Distribution and abundance of the argentinean (*Artemesia longinaris*) and red (*Pleoticus muelleri*) prawns (Decapoda:Penaeoidea) in Southern Brazil during the commercial double-rig trawl fishery season

Luiz Felipe C. Dumont and Fernando D'Incao

(LFCD, FD) Departamento de Oceanografia, Fundação Universidade do Rio Grande (FURG), Avenida Itália, km 7, Caixa Postal: 96201-900, Rio Grande, RS, Brasil.
(LFCD) E-mail:fdumont@vetorial.net; Phone-Fax: 0 (55) (53) 3233-6748.

Abstract

Declining in landings of more valuable prawn species, such as pink prawns *(Farfantepenaeus paulensis* and *F. brasiliensis),* expanded the targets of double-rig otter-trawlers to other species such as *Artemesia longinaris* and *Pleoticus muelleri.* In attempting to increase information on distribution and abundance of these prawns, 64 samples were analyzed in summer/2005 during the commercial trawling fishery season off Rio Grande do Sul coast. Samples were collected from a research vessel (NOc. Atlântico Sul – FURG) in depths varying between 5 and 29 as a contribution to SALVAR project. Temperature, salinity and substrate play an important role on distribution of *A. longinaris,* concentrating greater densities in areas of low temperature and high salinity, associated to summer upwelling. *Pleoticus muelleri* showed a more homogenous distribution and did not avoid areas of lower salinity under the influence of estuarine runoff. By using a swept area method, a total of 3369 tons of *A. longinaris* was estimated between isobaths of 10 and 20 meters. *Pleoticus muelleri* presented lower abundances and a total of 2527 tons was estimated by using the swept area method. Size distribution indicated that larger individuals of both species are located especially between 15 and 20. However, large individuals of *A. longinaris* clearly avoided the areas of lower salinity, suggesting that spawning takes place outside the direct influence of Patos Lagoon estuary. Conversely, *P. muelleri* takes advantage of lower salinity areas, avoided by *A. longinaris,* for spawning.

Key words: *Artemesia longinaris, Pleoticus muelleri,* distribution, abundance, environment factors, Southern Brazil.

Introduction

The argentinean (*Artemesia longinaris* Bate, 1888) and the red (*Pleoticus muelleri* Bate, 1888) prawns are monotypic and endemic species inhabiting shallow waters of southwestern Atlantic. The argentinean prawn is found from Atafona (Rio de Janeiro, Brazil, 21°37'S) to Puerto Rawson (Argentina, 43°00'S), whereas the red prawn presents a southern distribution, reaching the Santa Cruz Province (Argentina, 50°00'S) (D'Incao, 1999). These species are mainly distributed from the littoral zone to the 30 m isobaths, but occurrences at deeper waters (68 m) have been reported (Olivier *et al.,* 1968; Iwai, 1973a,b).

Both species play an important role on the trophic-web of coastal marine waters of Southern Brazil, as they are intensively predated by fishes (Capitoli *et al.,* 1994). Additionally, both species have been recently exploited by industrial and artisanal fisheries along their entire distribution area (Boschi, 1969; Valentini, *et al.,* 1991; D'Incao, *et al.,* 2002). Declining in landings of more valuable prawn species, such as pink prawns (*Farfantepenaeus paulensis* Pérez-Farfante, 1967 and *F. brasiliensis* Latreille, 1817), expanded the targets of double-rig otter-trawlers to other species such as *A. longinaris* and *P. muelleri* (D'Incao *et al.,* 2002). This commercial fishery takes place mostly in the summer, when higher landing values are usually recorded (Haimovici and Mendonça, 1996a; Pérez *et al.,* 2001).

Lack of information on the distribution and abundance of these prawns have been reported (Costa *et al.,* 2004; Costa *et al.,* 2005), especially in Southern Brazil (Nascimento, 1981; 1983, Pérez *et al.,* 2001; Dumont, 2005; Baptista-Metri, 2007). Lack of information on *P. muelleri* biology in Southern Brazil is even more noticeable, since investigations are restricted to geographical distribution (D'Incao, 1999) and landings reports (Haimovici and Mendonça, 1996b). No significant relationship between fishing effort and catches has been reported for both species, indicating that abundance is mainly regulated by environment factors (Haimovici and Mendonça, 1996b). Therefore, information on the main factors regulating distribution and abundance of *A. longinaris* and *P. muelleri* during the commercial fishery season must be investigated, as well as the main concentration areas for these species.

Material and Methods

Samples were collected during a scientific cruise, performed from February 13th to February 28th of 2005, onboard of the research vessel Atlântico Sul as part of the SALVAR project. The sampled area covered the entire coast of Rio Grande do Sul, from Santa Marta Grande Cape (28°36'S) to Chui Stream (33°45'S) in depths that ranged between 5 to 29 m, summing a total of 64 fishing stations (Figure 1). Sampling design was initially performed by separating the total area in 15 equidistant transects perpendicular to the coast line layers. Each of the 15 sectors received a number of stations proportional to its area.

To perform biological analysis of distribution and abundance, we adopted the three main areas previously defined by Vooren *et al.* (2005): a) the northern area 29°18'S and 31°13'S, b) the central area from 30°58'S to 32°14'S, and c) the southern area 32°01'S to 33°51'S. Additionally, each of the areas was further subdivided into two smaller zones according to depth (5-15 m and 16-20). The inner continental shelf subdivision was modified from Vooren *et al.* (2005) to include depth segregation.

Motivation to sub-divide each of three main areas in two groups came from previous investigation on *A. longinaris* that suggest differential size-composition according to depth (Dumont, 2008). Area 1 represents the shallow waters from southern region (5-15 m), while area 2 is located at further depths (16-20 m) also in southern region. Area 3 was located at central shore and it comprised the stations performed in depths varying from 5-15 m. Area 4 was also located in central shore, but includes only the stations performed in deeper waters (16-20 m). Areas 5 and 6 were positioned at northern shore and were also determined according to depth, in such a way that area 5 comprises shallow water stations (5-15 m) and area 6 deeper region (16-20 m) covered by the investigation cruise.

Biological samples were collected by using a prawn otter-trawl net. The footrope of the trawl net was 20 meters long, with a steel chain (1.3 kg/m) attached in attempt to increase vulnerability of prawns to the net. Mesh size (opposing knots) varied from 50 mm in the wings to 22 mm in the codend. A standardized time of trawling was adopted (30 minutes). Trawling speed was always around 5.5 km/h and distance between otterboards around 28 meters (Table I).

Total weight obtained in a fishing tow was recorded for each prawn species and sub-samples were taken to perform size-frequency analysis, and to estimate abundance in numbers. Relative abundance in weight and number was given by the total amount of catch divided by the standardized 30 minutes tows. To describe oceanographic features of shallow waters in Southern Brazil, a CTD Ocean Seven 316 (Idronaut-Italy) was used, registering temperature (°C), salinity (PPS-78) and depth of water column, always after each fishing station. The sediment type was classified according to samples obtained by using a Van Veen dredge and Scientific Ecosound SIMRAD EK-500 and classified as silt, mud and sand.

Carapace length (CLmm) was used to describe size structure of prawn stocks exploited by commercial trawlers and measured from post-orbital angle to the end of posterior carapace margin. Sex was determined through secondary sexual traits and proportion of megaspawners in each area was estimated. Only females larger than the size class in which the probability of being ripe was 100% (LM_{100}) were considered as megaspawners. To estimate LM_{100} a logistic model was adjusted to frequency of ripe females and values obtained were 22 mm (CL) and 26 mm (CL) for *A. longinaris* and *P. muelleri*, respectively (data not shown).

Relative abundance (CPUE) data was tested for normality (Lilliefor's < 0.2) and homogeneity of variances (Levene's > 0.05) prior to perform ANOVA and post-hoc Tukey's test (0.05). Normality was achieved for all groups, whereas homogeneity of variance was not. Differences in mean relative abundances and sizes were tested between the six areas previously described. The influence of environmental factors on the CPUE (kg/30 min) of *A. longinaris* and *P. muelleri* was assessed by a multiple regression analysis.

Swept area method was applied to estimate a total stock biomass available during the commercial fishery season. The swept area was estimated by the following equation:

$$a = W*TV*D,$$

where W is the effective width of the trawl net, TV is the towing velocity and D is the duration of the tow. Once swept area is estimated, total biomass in the fishing ground was given by:

$$B = Cw/v*(A/a),$$

where Cw is the catch per unit of effort, v is the vulnerability of prawns to the net, A is the total area and a is the swept area. Since high dispersion of CPUE values were noticed, total biomass was estimated for each of the six areas previously de-

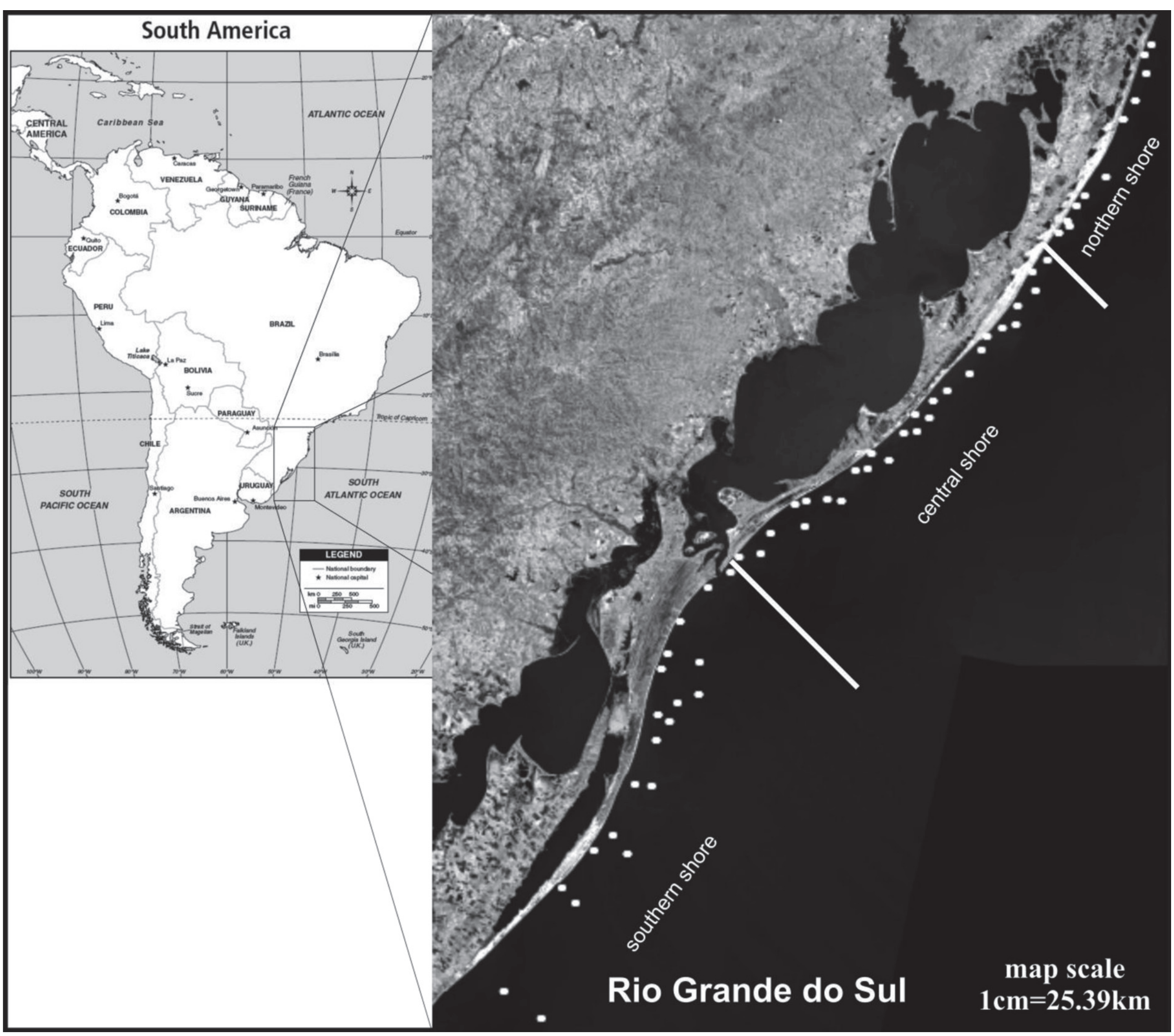

Figure 1. Rio Grande do Sul (Southern Brazil) and the three main sampling areas investigated during summer/2005. Each sampling area was subdivided into two subareas according to depth. White dots represent the fishing stations performed between 5 and 29 m.

Table I. Summary of fishing stations performed during summer/2005 off the coast of Rio Grande do Sul (Southern Brazil), containing position of trawl, environment parameters and net properties used to estimate total biomass through swept area method.

latitude	longitude	depth	surface temperature (°C)	bottom temperature (°C)	surface salinity	bottom salinity	net oppening (m)	trawl distance (m)	swept area (m^2)
33 51.402	52 54.624	29	22.9	22.9	34.0	34.1	19.36	4221.1	81707.5
33 45.511	53 05.567	23	23.1	23.6	34.4	35.0	17.46	3162.8	55233.1
33 25.365	52 46.994	17	23.5	23.7	33.9	34.0	15.52	4050.1	62845.7
33 21.803	52 50.218	10	24.1	23.7	33.6	33.7	13.31	2834.2	37716.6
33 13.064	52 41.246	10	24.0	23.8	33.8	33.9	13.31	2284.6	30403.2
33 09.812	52 34.276	13	23.4	23.5	34.2	34.2	14.25	3286.6	46849.6
33 13.247	52 30.505	15	23.5	23.5	33.6	33.6	12.83	2739.4	35158.4
32 58.581	52 29.581	12	23.5	23.4	34.2	34.2	17.04	4452.2	75875.4
32 58.647	52 25.520	16	23.4	23.3	33.9	33.9	15.20	4296.0	65305.8
32 48.475	52 23.518	13	23.7	23.6	33.6	33.8	14.25	4238.3	60414.9
32 42.200	52 22.552	10	23.4	23.5	34.2	34.2	16.53	3327.1	54986.4
32 43.562	52 19.700	13	23.5	23.5	34.1	34.2	8.63	2970.3	25623.0
32 38.841	52 16.339	14	23.6	23.5	34.3	34.3	21.04	2694.2	56687.1
32 36.996	52 12.223	17	23.9	23.3	34.3	34.3	17.57	3392.8	59605.5
32 31.612	52 21.795	8	24.3	23.8	34.3	34.4	12.68	3578.5	45363.9
32 27.399	52 19.881	8	24.1	24.1	34.2	34.3	12.68	1523.2	19308.9
32 29.725	52 11.585	17	23.5	23.4	34.3	34.3	15.52	2790.8	43305.2
32 20.712	52 16.581	9	24.4	23.9	34.5	34.4	13.26	2903.4	38484.6
32 12.378	52 09.175	7	24.6	23.8	34.5	34.5	9.05	3003.4	27172.4
32 04.704	51 54.658	13	24.3	23.5	34.5	34.6	15.52	3273.4	50793.7
32 04.282	51 59.069	8	24.2	24.2	34.5	34.5	12.68	3276.8	41538.8
32 07.822	52 01.616	9	23.9	23.9	35.9	35.9	3.88	3317.5	12878.1
30 58.335	50 39.646	12	23.9	22.7	36.2	36.0	14.41	3200.3	46123.8
30 50.819	50 33.936	11	23.8	23.1	36.2	36.2	14.41	3962.0	57101.8
30 46.312	50 30.248	10	23.8	23.7	36.1	36.0	18.15	3565.2	64697.2
30 47.590	50 29.508	14	24	21.8	36.2	36.2	14.41	3679.0	53023.3
30 44.770	50 28.920	12	24.4	22.5	36.0	36.1	14.41	3666.4	52841.4
29 24.074	49 44.343	18	22.1	20.5	36.1	36.1	15.99	3384.7	54122.9
29 27.896	49 48.401	9	21.5	20.9	35.6	36.1	11.78	3321.7	39137.6
29 36.304	49 54.376	8	23	20.7	36.2	36.1	10.73	3294.1	35347.2
29 41.381	49 56.697	19	21.8	20.4	36.0	36.1	12.83	3607.3	46297.0
29 47.961	50 01.161	12	23.3	20.6	36.0	36.1	14.41	3452.3	49755.6
29 56.114	50 05.130	10	23.3	20.5	35.3	36.2	12.31	3224.7	39690.6
30 05.373	50 08.233	19	21.6	20.4	36.1	36.2	17.04	3599.7	61348.3
30 07.832	50 10.054	12	21.4	20.6	36.1	36.3	13.36	3459.0	46214.3
30 11.902	50 09.711	20	22.2	20.9	36.0	36.2	14.4	3489.3	50289.9
30 18.499	50 12.590	18	22.3	21.6	36.0	36.2	13.4	3520.1	47029.
30 22.826	50 15.800	10	22.7	21.8	36.1	36.2	14.4	3407.8	49115.2
30 36.045	50 20.125	17	23.3	22.9	36.0	36.2	14.4	3769.3	54325.3
30 40.426	50 25.709	12	23.9	22.3	35.9	36.3	14.4	3259.3	46975.0
30 55.603	50 35.494	17	22.7	20.4	36.2	36.3	17.6	3737.3	65657.7
31 02.403	50 38.770	18	23.3	19.9	36.0	36.2	17.6	3691.2	64848.5
31 05.986	50 43.473	15	21.4	20.3	36.2	36.3	16.0	5063.9	80973.5
31 10.436	50 44.316	18	23.1	19.6	35.8	36.2	14.4	3907.7	56319.2
31 11.279	50 47.540	16	22.4	20.8	36.1	36.2	17.6	3414.1	59980.6
31 13.409	50 51.570	12	22.6	20.5	35.3	36.1	14.9	3435.9	51327.0
31 18.128	50 54.888	17	22.7	20.6	35.9	36.1	16.0	4695.1	75323.0
31 22.155	50 56.364	20	22.4	20.7	35.9	35.9	16.0	3414. 6	54779.8
31 26.138	51 02.602	19	22.7	21.9	35.8	35.8	16.0	3012.3	48325.7
31 28.321	51 06.235	15	23.6	23.6	35.8	35.8	14.9	3282.9	49040.9
31 31.398	51 11.046	9	24.2	24	35.9	35.9	14.4	3211.6	46287.1
31 32.370	51 07.309	19	23.3	23.1	35.8	35.8	16.0	2919.0	46676.4
31 35.916	51 10.244	17	23.9	23.6	35.4	35.7	14.9	3203.7	47858.7
31 35.830	51 14.125	15	24.2	24.2	35.7	35.7	16.0	3129.7	50044.5
31 42.103	51 17.888	18	24.2	23.7	35.5	35.6	17.0	3725.4	63490.2
31 40.804	51 22.835	12	24.7	24.4	35.6	35.6	14.4	3264.3	47046.3
31 44.276	51 23.872	16	24.7	24.3	35.5	35.5	15.5	3321.0	51356.7
31 44.813	51 27.375	14	25	24.4	35.2	35.5	14.4	2788.9	40194.1
31 51.658	51 31.206	20	24.7	23.9	35.2	35.5	14.9	3033.5	45316.4
31 51.784	51 34.606	17	24.7	24.6	35.3	35.5	14.4	3235.3	46629.1
31 51.795	51 40.700	15	25	24.8	35.2	35.3	15.5	2986.7	46188.1
31 53.317	51 45.486	13	25.1	24.9	34.8	35.2	15.5	3596.3	55614.1
31 57.377	51 41.011	17	24.6	24.5	35.3	35.6	17.0	3419.3	58273.4
31 58.791	51 50.383	13	24.9	25.2	35.7	35.8	17.0	3662.4	62415.5

scribed and total biomass was obtained by adding each of these values.

Vulnerability of prawns and fish to trawling nets is difficult to estimate (King, 1997). Values ranged from 0.5 to 1.0 and a value of 0.75 was adopted, since it represented the most coherent results among all the values tested (0.5-1.0 data not showed). Dimensions of each of the 6 areas were obtained from Weigert *et al.,* 2005 and values ranged from 3110 km^2 (area 2) to 332km^2 (area 5). Geographic Information System (GIS) was used to perform interpolation (natural neighbor) of biomass/km^2 data that was mapped to create visual representation of stock densities and confronted to interpolations created by using environmental parameters. Parameters used in environment data interpolation were bottom salinity and temperature, as well as sediment type. This analysis was performed in attempt to identify main fishing grounds, for argentinean and red prawns in Southern Brazil as well as the main factors influencing species distribution during commercial fishing season.

Results

Environmental factors

Overall distribution of water temperature showed a trend of warmer waters in near shore areas, except in areas 5 and 6, where bottom temperature in shallow waters (5-15) was lower than in further depths (15-20 m) (Figure 2). Lower mean bottom salinity values were recorded in shallower waters, whereas saltier water was found at deeper stations.

Lower salinities and higher temperatures were observed in areas 1 and 2, located at southern shore of Rio Grande do Sul State (Figure 2, 3). The areas 3 and 4 represented a transitional area, where salinity increases and temperature decreases, evidenced by wide confidence intervals observed. Central and northern shores were under the influence of Tropical Water (TW) explaining higher salinity values recorded. In addition, intrusions of colder oceanic water, in central and northern

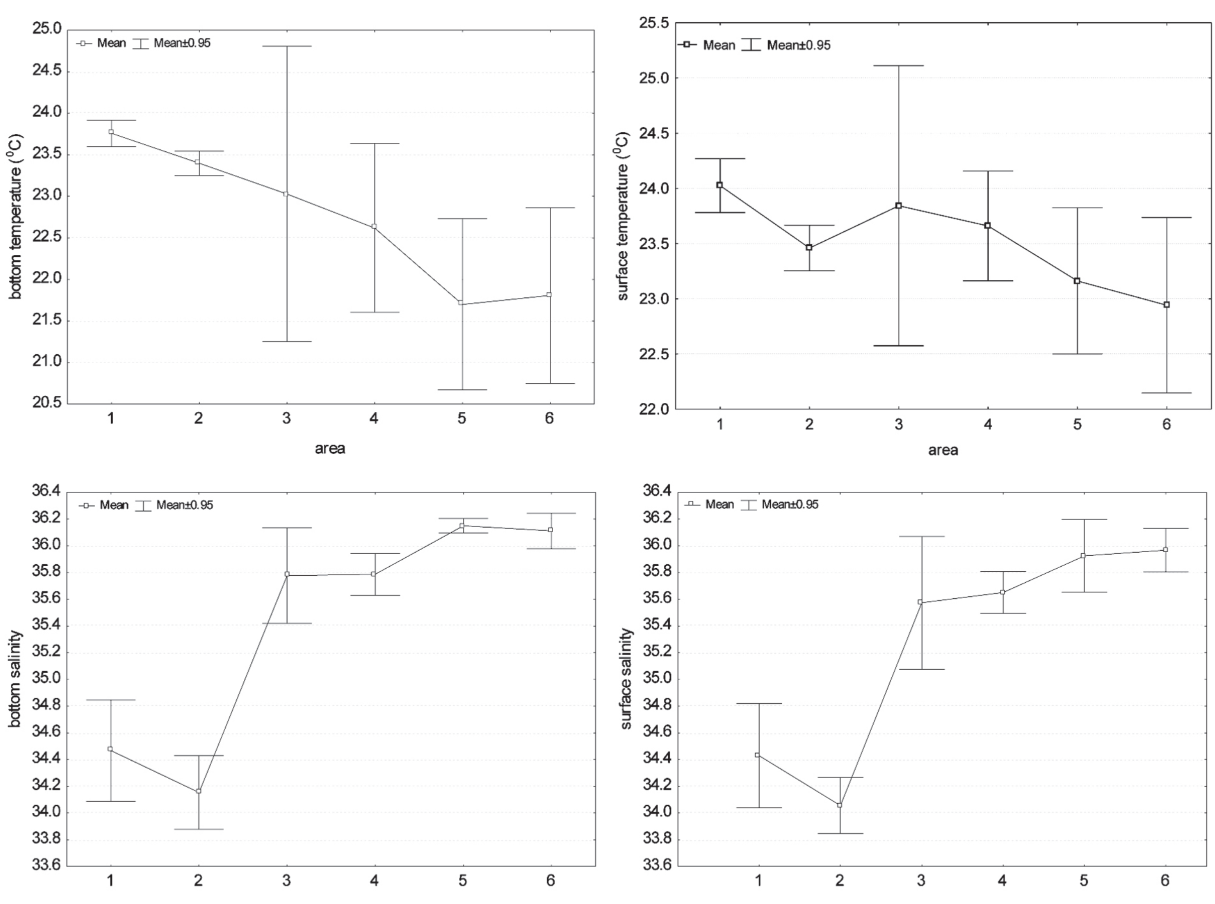

Figure 2. Trends in mean salinity and temperature (bottom and surface), recorded in Southern Brazil during summer/2005, for each of the six areas previously determined.

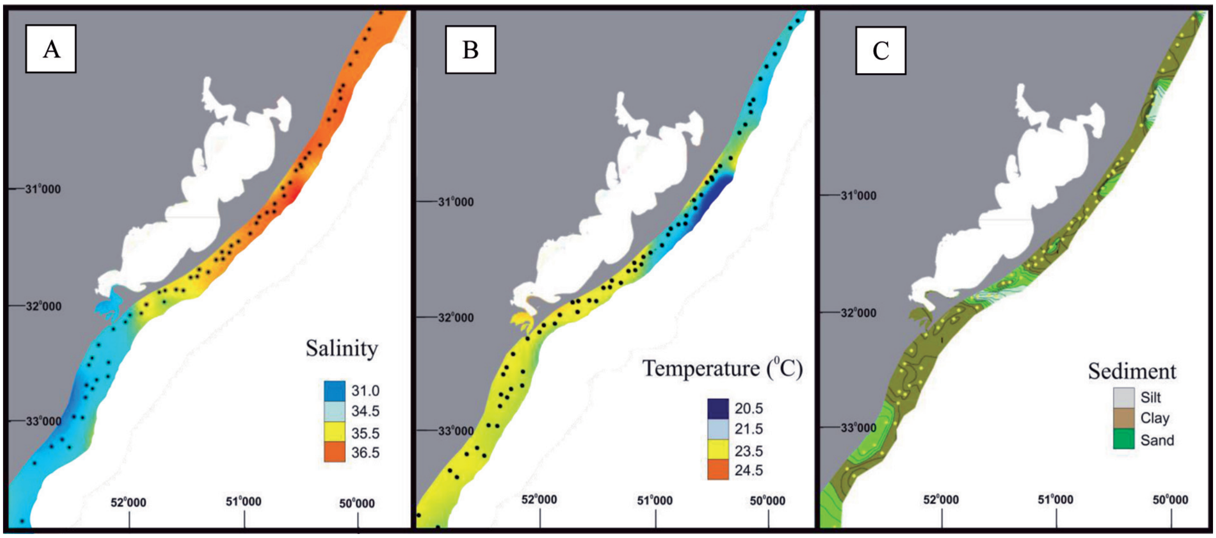

Figure 3. Contour maps of environmental parameters (A- salinity, B- temperature, and C- sediment type). Interpolation based on data collected during summer/2005 in the coast of Rio Grande do Sul, Southern Brazil. Dots represent fishing stations where information was collected.

shores were clearly detected when analyzing bottom water temperature and salinity contour maps (Figure 3a, 3b). Larger continuous areas of fine sediments (silt and clay) were observed in southern areas, while central and northern areas presented sparse distribution of these bottom types. In central areas, fine sediments grounds stretch from 20 meters isobaths to littoral zone as well as in southern area. Conversely, in northern area fine sediments are distributed in deeper stations away from the coast (Figure 3c).

Distribution and abundance of the argentinean and red prawn

Artemesia longinaris and *P. muelleri* were the most abundant prawn species caught during the summer, in weight or number. Both species were captured in 86% of tows and occurred at approximately same fishing stations. A total of 513.2 kg of *A. longinaris* and 282.2 kg de *P. muelleri* were captured during present investigation.

Mean CPUE (kg/30 min) values of the argentinean prawn ranged from 0.7 in area 5 to 21.8 in area 4. High densities were recorded in the central shore (both areas 3 and 4) as well as in deeper areas of northern shore (area 6), composing a distinct group in post-hoc Tukey's test. Conversely, lower abundances were observed in southern region (both areas 1 and 2) as well as in shallow waters of northern region (area 5) (Table II).

Unlike *A. longinaris,* the red prawn *P. muelleri* showed a more homogenous distribution in commercial fishing grounds during summer. Mean CPUE values ranged from 1.0 in area 5 to 6.9 in area 4. Significantly higher CPUE values were observed for *P. muelleri* only in area 4, while all the other five areas were not significantly different (Table III).

Multiple linear regression indicated bottom temperature as the main variable affecting relative abundance in weight (CPUE) of *A. longinaris* ($B = -0.32$, $p = 0.01$, $R^2 = 0.39$), with higher densities at lower temperatures. Conversely, no significant factors were estimated to explain *P. muelleri* abundance, reflecting a more homogeneous distribution of this species.

According to the swept area method, and considering the vulnerability of prawns to the net at 75%, an amount of 3369 tons of *A. longinaris* was estimated to be available between the isobaths of 10 and 20 meters. Assuming a similar distribution of the stock in the adjacent areas (< 10 and from 20 to 30), extrapolation of the values obtained, to an area stretching from 0 to 30 meters resulted in a total of 6069.02 tons for the entire fishing area covered by the commercial fleet (17349.46 km^2). Area 4 yielded a total of 2421 tons presenting the highest biomass recorded during the scientific cruise. Conversely, the lowest biomass was recorded in area 5 (2.0 tons) which is represented by shallow waters of the northern shore (Figure 4, Table IV).

Lower biomass of *P. muelleri* was estimated, summing a total of 2527 tons from 10 to 20 m range. Extrapolation of biomass estimated to total fishing area (17349 km^2) resulted in an estimate of 4594 tons. Highest biomass was observed in area 4 (851.69 tons) and lower in area 5 (6.63 tons) (Table V). Unlike *A. longinaris,* this species showed higher biomass even in the areas influenced by estuarine runoff, positioned southwards to latitude 32°S (Figure 5).

Size-frequency analysis

Carapace length of argentinean prawn females ranged from 2 to 30 mm, while in males ranged from 1 to 22 mm. The red prawn, presented carapace length values that varied from 1 to 41 mm for females and males from 1 to 26 mm. Mean CL comparison pooled by sex showed significant

Table II. *A. longinaris.* Summary of descriptive statistics obtained from mean CPUE values, containing number of stations (n), mean CPUE (kg/30 min), standard deviation (s.d.), standard error (s.e.) as well as 95% confidence intervals of means. Superscript letters within brackets indicate non-significant differences between groups, estimated trough Tukey's test.

area	n	CPUE (kg/30 min)	s. d.	s. e.	CI (95%)	
overall	64	8.6	20.6	2.6	3.4	13.7
1[(a)]	12	0.9	0.6	0.2	0.4	1.3
2[(a)]	10	3.2	2.9	0.9	1.1	5.2
3[(b)]	7	8.1	14.6	5.5	-5.5	21.6
4[(b)]	15	21.8	36.8	9.5	1.5	42.2
5[(a)]	8	0.7	0.9	0.3	-0.1	1.4
6[(b)]	12	9.7	14.7	4.3	0.4	19.1

Table III. *P. muelleri.* Summary of descriptive statistics obtained from mean CPUE values, containing number of stations (n), mean CPUE (kg/30 min), standard deviation (s.d.), standard error (s.e.) as well as 95% confidence intervals of means. Superscript letters within brackets indicate non-significant differences between groups, estimated trough Tukey's test.

area	n	CPUE (kg/30 min)	s. d.	s. e.	CI (95%)	
overall	64	4.3	6.0	0.8	2.8	5.8
1[(a)]	12	4.7	5.6	1.6	1.1	8.2
2[(a)]	10	4.5	3.2	1.0	2.2	6.8
3[(a)]	7	3.7	3.3	1.2	0.7	6.7
4[(b)]	15	6.9	9.5	2.4	1.7	12.2
5[(a)]	8	1.0	1.9	0.7	-0.6	2.6
6[(a)]	12	3.2	5.1	1.5	0.0	6.4

Table IV. *A. longinaris.* Summary of swept area method estimates for each of the six areas in the Southern coast of Brazil, containing number of fishing stations (n), mean density (ton/km^2) and confidence intervals (CI ± 95%), swept area (km^2), total area (km^2) and biomass estimates (ton). Bold value at bottom right corner represents the sum of biomass obtained from six areas.

area	n	mean ton/km^2	CI (± 95%)		swept area (km^2)	total area (km^2)	biomass (ton)
1	12	0.072	0.048	0.096	624.10	2292.40	165.05
2	10	0.123	0.072	0.175	403.16	3110.72	382.62
3	7	0.165	-0.107	0.438	406.18	816.51	134.72
4	15	1.149	0.026	2.271	777.28	2107.12	2421.08
5	8	0.006	0.000	0.011	533.90	332.54	2.00
6	12	0.244	0.017	0.471	490.04	884.53	215.83
sum							3368.97

Table V. *P. muelleri.* Summary of swept area method estimates for each of six areas in the coast of Southern Brazil, containing number of fishing stations (n), mean density (ton/km^2) and confidence intervals (CI ± 95%), swept area (km^2), total area (km^2) and biomass estimates (ton). Bold value at bottom right corner represents the sum of biomass obtained from six areas.

area	n	mean ton/km^2	CI (95%)		swept area (km^2)	total area (km^2)	biomass (ton)
1	12	0.364	0.171	0.557	624.10	2292.40	834.87
2	10	0.227	0.118	0.336	403.16	3110.72	705.79
3	7	0.071	0.004	0.138	406.18	816.51	58.03
4	15	0.404	0.093	0.716	777.28	2107.12	851.69
5	8	0.020	-0.011	0.051	533.90	332.54	6.63
6	12	0.079	0.002	0.157	490.04	884.53	70.23
sum							2527.23

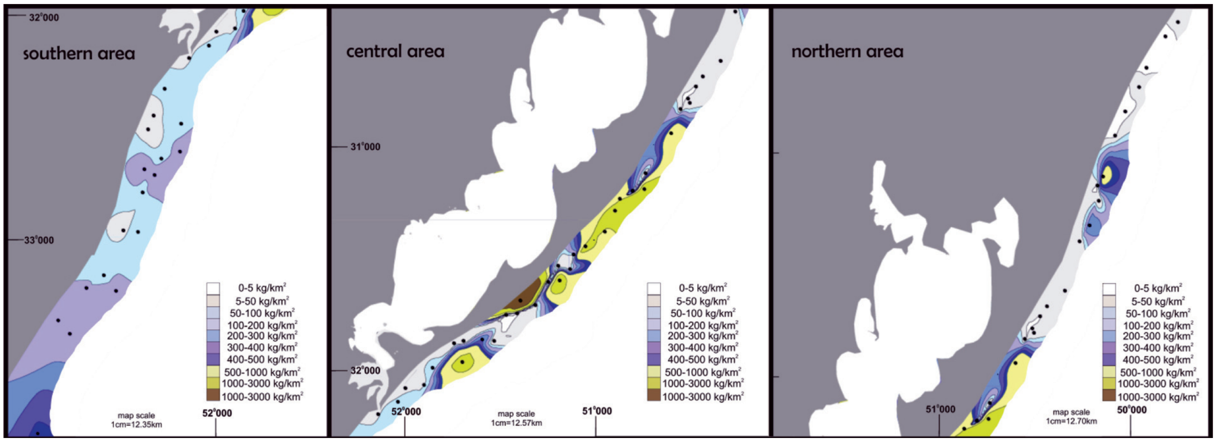

Figure 4. *A. longinaris.* Contour map showing densities of the argentinean prawn (kg/m²) in Southern Brazil during summer/2005, estimated by swept area method and considering vulnerability as 75%. Three main areas are showed (southern, central and northern) and extremes of each are overlapped.

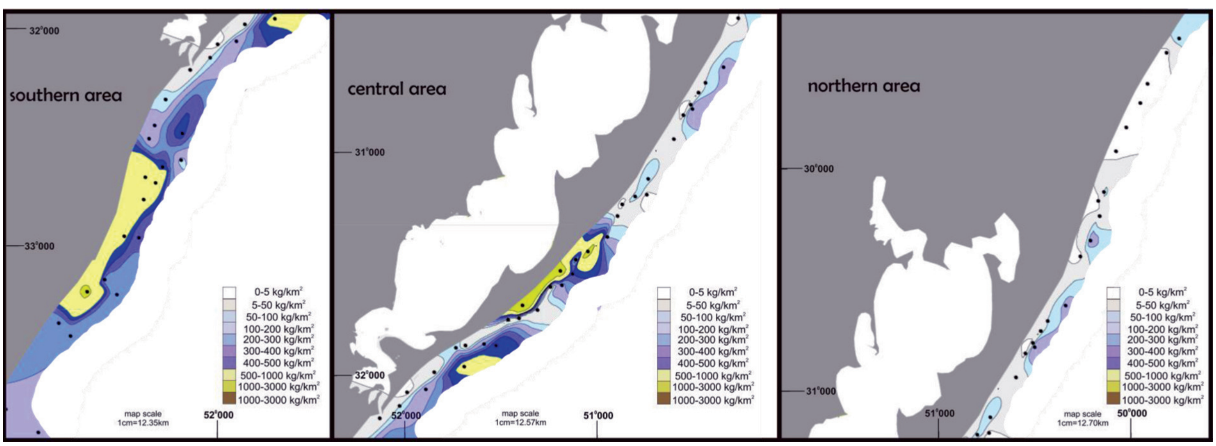

Figure 5. *P. muelleri.* Contour map showing densities of the argentinean prawn (kg/m²) in Southern Brazil during summer/2005, estimated by swept area method and considering vulnerability as 75%. Three main areas are showed (southern, central and northern) and extremes are overlapped.

differences ($p < 0.05$), suggesting size dimorphism related to sex, that is, females are larger for both species analyzed.

Largest females of *A. longinaris* inhabit area 6, located at deeper isobaths at northern shore of Rio Grande do Sul State. Zones 3 and 4 also showed high mean CL values, but these figures were not significantly different from the other areas (Table VI). Smallest males were found mainly in the southern region, forming a significant different group from the other regions. Accordingly to females, highest mean CL value of females was recorded in northern shore at the deeper area (area 6), but of non-significant differences was found compared to areas 5, 4 and 3 (Table VII).

Significant larger mean sizes of the red prawn females were detected in zones 2 and 6, while smaller ones were located at zone 3, corresponding to shallower waters in central shore. (Table VIII). Males from area 4 were significantly larger than the rest of regions, followed by those from area 2

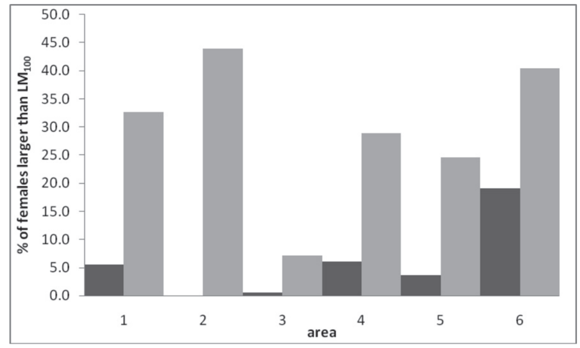

Figure 6. Relative frequency of *A. longinaris* (dark bars) and *P. muelleri* (light bars) megaspawners (females larger than LM_{100}) per area in southern coast of Brazil.

Table VI. *A. longinaris* – females. Summary of descriptive statistics obtained from mean carapace length (CL), containing number of prawns measured (n), mean carapace length (CLmm), standard deviation (s.d.), standard error (s.e.) as well as 95% confidence intervals of means. Superscript letters within brackets indicate non-significant differences between groups, estimated trough Tukey's test.

area	n	mean CL (mm)	s.d.	s.e.	CI (± 95%)	
overall	1763	15.07	3.63	0.09	14.90	15.24
1(a)	264	13.09	1.62	0.10	12.89	13.29
2(a)	30	13.17	1.34	0.24	12.67	13.67
3(a)	344	15.36	3.42	0.18	14.99	15.72
4(a)	606	15.13	3.68	0.15	14.83	15.42
5(a)	192	14.34	3.83	0.28	13.80	14.89
6(b)	327	16.86	3.98	0.22	16.42	17.29

Table VII. *A. longinaris* – males. Summary of descriptive statistics obtained from mean CPUE values, containing number of prawns measured (n), mean carapace length (CLmm), standard deviation (s.d.), standard error (s.e.) as well as 95% confidence intervals of means. Superscript letters within brackets indicate non-significant differences between groups, estimated trough Tukey's test.

area	n	mean CL (mm)	s.d	s.e	CI (± 95%)	
overall	1049	13.07	2.26	0.07	12.93	13.21
1(a)	123	11.69	1.13	0.10	11.49	11.89
2(a)	32	11.74	0.98	0.17	11.39	12.09
3(b)	170	12.98	2.19	0.17	12.65	13.31
4(b)	533	13.46	2.21	0.10	13.27	13.64
5(b)	93	12.89	2.89	0.30	12.29	13.49
6(b)	98	13.48	2.46	0.25	12.99	13.98

Table VIII. *P. muelleri* – females. Summary of descriptive statistics obtained from mean CPUE values, containing number of prawns measured (n), mean carapace length (CLmm), standard deviation (s.d.), standard error (s.e.) as well as 95% confidence intervals of means. Superscript letters within brackets indicate non-significant differences between groups, estimated trough Tukey's test.

area	n	mean CL (mm)	s.d.	s.e.	CI (± 95%)	
overall	1443	17.75	5.07	0.13	17.49	18.01
1(a)	291	17.11	3.76	0.22	16.68	17.55
2(b)	66	18.37	3.04	0.37	17.62	19.11
3(c)	209	15.20	2.77	0.19	14.82	15.58
4(a)	395	17.52	4.51	0.23	17.08	17.97
5(a)	114	17.21	3.32	0.31	16.59	17.82
6(b)	368	20.01	7.03	0.37	19.29	20.73

Table IX. *P. muelleri* – males. Summary of descriptive statistics obtained from mean CPUE values, containing number of prawns measured (n), mean carapace length (CLmm), standard deviation (s.d), standard error (s.e.) as well as 95% confidence intervals of means. Superscript letters within brackets indicate non-significant differences between groups, estimated trough Tukey's test.

area	n	mean CL (mm)	s.d	s.e	CI (± 95%)	
overall	781	15.53	2.75	0.10	15.34	15.72
1(a)	204	15.10	2.56	0.18	14.75	15.46
2(a)	60	15.89	2.45	0.32	15.26	16.52
3(a)	114	14.44	1.97	0.18	14.07	14.81
4(b)	192	16.64	2.67	0.19	16.26	17.02
5(a)	42	15.43	3.13	0.48	14.45	16.40
6(a)	169	15.43	3.07	0.24	14.96	15.89

(Table IX). Except by the pattern of higher mean CL recorded in shallower waters of central region observed for *A. longinaris* females, all the other regions that presented larger individuals, of both sexes and species, were concentrated in deeper areas.

Comparison of percentage of *A. longinaris* megaspawners, between six areas analyzed, also showed higher frequency in deeper areas, suggesting spawning activity. Frequency of megaspawners, was higher in area 6, and showed an increasing pattern from southern to northern region. Conversely, *P. muelleri* presented higher percentage of megaspawners in southern region, under the influence of estuarine runoff. This species also showed a high frequency of megaspawners in region six as well as *A. longinaris* (Figure 6).

Discussion

Environmental parameters

Trends in temperature and salinity followed the same pattern as observed in other coastal areas where *A. longinaris* and *P. muelleri* were investigated (Boschi, 1969; Costa *et al.,* 2005), with lower temperatures in deeper waters and lower salinities nearshore. It is also possible to observe that the southern region is influenced by Coastal Water (CW) (Vooren *et al.,* 2005), highly affected by Patos Lagoon and La Plata River runoff (Piola *et al.,* 2004, 2005), resulting in higher temperatures and lower salinities.

Another important oceanographic feature observed was the intrusion of colder waters from depths beyond 30 m, influencing deeper areas in central and northern shores of Rio Grande do Sul coast. The occurrence of this phenomenon is linked to summer upwelling over the Southern Brazil continental shelf. Upcoming of oceanic water during summer is explained by predominant northeast wind that pushes surface water offshore resulting in resurgence of colder and saltier oceanic waters (Garcia, 1996).

Distribution and abundance

Environmental factors determine to a large extent the abundance and distribution of prawn populations (Gulland and Rotschild, 1981). Both prawn species analyzed showed same general environmental requirements (Costa *et al.,* 2004; *Costa et al.,* 2005), since they occurred at approximately same fishing stations. In spite of that, *P. muelleri* showed a more homogeneous distribution than *A. longinaris,* tolerating areas of lower salinities and higher temperatures in southern shore of Rio Grande do Sul. High level of scattering around mean abundance values suggests patchy distribution for both species, concentrating elevated abundances in areas where environmental conditions are favorable.

The abundance of *A. longinaris* was partially explained by water temperature, presenting a clear preference for areas where lower values for this parameter were recorded. Same pattern was observed by Costa *et al.* (2005) in Southeastern Brazil (São Paulo), with higher abundances linked to intrusion of colder and saltier oceanic waters. This species has a life cycle where adult females migrate to further depths for spawning (Boschi, 1969; Dumont, 2008) and ontogenetic development is entirely completed in marine waters (Dall *et al.,* 1990), explaining the affinity for deeper areas.

Additionally to the influence of temperature and salinity, the distribution pattern was also influenced by sediment type, in such a way that fine granulometry sites provide suitable grounds for this species (Costa *et al.,* 2005), which is also verified for other penaeid species in literature (Gulland and Rotschild, 1981; Somers, 1987). The importance of sediment type for distribution of both species is not easily noticed when analyzing the abundance in shallow waters of northern shore. Salinity and temperature are favorable in this area; however the relative abundance of both species was the lowest. A likely explanation for this observation is the consolidated sandy bottom registered in this region, which may prevent prawns from entering this area.

Baptista-Metri (2007) analyzed relative abundance of *A. longinaris* and *P. muelleri* in the coast of Rio Grande do Sul, identifying two main areas where densities of these species are the highest. The first area coincides with a soft bottom (mud) observed in southern shore (areas 1 and 2), where *P. muelleri* was very abundant. High densities of prawns were also associated to soft bottoms (mud and clay) in central and northern shores, especially in areas between 15 and 20 meters, agreeing with previous reports on distribution of these species during commercial fishery season (Baptista-Metri, 2007).

Maximum sustainable yields (MSY) suggested for *A. longinaris* is 3579 ton/year (Baptista-Metri, 2007). This volume of catch represents 59% of biomass estimated during the investigation cruise analyzed, which may represent an excessive fishing mortality for the stock even if trends in biomass occurs along the main fishing season. Mean annual catches of this species is 2700 tons (Valentini and Pezzuto, 2005), however, reductions in landings during the last few years may indicate first signs of excessive fishing effort. The combination of elevated fishing mortality with adverse environment conditions may lead to recruitment overfishing if spawning stock is drastically reduced (Dumont, 2008).

Additionally, patchy distribution of the stock results in intense fishing effort extremely concentrated in areas where abundance is high. During present scientific cruise a great concentration of prawn trawlers was observed in areas 3 and 4 (Dumont, *personal observation*), coinciding with most abundant areas. As a result of that, fishing effort can remove great amounts of prawn in a short time period. Similarly, maximum sustainable yield suggested for *P. muelleri* (4447 ton/year) (Baptista-Metri, 2007) may be excessive, especially during seasons of adverse environment conditions. Assuming that stable biomass is maintained during commercial fishing season, the MSY reported would remove approximately 97% of biomass estimated resulting in total depletion of the stock. It is important to point out that this resource is also fished in Santa Catarina state and biomass estimates comprise only the stock inhabiting Rio Grande do Sul coast, resulting in an underestimated biomass of prawns. However, most of the catch is obtained from Rio Grande do Sul Coast and only landed in Santa Catarina (Baptista-Metri, 2007), indicating that for stock assessment purposes, biomass sustaining the fishery is located at Rio Grande do Sul coast.

It is also important to point out that vulnerability adopted may not exactly reflect the real value. Additionally, different species may present distinct catchability to prawn nets, related to behavior (e.g. burrowing or swimming habits) and environment parameters (e.g. turbidity and temperature) (Garcia and Le Reste, 1981). Therefore, values obtained must be taken as rough approximations, since vulnerability coefficient to trawl nets adopted was an intermediate value suggested by King (1997) that range from 50% to 100%. Vulnerability suggested for other crustaceans such as hermit crabs caught by a 2 m wide beam trawl is 51% (Reiss *et al.,* 2005) and therefore, vulnerability adopted by using a much larger net, towed by a much more powerful engine may represent a coherent value. On the other hand, the 100% vulnerability is very unlike, since prawns have a considerable swimming and burrowing capability and therefore escape from the net to a certain extent (Gulland and Rotschild, 1981).

Length distribution obtained from catches of *A. longinaris* indicate that smaller prawns of both sexes tend to inhabit lower salinity areas, under the influence of estuarine runoff, while largest females were mainly found in deeper areas where salinity is higher and temperature is lower. As previously discussed, marine prawns (life cycle type III according to Dall *et al.,* 1990) tend to migrate offshore to complete ovarian development and spawning (Garcia and Le Reste, 1981). Mating also seems to occur in spawning areas, since larger males were found concurrently with larger females. Percentage of megaspawners also suggests a more intense spawning activity in deeper areas, mainly in northern shore where the salinity was higher.

Conversely, *P. muelleri* also presented an important density of large females and males inhabiting the southern areas under the influence of estuarine runoff. Greater tolerance to lower salinity of this species may explain this pattern, since important abundances of large individuals and frequency of megaspawners in southern areas were verified. Nevertheless, the deeper area in central region concentrated higher densities of this species. If on one hand both prawn species analyzed presented similar environment requirements, on the other, competition may explain the more homogenous distribution of *P. muelleri* that searches for alternative spawning areas and therefore, reduces intraspecific competition.

Briefly, distribution of both species analyzed is patchy and related to environmental variations such as those caused by summer upwelling, making fishing effort intense and concentrated on relatively small areas. For instance, 77% of total biomass estimated for *A. longinaris* was restricted to 12% of total area available for prawn trawling, demanding a regulation in fishing effort applied. The use of try nets aggravates this problem since cost for searching for schools is reduced and main fishing grounds do not show remarkable yearly variations (Baptista-Metri, 2007), which was confirmed by the large number of boats observed in fishing in areas of highest abundance during the present investigation.

Acknowledgements

The authors would like to express their gratitude to Dr. C. M. Vooren and the SALVAR project for support in the developement of this research.

References

Baptista-Metri, C., 2007. Biologia pesqueira de *Artemesia longinaris* Bate, 1888 (Decapoda, Dendrobranchiata, Penaeidae) e de *Pleoticus muelleri* Bate, 1888 (Decapoda, Dendrobranchiata, Solenoceridae) no Sul do Brasil. PhD. Thesis, Universidade Federal do Paraná, Curitiba, 218 pp.

Boschi, E. E. 1969. Estudio biológico pesquero del camarón *Artemesia longinaris* Bate de Mar del Plata. Boletin del Instituto de Biologia Marina, Mar del Plata, Buenos Aires, 18:1-47.

Capitoli, R. R.; Bager, A. and Ruffino, M. L. 1994. Contribuição ao conhecimento das relações tróficas bentônico-demersais nos fundos de pesca do camarão *Artemesia longinaris* Bate, na região da barra da Lagoa dos Patos, RS, Brasil. Nauplius, Rio Grande, 2:53-74.

Costa, R. C., Fransozo, A. and Pinheiro, A. P., 2004. Ecological distribution of the shrimp *Pleoticus muelleri* (Bate, 1888) (Decapoda: Penaeoidea) of Southeastern Brazil. Hydrobiologia, 529:195-203.

Costa, R. C., Fransozo, A., Castilho, A. L., and Freire, F. A. M. 2005. Annual, seasonal and spatial variation of the shrimp *Artemesia longinaris* (Decapoda:Penaeoidea) in south-eastern Brazil. Journal of Marine Biology Association of United Kingdom, 85:107-112.

Dall, W., Hill, B. J., Rothlisberg, P. C. and Staples, D. J., 1990. The biology of the penaeidae. Advances in Marine Biology, 27:1-489.

D'Incao, F. 1999. Subordem Dendrobranchiata (camarões marinhos). pp: 271-299. *In:* Buckup, L. and Bond-Buckup, G. (eds.). Os camarões do Rio Grande do Sul. Editora da Universidade, Porto Alegre.

D'Incao, F., Valentini, H. and Rodrigues, L. F. 2002. Avaliação da pesca de camarões nas regiões Sudeste e Sul do Brasil. 1965-1999. Atlântica, 24(2):49-62.

Dumont, L. F. C., 2008. Identificação de estoques e aspectos biológicos e pesqueiros do camarão-barba-ruça *Artemesia longinaris* Bate, 1888 (Decapoda: Penaeidae). PhD. Thesis, Universidade Federal do Rio Grande, Rio Grande, 240 pp.

Garcia, C. A. E., 1996. Hydrographic characteristics. pp. 18-20. *In:* Seeliger, U., Odebrecht, C. and Castello, J. P. (eds.). Subtropical convergence environments, the coast and sea in the Southwestern Atlantic. Springer: Berlin.

Garcia, S. and Le Reste, L. 1981. Lyfe cycles, dynamics, explotation and management of coastal penaeid shrimp stocks. FAO Fisheries Technical Paper, 203:1-215.

Gulland, J. A. and Rotschild, B. J. 1981. Penaeid shrimps: their biology and management. Fishing news books: Farnham, 299 p.

Haimovici, M. and Mendonça, J. T., 1996a. Análise da pesca de arrasto de tangones de peixes e camarões no Sul do Brasil. Período 1989-1994. Atlântica, 18:143-160.

Haimovici, M. and Mendonça, J. T., 1996b. Descartes da fauna acompanhante na pesca de arrasto de tangones dirigida a linguados e camarões na plataforma continental do sul do Brasil. Atlântica, 18:161-178.

Iwai, M. 1973a. Pesca exploratória e estudo biológico sobre camarão na costa centro-sul do Brasil do N/O "Prof. Besnard" em 1969-1971. São Paulo, SUDELPA, Superintendência do Desenvolvimento do Litoral Paulista/Instituto Oceanográfico da Universidade de São Paulo.

Iwai, M. 1973b. Relatório sobre a segunda pesquisa oceanográfica e pesqueira do Atlântico Sul entre Torres e Maldonado (Lat. 29°S-35°S). Publicações Especiais. Universidade de São Paulo. Instituto Oceanográfico, São Paulo, 3(1):501-534.

King, M. G. 1997. Fisheries biology, assesment and management. Fishing news books. Osney Mead, Oxford, England. 341p.

Nascimento, P. A. M. 1981. Variações no tamanho médio de maturação em *Artemesia longinaris* Bate, 1888 (Crustacea, Decapoda, Penaeidae). Naturalia, 6:33-42.

Nascimento, P. A. M. 1983. Observações Preliminares sobre a Bionomia do Camarão *Artemesia longinaris* Bate, 1888 (Decapoda, Penaeidea) no Atlântico Ocidental (lat. 29°S-35°S). Naturalia, 8:33-47.

Olivier, S. R.; Bastida R., Torti, M. T. 1968. Resultados de las campañas oceanográficas Mar del Plata I-V. Contribución al trazado de una carta bionómica del área de Mar del Plata. Las asociaciones del Sistema Litoral entre 12 y 70 m. de profundidad. Boletin del Instituto de Biologia Marina, 16:1-85.

Piola, A. R., Möller., O. O. Jr., and Palma, E. D. 2004. El impacto del Plata sobre el oceano Atlántico. Ciencia Hoy, 14(2):20-37.

Piola, A. R., Matano, R. P., Palma, E. D., Möller., O. O. Jr., and Campos, E. J. D. 2005. The influence of the Plata River discharge on western South Atlantic shelf. Geophysical Research Letters, 32:1-4.

Reiss, H., Kröncke, I. and Ehrich, S. 2005. Estimating catching efficiency of a 2-m beam trawl for sampling epifauna by removal experiments. ICES Journal of Marine Science, 63:1453-1464.

Somers, I. F. 1987. Sediment type as a factor in the distribution ofcommercial prawn species in the Western Gulf. AustralianJournal of Marine Freshwater Research, 38:133-149.

Valentini, H.; D'Incao, F.; Rodrigues, L. F.; Rebelo-Neto, J. E. and Rahn, E. 1991. Análise da pesca do camarão-rosa *(Penaeus paulensis* e *Penaeus brasiliensis)* nas regiões e sul do Brasil. Atlântica, 13(1):143-157.

Valentini, H. and Pezzuto, P. R., 2005 Análise das principais pescarias comerciais da região Sudeste-Sul do Brasil com base na produção controlada do período 1986-2004. São Paulo, Instituto Oceanográfico-USP, 56 p.

Vooren, C. M. and Klippel, S., 2005. Ações para conservação de tubarões e raias no sul do Brasil. Porto Alegre: Igaré, 261 p.

Weigert, S. C., Klippel, S., Madureira, L. S. P., Vooren, C. M., Pinho, M. P. and Ferreira, C. S. 2005. As águas costeiras da Plataforma Sul como ambiente físico. pp. 24-31. *In:* Vooren, C. M. and Klieppel, S. (eds.). Ações para conservação de tubarões e raias no sul do Brasil. Porto Alegre: Igaré.

Received: September 2008
Accepted: November 2008