

# GROWTH PARAMETERS AND POPULATION STRUCTURE OF *ARISTEUS ANTENNATUS* (DECAPODA, PENAEIDAE) IN THE SOUTH TYRRHENIAN SEA (SOUTHERN COAST OF ITALY)

BY

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## ABSTRACT

The blue and red shrimp *Aristeus antennatus* (Risso, 1816) is one of the most important fishery resources in the Mediterranean Sea. Monthly samplings of blue and red shrimp from June 2006 to May 2007 were landed by the trawl fleet in two northwest Sicilian fishing harbours (San Vito Lo Capo and Terrasini). The carapace length (CL) frequency distribution of females ranged between 15.00 and 59.00 mm, whereas male CLs ranged between 17.00 and 34.00 mm. The estimated parameters of the Von Bertalanffy growth function (VBGF) for San Vito lo Capo females and males were:  $CL_{\infty} = 65$  mm,  $K = 0.58$   $y^{-1}$  and  $CL_{\infty} = 41$  mm,  $K = 0.71$   $y^{-1}$ , respectively; while for Terrasini females and males these were:  $CL_{\infty} = 69$  mm,  $K = 0.65$   $y^{-1}$  and  $CL_{\infty} = 37$  mm,  $K = 0.8$   $y^{-1}$ , respectively. In this study, we update the information on stock structure and growth parameters of the blue and red shrimp in two northwest Sicilian fishing grounds and compare these results with other data recorded in the Mediterranean Basin.

## RIASSUNTO

Il gambero viola *Aristeus antennatus* (Risso, 1816) è una delle risorse da pesca più importanti nel Mar Mediterraneo. L'indagine è stata effettuata in due marinerie della sicilia nord-occidentale (San Vito Lo Capo e Terrasini) dove mensilmente e in un periodo compreso tra giugno 2006 e maggio 2007, venivano acquistati allo sbarco campioni di gambero viola. La distribuzione di frequenza di lunghezza carapace (LC) delle femmine era compresa tra 15,00 e 59,00 mm, mentre nei maschi tra 17,00 e 34,00 mm. I parametri di crescita stimati con la funzione di Von Bertalanffy (VBGF) per le femmine e i maschi di San Vito Lo Capo sono risultati rispettivamente di:  $CL_{\infty} = 65$  mm,  $K = 0,58$   $y^{-1}$  e  $CL_{\infty} = 41$  mm,  $K = 0,71$   $y^{-1}$ , mentre per le femmine ed i maschi di Terrasini sono stati:  $CL_{\infty} = 69$  mm,  $K = 0,65$   $y^{-1}$  e  $CL_{\infty} = 37$  mm,  $K = 0,8$   $y^{-1}$ . In questo studio vengono

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aggiornate le informazioni sulla struttura dello stock e i parametri di crescita di questa specie in due aree precedentemente indagate e vengono, inoltre confrontati questi risultati con altri riportati in altre aree del Mediterraneo.

## INTRODUCTION

The blue and red shrimp *Aristeus antennatus* (Risso, 1816) is distributed throughout the Atlantic Ocean and the Mediterranean Sea, with the exception of the Adriatic Sea (Holthuis, 1980; Ribeiro-Cascalho & Arrobas, 1982), and it represents one of the most important fishery resources for many Mediterranean countries. Along the northwestern coast of Sicily this resource has been exploited for a long time by different fleets, and its catch is facilitated by the gently sloping seabed beyond the continental shelf.

The blue and red shrimp trawling takes place on the mud bottoms of the lower continental shelf and the upper continental slope down to ~800 m deep (Holthuis, 1980). Traditionally, along the northwestern coast of Sicily, fishing harbours like San Vito Lo Capo and Terrasini focused their interest quite exclusively on the crustacean trawl fishery in view of the economic advantages, rather than targeting fishes like, e.g., hake, *Merluccius merluccius* (Linnaeus, 1758) or red mullet *Mullus barbatus* (Linnaeus, 1758).

Considering its high economic value, the blue and red shrimp has been the object of numerous research studies addressing their reproductive cycle (Arculeo et al., 1995 and references therein), catch estimations, ecology, population structure (Demestre & Leonart, 1993; Fiorentino et al., 1998; Cau et al., 2002; Sardà et al., 2004; D'Onghia et al., 2005; Arculeo, 2008; Guijarro et al., 2008), and more recently genetic variation (Roldan et al., 2008; Maggio et al., 2009). Investigations on both population and genetic structure can contribute to the knowledge of, for example, whether or not the species is overexploited and whether or not it is represented by different unit stocks; knowledge that may provide useful information in recovery programmes or other management activities.

The main goal of the present study was to update the information on stock structure and growth parameters computed during a monitoring programme in two north-western Sicilian fishing harbours, and to compare these results with other data recorded in the Mediterranean Basin.

## MATERIAL AND METHODS

A preliminary survey was undertaken in each of the sample harbours of San Vito Lo Capo and Terrasini (fig. 1). Monthly samplings from June 2006 to May 2007 were landed by the trawl fleet in both these harbours.

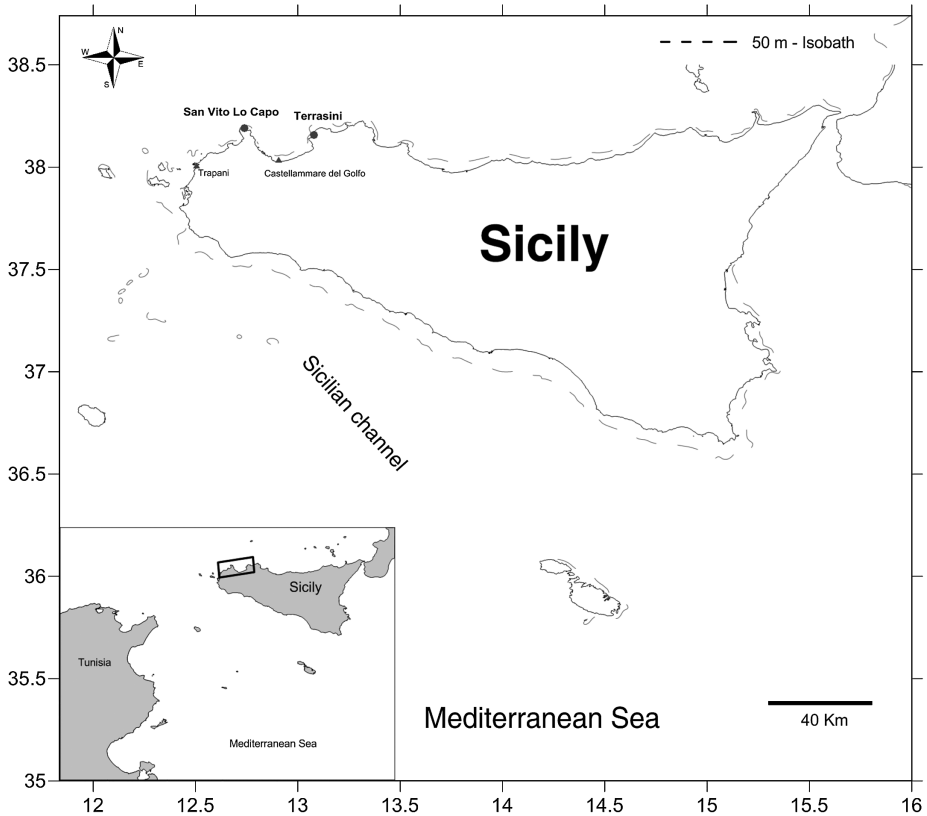


Fig. 1. Map of the study area showing the San Vito Lo Capo and Terrasini sample harbours.

Individual *Aristeus antennatus* were sexed and the carapace length (CL) and weight of each specimen was measured; the CL was measured to the nearest 0.01 mm, from the posterior margin of the orbit to the posterior edge of the carapace, using electronic callipers, and weight was measured to the nearest 0.01 g with a technical balance.

The VBGF (Von Bertalanffy Growth Function) was used to estimate growth parameters. The estimation of growth parameters was conducted using the electronic length frequency analysis I (ELEFAN I) routine incorporated in the FAO-ICLARM Stock Assessment Tools II (FISAT II) software (Gayani et al., 2005). Algorithms of the routinely required inputs of  $CL_{\infty}$  and  $K$  within an at least biologically acceptable range. The initial value of  $CL_{\infty}$  was computed according to the relationship obtained by Taylor (1962). In order to compare growth performance, the most common empirical equation by Pauly & Munro (1984) was used.

Length-frequency distributions for both sex and area were used to estimate the modal class values using the Bhattacharya method (FISAT II). Each modal separation, with a separation index (S.I.) greater than 2, was assumed to be a single

cohort. Monthly size frequency distributions at both sites were compared by sex. The statistical significance of the results of this comparison was tested by the Mann-Whitney U-test and the Kolmogorov-Smirnov test.

## RESULTS

The San Vito Lo Capo fleet operates two crustacean trawl fisheries near the Trapani area, while six crustacean trawl fisheries of the Terrasini harbour operate in the Gulf of Castellammare. Both fleets operate at the same depth, usually between 400 and 700 m, and use the same mesh size (40 mm diamond) at the cod ends of the nets. A total of 14 624 blue and red shrimps, *Aristeus antennatus* (12 920 female, 1704 male) were analysed from San Vito Lo Capo and 11 112 (9816 female, 896 male) from Terrasini. In the harbour of San Vito Lo Capo the CL frequency distribution of females ranged between 15.00 and 59.00 mm (female mean CL = 36.08 mm; sd = 6.69), whereas in the Terrasini harbour it ranged between 18.00 and 59.00 mm (female mean CL = 38.75 mm; sd = 7.72). Male CL ranged between 17.00 and 34.00 mm (male mean CL = 24.88 mm; sd = 2.85) in San Vito lo Capo, and between 18.00 and 32.00 mm (male mean CL = 24.66 mm; sd = 3.17) in Terrasini. The highest frequency of the female CL was between 32.00 and 42.00 mm in San Vito Lo Capo and between 38.00 and 48.00 mm in Terrasini, whereas the highest CL frequency of the males was recorded between 22.00 and 28.00 mm in San Vito Lo Capo and between 24.00 and 28.00 mm in Terrasini (fig. 2; table I). The statistical comparison of the overall and monthly size frequency distributions at both sites and by sex, highlighted a significant difference for females ( $p < 0.05$ ) while no significant difference ( $p > 0.05$ ) was recorded for males.

The estimated parameters of the VBGFs for San Vito lo Capo females and males were:  $CL_{\infty} = 65$  mm,  $K = 0.58 \text{ y}^{-1}$  and:  $CL_{\infty} = 41$  mm,  $K = 0.71 \text{ y}^{-1}$ , respectively; while for Terrasini females and males they were:  $CL_{\infty} = 69$  mm,  $K = 0.65 \text{ y}^{-1}$  and:  $CL_{\infty} = 37$  mm,  $K = 0.8 \text{ y}^{-1}$ , respectively. The estimated growth parameters of the blue and red shrimp within the Mediterranean Basin obtained from other studies are compared in table II.

The CL frequency distribution pooled over 12 months was used (Bhattacharya's method) to identify the modes for both sexes. In San Vito Lo Capo and Terrasini the females showed four dominant age groups, whereas three modes were identified for the males (table III).

## DISCUSSION

The observed CL values of *Aristeus antennatus* can be reasonably compared with the CL values reported for the same area in previous investigations (Arculeo et

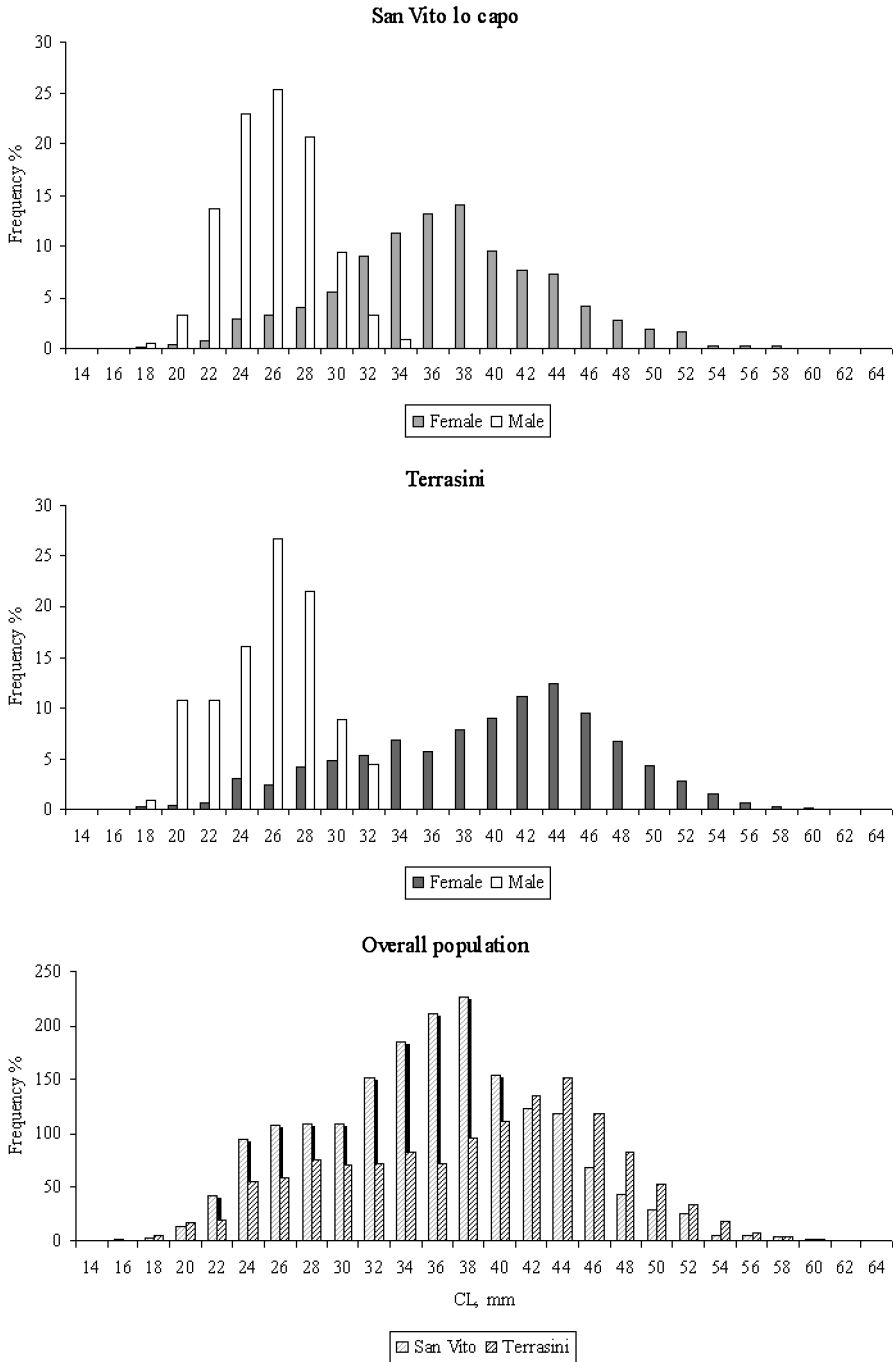


Fig. 2. Length-frequency distribution of the males and females of *Aristeus antennatus* (Risso, 1816) in the southern Tyrrhenian Sea.

TABLE I

Number of specimens, mean, modes and range values of the CL for sexes and sample harbours of *Aristeus antennatus* (Risso, 1816)

	N° specimens	Mean CL mm	CV	CL mode mm	CL range mm
San Vito Lo Capo					
Females	12 920	36.08	19%	32-42	15-59
Males	1704	24.88	11%	22-28	17-34
Terrasini					
Females	9816	38.75	20%	38-48	18-59
Males	896	24.66	13%	24-28	18-32

al., 1992, 1994; Arculeo, 2008) and with other exploited areas in the Mediterranean Sea (Yahiaoui et al., 1986; Matarrese et al., 1992; Spedicato et al., 1995; Ragonese & Bianchini, 1996; Cau et al., 2002). This similarity between the reported minimum and maximum values of the CL in the exploited fishing grounds analysed suggests, that over the last few decades the habits of the fishermen, the characteristics of the gear (mesh of cod end), and the depths of the blue and red shrimp catches in the Southern Tyrrhenian Sea, Strait of Sicily, and in some areas of the Ionian Sea, have probably not undergone substantial modifications. The least differences were recorded with the data reported by Papaconstantinou & Kaporis (2001) from the non-exploited stock in Greek Ionian waters and in the western part of the Mediterranean (Sardà et al., 2004).

The length frequency analysis showed four possible age classes in San Vito Lo Capo and Terrasini, and although the values of these modes were slightly different, they were reasonably comparable. The population structure of San Vito Lo Capo was found to be mainly characterized by specimens of the second age group (76%) for both sexes, whereas in Terrasini females were most abundant in the third age group (58%) and males in the second age group (87%). The data for the males were more unpredictable and conclusions harder to reach.

Considering that both fleets exclusively exploited each blue and red shrimp fishing ground, the above highlighted differences cannot be associated with the different fishing efforts enforced by the six vessels of Terrasini or the two vessels of San Vito Lo Capo. In addition, observing the CL distribution (fig. 2) and considering the fact that both fisheries operate at the same depths and with similar gear, it seems reasonable to hypothesize that environmental factors could have an influence on the spatio-temporal distribution, and therefore also on the recruitment of this species.

Along the fishing grounds off the Balearic Islands, Guijarro et al. (2008) showed moderate spatial and temporal differences between the two different sample sites analysed, that were related to the different environmental conditions. In fact, at

TABLE II  
Comparison of growth parameters for *Aristeus antennatus* (Risso, 1816) according to the publications cited

Sex	CL <sub>∞</sub> (mm)	K (year <sup>-1</sup> )	φ	Geographic region	Reference
Males	58	0.43	3.16	Greek Ionian Sea	Papaconstantinou et al., 2001
Females	66	0.39	3.23		
Males	55	0.99	3.48	Ionian Sea	Matarrese et al., 1992
Females	66	0.93	3.61		
Sexes combined	79	0.22	3.14	Ionian Sea	D'Onghia et al., 2005
Sexes combined	82	0.20	3.13	Greek Ionian Sea	D'Onghia et al., 2005
Sexes combined	69	0.53	3.40	Strait of Sicily	Ragonese & Bianchini, 1996
Females	69 (MPA)	0.34	3.21	South Tyrrhenian Sea	Arculeo et al., 1992
Females	67	0.60	3.43	Central Tyrrhenian Sea	Spedicato et al., 1995
Females	65	0.36	3.18	Algeria	Yahiaoui et al., 1986
Males	54	0.29	2.93	Catalan Sea	Sardà & Demestre, 1987
Females	76	0.30	3.24		
Males	46	0.47	3.00	Majorca Islands	Carbonell & Alvarez, 1995
Females	74	0.38	3.32		
Males	55	0.38	3.06	Balearic Islands	Carbonell et al., 1999
Females	73	0.36	3.32		
Males	55	0.38	3.06	Ibiza Chanel	Garcia-Rodriguez & Estebar, 1999
Females	73	0.36	3.28		
Males	54	0.25	2.86	Western Mediterranean	Demestre & Lleonart, 1993
Females	76	0.30	3.24		
Males	41	0.71	3.08	San Vito Lo Capo	Present study
Females	65	0.58	3.39		
Males	37	0.80	3.04	Terrasini	Present study
Females	69	0.65	3.49		

Legend: MPA, Modal Progression Analysis.

TABLE III  
Stock structure of *Aristeus antennatus* (Risso, 1816) for both sexes and sample harbours

Cohorts	1	2	3	4
		San Vito Lo Capo		
Females	25.25	36.19	46.44	57.00
S.I.	n.a.	2.33	2.11	2.22
Males	24.21	27.80	31.98	–
S.I.	n.a.	2.25	2.57	–
		Terrasini		
Females	23.91	32.29	42.86	51.85
S.I.	n.a.	2.22	2.18	2.10
Males	19.92	26.39	30.50	–
S.I.	n.a.	3.69	3.56	–

Legend: S.I., separation index.

one site they found a more demographically homogeneous population, whereas the other site showed important variations, such as a high abundance of juveniles being recruited to the fishing grounds. According to Guijarro et al. (2008) and references therein, the importance of water mass movements in size distribution and abundance of blue and red shrimp is indisputable.

The same observation was also reported by Maggio et al. (2009), who analysed the genetic variation in this species in different parts of the Mediterranean Sea; in particular, those authors did not find any significant difference between the samples and hypothesized, as also reported by Cartes et al. (2008), that such genetic homogeneity is strictly correlated with: (i) the biological characteristics of this species; (ii) the horizontal and vertical fluctuations of the water masses; and (iii) the spatio-temporal variations in the chemical/physical factors and the trophic resources. Of course, it is important that further ad hoc oceanographic investigations are undertaken to verify whether or not these differences between our sample sites are linked to environmental conditions.

The number of estimated age classes in the Tyrrhenian Sea (Arculeo et al., 1994; Arculeo, 2008; present study) is quite similar to the estimates reported by Ragonese & Bianchini (1996) from the Strait of Sicily, whereas it is lower than the estimates obtained at both western and eastern sides of the Ionian Sea by Papaconstantinou & Kapiris (2001) in non-exploited stocks, and by D'Onghia et al. (2005), respectively.

The comparison of the estimated growth parameters for females (table I) by the VBGF seemed to show more affinity to the central-southern Tyrrhenian Sea and the Strait of Sicily (Yahiaoui et al., 1986; Arculeo et al., 1992; Spedicato et al., 1995; Ragonese & Bianchini, 1996) than the higher growth parameter estimates



reported in the western Mediterranean Sea (Sardà & Demestre, 1987; Demestre & Leonart, 1993; Carbonell & Alvarez, 1995; Carbonell et al., 1999; Garcia-Rodriguez & Esteban, 1999) and in some areas of the Ionian Sea (Matarrese et al., 1992; Papaconstantinou & Kapiris, 2001; D'Onghia et al., 2005). The growth performance index suggests that in our sample, as reported in table I, growth is faster in females than in males. Such differences in growth parameters could be attributed to the diverse degree of exploitation of the blue and red shrimp over time, or to the different fishing habits (net size, depth of catch, etc.) among the fishermen exploiting the various Mediterranean fishing grounds. Moreover, as hypothesized above, these differences could be also attributed to the particular oceanographic conditions (Guijarro et al., 2008) that are able to influence the abiotic (climate and hydrodynamics) and biotic (trophic resources and predators) variables. In support of this consideration, we can add that this species shows a marked dissimilarity in reproductive behaviour between northern and more southern populations, and that these differences may be referred to as an expression of a biogeographical gradient, or a different adaptation to the conditions of the bathyal system (Margalef, 1985; Mura & Cau, 1989; Arculeo et al., 1995). An alternative hypothesis could sustain that such differences are strictly associated with the peculiar aspects of the fishing activities in both the central-southern Tyrrhenian Sea and the Strait of Sicily, being fishing grounds that have been traditionally exploited for decades already.

Generally, as reported worldwide, the action of the commercial trawl fishery incessantly removes the largest specimens, thereby reducing the overall abundance of the stock and changing its age-length structure; oddly, although this investigation could not provide information about the shrimp's abundance, the age-length structure of the blue and red shrimp in the investigated areas did not seem to be influenced by the action of the trawlers, although further studies are necessary for regular updates of abundance.

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