ICES CM 1998/O: 34

SOME ASPECTS OF THE BIOLOGY OF DEEP-WATER CRAB *CHACEON AFFINIS* (MILNE EDWARDS & BOUVIER, 1894) OFF THE AZORES

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Abstract

We present preliminary results from cruises during 1997 to study the deep-water crab, *Chaceon affinis* (A.Milne Edwards & Couvier, 1894) S. of the island of Pico in the Azores archipelago and at the Menez Gwen hydrothermal vent area SW of the Azores, within the Azorean EEZ.
The crabs were caught with bottom traps during each quarter of the year from the R/V "Arquipélago", according to a specified survey design. Different areas between 300 and 1200 m depth were surveyed. Information from previous collections was also compiled and analysed.
A total of 1153 individuals (726 males and 427 females) were caught at depths ranging from 600 to 1100 m on rocky and/or muddy bottoms. Size ranged from 40 to 177 mm carapace length (CL), the males being larger than females. Males were relatively more abundant in waters less than 800 m depth and females relatively more abundant deeper than 800 m. The greatest abundance occurred at depths from 700 to 800 m Ovigerous females, which had a carapace length of more than 70 mm, were found only in fourth and first quarters, from October to March. An annual reproductive cycle is suggested. Size at first maturity for the females, based on the appearance of the vulva, was estimated to c. 83 mm CL. Other ecological and biological information such as distribution, morphometric aspects related to reproduction and occurrence of parasites and epibionts, are discussed.

INTRODUCTION

Geryonid crabs are distributed world wide, at depths ranging from 100-2800 m, comprising 25 species in 3 genera (*Geryon, Chaceon* and *Zariquieyon*). Only two of these species (*Chaceon maritae* and *C. quinquedens*) support regular fisheries since the 1970's in the Atlantic ocean. Several other geryonid species have been the target of exploratory surveys around the world's oceans (see Hastie, 1995 for review). In Portugal exploratory surveys of deep-sea crabs have also been conducted (Dias, 1992a, 1992b; Biscoito et al. 1992)
The deep-water red crab *Chaceon affinis* was originally described as *Geryon affinis* by Milne-Edwards & Bouvier (1894), from specimens caught in the Azores during the 1887 and 1888 cruises of the yacht "l'Hirondelle" of Prince Albert of Monaco, and later reclassified into the genus *Chaceon* by Manning & Holthuis (1989). Since the original description, this species has been reported from the Azores only once as bycatch in shrimp traps (Martins & Hargreaves,

1991), although it has been known to local fishermen. Zaferman & Sennikov (1991), based on surveys conducted N. of the Azores (seamounts on the Mid-Atlantic Ridge) reported that this species could be a potential resource to support a fishery. Hastie (1995) also considered *C. affinis* as a marketable species and a possible candidate for further exploitation.

During the 1994 DIVA-2 cruise in the submersible "Nautile" this species was observed around the Menez Gwen hydrothermal vent in the Azorean ZEE (Gonçalves, 1994). Short surveys were carried out during the summer of 1994 in the Azores suggesting interesting yields of this species (Gonçalves & Santos, 1994; Gonçalves & Pinho, 1994), which results were preliminarily reported by Gonçalves et al. (1995). Similar exploratory surveys were also conducted previously in Madeira island (Biscoito et al., 1992), and in the Canary islands (López-Abellán et al., 1994; Balguerias et al., 1996; Santana et al., 1996). Following these independent surveys a collaborative research project (Canary, Madeira and Azores) has been recently implemented and the first results described by González et al. (1998). *C. affinis* constitutes a virgin stock of potential economic importance for these regions but, in spite of the exploratory surveys and the interest demonstrated by commercial companies, there is not yet any regular fishery for this species. The development of a potential fishery seems to be conditioned by lack of information on biology, bathymetric distribution and harvest potential. The present study addresses some of these aspects for the Azores, complementing the preliminary data reported by Gonçalves et al. (1995).

METHODS

Sampling strategy and areas

In order to obtain a first approach knowledge of the biology of *C. affinis* on a around the year basis for the Azores, a research project was established based on quarterly cruises (February/March, June, August and October/November) carried out during 1997. The 4 trap cruises were carried out with the R/V "Arquipélago", equipped with hydraulic winches. All the fishing operations were conducted during day time.

Two major areas were selected for prospecting: islands of the Central group of the Azores archipelago (south coast of Pico and S. Jorge); and around the "Menez Gwen" hydrothermal area (Fig. 1). In the first area several locations were randomly prospected in 8 depth strata (100 m stratum each) in order to cover the depths from 300 to1.100 m. Two single exploratory sets at 1200 and 1400 m were made in the first quarter (Winter) to examine the depth limit of the species. In the Menez Gwen area the survey was conducted only in the depth strata from 700 to 900 m. Overall sampling design involved replicate sets of traps at each depth stratum.

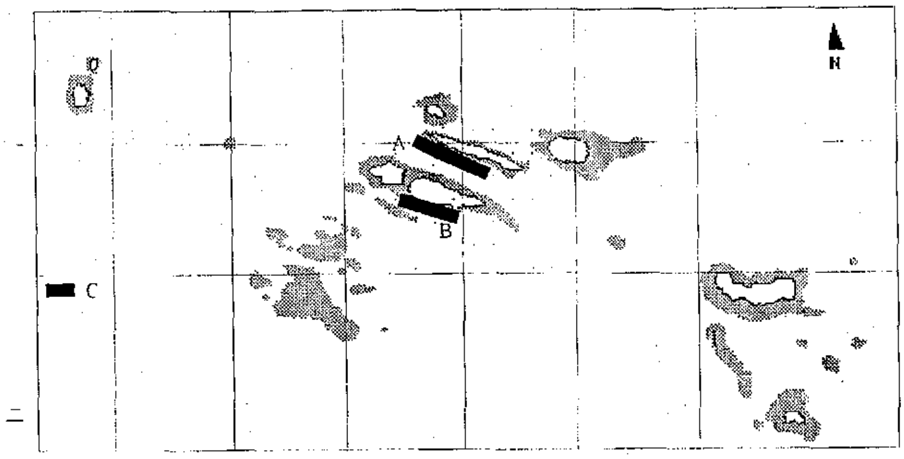


Fig. 1. Location of prospected areas in the Azorean EEZ during 1997 (A- South of Pico, B- S.Jorge, C- Menez Guen.

Fishing gear

The fishing gear used was made up by 5 sets of ground lines (14 mm Ø polypropylene rope), on which 8-16 oval plastic traps (Fathoms-plus®) were suspended through 5 m length branch lines (6 mm Ø nylon rope), and regularly spaced (50 m). At each extremity of the ground line, 20 kg weights were placed to anchor the line to the bottom. Two buoy-lines (14 mm Ø nylon rope), with a variable length (1,5 x local depth) were also tied to the extremities of the ground line. Clearly visible large buoys, equipped with radar reflectors (3 m height) and acoustic emission devices, facilitated sighting at sea (Fig. 2).

The two side-entry funnels of the traps were cut out leaving an opening of 14 cm x 22 cm. The traps were weighted with two strips of concrete, making the total weight of each trap 10 kg. 1-2 kg of salted mackerel (*Scomber japonicus*) was placed in the bait chambers.

Prior to deployment an echo-sounding survey was conducted to avoid very irregular substrata. As far as possible, the traps were deployed in the middle of each depth stratum. The retrieval was done the next day after deployment, standardising soaking time to *ca.* 24 hours.

An alternative fishing gear, constituted by 2 traps attached by a 3 m long rope to an acoustic release device was used in the Spring cruise in the Menez Gwen area.

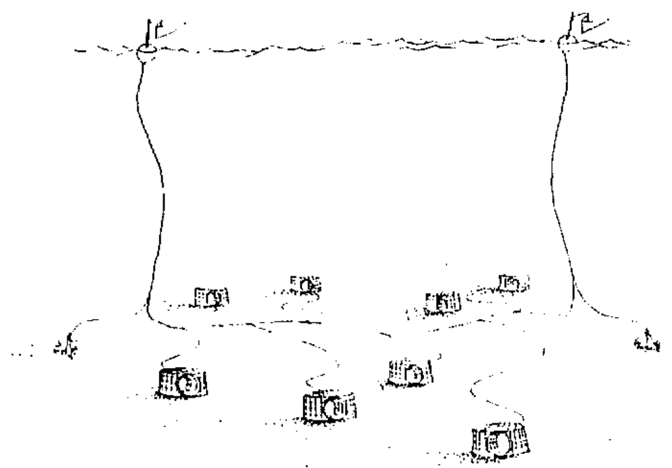


Fig. 2. Schematic representation of the fishing gear used in the exploratory trials.

Fishing and biological data

For each fishing trial the following information was recorded: date, GPS position, depth, no. of traps used, deploying and retrieval time (to calculate fishing time), species, numbers and weights of individuals caught.

For each crab, colour, sex and the following measurements to nearest mm using callipers were taken onboard according to Attrill et al. (1991): carapace length - CL; carapace width - CW; right chelae length - RCHL, and width - RCHW; left chelae length - LCHL, and width - LCHW; 5th abdominal segment width - ABW. Missing appendages (chelae, pereopods) and occurrence of parasites on the abdomen, epibionts and lesions on the exoskeleton were also recorded. Some of the crabs were maintained alive, refrigerated (- 5ºC) until arrival in port.

Total wet weight and gonad weight (to the nearest 0.1g), were recorded in the laboratory. Females were examined for presence of external eggs or eggs remnant on pleopods and egg colour and weight recorded. Evidence of copulation was determined by the condition of vulvae (open, closed, abrasions) (Hartnoll, 1969; Haefner, 1977). The maturity stage was determined macroscopically, according the following ovary colour scale: I-immature (colourless), II- early (ivory/light orange), III-intermediate (orange/lilac), IV- advanced (violet/grey), V-mature (purple/brown). Estimation of size at first sexual maturity was established separating immature and mature females based on vulvae condition criterion. A logistic curve was then fitted to the mature females grouped by size class (5 mm).

Moreover, the data collected during this project, and some other available biological data collected during a previous survey during the summer of 1994, were used for some biological analyses, whenever possible. Animals with missing appendages were excluded from morphometric relationships.

RESULTS

Fishing

A total of 62 sets of traps were considered valid. Of the 487 traps set, 36 were lost (7,4 %) and were not taken into account. Average setting time was 22.9 min and average retrieval time 47.5 min (Tab. 1).

Due to logistic problems and bad weather conditions, the Winter cruise in Menez Gwen area and the Spring cruise in the Central group were cancelled.

Table 1. Summary of fishing operations per depth stratum carried out in 1997 in the Azores during the *Chaceon affinis* surveys.

Stratum (m)	No. of sets	No. sets per Location*	Months	Average time (min)		Soaking time (h)			No. of traps	
				Deploying	Retrieval	Min	Max	Average	Total	Lost
300	5	3A, 1B, 1C	2, 3, 8, 9, 10	20,4	28,4	17,5	37,5	24,3	45	2
400	3	3A	2, 8, 10	19,6	40	18,0	64,5	33,9	30	1
500	4	3A, 1B	2, 3, 8, 10	21	31,7	8,0	24,8	20,1	36	1
600	5	4A, 1B	2, 8, 10	23	47,2	16,9	24,1	20,4	42	10
700	9	5A, 2B, 2D	2, 3, 6, 8, 10	19,5	43,4	18,7	44,0	25,0	72	10
800	14	5A, 2B, 7D	2,3,6,8, 10,11	24,4	47,7	4,1	69,2	20,3	102	10
900	14	5A, 2B, 7D	2,6,8,1 0,11	30,0	45,2	8,6	44,0	21,8	96	2
1000	5	4A, 1B	2,8,10	23,8	48,6	18	70,3	24,5	40	0
1100	1	1A	2	26	68	24,2	24,2	24,2	8	0
1200	1	1B	2	22	52	22,5	22,5	22,5	8	0
1300	0	0							0	
1400	1	1A	2	22	70	70,5	70,5	70,5	8	0
Total	62	3	7	22,9	47,5			28,0	487	36

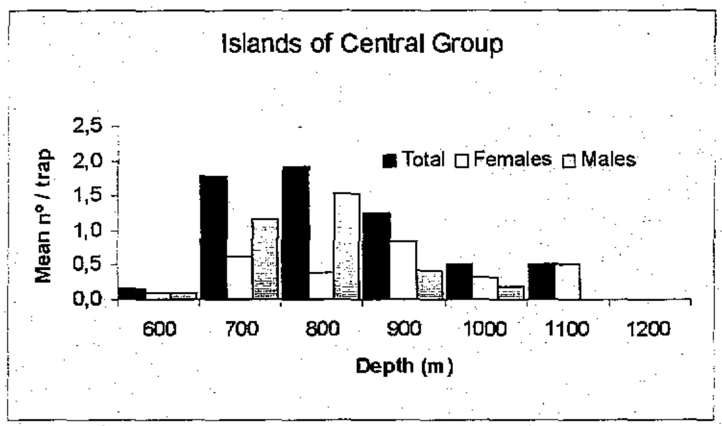
*Locations: A - S. of Pico (38°15,8-26,3'N;28° 17,0-29°29,9'W); B - S. Jorge (38°37,1-40,2'N; 28°08,2-15,3'W), C - Princess Alice Bank (38°01,0'N; 29°15,1'W), D - Menez Gwen (37°49,8 – 37°50.6; 31°12 - 31°32,5'W)
Note: Months 2 and 3 correspond to Winter, 6 to Spring, 8 and 9 to Summer; 10 and 11 to Autumn.

Crab distribution and abundance

A total of 1153 *C. affinis* crabs, 427 females and 726 males, were caught in the strata between 600 and 1,100m (Fig. 3). It should noted that between 300 and 600 m, no *C. affinis* was caught. However, these strata had the highest abundance of another crab species, *Cancer bellianus*. The 600 m depth contour seems to be a transition depth between these two species.

Highest abundance of *C. affinis* was found around the Menez Gwen hydrothermal area between 700 and 900 m. The catches from this area represented 77% of the total. Male abundance decreased significantly by depth, but females maintained a constant abundance and were even more abundant than males at 900 m (Fig.3). Overall, 64% of all crabs caught in this area were males. Quarterly analyses were not made, since the effort was not the same for all strata, but this was the general pattern observed. Several other associated species were caught in this area, mainly fishes (*Simencheelys parasitica* and *Sinophobrancus kaupi*) and shrimps (*Heterocarpus* sp.).

On the south coasts of Pico and S. Jorge islands (Central group) the abundance of *C. affinis* were generally poor compared with the Menez Gwen area. Several localities were surveyed within the same strata and a great variability in abundance of *C. affinis* between stations occurred suggesting a patchy distribution (see Hastie, 1995) which may be related to different bottom types at the sampled stations. *C. affinis* were found between 600 and 1,100 m, abundance decreasing with depth. (Fig. 3).Highest abundance occurred at 700-900 m. In general males dominate in shallower depths and females in the deeper. At the 1,100 m stratum only females were found. However, only one valid set was considered here yielding 4 female specimens. Several species were caught as bycatch in these areas, mainly echinoderms (*Aerosoma* sp., *Cidaris cidaris*, Asteroidea n.i.), shrimps (*Ligur ensiferus*, *Plesionika edwardsii*, *Plesionika narval*), crabs (*Bathynectes* sp., *Homola barbata*, *Cancer bellianus*), sharks (*Centrophorus granulosus*) and fish (*Sinophobrancus kaupi*, *Mora moro*, *Helicolenus dactylopterus* and *Conger conger*).



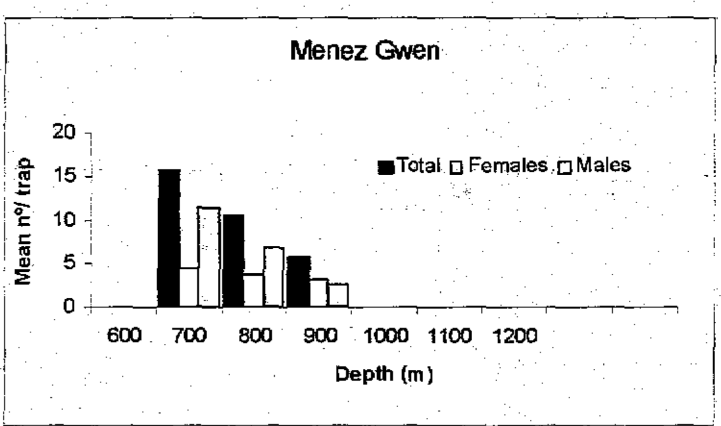


Fig. 3. CPUE of *Chaceon affinis* per depth strata for males (M), females (F) and sexes combined (total) for the two main areas surveyed during the 1997.

Size variables and morphometric relationships

The average size of the main variables (wet weight, carapace length and width) were higher in males than in females (Table 2). The frequency distribution of the size classes (5 mm) was clearly bimodal for males (95 and 125 mm) and unimodal (95 mm) for females (Fig. 4).

Table 2. Summary statistics of the main size variables of *C. affinis* caught in the Azores.

		Variables		
		Carapace Length (mm)	Carapace Width (mm)	Wet Weight (g)
Females	Number	427	427	357
	Range	40-136	55-165	48-720
	Average	91	111	324
	St. dev.	15.6	18.5	124.4
Males	Number	726	726	579
	Range	40-177	50-190	33-1854
	Average	107	132.1	603
	St. dev.	23.2	28.3	345.3
All individuals	Number	1153	1153	936
	Range	40-177	50-190	33-1854
	Average	101.3	124.5	526
	St. dev.	22.9	27.11	334.9

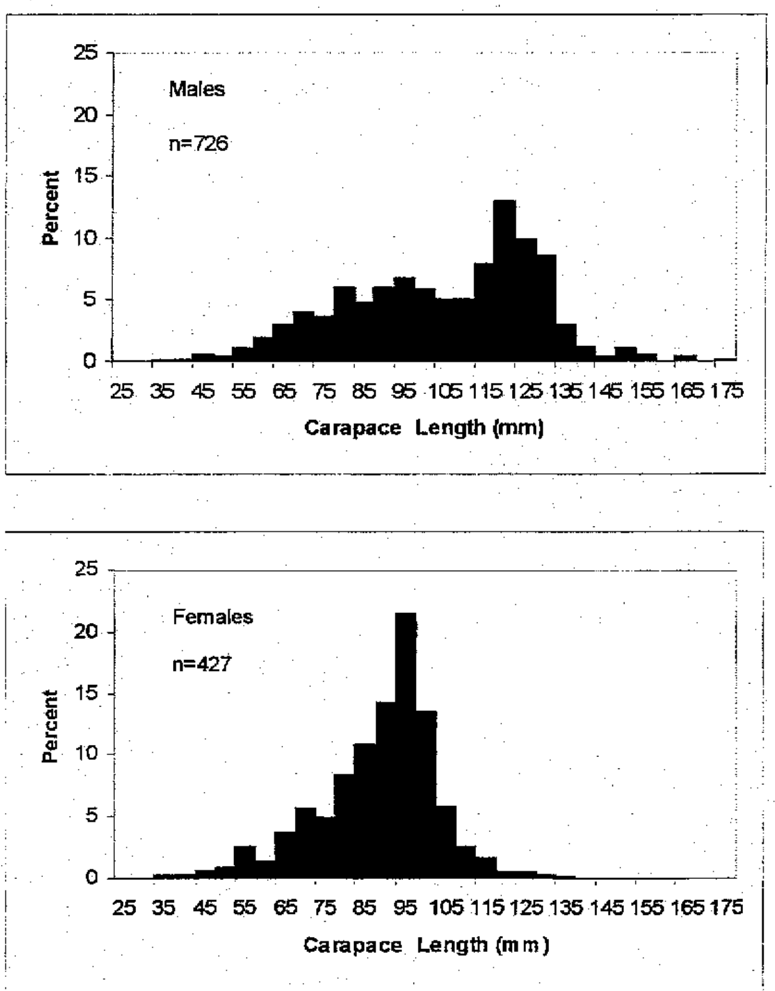


Fig. 4. Size frequency distribution of males and females *C. affinis* captured in Azores.

The relationship between size (carapace length) and weight is significantly different (t-test, P<0.05) between the sexes, being almost isometric in females and positively allometric in males (Table 3).

Table 3. Parameters of Carapace Length - Wet Weight relationship ($WW=a*CL^b$) for males, females and all crabs.

Group	A	B	Se(b)	R	N	WW range (g)	CL range (mm)	t
Male	0.0001	3.2587	0.0600	0.963	517	33-1531	40-150	2.61*
Female	0.0004	3.0032	0.0774	0.946	317	48-719	47-119	
All crabs	0.0001	3.3149	0.0375	0.968	834	33-1531	40-150	

* Indicates significance at 0.05 level.

As suggested by Somerton (1980) and Attrill et al. (1991) length and width of both chelae and abdomen width were plotted against the carapace length for both males and females and, as no evident discontinuites were observed, all points were used for the calculations of regressions. Parameters of these linear regressions, including carapace width, are presented in Table 4. These relationships are significantly different between sexes (t-test, P<0.05), except for carapace width in which growth is almost isometric for both sexes. Moreover, no significant difference (t-test, P>0.05) were found between right and left chela length and width, neither in males nor in females. (Table 4).

Table 4. Parameters of power relationships ($Y=a*CL^b$) between named variables on carapace length (CL) for males, females and all crabs

Variable	Group	a	B	se(b)	R	n	Variable Range	Range (CL,mm)	T
CW	Male	1.4873	0.9603	0.0086	0.977	726	50-190	40-177	1.82
	Female	1.6859	0.9282	0.0154	0.954	427	55-165	40-136	
	All crabs	1.3919	0.9731	0.0070	0.975	1153	50-190	40-177	
LCHW	Male	0.0720	1.2854	0.0138	0.975	599	10-47	40-177	13.30*
	Female	0.3137	0.9327	0.0226	0.947	369	9-29	40-118	
	All crabs	0.0431	1.3873	0.0155	0.957	968	10-47	40-177	
LCHL	Male	0.3590	1.1717	0.0136	0.969	617	30-137	40-150	12.13*
	Female	1.0272	0.9174	0.0160	0.965	361	30-88	40-118	
	All crabs	0.2460	1.2465	0.0125	0.961	978	30-137	40-150	
RCHW	Male	0.0948	1.2454	0.0188	0.950	603	10-54	40-177	10.03*
	Female	0.3914	0.9019	0.0286	0.894	358	11-32	40-119	
	All crabs	0.0536	1.3591	0.0184	0.935	961	10-54	40-177	
RCHL	Male	0.3421	1.1874	0.0138	0.970	607	30-143	40-177	13.32*
	Female	1.1959	0.8875	0.0178	0.951	354	30-88	40-119	
	All crabs	0.2327	1.2635	0.0132	0.959	961	30-143	40-177	
ABW	Male	0.2309	1.0341	0.0158	0.951	637	9-44	40-149	9.96*
	Female	0.1270	1.3160	0.0235	0.969	390	14-70	40-126	

* Indicates significance at 0.05 level.

The mean size of females decreased with depth in the islands of the Central group, while the mean size of males increased until 800 m depth and then decreased down to 1000 m. In the Menez Gwen area no clear tendency was observed, the average CL being 102.7 mm (s=4.3) for males and 89.7 mm (s=0.6) for females. Males sampled at Menez Gwen were smaller than those from the islands of the Central group (Fig. 5).

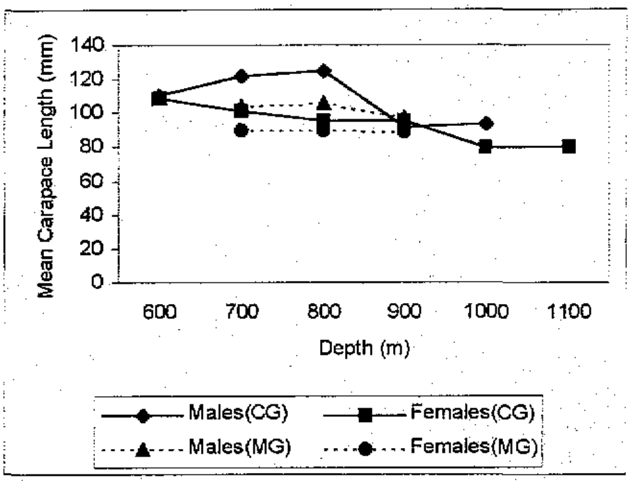


Fig. 5. Mean carapace length of male and female of *C. affinis* from depth strata sampled at islands of Central group (CG) and Menez Gwen area (MG).

Sex ratio

Males were significant more numerous than females, outnumbering them by ~1.7:1. Dominance of males was statistically significant for strata 700-800 m while the opposite occurred in deeper strata (Table 5).

Table 5. Frequency of male (M) and female (F) crabs *C. affinis* at different areas and depth strata during 1997 (CG – islands of Central group, MG – Menez Gwen, and All – both areas combined).

		Stratum (m)					
Sex	Areas	600	700	800	900	1000	1100
M	CG	2	44*	76*	23	7	0
	MG		172*	313*	74		
	All	2	216*	389*	97	7	0
F	CG	2	24	20	46*	13*	4*
	MG		66	167	85*		
	All	2	90	187	131*	13*	4*
M+F	CG	4	68	96	69	20	4
	MG		238	480	159		
	All	4	306	576	228	20	4

* - Significant differences (χ^2-test, $P<0.05$)

Analysis by quarter for combined areas showed that males predominated significantly in all quarters (χ^2-test, $P<0.05$) except in the fourth (Table 6), but this results should be taken with some reserve as the surveys did not cover equally all the strata in each quarter.

Table 6. Number of crabs *C. affinis* by sex caught by quarter during the surveys carried out in the Azores during 1997.

Quarter	No. males	No. females	Sex-ratio	χ^2
Jan-Mar	51	25	1:0.49	8.89*
Apr-Jun	364	127	1:0.35	114.4*
Jul-Set	171	131	1:0.77	5.3*
Oct-Dec	125	144	1:1.15	1,34

*($\chi^2 > \chi^2_{t1,0.05}$ =3.84

Males predominate almost in all size classes except in the intermediate lengths (85-100 mm CL). However, significantly differences in sex ratios (χ^2-test, P<0.05) were only observed in 7 size classes (almost all the largest ones), fact that affected the overall sex-ratio (Figure 6).

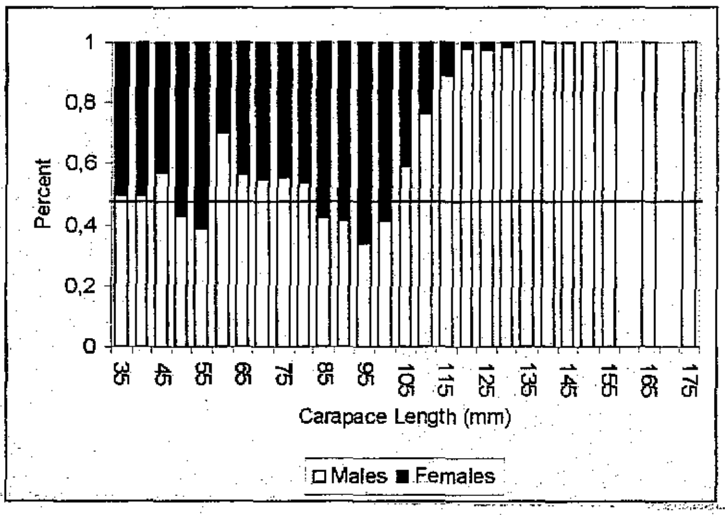


Figure 6. Sex-ratio by size classes (5mm CL) of *Chaceon affinis*.

Reproduction

Of a total of 427 female *C. affinis*, an attempt was made to determine maturity stages for 318 individuals (74.5%) using the colour of the ovaries as a criterion (see Methods).

The majority (90%) of the smaller females (< 85 mm CL) were classified from immature to early stages of ovary development. The majority (74%) of larger females ($\geq$ 85 mm CL) were classified from intermediate to mature stages. The 49 ovigerous females sampled ranged from 80 mm to 110 mm CL.

Quarterly analyses of mean gonadosomatic index (GSI), occurrence of ovigerous females and females with egg remnants seem to suggest an annual reproductive cycle with a peak of spawning activity during the fourth and first quarters (Fig. 7). The GSI increased from the first quarter to the third and decreased by the fourth. Ovigerous females occurred only in the first (4%) and fourth quarters (33%) with highest occurrence in the latter. Females with remnant eggs were found all around the year (Fig. 7).

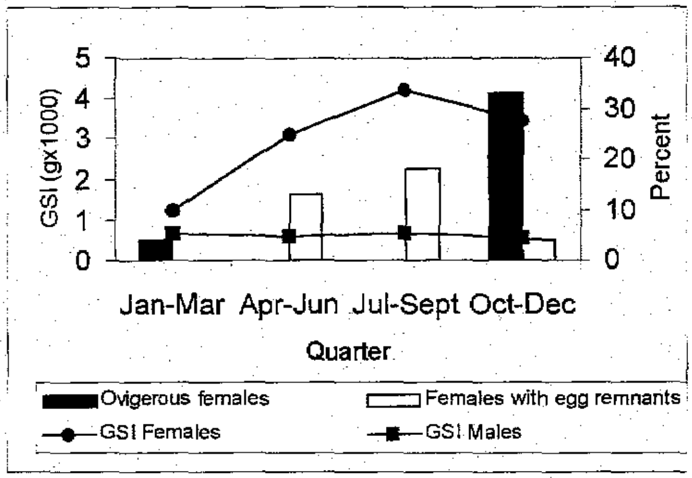


Fig. 7. Quarterly evolution of gonadosomatic index (GSI), and percentage of ovigerous females and females with egg remnants.

The majority (77%) of the larger females (≥ 75 mm CL) examined (n=288) were classified as having open and discoloured vulvae (Fig. 8).

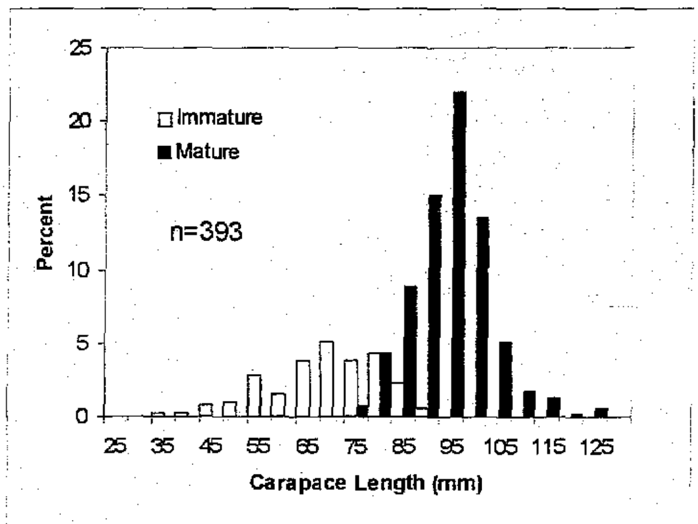


Fig. 8. Size frequency distribution of immature (closed vulvae) and mature (open vulvae) females *C. affinis*.

All the smaller immature females (<75 mm CL) had their vulvae closed and the margins intact. Females become sexually mature within the size range of 80-85 mm, with an estimated length at first maturity of 83.1 mm (Fig. 9). In males the GSI varied little throughout the year.

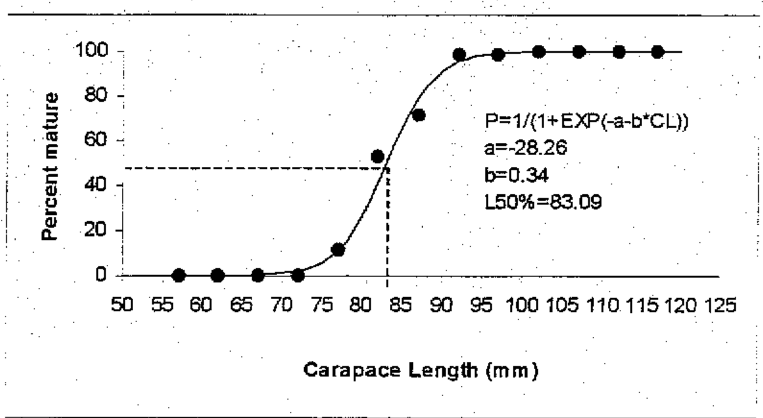


Fig. 9. Logistic curve fitted to the percentage of data classified as adult by size, to calculate the size at first maturity for females of *C. affinis*.

Parasitism and epibionts

A minor fraction of the crabs caught (2.8%) presented infection of Rhizocephala parasites (1,2% of females and 1,6% females). This infection affected mainly smaller crabs (55-90 mm CL for males and 55-80 mm CL for females) from strata deeper than 800 m (Fig. 10).

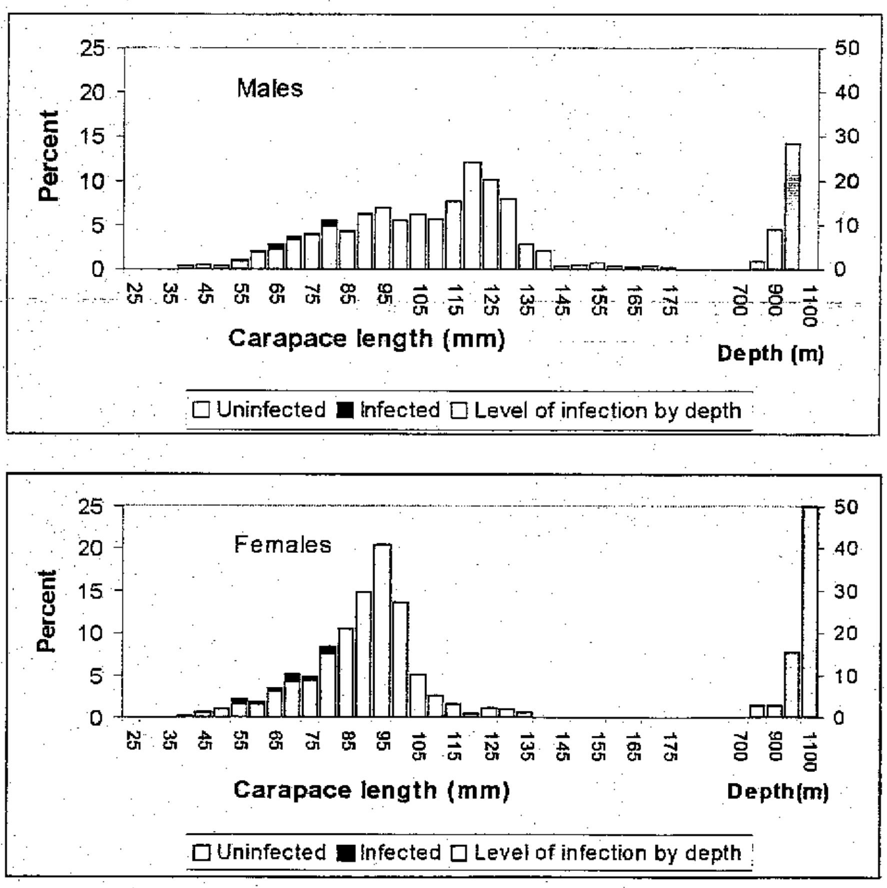


Fig. 10. Infection of Rhizocephala parasites on *C. affinis* by size classes and depth strata.

The majority of the crabs (90%) presented signs of darkly pigmented lesions of the exoskeleton caused by chitinolytic bacteria reported by Biscoito et al., (1992) from *C. affinis* and from other species of geryonid crabs by several authors Wenner et al.,1987; Bullis et al. 1988; Hines, 1990)
The presence of epibionts on the exoskeleton was recorded, mainly barnacles, which were found on 59.6% of the crabs. Two species of stalked barnacles were recorded, the white barnacle, *Poecilasma crassa* and the orange barnacle, *Poecilasma aurantia*. These species are found widespread on crabs (A. Southward pers. commn).

DISCUSSION

The fishing gear were found efficient and the Phantom Plus traps had the advantage of light weight, easy handling and stacking abilities which greatly saved deck space. Other traps used previously did not have the same advantage.
The irregular bottom topography caused some problems to the experimental design, especially in deeper strata.
The greater abundance of *C. affinis* in the Menez Gwen area could be caused by the type of sediment in the area and, the particular ecosystem of the hydrothermal vents might offer a source of attraction.
As has been reported for other geographic areas of the NE Atlantic (e.g. López-Abéllan et al., 1994; M. Biscoito, pers.commn) the maximum abundance of *C. affinis* was obtained in the 700-900 m strata.
For other species of geryonid crabs males have been reported to dominate in deeper water (Hastie, 1995). Zaferman & Sennikov (1991) found a dominance of males of *C. affinis* in strata from 900 to 1200 m N of the Azores which is contrary to our findings. The different depth distribution of the sexes is typical of Geryonid crabs and Hastie(1995) attributed this to reproductive behaviour which could be variable during a yearly cycle. However, to be sure about this sex segregation by depth in the Azores it will be necessary to increase the sampling effort in deeper strata (>1,000 m) in further studies. It will be also very useful to study the relation between abundance and bottom type.
The occurrence of ovigerous females in the fourth and first quarters has also been reported from the Canary Islands (Balgueiras et al., 1996) and Zafferman & Sennikov (1991) reported ovigerous females during autumn and winter from N of the Azores.
The determination of maturity stages by macroscopical observation of the colour of the ovaries could often be subjective and was not satisfactory carried out. A validation of the colour scale used ought to be confirmed by histological studies in the future.
Prior to the establishment of a regular fishery of this species it will be convenient to improve the biological studies, mainly on reproduction and growth. Also stock assessment should be further developed as this deep-water species would probably not support high exploitation of a long-term fishery.

ACKNOWLEDGEMENTS

First of all we would like to thank to the crew of the R/V "Arquipélago" for their friendship and help during biological sampling onboard. Also we appreciate the valuable collaboration of Afonso Marques, Filipe Porteiro, Rui Prieto and Adriana Alves during the cruises. Prof. Alan Southward kindly identified the epibiont barnacles. This study was done under the auspices of Project D.G. XIV/C 95/032 "Biology of some Macaronesian deep-sea commercial species".

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