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Larvae of *Illex argentinus* from five surveys on the continental shelf of southern Brazil

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Three types of rhynchoteuthion larvae and one of small juvenile ommastrephid were collected in 116 of 371 samples obtained in five surveys on the shelf of southern Brazil. The cruises were between Santa Marta Grande Cape (28°30′S) and Chui (34°40′S); one cruise in autumn 1980–1982, one in winter, and three in spring. Samples were collected with a bongo net of 0.33-mm mesh in oblique hauls from bottom to surface between the coast and approximately the 200-m isobath line. Juveniles and the type of larvae that accounted for over 90% of the total were identified as *Illex argentinus*. They were found mostly in winter and spring in association with the western boundary of the Brazil Current and Subtropical Waters and rarely with Coastal and Subantarctic Waters. Their abundance in southern Brazil may be explained by spawning in the region and northward transport of egg masses.

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Introduction

Illex argentinus de Castellanos 1960 is distributed in the southwest Atlantic between Rio de Janeiro (lat. 220) in Brazil and the southern tip of South America (lat. 550). In 1988 and 1989 it became the most fished cephalopod (Fishing News International, June 1990). Fishing is intense in the southern part of its range, whereas it is abundant and has been intensively studied in recent years (Hatanaka *et al.*, 1985; Hatanaka, 1988; Csirke, 1987; Brunetti, 1988; Brunetti and Perez Comas, 1989a, b; Burnetti *et al.*, 1991; Rosenberg *et al.*, 1990). In southern Brazil only limited information on juveniles and adult distribution and sexual maturity is available (Haimovici and Andriguetto, 1986; Haimovici and Perez, 1990).

In spite of recent efforts, there are significant gaps in the knowledge of the life cycle of *Illex argentinus*. Especially lacking is information on spawning sites and where larvae and juveniles develop. In fact, approximate spawning areas have only been reported for the summer spawning group in the northern Patagonian region off the Argentinian Shelf (Brunetti, 1988; Brunetti *et al.*, 1991).

Plankton samples collected in a series of pelagic survey cruises along the southern Brazil Shelf yielded a considerable number of rhynchoteuthion larvae among which three types were recognized. In this article, the three types of larvae are briefly compared. The most abundant fits the description of *I. argentinus*, whose distribution is analysed in relation to available information on adults and the hydrographic conditions prevailing in the region.

Materials and methods

Samples were collected by the RV 'Atlântico Sul" in five acoustic surveys for pelagic fishes on the shelf of southern Brazil from the coast to approximately the 200-m isobath line (Fig. 1) with a bongo net of 0.33-mm mesh in oblique hauls from bottom to surface. The spring cruises of 1980 and 1982 and the winter cruise of 1980 covered all the studied area between Santa Marta Grande Cape (Lat. 28°30′S) and Chui (Lat. 34°40′S). The cruise in April 1980 covered only the northern part and the spring cruise of 1981

Table 1. Rhynchoteuthion larvae collected during five cruises off southern Brazil. n = number of larvae collected; % = percentage of tows with larvae; <ML = mantle length of the smaller larvae in millimeters; D = number of larvae per 100 cubic meters of filtered water.

		Type A				Type B				Type C			
Cruises	Hauls	n	%	<ML	D	n	%	<ML	D	n	%	<ML	D
April 1980	33	5	15.1	2.0	0.0095								
July–August 1980	88	8	4.5	1.2	0.0085	19	11.3	1.5	0.0410	382	59.0	1.1	1.170
October–November 1990	92	7	5.4	1.6	0.0070	3	2.2	2.4	0.0065	21	15.2	1.8	0.081
November 1981	59									9	11.9	2.0	0.031
October–November 1992	100	2	2.0	2.6	0.0010	6	6.0	1.5	0.0080	73	30.0	1.5	0.157

covered only the southern part (Table 1). Samples were preserved in 4% buffered formalin. Temperature and salinity profiles were developed from data collected at various depths from surface to bottom in most stations (J. P. Castello, unpubl. data).

The dorsal mantle length (ML), mantle width, proboscis length, head width and arms length of rhynchoteuthion specimens in good condition were measured in millimeters. The tentacular index, TI: ratio of proboscis length to mantle length, was also calculated.

Results

Rhynchoteuthion larval types

Rhynchoteuthion larvae were found in 116 of the 372 samples. Three types were recognized, mainly differentiated by the size and shape of the proboscis and the relative sizes of suckers on its tip (Fig. 2). Unfortunately, larvae were not examined until several years after collection and the chromatophore pattern was too faint to be useful for identification. Some larvae, usually those smaller than 3 mm ML, had the head all or partially retracted into the mantle cavity.

Type "A" larvae have a thick and short proboscis, and the two lateral suckers are up to three times larger than the other central six. In larvae over 4 mm ML, the proboscis is shorter than the arms. A total of 22 type "A" larvae were found; of the eight that were measurable, ML ranged from 1.2 to 5.7 mm and the tentacular index from 2.7 to 6.2. Four of those smaller than 3 mm had the head retracted into the mantle cavity.

Type "B" have a slender and long proboscis with the two lateral suckers slightly bigger than the rest. In larvae over 4 mm ML, the proboscis is equal to or longer than the arms. The head is wide, with large prominent eyes. A total of 27 larvae were found, of which nine were measurable with 1.5–5.0 mm ML and tentacular indices ranging from 2.9 to 7.9.

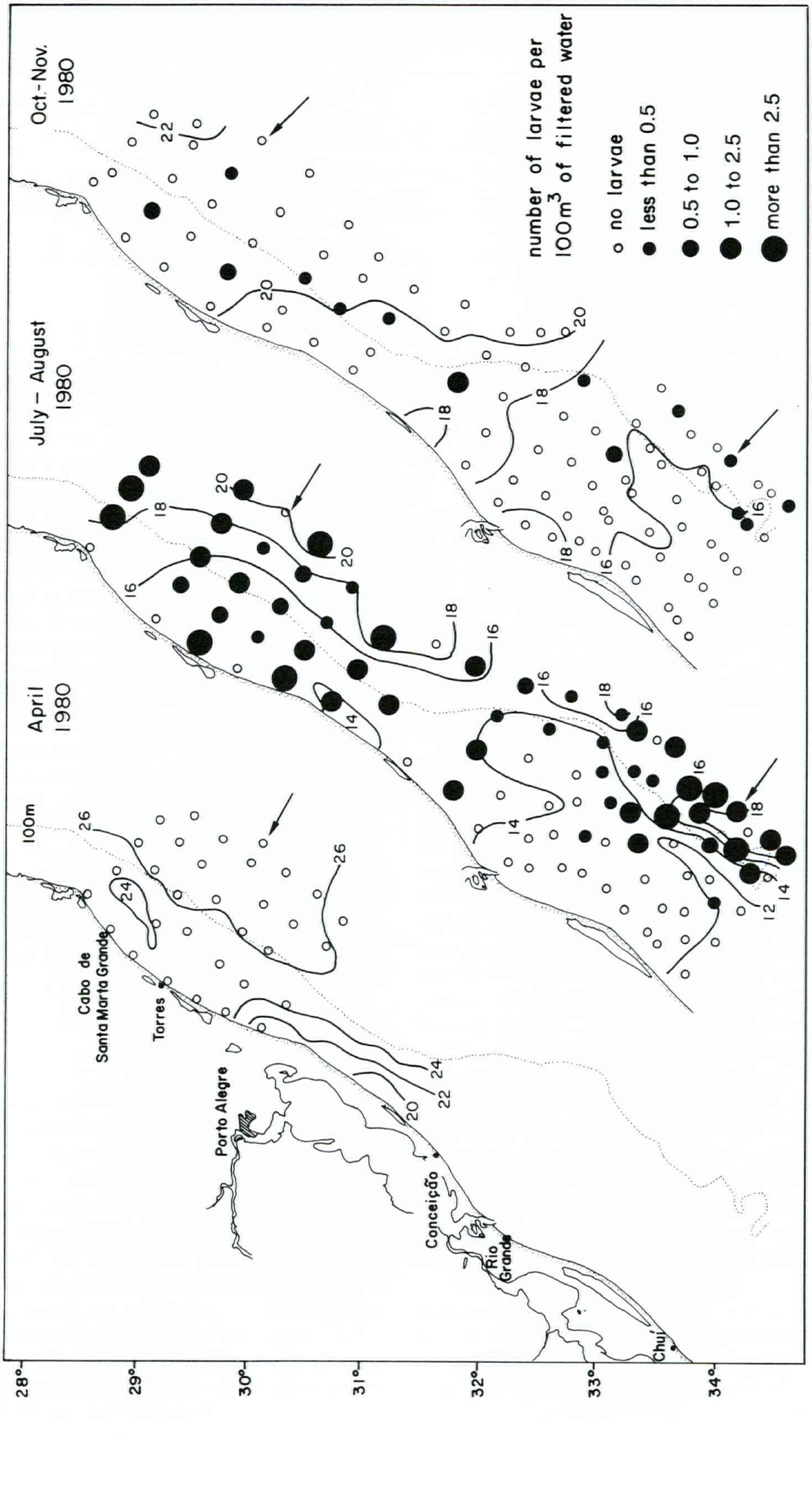
A total of 489 larvae of type "C" and juvenile of *I. argentinus* with mantle length from 1 to 11 mm were obtained. Type "C" larvae have a slender and long proboscis with eight suckers of equal diameter. Third arms form with the ML at about 1.5 mm and the fourth arms at about 2.5 mm ML, relatively far from the basis of the proboscis, which is longer then the longer arms. The proboscis starts dividing to form a splitting groove along its base when larvae attain 4–5 mm ML and is complete at 6.0–6.5 mm ML. Tentacular indices were 2.5–8.2. In 14.5-mm ML juveniles, the typical eight rows of suckers in the tip of the tentacles can be observed. The proboscis in type "C" larvae remains unsplit up to a larger size than in the others. The third arms in type "A" form at a bigger size than in the rest of the larvae (Table 2).

The description of *Illex illecebrosus* larvae for the Northwest Atlantic (Roper and Lu, 1979) fits approximately with our type "C" larvae, as also does the description of *I. argentinus* from samples obtained over the Argentinian inner shelf by Brunetti (1990) and Leta (1987).

Distribution of larvae

The number of each type of rhynchoteuthion larvae captured per 100 m^3 of water sampled is given, by cruise, in Table 1. *I. argentinus* was dominant, being captured in 27.8% of the hauls and representing 90.7% of the total number of ommastrephid larvae. The distributions of larvae and juveniles of *I. argentinus* and isotherms at 10 m depth are shown in Figure 1. Temperature profiles perpendicular to the coastline representative of each cruise are shown in Figure 3.

The larvae and juvenile distribution patterns are more easily described if hydrographic conditions prevailing in the study area are examined first. Four main water masses may be found over the continental shelf


Oct.-Nov. 1980
July – August 1980
April 1980
100m
number of larvae per 100m³ of filtered water
no larvae
less than 0.5
0.5 to 1.0
1.0 to 2.5
more than 2.5
Cabo de Santa Marta Grande
Torres
Porto Alegre
Conceição
Rio Grande
Chuí
28°
29°
30°
31°
32°
33°
34°

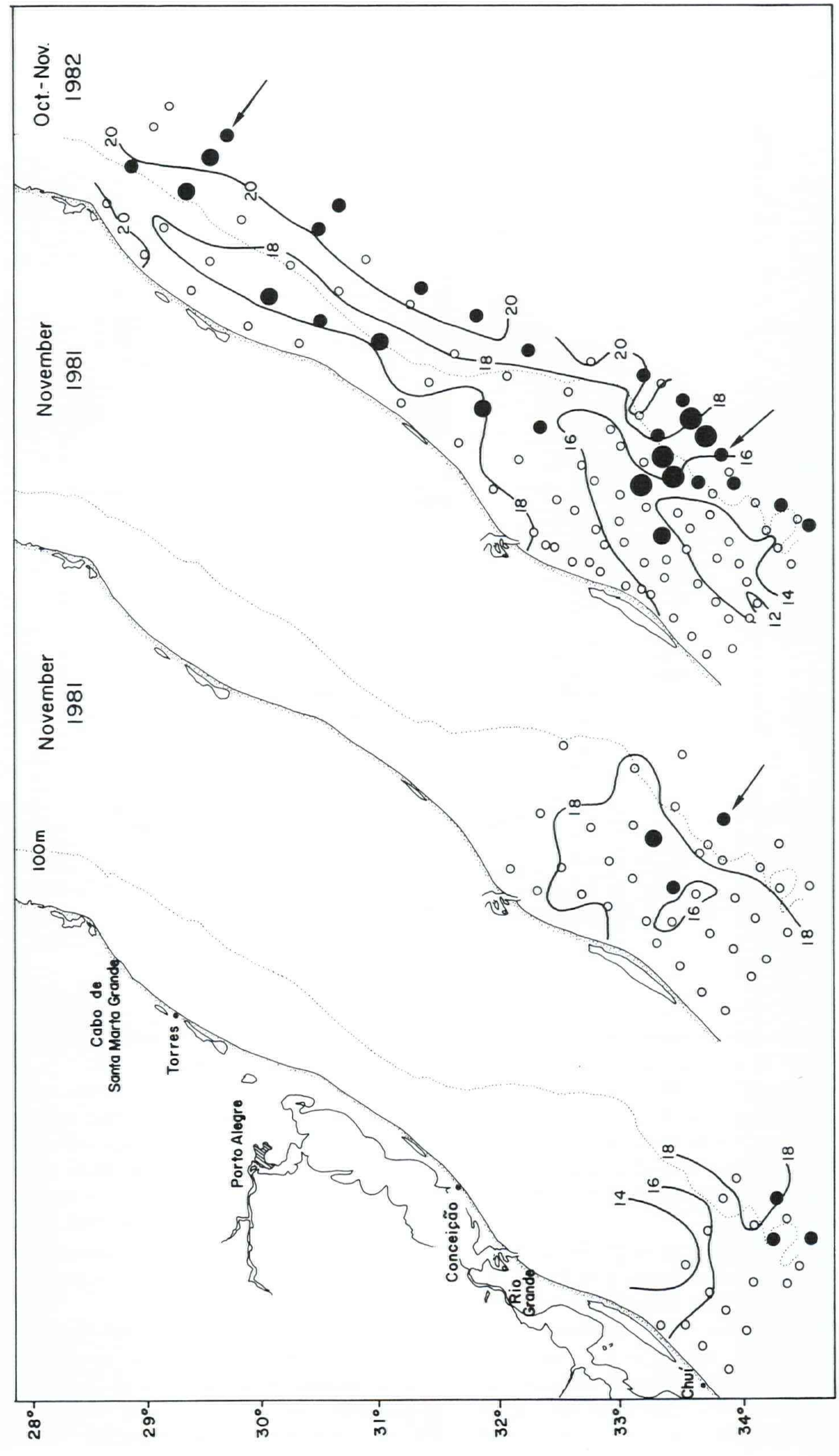


Figure 1. Distribution and relative abundance of *Illex argentinus* larvae over the continental shelf. Isotherms at 10 m depth are also shown. Arrows identify the transects on which the temperature profiles shown in Figure 3 were taken.

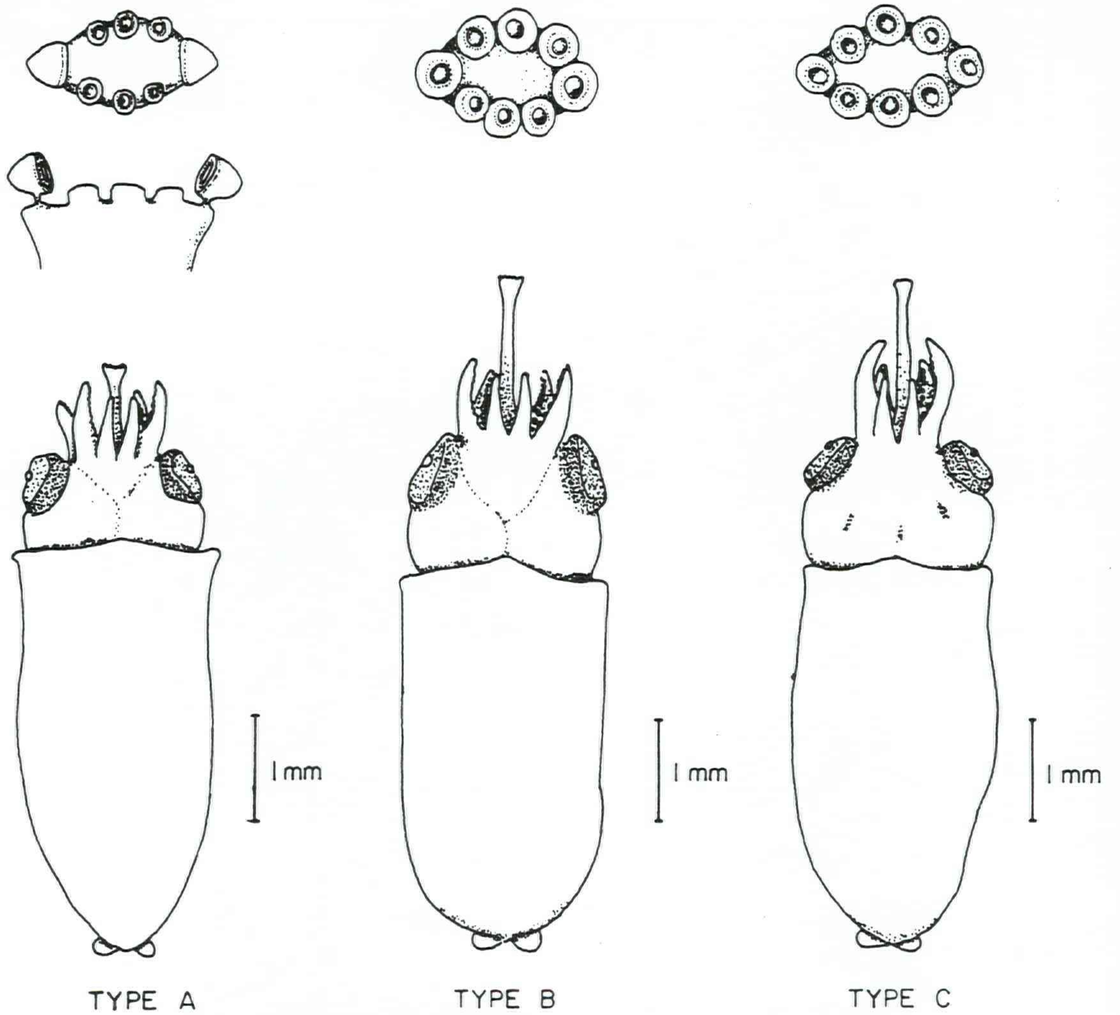


Figure 2. Rhynchoteuthion larval types found in the study area.

and upper slope off southern Brazil (Emílsson, 1961; Miranda *et al.*, 1973; Castello and Moller, 1977; Hubold, 1980a, b; Matsuura, 1986) (Fig. 4).

Tropical Water (TW) of the Brazil Current (Temperature > 20°C, Salinity > 36.0) flows over the slope and, because of eddies and meander structures, occasionally reaches the continental shelf, especially during winter.

Subtropical Water (STW), also called South Atlantic Central Water, with temperatures from 10 to 20°C and salinity from 34.3 to 35.9 runs northward below the Brazil Current as a result of the mixture between Tropical and Subantarctic waters in the Subtropical Convergence Zone, which fluctuates seasonally between latitude 35°S and 45°S. This water may upwell seasonally off northern Rio Grande do Sul, Santa Catarina, and Cabo Frio or follow the meander-like pattern of the Brazil Current.

Coastal Water (CW) with different temperatures and salinities occasionally covers part of the shelf. In Rio Grande do Sul, salinities may be as low as 26 because of the runoff by the Rio de la Plata and the Patos Lagoon, and temperatures vary between 12 and 20°C. North of 31°S, salinities of 35.0 and temperatures up to 23°C are due to high solar radiation, mixture with waters of the Brazil Current and low river runoff.

Subantarctic Water (SAW), derived from a coastal branch of the Malvinas/Falkland Current, extends up to 32°S but may reach further north in winter. Usually it penetrates beneath the Coastal Water between the 50- and 100-m isobath. Its temperature in Chui is 10–

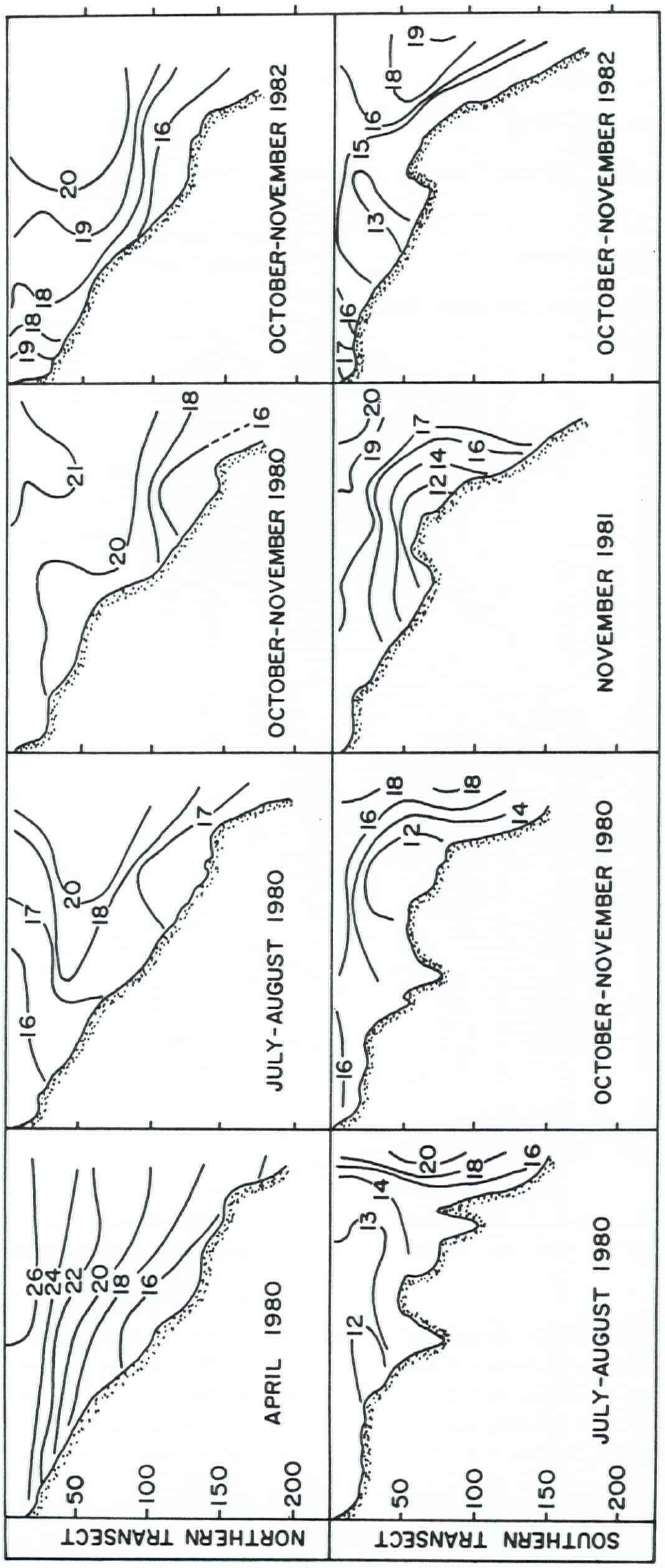


Figure 3. Temperature profiles over the shelf area during the period of sampling.

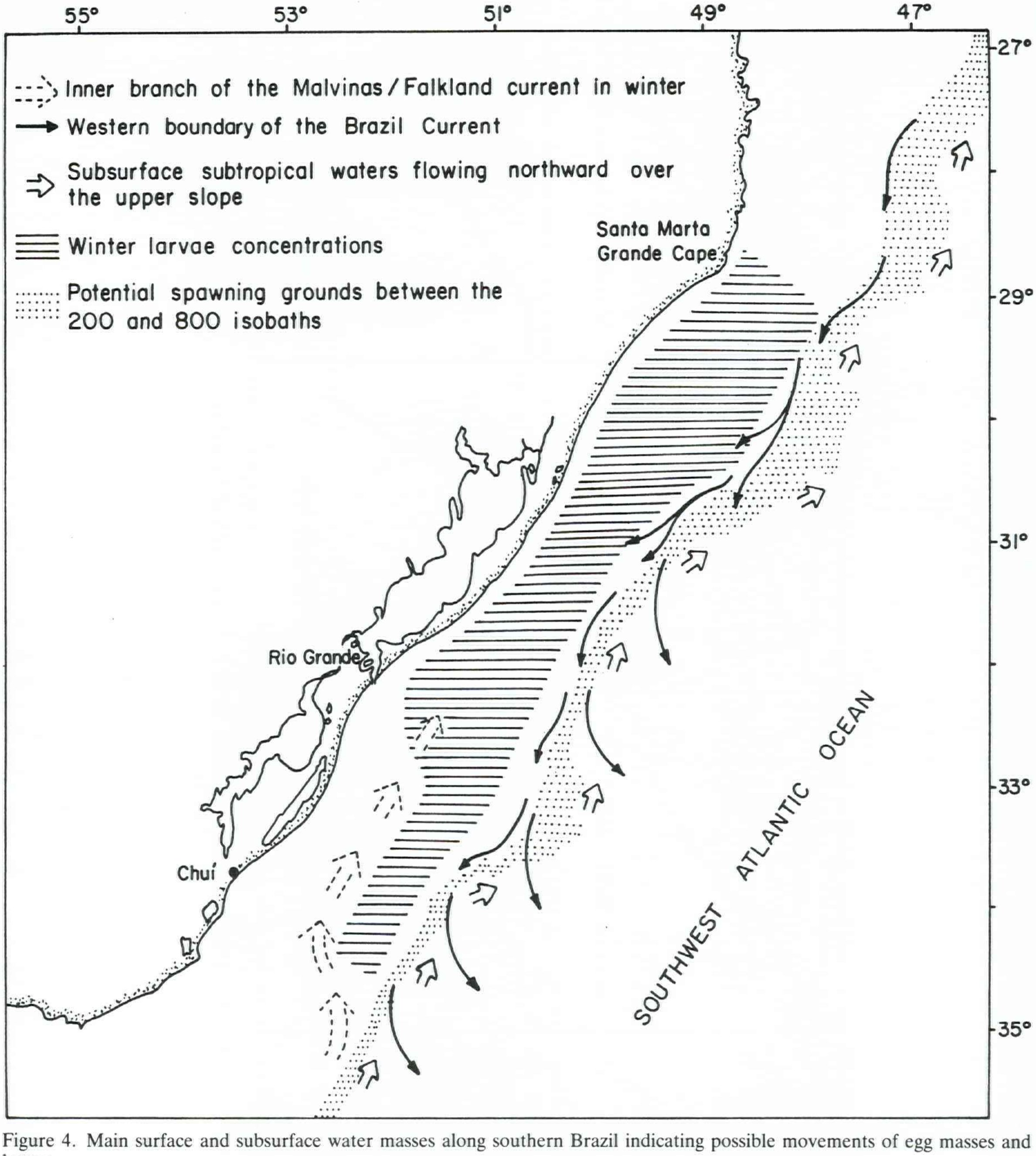


Figure 4. Main surface and subsurface water masses along southern Brazil indicating possible movements of egg masses and larvae.

12°C and can approach 14–16°C off Rio Grande; salinity ranges from 33.7–34.15. Along its eastern boundary, a strong thermal gradient, classified by Miranda *et al.* (1973) as "Slope Water" with intermediate temperatures and salinities separate it from the Brazil Current.

The bottom morphology also helps to explain the behavior of the water masses: the shelf from Chui to Rio Grande (latitude 32°S) is wide. In winter, SAW of the inner branch of Malvinas Current penetrates. To the north of Rio Grande, the shelf is narrow and the influence of Brazil Current is more evident, especially in the warm seasons, while in the cold season, Subtropical Waters may upwell on the shelf near the coast.

In the area sampled in early autumn in April 1980, waters attained a temperature of more than 26°C at the surface and over 16°C at the bottom. On the slope, a thermocline at 50 m depth separates the southward running Brazil Current from the STW running in the opposite direction. Bongo net samples were obtained only from the northern portion of the study area. Type "A" larvae were found in 5 of the 33 hauls, all in the outer shelf, and *I. argentinus* larvae were not found.

The water temperature pattern in July and August of 1980 was typical for the winter; SAW of 12–14°C occupied most of the shelf up to Conceição (lat. 31°40'S) and reached Torres (latitude 29°20'S) near the coast, compressed by meanders of Brazil Current and the incomplete upwelling of STW. *I. argentinus* occurred in 52 of the 88 hauls and mean relative abundance was the highest of all five cruises. Larvae were found in the south in the outer edge of the shelf in the western boundary of the Brazil Current; in the north, where TW occupies the shelf under an inverse thermocline, they occurred in most of the samples. Minimum mantle length in each sample was plotted against the bottom depth over which it was collected in Figure 5. An inverse relationship was detected as smaller larvae were absent over shallower waters, meaning that hatching takes place over deeper waters off the coast.

In October and November of 1980, coastal waters of low salinity and between 18 and 20°C were found near the coast and from the surface to the 100-m isobath. In the south, a steep thermocline separates SAW cold waters running northward on the shelf under warmer CW and from TW on the slope. In the north, TW over 20°C meanders onto the shelf, and subtropical water can be found over the bottom of the outer shelf and the slope. A small number of larvae occurred in 14 samples along the boundary between SAW and TW in the outer shelf in the south and in TW in the north.

In November 1981, the survey twice covered a small region in the south. The oceanographic pattern was similar to the earlier spring cruise of 1980. Nine larvae were found in seven samples, all associated with TW on the slope.

The last cruise, also in spring (October 1982), covered all the study area. In the south, SAW influence seemed more intense than in former years and in the north TW meandered over most of the shelf, while STW was near the bottom of the outer shelf and slope. *I. argentinus* larvae were fairly abundant, 73 specimens were obtained in 30 samples. In the south, larvae concentrated in the outer shelf and slope and in the north were found in most stations except those in very shallow waters.

Discussion

Six species of ommastrephids are reported to occur off southern Brazil: *I. argentinus, Ornithoteuthis antillarum, Ommastrephes bartrami, Symplectoteuthis luminosa, Hyaloteuthis pelagica* and *Todarodes filippovae* (Nesis, 1987; Warneke-Cremer, 1986; Haimovici and Perez, 1991). Juveniles of *I. argentinus* were caught throughout the year on the shelf (Haimovici and Andriguetto, 1986). Maturing and mature specimens, fished with trawls, were also found throughout the year over the outer shelf and upper slope, but were more abundant in winter (Haimovici and Perez, 1990). *O. bartrami* was occasionally caught over the slope, in areas associated with warm tropical surface waters off southern Brazil and Uruguay (Leta, 1986; Haimovici and Perez, 1991) and *Ornithoteuthis antillarum* was frequent in tuna stomach contents (Santos, pers. comm.). The other ommastrephids were absent over the shelf and rare over the slope. *I. argentinus* larvae were identified because size series up to juveniles were available and fit former descriptions by Leta (1987) and Brunetti (1990). Roper and Lu (1979) suggest that rhynchoteuthion larvae of the North Atlantic with greatly enlarged lateral suckers, like our type "A" larvae, pertain to the genera *Ommastrephes* and larvae with lateral suckers slightly bigger than the rest, as our type "B" larvae, as *O. antillarum*. Following Nesis (1979), our type "A" could be *O. antillarum*. No description of *S. luminosa* and *T. filippovae* larvae was found and only juveniles of *H. pelagica* were described by Nesis (1979). Thus, samples including a wider range of sizes of larvae and juveniles are necessary for identification of types "A" and "B" larvae.

I. argentinus has a long geographical range in the Southwest Atlantic and several spawning groups are postulated (Hatanaka *et al.*, 1985; Brunetti, 1988; Nigmatullin, 1989). A South Patagonian group reproduces somewhere north 45°S, from late autumn to winter (Hatanaka *et al.*, 1985). Its spawning grounds are not clearly located, but Hatanaka *et al.* (1985) suggest they should not be far because the proportion of mature specimens in the feeding grounds was high. Rodhouse *et al.* (1990) propose that spawning grounds are in the northern part of the Patagonian Shelf and egg masses may be carried northward by the cold Malvinas/Falkland current, hatch in the inner edge of the subtropical convergence, and larvae be carried southward by the warm Brazil Current.

A group of small adults spawns in summer in the Argentinian Shelf between 42 and 45°S. Mature specimens, larvae, and post-spawned males and females of this group were observed by Brunetti (1988) and Brunetti *et al.* (1991).

Another group grows and feeds in the northern Patagonian and Buenos Aires province Shelf. Maturing specimens are found from autumn to spring on these grounds and leave while most of the females are still unfertilized (Brunetti and Comas, 1989b). Brunetti *et al.* (1991) suggest they spawn in the western edge of the Subtropical Convergence in the early spring. In fact, rhynchoteuthion larvae, including *I. argentinus*, were found in summer, autumn and winter in the subtropical convergence area off Uruguay and Argentina (Brunetti, pers. comm.).

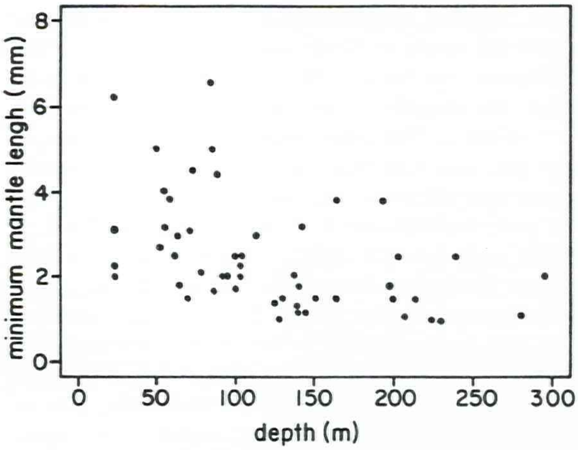


Figure 5. Relationship of the minimum mantle length of *Illex argentinus* larvae and bottom depth in the haul position in July and August 1980.

In southern Brazil, larvae of *I. argentinus* were found in winter and spring. As the degree of maturation in the feeding grounds may be an indicator of the length of the reproductive migration of ommastrephids (Hatanaka *et al.*, 1985), spawning is probably near our study area. In fact, recently hatched larvae less than 2 mm ML were found in the winter and spring cruises (Table 2).

Table 2. Mantle length at arm formation and proboscis splitting of the three types of rhynchoteuthion larvae.

	Type A	Type B	Type C
Third arm formation	1.7–2.0	1.4–1.6	1.5–1.7
Fourth arm formation	2.0–2.5	2.8–3.0	2.0–2.6
Proboscis splitting			
Beginning	3.8–4.0	3.0–3.5	4.0–5.0
End	?	?	6.0–6.5

I. argentinus larvae were common in the samples from the western boundary of the Brazil current, slope waters, and subsurface, subtropical waters but not in the Malvinas inner branch or in low salinity coastal waters. They may originate from adults spawning along the slope of southern Brazil or from winter and spring spawners that grow in the Argentinian and Uruguayan shelf (Fig. 4).

Nigmatullin (1989) states that *I. argentinus* spawns at night near the bottom along the slope in depths of 500–700 m. He observed a different diel migration behaviour in prespawners that gathered near the bottom along the slope in depths of 500–700 m during the night and dispersed in the lower 200–300 m water column during the day, presumably feeding on mictophids. If spawning takes place in the same way in southern Brazil, egg masses could be slowly transported northward while maturing in the low salinity STW. According to O'Dor and Balch (1985), egg mass density equilibrium requires a relatively long time, if due to differences in the salinity, while differences due to temperature equilibrate in around 10 h. The Brazil Current is warmer and higher in salinity than the underlying Subtropical Waters. As the subtropical water gradually mixes with the tropical waters of the Brazil Current, the egg masses increase their temperature, decrease their density and tend to buoy. In addition, the eggs develop faster as their northward transport speed decreases. Eventually, they could start moving in the opposite direction before hatching. Thus, larvae found off Rio Grande do Sul may originate from a local spawning and be retained in the same area.

Spawning off Buenos Aires and Uruguay could also produce larvae found off southern Brazil. In winter, egg masses spawned in SAW or STW could be carried northward for longer distances because the embryonic development is slower at lower temperatures (O'Dor *et al.*, 1982). Transport of egg masses from the south may contribute to the higher abundance of larvae in our study area in the winter.

Larvae in the meandering western edge of the Brazil Current were bigger nearer the coast where the current influence was lower and productivity, due to the partial upwelling, higher (Hubold, 1980a). Thus, after hatching, part of the larvae may be transported south by the Brazil Current, but those that develop on the continental shelf are more likely to recruit as juveniles in southern Brazil. In April of 1980, very warm waters covered all the shelf and no *I. argentinus* larvae were found. This cruise only covered the northern portion of the study area but the same absence was observed in our unpublished data from a former summer cruise in the southern portion of the study area. Nevertheless, some spawning is expected to take place in autumn as Haimovici and Perez (1990) found mature fertilized females from March to September. Thus, if some spawning occurs, egg masses may be transported out of our study area.

Hubold (1980a) detected patches of Subtropical Water, rich in zooplankton, in coastal waters to the north of Rio Grande in winter and spring (Hubold's Fig. 14) where we found larvae of *I. argentinus*. He also found these waters offshore in the subtropical convergence area off Uruguay and Argentina, where Brunetti and Leta (pers. comm.) also found larvae and juveniles. Thus, larval development probably takes place in the boundary of the tropical waters of the Brazil Current and subtropical waters.

Wider-scale studies, including the efforts of several countries, would be useful for a better understanding of the relationship between adult and larvae abundance of this important species.

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