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Selectivity parameters and size at first maturity in deep-water shrimps, *Aristaeomorpha foliacea* (Risso, 1827) and *Aristeus antennatus* (Risso, 1816), from the North-Western Ionian Sea (Mediterranean Sea)

R. Carlucci*, G. D'Onghia, L. Sion, P. Maiorano & A. Tursi
Department of Zoology, University of Bari, Via Orabona 4, 70125, Bari, Italy
*(*Author for correspondence: E-mail: r.carlucci@biologia.uniba.it)*

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Abstract

Selectivity experiments were carried out during trawling targeting deep-water shrimps *Aristaeomorpha foliacea (*Risso, 1827) and *Aristeus antennatus* (Risso, 1816) (Crustacea, Decapoda, Aristeidae) in the North-Western Ionian Sea (Eastern-Central Mediterranean). Different criteria were employed to analyse maturity; however, the proportion at 50% of retained, mated and mature specimens was always used to indicate the size, expressed as Carapace Length (CL, mm), at first capture (CL_c), mating (CL_{sp}) and at first maturity (CL_m), respectively. In order to estimate the size at 50% maturity (CL_m) for females of both species, three criteria were adopted. In particular, CL_m was computed for the mature females not considering the presence of spermatophores, for the mature females with spermatophores and for the mature females intersected by the decreasing proportion with size of females without spermatophores. Three diamond stretched mesh codends of 40, 50 and 60 mm were tested using a cover of 20 mm.The 40-mm stretched mesh size (European Union legal size in the Mediterranean) was not selective for the sampled population of each species. The size at first capture (CL_c), calculated in both species for the two sexes combined, increased significantly with mesh size. Even for the mesh size of 60 mm, the size at first capture was still smaller than the sizes at 50% maturity, whatever the criterion adopted. Since the differences between the size at first maturity and the sizes at first capture are greater in *A. foliacea* than *A. antennatus*, the former species appears in this respect to be more vulnerable to trawling than the latter.

Introduction

The deep-water shrimps *Aristaeomorpha foliacea* (Risso, 1827) and *Aristeus antennatus* (Risso, 1816) represent important economic demersal resources of the Mediterranean Sea. As observed in various geographic areas, the abundance of these shrimps can be subject to marked fluctuations (Relini & Orsi Relini, 1987; Orsi Relini & Relini, 1988; Sardà, 1993; Bianchini & Ragonese, 1994; Carbonell et al., 1999; Cau et al., 2002). Since the exploitation of *A. foliacea* and *A. antennatus* concerns both juveniles and adults, the regulation of the mesh size codend would appear to be an effective management measure to assure the sustainability of the catches of these resources (Ragonese et al., 2001, 2002). The adoption of a mesh size greater than 40 mm stretched (European Union legal size in the Mediterranean) should be attempted, taking into account the reproductive patterns of these shrimps and the selection process of the trawl net.

In the Ionian Sea, data on selectivity parameters for *A. foliacea* and *A. antennatus* are only available for the Calabrian sector (South-Western Ionian Sea) where these resources are intensively exploited (D'Onghia et al., 1998b). Size at maturity was only estimated for *A. foliacea* in the whole Ionian basin (D'Onghia et al., 1998a).

Along the Apulian coast of the Ionian basin, the Gallipoli fishery targets primarily deep-water shrimps throughout the year (D'Onghia et al., 1998c). For this fishery, which is characterized by small trawlers (GRT <10 tons, engine power <100–150 kW) operating daily for five days a week (Carlucci et al., 2003), no data on the selectivity parameters and maturity are available.

In this paper, basic information on the selectivity of the bottom trawl net and on the sizes at 50% maturity of *A. foliacea* and *A. antennatus* females in the Gallipoli fishery (North-Western Ionian Sea) is reported.

Materials and methods

Selectivity experiments during trawl fishing on deep-water shrimps *A. foliacea* and *A. antennatus* were conducted during June–July 2000 and June–July 2001 in the Gallipoli fishery (North-Western Ionian Sea) (Fig. 1).

A professional trawler of 9.9 tons gross tonnage (161.8 kW), equipped with a nylon otter trawl net, was hired. The experimental survey was carried out on the slope, in the depth range from 400 to 700 m, where trawl fishing on deep-water shrimps occurs.

The selectivity of 40- (European Union legal codend in the Mediterranean), 50- and 60-mm stretched mesh size codend was evaluated by means of the covered-codend method as reported in Sparre & Venema (1998).

A total of 36 hauls of 3 h in duration were carried out, from dawn to dusk, emulating the commercial trawling in the area. A cover with 20-mm stretched mesh size and proportionally 30% longer and larger than each codend was employed. Three arrays of plastic floats were attached to its top to prevent it from collapsing.

For both species, the carapace length (CL, mm) of the specimens collected both in codend and cover was measured.

The estimates of the selectivity parameters (selection range SR, selection factor SF and size at first capture CL_c) using different mesh sizes were computed for the two sexes combined using both the antisymmetric logistic (Sparre & Venema, 1998) and the asymmetric (Sardà et al., 1993) model. The former, which is the most widely used model, is based on the assumption that the selectivity curve has a sigmoidal shape with a flex point in CL_c. On the contrary, the asymmetric model does not admit an inflection point and the curve is plotted using the equation $S_{CL} = 1-1/\exp^{a(CL-CL0)}$ where S_{CL} is the probability of retention, a is a constant value and CL_0 the smallest size retained. The CL corresponding to $S_{CL} = 0.5$ represents CL_c.

Data on the maturity of *A. foliacea* and *A. antennatus* females were collected. Results refer to all specimens caught both in the cover and codend independently of the stretched mesh size used. The gonads were macroscopically examined using the scale proposed by Levi & Vacchi (1988) and Orsi Relini & Relini (1979) for *A. foliacea* and *A. antennatus*, respectively. For both species, specimens at stages III and IV were considered mature. Furthermore, the presence/absence of spermatophores on thelycum was recorded. The logistic model was applied to estimate the size at which 50% of females had mated (CL_{sp}). Three criteria were adopted in order to estimate the size at 50% maturity (CL_m) for females of both species. In particular, such a size was computed applying the logistic model to:

1. proportion (p) of mature females, not considering the presence of spermatophores
2. p of mature females with spermatophores
3. p of mature females intersected by the decreasing with size proportion of females without spermatophores.

This latter criterion combines the gonadic maturity curve and the mating complementary curve (absence of spermatophores) according to the functional criteria indicated by Morizur (1983) and to the empirical approach proposed by Ragonese & Bianchini (1995). The size of the "maximum reproductive potential" (CL_{mrp}) was obtained following this approach.

Both selectivity parameters and sizes at maturity were estimated for the pooled data of the two years.

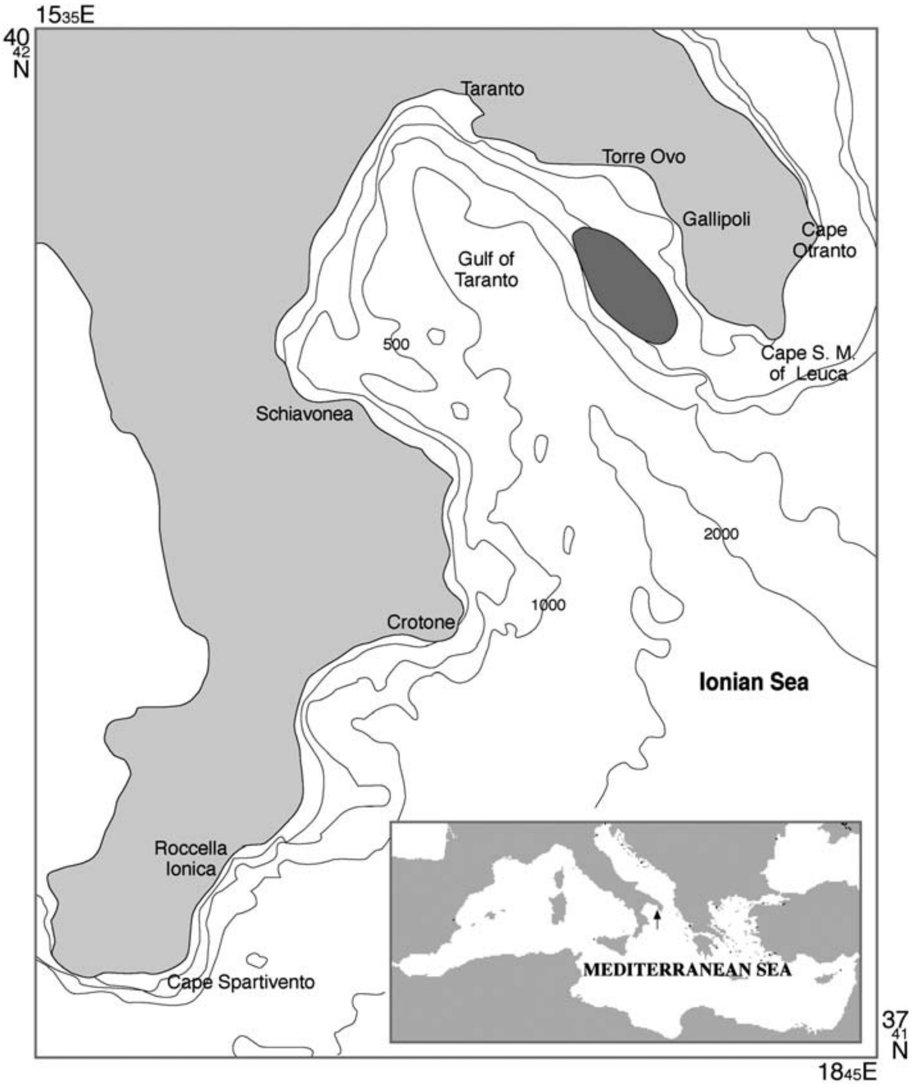

Figure 1. Map of the North-Western Ionian Sea (Mediterranean Sea) with indication of the area investigated (black) during June–July 2001.

Results

Aristaeomorpha foliacea

The length structure of the catch in the codend and the number of specimens escaped in the cover using the different mesh sizes are shown in Figure 2. Only 16 small specimens (0.6% of the total) were collected in the cover employed on the 40-mm mesh size codend. A slight increase in escaped specimens (3.4%) was observed for the 50-mm codend, while 1562 specimens (27.5%) were collected in the cover using the 60-mm codend. The largest specimens that escaped into the cover measured 30 mm CL for the 50-mm and 36 mm CL for the 60-mm codend.

Using the logistic and the asymmetric function for the 50-mm codend, the sizes at first capture were 16.2 mm CL (SR = 6.30 mm and SF = 0.32) and 15.2 mm CL (SR = 3.51 mm and SF = 0.30), respectively. Concerning the 60-mm codend, the values were 21.2 mm CL (SR = 10.66 mm; SF = 0.35) and 20.5 mm CL (SR = 8.72 mm; SF = 0.34), respectively (Table 1).

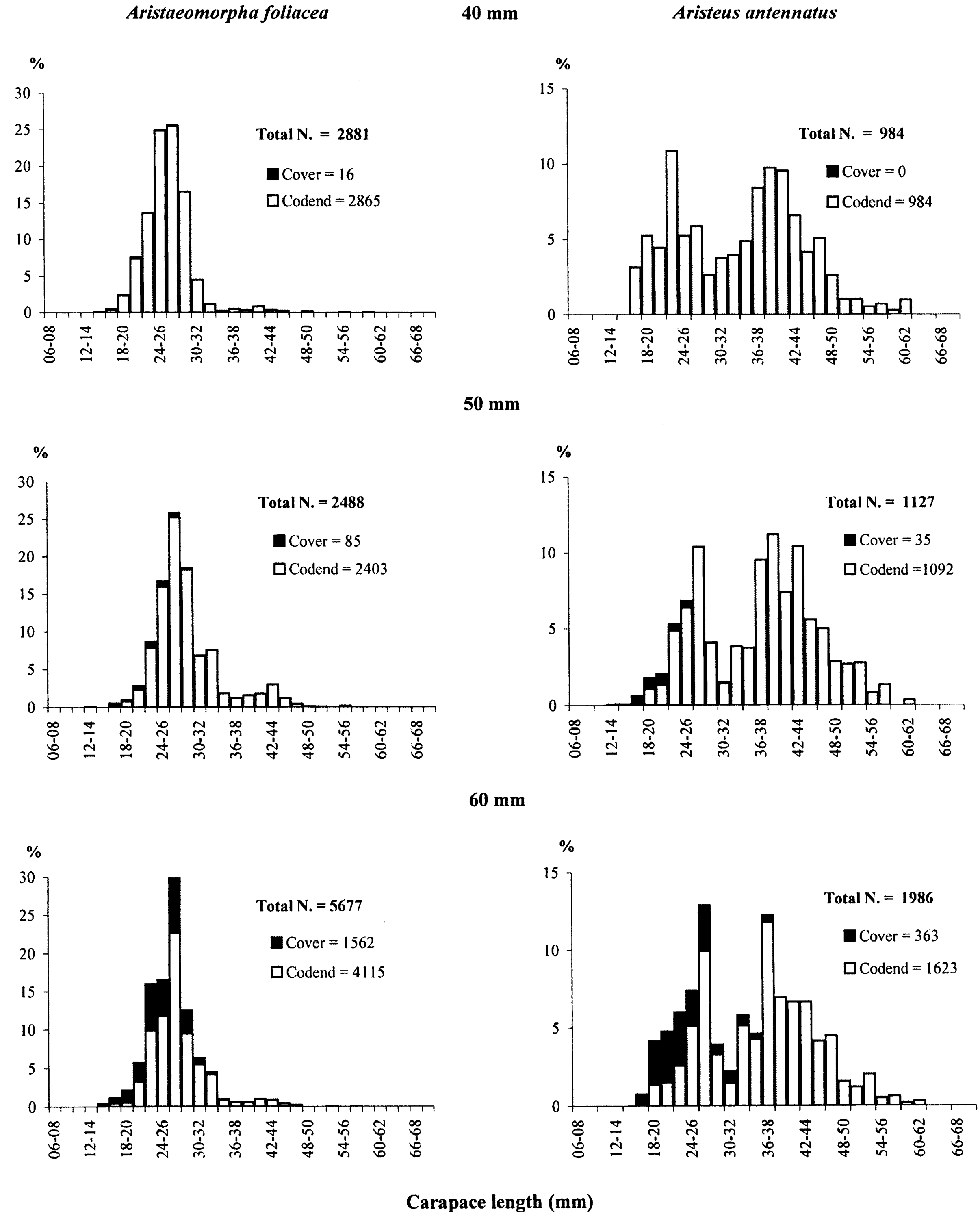

Figure 2. Length-frequency distribution in the codend and cover of *Aristaeomorpha foliacea* and *Aristeus antennatus* specimens caught with 40-, 50- and 60-mm mesh size codends.

Regarding maturity, a total of 5442 females of *A. foliacea* were collected during this study. The smallest mated and the smallest mature (stage III) female measured 21 and 34 mm CL, respectively (Fig. 3). The size at which 50% of the females had mated was 35.9 mm CL (Fig. 4). The female size at first maturity, not considering the presence of spermatophores, was 44.1 mm CL and that of females with spermatophores, 44.14 mm CL (Fig. 4a). The size of the "maximum reproductive potential" defined as the point of intersection of the gonadic maturity curve and the mating complementary curve (absence of spermatophores) was 39.3 mm CL (Fig. 4).

Aristeus antennatus

The number of the individuals that escaped into the cover also increased with mesh size for this species as shown in Figure 2. The 40-mm mesh size codend was not selective. The 50- and 60-mm codends allowed 3% and 18% of the total specimens caught to pass into the cover, respectively. The largest specimens that escaped into the cover employed on the 50- and 60-mm codends was 32 and 38 mm CL, respectively.

The sizes at first capture (CL_c) for the 50-mm codend computed by the logistic and the asymmetric curves were 19.4 and 16.5 mm CL, respectively (Table 1). Moreover, according to the logistic curve the SR was 3.62 mm and the SF = 0.39, while according to the asymmetric curve they were 5.57 mm and 0.33 mm, respectively.

Concerning the 60 mm codend, the CL_c calculated using the logistic and the asymmetric functions were 23.6 mm CL (SR = 9.72 mm; SF = 0.39) and 22.0 mm CL (SR = 7.69 mm; SF = 0.39), respectively.

A total of 2951 females of *A. antennatus* were collected. The smallest mated and mature (stage III) female measured 22 mm CL (Fig. 3).

The size at which 50% of the females had mated was 25.2 mm CL. The size at first maturity (not considering the presence of spermatophores)

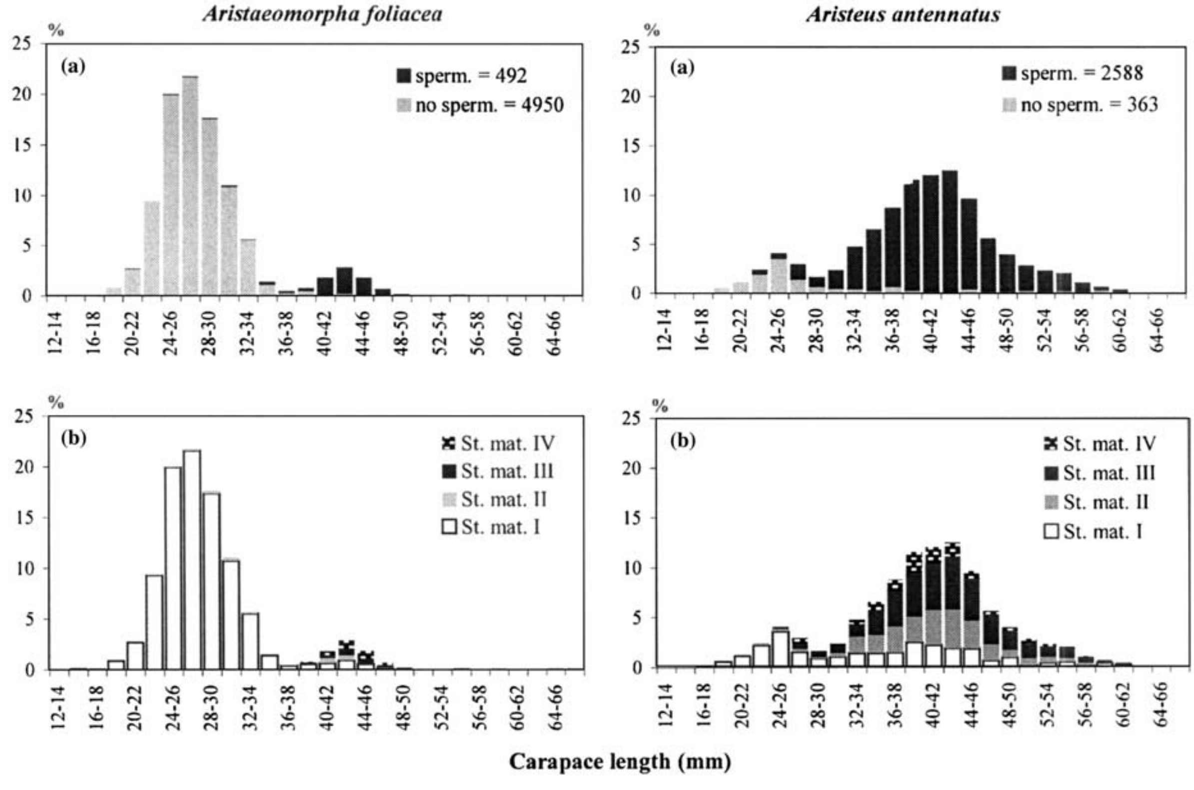

Figure 3. Length-frequency distribution by presence of spermatophores (a) and maturity stage (b) for females of *Aristaeomorpha foliacea* and *Aristeus antennatus* specimens caught in the North-Western Ionian Sea.

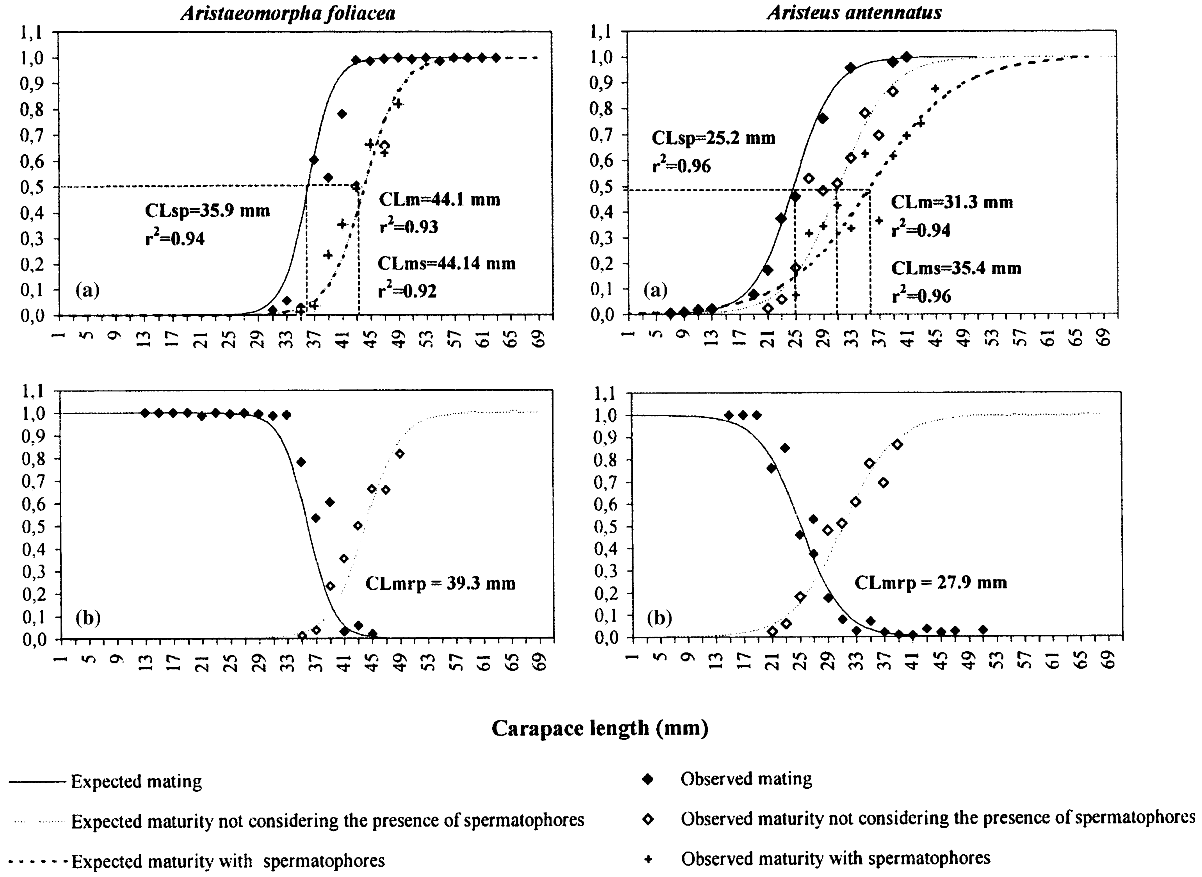

Figure 4. Aristaeomorpha foliacea and *Aristeus antennatus* in the North-Western Ionian Sea. (a) expected and observed percentage by size of mated females (CL_{sp}), mature females not considering the presence of spermatophores (CL_m) and mature females with spermatophores (CL_{ms}); (b) size of "maximum reproductive potential" (CL_{mrp}).

Table 1. Size at first capture (CL_c in mm), selection factor (SF), selection range (SR) and index of fitting (r^2) by stretched mesh size (mm) for *Aristaeomorpha foliacea* and *Aristeus antennatus* (sexes combined), estimated in the North-Western Ionian Sea

Mesh size (mm)	Logistic model				Asymmetric model			
	CL_c	SF	SR	r^2	CL_c	SF	SR	r^2
Aristaeomorpha foliacea								
40	–				–			
50	16.2	0.32 ± 0.03	6:30	0.96	15.2	0.30 ± 0.02	3.51	0.97
60	21.2	0.35 ± 0.07	10.66	0.92	20.5	0.34 ± 0.08	8.72	0.90
Aristeus antennatus								
40	–				–			
50	19.4	0.39 ± 0.04	3.62	0.98	16.5	0.33 ± 0.04	5:57	0.94
60	23.6	0.39 ± 0.07	9.72	0.94	22.0	0.39 ± 0.09	7.69	0.91

was 31.3 mm CL and that strictly concerning females with spermatophores was 35.4 mm CL (Fig. 4). The size of the "maximum reproductive potential" was 27.9 mm CL (Fig. 4).

Discussion and conclusions

The values of size at first capture and selection factor estimated for *A. antennatus* in this research are in agreement with those from the Sicily Channel (Ragonese et al., 1994, 2001, 2002) and the Ionian Sea along the Calabrian coast (D'Onghia et al., 1998b, 2003) (Table 2). The values estimated for *A. foliacea* are smaller than those obtained in the Sicily Channel where the selectivity in this shrimp was also shown for the 40-mm codend (Ragonese et al., 1994, 2001, 2002).

In the Gallipoli fishery, although the 40-mm codend allowed a minimal fraction of *A. foliacea* juveniles to pass through, it proved to be substantially not selective for the sampled populations of both species. This could be the consequence of the fact that in both species recruitment occurs during spring (D'Onghia et al., 1997, 1998a). In fact, the numerical changes of the first modal component and the presence of small individuals in the fished stock play an important role in affecting selectivity (Ragonese et al., 1994, D'Onghia et al., 1998b).

Data from the 50- and 60-mm fit both models used, though the logistic model provides CL_c values and determination coefficients slightly greater than the asymmetric one in both species and for both stretched mesh sizes. Moreover, from the SF values obtained, it seems that the selection processes did not differ between the 50- and 60-mm codends, especially in *A. antennatus*.

Regarding reproductive aspects, the sampled population of *A. foliacea* and *A. antennatus* showed different percentages of mated and mature females. The bulk of the *A. foliacea* stock consisted of immature and unmated specimens. In both species, mating in the population occurs before reproduction, as reported in D'Onghia et al. (1997, 1998a).

In *A. foliacea*, reproduction concerns exclusively large specimens, as shown from the size at first maturity of females not considering the presence of spermatophores (44.1 mm CL) and that of females with spermatophores (44.14 mm CL). The superimposition of these two sizes is due to the fact that only very few mature females did not bear spermatophores.

In *A. antennatus*, on the contrary, the female size at first maturity with and without spermatophores (31.3 mm CL) was smaller than the size at 50% maturity of females with spermatophores (35.4 mm CL), indicating that many mature females could not be mated.

Table 2. Size at first capture (CL_c in mm) and selection factor (SF) for *Aristaeomorpha foliacea* (AF) and *Aristeus antennatus* (AA) (sexes combined) estimated in the Mediterranean Sea (diamond mesh, stretched size in mm)

Authors	AF		AA	
	CL_c	SF	CL_c	SF
Ragonese et al. (1994)	17.7 (40 mm)	0.44		
	20.1 (48 mm)	0.42	19.9 (48 mm)	0.42
	22.8 (56 mm)	0.41	25.0 (56 mm)	0.45
Ragonese et al. (2002)	18.6 (40 mm)	0.46		
	20.8 (48 mm)	0.44		
	24.5 (56 mm)	0.44		
D'Onghia et al. (1998b)	19.5 (60 mm)	0.32	23.7 (60 mm)	0.40
D'Onghia et al. (2003)			19.0 (50 mm)	0.38
			25.4 (60 mm)	0.42
Carlucci et al. (present study)	16.2 (50 mm)	0.32	19.4 (50 mm)	0.39
	21.2 (60 mm)	0.35	23.6 (60 mm)	0.39

Both sizes at first maturity estimated for *A. antennatus* were smaller than those calculated for *A. foliacea* confirming observations throughout the Mediterranean Sea (Table 3).

In both species, the size of maximum reproductive potential was smaller than the size at 50% maturity estimated using the other two criteria. The size of maximum reproductive potential computed in this study for *A. foliacea* corresponds to that obtained by Ragonese & Bianchini (1995) (39.667 mm CL) and is barely greater than that reported by D'Onghia et al. (1998a) (37.11 mm CL).

For both species and mostly for *A. foliacea*, the sizes at first capture obtained with the 50- and 60-mm sMS were smaller than the size at first maturity estimated by using the three criteria. This points out the marked impact of the trawl net on the population structure of both species. Since the differences between the sizes at first maturity and the sizes at first capture are greater in *A. foliacea* than in *A. antennatus*, the former shrimp can be considered more vulnerable to trawling than the latter. In addition, further bio-ecological features of *A. foliacea* reported in Orsi Relini & Relini (1985) and Matarrese et al. (1997) could explain the marked depletion of the parental stock of this shrimp in the study area.

According to the present study and other observations made until now in the Mediterranean Sea (Tables 2 and 3) it is evident that a larger mesh than 40-mm stretched should be adopted in the fishing of deep-water shrimps in order to reduce mortality in juveniles. The 60-mm codend mostly reduces the capture of specimens smaller than 30 mm CL, which have the lowest market value. The rigid integument and the "backward" escaping pattern should allow a good survival rate for these individuals (Bianchini et al., 1998). In the Gallipoli fishery, the regulation of a greater mesh size might be justified since the fishery targets primarily deep-water shrimps on bathyal bottoms where other resources, such as *Nephrops norvegicus* (Linnaeus, 1758), are exploited and there has been a marked depletion of the adult component in the stocks (Tursi et al., 1998a, b).

Finally, as indicated in this and previous studies (D'Onghia et al., 1998a, b; Ragonese et al., 2001, 2002), the regulation of a mesh greater than 40 mm should be adopted together with the

Table 3. Values of the size at first mating (CL_{sp} in mm) and at first maturity (CL_m in mm) for females of *Aristaeomorpha foliacea* (AF) and *Aristeus antennatus* (AA) estimated in the Mediterranean Sea

Authors	AF		AA	
	CL_{sp}	CL_m	CL_{sp}	CL_m
Mura et al. (1992)		Between 30 and 34		Between 18 and 24
Campillo (1994)*			28.8	
Carbonell (1994)*				26.0
Cau et al. (1994)		39.0		21.0
Demestre (1994)*				26.0
D'Onghia et al. (1994)*		39.0		35.0
Greco et al. (1994)*	34.0			
Martinez Banos & Mas (1994)*				27.0
Mori et al. (1994)*	46.6 ± 3.6	47.0 ± 4.7		
Spedicato et al. (1995)				35.0
Yahiaoui (1994)*				23.0
Ragonese & Bianchini (1995)	36.4	41.8		
Colloca et al. (1998)				27.0
Matarrese et al. (1997)		43.0		38.0
D'Onghia et al. (1998°)	39.3	47.0		
Carlucci et al. (present study)	35.9	44.14	25.2	35.4

*In Bianchinni & Ragonese (1994).

management tool of a closed season during the spring-early summer period.

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