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Distribution Patterns and Biological Characteristics of *Aristeus Antennatus* (Risso, 1816) and *Aristeus Virilis* (Bate, 1881) in Mozambique Waters of the Western Indian Ocean

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Abstract— The blue and red shrimp, *Aristeus antennatus* (Risso, 1816), and the stout red shrimp, *Aristeus virilis* (Bate, 1881), represent two of the most valuable demersal deep waters shrimp species subject to exploitation in Mozambique. This paper analyses the distribution, abundance and biological parameters of these species for the first time in this area. During 13th March to 10th April a survey on board the R/V *Vizconde de Eza* has been carried out to assess deep water crustacean resources in Mozambique waters. The sampling design followed a random stratified scheme with five sectors (Sofala, Bazaruto A, Bazaruto B, Boa Paz and Inhaca) and also five depth strata (A: 100-200 m, B: 200-400 m, C: 400-500 m, D: 500-600 m, E: 600-700 m).

For the overall area surveyed, *A. virilis* was twice more abundant than *A. antennatus* (95.44 tons and 37 tons respectively) and more abundant in central and south area (Bazaruto B; Boa Paz and Inhaca), while *A. antennatus* was more abundant in the north area (Sofala). Both species live in deep water and were caught between 420 to 675 m and 520 to 690 m, for *A. antennatus* and *A. virilis* respectively. Size of first maturity occurred at of 19.8 mm and 25.5 mm of cephalotorax length (CL) for males of *A. antennatus* and *A. virilis* respectively, and 34.7 mm and 47.5 mm of CL for females of *A. antennatus* and *A. virilis*, respectively.

INTRODUCTION

The fisheries sector in Mozambique is an important source of economic earning, animal protein and employment. Total marine products are estimated at between 100,000 to 120,000 tonnes per year and consumption is estimated at 7.5 kg per capita. The fisheries industries provide direct employment for around 90,000 people, excluding those involved in trading and processing (Afonso, 2006).

The industrial fishery using bottom trawl is responsible for deep water shrimp catches. Deep water shrimps contribute with about 7 % of the total value of industrial fisheries; between 2001 and 2003 deep shrimp fisheries realised about 1,500 tonnes with a 7,125,000 US$ value. This subsector consists of joint ventures between the Government of Mozambique and foreign companies form Japan and Spain and Portugal. They have sufficient financial resources to enable them to support a modern fleet, and export their products to the international markets in which they are well established, such as Spain and Japan (FAO, 2004). The fleets of these companies have the major part of the quotas – more than 70 % of the Total Allowable Catch (TAC). The major products include shallow- and deep-water shrimps, lobster,

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fish and some tuna, most of which are for export markets. In 2001, exports reached US$ 100 million, representing over 40 % of the country's earnings. Frozen directly on trawlers, shrimps are exported mainly to Japan, South Africa and the European Union. According to recent assessments carried out by Dias and Caramelo (2007), the main deep water shrimp fisheries are currently under-exploited.

Deep water shrimps occur in Mozambique waters from 18º00' S to 26º50' S. In the northern part, trawling is difficult due to the existence of canyons and coral reefs and it is not possible to survey this area.

The main deep water shrimp resource is comprised chiefly of the following species: *Haliporoides triarthrus vniroi* (Stebbing, 1914) and *Aristaemorpha foliacea* (Risso, 1827), and secondary are *Aristeus antennatus* (Risso 1816) and *Aristeus virilis* (Bate, 1881) (FAO, 2006). Management measures include TACs, mesh size limits and vessel licensing requirements.

In the western Mediterranean Sea, the blue and red shrimp, *A. antennatus*, is one of the most valuable demersal species exploited. Although growth parameters, reproductive aspect and population dynamics of *A. antennatus* have been widely investigated in different areas of the Mediterranean Sea (Sardá & Demestre 1987, Demestre 1995; Demestre & Lleonart 1993, Demestre & Martín 1993, Martínez-Baños 1997, Carbonell *et al*. 1999, García-Rodríguez & Esteban 1999a,b,. Sardá *et al*. 2001), in the Indian Ocean only its presence is described (Holthius, 1980), while biological information is very scarce. The stout red shrimp *A. virilis* has a wide distribution in the Indian Ocean but biological information about this species is also very scarce (Pérez-Farfante and Kensley 1997).

The present work aims to contribute to the knowledge of two *Aristeus* species, *A. antennatus* and *A. virilis*, in Mozambique waters using data obtained during a scientific survey carried out under a cooperation programme between the government of Spain and Republic of Mozambique.

MATERIALS AND METHODS

Sampling

The data used in the study comes from a survey whose main purpose was to assess the deep water crustacean resources in Mozambique's EEZ, between latitudes 17º00' and 26º 50' S, from 100 to 700 m depth. This survey (Mozambique 0307) was carried out using the R/V *Vizconde de Eza* from 13th March to 10th April 2007, using an otter trawl as sampling gear. A random stratified sampling design was applied, taking into account five geographical sectors (Sofala Bank, Bazaruto A, Bazaruto B, Boa Paz and Inhaca) and five bathymetric strata (A: 100-199 m; B: 200-399 m; C: 400-499 m; D: 500-599 m; E: 600-700 m) (Figure 1). A total of 129 fishing stations of 30 min duration and a speed of 3 knots were sampled. An estimation of the biomass was made using the swept area method (Sparre and Venema, 1992)

The trawling speed and geographic position were measured using differential GPS, and the trawl geometry and performance were observed using a SIMRAD ITI remote sensor system. All fishing operations were carried out during daylight hours (07:00-19:00h).

Carapace Length and body weight

From each haul, catch was sorted by species, counted and weighed. The individuals were sexed and measured by their cephalotorax length (CL in mm), taken from the posterior part of the left orbit to the centre of the posterior edge of the carapace, to the nearest millimetre. Total catch was weighed and individual specimens weighed to the nearest 0.1 g. Significant deviations from the 1:1 sex-ratio were tested by the $\chi 2$-test ($P< 0.05$).

Aspects of reproduction

Others biological data were also recorded, notably sex, presence of spermatophore on the thelycum and gonad maturity stage of females. A four-stage maturity scale based on the macroscopic observation of the gonad (size and colouring) was applied to females, according to Sobrino (1998): 1: virgin,

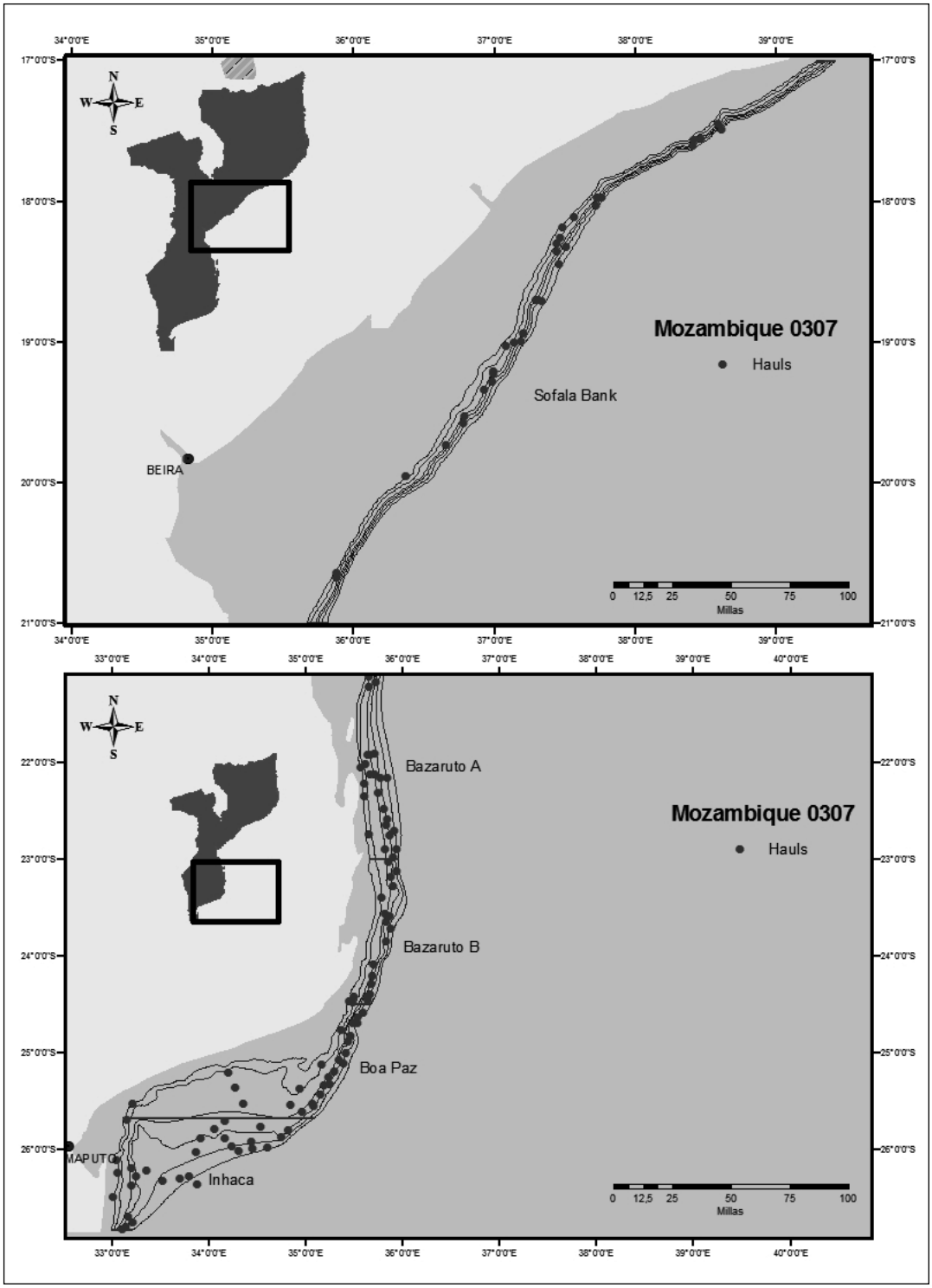


Fig. 1. Study area in Mozambique waters. Dot symbols indicate locations of hauls

2: developing, 3: pre-spawning and 4: spawning, considering stages 1 and 2 as immature and 3 and 4 as mature. For males, a two-stage maturity scale was applied (immature and mature) based on the presence or absence of spermatic mass in the coxae of the fifth pair of pleiopods. The formation of the petasma (separate or joint) was moreover followed as a secondary sexual characteristic (Demestre, 1990). The moulting activity was also considered and the specimens in moulting process or with soft body were recorded.

The size at maturity ($CL_{m50\%}$) was estimated after fitting, by the least squares method, the relative length frequency distribution of mature individuals to a logistic curve from the expression: $P_i = 1/(1+\exp(a+bCL_i))$, where P_i represents the relative frequencies of fully mature individuals in length-class CL_i, a and b are the regression constants, and $CL_{m50\%} = -a/b$ (see Sparre and Venema, 1992).

RESULTS

Distribution pattern and abundance

In Mozambique waters *A. virilis* is more abundant than *A. antennatus*. Total biomass for *A. virilis* was of 95.44 tonnes and 37 tonnes for *A. antennatus* (72% and 38% respectively). Both species were more abundant in the north area (Banco de Sofala) and in the south area (Inhaca). In the case of *A. antennatus* this species was inexistent in Boa Paz and Bazaruto B (Figure 2a).

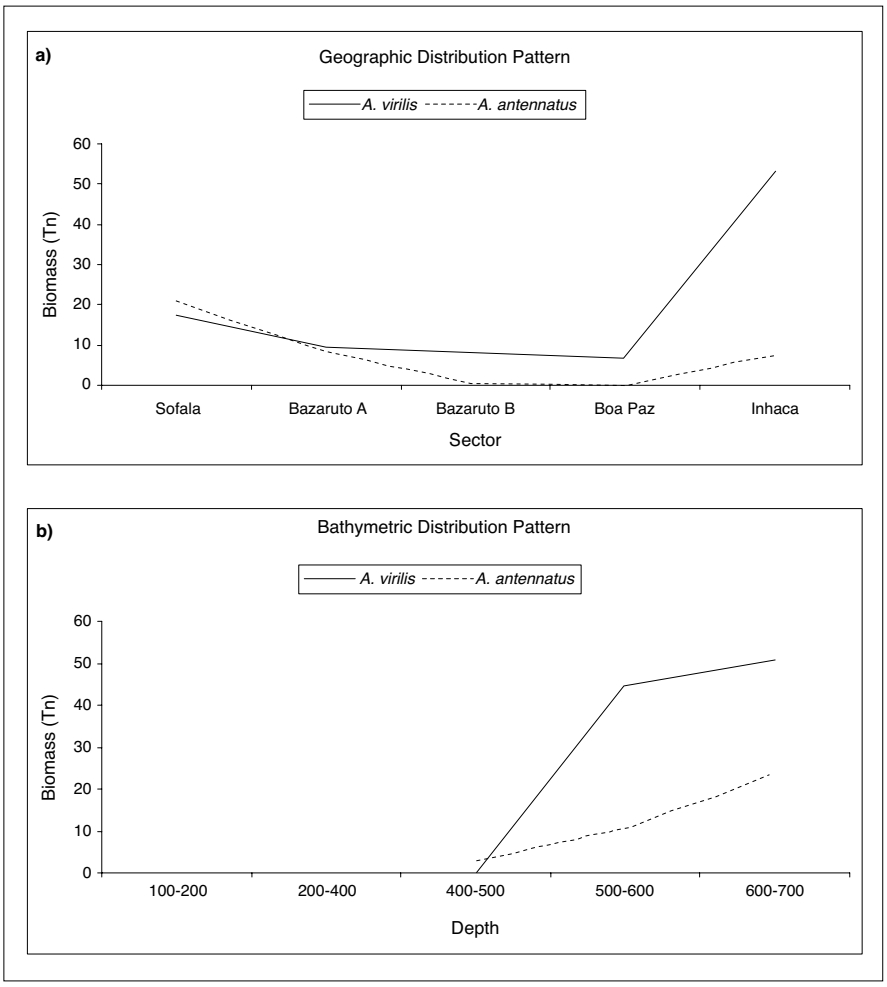


Fig. 2. Abundances of both species by geographic sector (a) and depth (b)

With respect to water depth, theses species were caught between 531 to 674 m and 456 to 679 m for *A. virilis* and *A. antennatus* respectively. The higher abundances were recorded between 600 to 700 m for both species (Figure 2b). For *A. virilis* a similar yield was obtained in the last two deeper strata, while for *A. antennatus* in 600 to 700 m depth the biomass was higher than in the 500 to 600 m range.

Size frequency distribution and sex ratio

The size range for *A. virilis* was 20 to 73 mm of CL with a mean value of 31.4 and 39.1 mm CL for males and females respectively (see Figure 3), where a single mode for both sexes was observed. In the case of *A. antennatus*, the size range was between 14 to 64 mm of CL. Mean CL for males was 25.6 mm and for females 35.7 mm CL. For

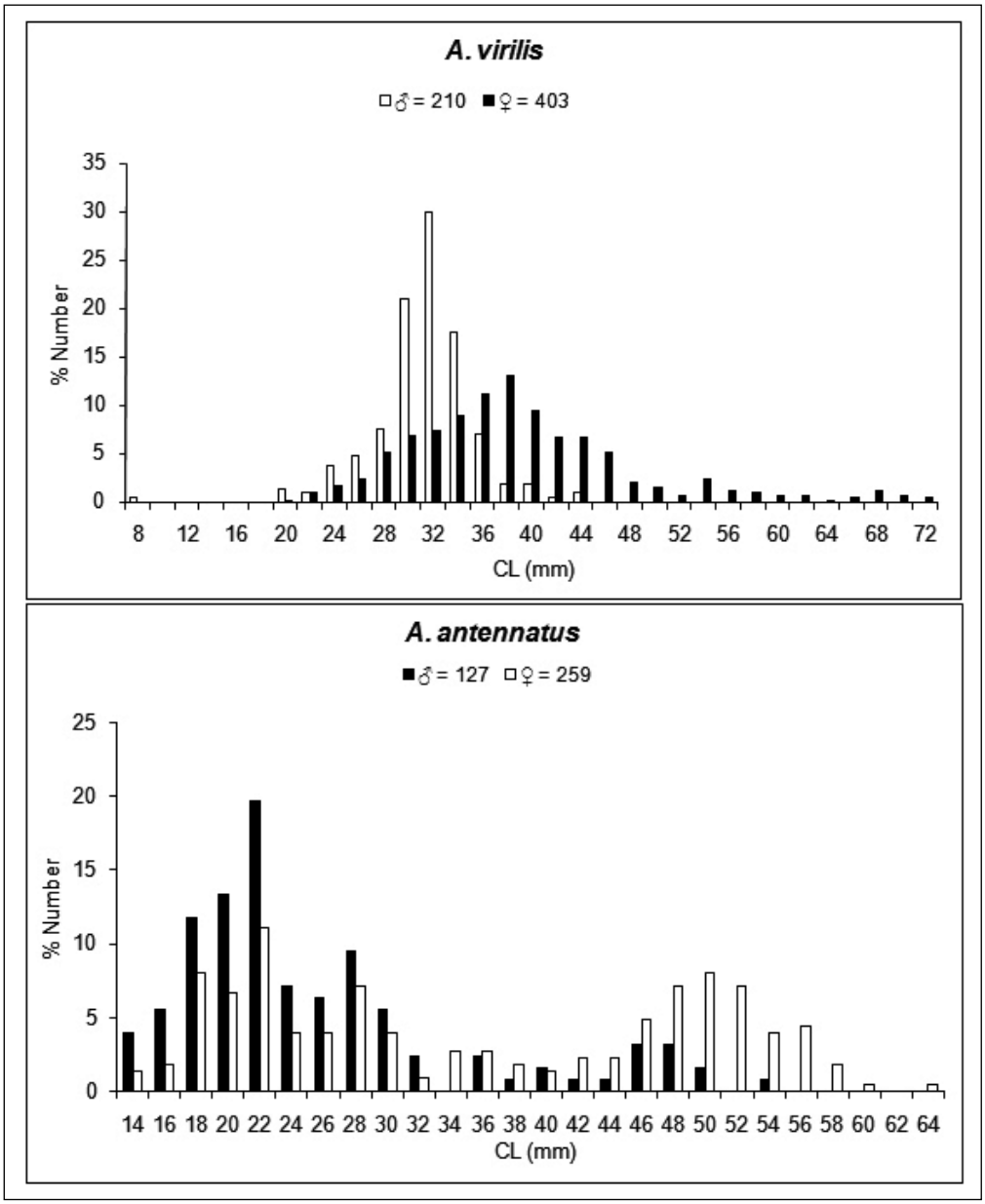
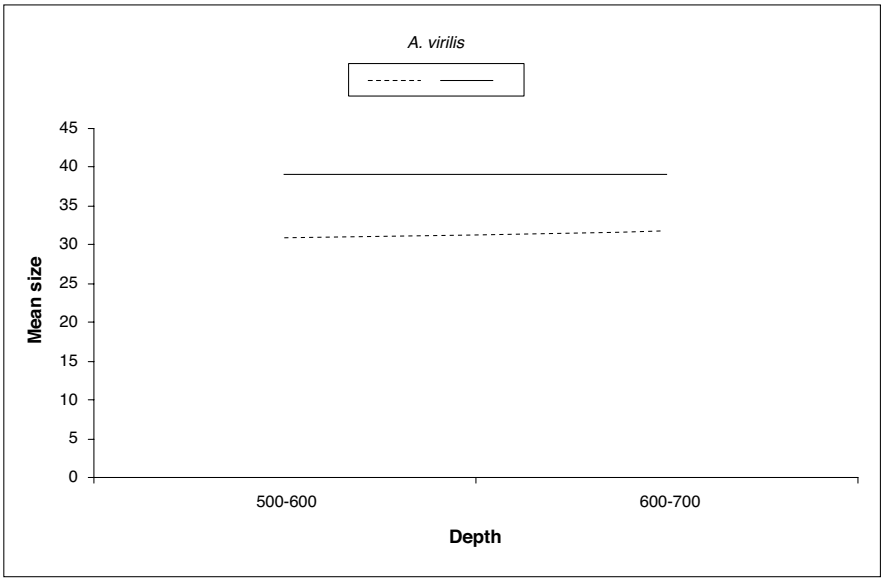


Fig. 3. Percentage by sex of size-class in the total studied area

this species two different modes were noted: one between 14 to 34 mm (medium size) and other of 42 to 62 mm (large size). All large specimens were concentrated in the north area (Sofala). Also for *A. antennatus* females are larger than males, with a mean CL of 25.6 mm and 35.7 mm for males and females, respectively.

When the mean size by depth is analysed (see Figure 4), there is no difference in the case of *A. virilis* and the mean size by depth stratum are similar in each sex, but for *A. antennatus* mean size increases with depth until 500-600 m, decreasing afterwards for both sexes.

The overall sex ratio for both species was significantly in favour of females (65.7% for *A. virilis* and 71.8% for *A. antennatus*). It was observed that at small and medium sizes, the sex ratio was nearly 50%, but at the large size the sex ratio was significantly in favour of females for both species (see Figure 5).



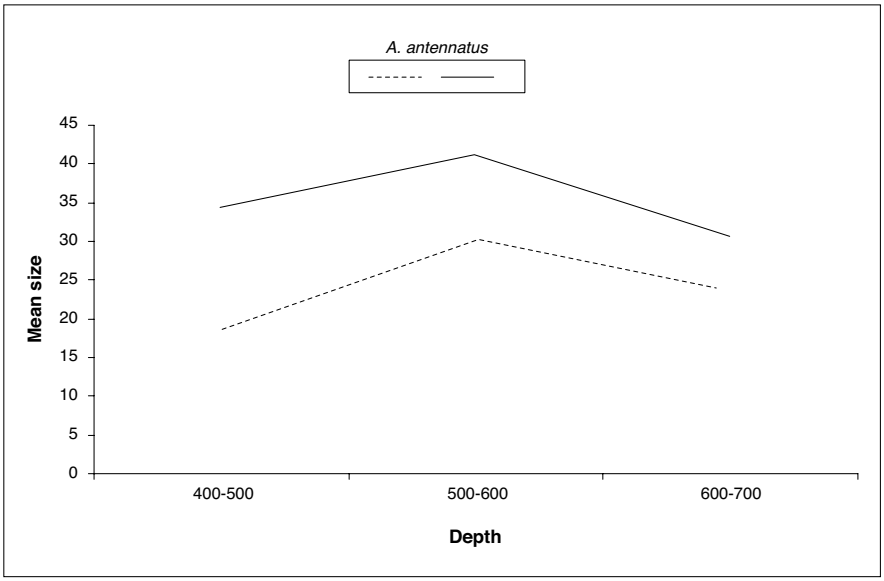


Fig. 4. Mean size by depth for *A. virilis* (a) and *A. antennatus* (b)

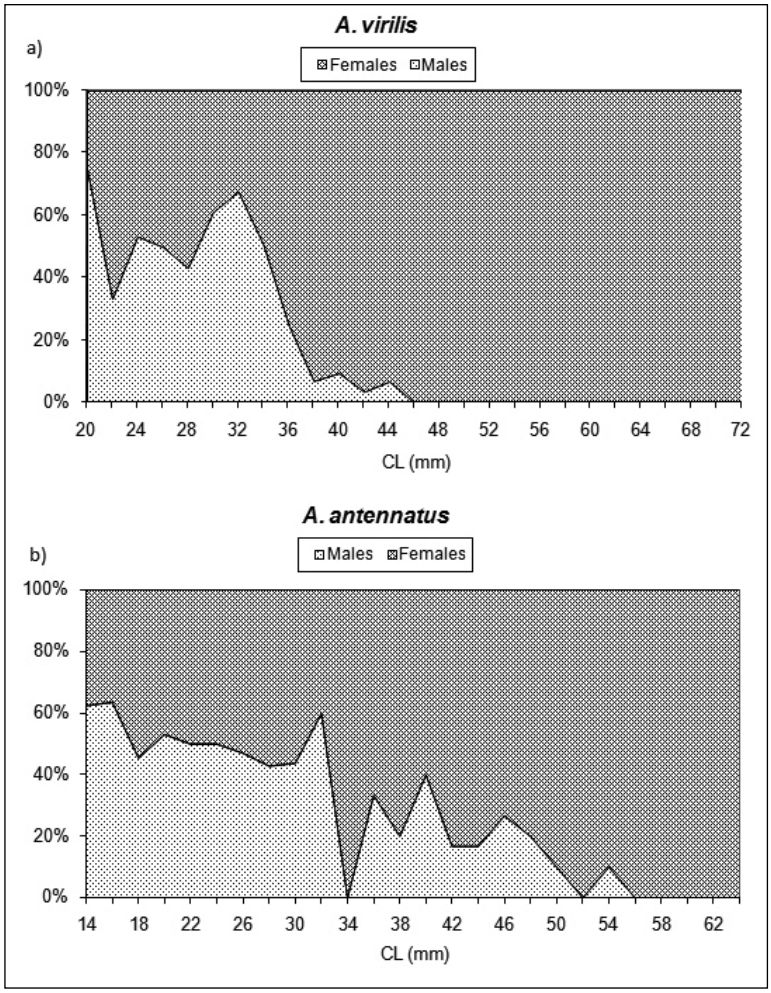


Fig. 5. Sex-Ratio by length for both species (*A. virilis* (a) and *A. antennatus* (b))

Reproductive aspects

For *A. virilis* females only 12.5% of specimens were mature but 47.3% of females were carrying spermatophore in their thelycum. All mature females were impregnated. The smallest mature impregnated female *A. virilis* measured 27.8 mm CL and the smallest immature impregnated female was 20.13 mm CL. Regarding depth distribution, as seen in Figure 6, it is observed that the majority of mature females were caught between 550-575 m depth. These results show that the period of survey did not coincide with the spawning time, reflected in the calculated maturity size data for females not fitting well to the model ($r^2 = 0.69$), as shown in Figure 7. For males, maturity size was calculated at between 25.5 mm CL (% spermatic mass in coxae) and 27.0 mm CL (% petasma joint) (see Figure 7).

With regard to *A. antennatus* 31.65% of specimens were mature and 34.3% of females were carrying spermatophore in their thelycum. The majority of mature females were impregnated. The smallest impregnated mature *A. antennatus* measured 18.4 mm CL and the smallest immature impregnated female was 18.7 mm CL.

Regarding water depth, (Figure 6) the majority of mature females were founded between 550-575 m and 675 m depths. These results show that the period of survey was close to the spawning time. The calculated maturity size was found to correlate well ($r^2 = 0.74$) as seen in Figure 8. The calculated

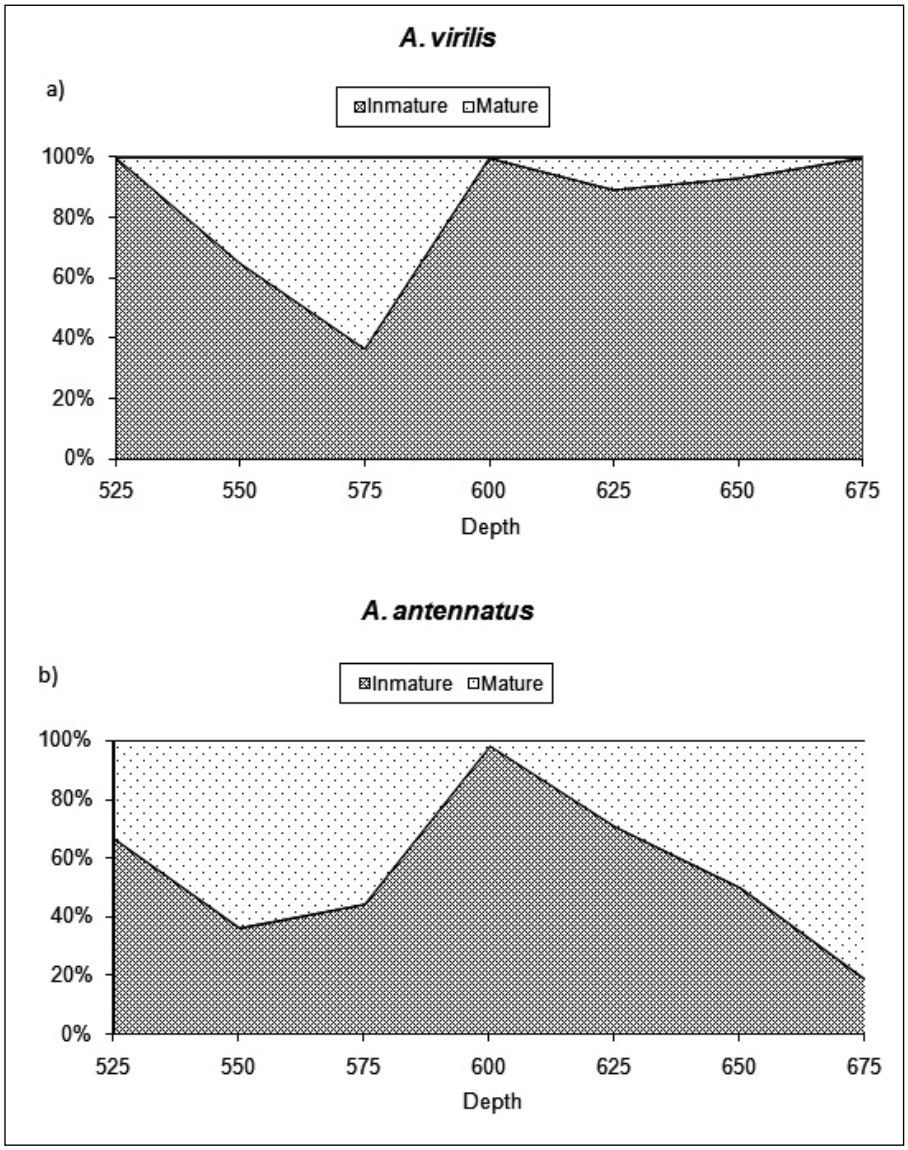


Fig. 6. Percentage mature females by depth (*A. virilis* (a) and *A. antennatus* (b))

size of maturity was 34.7 mm CL (% mature stage) and 37.0 mm CL when the % of impregnated females was used. For males, the calculated size at maturity varied between 19.8 mm CL (% spermatic mass in coxae) and 22.3 mm CL (% petasma joint) (Figure 8).

Moulting activity was very limited in both species during the study period. Only six of 397 specimens of *A. antennatus* and 21 of 469 of *A. virilis* were soft-shelled.

DISCUSSION

Both species constitute part of the resource exploited by the trawling fleet targeting deep water shrimp resources, of high economic value.

Even though there is no precise catch information for these two species in Mozambique waters, the results obtained during this survey indicate that these two species constitute 3% of the total crustaceans of commercial interest. Among the deep water shrimp species are also included the knife

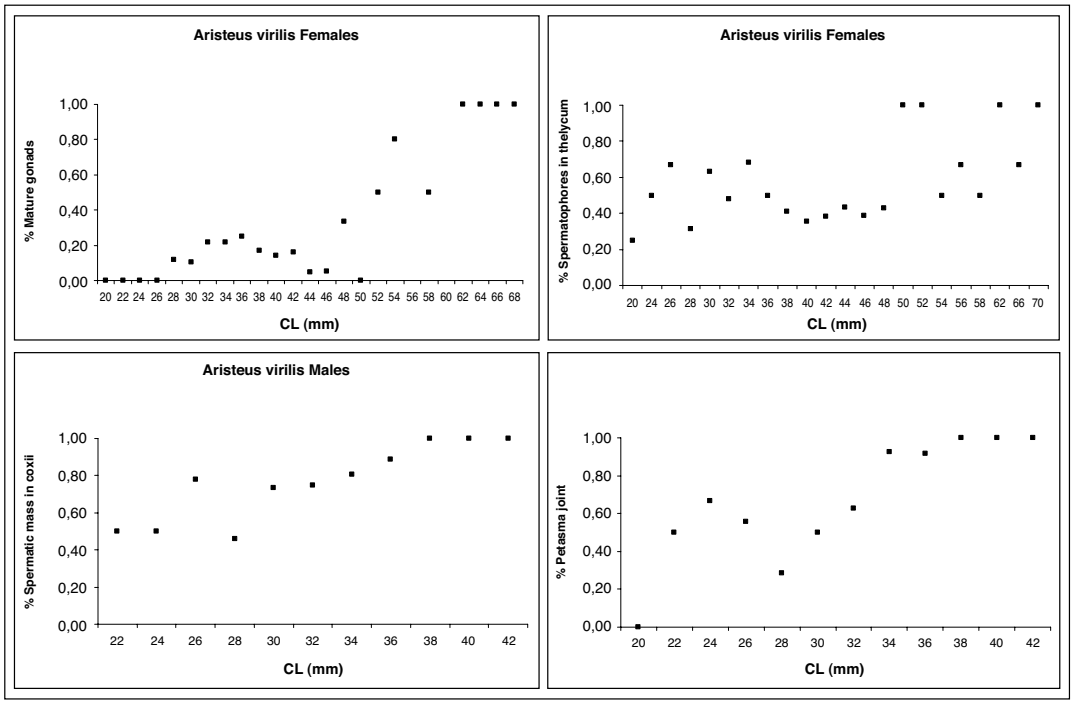


Fig. 7. Maturity at length ogive by sex for *A. virilis*, for females with mature gonads (top left), fecund females with spermatophores in thelycum (top right); males with spermaceti mass in coxii (bottom left) and males with petasma joints (bottom right)

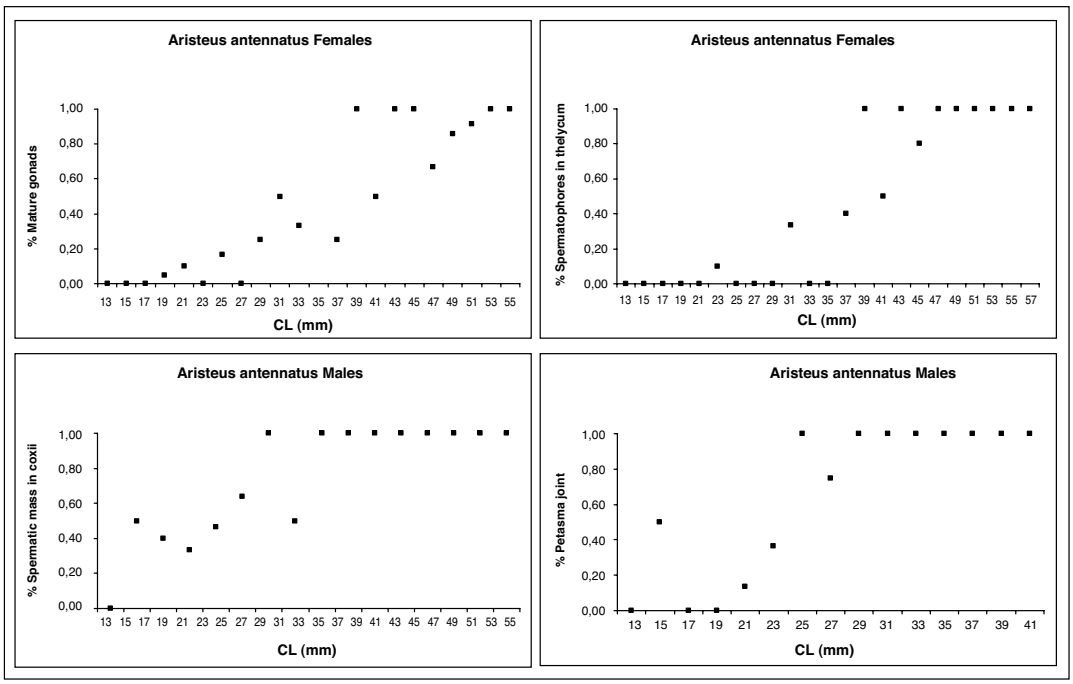


Fig. 8. Maturity at length ogive by sex for *A. antennatus*, for females with mature gonads (top left), fecund females with spermatophores in thelycum (top right); males with spermaceti mass in coxii (bottom left) and males with petasma joints (bottom right)

shrimp (*Haliporoides triarthrus*, Stebbing, 1914); Giant red shrimp (*Aristaeomorpha foliacea*. Risso, 1827); Scarlet shrimp (*Aristaeopsis edwardsiana*. Johnson, 1863) and Needle shrimp (*Penaeopsis balssi*. Ivanov and Hassan 1976). Similar results were previously found by Fennessy and Groeneveld (1997) in Indian Ocean waters of South Africa's coast.

In spite of some differences in distribution patterns, the two *Aristeus* species were found along all surveyed areas. *A. antennatus* was more abundant between 550 and 650 m, while *A. virilis* abundance increases with the depth having a maximum valour in the range of 600-700 m.

However, there is an indication that the depth limit of 700 m would not be the limit of the vertical distribution of the two species. Also observed was a distinct geographical preference along the coast for the two species, with *A. antennatus* virtually absent from the central areas surveyed.

In Mediterranean waters, where the fishery for thess species is predominant, the sames species occurs in a bathymetric range from 400 to 3,300 m depth (Sardá *et al*., 2004), with highest abundance between 400 and 800 m depth. According to Sardá and Demestre (1987), the main fishery occurrs over grounds between 400 and 1,000 m depth. In Portugal, according to Ribeiro-Cascalho and Arrobas (1982) these species occur between 350 and 650 m depth. The latter depth ranges are in accordance with the deep water shrimp fishery in Mozambique, which does not occur deeper than 700 m of depth (Dias and Caramelo 2007). Similarly, in South Africa there is a fishery between 300 and 600 m (Fenessy and Groeneveld, 1997). However, it has to be taken in consideration that the fisheries in the latter two countries mentioned have as the main target *H. thriarthrus*, whose bathyimetric distribution range is restricted to 700 m depth (Muñoz *et al*., 2007).

The distinction on both species in terms of depth and latitude were mainly due to the absence of *A. antennatus* in such areas as Bazaruto A, Bazaruto B and Boa Paz. In 95% of the trawling samples where *A. antennatus* were caught, it occurred with *A. virilis*. However, 48.5% of the trawling samples where *A. virilis* was caught were not accompanied by *A. antennatus*.

The population structure of *A. antennatus* was similar to results from other surveys. In diverse studies in western Mediterranean waters it is shown a cephalothorax length range between 18 and 42 mm for males and 15 to 61 mm for females (Demestre 1990). In Atlantic waters of southern Portugal, males were reported with similar values (19-40 mm) and 17-68 mm for females (Arrobas andRibeiro-Cascalho, 1987). Meanwhile in this survey, the males present a maximum carapace length at 54 mm. The sex ration pattern found in other studies (Arrobas and Ribeiro-Cascalho, 1987; Demestre, 1990) where similar to the findings of the present study.

The lack of previous reproductive studies of *A. virilis* does not allow comparison with other regions, therefore the values obtained can be considered as a first approximation, mainly because there were not sampled during the reproduction peak season. On the other hand, a higher percentage of *A. antennatus* females were found, which can suggest that they were close to a reproduction peak season, therefore the results show a better adjustment to the calculated length at maturity. These results are also considered the first estimates in Mozambique waters. From diverse studies performed with this species in Mediterranean waters (Demestre, 1990; Martínez Baños and Mas, 1994; Carbonell, 1994; García-Rodríguez, 2003), calculated maturity lengths given are about 17 to 22 mm CL for males, close to the results obtained in the present study, and 22 to 27 mm CL for females, lower than the present results.

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