UNIVERSIDADE FEDERAL DO RIO GRANDE

PÓS-GRADUAÇÃO EM OCEANOGRAFIA BIOLÓGICA

BIOLOGIA REPRODUTIVA DE *Octopus tehuelchus*, ORBIGNY 1834 (CEPHALOPODA: OCTOPODIDAE) NO SUL DO BRASIL

JONATAS ALVES

Dissertação apresentada ao Programa de Pós-graduação em Oceanografia Biológica da Universidade Federal do Rio Grande, como requisito parcial à obtenção do título de MESTRE

ORIENTADOR: DR. MANUEL HAIMOVICI

RIO GRANDE

AGOSTO – 2010

A Deus e a capacidade humana de sonhar...

AGRADECIMENTOS

Ao meu pai e minha mãe, por dividirem comigo este sonho e por me apoiarem na sua concretização, mas principalmente pelo amor, pelo carinho e pelo exemplo de caráter e de determinação.

A minha irmã Dani, pelo amor e atenção, pelos ensinamentos e pelas valiosas conversas nos momentos mais oportunos.

A minha inseparável companheira Tassinha, por acreditar em mim, me apoiar e principalmente por estar do meu lado todo esse tempo, pelo carinho e atenção com que ouviu meus desabafos, angústias e receios e pelo amor com que me ajudou a superá-los.

A todos os amigos conterrâneos de cima da serra, que acreditaram no fato de que morar a quilômetros de distância do mar não impede um homem de querer desbravá-lo.

A CAPES pela concessão da bolsa de estudo a qual tornou viável este produto final.

Ao Instituto de Oceanografia e ao Programa de Pós-Graduação em Oceanografia Biológica da FURG pelo suporte e prestatividade, em especial aos secretários Vera e Votto.

Ao Dr. Manuel Haimovici, pela oportunidade, pela orientação neste trabalho, pelos debates e principalmente pelo repasse do conhecimento e da vivência.

A toda equipe do Laboratório de Recursos Pesqueiros Demersais e Cefalópodes, em especial a Marcio de Araújo Freire, pela amizade, ajuda e parceria.

Aos membros da banca de avaliação: *Ph*.D. Eduardo Resende Secchi, Dra. Roberta Aguiar dos Santos, *Ph*.D. Leandro Bugoni e Dr. Roger Villanueva pelos seus valiosos comentários e contribuições.

Aos verdadeiros amigos (disfarçados de colegas de Mestrado e Doutorado) Gisele Oliveira, Paloma Lumi, Marcelo Burns, Leonardo Moraes, em especial Luciano Gomes Fischer, Pablo Mendonça e Luis Gustavo Cardoso, pelos intensos debates, conversas e contribuições que tornaram possível a realização deste trabalho e principalmente o meu crescimento como ser humano.

Ao mestre Jailson e toda a equipe do barco ABI Pesca II, pela acolhida e companheirismo.

A todos que não foram citados, mas que de uma forma ou de outra se fizeram presentes e contribuíram em mais esta etapa da minha vida....Obrigado!

RESUMO

Octopus tehuelchus é um pequeno polvo bentônico endêmico das águas subtropicais e temperadas da plataforma continental do Atlântico Sul ocidental. Sua biologia reprodutiva foi estudada a partir de 319 exemplares, medindo entre 20 e 79 mm de comprimento do manto (ML), coletados entre 1979 e 2009 na plataforma interna do Sul do Brasil. As fêmeas foram mais numerosas águas menos profundas e alcançaram tamanhos maiores que os machos. Fêmeas e machos totalmente maturos foram observados em todos os meses amostrados e o tamanho médio do manto na maturação sexual foi de 46 mm nas fêmeas e 27 mm nos machos. O número de ovócitos intraováricos variou entre 20 e 448 e se correlacionou positivamente com o tamanho das fêmeas. Nas fêmeas maturas (estágios III e IV) se observou uma grande amplitude de diâmetros nos ovócitos intraováricos, em alguns casos com uma distribuição bimodal. O número de ovos das quatro posturas observadas variou entre 86 e 237 e não foi observada bimodalidade nas suas distribuições de diâmetros. A glândula digestiva cresceu proporcionalmente ao peso corporal nas fêmeas, porém não nos machos, o que sugere uma acumulação de reservas para um longo período de postura e cuidado parental das desovas nas fêmeas e uma priorização da reprodução em detrimento ao crescimento nos machos. A comparação do ciclo reprodutivo de *O. tehuelchus* no Sul do Brasil com o de populações do Norte da Patagônia mostra que a espécie possui o potencial para desovar o ano todo, porém as limitações ecológicas permitem que este potencial se expresse somente nas latitudes mais baixas da sua distribuição.

Palavras-chave: *Octopus tehuelchus*, ciclo reprodutivo, maturação sexual, fecundidade, Atlântico Sul ocidental.

O presente trabalho foi submetido á revista Scientia Marina em 22 de Julho de 2010 sob o título “Reproductive biology of *Octopus tehuelchus,* Orbigny 1834 (Cephalopoda: Octopodidae) in Southern Brazil”, conforme anexo.

Reproductive biology of *Octopus tehuelchus*, Orbigny 1834 (Cephalopoda: Octopodidae) in Southern Brazil

Jonatas Alves [1] and Manuel Haimovici [2]

[1] Graduate Program in Biological Oceanography – Federal University of Rio Grande - FURG, Institute of Oceanography, Av. Itália Km 08, CP 474, CEP 96201-900. Rio Grande – RS – Brazil. jon.alves13@hotmail.com;

[2] Institute of Oceanography - Federal University of Rio Grande – FURG, docmhm@furg.br

RUNNING TITLE: Reproduction of *Octopus tehuelchus* in southern Brazil

SUMMARY

Octopus tehuelchus is a small octopus endemic to subtropical and temperate waters of the southwestern Atlantic continental shelf. Its reproductive biology was studied by examining 319 individuals, measuring 20 to 79 mm mantle length (ML), collected between 1979 and 2009 along southern Brazil. Females are more numerous in shallower waters and attain larger size than males. Fully mature males and females were observed in all seasons and mean mantle length at maturity was 46 mm for females and 27 mm for males. The number of intraovaric oocytes of maturing females ranged from 20 to 448 and was positively correlated with female size. In mature females, a wide range of intraovaric oocytes diameters was observed, in some cases with a bimodal distribution. The number of eggs of four egg layings ranged from 86 to 237 and no bimodality in the diameters was observed. Digestive gland grew proportionally to body weight along maturation in females but not in males, suggesting accumulation of reserves for spawning and parental care in females and priority for sexual maturation over growth in males. The comparison of the reproductive cycle of *O. tehuelchus* in southern Brazil with populations from northern Patagonia shows that the species has the potential for year round spawning, but ecological constrains only allows it to express this potential in the lower latitudes of its distribution.

KEY WORDS: *Octopus tehuelchus*, reproductive cycle, sexual maturation, fecundity, southwestern Atlantic.

RESUMEM

Octopus tehuelchus es un pequenõ pulpo endémico de las aguas subtropicales y templadas de la plataforma continental del Atlántico Sudoccidental. Su biología reproductiva se estudió examinando 319 ejemplares, entre 20 y 79 mm de longitud del manto (ML), recolectados entre 1979 y 2009 en la plataforma interior del sur de Brasil. Las hembras fueron más numerosas en aguas menos profundas y alcanzaron tamaños mayores que los machos. Machos y hembras totalmente maduros fueron observarvados en todas las estaciones y la talla media del manto en la madurez sexual fue 46 mm en las hembras y 27 mm en los machos. El número de ovocitos intraováricos osciló entre 20 y 448 y se correlacionó positivamente con el tamaño de las hembras. En las hembras maduras, se observó una amplia gama de diámetros de ovocitos intraováricos, en algunos casos con una distribución bimodal. . El número de huevos de las cuatro puestas observadas osciló entre 86 hasta 237 y no se observó bimodalidade en sus diámetros. La glándula digestiva creció proporcionalmente con el peso corporal en las hembras pero no en los machos, lo que sugiere la acumulación de reservas para la puesta y cuidado de los huevos en las hembras y la priorización de la reprodución sobre el crecimiento en los machos. La comparación del ciclo reproductivo de *O. tehuelchus* en sur de Brasil con poblaciones del norte de la Patagonia muestra que la especie tiene el potencial para desovar todo el año, pero limitaciones ecológicas permiten que este potencial se exprese solo en las bajas latitudes.

PALABRAS – CLAVE: *Octopus tehuelchus,* ciclo reproductivo, maduración sexual, fecundidad, Atlántico Sudoccidental.

INTRODUCTION

Cephalopods have developed a wide array of reproductive strategies, which enable them to occupy all marine habitats (Rocha *et al.*, 2001). Particularly, the family Octopodidae has experienced an intense speciation, occupying coastal benthic environments from the tropics to temperate regions (Norman, 2003). In this genera, a range of reproductive strategies occurs, from species with wide distribution, large body size, small eggs, high fecundity and pelagic hatchlings, such as *Octopus vulgaris* (Guerra, 1975; Mangold, 1987; Rocha *et al.*, 2001; Otero *et al.*, 2007; Villanueva and Norman, 2008) to endemic species, with small body size, larger eggs, low fecundity and benthic development, such as *Octopus tehuelchus* (Pujals, 1982; Iribarne, 1991; Ré, 1998). This last species occurs from subtropical southeastern Brazil (20ºS) (Haimovici and Perez, 1991) to the temperate habitats of San Jorge Gulf, in northern Patagonia, Argentina (43ºS) (Ré and Simes, 1992; Ré, 1998).

In southern Brazil, *Octopus tehuelchus* occurs over the continental shelf, on sandy and muddy bottoms, up to 100 m depth and usually associated with gastropod shells (Haimovici and Andriguetto, 1986). Due its low abundance in commercial landings, its life cycle and biology are poorly known in Brazil. However, the species is frequently found in stomach contents of demersal teleosts and marine mammals from this region (Santos and Haimovici, 2002). In the Patagonian gulfs, the species is commercially exploited on a small artisanal fishery. (Storero, 2010).

Most information on the growth and reproductive biology of the species comes from studies conducted in Patagonia, in an environment with the predominance of rocky bottoms, discharge of freshwater creeks and channels, high tidal range (up to 9 m) and large seasonal variation of temperature and luminosity (Pollero and Iribarne, 1988; Iribarne, 1991; Navarte *et al*, 2006; Klaich *et al*, 2008; Storero *et al*, 2010). This environment contrasts with southern Brazil, which presents sandy and muddy bottoms, small tidal range, temperature rarely below 12ºC, even in the cold months (Haimovici *et al.*, 1996) and lower variation in luminosity between winter and summer (Bakun and Parrish, 1990).

The aim of this work is to study the reproductive biology of *Octopus tehuelchus* in the subtropical environment of the continental shelf in southern Brazil, allowing a better understanding of the reproductive strategy along its distribution.

MATERIAL AND METHODS

Data Collection

Individuals of *Octopus tehuelchus* were collected from bottom trawl surveys by the R/V Atlântico Sul and from commercial trawling along southern Brazil in the 28°S to 34ºS range at depth from 15 to 100 m, between 1979 and 2009. Specimens were fixed in 10% formalin and preserved in 70% ethanol. A total of 125 males and 194 females were examined.

All preserved individuals had their Total Length (TL), Dorsal Mantle Length (ML), Total Body Weight (BW) and Digestive Gland Weight (DGW) recorded. Females had their Ovary Weight (OW), Oviducts Weight (including the oviducal glands) (OvW) and maximum diameter of oviducal glands recorded. All developing intraovaric oocytes were counted and the Maximum Diameter of Oocytes (MDO) was recorded. Four egg layings (one of them accompanied by female) were observed, spawned eggs were measured and recently spawned hatchlings were measured and weighed. In males, Testis (TW) and the Spermatophoric Sac (including the glandular system) (SSW) were weighted. Spermatophores in the Needham's sac were counted and measured. All the measurements were taken to 0.1 mm and weights to 0.01 g.

The reproductive cycle was analyzed by a combination of the monthly frequencies of males and females in each maturity stage and the monthly variations of the maturity and gonadosomatic indices.

A Maturity Index (MI) was calculated as MI= SSW/ (TW + SSW) for males and MI= OvW/ (OW + OvW) for females (Hayashi, 1970). The Gonadosomatic Index (GSI) was calculated as GSI= (SSW/ (BW – SSW)) x 100 for males and GSI= (OW/ (BW – OW)) x 100 for females (Otero *et al.*, 2007). Digestive Gland Index (DGI) was calculated as DGI = (DGW/ (BW – DGW)) x 100, similar to the one used for *Octopus vulgaris* (Otero *et al*., 2007).

The maturity scale was modified of Guerra (1975), Pujals (1982) and Perez and Haimovici (1991). For females, five stages were defined based on the size and colour of the oviducts and oviducal glands and the mean diameter of the developing oocytes: *Immature (I):* translucent oviducts, oviducal glands little differentiated, with diameter usually smaller than 2 mm; *Initial Maturity (II):* whitish oviducal glands between 2 and 3 mm in diameter and developing oocytes 2 to 4 mm long; *Intermediate Maturity(III):* oviducal glands brown/black, 3 to 4.5 mm in diameter, most oocytes between 4 and 7.5 mm long; *Advanced Maturity (IV):* enlarged oviducts, sometimes with oocytes being released, mean diameter of the larger oocytes over 7.5 mm; *Post-Spawning (V):* ovary clearly flaccid with reduced size and few eggs in it, oviducts dilated and small oviducal glands.

The maturity scale for males included four stages: *Immature (I):* small and whitish testis, glandular system slightly differentiated and absence of spermatophores in the

Needham’s sac; *Initial Maturity (II):* testicle in development, usually heavier than the glandular system and Needham’s sac with few (<20) spermatophores; *Advanced Maturity (III):* testicle weight lighter than glandular system and Needham’ s sac full; *Post-liberation of spermatophores* (IV): glandular system still bulky, Needham’s sac partially or totally empty, with spermatophores being released and testicle relatively small, striped and usually lighter than the glandular system.

Potential fecundity was defined as the number of developing oocytes with the largest diameter above 4 mm in ovaries of stages III and IV females.

Data analysis

Reproductive indices were compared with the non-parametric Kruskal-Wallis test for multiple comparisons, because assumptions for normality and homogeneity of variance were not satisfied.

Sex ratio was calculated monthly, for 15 mm dorsal mantle length classes (ML 15 mm) and for 30 m depth classes. Significant deviations from the 1:1 proportion were tested using the χ^2 test, adjusted to Yates correction (Zar, 1984).

Length-weight relationships were estimated for the total sample and according to sex. Data were adjusted to power model ($y = ax^b$), where y= BW; x= ML; a= the y-intercept; and b= the slope. The goodness of fit was expressed by r^2 and the analysis of covariance (ANCOVA) (Zar, 1984) was used to test for differences in the slope of log-transformed relationships.

The mean mantle length at maturity (ML50%) was estimated starting from the proportion (Pi) of stages III and IV individuals, grouped in 6 mm ML classes, adjusted to the logistic model: $Pi = 1- \{1/ 1 + \exp [- (\alpha + \beta MLi)]\}$

The Bhattacharya method (Bhattacharya, 1967; King, 2007) was used to discriminate normal components in the diameter frequency distribution of intraovaric oocytes.

RESULTS

Sex Ratio

In total, 174 females and 125 males were sampled. The sex ratio did not differ significantly among sampling months (Table 1) but the proportion of females was significantly higher among the specimens over 45 mm ML (χ^2= 13.89 and 5.18; p <0.05) (Table 2). Regarding the depth of capture, the proportion of females was higher in all depth ranges. However, the differences was significative only under 30 m depth (χ^2= 4.17; (p <0.05) (Table 3). These results indicate that females grow larger than males and that spawning may occur mainly in shallow waters.

Length-weight relationships

Females *O. tehuelchus* ranged from 21 to 79 mm ML (mean 47.2) and from 8.3 to 228.5 g BW (mean 69.5) and males ranged from 20 to 76 mm ML (mean 42.6) and 4.7 to 125.1 g BW (mean 46.0). . The dorsal mantle length/total body weight relationships (ML/BW) were calculated only for individuals caught in 2009 (n= 64), which were less affected by the dehydration observed in specimens preserved in alcohol for long periods. Relationships were best described by the power equations (Table 4): females: $BW = 0.0211 \times ML^{2.2098}$, males: $BW = 0.0113 \times ML^{2.3337}$ and both sexes combined: $BW = 0.0072 \times ML^{2.4772}$. Slope comparisons did not show heterogeneity between sexes (ANCOVA, p = 0.634). However, these results should be considered with care by the low number of individuals, manly males (Table 4).

Maturation and size-at-maturity

Fully mature males and females were observed in all seasons. Therefore, the mean size and weight at maturity were calculated including specimens collected year round.

Females in stages I and II (n = 76) were observed in all size range including seven females over 60 mm ML (Fig 1). Females in stages III and IV (n= 95) measured over 24 mm ML and weighed over 30 g. Although the small variation, the mean ML increase significantly along maturation (p <0.05) (Table 5). The maturity curve of females showed a good fit to the logistic model (r^2 = 0.980) and $ML_{50\%}$ calculated was 45.9 mm (Fig. 2).

Males in stages I and II (n= 58) were observed in all sizes including five individuals over 60 mm (Fig. 1). All males in stages III and IV (n = 65) were over 30 mm ML and 15 g BW. The $ML_{50\%}$ was 27.4 mm, however, the maturity curve of males did not show a good fit to the logistic model (r^2 = 0.129) (Fig 2).

Seasonality

Females in stages I or II were observed in all months sampled. Stage III individuals were caught more frequently in April, June and November and stage IV individuals were caught in all months sampled, mainly in January, August and September (Fig. 3). A single stage V female with an egg laying was observed in July. Three other egg layings without the spawned female were found in the same month and a fourth was observed in November. Reproductive indices were not homogeneous throughout all months (p <0.05) (Fig 4). Higher (GSI) and lower (MI) associated to sexual maturity were observed in January (summer) and June, August and September (late autumn to late winter).

Immature and initial maturity males (stages I and II) occurred year round, but more frequently in April, June and December. Stages III and IV also occurred in all sampled months, more frequently in January (summer), September, October and November (late winter and early spring) (Fig. 3). There were no significant differences in the monthly means of IM and GSI (p >0.05), indicating mature males in all seasons (Fig.4).

In both sexes, maturity stages and reproductive indices support a year round sexual maturation cycle.

Pre-spawning oocytes and spermatophores

The mean number of oocytes counts in the ovaries of 67 maturing females (stages III and IV) was 246.8 oocytes (ranging from 20 to 448). In these ovaries, the diameter of the oocytes ranged from 1.8 to 13.9 mm (Table 5). A wide range of oocytes diameters was observed, in some cases with a bimodal distribution (Fig 5).The number of oocytes (ON) increased significantly with female ML (ON = 1.4889 x (ML) 1.3094; r = 0.524 n = 67) (Fig. 6). Immature and initial maturity females (stages I and II, n = 68) had 185 oocytes in average (50 to 514), most of them with diameter under 4 mm (Table 5).

In stages III and IV males (n= 67), the number of developing spermatophores ranged from 1 to 62 (21.2 ± 12.3), with maximum length ranging from 1.7 to 57.4 mm (21.2 ± 8.9). Non-significant correlation was found between the number of spermatophores and the male size (r = 0.086) (Fig. 6).

Spawning and hatchlings

All the egg layings were observed in gastropod shells of *Tonna galea* and *Adelomenon brasiliana*. The number of eggs attached to the shells in the layings ranged from 86 to 237 (165.2 ± 60.5; n = 4). The maximum diameter of these eggs ranged from 8.1 to 14.4 mm and their diameter distribution were unimodal.

Recently spawned juveniles (n = 16) resembled small adults, and measured from 5.0 to 6.40 mm ML and from 10.5 to 15.0 mm TL and weighed from 0.07 to 0.12 g (Table 6).

Digestive gland index and reproductive investment

The Digestive Gland Weight (DGW) of females increased significantly along the sexual maturation (p <0.05). The Digestive Gland Index (DGI) was significantly lower in stage I (p <0.05), and remained constant in the others stages (Fig. 7). Monthly DGI of females did not follow a regular pattern: the lowest values were observed in April and May and the highest ones, in January, March, August and December (Fig. 8).

Digestive gland weight and index of males did not show significant changes along maturation (p >0.05), although small decrease in DGI means along maturation was observed (Fig. 7). Seasonally, higher DGI values were observed in spring (Fig. 8).

DISCUSSION

Octopus tehuelchus is a small species with large eggs and low fecundity, endemic of the subtropical and temperate waters of the southwestern Atlantic continental shelf (Haimovici and Perez, 1991; Ré, 1998). This study shows that its reproductive biology can adapt to both environments, with seasonal spawning in temperate waters and year round spawning in subtropical environments. Temperature and daily photoperiod can influence growth and reproduction in cephalopods (Richard, 1967; Van Heukelem, 1973; Mangold, 1987). Seasonal differences in the day length and water temperature are smaller in the subtropical environment of southern Brazil (32°S), where daylight ranges from 10 to 14 h (Bakum and Parrish, 1990) and bottom temperatures on the continental shelf range between 12°C and 24ºC (Haimovici *et al.*, 1996). In contrast, in northern Patagonia (40 to 42°S), daylight ranges from 9 to 15 h and air temperatures along San Antonio Bay coast range between 6°C and 24ºC (Iribarne, 1991) (Fig. 9). Despite not discriminating the effects of each factor, Iribarne (1991) observed that high intensity of light and temperature were associated to the intensification of growth and sexual maturation of *Octopus tehuelchus* in northern Patagonia, where sexual maturation occurs between December and May and spawning occurs from June to November (Pujals, 1982; Ré 1989). Storero *et al* (2010) observed two distinct sub-annual cohorts in the mantle length distributions within San Antonio Bay, suggesting that *O. tehuelchus* can have a more extended spawning season even in the higher latitudes of its distribution. In contrast, in southern Brazil, mature males and females were observed year round and egg broods were sampled both in cold and warm months.

Octopus tehuelchus uses a wide variety of bottoms types to deposit eggs. On the rocky bottoms of San Matias Gulf (41º to 42ºS), the eggs are attached directly to the substrata (Ré, 1998). On the sandy bottoms of the San Antonio Bay (40º 40'S), the eggs are attached to shelters, mainly bivalve shells: *Ostrea puelchana*, *Ammiantis purpurata, Mytilus edulis platensis*, *Chlamys tehuelchus* and *Pitar rostratus* and gastropods: *Buccinanops gradatum*, *Odontocymbiola subnodosa* e *Zidona dufresnei* (Iribarne, 1990). Although most of these mollusks also occur in southern Brazil (Rios, 2009), egg laying of *Octopus tehuelchus* in this region was found only inside shells of large sized gastropods *Tonna galea* and *Adelomenon brasiliana.* Iribarne (1990) notes that the abundance of small shells in San Antonio Bay could favor the selection of smaller octopuses. However, the availability of larger shells in southern Brazil does not seem to have favored larger individuals in this region.

In southern Brazil, a wide range of sizes of developing intraovaric oocytes (Fig. 5) and of egg sizes in the spawning (Fig. 10) were observed. In northern Patagonia, some females also showed oocytes at different stages of development (Pujals, 1982). These wide ranges in oocytes size may decrease competition among siblings. However there are differences in the evolution of the DGI between regions, that suggest that the individual spawning period may be longer in southern Brazil: in northern Patagonia, the DGI decreases along sexual maturation and can be associated to intense reserve mobilization along a short spawning season (Pujals, 1982; Iribarne, 1991); in southern Brazil, the DGI remains high along maturation, suggesting the accumulation of reserves for a longer period of spawning and parental care of the eggs. However, it is not consensual that the digestive gland has an important role in energy storage in cephalopods, as many authors also consider the reserves in the muscle and gonads (Moltchaniwskyj and Semmens, 2000; Rosa *et al*., 2004; Semmens et *al*., 2004).

In males, the DGI decreases in both regions, characterizing a larger mobilization of energy reserves for the reproduction and anticipation of sexual maturation rather than growth (Iribarne, 1991). Moreover, males mature at smaller sizes than females in both areas (Ré, 1989). In the San Matias Gulf, females mature up to three months after males. After copulation, the sperm is stored in the oviducal glands of females (Ré, 1998).

The lack of seasonality in the spawning in southern Brazil may be associated to year round availability of food for hatchlings. Productivity on the inner shelf of southern Brazil is relatively high (Ciotti *et al.,* 1995) mainly as a consequence of the runoff of nutrient-rich waters, carried from the La Plata River and Patos Lagoon (Piola *et al*, 2005). In this region, other neritic cephalopods such as *Doryteuthis(Loligo) sanpaulensis* spawn year round (Andriguetto and Haimovici, 1991; Haimovici, 1998a) and many bony fishes are multiple spawners (Haimovici, 1998b). In the Patagonian gulfs, productivity is dependent of the tidal fronts and shows a strong seasonal variation, where higher productivity rates are concentrated in spring and summer (Acha *et al.,* 2004). In temperate environments, such as the northern Patagonian gulfs, seasonality in the productivity makes availability of food and consequent survival for young octopus in the cold season more difficult. Furthermore, according to Klaich *et al*. (2006), food intake, growth and food conversion of *O. tehuelchus* in experimental conditions were lower at 10°C when compared to 15°C. Therefore, the conclusion is that *O. tehuelchus* has the potential for year round spawning, but ecological constrains only enable it to express this potential in the lowest latitudes of its distribution range.

ACKNOWLEDGMENTS

The authors thank Roger Villanueva and Roberta Aguiar dos Santos for their comments on the manuscript and the skippers Bjarne Bager and Jailson for providing specimens. J.A. was supported by a scholarship from CAPES (Coordination of Improvement of High Education), provided by the Graduate School in Biological Oceanography at the Federal University of Rio Grande (FURG). M.H. was partly supported by a research grand from the Brazilian Research Council (CNPq).

REFERENCES

Acha, E.M., W. Hermes, R.A. Mianzan, M.F. Guerrero and J. Bava. – 2004. Marine fronts at the continental shelves of austral South America Physical and ecological processes. *J. Mar. Syst.*, 44: 83-105.

Andriguetto, J.M. and M. Haimovici. – 1991. Abundance and distribution of *Loligo sanpaulensis* Brackoniecki, l984 (Cephalopoda, Myoposida) in southern Brazil. *Sci. Mar.*, 55(4): 611-618.

Bhattacharya, C.G. – 1967. A simple method of resolution of a distribution into Gaussian components. *Biometrics*, 23: 115-135.

Bakun, A. and R.H. Parrish. – 1990. Comparative studies of coastal pelagic fish reproductive habitats: the Brazilian sardine (*Sardinella aurita*). *J. Mar. Sci.*, 46(3): 269-283.

Ciotti, A.M., C. Odebrecht, G. Fillmann and O.O. Möller Jr., – 1995. Freshwater outflow and subtropical convergence influence on phytoplankton biomass on the southern Brazilian continental shelf. *Cont. Shelf Res*., 15(14): 1737-1756.

Guerra, A. – 1975. Determinación de las diferentes fases del desarrollo sexual de *Octopus vulgaris* Lamark, mediante un índice de madurez. *Inv. Pesq*., 39(2): 397-416.

Haimovici, M. – 1998a. Ambientes costeiros e marinhos e sua biota: Cefalópodes. Em: U. Seeliger, C. Oderbretch and J.P.Castello (eds.), *Os Ecossistemas Costeiro e Marinho do Extremo Sul do Brasil*. pp 162-166. Editora Ecoscientia.

Haimovici, M. – 1998b. Ambientes costeiros e marinhos e sua biota: Teleósteos demersais e bentônicos. Em: U. Seeliger, C. Oderbretch and J.P.Castello (eds.), *Os Ecossistemas Costeiro e Marinho do Extremo Sul do Brasil*. pp 143 – 152. Editora Ecoscientia

Haimovici, M. and J.M. Andriguretto. – 1986. Cefalópodes costeiros capturados na pesca de arrasto do litoral sul do Brasil. *Arq. Biol. Tecnol*., 29(3): 473-495.

Haimovici, M. and J.A.A Perez. – 1991. The coastal cephalopod fauna of Southern Brazil. *Bull. Mar. Sci*., 49(1-2): 221-230.

Haimovici, M., A.S.Martins and P.C. Vieira. – 1996. Distribuição e abundancia de peixes teleósteos demersais sobre a plataforma continental do sul do Brasil. *Rev. Brasil. Biol.,* 56(1): 27-50.

Hayashi, Y. – 1970. Studies on the maturity conditions of the common squid. A method of expressing maturity conditions by numeric values. *Bull. Jap. Soc. Fish*., 36: 995-999.

Iribarne, O.O. – 1990. Use of shelter by the small Patagonian octopus *Octopus tehuelchus*: availability, selection and effects on fecundity. *Mar. Ecol. Prog. Ser*., 66: 251-258.

Iribarne, O.O. – 1991. Life history and distribution of the small south-western Atlantic Octopus, *Octopus tehuelchus* Orbigny. *J. Zool. Lond.*, 223: 549-565.

Klaich, M.J., M. E. Ré and S.N. Pedraza. – 2006. Effect of temperature, sexual maturity and sex on growth, food intake and gross growth efficiency in the “pulpito” *Octopus tehuelchus* (d’Orbigny, 1834). *J. Shellfish Res.*, 25(3): 979-986.

Klaich, M.J., M.E. Ré and S.N. – 2008. Gross growth efficiency as a function of food intake level in the "Pulpito" Octopus tehuelchus: A multimodel inference application. *Aquaculture,* 284: 272-276.

Mangold, K. – 1987. Reproduction. In: P.R.Boyle (ed.), *Cephalopod Life Cycles, vol. 2. Comparative Reviews.* pp 157 - 200. Academic Press, London.

Moltchaniwskyj, N.A. and J.M. Semmens. – 2000. Limited use of stored reserves for reproduction by the tropical loliginid squid *Photololigo* sp. *J. Zool. Lond.*, 251: 307-313.

Narvarte, M., R. Gonzalez and M. Fernandez. – 2006. Comparison of Tehuelche octopus (Octopus tehuelchus) abundance between an open-access fishing ground and a marine protected area: Evidence from a direct development species. *Fish. Res.,* 79: 112-119.

Norman, M. – 2003. *Cephalopods: A World Guide*. ConchBooks. Germany. 320 pp.

Otero, J., A.F. González, P.M. Sieiro and A. Guerra. – 2007. Reproductive cycle and energy allocation of *Octopus vulgaris* in Galician waters, NE Atlantic. *Fish. Res.*, 85: 122–129.

Perez, J.A.A and M. Haimovici. – 1991. Sexual maturation and reproductive cycle of *Eledone massyae*, Voss 1964 (Cephalopoda: Octopodidae) in Southern Brazil. *Bull. Mar. Sci.*, 49(1-2): 270-279.

Piola, A. R., R.P. Matano, E.D.Palma, O.O. Möller Jr. and E.J.D.Campos. – 2005. The influence of the Plata River discharge on the western South Atlantic shelf. *Geophys. Res. Lett*., 32: L01603. 4pp.

Pollero, R.J., O.O. Iribarne. – 1988. Biochemical-Changes during the Reproductive Cycle of the small Patagonian Octopus, *Octopus tehuelchus*, D'Orb. *Comp. Biochem. Physiol*., Vol. 90B No. 2: 217-320.

Pujals, M.A. – 1982. Contribuición al conocimiento de la biologia de *Octopus tehuelchus* (Orbigny, Mollusca, Cephalopoda). *Anales de la Sociedad Científica Argentina Série I: Ciências* 46: 30-71.

Ré, M.E. – 1989. *Estúdios ecológicos sobre el crecimiento y la alimentación de Octopus tehuelchus d'Orbigny en Puerto Lobos, Golfo San Matias*. Tesis Doctoral, Uniersidad Nacional de La Plata, Argentina.

Ré, M.E. – 1998. Pulpos octopódidos (Cephalopoda, Octopodidae). In: E.E. Boschi (ed.), *El Mar Argentino y sus recursos pesqueros. Los moluscos de interés pesquero. Cultivos y estrategias reproductivas de bivalvos y equinoideos. Tomo 2*. pp. 69-80. Instituto Nacional de Investigación y Desarrollo Pesquero, Secretaría de Agricultura, Ganadería, Pesca y Alimentación, Mar del Plata.

Ré, M.E. and E.G.Simes. – 1992. Hábitos alimentares del pulpo (*Octopus tehuelchus*).Análisis cuali-cuantitativo de la dieta em el intermareal de Puerto Lobos, golfo de San Matias (Argentina). *Frente Marit*., 11(A): 119-128.

Richard, A. – 1967. Role de la photoperiode dans lê determinisme de la maturation genitale femelle du cephalopode *Sepia officinalis* L. *C.r. hebd. Seanc. Acad. Sci. Paris*, 264: 1315-1318.

Rios, E.C. – 2009. *Compendium of Brazilian Sea Shells*. Evangraf. Rio Grande-RS. 668 pp.

Rocha, F., A. Guerra and A. González. – 2001. A review of reproductive strategies in cephalopods. *Biol. Rev*., 76: 291–304.

Rosa, R., P.R. Costa and M.L. Nunes. – 2004. Effect of sexual maturation on the tissue biochemical composition of *Octopus vulgaris* and *O. defilippi* *(*Mollusca:Cephalopoda). *Mar. Biol*., 145: 563–574.

Santos, R. A. and M. Haimovici. – 2002. Cephalopods in the trophic relations off southern Brazil. *Bull. Mar. Sci*., 71(1): 753-770.

Semmens, J.M., G.T. Pecl, R. Villanueva, D. Joufre, I. Sobrino, J.B. Wood and B.R. Rigby. – 2004. Understanding octopus growth: patterns, variability and physiology. *Mar. Freshw. Res.*, 55: 367-377.

Storero, L.P., M. Ocampo-Reinaldo, R.A. Gonzalez and M.A. Narvarte. – 2010. Growth and life span of the small octopus *Octopus tehuelchus* in San Matias Gulf (Patagonia): three decades of study. *Mar. Biol*., 157: 555-564.

Van Heukelem, W.F. – 1973. Growth and life-span of *Octopus cyanea* (Mollusca:Cephalopoda). *J. Zool. Lond*., 169: 299-315.

Villanueva, R. and M.D. Norman. – 2008. Biology of the planktonic stages of benthic octopuses, *Oceanog. Mar. Biol. Annu. Rev*., 46: 105-202.

Zar, J.H. – 1984. *Biostatistical Analysis*. Prentice-Hall Inc. Englewood Cliffs.

TABLES

Table 1: Monthly variation in sex ratio of *Octopus tehuelchus* in southern Brazil (*significant χ2 departures from the 1:1 sex ratio $p < 0.05$).

Month	Number	Females	Males	X^2
Jan	49	59%	41%	1.67
Mar	5	40%	60%	0.40
Apr	14	50%	50%	0.07
May	18	67%	33%	2.00
Jun	43	51%	49%	0.05
Aug	14	64%	36%	1.21
Sep	44	64%	36%	3.30
Oct	14	57%	43%	0.36
Nov	56	63%	38%	3.52
Dec	30	40%	60%	1.23

Table 2: Sex ratio variation of *Octopus tehuelchus* according to ML 15 mm classes in southern Brazil (*significant χ^2 departures from the 1:1 sex ratio p <0.05).

ML Classes range (mm)	Number	Females	Males	X^2
15 – 29.9	17	35%	65%	1.53
30 – 44.9	140	51%	49%	0.04
45 – 59.9	104	68%	32%	13.89*
> 60	38	68%	32%	5.18*

Table 3: Sex ratio variation of *Octopus tehuelchus* according to 30 m depth classes in southern Brazil (*significant χ^2 departures from the 1:1 sex ratio p <0.05).

Depth range (m)	Number	Females	Males	$\chi 2$
< 30	24	71%	29%	4.21*
30 – 59.9	171	56%	44%	2.58
> 60	58	60%	40%	2.50

Table 4: Range of Mantle Length (ML) and Total Body Weight (BW) and power regression parameters of length/weight relationships for females and males of *Octopus tehuelchus* caught in southern Brazil in 2009.

	n	Min-Max (Mean) ML	Min-Max (Mean) BW	A	B	r^2
Females	47	30-65 (49.9) mm	21.9-228.5 (123.4) g	0.0211	2.2098	0.7240
Males	17	28-52 (40.1) mm	32.5-119.4 (65.1) g	0.0113	2.3337	0.8290
Both sexes	64			0.0072	2.4772	0.8347

Table 5: Variation in the number and Maximum Diameter (MDO) of intraovaric oocytes in females of *Octopus tehuelchus* in different maturation stage (Stages I, II, III and IV) in southern Brazil.

	Stage I	Stage II	Stage III	Stage IV
Number of females	12	56	22	45
Mean Female ML (± SD) (mm)	32.8 ± 7.4	43.9 ± 9.5	46.6 ± 9.1	48.5 ± 8.4
Range oocytes number	50 to 350	65 to 514	20 to 410	112 to 448
Mean oocytes number (± SD)	139.7 ± 76.6	226.9 ± 108.0	205.1 ± 93.3	267.1 ± 83.5
Range MDO (mm)	0.2 to 3.0	1.0 to 7.4	1.8 to 10.8	1.5 to 13.9
Mean MDO (± SD) (mm)	1.4 ± 0.7	3.1 ± 0.8	5.5 ± 1.8	8.0 ± 2.2

Table 6: Variation in the number and Maximum Diameter of Eggs (MDE) and in the Mantle Length (ML), Total Length (TL) and Total Body Weight (BW) of hatchling on four eggs laying of *Octopus tehuelchus* in southern Brazil in comparison with northern Patagonia. (1) Iribarne, 1991; (2) Ré, 1998.

	Southern Brazil	Northern Patagonia
Maximum of eggs per laying	237	227 (2)
mean egg laying fecundity (± SD)	165.15 ± 60.84	No data
Spawning egg measured	445	300 (1)
range MDE (mm)	8.13 to 14.44	9.0 to 12.0 (1)
mean MDE (± SD) (mm)	10.33 ± 1.09	9.87 ± 0.61 (1)
Juveniles sampled	16	280 (1)
mean ML (± SD) (mm)	5.77 ± 0.46	6.64 ± 0.38 (1)
mean TL (± SD) (mm)	12.06 ± 1.06	14.23 ± 0.83 (1)
mean BW (± SD) (g)	0.095 ± 0.014	0.139 ± 0.019 (1)

FIGURES

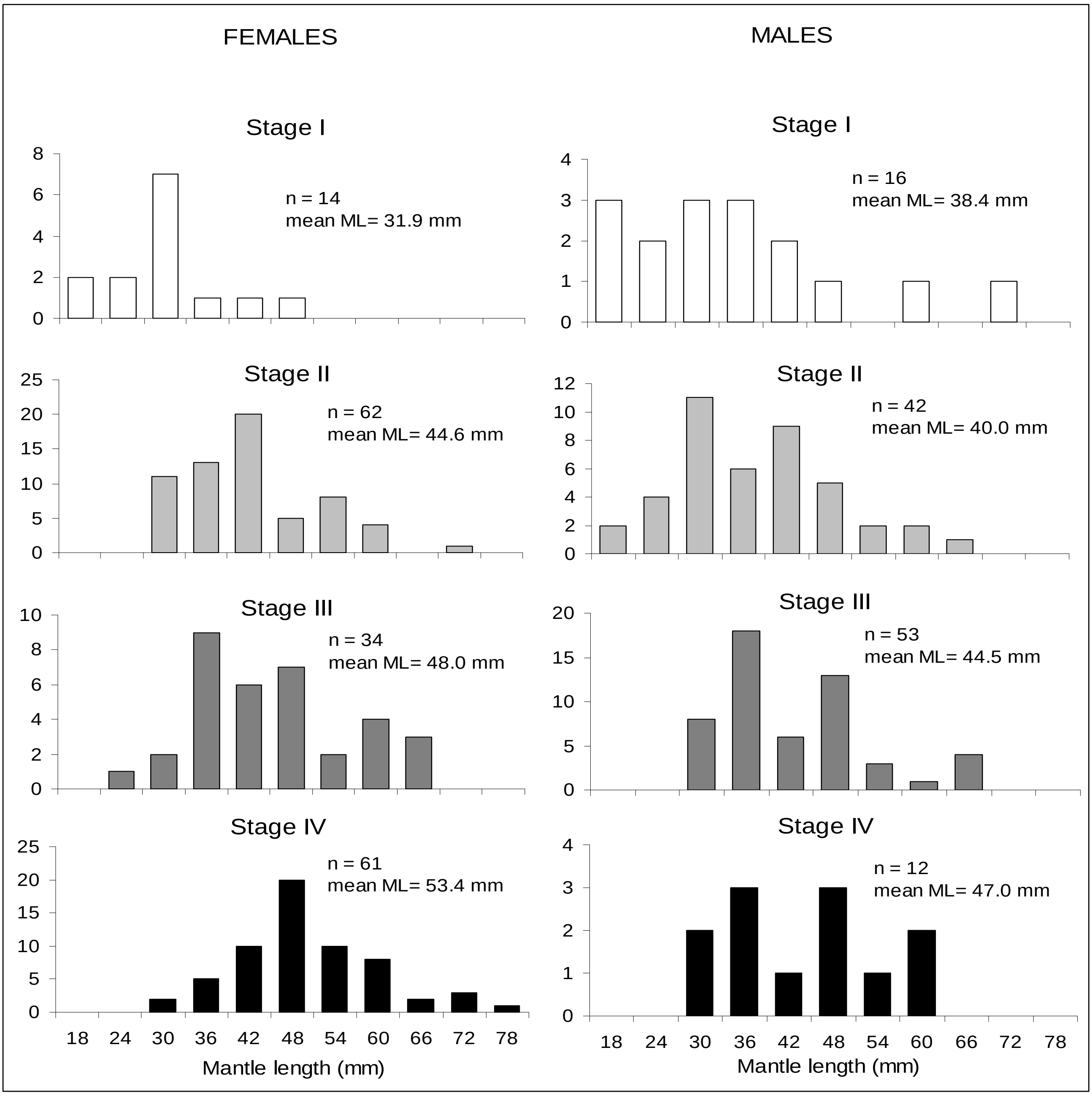

Fig. 1: Frequency of Mantle Length (ML) classes in each maturity stage of females and males of *Octopus tehuelchus* in southern Brazil.

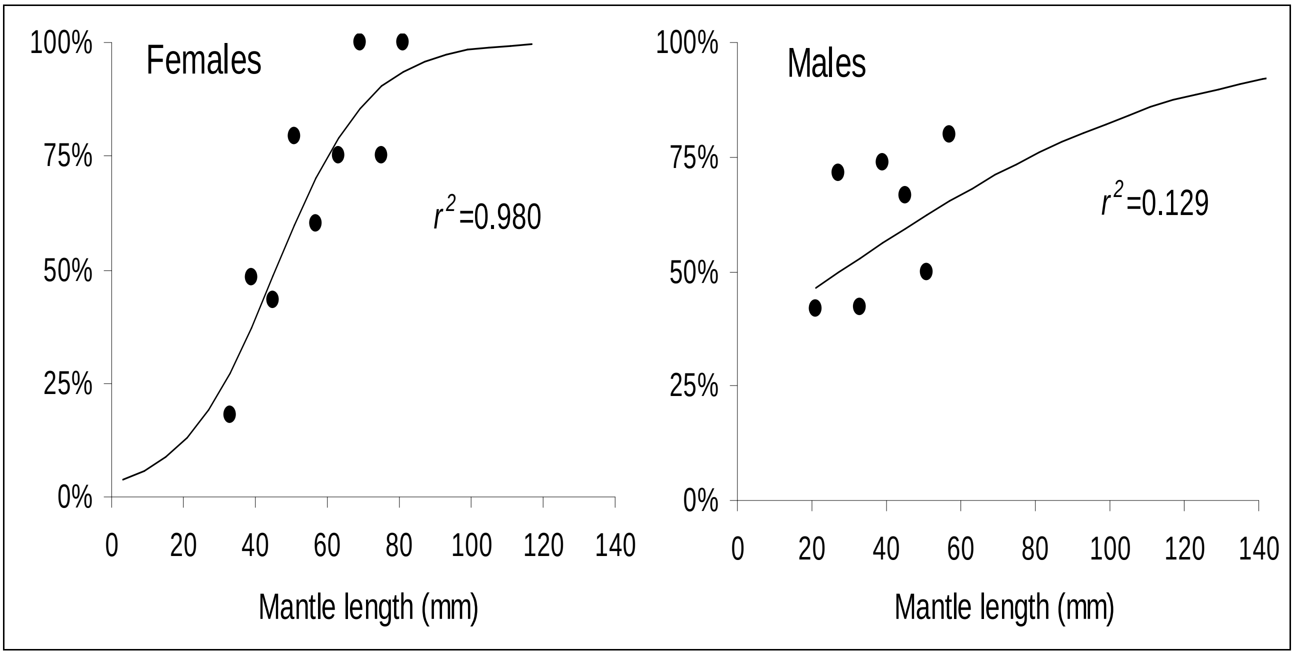

Fig. 2: Relative frequency curve of mature individuals by Mantle Length (ML) classes (mm), of females and males of *Octopus tehuelchus* in southern Brazil.

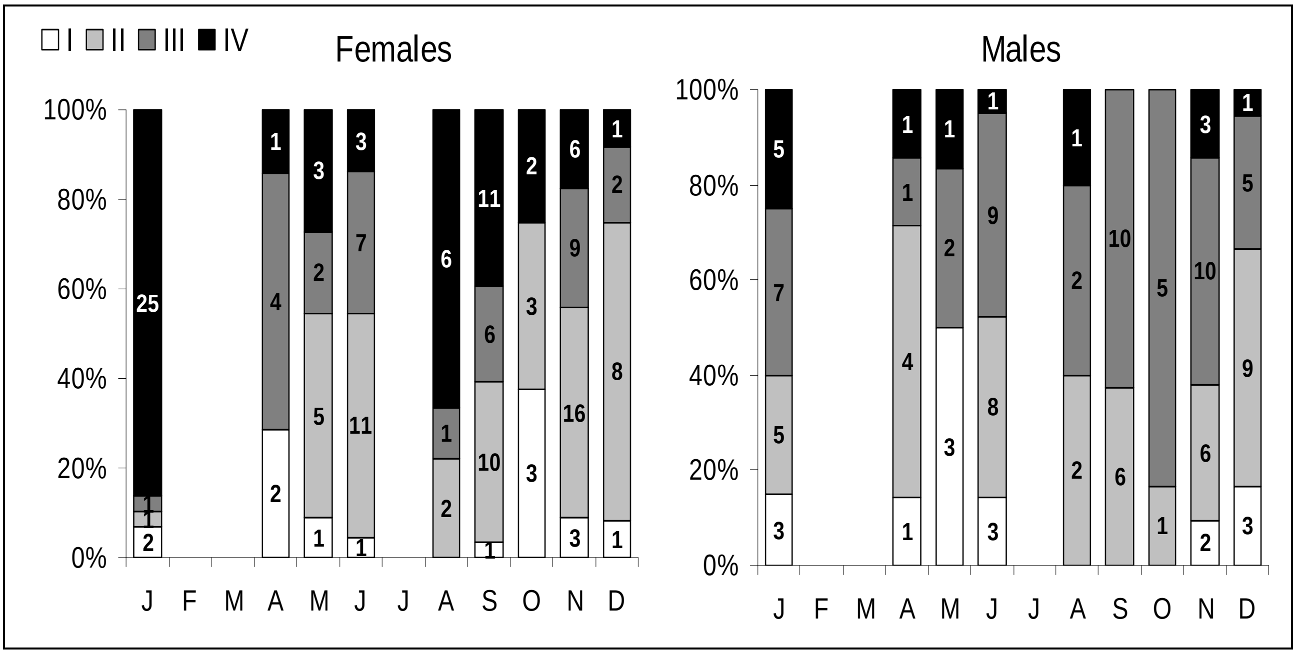

Fig. 3: Monthly frequency (%) of the maturity stages of *Octopus tehuelchus* females and males in southern Brazil (values in the bars indicate the number in each stage).

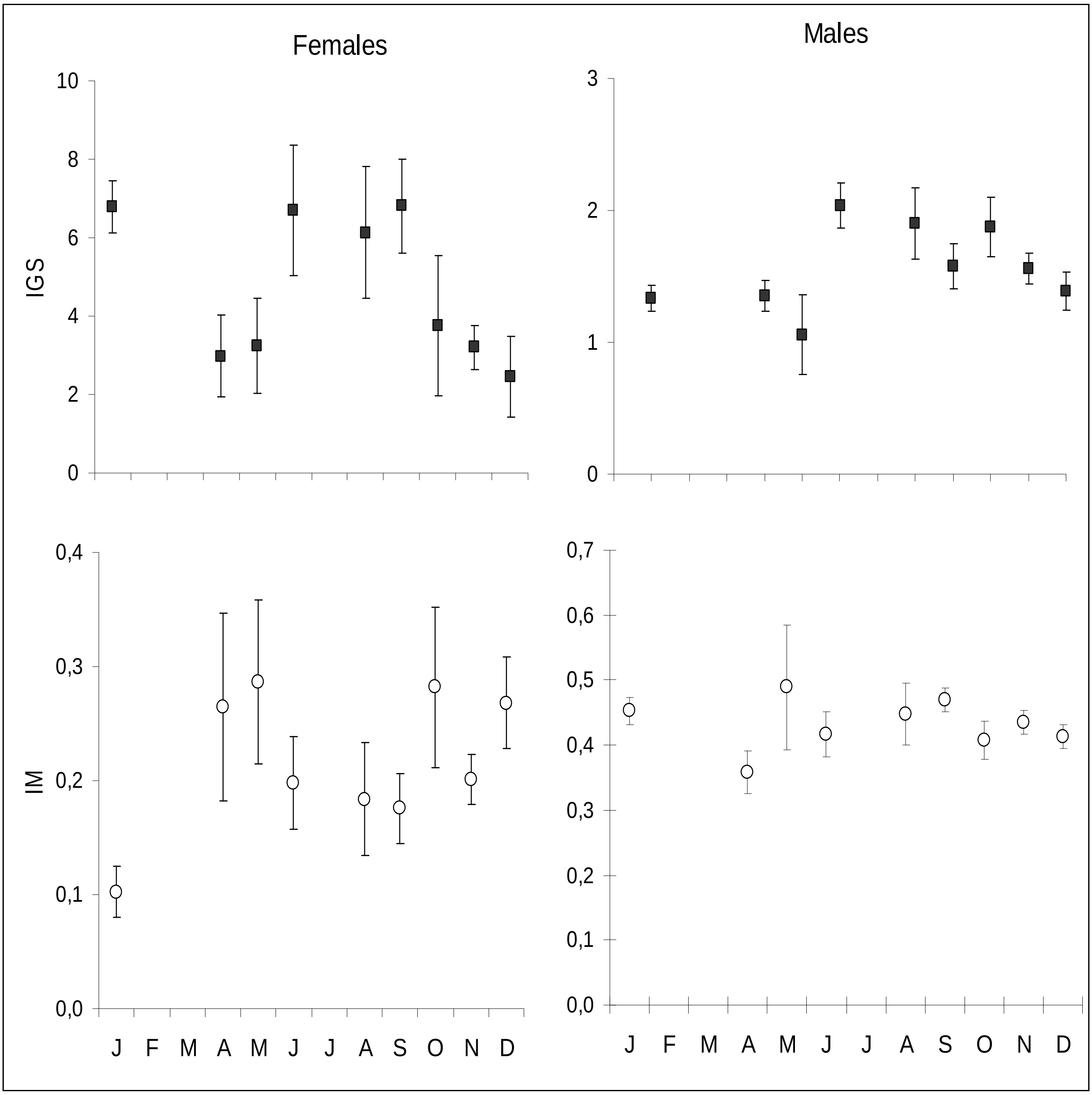

Fig. 4: Monthly trends of mean (±SE) values of the Gonadosomatic Index (GSI) and the Maturity Index (MI) of *Octopus tehuelchus* females and males in southern Brazil.

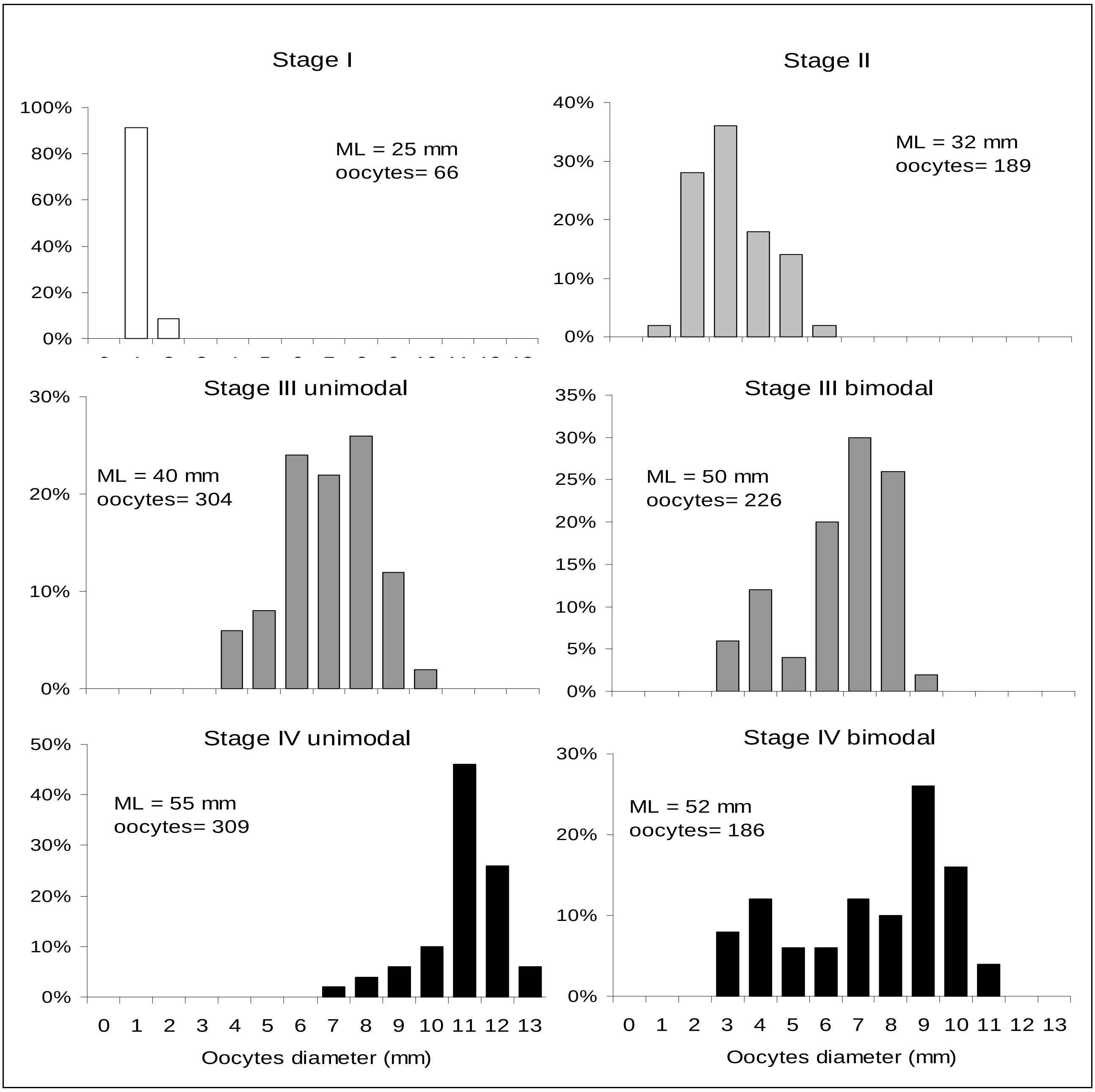

Fig. 5: Frequency of oocytes length classes of *Octopus tehuelchus* females at different maturity stages in southern Brazil. The Mantle Length (ML) and Total Fecundity (oocytes) of each individual were specified.

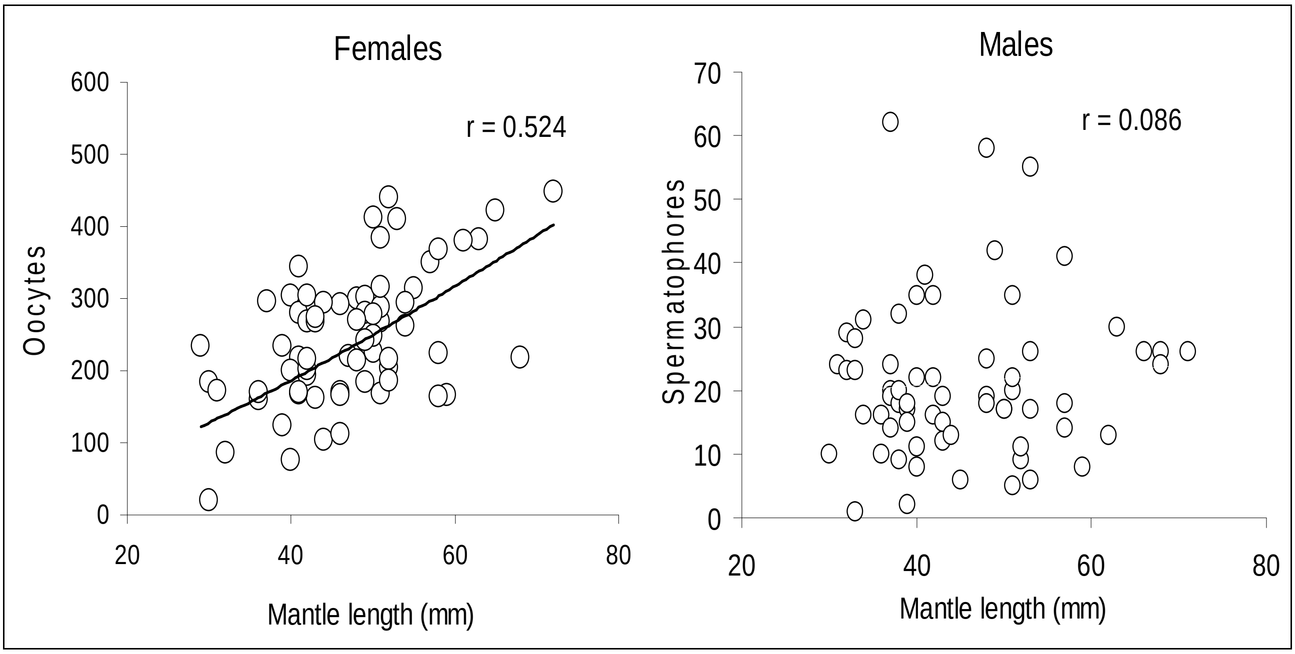

Fig. 6: Relationship between Mantle Length (ML) and Potential Fecundity (number of developing oocytes and spermatophores) of mature females and males of *Octopus tehuelchus* in southern Brazil.

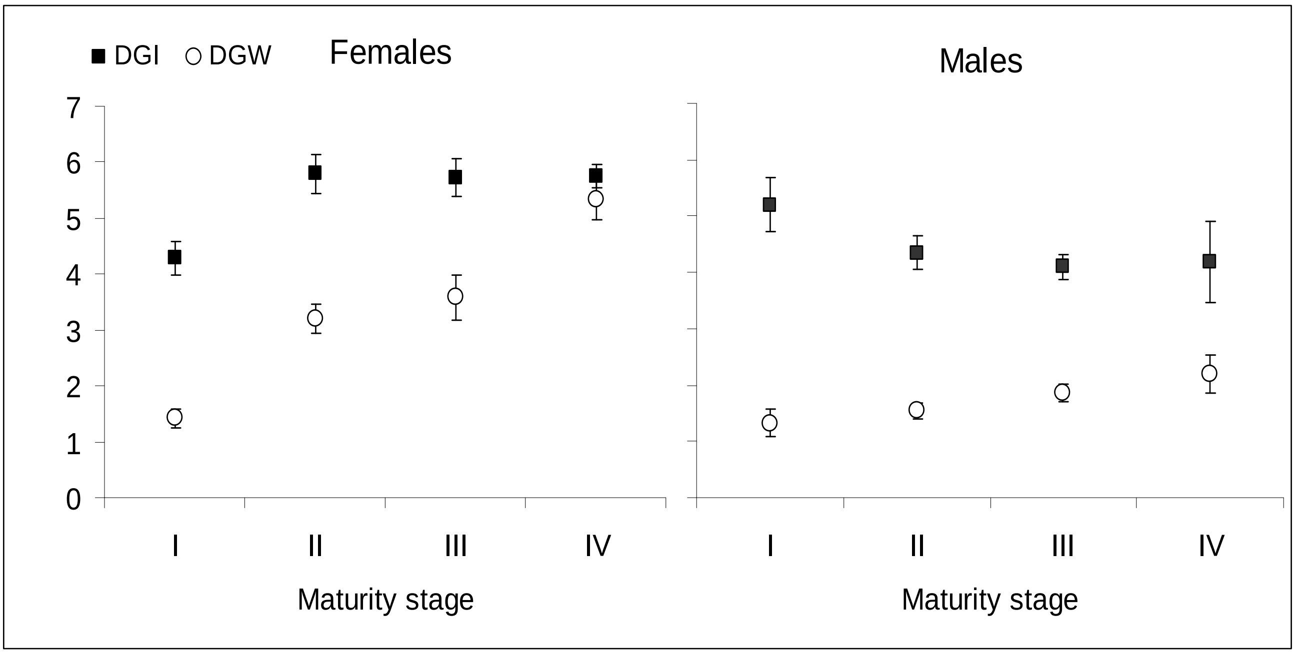

Fig. 7: Mean (±SE) of Digestive Gland Weight (DGW) and Digestive Gland Index (DGI) in each maturity stages of *Octopus tehuelchus* females and males in southern Brazil.

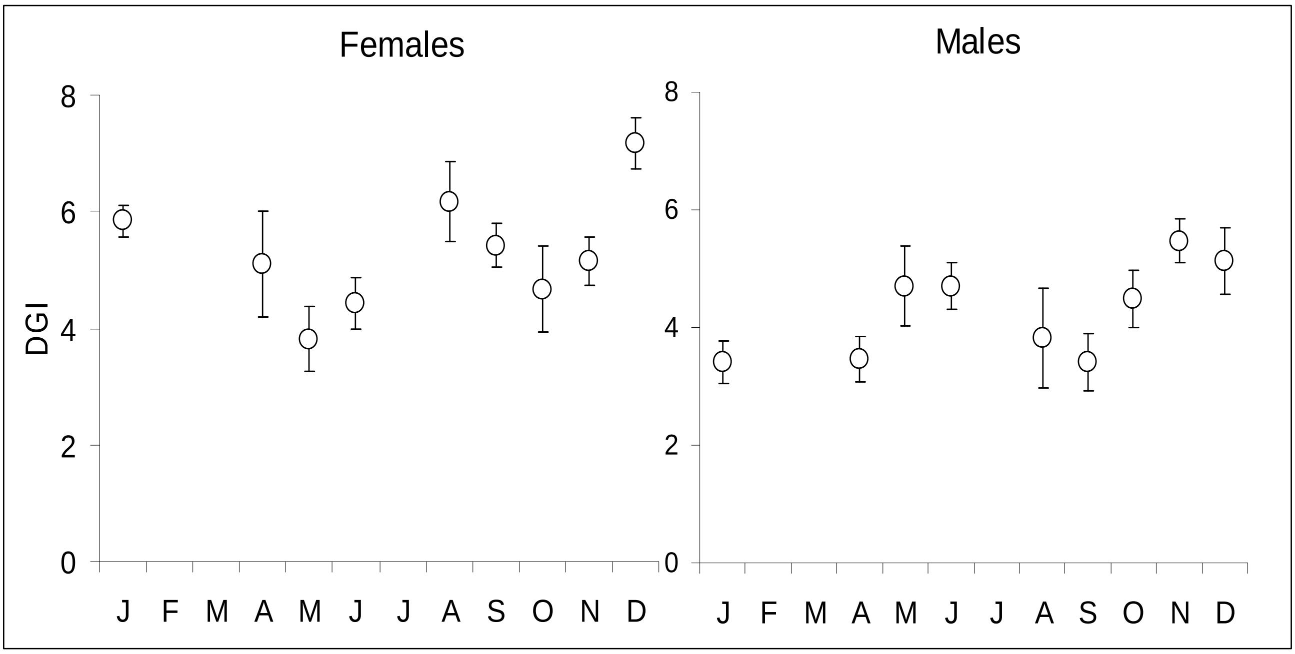

Fig. 8: Monthly trends of mean (±SE) values of the Digestive Gland Index (DGI) of *Octopus tehuelchus* females and males in southern Brazil.

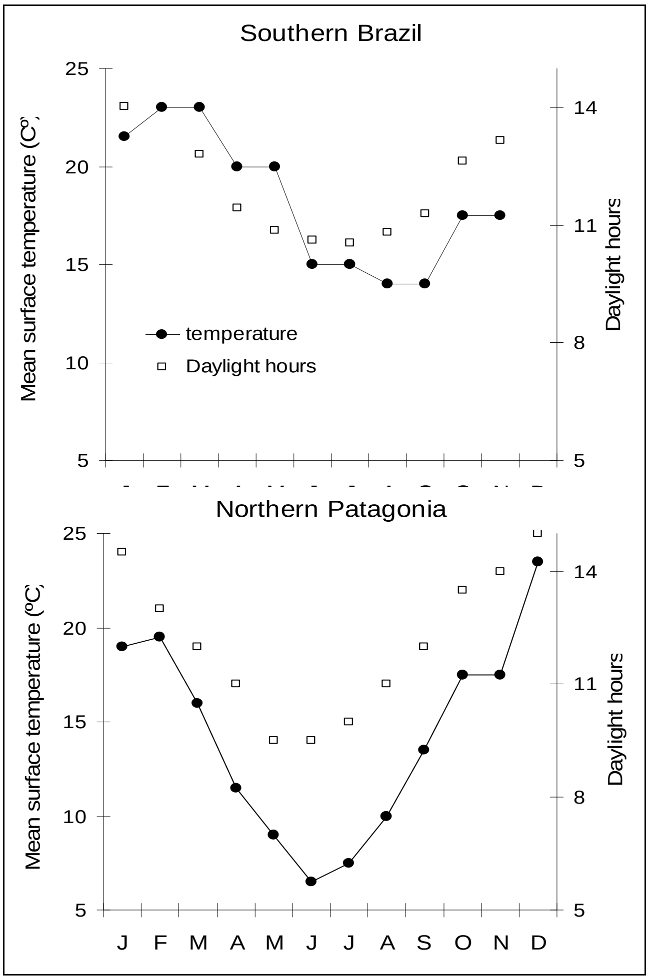

Fig. 9: Comparison of surface temperatures (Bakun and Parrish, 1990) and daylight hours in southern Brazil and San Antonio Bay, northern Patagonia (Iribarne, 1991).

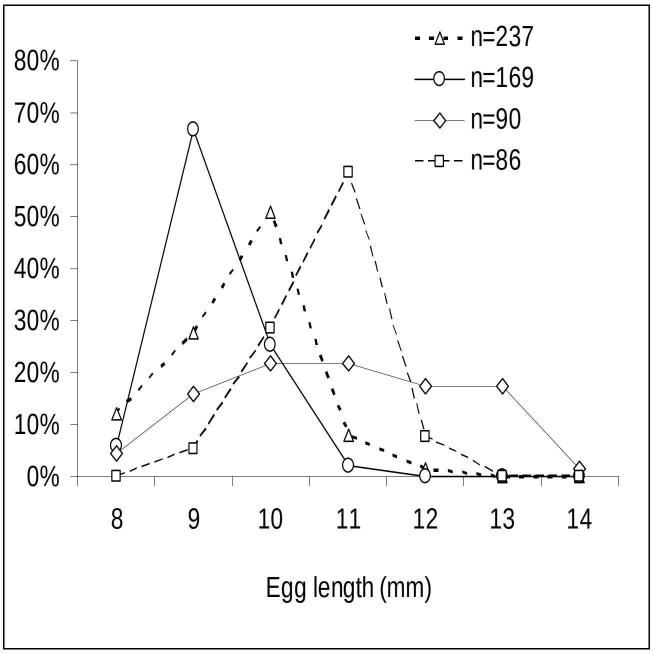

Fig. 10: Frequency of spawning eggs size in four egg layings of *Octopus tehuelchus* in southern Brazil.