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Further evidences of deep-sea recruitment of *Aristeus antennatus* (Crustacea: Decapoda) and its role in the population renewal on the exploited bottoms of the Mediterranean

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ABSTRACT

Data were collected during four trawl surveys (April, May, June and September 2006) in the north-western Ionian Sea (Eastern Mediterranean) with the aim of investigating the recruitment and population structure of *Aristeus antennatus* and evaluating whether population processes on bottoms deeper than 800 m could have a role to the renewal of the exploited population on fishing grounds, above 800 m. Samples were taken randomly between 400 and 1200 m using a professional fishing vessel equipped with an experimental otter trawl net, with 20 mm stretched mesh size in the cod-end. No variation in density index was shown across the whole depth range while the negative trend of biomass index with depth was due to the increasing proportion of small individuals and males. The recruitment was observed on a wide depth range with an increasing frequency of occurrence at greatest depths. It seems to occur as a discrete phenomenon. A significant bigger-shallower phenomenon was detected in the female population indicating upwards displacement from virgin grounds to fishing ones. The exploited population mostly consists of large females. Mating and reproduction also occur in deep waters. The contribution to the renewal of the fishing population by the virgin one seems to be mostly due to the recruitment on unexploited deep areas and displacement of individuals from these areas to fishing ones. The deep waters act as a refuge area mostly for the recruitment of *A. antennatus* and, to lesser extent, for spawners. On the basis of all these results the authors discuss the optimum exploitation conditions often detected for this shrimp throughout the Mediterranean highlighting the fact that, since the exploited population mostly consists of reproductive females, conditions of "recruitment overfishing" might occur in *A. antennatus* contrary to other Mediterranean demersal resources.

1. Introduction

The blue-and-red shrimp *Aristeus antennatus* (Risso, 1816) is most probably the species with the widest depth distribution in the Mediterranean Sea. In fact, it has been collecetd from 80 m (Nouar, 2001) to 3300 m in depth (Sardà et al., 2004). This ecological feature makes the species less vulnerable to fishing carried out on the shelf and upper slope within the first 800 m of depth. In this respect, according to the refuge paradigm of Mediterranean fisheries (Caddy, 1993) and in relation to life-history traits of this shrimp (Orsi Relini and Semeria, 1983; Sardà, 1993; Matarrese et al., 1997; Carlucci et al., 2006), the population accessible to fishing generally shows conditions of optimum exploitation (e.g. Demestre and Martin, 1993; Ragonese and Bianchini, 1996; Fiorentino et al., 1998; D'Onghia et al., 2005). However, due to the eurybathic nature of *A. antennatus* several aspects of its bio-ecology remain rather uncertain and unknown. Indeed, the large number of studies conducted in the last twenty years on this shrimp throughout the Mediterranean regard the population sampled on the fishing grounds (e.g. Bianchini and Ragonese, 1994 and references therein; Cau et al., 2002 and references therein) while the knowledge on its distribution and size structure at depths greater than 800 m comes mainly from some investigations carried out in the western Mediterranean (Sardà, 1993; Sardà and Cartes, 1992, 1993, 1997; Cartes and Demestre, 2003; Sardà et al., 2003, 2004).

Although such investigations generally consisted of a small number of samples, due to the sampling difficulties in deep waters, they gave an insight into the recruitment and sex-ratio of *A. antennatus* from upper to lower slope supporting the hypothesis on the presence of a population unaffected by fishing ("virgin population") that could contribute to replenish the stock exploited on the fishing grounds (Sardà et al., 2003a,b).

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In the eastern Mediterranean information on the population structure of *A. antennatus* below the depth of 800 m has been collected during some explorative hauls carried out in the western and eastern Ionian Sea (Sardà et al., 2004) as well as in the north-western Ionian Sea (D'Onghia et al., 2005). The occurrence of juveniles was confirmed at depths greater than 1000 m in the former study while small individuals were almost exclusively collected above 800 m in the latter. In the north-western Ionian Sea the occurrence of *A. antennatus* recruitment was recorded on the fishing bottoms (D'Onghia et al., 1997) while nothing is known at greater depths. In addition to the several limitations of sampling at greater depths, often related to the lack of bottoms suitable for trawling, the very broad surface covered by the bathyal ground and the reduced density of the species often prevent adequate sampling of the living population using a few explorative tows.

In this regard a project aiming to study the recruitment and population structure of *A. antennatus* in a depth range between 400 and 1200 m was conducted in the north-western Ionian Sea where

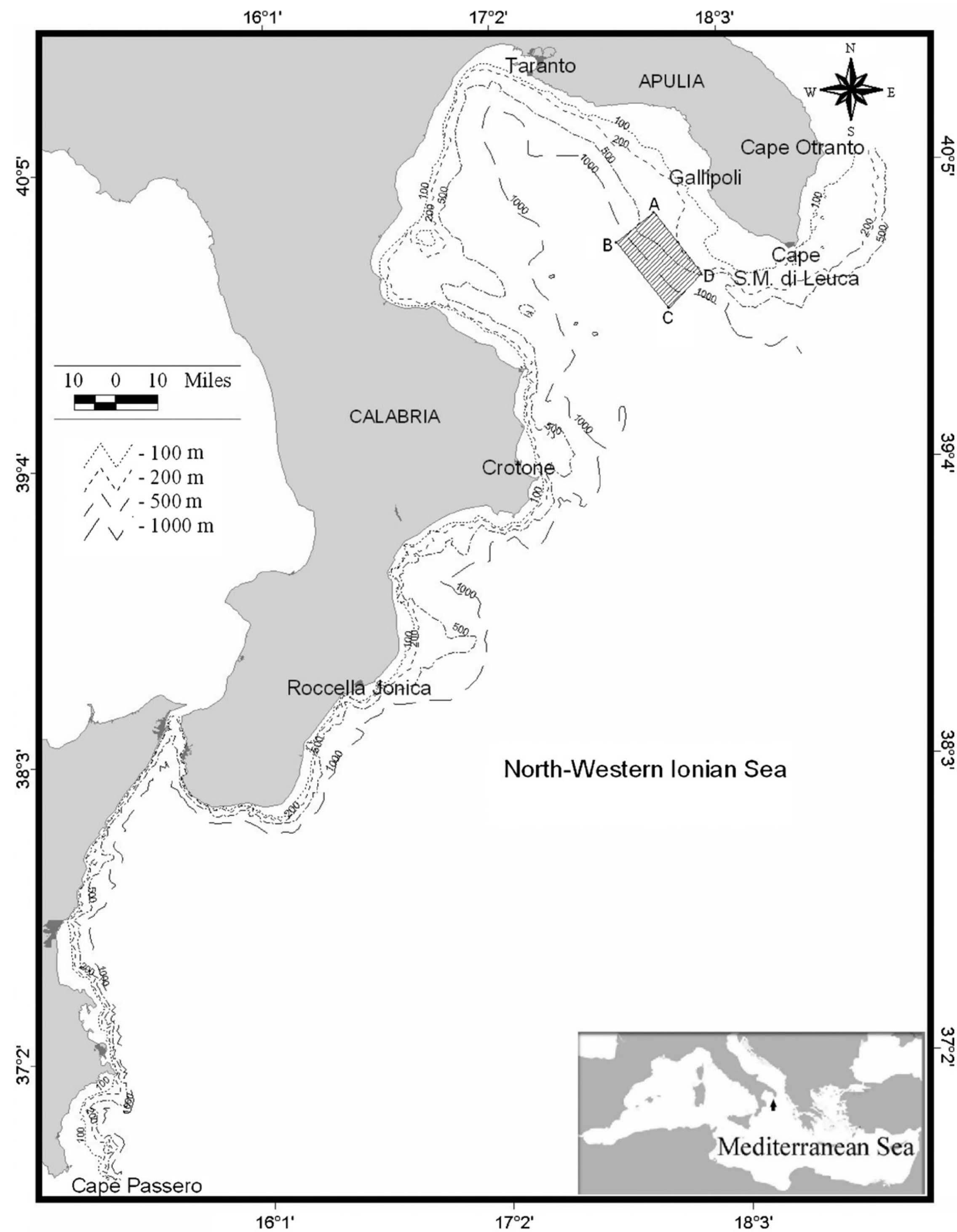

Fig. 1. Map of the north-western Ionian Sea with indication of the studied area (shaded).

Table 1
Number of hauls by each depth stratum carried out in April, May, June and September 2006 in the north-western Ionian Sea.

Depth stratum (m)	Surface (km^2)	N. hauls April	N. hauls May	N. hauls June	N. hauls September
400–600	160.37	7	7	7	7
600–800	54.76	2	3	3	2
800–1000	109.51	5	4	4	5
1000–1200	149.36	6	6	6	6
TOTAL	474	20	20	20	20

exploitation occurs in the upper slope down to 800 m while at greater depths large marine grounds remain unexploited (D'Onghia et al., 2005). Even though human activity impacts, due to pollution as well as dumping of wastes and rubbish, might occur on these grounds, *A. antennatus* can be studied at depths greater than 800 m excluding the direct fishing effects. Thus, the aim of the present work is that of studying the population structure and recruitment of *A. antennatus* on the slope of the north-western Ionian Sea (eastern Mediterranean) to evaluate whether population processes at depths greater than 800 m could play a role in the maintenance of the exploited population on fishing bottoms.

2. Materials and methods

2.1. Study area

An area in the north-western Ionian Sea (Eastern Mediterranean) (Fig. 1), between 400 and 1200 m, has been recently investigated through geological and biological surveys. This area is located on the eastern side of the Taranto valley which separates the Apulia shelf from that of Calabria. It is characterized by a variable geomorphology due to the presence of fault steps and landslide deposits. Such variability determines the occurrence of different substrates and therefore greater potential variability regarding the macrobenthos communities able to settle. Indeed, these communities were found to be differentiated in a shallower cluster (400–600 m), due to the superimposition of two biocoenoses, that is the coastal terrigenous muds and deep mud, and a deeper one (beyond 600 m), due to the presence of either typical bathyal species or species related to the neighbouring areas in which rock substrates and deep-water corals are present (Tursi et al., 2004). There are no canyons in this study area. In terms of hydrology, the depths between 400 and 1200 m are characterised by homeothermic conditions around 13.7–14.0 °C (Anonymous, 2007).

In this area, at depths between 350–400 and 700–750 m, the Gallipoli fishery exploits the deep-water shrimps *A. antennatus* and *Aristaeomorpha foliacea*, with the former being generally more abundant than the latter (Carlucci et al., 2007). During 1998–1999, their CPUE ranged from 5 to 48 kg/boat/day and its contribution to the total catch made up 58.6% in weight and 66.1% in economic value (Carlucci et al., 2003). Other important groundfish resources are the hake (*Merluccius merluccius*), blue whiting (*Micromesistius poutassou*), greater forkbeard (*Phycis blennoides*), rockfish (*Helicolenus dactylopterus*), deep water rose shrimp (*Parapenaeus longirostris*) and Norway lobster (*Nephrops norvegicus*) which can often provide an important contribution to the whole catch (Tursi et al., 1998).

The Gallipoli fishery is mostly characterized by trawlers which seek demersal resources from Monday to Friday only during daylight hours. The trawlers are generally smaller than 10 tons of gross tonnage and are equipped with an Italian type otter trawl net with 40 mm stretched mesh size in the codend. Trawlers generally go out on daily trips; they set off at 3–4 am and return to the harbour at 3–4 or 5–6 pm during wintertime and summertime, respectively. Fishing is not allowed at night or weekends. The deep-water shrimp fishing bottoms are about 15–22 nautical miles from Gallipoli harbour and are mainly sought from spring to autumn. Since trawling does not occur below 800 m we can assume that *A. antennatus* population is pristine at these depths.

2.2. Data collection

Considering previous observations on the recruitment of *A. antennatus* (D'Onghia et al., 1997; Sardà and Cartes, 1997; Sardà et al., 2003a,b, 2004), sampling was conducted during April, May, June 2006. Further sampling was also carried out during September 2006 to verify the occurrence of recruitment in early autumn. A professional motor powered vessel, equipped with an experimental otter trawl Maireta net (Sardà et al., 1998a) with double

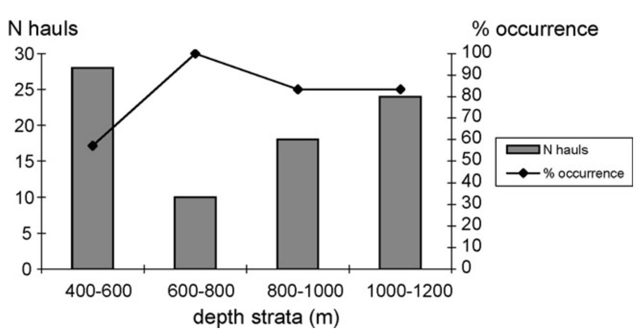

Fig. 2. Number of hauls carried out in each depth stratum and percentage of occurrence of *A. antennatus* in the north-western Ionian Sea.

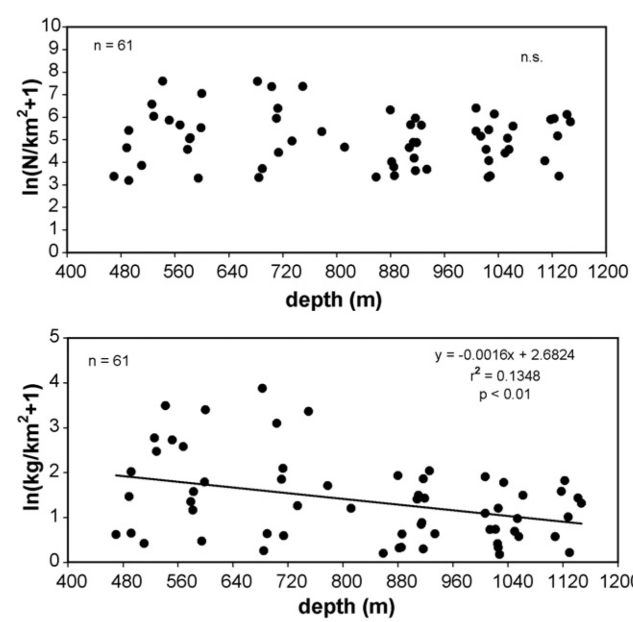

Fig. 3. Relationship between density (above) and biomass (below) indices and depth in *A. antennatus* from the north-western Ionian Sea.

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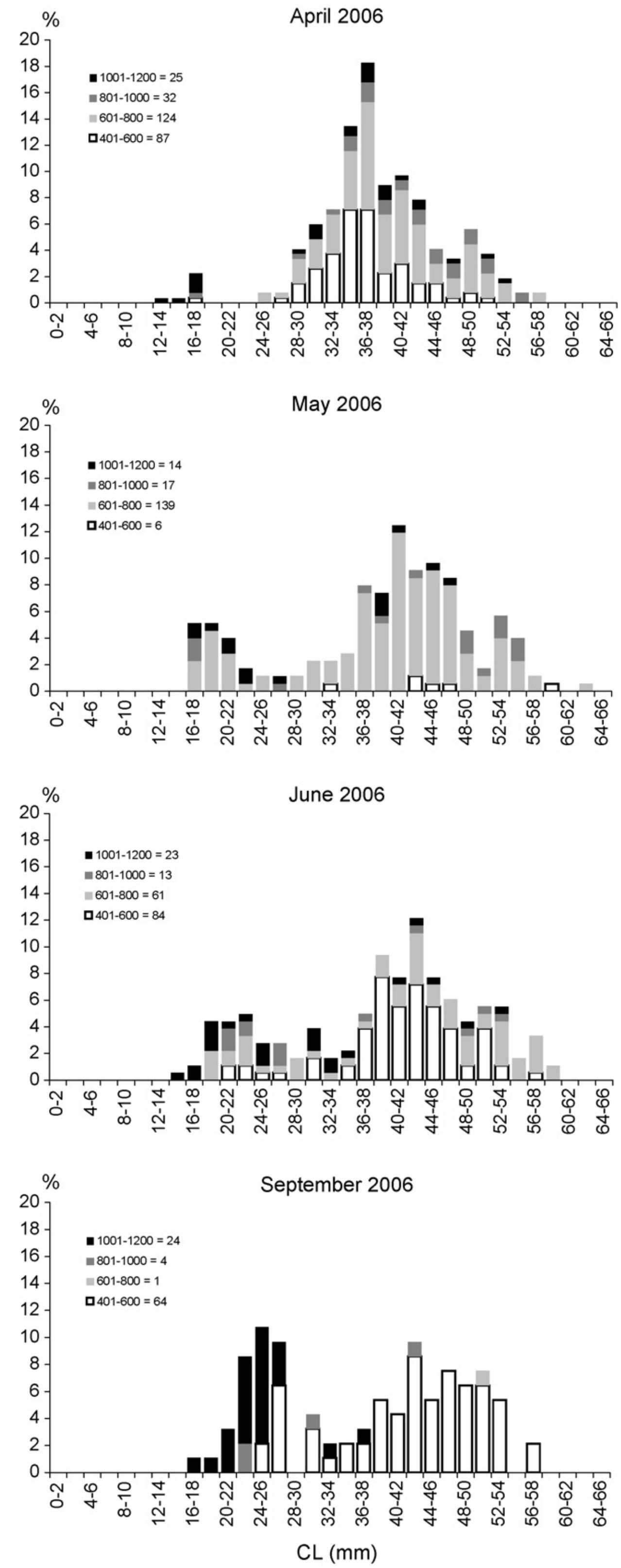

Fig. 4. Length-frquency distribution by survey and depth strata of *A. antennatus* females caught in the north-western Ionian Sea.

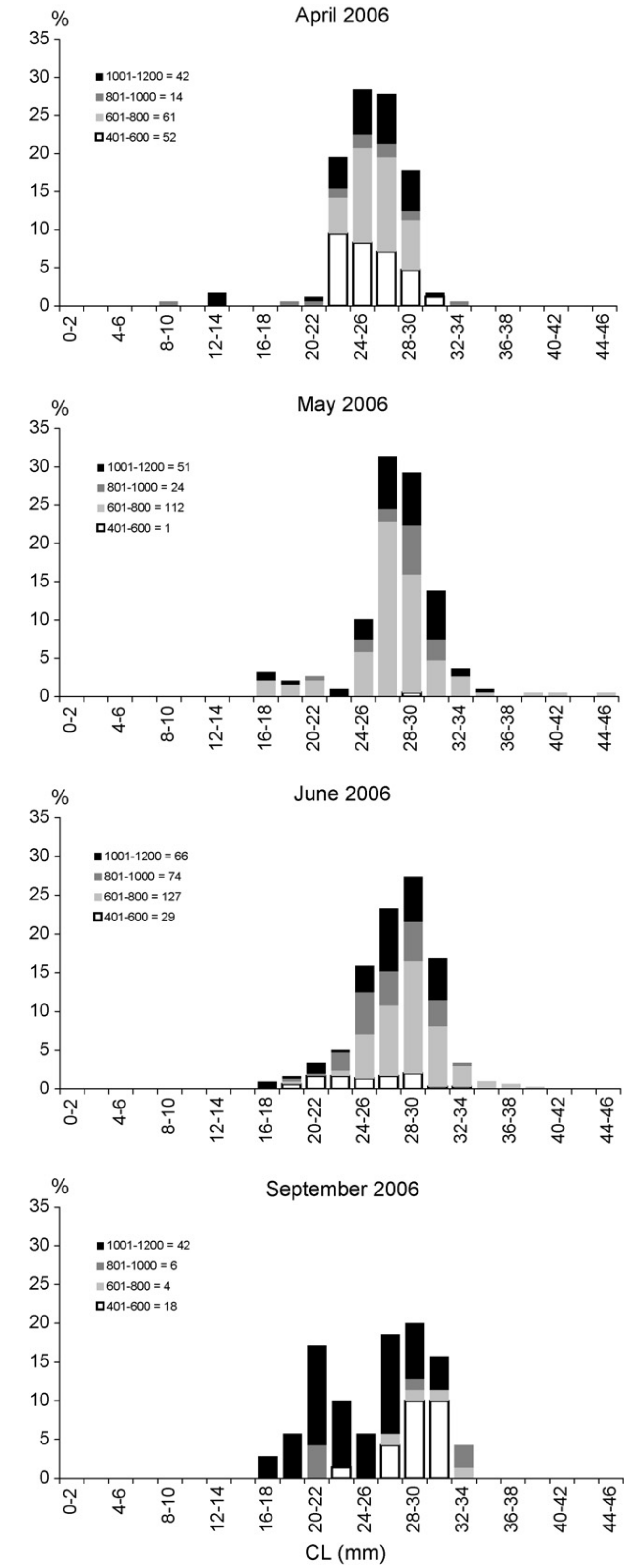

Fig. 5. Length-frquency distribution by survey and depth strata of *A. antennatus* males caught in the north-western Ionian Sea.

warps, was used. The stretched mesh in the codend was 20 mm. The horizontal and vertical opening of the net, measured by the SCANMAR acoustic system, depended on depth, wire length, towing speed etc. (Fiorentini et al., 1999). The sampling design adopted was random-stratified according to the following depth strata: 400–600, 600–800, 800–1000, and 1000–1200 m. The number of hauls, allocated in each depth stratum in proportion to their surface, is reported in Table 1. The hauls were repeated approximately in the same location. They were carried out from dawn to dusk and had an average duration of between half an hour and 1 h. The capture was standardized to km^2 for subsequent numerical processing. The vessel speed, measured using GPS, was maintained at 2.5–3.0 knots.

2.3. Methods

Using the number and weight of the individuals for each haul swept area, the density (N/km^2) and biomass (kg/km^2) indices were computed. The swept area was estimated according to the wing spread of the net (horizontal opening) and the speed of the vessel (Pauly, 1983). Changes in density and biomass with depth were tested by means of regression analysis.

For each specimen of *A. antennatus* the carapace length (CL) was measured to the nearest mm, from behind the orbit of the eye to the posterior border of the cephalothorax. The change in size with depth was statistically tested by means of regression analysis, using the median carapace length of each haul for the two sexes separately. The median length was adopted in order to minimize the effect due to the extreme values and asymmetric distributions. Sex was determined macroscopically and the sex-ratio [F/(F + M)] was computed by depth. Maturity stage of gonads in females was evaluated according to the four stage scale proposed by Orsi Relini and Relini (1979). Males were distinguished into immature and mature according to the presence of hemispermatophores in the terminal ampullae and joined petasma (Sardà and Demestre, 1989). The presence of spermatophores on the thelycum was recorded in females. Density indices of mature females and males as well as of females with spermatophores were estimated for each haul and their variations with depth were evaluated by means of regression analysis. The percentages of mature females and males and females with spermatophores were also computed by depth. The size distributions were calculated for each sex, survey and depth stratum.

Adopting the Von Bertalanffy growth parameters estimated for the stock in the same study area (D'Onghia et al., 2005), individuals smaller than 19.8 mm CL in females and 18.2 mm CL in males were considered as belonging to the first age class and thus as young-of-the-year. The density index was also estimated for these specimens for each haul in which they were found. Changes in their density with depth was tested by means of regression analysis. Differences in the frequency of occurrence of young-of-the-year between 400–800 and 800–1200 m depth strata were evaluated using the non parametric test of Kruskal-Wallis (Conover, 1980).

Gaussian components in the length-frequency distributions by sex and survey were separated with the Bhattacharya method by means of the FiSAT program (Gayanilo et al., 2006). Each representative component, with a separation index greater than 2, was assumed to be a single cohort. Differences between observed and expected length-frequency distributions were evaluated using the χ^2 method.

Furthermore, in order to compare the population on fishing (400–800 m) and virgin grounds (800–1200 m), the size distributions were calculated for each depth macro-stratum and sex and then each sex was compared separately using the percentage of Similarity (Kohn and Riggs, 1982).

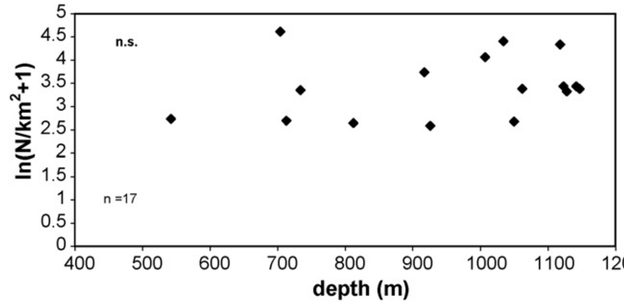

Fig. 6. Relationship between young-of-the-year density indices and depth in *A. antennatus* caught in the north-western Ionian Sea.

3. Results

The shrimp *A. antennatus* was collected between 470 and 1147 m in 61 out of 80 hauls (76.25%). The highest percentage of occurrence was obtained in the depth stratum of 600–800 m while the lowest between 400 and 600 m (Fig. 2). Both density and biomass indices varied largely during each survey and in each depth range. However, a significant decrease with depth was only shown for biomass indices (Fig. 3).

The population structures by depth in females and males are presented in Figs. 4 and 5, respectively. The sizes of females ranged from 12 to 64 mm CL showing a multimodal trend during each survey. The most abundant individuals had sizes generally between 30 and 50 mm CL and were mainly caught between 400 and 800 m. The males measured between 8 and 46 mm CL and exhibited a bimodal distribution in each month with the second mode always more abundant than the first. The occurrence of small specimens constituting a first well separated modal component was observed in both sexes during each cruise and across the investigated depth range. In the length-frequency distributions of females and males up to five and two modal components were detected, respectively (Table 2). The progression of the first mode from April to September was

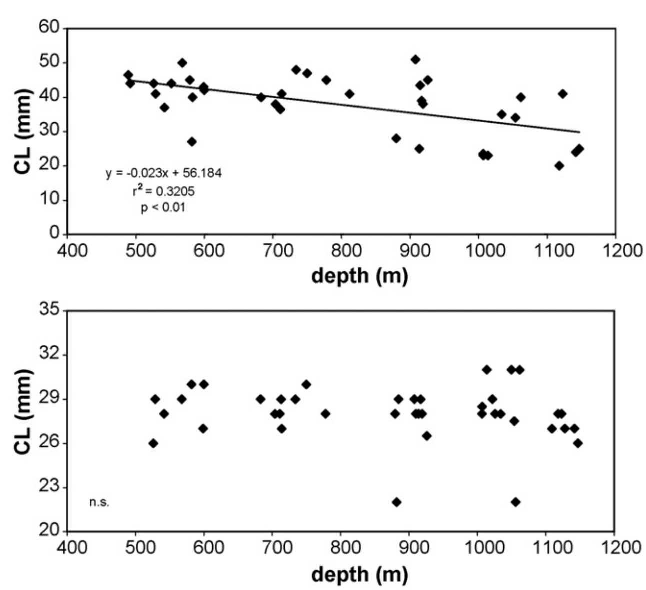

Fig. 7. Relationship between the median length of each haul and depth in *A. antennatus* females (above) and males (below) caught in the north-western Ionian Sea.

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Table 2
Mean values of the modal components of the length-frequency distributions in females and males of *Aristeus antennatus* caught in the north-western Ionian Sea. Standard deviation (S.D.); separation index (S.I.).

	Modal components	April 2006 $N = 268$			May 2006 $N = 176$			June 2006 $N = 181$			September 2006 $N = 93$		
		Mean CL	S.D.	S.I.	Mean CL	S.D.	S.I.	Mean CL	S.D.	S.I.	Mean CL	S.D.	S.I.
Females	1	17.00	1.49	–	18.16	2.59	–	20.79	2.63	–	24.35	2.71	–
	2	30.96	2.28	3.10	31.00	2.39	2.76	30.05	1.50	2.44	–	–	–
	3	35.88	1.81	2.05	39.71	2.85	2.21	–	–	–	–	–	–
	4	48.35	2.96	2.41	45.69	2.56	2.03	42.10	4.45	2.39	38.39	2.33	2.67
	5	–	–	–	52.37	2.06	2.09	51.43	1.60	2.14	49.63	2.85	2.30
Males	Modal components	April 2006 $N = 169$			May 2006 $N = 188$			June 2006 $N = 296$			September 2006 $N = 70$		
		Mean CL	S.D.	S.I.	Mean CL	S.D.	S.I.	Mean CL	S.D.	S.I.	Mean CL	S.D.	S.I.
	1	–	–	–	19.39	1.87	–	–	–	–	20.34	1.56	–
	2	26.85	3.12	–	27.39	2.23	2.37	26.83	2.46	–	28.01	2.15	2.36

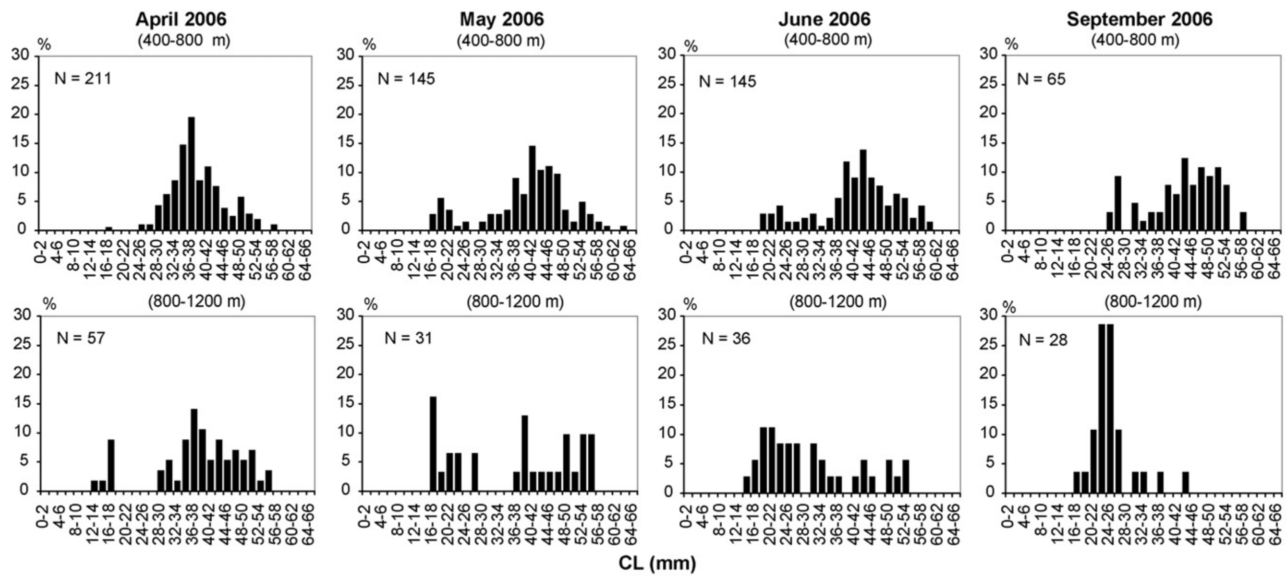

Fig. 8. Length-frequency distribution by survey and depth macro-strata of *A. antennatus* females caught in the north-western Ionian Sea.

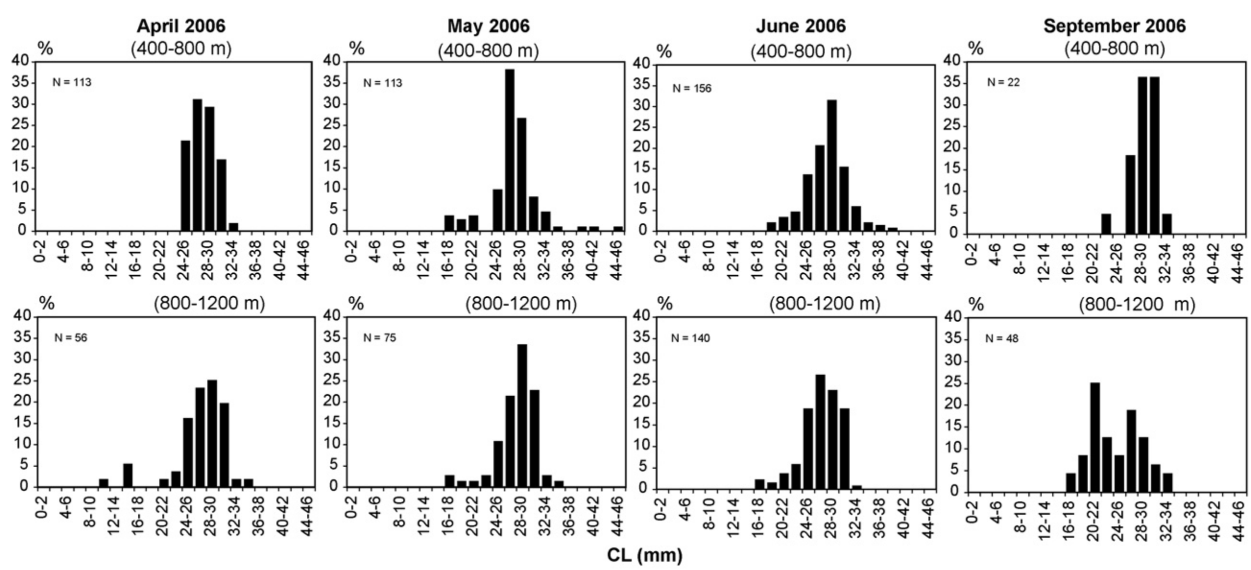

Fig. 9. Length-frequency distribution by survey and depth macro-strata of *A. antennatus* males caught in the north-western Ionian Sea.

Table 3
Percentage similarity matrices of size distributions by survey and depth macro-strata for *Aristeus antennatus* caught in the north-western Ionian Sea.

Females	400–800 April	400–800 May	400–800 June	400–800 September	800–1200 April	800–1200 May	800–1200 June	800–1200 September
400–800 April	100%							
400–800 May	57%	100%						
400–800 June	56%	76%	100%					
400–800 September	41%	51%	58%	100%				
800–1200 April	37%	52%	48%	60%	100%			
800–1200 May	16%	31%	30%	38%	48%	100%		
800–1200 June	17%	32%	33%	40%	37%	54%	100%	
800–1200 September	8%	14%	21%	19%	12%	34%	56%	100%

Males	400–800 April	400–800 May	400–800 June	400–800 September	800–1200 April	800–1200 May	800–1200 June	800–1200 September
400–800 April	100%							
400–800 May	77%	100%						
400–800 June	80%	71%	100%					
400–800 September	31%	31%	25%	100%				
800–1200 April	57%	57%	49%	56%	100%			
800–1200 May	72%	69%	63%	45%	78%	100%		
800–1200 June	88%	77%	84%	27%	52%	68%	100%	
800–1200 September	30%	41%	37%	43%	50%	49%	40%	100%

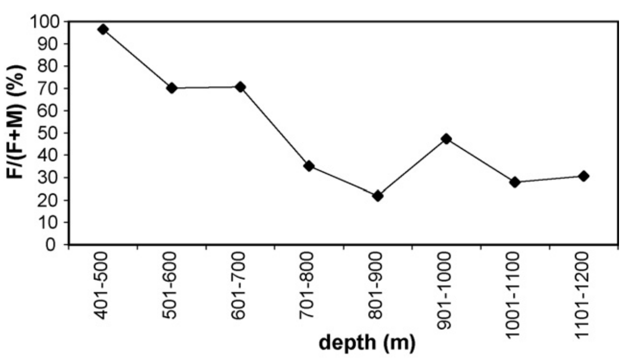

Fig. 10. Sex-ratio by depth in *A. antennatus* caught in the north-western Ionian Sea.

shown in both females and males. In particular, the females belonging to the first mode in April with a mean size of 17.00 ± 1.49 mm reached a mean size of 18.16 ± 2.59 mm in May, 20.79 ± 2.63 mm in June and, three months later, 24.35 ± 2.71 mm in September. In males the identification of the first modal group was only obtained during May (19.39 ± 1.87 mm) and September (20.34 ± 1.56 mm).

The frequency of occurrence of the young-of-the-year was significantly greater below 800 m than above this depth ($p < 0.01$). However, no significant changes in their density indices were observed across the investigated depth range (Fig. 6). The median lengths of the females decreased significantly in relation to depth while no significant variations in the sizes with depth were detected in males (Fig. 7). The size distributions computed for female and male populations sampled above and below 800 m showed marked differences between the depth macro-strata in the former and comparable trends in the latter (Figs. 8 and 9; Table 3). In fact, although high variations were shown in the percentage of similarity between macro-strata and months, the values computed for females were markedly lower than for males (Table 3). For example, during June the percentage of similarity between 400–800 and 800–1200 m was 33% in females and 84% in males.

The sex-ratio changed with depth: the females greatly outnumbered the males above 700 m while males were generally more abundant than females at the greatest depths (Fig. 10). The percentages of mature and immature individuals by sex and survey are reported in Table 4. The highest percentages of mature females were recorded in May and June while those of mature males were computed during April, May and June. A negative trend was observed between the density indices of mature females and depth while no significant changes with depth were shown for the density indices of mature males (Fig. 11). The percentage of mature individuals varied according to depth with a decreasing trend both in females and males (Fig. 12). The density indices and percentage of

Table 4
Percentage of immature and mature individuals of *Aristeus antennatus* collected in the north-western Ionian Sea.

	Date	*N*	Immature (%)	Mature (%)
Females	April 2006	268	97.76	2.24
	May 2006	176	38.07	61.93
	June 2006	181	35.36	64.64
	September 2006	93	95.7	4.3
Males	April 2006	169	5.33	94.67
	May 2006	188	5.32	94.68
	June 2006	296	2.36	97.64
	September 2006	70	27.14	72.86

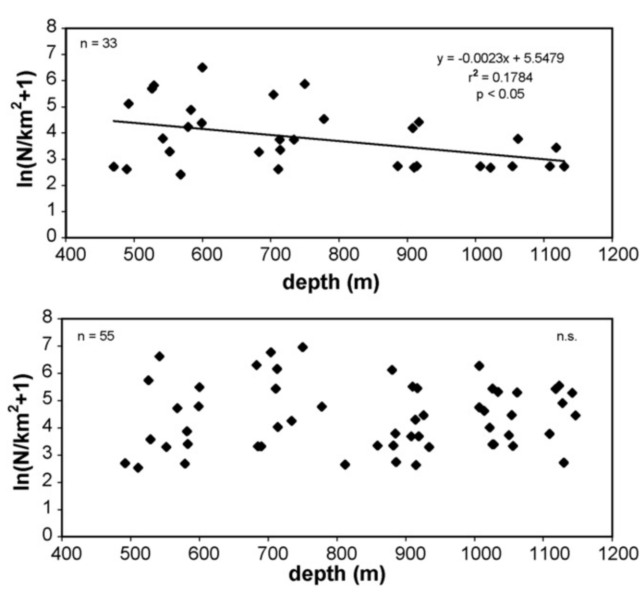

Fig. 11. Relationship between the density indices of mature females (above) and mature males (below) and depth in *A. antennatus* caught in the north-western Ionian Sea.

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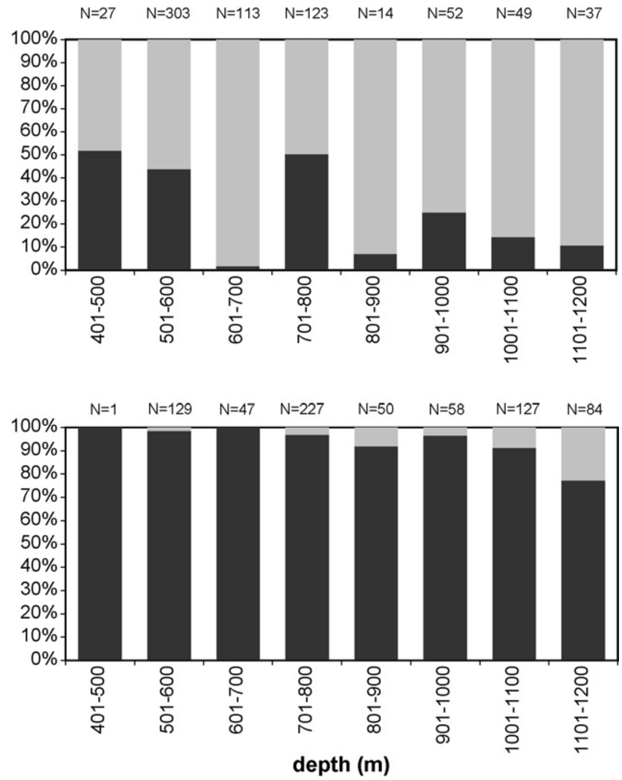

Fig. 12. Percentage of mature females (above) and mature males (below) by depth in *A. antennatus* caught in the north-western Ionian Sea (light grey = immature; dark grey = mature).

females with spermatophores also showed negative trends with depth (Figs. 13 and 14).

4. Discussion

Although this study was carried out in a relatively small sample area with a sampler smaller than the commercial trawl net, the results obtained are in general agreement with previous observations on the population biology of *A. antennatus* (e.g. Sardà, 1993; Relini et al., 1999; Sardà et al., 2003a,b, 2004) providing further contributions to the knowledge on its recruitment and population structure in deep waters.

In particular, within the depth range 400–1200 m no variations in density indices were shown. This could apparently support hypothesis 2 stated by Sardà et al. (2003b) which is that the number of individuals on the fishing grounds is equal to the number of individuals on the virgin grounds. In this respect, the objection that the abundance of *A. antennatus* above 800 m is affected by fishing,

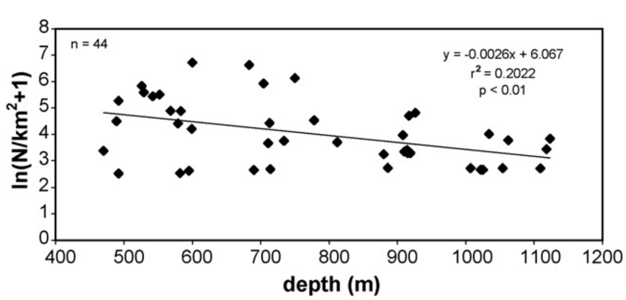

Fig. 13. Relationship between the density indices of females with spermatophores and depth in *A. antennatus* caught in the north-western Ionian Sea.

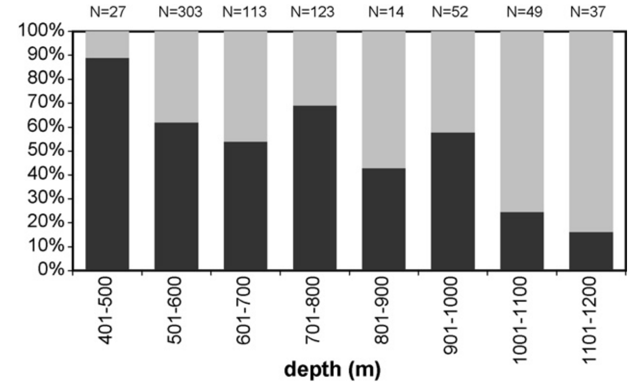

Fig. 14. Percentage of females with spermatophores (dark grey) by depth in *A. antennatus* caught in the north-western Ionian Sea.

can be counter-balanced by the fact that the abundance of individuals below this depth should be largely greater in relation to the greater extension of the virgin grounds (Sardà et al., 2003b). Indeed, we have to take into account that *A. antennatus* has been caught as deep as 3300 m (Sardà et al., 2004). Thus, hypothesis 3 by Sardà et al. (2003b) could well be realistic, which is that the number of individuals on the fishing grounds is smaller than the number of individuals on the virgin grounds.

Confirming previous studies (e.g. Sardà, 1993; D'Onghia et al., 1998; Sardà et al., 2003a,b, 2004), the negative trend of biomass indices with depth is due to the increasing proportion of small individuals as well as to the greater proportion of males.

In the Mediterranean Sea, very small specimens (<8.5 mm CL) of *A. antennatus* have been collected between 500 and 550 m in Sardinian waters from October to December (Mura et al., 1997). Young-of-the-year (12–15 mm CL) have been caught on fishing grounds in the north-western Ionian Sea during May (D'Onghia et al., 1997, 2005) and in the Greek Ionian Sea during January (12–18 mm CL) (Papaconstantinou and Kapiris, 2001). The recruitment of *A. antennatus*, represented by individuals smaller than 10–15 mm CL from December to June, has also been observed at depths greater than 1000 m both in Catalan, Balearic and western Ionian Sea (Sardà and Cartes, 1997; Cartes and Demestre, 2003; Sardà et al., 2003a,b, 2004). In this regard, the recruitment occurs on a wide depth range with an increasing frequency of occurrence with depth. Moreover, it seems to occur as a discrete phenomenon.

The larval distribution most probably represents the main gap of knowledge in the context of the life cycle of *A. antennatus*. Considering that larvae shift up across the water column to the surface during pelagic development phases and that post-larvae would go to deep waters for settlement (Sardà et al., 2004), the occurrence of small individuals from the upper to lower slope indicates a sinking phase which covers a wide depth range. The objection that, after the pelagic development phases of larvae in surface waters, the young-of-the-year individuals recruit on the upper slope and then migrate towards deeper bottoms can be rejected by the fact that the same recruitment pattern has been shown in the two depth macro-strata examined. Furthermore, there is no evidence of young-of-the-year migration towards deep waters while there is strong evidence of female upward displacement as they grow. This would make realistic the 1st corollary of hypothesis 3 by Sardà et al. (2003b), that is the exchange of individuals from virgin grounds to fishing grounds. In this respect, *A. antennatus* is a species capable of remarkable displacements (Orsi Relini et al., 1986; Sardà, 1993; Sardà et al., 1994; Matarrese et al., 1995; Sardà et al., 1998b; Relini et al., 2000, 2004). The recruitment on a wide depth range could be a consequence of larval dispersal linked to downward flux of water masses which satisfy density-dependent mechanisms aiming to avoid competition processes for food resources and/or reduce predator pressure on juveniles (Gage and Tyler, 1991).

As a consequence of widespread recruitment in deep waters, the separation of the different modal components in the length-frequency distributions of *A. antennatus* is often very difficult throughout the Mediterranean. In order to explain such a difficulty the prolonged spawning period of this shrimp has been considered as the source of the micro-cohort superimposition (Orsi Relini and Relini, 1998). Given that the observations on the recruitment as a discrete phenomenon contrast with the prolonged spawning period of *A. antennatus*, the following hypothesis can be suggested to explain the difficulty in the separation of different modal classes: the very wide depth distribution of the young-of-the-year determines different growth rates among individuals, which in migrating upwards according to their growth mix up the modal components in the length-frequency distributions. Unfortunately, even though studies on the metabolism of *A. antennatus* have revealed high metabolic rates in this nektobenthic species (Company and Sardà, 1998), no information is available for different depths. However, it is well known that the species living in the deep-sea have a very slow metabolic rate due to the low temperature values and scarce trophic resources (Gage and Tyler, 1991). Although in the Mediterranean there are homeothermic conditions at depths greater than approximately 200 m, the availability of the trophic resources generally decreases from the upper to lower slope (Miquel et al., 1994). Individuals that recruit on the lower slope could grow slower than those recruited in the uppermost depths. Thus, when small individuals with different growth rates migrate upwards to join in the same stock the sizes of different cohorts become indistinguishable.

The structure of the female population on fishing grounds has been found to be significantly different from that on virgin grounds while the population structure in males shows the same pattern across the investigated depth range. This confirms that the exploited population mostly consists of large females.

Mature females and females with spermatophores have been caught across the whole investigated depth range showing a negative trend of their densities and percentages. This seems to be in relation to the fact that the size of females decreases with depth.

According to previous considerations on greater number of individuals related to greater extension of virgin grounds also the abundance of mated and ripe females below 800 m should be largely greater than above this depth. However, since large reproductive females are mostly distributed above 800 m and a bigger-shallower phenomenon is evident in the female population, the contribution to the maintenance of the fishing population by the virgin one seems to be mostly due to the displacement of individuals from deep waters to fishing bottoms. In other words, the deep waters act as a refuge area mostly for the recruitment of *A. antennatus* and only partially for spawners. That is why no signs of "growth overfishing" have been detected until now in the Mediterranean stocks. Indeed, the population seems to be in optimum exploitation conditions even in areas with high fishing pressure (e.g. Demestre and Martin, 1993; García-Rodríguez and Esteban, 1999; D'Onghia et al., 2005).

Taking into account that the exploited population mostly consists of reproductive females, conditions of "recruitment overfishing" might occur in *A. antennatus* contrary to other demersal resources. In fact, the disappearance verified in the Ligurian Sea (Orsi Relini and Relini, 1985), followed by a new uncommon recruitment pulse after some years (Orsi Relini and Relini, 1988), could be due to the marked overexploitation of the spawning stock on bottoms shallower than 800 m.

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