Seasonal larval composition and abundance of shrimps in the surrounding area of the Patos Lagoon Mouth.

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Abstract

Larval phases of seven species of shrimps were found in the surrounding area of the Patos Lagoon mouth. Zooplankton and hydrographic samples in four seasonal cruises were undertaken between November 1982 and August 1983 in the coastal marine area around the Patos Lagoon mouth. Seasonal species composition and their abundance were compared showing variations according to the season. *Artemesia longinaris* and *Pleoticus muelleri* were well represented throughout the year; *Acetes americanus* was present during summer and autumn; *Sicyonia typica* only during autumn; *Lucifer faxoni* during summer and autumn; *Peisos petrunkevitchi* during autumn, winter and spring and *Farfantepenaeus paulensis* during spring and summer.

Key words: Penaeidean larvae, distribution, abundance, southtern Brazilian coast

Introduction

Decapod larvae are distributed in almost all coastal and estuarine areas around the world, and they may be very abundant during certain periods of the year. Some areas are used as nursery grounds for many decapod larvae, providing abundance of food and protection from predators.

The larval period of the life history of most decapods plays an important role in maintenance of adult stocks and affects the possibility of colonization of new areas, determined by the duration of the larval period and the nature of marine currents in the area.

Free-swimming decapod larvae have morphological adaptive features allowing survival and growth to the next phase in which new requirements are associated with new morphological characters. The larvae are therefore different in appearance from the adults. Furthermore the larvae and adults usually live in different habitats, and this can cause difficulties in understanding the life cycle. However, the presence of early larval stages in the water column indicates recent reproductive activity.

Studies on the distribution and abundance of penaeidean decapods at the generic level have been published by several authors including Kurata (1970), Subrahmanyam (1971), Paulinose and George (1976), Makarov (1967), Temple and Fischer (1967), Rothlisberg *et al.* (1983, 1985, 1987); or at the species level when only a few species are present in a particular area, as by Eldred *et al.* (1965), Boschi and Scelzo (1969), Jones *et al.* (1970), Prince (1979, 1982), Mallo and Cervellini (1988) and Calazans (1994).

In the present study the composition and abundance of the larval phases of seven penaeideans of the region surrounding the mouth of the Patos Lagoon are described and discussed in order to know their seasonal distribution.

Material and Methods

Decapod larvae were collected along the South Brazilian coast between 31°49'S and 33°S during four cruises at different seasons during 4-5 days each cruise (Table I), using the R/V "Atlântico Sul" (35.9m), of Rio Grande University.

Nauplius

Study Area

The Southern Brazilian Shelf (SBS) area (Fig. 1) is peculiar hydrographically because of the seasonal oscillations observed in shelf currents and also by the low-salinity water originated from the river runoff of Patos Lagoon mostly during winter. During autumn and winter is influenced by the La Plata River runoff is driven toward the SBS by Argentina coastal winds. The intrusion of water from Uruguay and Argentina shelves creates a cold, less-saline mid-shelf water mass that together with local river runoff and the Brazil Current, are responsible for the Brazil-Malvinas Confluence in the region between 20°S and 40°S. On the basis of temperature-salinity relation, two distinct water masses are identified namely Subantartic Shelf Water (SASW, S:~ 33 to 34 and T: ~16°C) cold and lower salinity mass that dominates south of 33°S while warm and salty Subtropical Shelf Waters (STSW S:>35; T:>18°C) extends primarily north of that latitude. These waters masses are separated by a relatively narrow frontal zone referred to as Subtropical Shelf Front located between 32°S and 36°S (Piola *et al.*, 2000). The front is oriented along the north-south direction, located on average near to the 50 m isobath at the Patos lagoon mouth (32°S). The Patos Lagoon (Fig. 1) runoff produces a seasonal variation at the sea surface salinity because all major river of the southernmost Brazilian State, Rio Grande do Sul, flow toward the lagoon to the ocean through the two breakers at the lagoon mouth. These seasonal variations of the lagoon discharge follow the rainfall cycle with a maximum in July (approximately 10.000m³/s) and minimum in January (approximately 1.000 m³/s) (Möeller *et al.*, 2001).

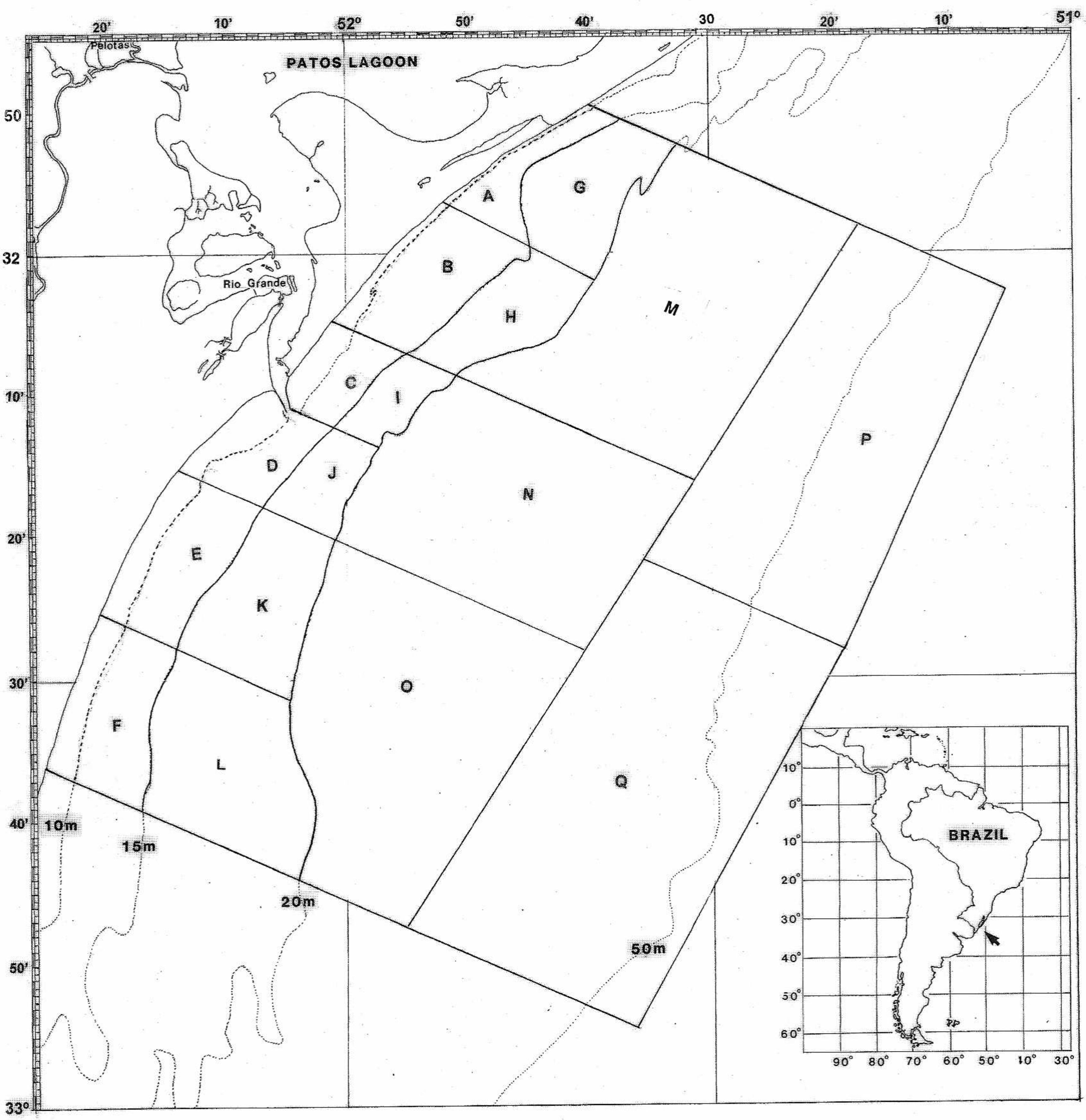

Figure 1: Surrounding area of the mouth of Patos Lagoon with sampling subareas.

The sampling area (Fig. 1) consisted of an approximately rectangular area of about 60 nautical miles in length and about 40 nautical miles width. The mouth of the Patos Lagoon was situated about midway down the western side as demarcated by the coastline, the eastern edge approximately following the 60m isobath. The sampling area of approximately 2,900 nautical square miles was subdivided into 17 subareas, each 10 nautical miles long and lying between two isobaths, demarcating four depth levels: 10 and 15m (6 subareas), 15 and 20m (6 subareas), 20 and 30m (3 subareas), and 30 and 60m (2 subareas). Each subarea was again subdivided into one nautical mile squares, giving the possible sample position. The sample positions themselves were chosen randomly for each subarea. The numbers of samples were established as 2 for each subarea between isobaths of 10 and 20m, 4 for the subareas between 20 and 30m, and 6 for the subareas between 30 and 60m. However, because of bad weather during the second and third cruises it was only possible to complete 43 stations, and during the last cruise only 24 stations were completed across the whole area (Table I).

Table I: Dates and numbers of stations per cruise

	Dates	No. of stations
Cruise 1 (winter)	31/08-04/09/1982	48
Cruise 2 (spring)	17-21/11/1982	43
Cruise 3 (summer)	19-23/01/1883	43
Cruise 4 (autumn)	17-22/05/1983	24*

*bad weather

Samples

At each station zooplankton were collected in oblique hauls from one metre above the bottom to the surface. At stations with a depth of 10 metres or less, double oblique hauls (bringing the net to the surface and letting it down again) were carried out to increase the volume of water filtered at a minimum of 50 m^3 approximately. The plankton net was a conventional conical net of 330 μm mesh size, 60 cm mouth diameter and 250 cm length, with a flow meter centrally mounted in the mouth and a 20 kg hydrodynamic depressor. Towing speed was estimated to be between 1.5 and 2.0 knots. The angle of the towing wire was monitored frequently in order to keep it constant. The appropriate lengths of cable, read from a prepared chart (cable length = (depth) cosecant of wire angle), were let out to enable sampling to start at the correct depth, usually 1m above the bottom. Samples were immediately fixed and preserved in 4% buffered formalin. All penaeidean larvae were sorted and removed from all zooplankton samples under a dissecting microscope. Identification to species and stage of development was possible by comparison with reared larvae, and from a key to genera prepared by Calazans (1993).

In general, abundance of penaeidean larvae, expressed as number per $100m^3$, varied significantly between individual tows, ranging from absent to very abundant. Therefore, for graphical presentation and in order to allow use of particular statistical procedures, this number (x) was compressed by the transformation log(x+1), thereby effecting the variance to be independent of the mean (Sokal and Rohlf, 1981). A three-way analysis of variance (ANOVA) was used to investigate the effect of 1) season; 2) bottom depth; and 3) position of sampling point to the north or south of the lagoon mouth, against larval abundance. Regression analysis was used to assess the effect of temperature, salinity and depth on the abundance of the larvae.

Water temperatures (°C) were taken by a reversing thermometer attached to a Nansen bottle near the bottom, and by a thermometer at the surface, both with 0.1 °C of precision. Salinity values were obtained using a refractometer from water samples near to the bottom taken by the Nansen bottle and surface.

Results

Temperature and Salinity

Mean surface and bottom temperatures did not show any marked variations for the same period of the year, nor did they vary north and south of the Lagoon mouth. The surface temperature was consistently higher than that at the bottom. Seasonal variation on the other hand are marked (Table II).

Mean salinity values were lower at surface than that at the bottom during August/September (winter), November (spring) and May (autumn), probably as result of the freshwater outflow influence from the Patos Lagoon. During January (summer) no difference between salinities of surface and bottom samples was detected. Salinity was variable between seasons (Table III).

Table II: Means and ranges of temperature (C) per cruise

	Surface	Bottom
Cruise 1 (winter)	15.2 (14.3-17.0)	13.9 (13.2-15.5)
Cruise 2 (spring)	18.1 (17.0-19.8)	16.1 (13.7-18.1)
Cruise 3 (summer)	24.5 (23.1-25.6)	20.7 (15.9-24.9)
Cruise 4 (autumn)	20.0 (19.0-20.9)	19.6 (18.8-20.8)

Table III: Means and ranges of salinity per cruise

	Surface	Bottom
Cruise 1 (winter)	25.0 (15.0-31.0)	29.5 (25.0-34.0)
Cruise 2 (spring)	26.4 (18.0-30.0)	29.5 (23.0-35.0)
Cruise 3 (summer)	34.0 (29.0-36.0)	34.6 (30.0-36.0)
Cruise 4 (autumn)	27.7 (20.0-33.0)	33.5 (22.0-35.0)

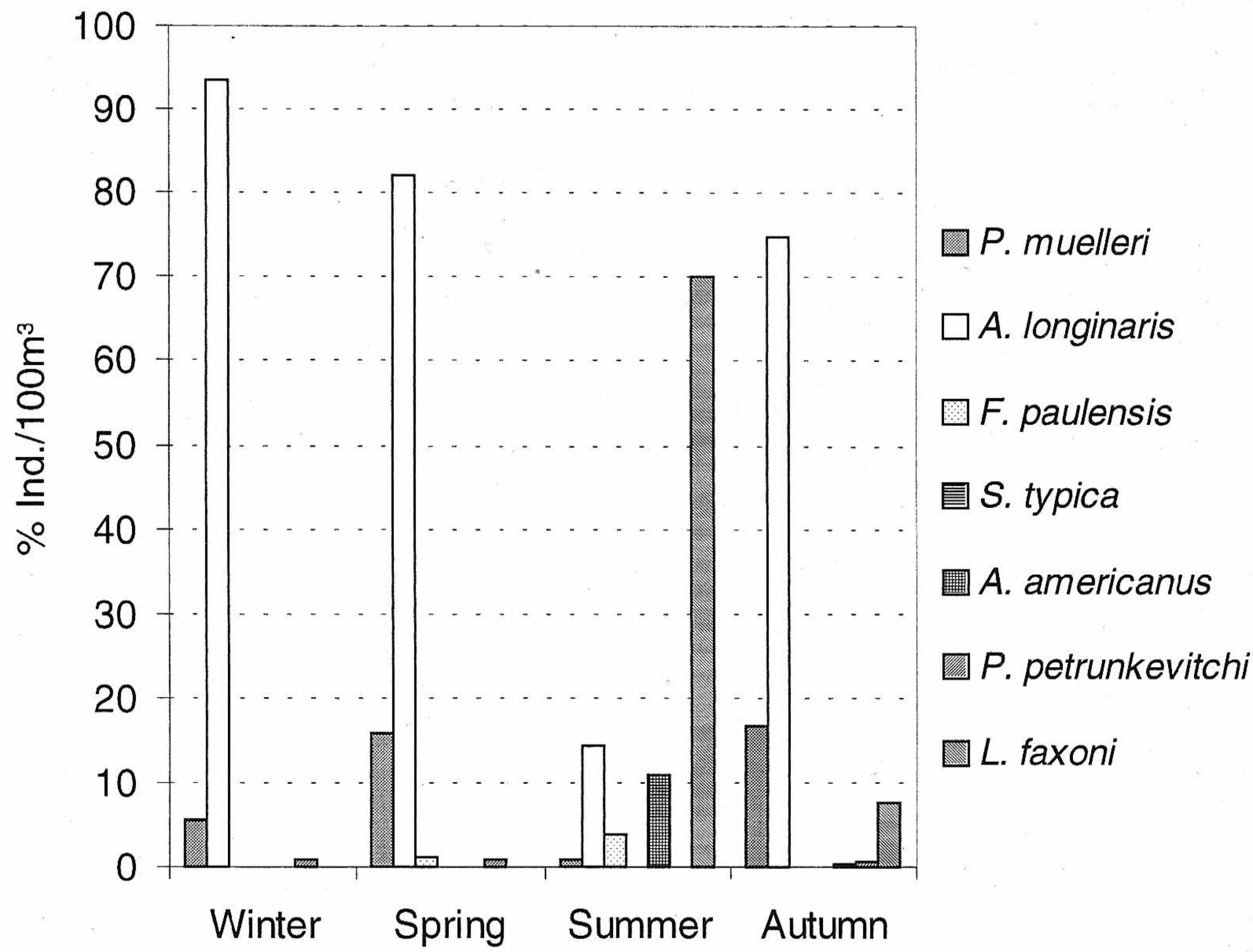

Figure 2: Seasonal species compositions (% of ind/100m³) of penaeidean decapod larvae off Southern Brazilian coast.

Species Composition

Total abundance of penaeidean larvae varied in the area according to the season as follows: winter 22.8%, spring 8.9%, summer 10.7% and autumn 57.6% (Fig. 2). The seasonal numbers of species and their relative abundance (Fig. 2) were represented as follows: In winter only 3 species were represented: *Artemesia longinaris* (93.6% of total larvae collected), *Pleoticus muelleri* (5.5%) and *Peisos petrunkevitchi* (0.9%). The low temperature of the bottom water (13.9°C) indicates an influence of the SASW during this period, with probable influence on the distribution of other species. During spring with the bottom temperature rising to 16.1°C, larval stages of a fourth species, *Farfantepenaeus paulensis* (3.8%), were present in addition to the other three species which now had the following relative abundance: *A. longinaris* (82.1%), *P. muelleri* (15.7%), *P. petrunkevitchi* (1.0%). In summer, the temperature of the bottom water rose to a maximum of 20.7°C. *Peisos petrunkevitchi* was now absent from the area but *Lucifer faxoni* (70.2%) and *Acetes americanus* (10.9%) were strongly represented, probably because of the higher temperature. *Artemesia longinaris* (1.4%) and *P. muelleri* (0.8%) had their lowest seasonal representation in the summer, perhaps indicating a preference for lower temperatures. *Farfantepenaeus paulensis* (3.8%) showed no difference in percentage abundance between summer and spring. During autumn, the bottom water temperature showed a small decrease to 19.5°C and a maximum of six species was present in the area: *Peisos petrunkevitchi* (30.6%), *Acetes americanus* (25.9%), *A. longinaris* (21.0%), *L. faxoni* (17.8%), *P. muelleri* (4.77%) and *Sicyonia typica* (0.03%).

Abundance of Penaeidean Larvae

Pleoticus muelleri

All larval stages of this species were taken in the plankton samples during each of the four surveys, indicating spawning activity throughout the year. A mean total number of 218.4 larvae per 100m^3 were caught.

There were highly significant differences ($P<0.01$) between abundances of protozoea, mysis and megalopa phases during both winter and autumn, indicating a high disappearance rate mainly during winter. There were significant differences ($P<0.05$) between abundances of protozoea and megalopa phases during spring, but no difference between the abundance of larval phases during summer (Table IV).

The mean abundance of protozoea larvae per survey (Table IV) indicated a greater spawning activity of this species during autumn when the protozoea phase showed a significant peak ($P<0.01$), representing 67.6% of total capture. A second smaller peak was present in the winter but the small number of winter megalopae indicated that winter spawning is less important to total recruitment than spring and summer spawnings even though protozoea number in each of the latter is smaller than in winter. The abundance of protozoea larvae is distributed homogeneously in relation to depth, and to position north or south of the lagoon mouth.

The abundance of mysis larvae showed a highly significant increase ($P<0.01$) during autumn. In relation to depth, there is a highly significant difference ($P<0.01$) in mysis abundance between 30 and 60m, and abundance at other depths (Table V).

Megalopa abundance showed a highly significant rise ($P<0.01$) during autumn. Abundance was homogeneous between 10 and 20m, and from 30 to 60m, with a highly significant increase ($P<0.01$) of abundance between 20 and 30m during autumn. No difference in megalopa abundance was detected between sample positions to the north and south of the lagoon mouth (Table V).

Artemesia longinaris

Larval stages of this species were very abundant in the area during the four surveys, indicating spawning activity throughout the year. A mean total number of 1282.3 larvae per 100m^3 were caught.

Highly significant differences ($P<0.01$) between the abundances of protozoea and megalopa phases during winter, spring and autumn indicate high disappearance rates, particularly during winter. During summer, there was no difference in abundance between the larval stages (Table V).

The mean abundances of all the larval stages per survey (Table IV) fell into three significantly different categories ($P<0.01$) - winter/autumn, spring and summer. The high equal abundances of larvae in winter and autumn indicated continuous high spawning activity then, with protozoea stage I representing 38% and 37% of the total abundance of the protozoea phase.

The abundance of mysis larvae varied significantly ($P<0.01$) between all seasons, the larvae being more abundant during winter, summer and autumn and less abundant during spring. Abundance also varied significantly ($P<0.05$) with depth, the larvae being more common between 10 and 30m than between 30 and 60 metres (Table V).

The abundance of megalopa larvae showed highly significant differences ($P<0.01$) between autumn and both winter and summer, and a significant difference ($P<0.05$) between autumn and spring. The abundance of megalopae varied significantly ($P<0.01$) with depth, being greater between 10 and 30 metres in comparison to that between 30 and 60 metres (Table V).

Table IV:.Seasonal abundance (mean number/100m3 and percentage of the total species catch) of penaeidean larvae.

Species	Phase	Winter		Spring		Summer		Autumn	
		n	%	n	%	n	%	n	%
P. muelleri	Protozoea	21.0	*9.6*	12.9	*5.9*	0.6	*0.3*	147.7	*67.6*
	Mysis	1.2	*0.6*	11.1	*5.1*	0.7	*0.3*	20.0	*9.2*
	Megalopa	0.04	*0.0*	0.6	*0.3*	0.4	*0.2*	2.2	*1.0*
	Total	22.2	*10.2*	24.6	*11.3*	1.7	*0.8*	169.9	*77.8*
A. longinaris	Protozoea	322.0	*25.1*	93.1	*7.2*	9.6	*0.8*	477.8	*37.3*
	Mysis	50.6	*3.9*	31.9	*2.5*	15.6	*1.2*	266.5	*20.8*
	Megalopa	1.3	*0.1*	3.3	*0.3*	1.7	*0.1*	8.9	*0.7*
	Total	373.9	*29.1*	128.3	*10.0*	26.9	*2.1*	753.2	*58.7*
F. paulensis	Protozoea	--	--	1.2	*13.1*	4.9	*53.7*	--	--
	Mysis	--	--	0.7	*7.7*	2.0	*21.9*	--	--
	Megalopa	--	--	0.03	*0.3*	0.3	*3.3*	--	--
	Total	--	--	1.93	*21.1*	7.2	*78.9*	--	--
S. typica	Protozoea	--	--	--	--	--	--	0.6	*42;9*
	Mysis	--	--	--	--	--	--	0.5	*35.6*
	Megalopa	--	--	--	--	--	--	0.2	*14.3*
	Total	--	--	--	--	--	--	1.4	*100.0*
A. americanus	Protozoea	--	--	--	--	5.6	*25.2*	1.1	*5.0*
	Mysis	--	--	--	--	2.5	*11.3*	0.4	*1.8*
	Megalopa	--	--	--	--	12.5	*56.3*	0.1	*0.5*
	Total	--	--	--	--	20.6	*92.8*	1.6	*7.2*
P. petrunkevitchi	Protozoea	2.7	*25.7*	0.2	*1.9*	--	--	2.7	*25.7*
	Mysis	0.5	*4.8*	0.4	*3.8*	--	--	0.9	*8.6*
	Megalopa	0.4	*3.8*	1.0	*9.5*	--	--	1.7	*16.2*
	Total	3.6	*34.3*	1.6	*15.2*	--	--	5.3	*50.5*
L. faxoni	Protozoea	--	--	--	--	--		0.1	*0.0*
	Mysis	--	--	--	--	92.7	*44.4*	51.6	*24.7*
	Megalopa	--	--	--	--	39.2	*18.8*	25.1	*12.0*
	Total	--	--	--	--	131.9	*63.2*	76.8	*36.8*
	TOTAL	399.7	*22.8*	156.4	*8.9*	188.3	*10.7*	1008	*57.6*

Table V: Summary of the results of ANOVA on the effect of season, bottom depth and position to the north or south of the lagoon mouth and larval abundance (Transformed data) of 6 penaeidean decapods.

Species	Phase	Season	Depth	Position
P. muelleri	Protozoea	**	n.s.	n.s.
	Mysis	**	**	n.s.
	Megalopa	**	**	n.s.
A. longinaris	Protozoea	**	*	n.s.
	Mysis	**	*	n.s.
	Megalopa	**	**	n.s.
F. paulensis	Protozoea	**	**	n.s.
	Mysis	**	**	n.s.
	Megalopa	*	n.s.	n.s.
A. americanus	Protozoea	**	n.s.	n.s.
	Mysis	*	n.s.	n.s.
	Megalopa	**	**	*
P. petrunkevitchi	Protozoea	**	n.s.	n.s.
	Mysis	*	n.s.	n.s.
	Megalopa	**	n.s.	n.s.
L. faxoni	Protozoea	-	-	-
	Mysis	**	n.s.	n.s.
	Megalopa	**	n.s.	n.s.

** = P<0.01; * = P<0.05; n.s. not significant; — not present

Farfantepenaeus paulensis

Small numbers of protozoea, mysis and megalopa larvae of this species were taken in the plankton samples during two of the four surveys, indicating a very weak but homogeneous spawning activity during spring and summer. Protozoea I represented 41.8% and 48.8% of the total protozoea phase abundance in these seasons, respectively. A mean total of only 9.13 larvae per 100m^3 were caught with no difference of abundance between larval stages (Table IV).

The abundances of protozoea and mysis phases varied significantly (P<0.01) in relation to depth, the larvae only being present in the 30 to 60 m depth layer. There was no variation between megalopa abundance and depth (Table V).

Sicyonia typica

Very few larvae of this species were taken during autumn in the area. A mean total number of 1.4 larva per 100m^3 was caught with no differences between the abundances of the different larval phases (Table IV). The limited presence of larval stages of this species indicates an occasional spawning activity concentrated in the area to the north of the lagoon mouth.

Acetes americanus

All larvae of this species were taken in plankton samples during summer and autumn. A total mean number of 22.2 larvae per 100m^3 were caught. There were no significant differences between the abundances of the different larval phases (Table IV).

There were significantly higher ($P<0.01$) peaks of protozoea I and total protozoea abundance during summer than in autumn, the larvae being more abundant ($P<0.05$) at 10 to 15m than at other depths. Mysis larval abundance showed no difference between seasons or depth levels (Table V).

The abundance of the megalopa on the other hand did show highly significant variation ($P<0.01$) with season (Table IV) and depth, being higher in the 10 to 15 m depth level. There was also a significant difference ($P<0.05$) in megalopa abundance to the north and south of the lagoon mouth (Table V).

Peisos petrunkevitchi

All larval stages of this species were taken in plankton samples during winter, spring and autumn. A mean total of 10.5 larvae per 100m^3 were caught. There was a significant difference ($P<0.05$) between the abundances of protozoeae and megalopae during the winter, but no such difference during spring and autumn (Table IV).

The abundance of protozoea was equal for winter and autumn, but significantly lower ($P<0.01$) in spring. The abundance of mysis larvae was homogeneous between seasons, and megalopae numbers were significantly different ($P<0.05$) between seasons, being lower during autumn (Table V).

There was no difference in larval abundance with depth (Table V). There was no significant correlation between larval abundance and either temperature or salinity.

The higher peak of protozoea I during winter showed that the distribution of *P. petrunkevitchi* in the region is probably related to the Subantartic Shelf Water and spawning activity is associated with low temperature (14-17°C).

Lucifer faxoni

Only one protozoea III of this species was collected, this being during autumn. Mysis larvae and megalopae of this species were collected during summer and autumn. A total mean number of 208.7 larvae per 100m^3 were caught.

There were highly significant differences between abundances of mysis larvae and megalopae during summer and autumn (Table IV). There were no significant variations in larval abundance with depth, or with position north and south of the lagoon mouth (Table V).

Discussion

In temperate areas such as the Southern Brazilian coast, the relatively low species diversity of penaeidean decapods does allow the identification of temporally and spatially distinct spawning activities of different local species. Typically the high abundance of early larval stages like protozoea I (2 days old) provides good evidence of any recent hatching and also recent presence of adult stock.

The presence of an adult population in one area is little influenced by currents, but the horizontal displacement of their larval stages is at the mercy of the currents with larval transport dependent on: 1) current velocity; 2) species distribution with depth; and 3) the reactions of larvae to changes in environmental conditions.

During the winter the influence of Subantartic Shelf Water was marked by bottom mean water temperature of 13.9°C providing the presence of the southerly species *Artemesia longinaris*, *Pleoticus muelleri* and particularly *Peisos petrunkevitchi* because this area is the extreme northward point of the distribution of this latter species. The influence Subtropical Shelf Water with bottom mean water temperature of 20.7°C during the summer was notable given the presence of the northerly species *Farfantepenaeus paulensis*, *Lucifer faxoni* and *Acetes americanus*.

Although there were high numbers of protozoea I larvae of *P. muelleri*, *A. longinaris* and *F. paulensis* during the winter and low numbers of protozoea I in the summer, the numbers of subsequent megalopae were similar in winter and summer, indicating that there was a high disappearance rate in the winter, probably because of the low temperature of the water. Low temperatures are however tolerated for spawning activity by all three species (Boschi and Scelzo, 1977, Boff and Marchiori, 1984).

Two species, *P. muelleri* and *A. longinaris*, showed spawning activity throughout the year in shallow waters near to the lagoon mouth. Nevertheless the relatively high abundances of their larvae during winter and autumn indicate preferences for the low temperatures of 14-20°C for development. The spawning activity does denote the presence of an annual adult stock in the region. This stock can support an artisanal fishery, mainly during winter, when the higher number of larval stages suggests a higher number of adults in the area. The similar numbers of megalopae in spring and summer also suggest that the high concentrations of adults present during the winter have only the same importance in terms of recruitment as the lower concentrations of adults present in the summer. These two species spend their entire life in shallow coastal waters. Based on the seasonal presence of protozoea I larvae, *P. muelleri* shows preferences for depths between 25 and 50m while *A. longinaris* seems to prefer depths between 10 and 20m. No influences of salinity on larval distribution were detected during this study and the influence of temperature was observed only during larval development when low temperature was related to high mortality.

The most commercially important shrimp in the area, *Farfantepenaeus paulensis*, showed very weak spawning activity during spring and summer, without significant larval abundance to indicate a significant adult stock in the area. This species has a mixed life cycle with larval stages migrating (with the help of currents) from the open sea into estuaries which act as nursery areas for 3-4 months, after which sub-adults migrate back to oceanic waters to Santa Catarina State to complete their life cycle. Zenker and Agnes (1977) suggested that the adult stock of *F. paulensis* responsible for the recruitment in the Patos Lagoon is based off the Santa Catarina coast (600 km north of the area studied), and strong coastal currents during spring and summer are responsible for larval transport from that area to the more southerly coastal lagoons mostly megalopae stages. The low number of protozoea I larvae found during this study indicates a small adult stock of this species at depths between 45 and 60m in front of the lagoon mouth with no commercial importance. The rise of temperature between spring and summer is probably the main factor controlling the start of the spawning activity of this species in the area.

Acknowledgements

Financial support was given by CNPq - Conselho Nacional de Desenvolvimento Científico e Tecnológico (Proc. n° 20.0527/87.8). I wish to thank Suelma R. Silveira and Rony Roberto Ramos Vieira for their help during this work.

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Received: 11th Nov 2002
Accepted: 19th Mar 2003