatus* and *Aristaeomorpha foliacea* based on the hypothesis of discrete recruitment (Ragonese et al., 1994; D'Onghia et al., 1998). On the other hand, Hoening (1983) stressed that "fast growing, short-

lived species with minimal variability in length about age are best suited for his method", and these exact characters describe these species. This method applies to the prediction of mortality rates of unexploited stocks for which $Z = M$ (Hoening, 1983).

3. RESULTS

3.1. Size frequency distributions

A total of 8 618 red shrimps (7 273 females, 1 345 males) were caught in the study area between January and December 1997. Monthly size frequency distributions, by sex for both depth zones combined, are given in figure 2. One-way ANOVA showed statistically significant differences between the mean monthly carapace length of both sexes ($F = 24.5$, $P < 0.001$ for males and $F = 21.2$, $P < 0.001$ for females).

Females had a CL range of 12–62 mm, with the bulk of the stock being between 27 and 45 mm (mean $CL = 37.8 \pm 3.2$ mm). Modes were observed in January 1997 at 12–20 mm CL coinciding with the beginning of recruitment, but the young-of-the-year appeared to be fully recruited only in the late winter/early spring (figure 2), attaining a greater mean CL than males in age groups I through IV, ($t = 9.30$, $P < 0.05$).

The length frequency distribution of the data pooled over 12 months suggested that the female population consisted of only four age groups, with modes at approximately 30.0, 41.0, 49.0 and 54.0 mm CL.

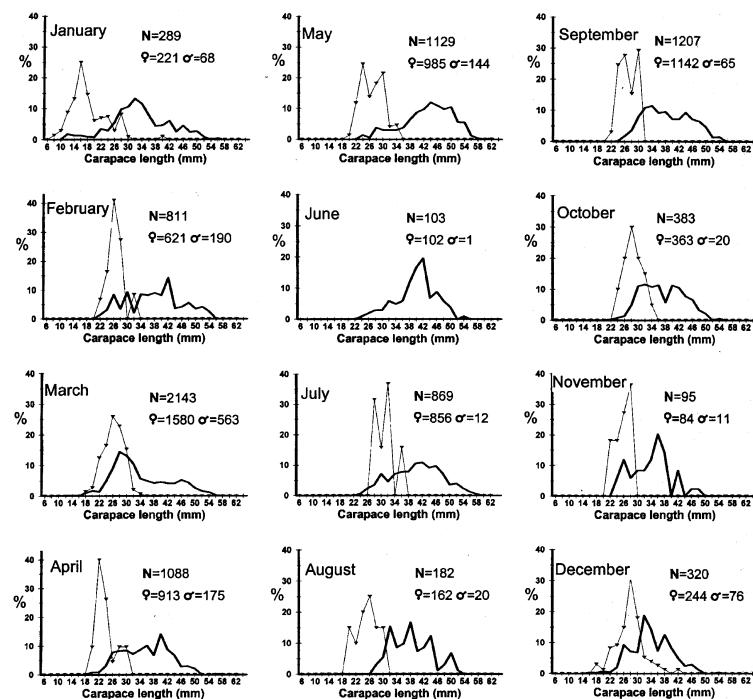


Figure 2. Carapace (CL) size distribution (in mm, size interval: 2 mm) of *Aristeus antennatus* caught between January and December 1997 in the Greek Ionian Sea (male: thin line; female: thick line).

The annual size frequency distribution of males obtained from monthly sampling, showed that the carapace length range of exploited sizes was 9–45 mm CL, with the bulk being between 22 and 29 mm, (mean CL = 26.8 ± 2.6 mm). Recruitment takes place in January, with a modal size of recruits between 9 and 12 mm CL. Based on the pooled data of the male population, three year classes were identified with mean CL of 24.0, 29.5 and 34.0 mm, respectively.

3.2. Size and abundance distribution by depth

Size frequency distributions of red shrimps from shallow and deep water (i.e. > 550 m and < 550 m) are presented separately for each sex in figure 3. The results reveal that in both depth zones the species was more abundant during the first semester. However, there is a difference in the abundance (in terms of $\text{ind} \cdot \text{h}^{-1}$) of both sexes between the two depth zones. In the deep zone, the mean abundance (in terms of CPUE; individuals per hour) was 136 and 31 $\text{ind} \cdot \text{h}^{-1}$ for females and males, while in the shallow zone was 50 and 7 $\text{ind} \cdot \text{h}^{-1}$, respectively.

A tendency of the size to increase with depth was clearly observed in females from the length frequency distributions in the two depth zones. It was difficult to determine any trends in size with depth for males because of their low abundance. Thus, differences in mean CL by depth were statistically significant only for females in the monthly surveys (analysis of variance, $F = 3.58$, $df = 33$, $P < 0.05$). Consistent with the observed depth distribution, young recruits of both sexes appeared at the shallower zone in January.

3.3. Age and growth

The age groups and their abundance, from the monthly LFD analyses showed that the increments between consecutive groups generally decrease in both sexes of red shrimp (table I). More year classes were present in females than in males. For males, the data in some year classes were too few to allow for acceptable distributions to be drawn. Winter months were better represented for both sexes as these included more age groups with high S.I. values.

The application of FiSAT determined modal lengths of females ranging from 13 mm (in January) to 52 mm (in July), with satisfactory separation indices (table I). Modal groups varied from 3 (in August) to 5 (in January) and were well discriminated. These reflect different annual cohorts, because of the discrete recruitment observed in January. The estimated modal lengths of males ranged from 14.1 to 38.5 mm, and notwithstanding the limited sample sizes, the S.I. appeared to be satisfactory. Maximum of four (December and January) well-discriminated modal groups were identified reflecting different annual cohorts, because of the discrete recruitment observed in January (table I). Calculated growth during the first year of life was found to be 30.25 and 25.58 mm CL for females and males respectively, while the calculated

growth increment was 11.0, 8.3 and 4.8 mm CL from the 2nd to the 4th year in females and 4.9 and 4.4 mm CL from the 2nd to the 3rd year in males. The growth performance index φ' (Pauly and Munro, 1984) of the red shrimp in the study area was calculated as $\varphi' = 1.16$ for males, and 1.23 for females.

3.4. Estimation of growth parameters

3.4.1. Size-weight relationship

During the course of the survey, a total of 2 437 females and 502 males were weighed and the computed length-weight relationships were:

$$W = 0.011439 \times L^{2.0547}, r^2 = 0.92, \text{ for females, and}$$

$$W = 0.01064 \times L^{2.0555}, r^2 = 0.94, \text{ for males.}$$

An analysis of covariance (ANCOVA) was performed using all the data sets to provide a single regression equation for females and another for males covering the whole sampling period. In the case of both sexes, the hypothesis that slopes were equal was rejected ($F = 94.27$, $P < 0.01$), indicating significant heterogeneity of b with sex/sampling month.

3.4.2. von Bertalanffy model

Parameters of the von Bertalanffy growth equation L_∞ , k , t_0 and W_∞ were estimated (table II) for each sex by running the program ELEFAN – included in FISAT package (Gayanilo et al., 1988) – on the overall distribution. R_n was calculated as 0.17 and 0.16 for males and females, respectively.

3.5. Reproduction

Spermatophores were present in the thelycum of females in almost all the sampling months, although in winter they appeared in relatively fewer specimens. A higher percentage of specimens bearing spermatophores appears during summer, indicating that this season is the peak breeding period. No information is available on deep-sea decapod larvae in the Mediterranean sea. The smallest female with spermatophores (19.2 mm CL) was found in March, at a depth of 540 m.

3.6. Sex ratio

The abundance of female red shrimps was higher (148 specimens/trawling hour) than that of males (36 specimens/trawling hour). The overall sex ratio per month (males:females) deviated significantly from the expected 1:1, (ANOVA $P < 0.05$), showing a predominance of females, ranging between 65 and 99 % (figure 4). The sex ratio of red shrimp in the study area varies considerably, possibly as a result of differential behaviour of the sexes (e.g. the lower growth rates of males, males are less abundant than females). The highest abundance of males was observed in March and decreases considerably from March to October, while from October to March their number increases

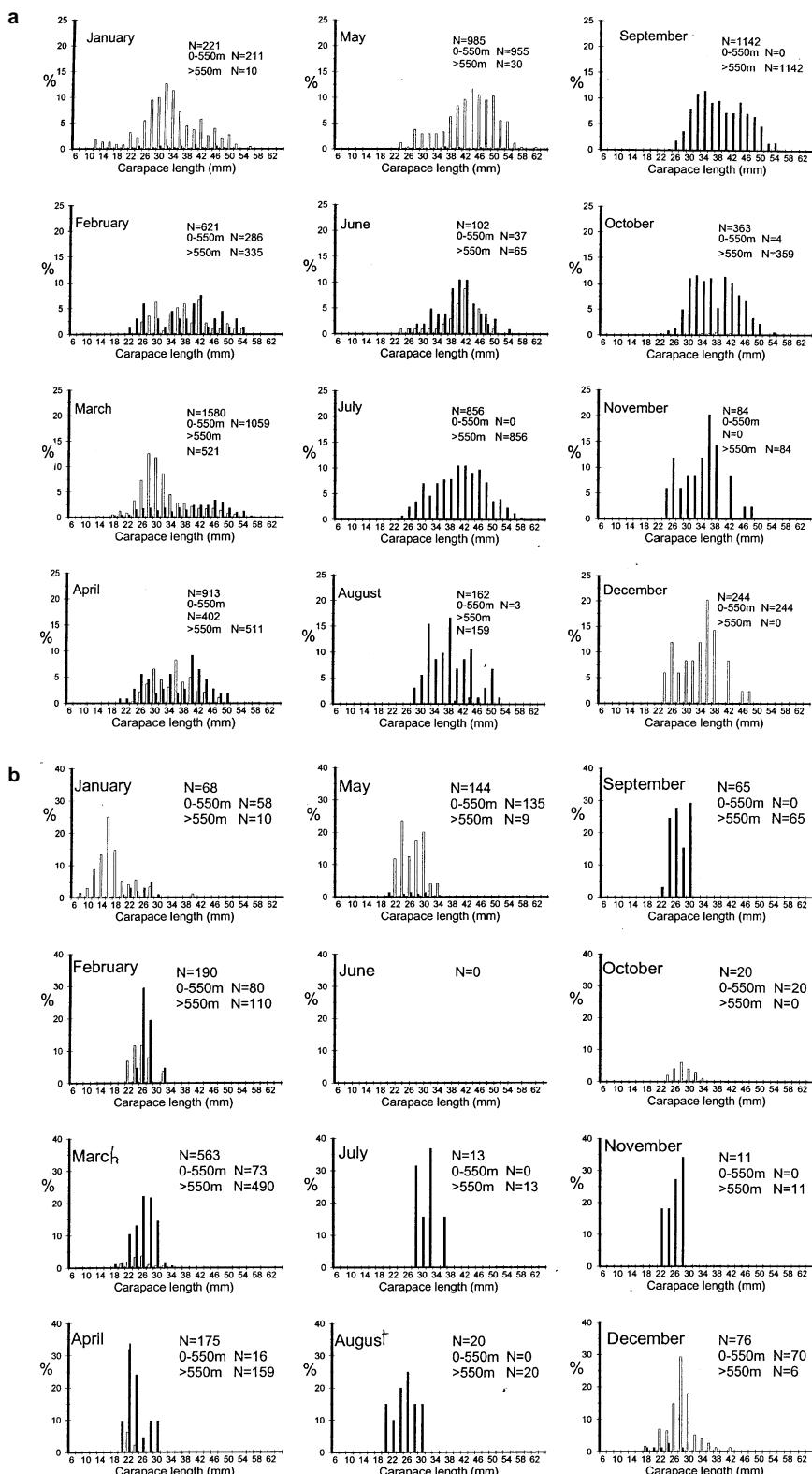


Figure 3. Carapace (CL) size distribution (in mm, size interval: 2 mm) by depth in the Greek Ionian Sea (0–550 m: clear bars; > 550 m: filled bars).
a. Females. **b.** Males.

Table I. Identified age groups from the length-frequency analysis of females and males *Aristeus antennatus* during the twelve monthly sampling cruises (January–December 1997), using Bhattacharya's method.

Months	Females				Males			
	Mean CL (mm)	SD (mm)	N	SI	Mean CL (mm)	SD (mm)	N	SI
January	13.3	1.2	8		14.1	1.8	16	
	23.5	2.1	21	6.00	19.0	1.1	13	3.38
	32.7	2.4	77	4.08	24.0	1.1	12	4.53
	41.7	3.5	36	3.08	28.3	0.7	7	4.63
	47.9	1.0	11	2.75				
February	25.2	2.0	82		24.7	1.1	38	
	35.5	2.1	135	4.97	26.9	1.0	94	2.43
	41.7	1.7	176	3.20				
	48.6	2.3	108	3.42				
March	14.0	2.2	13		19.7	1.2	25	
	27.5	2.7	789	5.45	26.7	1.8	329	4.78
	34.6	1.9	261	3.00	30.7	0.9	69	2.99
	43.5	5.4	463	2.42				
April	28.5	6.1	285		23.1	0.8	116	
	35.2	1.1	108	1.87				
	40.7	1.8	242	3.76				
	46.5	2.9	89	2.46				
May	29.9	3.1	87		24.7	0.5	26	
	39.1	2.5	227	3.27	30.0	1.3	37	5.67
	48.9	2.2	259	4.16				
June	31.6	3.9	15					
	41.2	2.7	58	2.91				
	48.2	1.3	14	3.47				
July	31.0	3.5	190					
	41.0	3.9	332	2.72				
	46.7	1.9	120	1.96				
	52.3	2.4	69	2.63				
August	32.2	2.5	59					
	39.1	1.8	52	3.21				
	49.4	2.2	21	5.24				
September	34.7	3.5	656		24.6	0.8	16	
	43.2	2.5	264	2.82	26.5	0.9	17	2.12
	48.9	2.9	157	2.07	30.1	0.4	22	5.64
October	33.0	4.1	85		28.2	0.7	15	
	41.2	2.3	87	2.52				
	46.5	1.4	41	2.84				
November	25.6	1.6	14					
	31.1	1.4	21	3.62				
	36.9	2.0	38	3.34				
	44.0	1.3	5	4.27				
December	24.0	2.8	13		22.8	1.0	9	
	33.1	1.7	94	4.05	28.8	1.9	47	4.12
	39.2	1.7	67	3.57	35.1	0.9	4	4.46
	44.2	2.4	17	2.40	38.5	2.4	2	2.06

CL, carapace length; SD, standard deviation; SI, separation index; N, number of individuals.

again slowly. Concerning the correlation between sex ratio and the two depth zones, a Kolmogorov-Smirnov test was performed. The results showed that there was no statistically significant difference between the two distributions at the 95 % confidence level ($P = 0.18$).

3.7. Mortality

The results of mortality estimates for males and females are summarized in table II. Total instantaneous mortality, Z calculated by the Pauly (1983)

method was estimated to be 0.79 for males and 0.70 for females (figure 5). Natural mortality, M calculated according to Hoenig's method (Hoenig, 1983), was 0.65 ($t_{\max} = 4$, $t_c = 1$, $n = 7$) for males and 0.62 for females ($t_{\max} = 5$, $t_c = 1$, $n = 5$), while the natural mortality according to the Pauly (1980) method was found to be 0.62 and 0.55, respectively. As it has been reported, the absence of fishing pressure in the area presumed zero fishing mortality. Thus, the instantaneous mortality Z is almost equal to the M calculated according to Hoenig's and Pauly's methods.

Table II. Summary of biological parameters and mortality estimates for the Mediterranean population of red shrimp *Aristeus antennatus* (CL: carapace length).

Sex	CL ∞ (mm)	k (year $^{-1}$)	t _o (year)	Geographic region	Reference	M	Z
Males	58 (W ∞ = 47.4 g)	0.43	-0.46	Greek Ionian Sea	Present study	0.65**	0.79◆
	66 (W ∞ = 62.6 g)	0.39	0.38			0.62*	Z = M
Females	65	0.36	0.05	Algeria	Yahiaoui et al., 1985	0.62**	0.70◆
	44–54	0.27–0.29	0.5–0.8	Catalan Sea	Sardà and Demestre, 1987	0.41*	1.46◆
Females	68–76	0.20–0.30	0.7–1.1	Straight of Sicily	Arculeo et al., 1992		1.33◆◆
Females	87	0.25		Straight of Sicily	Ragonese and Bianchini, 1996		
Sex combined	69	0.53	~0			0.4–1.1◆	1.3–1.5◇
Females	67	0.60	-0.23	Tyrrhenian Sea	Spedicato et al., 1995		
Males	55	0.99		Ionian Sea	Matarrese et al., 1992		
Females	66	0.93					
Males	46	0.47	0.13	Majorca Island	Carbonell and Alvarez, 1995		
Females	74	0.38	0.07				
Males	55	0.38	-0.43	Balearic Islands	Carbonell et al., 1999	0.56*	
Females	73	0.36	-0.41			0.54*	
Males				Western Mediterranean	Demestre and Martin, 1993	0.98 +	
Females						0.42*	
Males	54	0.25	-0.5	Western Mediterranean	Demestre and Lleonart, 1993	1.11+	
Females	76	0.3	-0.07			0.44*	

* Pauly (1980); ** Hoening (1983); ◆ Pauly (1983); ◆◆ Beverton and Holt (1957); + Rikhter and Efimov (1976); ◇ Ricker (1975).

4. DISCUSSION

No historical information is available on red shrimp in the Greek Ionian Sea because Greek fishers have not exploited it until today. Its unpopularity has been due to: (a) fishing at these depths yields a relatively low economic return; (b) knowledge and gear technology for fishing red shrimps is limited; and (c) red shrimps have a low local value, because they are unknown to Greek consumers. Thus, the presence of a stock of potentially high commercial value in such a pristine condition is scientifically valuable because of the possibilities offered to understand the population dynamics of an unexploited population. Moreover, this species is widely distributed and is exploited in other

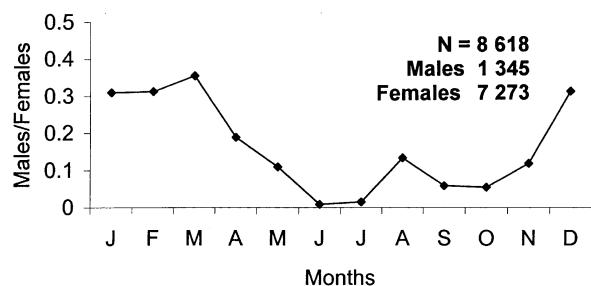


Figure 4. Monthly distribution of the sex ratio of red shrimp in the Greek Ionian Sea.

Mediterranean areas offering the possibility to compare the effects of fishing on unexploited and exploited populations.

The size structure of the population in the sampling area consists of a relatively higher percentage of large specimens than others found in other areas in the Mediterranean reflecting the unexploited status of the population. Females attained a greater size indicating a size dimorphism. This size difference between the two sexes is evident in all the modes, corroborating the view that the males are characterised by a lower rate of

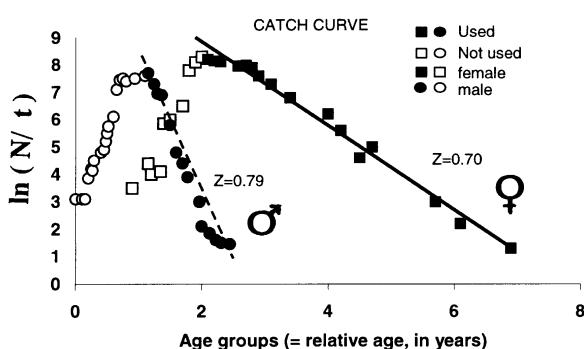


Figure 5. A length-converted catch curve for *Aristeus antennatus*. N: number of shrimps in length class i , Δt : time needed for the shrimp to grow through length class i , t: age (or the relative age, computed with $t_0 = 0$) corresponding to the mid-length of class i .

growth (Sardà and Gordo, 1986; Sardà and Demestre, 1987). This slower growth pattern of males is also proved from the growth estimated parameters (lower L_{∞} , higher K , smaller φ').

The spatial distribution of this shrimp is quite complex, but normally the species shoals in deep waters of the upper and middle slope (Sardà et al., 1994). The recruitment of both sexes in the study area occurred mainly in the shallower depth zone (< 550 m) during winter. It takes place about 4 and 5 months after spawning, which is not significantly different from the 3-month interval reported by Sardà and Cartes (1997). Different time of recruitment of red shrimps mentioned by different authors in the Mediterranean. Sardà and Cartes (1993) reported one recruitment during winter in the north-western Mediterranean sea, while one more autumn peak was mentioned by Carbonell et al. (1999), indicated by the percentage of virgin individuals. In the Italian Ionian Sea, two recruitments periods were observed, one during late winter and another during summer (D'Onghia et al., 1997, 1998). The percentage of recruits to the total population fished in the study area during the whole year was remarkably low (1.8 % for males, 0.4 % for females). The female percentage is too low to allow any conclusion on how the population maintains itself. It is possible that due to the sampling strategy followed, the mode of early recruits is not well represented or there exists a second recruitment period, although the data do not support it. However, relative low frequencies of recruitment are in agreement with other studies in different geographic areas. In the western Mediterranean young-of-the-year recruited overtime cover a very small fraction (approximately 1–4 %) of all shrimps caught on the whole (Arrobas and Ribeiro-Cascalho, 1987; Sardà and Demestre, 1987). A similar situation was mentioned for the Calabrian Ionian Sea (Vacchi et al., 1994) and the Sicilian channel (Ragonese and Bianchini, 1996).

The growth of red shrimp from the Greek Ionian Sea differs significantly between sexes and the observed maximum age of females exceeded that of males. Growth for both sexes was most rapid during the first year. The estimated growth during the first year, the growth increment and the maximum age observed of the sexes are in close agreement with studies in other Mediterranean regions, such as the Ionian Sea (Otranto Cape) (Matarrese et al., 1992), Algeria (Yahiaoui et al., 1986), Tyrrhenian Sea (Spedicato et al., 1995), Murcia (SE Spain) (Martinez-Banos et al., 1990), Catalan Sea (Demestre and Lleonart, 1993; Demestre, 1995) and the Mediterranean coast of France (Campillo et al., 1991).

These are the first data on the length-weight relationship of the species in the study area, but data from other areas in the Mediterranean indicated a strong negative allometry between sexes, females being bigger than males (Demestre and Lleonart, 1993; Ragonese and Bianchini, 1996).

Continuous asymptotic models, such as VBGF, are considered a reasonable approximation for shrimps (Pauly and Munro, 1984), despite the discontinuities in the growth process (Dall et al., 1990). The asymptotic weight estimated according to the VBGF and the asymptotic weight relationship (W_{∞}) of the Greek Ionian Sea red shrimp, are very close to the values calculated for the Sicilian channel (Ragonese et al., 1994).

The values of L_{∞} and φ' , reinforce the view that growth is faster in females than in males. The growth performance index of red shrimp in the Greek Ionian exhibited an intermediate value in relation to those appearing in other Mediterranean areas, suggesting that the species in this area exhibits a moderate growth rate. The estimated φ' does not differ significantly between the study area and other Mediterranean regions. The φ' values found were 1.27 for females in Castellamare (Italy) (Arculeo et al., 1992), 0.99 for males and 1.31 for females in Majorca island (Carbonell and Alvarez, 1995), 0.86 for females and 0.48 for males in the western Mediterranean (Company and Sardà, 2000), 1.4 for females in the Tyrrhenian Sea (Spedicato et al., 1995), and 1.47 and 1.61 for males and females respectively in the Italian Ionian Sea (Matarrese et al., 1992).

Methods for deriving estimates of M from catch data can be applied, mainly, to unexploited or lightly exploited populations (Vetter, 1988), where F (fishing mortality) equals or approximates zero, and therefore, Z equals or approximates M . In the present study, both the empirical method of Pauly (Pauly, 1980) and the Hoenig method (Hoenig, 1983) have been used in the calculation of M (table II). In addition, Hoenig's method is not affected by the way in which growth parameters are estimated and by probable errors arising from age-length keys. It is worthy mentioning that the number of red shrimp attaining t_{\max} was very large in the study area due to the small fishing pressure. Hence, the estimates of M from t_{\max} are likely to be maximal; for instance, if we use as t_{\max} the mean ages of the oldest specimens (5.2 and 4.6 years for males and females), then M from the combined Hoenig's regression is 0.65 and 0.62 for males and females respectively. By using a relatively large number of specimens for the ageing of red shrimp, this method appears to have great potential for use with unexploited populations. The analysis of the various mortalities' values showed small differences between the Greek Ionian Sea, where the shrimp stock is unexploited, and other areas in the Mediterranean, where a high fishing pressure is exerted on the stock (e.g. the Italian Ionian Sea and the NW Mediterranean).

Both sexes show higher abundance in the deeper zone during the studied period. The low recruitment found during the study – which occurred in depths down to 750–800 m – reinforces the point of other authors which reported that small specimens (< 15 mm CL) have been found at depths lower than 1 500 m

(Cartes, 1991). Therefore, the vertical distribution of the younger fraction of the population at depths inaccessible to commercial trawling indicates that there is not a high exploitation for the young red shrimps. The presence of this fraction of the population at these depths leads to the conclusion that a part of the spawning stock remains at the lower depths, at least during the reproductive period that lasts for several months (Demestre and Fortuño, 1992). This reinforces the view that the species is associated with evidence of migrations. The above appear to be in accordance with the view that the red shrimp in the NW Mediterranean is not overexploited or it is exploited near to the optimum, because the whole stock was not available for fishing (Demestre and Lleonart, 1993). The results of the current study indicate that various characteristics describing the life cycle and certain biological aspects, such as growth and natural mortality, are quite similar between the study area, where the species is unexploited, and the western and central Mediterranean where the species is highly exploited. In any case, the facts that unexploited demersal resources are scarce in the Mediterranean due to the high pressure of bottom trawling on almost all the available fishing grounds and that there is no fishing pressure on the Greek Ionian Sea red shrimp, suggest that it could constitute a fishery target having a new and potential perspective for the Greek fisheries sector. A longer study period is required, however, to clarify the population dynamics of the red shrimp stock and elucidate specific aspects associated with the biology/ecology of the species, validating at the same time the results of the present study.

5. CONCLUSION

The absence of fishing pressure in depths beyond 500 m in the Greek Ionian Sea makes the red shrimp populations dwelling mainly at depths > 400 m an unexploited resource. Certain biological characteristics of the species, i.e. the growth, carapace length by sex, sex ratio etc., as well as the low frequencies of young recruits and the time of recruitment do not seem to differ significantly from other Mediterranean areas. The size structure of the population in the study area consisted of a relatively higher percentage of large specimens in relation to other regions in the Mediterranean, reflecting the unexploited status of the population. Based on the biology and population structure, the red shrimp stock of the Greek Ionian Sea appears to have the potential to support a commercial fishery in the area.

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