UNIVERSIDADE FEDERAL DO RIO GRANDE
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DINÂMICA POPULACIONAL DO CAMARÃO SANTANA *Pleoticus muelleri* (BATE, 1888) (DECAPODA: SOLENOCERIDAE) NA ENSEADA DE BALNEÁRIO CAMBORIÚ, SC, BRASIL

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RESUMO GERAL

Com o declínio das capturas do camarão rosa (*Farfantepenaeus paulensis e F. brasiliensis*) a partir da década de 80, a pescaria de camarão no Sudeste e Sul do Brasil tornou-se multi-específica, buscando espécies alternativas para a manutenção da rentabilidade econômica, dentre elas, o camarão santana *Pleoticus muelleri* (Bate, 1888). Dessa forma, o objetivo deste trabalho foi determinar aspectos da dinâmica populacional de *P.muelleri* na costa de Santa Catarina, a fim de gerar subsídios para um manejo adequado desta importante espécie de interesse comercial na costa sul do Brasil. Foram realizadas coletas mensais entre maio de 2008 e abril de 2010, com um barco característico da frota artesanal camaroeira. As capturas foram feitas nas profundidades de 7, 14 e 19 m, onde foram medidos valores de variáveis ambientais como temperatura e salinidade de fundo. No laboratório, foi feita a biometria dos indivíduos e a determinação dos estágios de maturação gonadal. Foram coletados 15.153 indivíduos, 4.270 no primeiro ano e 10.883 no segundo ano, com picos de abundância no outono e na primavera, o que pode ser explicado pela flutuação de fatores ambientais, como temperatura e salinidade. As fêmeas atingiram maiores tamanhos que os machos, observando-se também uma diferença na média de tamanho de carapaça entre as três profundidades para ambos os sexos, com os maiores indivíduos encontrando-se na profundidade de 19 m. A razão sexual foi diferente de 1:1, com 0,6 em favor das fêmeas. As relações biométricas entre comprimento de carapaça e comprimento total indicaram alometria positiva para ambos os sexos e a relação entre comprimento da carapaça e peso indicou alometria negativa para ambos os sexos. Os parâmetros que influenciaram significativamente a abundância da espécie foram salinidade de fundo e profundidade. A análise dos cortes histológicos permitiu a determinação do tamanho e frequência dos diferentes tipos de oócitos, que teve um padrão polimodal, e diferentes estágios da célula foram observados nos ovários maduros, indicando a ocorrência de desova múltipla para a espécie. O tamanho médio de primeira maturação foi 19 mm de tamanho da carapaça. O principal período reprodutivo da espécie aconteceu durante o outono e a primavera, sendo que houve a presença de fêmeas reprodutivas durante todas as estações do ano, assim como de recrutas, o que sugere que a espécie *P. muelleri* tenha uma reprodução contínua ao longo do ano, com o pico reprodutivo ocorrendo na primavera, devido ao decréscimo da temperatura decorrente do afloramento da Água Central do Atlântico Sul sobre a plataforma. Os parâmetros de crescimento estimados foram: L_{∞}= 34,20; k= 2.55/ano; t_0=-0,53, com longevidade de 1,80 anos para fêmeas e L_{∞}= 28,34; k= 2,92/ano; t_0=-0,03, com longevidade de 1,58 anos para machos. Os coeficientes de mortalidade estimados foram: mortalidade total (Z) de 4,56 e 4,68; mortalidade natural (M) de 1,57 e 1,80; mortalidade por pesca (F) de 2,99 e 2,88; e taxa de explotação (E) de 0,65 e 0,61, para fêmeas e machos, respectivamente. Concluindo, esta espécie, embora pertencente à família Solenoceridae, apresenta características comuns aos Penaeidae de interesse comercial, com ciclo de vida curto, crescimento rápido, tamanho de primeira maturação reduzido e elevada mortalidade natural. Sendo assim, os parâmetros populacionais estimados podem servir como subsídio para elaboração de planos de manejo que contribuam para a manutenção deste importante estoque no sul do Brasil.

ABSTRACT

With declining in landings of the pink prawn species (*Farfantepenaeus paulensis* and *F. brasiliensis*) from the 80's, the shrimp fisheries in the Southeast and Southern Brazil has become multi-specific, and have contributed to the incorporation of additional species in those fisheries, such as the red shrimp *Pleoticus muelleri*, to the maintenance of economic profitability. Thus, the goal of this study was to determine aspects of population dynamics of *P.muelleri* off the Santa Catarina coast, in order to generate subsidies for management of this important species of commercial interest in the southern coast of Brazil. Shrimps were monthly collected from May 2008 to April 2010 in the surrounding area of the Camboriú Beach, with a typical boat of the artisanal fleet shrimp. Three transects were established at depths of 7, 14 and 19 m, where were measured values of bottom water temperature and salinity. In the laboratory, the individuals were measured and the stage of maturation was determined. Were collected 15,153 individuals, 4,270 in the first year and 10,883 in the second, with peaks of abundance in autumn and spring, which can be explained by the fluctuation of environmental factors such as temperature and salinity. Females reached larger sizes than males, with a difference in the mean size of the carapace lenght between the three depths, for both sexes, with the largest individuals at a depth of 19 m. The sex ratio was different than 1:1, with 0.6 to females. The biometric relationship between carapace length and total length showed positive allometry for both sexes and the relationship between carapace length and weight showed negative allometry for both sexes. The parameters which significantly influenced in the abundance of the species were bottom water salinity and depth. The histological analysis allowed the determination of the size and frequency of different types of oocytes, which had a polymodal pattern, and different stages of the cell was observed in mature ovary, indicating the occurrence of multiple spawning for the species. The length at first maturity was 19 mm of carapace length. The main reproductive period of the species occurred during autumn and spring, and there was presence of reproductive females during all seasons, as well as recruits, which suggests that the species has a continuous reproduction over the year, with the reproductive peak occurring in spring, due to the decrease of temperature due to upwelling of South Atlantic Central Water (SACW) over the continental shelf. The estimated growth parameters were: $L\infty$ = 34.20 mm, K = 2.55/year, t0 = -0.53, with longevity of 1.80 years for females and $L\infty$ = 28.34 mm, K = 2.92/year; t0 = -0.03, with longevity of 1.58 years for males. Mortality rates estimated were: total mortality (Z) of 4.56 and 4.68, natural mortality (M) of 1.57 and 1.80; fishing mortality (F) of 2.99 and 2.88; and exploitation rate (E) of 0.65 and 0.61 for females and males, respectively. In conclusion, this species, although belonging to the Solenoceridae family, present common features to the Penaeidae of commercial interest, with a short life cycle, rapid growth, reduced size at first maturity and high natural mortality. Therefore, the estimated population parameters can serve as subsidies for the preparation of management plans that contribute to the maintenance of this important stock in southern Brazil.

INTRODUÇÃO GERAL:

A espécie *Pleoticus muelleri* (DECAPODA: Solenoceridae) ocorre no Atlântico Ocidental, desde o Rio de Janeiro, Brasil (22°'S) até Santa Cruz na Argentina (49°45'S) (D`Incao, 1999), com as maiores abundâncias entre 15 e 30 metros de profundidade. Além disso, os maiores comprimentos médios são encontrados nessa faixa batimétrica durante a temporada de pesca comercial, que se dá principalmente durante os meses de verão e primavera. A espécie tem uma maior ocorrência em sedimentos finos, evitando áreas com fundos consolidados (Costa *et al*., 2005; Dumont & D`Incao, 2008).

A extração indiscriminada de camarões nas regiões Sudeste e Sul do Brasil, acompanhada do impacto ambiental causado pelo turismo, agricultura e outras atividades antrópicas, tem causado a diminuição dos estoques naturais de espécies como os camarões-rosa *Farfantepenaeus brasiliensis* (Latreille, 1817) e *F. paulensis* (Pèrez-Farfante, 1967), camarão-branco *Litopenaeus schmitti* (Burkenroad, 1936) e o camarão sete-barbas *Xiphopenaeus kroyeri* (Heller, 1862). Atualmente, os estoques dessas espécies encontram-se comprometidos, o que levou à exploração de outras espécies, que não eram originalmente alvos da frota pesqueira, como os camarões ferrinho *Artemesia longinaris* Bate, 1888 e santana *Pleoticus muelleri* (Bate, 1888) (D'Incao *et al.,* 2002).

As grandes concentrações de *P.muelleri*, que impulsionaram o desenvolvimento da pescaria patagônica, foram encontradas na Argentina, a partir da década de 80, entre 20 e 120 metros de profundidade. *P. muelleri* também representa uma importante fração nos desembarques de camarão em Santa Catarina, tendo sido o 2° crustáceo mais desembarcado nos anos de 2000 e 2003 com 25% e 13% da produção do grupo, respectivamente (GEP, 2010). Dessa forma, apesar da tendência de ascensão dessa pescaria, acentuadas oscilações interanuais são atribuídas ao ambiente, ao ciclo de vida curto e oscilações do recrutamento (Boschi, 1997; D'Incao *et al.*, 2002) Portanto, é imprescindível para a manutenção desses estoques a investigação dos principais fatores que regem essa dinâmica.

O ciclo de vida da espécie é exclusivamente marinho, havendo migrações entre águas rasas e profundas, onde se reproduzem e se desenvolvem. *P.muelleri* tem suas maiores concentrações na Argentina, no litoral patagônico, na província de Chubut, em áreas com variação de temperatura entre 6°C e 20°C e salinidade entre 31.5 e 33.5 (Boschi, 1986). Poucos trabalhos relacionados à distribuição e abundância da espécie foram realizados na costa brasileira. Dentre eles, podemos citar os trabalhos de Dumont & D`Incao (2008) na costa do Rio Grande do Sul e de Costa *et al.* (2004) e Carvalho-Batista *et al.* (2011) na costa de São Paulo. O ciclo de vida possivelmente está associado a migrações entre a costa sul do Brasil e do Uruguai. *P. muelleri* migra para o norte do Estado de São Paulo durante a chegada de águas frias vindas do sul, mais precisamente a Água Central do Atlântico Sul (ACAS). (Costa *et al.,* 2004). Já no Sul do Brasil, *P. muelleri* mostrou uma distribuição mais homogênea, tolerando áreas de menor salinidade sob influência do deságüe da Lagoa dos Patos, diminuindo assim a competição com a espécie simpátrica *Artemesia longinaris* (Bate, 1888) (Dumont & D`Incao, 2008). Já que reconhecidamente se considera os fatores ambientais como determinantes do sucesso de recrutamento de crustáceos, faz-se necessária uma investigação detalhada da influência desses parâmetros na variação sazonal e interanual de abundância dessa espécie no litoral de Santa Catarina.

As relações biométricas podem fornecer informações importantes a respeito de eventos biológicos que possam estar ocorrendo em uma população, como variações na relação comprimento-peso durante o período reprodutivo ou sob condições ambientais adversas. (King, 1997). Além disso, a determinação das relações biométricas pode se tornar uma forma de estimar dados de comprimento e peso perdidos, permitindo a comparação com investigações anteriores. (Rangonese *et al.,* 1997). Outra informação importante que as relações biométricas podem fornecer é a diferenciação de estoques, uma vez que as relações morfométricas podem refletir em um isolamento reprodutivo. (Begg *et al.,* 1999).

Análises histológicas são amplamente utilizadas para descrever estágios de maturação do ovário de camarões tanto de interesse comercial quanto de cativeiro (Tan-Fermin & Pudadera 1989; Quinitio *et al*., 1993; Medina *et al.,* 1996; Palacios *et al.,* 1999). A observação da coloração e da morfologia do ovário representa um procedimento prático para avaliar o grau de maturação, e vem sendo aplicado em espécies de interesse comercial (Browdy, 1992). Entre eles, podemos citar os trabalhos de Dumont & D`Incao (2004) com a espécie *Artemesia longinaris*; Machado *et al.* (2009) com *Litopenaues schmitti*; e Peixoto (2003) e Dumont *et al.* (2007) com o camarão rosa *Farfantepenaues paulensis.* Na Argentina, Macchi *et al.* (1998) analisou os estágios de maturação gonadal de *P.muelleri*, o que evidenciou uma desova gradual na coluna d’água. Sendo assim, observações macroscópicas, aliadas a análises histológicas, podem ser utilizadas para uma associação confiável com o estágio de maturação.

Além do período de reprodução e recrutamento, é de grande importância a definição do tamanho de primeira maturação, para que sejam tomadas medidas como, por exemplo, o tamanho mínimo para captura (Gulland & Rotschild, 1981). Este parâmetro é amplamente utilizado como um ponto de referência biológica para o manejo de estoques explotados ou com eminente explotação, já que a preservação de indivíduos menores do que o tamanho médio de primeira maturação aumenta as chances de sucesso da próxima geração (Garcia & Le Reste, 1981; King, 1997).

Outro fator importante na manutenção dos estoques de espécies comercialmente importantes é o conhecimento da dinâmica reprodutiva, o que leva ao entendimento dos processos de recrutamento e desenvolvimento do estoque desovante, uma vez que isso pode variar de acordo com a latitude, em função das variáveis ambientais (Castilho *et al.,* 2007). Dessa forma, a determinação do período em que ocorre a atividade reprodutiva da espécie, aliado ao período de recrutamento, pode mostrar como os fatores ambientais influenciam esses processos, refletindo na abundância temporal de fêmeas maduras e recrutas, e assim prevendo uma pressão seletiva, correspondendo a um padrão sazonal particular de desova e recrutamento de juvenis, além de fornecer uma base para prever possíveis mudanças biológicas (Bauer & Vega, 1992; Bauer & Lin, 1994).

Na Argentina, o período reprodutivo ocorre de outubro a abril, com máxima intensidade entre novembro e janeiro (Fernandez, 2005). Trabalhos realizados na costa argentina identificaram uma migração reprodutiva em direção a maiores profundidades, na busca por águas de maior salinidade, onde a espécie atinge a maturação sexual e realiza a desova, retornando à zona costeira (Macchi *et al*., 1998). No litoral do Rio Grande do Sul, duas áreas de desova foram localizadas, uma ao sul do estado e outra no extremo norte, ambas localizadas além dos 15 metros de profundidade (Dumont & D`Incao 2008). De acordo com Castilho *et al.* (2008), a presença de juvenis e fêmeas maduras ao longo do ano sugere que a espécie se reproduz continuamente no Sudeste brasileiro.

Outros dois fatores de grande importância no estudo da dinâmica populacional de espécies exploradas comercialmente são o crescimento e a mortalidade, pois com isso é possível determinar, por exemplo, como ocorre a variação do tamanho dos indivíduos com a idade, assim como os efeitos da pesca no estoque. No caso dos crustáceos, o estudo do crescimento é particularmente dificultado por ser um processo descontínuo, que ocorre por saltos, dado pela presença de um exoesqueleto rígido, que não permite um crescimento em tamanho e peso de forma contínua (Dall, 1990; Petriella *et al.,* 1997). Consequentemente, não existe uma estrutura rígida de aparição que possa ser associada com a idade, impossibilitando a determinação direta da mesma. Desta forma, a análise de progressão modal é a técnica utilizada para identificar classes de idade. O acompanhamento das coortes ao longo do tempo é a técnica normalmente empregada para o cálculo dos parâmetros da equação de crescimento de Von Bertalanffy (Ricker, 1975; Sparre & Venema, 1989). A falta de estruturas rígidas associadas com a idade também prejudica as estimativas de mortalidade, principalmente a mortalidade natural, que é assumida como constante ao longo da vida da coorte, e constante para a população como um todo (Beverton & Holt, 1959; Vetter, 1988). Sendo assim, alguns autores desenvolveram diversas fórmulas empíricas para calcular M de forma indireta, a partir de parâmetros populacionais mais fáceis de serem estimados, como o método de Taylor (1960), que vendo sendo utilizado com sucesso em crustáceos, além do método de Pauly (1980).

Todos os trabalhos de crescimento e mortalidade foram realizados em populações na costa da Argentina, como os recentemente desenvolvidos por De La

Garza (2006); De La Garza & Fischbach (2007); e De La Garza & Fischbach (2009). Estudos de crescimento de *P. muelleri* nunca foram desenvolvidos na costa brasileira, assim como também estudos de mortalidade.

OBJETIVO GERAL

- Investigar a dinâmica populacional de *P. muelleri* na Enseada de Balneário Camboriú (SC).

OBJETIVOS ESPECÍFICOS

- Analisar a distribuição e abundância de *P.muelleri*, sua variação sazonal, interanual e batimétrica, relacionando com a temperatura e salinidade de fundo da água.
- Analisar a variação do tamanho de carapaça (Cc) de fêmeas e machos de acordo com a estação do ano e com a profundidade;
- Estabelecer relações biométricas para fêmeas e machos;
- Caracterizar os estágios de desenvolvimento gonadal das fêmeas utilizando uma escala cromática, validada por cortes histológicos;
- Estimar o tamanho médio de primeira maturação;

- Identificar o período reprodutivo e relacioná-lo ao pico de abundância de recrutas;
- Estimar o crescimento de fêmeas e machos segundo o modelo de Von Bertallanfy;
- Estimar a mortalidade total, natural, por pesca e a taxa de explotação para fêmeas e machos, utilizando dois modelos empíricos.

METODOLOOGIA GERAL

Área de Estudo

As amostragens foram feitas na região de Balneário Camboriú (26º 59' 07" S - 48º 35' 58”W), escolhida por ser uma área tradicional de pesca no litoral de Santa Catarina. Além disso, a região é um importante pólo turístico, altamente impactado pela ação antrópica, e onde, até agora, não foram realizados estudos avaliando a população de *P.muelleri*.

Esta área sofre influência de três massas de água: Água Central do Atlântico Sul (ACAS), Água Tropical (AT) e Água Costeira (AC), as quais podem exercer uma importante influência sobre a dinâmica populacional da espécie.

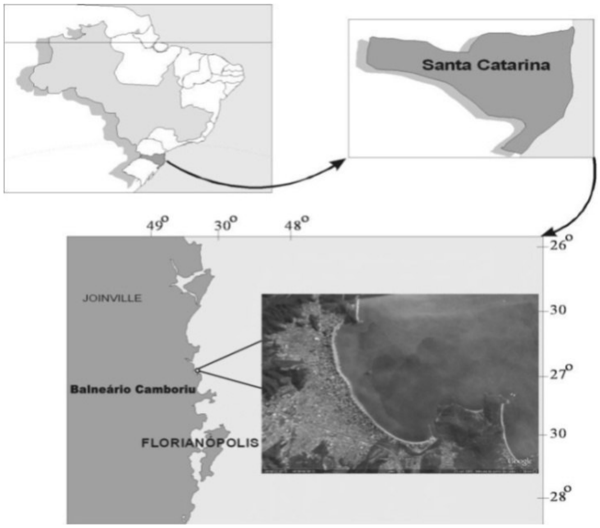

Figura 1: Foto da Região de Balneário Camboriú, Santa Catarina, Brasil

Amostras de campo

As coletas foram feitas nas profundidades de 7 metros, 14 metros e 19 metros, durante o período de maio/2008 a abril/2010 na região de Balneário Camboriu, SC. Em cada isóbata, foram realizados 2 arrastos de 15 minutos, paralelos à linha de costa, utilizando um barco característico da frota artesanal camaroeira (barco tangoneiro, com rede de arrasto dupla). Tendo em vista que são operadas duas redes ao mesmo tempo, as duas amostras foram agrupadas em cada estação e um segundo arrasto, na mesma profundidade, foi utilizado como réplica. A embarcação utilizada possui redes com malhas de 3,0 cm no corpo e 2,0 cm no ensacador. Os arrastos foram realizados a uma velocidade média de 2,0 nós. Foram obtidos os seguintes dados ambientais: temperatura da água de fundo (termômetro – 0,1°C), transparência da água (disco de Secchi), salinidade (refratômetro) de fundo e profundidade (eco-sonda do barco). A água de fundo foi coletada com a garrafa Van-Dorn.

Processamento amostral

Em laboratório, os camarões foram identificados quanto ao sexo (presença de petasma em machos e ausência em fêmeas) e medidos. A biometria consistiu na obtenção do comprimento total (CT), do comprimento da carapaça (CC) e do peso total (PT). As fêmeas adultas foram determinadas por observação macroscópica do grau de desenvolvimento do ovário (cor e volume ocupado pelas gônadas). Ovários classificados como imaturos tinham uma coloração branca translúcida ou verde clara, já os classificados como maduros tinham uma coloração verde escura. O status reprodutivo dos machos era feito através da análise da forma do petasma, em que nos adultos, no primeiro par de pleópodos, os endopoditos são fusionados e nos imaturos separados.

Biologia Populacional

As abundâncias média de juvenis, adultos e fêmeas maduras foram comparadas por estrato de profundidade mensalmente e interanualmente através de uma Análise de Variância Fatorial (ANOVA-Fatorial) e um teste *a posteriori* de Tukey (Venables & Dichmont 2004). Foram testados os pré-requisitos de normalidade (Kolmogorov-Smirnov) e homogeneidade de variâncias (Bartlett). Foi aplicado o teste do χ^2, com nível de significância 5% e n-1 graus de liberdade para verificar a possível diferença entre a razão sexual ao longo dos meses do ano e entre faixas de profundidade (Zar, 1984). Uma regressão múltipla foi usada para estabelecer relações entre a abundância da espécie e variáveis ambientais. As variações das médias de tamanho de carapaça (CC) de fêmeas e machos por estação do ano e por profundidade foram verificadas através de Análise de Variância Fatorial (ANOVA-Fatorial) e um teste *a posteriori* de Tukey (Venables & Dichmont 2004). As relações biométricas entre comprimento de carapaça (CC) e comprimento total (CT) e comprimento de carapaça (CC) e peso (PT), foram determinadas separadamente para fêmeas e machos.

Desenvolvimento Gonadal e Tamanho de Primeira Maturação

As gônadas femininas foram escolhidas macroscopicamente para a análise devido ao maior tamanho e facilidade de identificação cromática em campo. A cor predominante de cada estágio de maturação foi comparada com um catálogo de cores (Pantone, 1999) para estabelecer um ponto de referência cromática. Os cortes histológicos foram realizados utilizando o método de impregnação em parafina, que consistiu em fixação, emblocamento em parafina, coloração e montagem (Bell & Lightner 1988). As lâminas foram analisadas em microscópio óptico, munido de um sistema de captura de imagens. O tamanho médio de primeira maturação ($CC_{50\%}$) foi definido como o tamanho em que 50% dos indivíduos são considerados maduros/adultos. O ajuste da curva foi feito pelo método dos mínimos quadrados (Aguillar *et al.* 1995).

Reprodução e Recrutamento

O período reprodutivo da população foi estimado com a média da CPUE (g/15min) de fêmeas reprodutivas (ovário desenvolvido e maduro) em cada mês e/ ou estação do ano e profundidade. O período de recrutamento foi determinado como a CPUE de juvenis (captura por unidade de esforço =CPUE) capturados.

Crescimento e Mortalidade

A estimativa dos parâmetros de crescimento foi feita através da análise de progressão modal (MPA) e os grupos etários foram ajustados ao modelo de Von Bertalanffy (1938) (VBGM) através de ajuste não linear. Diferenças no crescimento entre machos e fêmeas e entre os dois anos amostrados foram testadas pelo quociente de máxima verossimilhança utilizando um teste F (Cerrato, 1990). Os coeficientes de mortalidade foram determinados pelos métodos tradicionais da biologia pesqueira, com três componentes denominados: coeficiente instantâneo de mortalidade total (Z), mortalidade natural (M) e mortalidade por pesca (F) (D´Incao, 1990). O coeficiente de mortalidade total foi calculado para fêmeas e machos através da curva de captura, baseada no tamanho (Ricker, 1975). Através do modelo de Von Bertallanfy foi gerada uma tabela associando a idade em meses para cada classe de tamanho. A abundância por classe de idade foi transformada em logaritmo, e ajustada a um modelo linear y=ax+b, onde a é o valor do coeficiente de mortalidade total. O coeficiente de mortalidade natural (M) foi determinado pelo método de Taylor (1960). A taxa de explotação do estoque (E) foi feita dividindo a mortalidade por pesca (F) pela mortalidade total (Z).

REFERÊNCIAS BIBLIOGRÁFICAS

AGUILLAR, AT, ZC MALPICA, BV URBINA. 1995. Dinámicas de poblaciones de peces. Lima: Libertad. p .304.

BATISTA, AC, SM SIMÕES, M, LOPES, RC COSTA. 2011. Ecological distribution of the shrimp *Pleoticus muelleri* (Bate, 1888) and *Artemesia longinaris* Bate, 1888 (Decapoda: Penaeoidea) in the Southeastern Brazilian littoral. *Nauplius* 19 135-143.

BAUER, RT & LWR VEGA. 1992. Pattern of reproduction and recruitment in two sicyioniid shrimp species (Decapoda:Penaeoidea) from a tropical seagrass habitat. *Journal of Experimental Marine Biology and ecology*. 161: 223-240.

BAUER, RT & LIN. 1994. Temporal patterns of reproduction and recruitment in populations of the penaeid shrimps *Trachypenaeus similis* (Smith) and *T.constrictus* (Stimpson) (Crustacea:Decapoda) from the north-central Gulf of Mexico. *J.Exp.Mar.Biol.Ecol*. 182: 205-222.

BEGG, G.A, JA HARE & DD SHEEHAN. 1999. The role of life history parameters as indicators of stock structure. *Fisheries Research.* 43, 141–463.

BELL, TA & DV LIGHTNER. 1988. A Handbook of Normal Penaeid Shrimp Histology (Special Publication). World Aquaculture Society, Baton Rouge, USA. 114 pp.

BEVERTON, RJH, SJ HOLT. 1959. A review of the lifespans and mortality rates of fish in nature and their relation to growth and other physiological characteristics. *In: the lifespan of animals. CIBA Foundation Colloquium on Ageing 5*: 142-177.

BOSCHI, EE. 1986. La pesqueria del langostino del litoral patagonico. *Redes*. 20: 8 pp.

BOSCHI, EE. (1997) Las pesquerías de crustáceos decápodos en El litoral de la Repú blica Argentina. *Investigaciones Marinas* 25, 19-40.

CASTILHO, AL, MA GAVIO, RC COSTA, EE BOSCHI, RT BAUER & A FRANSOZO. 2007. Latitudinal Variatin in Population Structure and reproductive pattern of the endemic South American shrimp *Artemesia longinaris* (Decapoda: Penaeoidea). *Journal of Crustacean Biology*. 27: 548-552.

CASTILHO, AL, RC COSTA, A FRANSOZO, MLN FRANSOZO. 2008. Reproduction and recruitment of the South American red shrimp, *Pleoticus muelleri* (Crustacea: Solenoceridae), from southeastern coast of Brazil. *Marine Biology Research* (4): 361-378

CERRATO, RM. 1990. Interpretable statistical tests for growth comparisons using parameters in the von bertalanffy equation.*Can.J.Fish.Aquat.Sci.* 47: 1416 - 1426.

COSTA, RC, A FRANSOZO & AP PINHEIRO. 2004. Ecologic Distribution of the shrimp *Pleoticus muelleri* (Bate, 1888) (Decapoda:Penaeoidea) of Southeastern Brazil. *Hydrobiologia*, 529: 195-203.

COSTA, RC, A FRANSOZO, AL CASTILHO, & FAM FREIRE. 2005. Annual, seasonal and spacial variation of abundance of the shrimp *Artemesia longinaris* (Decapoda: Penaeoidea) in south-eastern Brazil. *Journal of the Marine Biological Association of the United Kingdom*, 85(1): 107-112.

DALL, W, BJ, PC ROTHLISBERG & DJ STAPLES. 1990. The Biology of the Penaeidae. *Advances in Marine Biology*, Academic Press, London, UK. 489 pp.

DE LA GARZA, J. 2006. Estimación de los parâmetros de crecimiento Del langostino patagônico utilizando frecuencia de tallas paera lãs temporadas 2004 a 2006. *Informe técnico INIDEP* N°078/06. 12pp

DE LA GARZA, J & C FISCHBACH. 2007. Variaciones interanuales en el crecimiento y La talla Del langostino (*Pleoticus muelleri*) em El período 1992-2003, a partir de datos de producción. *Informe técnico INIDEP* N°14, 29pp.

DE LA GARZA, J & C FISCHBACH**.** 2009. Obtención de índices de mortalidad y tasas de explotación Del langostino (*Pleoticus muelleri*) em lãs temporadas de pesca 1992-2008 a partir de dados de producción y desembarque. *Informe de Investigación, INIDEP*, N°63, 18pp.

D'INCAO, F. 1990. Mortalidade de Penaeus (Farfantepenaeus) paulensis Pérez Farfante, 1967 no estuário da Lagoa dos Patos, Rio Grande do Sul, Brasil. *Atlântica*, 12(1): 31-51. Editora da Universidade, Porto Alegre

D`INCAO, F. 1999. Subordem Dendrobranchiata (camarões marinhos). *In:* Buckup, L. and Bond- Buckup, G. (eds.). Os camarões do Rio Grande do Sul Editora da Universidade, UFRGS. 271-299

D`INCAO, F, H VALENTINI & LR RODRIGUES. 2002. Avaliação da pesca de camarões nas regiões sudeste e sul do Brasil. *Atlântica* 24, 103-116.

DUMONT, LFC & F D'INCAO. 2004. Estágios de desenvolvimento gonadal de fêmeas do camarão-barbaruça (*Artemesia longinaris* – Decapoda:Peneidae). *Iheringia.* 94 (4), 389-393

DUMONT, LFC, F D'INCAO, R SANTOS, S MALUCHE, FL RODRIGUES. 2007. Ovarian devolopment of wild pink prawn Farfantepenaeus paulensis in the northern shore of Santa Catarina State. *Nauplius*, 15: 65-71

DUMONT, LFC & F D`INCAO. 2008. 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. *Nauplius*, pp. 1-12.

FERNÁNDEZ, M. 2005. Localización de las concentraciones reproductivas del langostino en el litoral patagónico. Periodo analizado: Diciembre de 2000 a enero de 2005. *Informe Técnico Interno INIDEP* 77: 1-13.

GARCIA, S & L LE RESTE**.** 1981. Life cycles, dynamics, exploitation, and management of coastal penaeid shrimp stocks. *FAO Fisheries Technical Papers* 203, 1-215.

GEP, 2010. Grupo de estudos pesqueiros. Disponível em: http://siaiacad04.univali.br/consulta/. Acessado em: 20/05/2010.

GULLAND, JA & BJ ROTHSCHILD. 1981. Fish stock assessment. A manual of basic methods. *FAO* of the United States.

KING, MG. 1997. Fisheries biology, assesment and management. *Fishing news books. Osney Mead, Oxford*. England. pp. 341.

MACCHI, GJ, MI IORIO, A AUBONE. 1998. Estimación de La fecundidad Del langostino argentino *Pleoticus muelleri* Bate, 1888 de Patagonia (sur de Argentina). *Boletín del Instituto Español de Oceanografía* 14(1/2): 19-29

MACHADO, IF, LFC DUMONT, F D`Incao. 2009. Stages of Gonadal Development and mean length at first maturity of wild females of white shrimp (*Litopenaeus schimitti* – DECAPODA, PEANEIDAE) in Southern Brazil. *Atlântica Rio Grande*, 31(2): 169-175.

MEDINA, A, Y VILA, G MOURENTE & A RODRÍGUEZ. 1996. A comparative study of the ovarian development in wild and pond-reared shrimp, *Penaeus kerathurus* (Förskal, 1775). *Aquaculture*, 148: 63-75.

PALACIOS, E, C RODRÍGUEZ-JARAMILLO & IS RACOTTA. 1999. Comparison of ovary histology between di!erent-sized wild and pond-reared shrimp *Litopenaeus vannamei* (*Penaeus vannamei*). *Invertebrate Reproduction and Development* 35: 251-259.

PANTONE. 1999. *Pantone Professional Color System.* 14th ed. New Jersey, Carlstad. 260p.

PAULY, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *J.cons.int.explor.mer.* 39(2): 175-192.

PEIXOTO, S, OR CAVALLI, F D'INCAO, AM MILACH & W WASIELESKY. 2003. Ovarian maturation of wild *Farfantepenaeus paulensis* in relation to histological and visual changes. *Aquaculture Research*, 34: 1255-1260.

PETRIELLA, AM, & EE BOSCHI. 1997. Crecimiento en crustáceos decápodos: resultados de investigaciones realizadas em Argentina. *Investigacones Marinas Valparaiso*, 25: 135-157.

QUINITIO ET, RM CABALLERO & L GUSTILO. 1993. Ovarian development in relation to changes in the external genitalia in captive Penaeus monodon. *Aquaculture* 114: 71-81.

RANGONESE, S, F BERTOLINO & ML BIANCHINI. (1997). Biometric Relatinsships of the red shrimp *Aristeomorpha foliacea* Risso 1827, in the Strait of Sicily (Mediterranean Sea). *Scientia Marina,* 61(3):367-377.

RICKER, WE 1975. Computation and interpretation of biological statistics of fish populations. *Bulletin of the fisheries research board of Canada.* 191, 1-382.

SPARRE, P, E URSIN & SC VENEMA**.** 1989. Introduction to tropical fish stock assessment. Part 1: manual. *FAO. Fisheries Technical paper* N°306.1. Rome, Italy, 337p.

TAN-FERMIN, JD & RA PUDADERA. 1989. Ovarian maturation stages of the wild giant tiger prawn Penaeus monodon Fabricius. *Aquaculture;* **77**: 229-242.

TAYLOR, CC. 1960. Temperature, growth and mortality; the Pacific cockle. *J. Cons. perm. int. Explor. Mer*, Copenhague, 26(1): 117-124.

VENABLES, WN & CM DICHMONT. 2004. GLMs, GAMs and GLMMs: an overview of theory for application in fisheries research. *Fisheries Research..* 70 (2004): 319-337.

VETTER, EF. (1988). Estimation of Natural mortality in fish stocks: a review. *Fisheries bulletin.* 86(1): 25-43.

ZAR, JH. 1984. Biostatistical Analysis. London: Prentice-Hall International Editions.

Capítulo 1

Population Structure of the red shrimp *Pleoticus muelleri* (Decapoda: Solenoceridae) off the Santa Catarina State, Brazil. Prata, P.F.S; Machado, I.F; Sarda, F.O; Dumont, L.F.C.

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Population Structure of *Pleoticus muelleri* (DECAPODA: Solenoceridae) off the Santa Catarina State, Brazil.

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ABSTRACT

The increase in the fishing fleet in southern Brazil and the decrease in the landings of profitable shrimp species have contributed to the incorporation of additional species in those fisheries, such as the red shrimp *Pleoticus muelleri.* The goal of this study is to investigate the influence of environmental factors on the abundance and spatial-temporal distribution of the shrimp *P. muelleri*, and population parameters such as size variations according to season and depth, biometric relationships and sex ratio were also analyzed. Samples were performed monthly, from May 2008 to April 2010 in the Balneário Camboriú region, Santa Catarina state, Brazil. Three transects were established at mean depths of 7, 14 and 19 m. A shrimp fishing boat equipped with a double rig net was used for trawling and performed standardized 15 minutes trawlings. A total of 15,153 individual was collected, 4,270 during the first year and 10,883 during the second year of sampling. Higher densities were recorded in the deeper waters (19 m), where the temperature is lower, in autumn during the first year, and mainly in spring months during the second year, associated with the intrusion of the South Atlantic Central Water. Females reached larger sizes than males (mean= 16.74± 4.78 mm), ranging from 4.78 to 35.5 mm of carapace length. The mean size for males was 13.87±2.68, ranging from 4 to 31.58 mm. Significant larger females were recorded during spring, while larger males were more abundant in autumn. The sex ratio was significantly different from 1:1, being 0.6 in favor to females in all depths, mainly during spring and summer months. The length-weight relationship presented a negative allometry for females (b=2.7) and males (b=2.6).The carapace length (CL) and total length (TL) had a positive allometry for females (*b*=3.82) and males (*b*=3.70). The parameters which were significant in the abundance of this species were the bottom water temperature, salinity and depth.

Keywords: Distribution and abundance, population biology, *Pleoticus muelleri*, Southern Brazil.

RESUMO

O aumento da frota pesqueira no sul do Brasil e a redução nos desembarques de espécies de camarão rentáveis, têm contribuído para a incorporação de espécies alternativas nessas pescarias, como o camarão vermelho *Pleoticus muelleri.* O objetivo deste estudo é investigar a influência de fatores ambientais sobre a distribuição e abundância espaço-temporal do camarão *P. muelleri*, e determinar aspectos populacionais, tais como variações do tamanho médio de carapaça de acordo com a estação do ano e profundidade, relações biométricas e razão sexual. As coletas foram realizadas mensalmente, entre maio/2008 e abril/2010, com arrastos de 15 minutos de duração, nas profundidades de 7, 14 e 19 metros, utilizando um barco característico da frota artesanal camaroeira (tangoneiro). Um total de 15.153 indivíduos foi coletado, 4.270 durante o primeiro ano e 10.883 no segundo ano de amostragem. Densidades mais elevadas foram registradas em águas mais profundas (19 m), onde a temperatura é mais baixa, no outono, durante o primeiro ano e, principalmente, nos meses de primavera, durante o segundo ano, associados à intrusão da Água Central do Atlântico Sul (ACAS). Fêmeas alcançaram maiores tamanhos que os machos (média = 16,74 ± 4,78 milímetros), variando de 4,78 a 35,5 mm de comprimento da carapaça. O tamanho médio para os machos foi 13,87 ± 2,68, variando de 4 a 31,58 mm. As fêmeas tiveram maiores médias de tamanho de carapaça na primavera, enquanto os machos no outono. A razão sexual foi significativamente diferente de 1:1, sendo de 6:1 em favor das fêmeas, que foram mais abundantes em todas as profundidades, principalmente durante os meses de primavera e verão. A relação peso-comprimento apresentou uma alometria negativa para as fêmeas (b = 2,7) e machos (b = 2,6). O comprimento da carapaça (CC) e comprimento total (CT) teve uma alometria positiva para as fêmeas (b = 3,82) e machos (b = 3,70). Os parâmetros que mostraram ser significativos na abundância desta espécie foram salinidade de fundo e profundidade.

Palavras chave: distribuição e abundância, biologia populaconal, *Pleoticus muelleri*, sul do Brasil.

INTRODUCTION

The red shrimp *Pleoticus muelleri* is an endemic, commercially exploited, Soloenoceridae from the Southwestern Atlantic coast, distributed from 22ºS (Rio de Janeiro, Brazil), to 50ºS (Santa Cruz, Argentina) (Boschi, 2000; Costa *et al*., 2000). The species inhabits muddy soft bottoms, where it plays a key ecological role, been intensively predated by the commercially exploited Brazilian codling *Urophycis brasiliensis (*Kaup, 1858*)* (Lalli & Parsons, 2006). The distribution of *P. muelleri* is restricted to shallow coastal waters, in depths not further than 30 m, where it is subjected to the great dynamics of these ecosystems. The sudden shifts in environmental parameters, the short life cycles and the huge larval mortality, turn the prediction of shrimp densities in these fishing grounds very tricky (De la Garza, 2009).

Several efforts have been made to understand the factors influencing the distribution and abundance of commercial shrimps worldwide (FAO, 2010). Similarly, the factors affecting the biomass of the red shrimp stocks in the Brazilian coast have been investigated off the coasts of São Paulo (23°55’ -24°00’S and 46°20’- 46°25’) by Costa *et al.* (2004) and Carvalho-Batista (2011) and Rio Grande do Sul (28°36’S – 33° 45’S) States, by Dumont & D’Incao, 2008.

The temperature is likely a key factor on the abundance of *P. muelleri*. The biomass of this species seems to increase from the northern limit of distribution towards the higher latitudes, inversely related to the bottom temperature. In the northern limit of the species distribution, off the São Paulo coast, higher densities usually occurs associated with the South Atlantic Central Water (SACW), which takes place in November/December (Costa *et al.*, 2005). The preference of the red shrimp for colder waters was also observed off the coast of RS, provided that elevated densities were found to be associated to short-term coastal upwelling, pumped by discrete northeasterly wind events during summer. The biomass of *P. muelleri* in the Argentinean fishing grounds is the largest, with mean landing values of 20,000 ton and a maximum of 80,000 tons, while the mean production in the state of Santa Catarina, Southern Brazil, according to industrial fisheries statistical bulletins, in the last 11 years averages approximately 713.53 kg, with a maximum of 1.577 tons in 2008. (GEP, 2010).

Regarding on the population biology, most of the information is available for the Argentinean waters (Boschi, 1986; Boschi, 1989; Fernandez, 2003; Fernandez, 2005). The fishery pattern and yields of commercial double-rig trawling were investigated in southern Brazil (Rio Grande do Sul State) during the 90's (Haimovic & Mendonça, 1996), while recent stock biomass assessment was estimated during the fishery season (mainly in summer) (Dumont & D'Incao, 2008).This resource presents a very patchy distribution, concentrating 77% of the biomass in only 12% of the fishing area, resulting in a high vulnerability to fishing effort (Dumont & D'Incao, 2008). Several environmental factors, such as salinity and temperature can affect the temporal and spatial distribution of *P.muelleri* (Boschi, 1989). Dall (1990) reported that the ontogenetic and reproductive migrations of shrimp species are of utmost importance in influencing the temporal and spatial distribution, since the stakeholders often rely on distribution and abundance patterns to establish management strategies.

The worldwide trawling for coastal shrimps is an activity that has resulted in the overexploitation of many stocks (FAO, 2010). In the Brazilian coast is just the same with collapse of shrimp stocks been detected in several commercial fisheries (D'Incao *et al*., 2002; Carvalho-Batista *et al.,* 2011). The most valuable stock (the pink shrimp *Farfantepenaeus paulensis* (Pérez-Farfante, 1967) and *F. brasiliensis* (Latreille, 1817) was considered overexploited in the late 80's, which was attributed to the use of subsides to increase production by supporting the fleet increment as a direct consequence of the overexploitation of the main shrimp fishery, other species have become intensively exploited, such as the white shrimp *Litopenaeus schmitti* (Burkenroad, 1938), the seabob shrimp *Xiphopenaeus Kroyeri* (Heller, 1862), the argentine shrimp *Artemesia longinaris* Bate, 1888, and the red shrimp *Pleoticus muelleri* (Bate, 1888).

Thus, the goal of this study is to analyze the population biology of *P. muelleri* in the region of Camboriú, Santa Catarina, Brazil; including the trends in distribution and abundance; as well as size structure, its dynamic and the abiotic factors influencing this pattern.

MATERIALS AND METHODS

Study area:

This area is influenced by three water masses: the South Atlantic Central Water (SACW), Tropical Water (TW) and Coastal Water (CW), which may exert an important influence on population dynamics of species, especially through the upwelling, which occurs with the arrival of spring and summer, when there is the presence of the SACW.

The samples were obtained from Camboriú Beach, (26º 59' 07''S – 48º 35' 58'' W), in the State of Santa Catarina, Brazil. This area was chosen since it is a traditional fishing area in South Brazil. Besides, the region is an important tourist center, highly impacted by human action, and where, until now, no studies have been conducted in this regard.

Sampling strategy and biometry:

Shrimps were monthly collected from May 2008 to April 2010 in the surrounding area of the Camboriú Beach (Figure 1). Three transects were established at depths of 7, 14 and 19 m. A double rig shrimp trawler with a mesh size of 30 mm in the body and 20 mm (opposing knots) in the cod end was used for sampling. The abundance index (CPUE) was composed by a catch unit, either weight (g) or number (n), and a standardized effort of 15 minutes trawling.

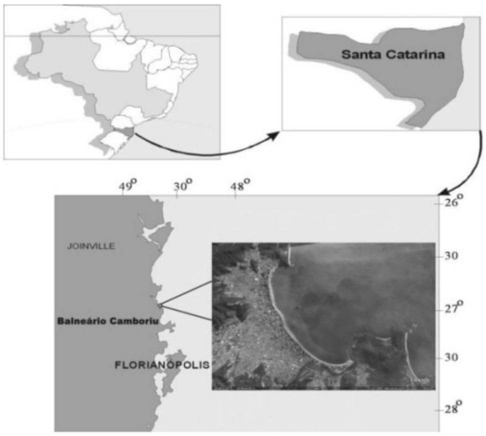

Fig.1. Map of the region of Camboriú, State of Santa Catarina, South Brazil, where investigation took place between May 2008 and April 2010

The shrimps were sexed by the identification of the petasma in males and the thelicum in females. Carapace length (CL, mm) was measured as the distance from the postorbital margin to the mid-dorsal posterior edge of carapace. Total length (TL, mm) was considered as the distance from the tip of the rostrum to the end of the telson. The weight (Wg) of each specimen was measured to the nearest 0.01 g. Length-frequency distributions were constructed separately for each sex, using1.0 mm CL size intervals.

Salinity and temperature (°C) were measured in bottom-water samples using a thermosalinometer. An ecobathymeter coupled with a GPS (Global Positioning System) was used to record depth at sampling sites.

A Factorial Analysis of variance (ANOVA) was used to compare the relative abundance (CPUE – g/15min) of the shrimps between the two years sampling, and among seasons (autumn, winter, spring and summer) and depths (7, 14 and 19 meters). The data was tested for normality and homogeneity of variances (Bartlett > 0.05) prior to the ANOVA and post-hoc Tukey's test. Normality was achieved for all groups, whereas homogeneity of variance was not. Therefore, the data were transformed ($\log_{10} +1$) to achieve both pre-requisites. Similarly, the possible differences in the mean carapace length according to sex, depth and season, were tested by using a Factorial Analysis of Variance (ANOVA). All statistical procedures followed Zar (1999), and the significance level adopted was 5% ($p<0.05$).

The sex ratio in each year, month and depth was compared according to the year, month and depth by using the χ^2 test ($P<0.05$ and df N-1). The influence of environmental factors on the CPUE (g/15 min) of *P. muelleri* was assessed by a multiple regression analysis, and the significance level adopted was $p<0.10$.

The carapace length-weight relationship was described by the power model $W=aCL^b$, where W(g) is the total weight, a is the intercept, CL(mm) is the carapace length and b is the coefficient of allometry.The total length-carapace length relationship was described by the linear model $TL= a+bCL$, where the TL is the total lenght, CL(mm) the carapace length (mm), a is the intercept with dependent variable axis and b is the slope. Both models were fit for each sex separately, through the Table Curve program 2D v5.01(Software Inc., 2002). Points outside the 95% confidence intervals were automatically excluded since they were considered as outliers, caused by undetected, broken or regenerating rostrum as well the result of a deformed carapace. Differences in slopes were pairwise tested based on confidence intervals, in such way that non-overlapping intervals were considered as statistically different (Dumont & D'Incao, 2010).

RESULTS

Enviromental factors

A marked seasonal pattern was observed for bottom water temperature, with higher values recorded during summer and autumn and lower values during winter and spring. There was not significant differences of bottom temperature between the two years ($P>0.05$). (One-way ANOVA). During the first year, the highest values were recorded in February (24.70°C± 2.25°C) and March (25.33°C± 0.76°C). The lowest values were recorded in May (18.33°C±1.15°C) and June (18.36°C±0.05°C). In the second year, the highest values were recorded in December (25.06°C ± 0.41°C) and February (25.16°C±0.61°C), while the lowest values were recorded in August (17.86°C±0.20°C) and July (18.33°C ± 0.05°C) (Figure 2).

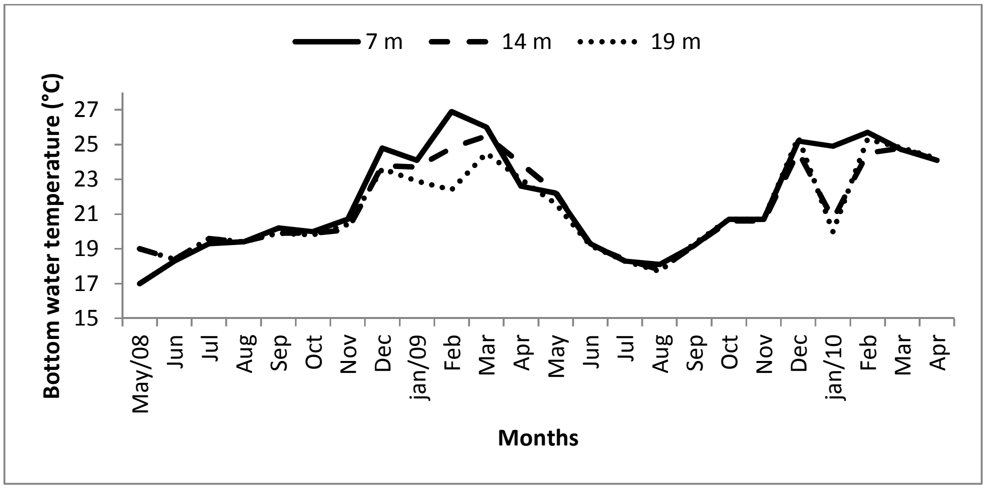

Fig.2. Variation of the mean monthly bottom water temperature for each depth (7, 14 and 19 m), from May 2008 to April 2010, in the region of Camboriú, Santa Catarina State, Brazil.

The bottom salinity presented remarkable trends during the first year, while the second year presented a more stable pattern. There was significant differences between the two years ($P<0.05$). In both years, the highest average values were recorded in autumn (35.39±1.79) and summer (34.83±1.52), while the lowest values were observed during winter (34.59±1.81) and spring (32.98±2.35). In the first year, the highest values were recorded in March (37.3± 0.81) and April (37.5 ± 1.97) and the lowest values were recorded in June (32.8±0.23) and November (30.1±3.43). In the second year, the highest values were recorded in May (34.9± 0.13) and March (34.9±0.31). The lower values were recorded in August (32.8±0.13) and September (33.2±0.19).

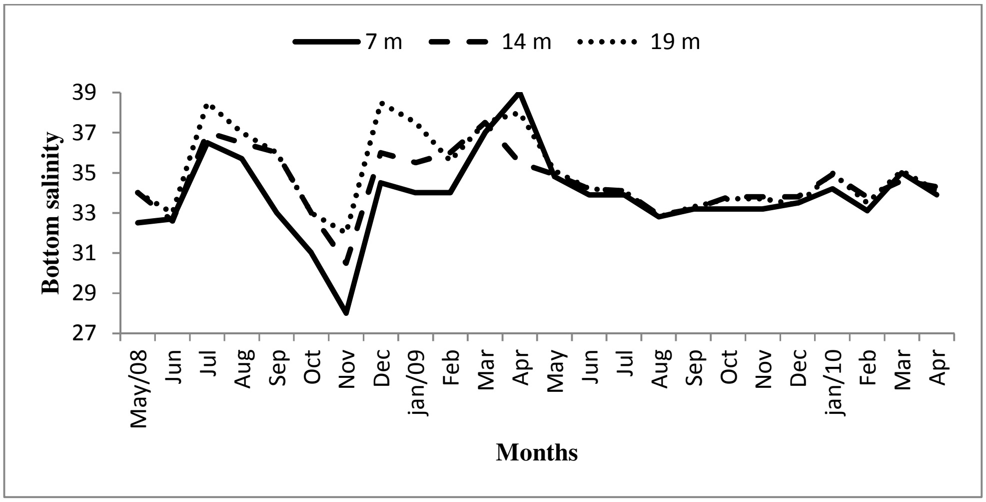

Fig. 3. Variation of the mean monthly bottom water salinity for each depth (7, 14 and 19 m), from May 2008 to April 2010, in the region of Balneário Camboriú, Santa Catarina State, Brazil.

Distribution and abundance

A total of 15,153 individual was collected, 4,270 during the first year and 10,883 during the second (interannual differences are statistically significant, F=7.75, P<0.05). Significant higher abundance at the depth of 19 m (N=12,178) was recorded, while the depths of 7 (N=36) and 14 m (N=2,929) presented lower densities. The highest average CPUE (kg/15min) values were recorded in autumn during the first year, and in spring in the second year (P<0.05), always at deeper waters (19 m) (Figure 4). The months with

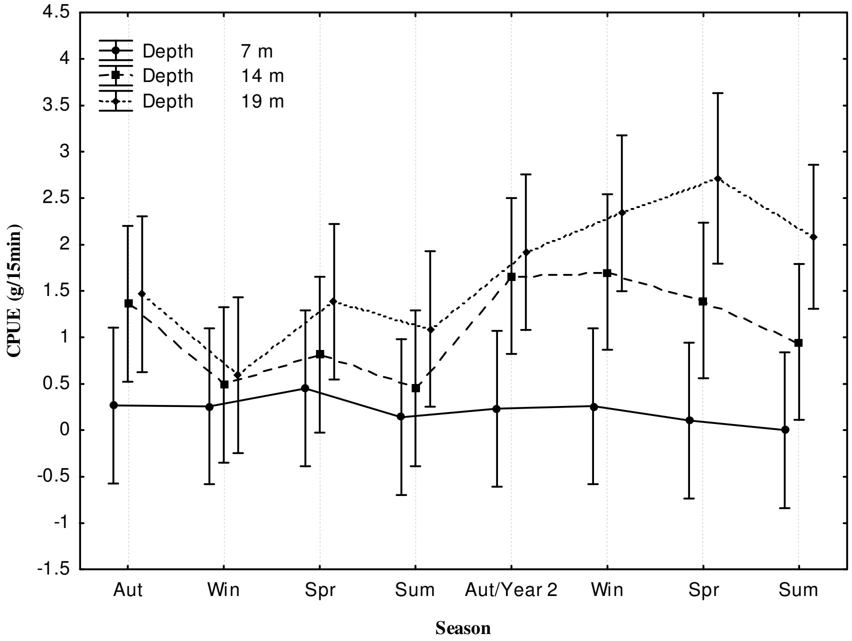

Fig. 4. Variation in the mean log CPUE (g/15min) of *P. muelleri* by season and depth (7, 14 and 19 m), in the region of Balneário Camboriú, state of Santa Catarina, Brazil.

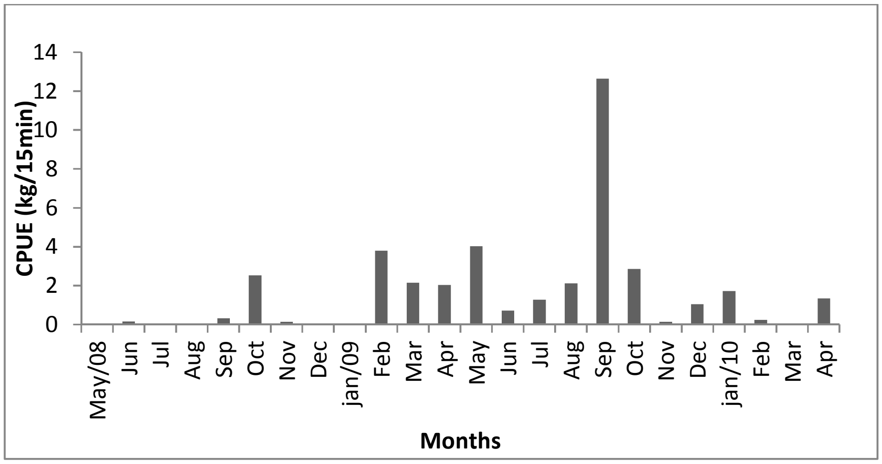

Fig.5. Variation of the monthly CPUE (kg/15min) of the shrimp *P. muelleri* in the region of Balneário Camboriú, state of Santa Catarina, Brazil, from May 2008 through April 2010.

The highest CPUE values occurred in October and February in the fisrt year, and in September in the second year (Figure 5).

Seasonal and Spatial variation in the Carapace Length

Females reached larger sizes than males. The mean size estimated for females was 16.74± 4.78 mm, ranging from 4.78to 35.5 mm and the mean size for males was 13.87±2.68, ranging from 4 to 31.58 mm. The size distribution, according to depth, showed that the significantly larger individuals, of both sexes, inhabit the isobaths of 19 m (17.09±4.80 and 13.98±3.45) for females and males respectively (Table 1).

Table 1. Variation in the mean carapace length (mm) of females and males of *P. muelleri* by depth (7, 14 and 19 m), in the region of Balneário Camboriú, Santa Catarina State, Brazil.

Females	**Depth**	**CL (mm)**	**Std Dev**	**Std Err**	**95% Confidence Limits**	
	7	11.40	10.05	1.62	8.05	14.76
	14	15.57	4.24	0.10	15.37	15.78
	19	17.09	4.80	0.06	16.97	17.22
Males	**Depth**	**CL (mm)**	**Std Dev**	**Std Err**	**95% Confidence Limits**	
	7	4.34	6.03	1.12	2.05	6.64
	14	13.23	2.83	0.11	13.01	13.4
	19	13.98	2.55	0.03	13.9	14.05

The analysis of seasonal trends in the mean carapace length of females (Figure 6) showed that in both years, the larger individuals occurred in spring (14.05±2.31) and autumn (14.52±3.03) in the 19 m isobath (seasonal and depth differences are statistically different, F=7.06, P<0.05). (Anova).

In spring and summer, were found the smaller individuals in shallow waters, while the larger ones remained in deeper waters, as was expected.

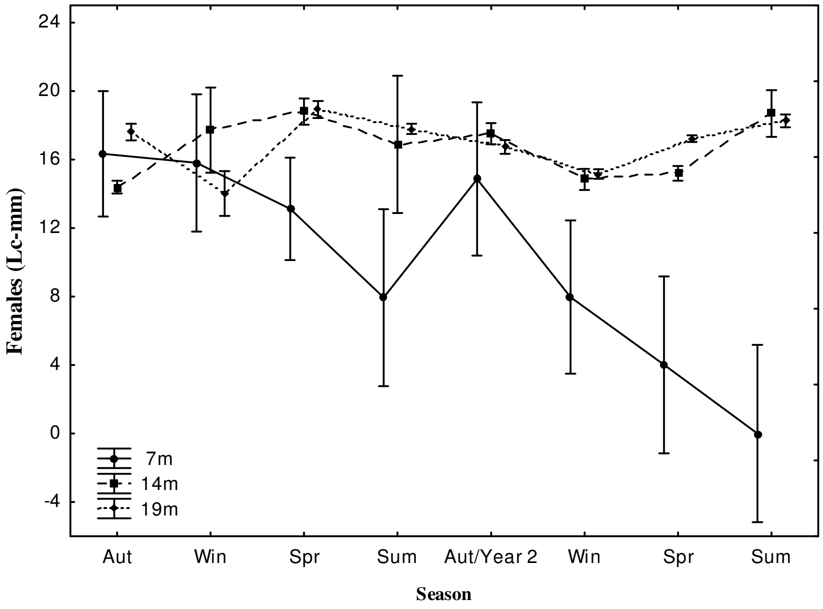

Fig. 6. Seasonal variation of the mean of the carapace length (CL), for females of *P. muelleri,* by depth, in the region of Balneário Camboriú, State of Santa Catarina, Brazil. The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values.

On the other hand, the seasonal variation of the carapace length of males (Figure 7) presented the highest mean values in autumn (14.52±3.03) in the 19 m isobath (seasonal and depth differences are statistically different, F=12.16 P<0.05) (Anova). In both years, the larger individuals remained in deeper areas, while the smaller ones were found in shallow waters, in autumn and summer.

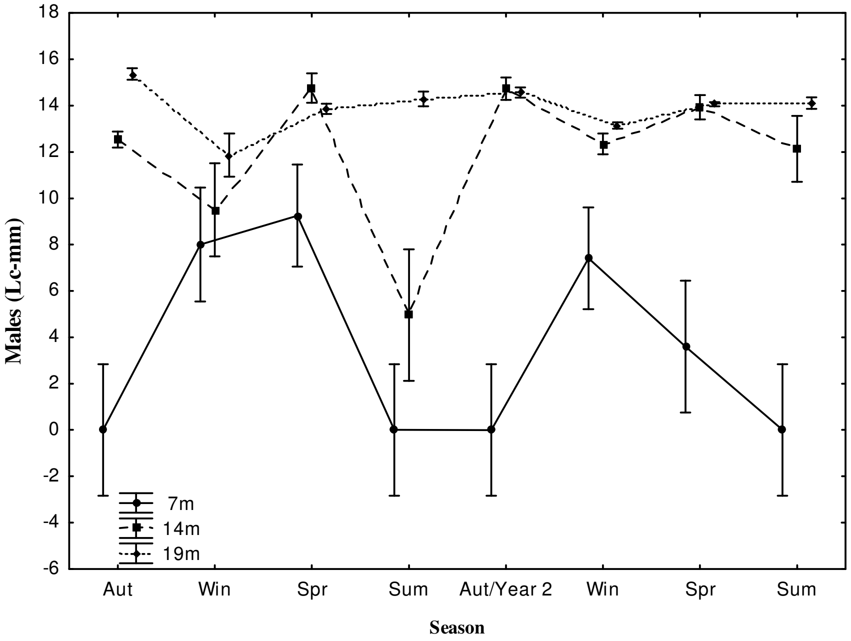

Fig.7. Seasonal variation of the mean of the carapace length (CL), for males of *P. muelleri,* by depth, in the region of Balneário Camboriú, State of Santa Catarina, Brazil. The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values.

Sex ratio

Considering the 15,153 individuals analyzed, 9,866 (65.11%) were females and 5,287 (34.89%) were males. The sex ratio, calculated for all the individuals caught, was significantly different from the expected 1:1 ratio ($P<0.05$, χ^2 test). Considering the first year, the monthly pattern indicated significant differences ($P<0.05$) towards females in May, August, October, February and March, and towards males in September and April. In the second year (May 2009 to April 2010), the χ^2 test indicated significant differences ($P<0.05$) toward females in all months, except in March, when a very low abundance was obtained for the species in the study area.

In general, at the deeper areas (14 and 19 m), the F:M ratio showed a similar pattern during the sampling period, with a higher proportion of females over males at a depth of 14 (2.25) than the depth of 19 (1.78).At a depth of 7 m, the F:M proportion was higher toward females only in June (1.5) and September (2). (Fig.8).

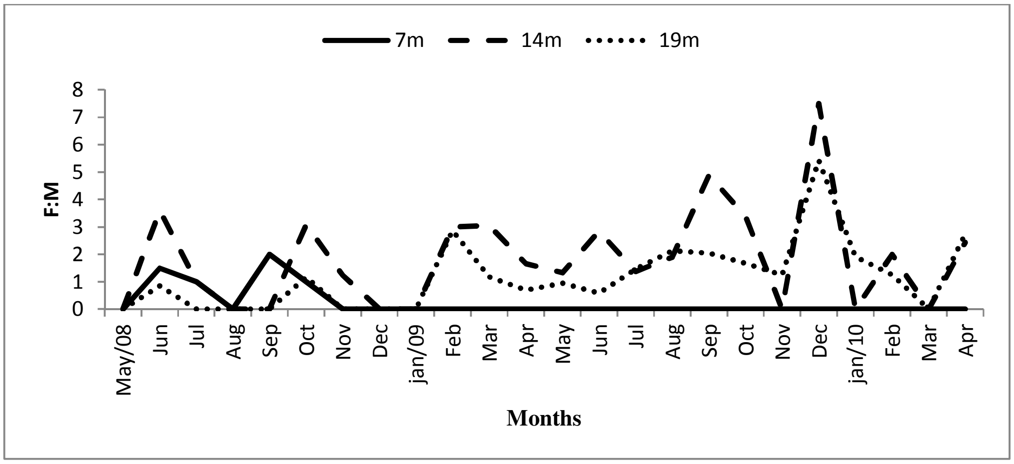

Fig. 8. Monthly proportion F: M, by depth (7, 14 and 19 m), during the two years of sampling, in the region of Balneário Camboriú, State of Santa Catarina, Brazil.

Biometric Relationships

The length-weight relationship presented a negative allometry for females (b=2.7) and males (b=2.6). (Fig. 9; Fig. 10), without significant differences between the sexes.

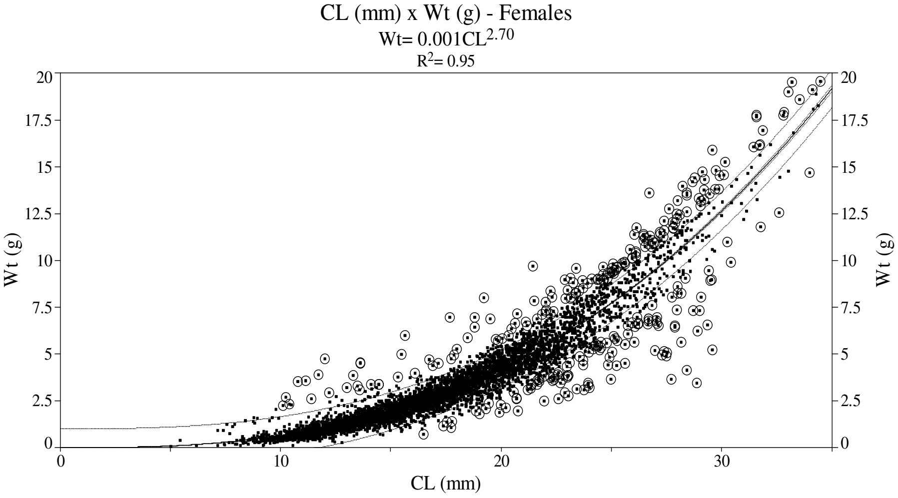

Fig. 9. Carapace length-weight relationship of females of the shrimp *P. muelleri.* region of Balneário Camboriú, State of Santa Catarina, Brazil. May 2008 to April 2010.

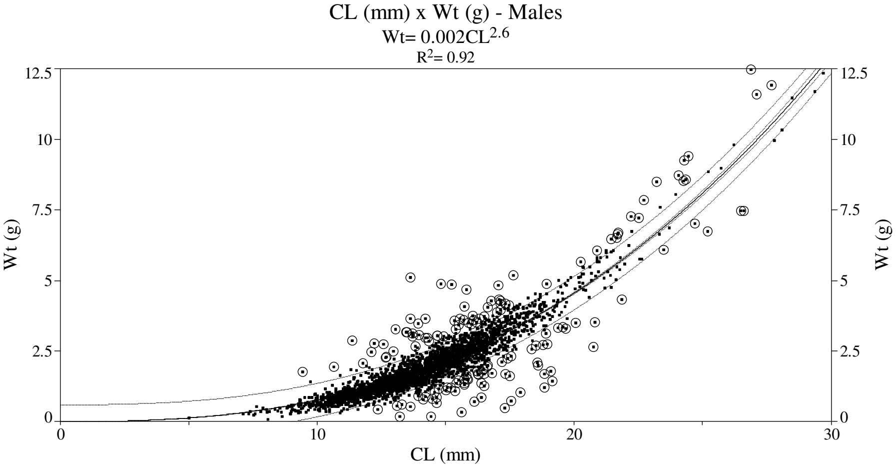

Fig. 10. Carapace length-weight relationship of males of the shrimp *P. muelleri.* region of Balneário Camboriú, State of Santa Catarina, Brazil. May 2008 to April 2010.

On the other hand, the length-length relationships showed a positive allometry for females (*b*=3.82) and males (*b*=3.70). (Figure 11; Figure 12), with significant differences between them, indicating a difference in the relative growth.

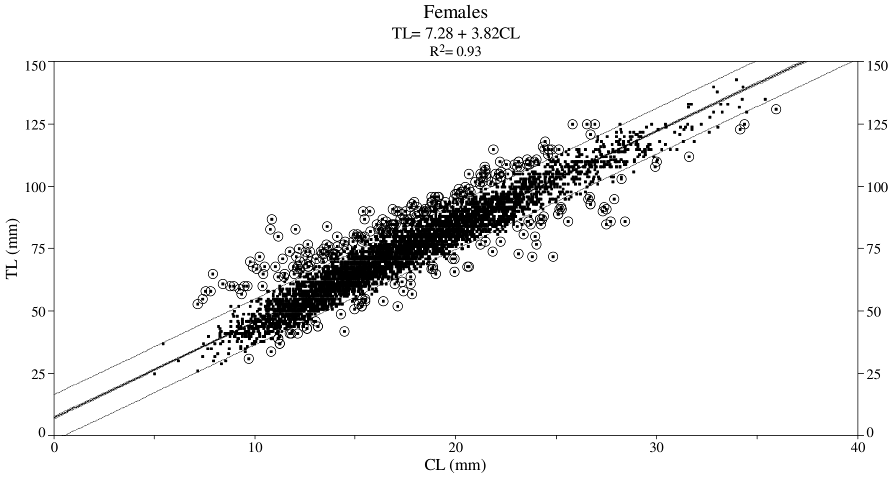

Fig.11. Carapace length-total length relationship of females of the shrimp *P.muelleri.* Region of Balneário Camboriú, State of Santa Catarina, Brazil. May 2008 to April 2010.

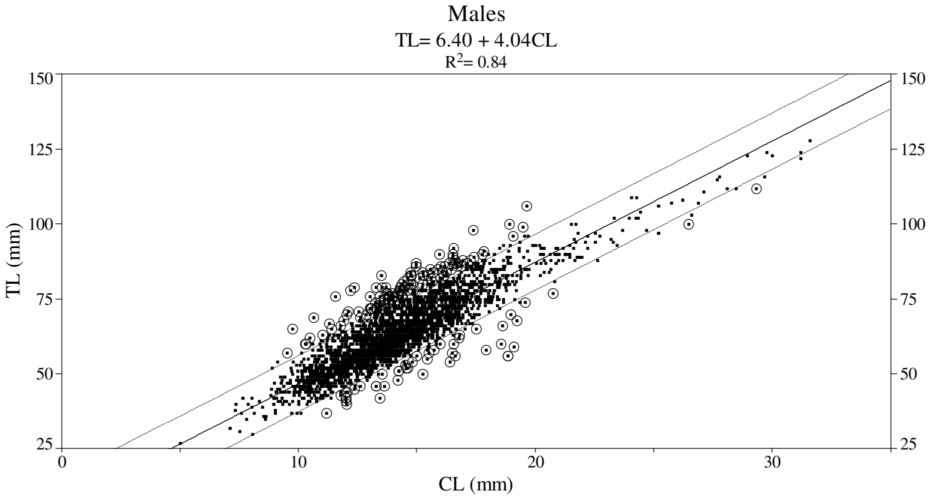

Fig. 12. Carapace length-total length relationship of females of the shrimp *P. muelleri.* Region of Balneário Camboriu, State of Santa Catarina, Brazil. May 2008 to April 2010.

The multiple regression analysis indicated that the main environmental factors regulating the abundance of *P.muelleri* were salinity and depth (r=0.53, p<0.01, F=10.90).

Table 2. Factors which were significantly correlated with the abundance of *P.muelleri* ($p<0.05$).

Enviromental factor	ß	p
Depth	0.52	0.00*
Bottom salinity	-0.22	0.01*

DISCUSSION

The distribution of most shrimp species depend on a variety of environmental factors (Boschi, 2000), which influence the abundance, among different seasons, of diverse species of Penaeoidea around the world, which generates a high variability in catch rates between consecutive years. An example can be seen in a work done by Ye *et al.* (2000) off the coast of Kwait, with *Penaeus semisulcatus*, which showed that catchability was not constant between two years, due to higher values at the beginning of the fishing season and lower values at the end. Reduced activity caused by low temperature is another identified cause for the decline of catchability of Spencer Gulf prawns (*Penaeus latisulcatus*) in Australia during the winter months (June to August) (Sluczanowski, 1984). Off the coast of China, in the Pohai sea, a work done by Cheng *et al* (1980) with the fleshy prawn (*Penaeus orinetalis*), showed that catches fluctuated between 10000 and 90000 tons. During this period, the 1968 generation was the least abundant while the 1979 generation was the most abundant. Based on primary investigations, they concluded that the amount of prawns is in direct correlation with the rainfall in Pohai sea and the runoff of the Huanghe River, and is in inverse correlation with the salinity of the sea water. In Argentina, the interannual variations in the catchability of *P.muelleri* is related mainly with stages of lifecycle and the magnitude of each cohort that enters the growing area to then go into recruitment and beginning the phase of exploitation. However, there is a tendency that in penaeids, recruitment is influenced by environmental conditions. As a result, fluctuations in abundance are pronounced throughout the year and between different annual periods (Boschi, 1989). For instance, between 1992 and 2006, there was a large variability in abundance, with maximum records of about 80,000 tons in 2001 to 6,500 tons in 1997. The fluctuation of recruitment directly influences the biomass available to be fished each year, affecting the annual landings (Bertuche *et al.,* 2000*).*

The marked difference in the densities of *P.muelleri* observed for both years, in the coast of Santa Catarina, is also likely to be attributed to salinity and temperature variations. As was expected, lower temperatures and higher salinities were found in deeper waters, mainly between January and March, in both years, probably due to the upwelling near Santa Catarina coast, when there are predominant northeast winds, which facilitate the penetration of the South Atlantic Coast Water (SACW) on the continental shelf in depth (Acha *et al*., 2004).

The distribution of *P. muelleri* seems to be associated with the spacial and temporal trends in the environmental factors. Clearly, the species selectively chooses the deeper waters (19 m) and population higher densities are related to salinities between 33 and 35, and temperatures below 20°C. Higher abundance of *P.muelleri* in the Region of Camboriú at greater depths can be explained by the intrusion of the South Atlantic Coastal Waters (SACW) in the bottom layer of the inner continental shelf, especially during the spring. The combination of the low temperature water mass and the light winds during summer, results in a marked termocline at a depth of 10 to 15 m.

Also, according to Costa *et al.* (2004), there is a positive association between the abundance of *P.muelleri* and depth off the coast of São Paulo, with highest densities occurring at depths greater than 9 m, always associated with the presence of colder water masses near the coast. With the offshore displacement of SACW in the winter, the distribution of the temperature and the salinity becomes more homogeneous trough the isobaths. In Argentina, the greatest densities of this species takes place in areas with bottom temperatures ranging from 7.5°C in the winter to 14.5°C in the summer, and salinity between 32.8 and 33.5. These temperatures are much lower than those found in the coast of Santa Catarina, but because of the higher abundance of the populations in the southern limit of occurrence, one may say that the optimum area for *P.muelleri* is the Patagonian coast, which is confirmed by the annual landings (Boschi, 1989). According to Odum (1988), certain environmental conditions are more likely to be critical for a given organism due to the larger amplitudes than the tolerance range of the species, limiting these species distributions concentrated in certain areas. Alternatively, variation in the abundance patterns between different regions might result from the influence of other biotic and abiotic factors too, that were not considered, such as intraespecific migration patterns. Therefore, the variation in abundance between different regions can be related to the physiological demands associated with the reproductive behavior, such as the migration of adults for spawning, rather than to environmental factors responsible for the permanence of the species in a determined region.

Pleoticus muelleri is sexually dimorphic in size, with females reaching larger sizes CL than males, indicating differential growth rates between sexes. According to

Costa & Fransozo (2004) and Castilho *et al*. (2008), the sexual dimorphism is caused by the larger body size of females in an adaptation to increased egg production. Several authors have suggested a paradigm of latitudinal trends in the population dynamics of penaeoidean shrimps (Boschi, 1997; Gavio & Boschi, 2004; Costa & Fransozo, 2004; Costa *et al.,* 2005; Castilho, 2004; Castilho *et al.,* 2008). In Argentina, Diaz *et al*. (2003) found females as large as 42 mm CL, 7 mm larger than the largest specimens collected in the state of Santa Catarina. In the Chubut province, Argentina (43°S), Boschi, (1989) found the smaller size of specimens with 10 mm CL and larger size of 55 mm CL. Another factor that reinforces this latitudinal variation refers to the size at first maturity. While off the coast of São Paulo, Castilho *et al*. (2008) found females with 11 mm of carapace length, Prata (2012, *in press*) found the smallest reproductive females with 19 mm of carapace length, and Fernandez (2003), in Argentina, found reproductive females with carapace larger than 31 mm. These differences can be explained by the difference in the water temperature between the occurrence limits of the species, and of more favorable oceanographic conditions in Argentina. According to Castilho *et al*. (2007), the variations in the life history parameters such as body size and size at sexual maturity are modified by habitat conditions correlated with latitude, such as water temperature, nutrient supply, and resultant primary productivity that form the basis of the larval food supply.

The analysis of the shifts in the mean carapace length (CL) of females and males of *P.muelleri*, by depth and season, indicated that the smaller individuals are concentrated in shallow waters during the spring and summer, probably indicating an essential recruitment habitat. Conversely, the highest average carapace size of individuals, including the reproductive females, was found in deep waters during both years analyzed, suggesting that reproduction takes place in depths further than 14m.

It is in agreement with investigations performed in the São Paulo Coast, the juveniles were found in lower numbers in all seasons during 5 years of sampling. Nevertheless, recruitment for *P.muelleri* was continuous, with interannual differences, but with pronounced peaks in spring and summer (Costa *et al.,*2008). According to Castilho *et al.* (2007, 2008), penaeoid shrimps seem to adjust their reproductive behavior to variations in the bottom temperature and phytoplankton production, especially in spring and summer months, resulting from the upwelling of the SACW. In Argentina, Fernandez *et al*; (2003) observed that *P.muelleri* breeds in spring and summer, with the peak starting in October, declining in April, and breeding continuing at a lower level. This period coincides with the highest average rates of abundance in the Santa Catarina coast, since in spring months, we found a significant number of females, probably doing a reproductive migration to deeper waters, between 14 and 20 meters.

P. muelleri showed a sex ratio around 0.6:1 in favor of females. This result is similar by those found by Diaz *et al.* (2003) in Argentina. This predominance of females was not constant over the two years of sampling. Deviations were found in favor of males during spring and autumn months. This can be an evidence of a reproductive migration of females for spawning towards the deeper and higher salinities waters, as reported in the State of Rio Grande do Sul for *Artemesia longinaris* (Dumont, 2005) and in Argentina for *P.muelleri* (Macchi *et al*., 1992).

Measurements of carapace length, total length and weight are those which are usually used in decapods and models to estimate it are very usefull in fishery and ecological investigations (De la Garza, 2003, Dumont & D'Incao, 2011). In Argentina, Diaz *et al.* (2003) and Ruiz *et al.* (2008) found W slope lower in females, probably a result of greater investment in weight of males for the reproductive period. The relationship between carapace length (CL) and total length (TL) of females had a higher TL slope (*b*=3.82) than males (*b*=3.70), indicating a pattern of higher relative growth in TL for females.

REFERENCES

Acha E.M; Mianzan H.W; Guerreiro R.A; Faveiro M. & Bava J. (2004). Marine fronts at the continental shelves of Austral South America: Physical and ecological processes. *Journal of Marine Systems* 44, 83-105.

Batista A.C; Simões S.M; Lopes M; Costa R.C. (2011). Ecological distribution of the shrimp *Pleoticus muelleri* (Bate, 1888) and *Artemesia longinaris* Bate, 1888 (Decapoda: Penaeoidea) in the Southeastern Brazilian littoral. *Nauplius* 19 135-143.

Bertuche D; C Fischbach; A Roux; M Fernández & R Piñero. (2000). Langostino (*Peoticus muelleri*). En: Bezzi SI, R Akselman & EE Boschi (eds), Síntesis del estado de lãs pesquerías marítimas argentinas y de la cuenca del Plata. Años 1997-1998, con actualización de 1999. Publicaciones Especiales. *INIDEP*, 179-190.

Boschi E.E. (1986). La pesqueria del langostino del litoral patagonico. *Redes* 20: 8 pp.

Boschi E.E. (1989). Biologia pesquera Del lagostino Del patagonico de Argentina (*Pleoticus muelleri*). *Contribución Instituto Nacional y Desarrollo Pesquero* 646: 5-71

Boschi E.E. (1997) Las pesquerías de crustáceos decápodos en El litoral de la Repú blica Argentina. *Investigaciones Marinas* 25, 19-40.

Boschi E.E. (2000). Species of decapods crustaceans and their distribution in the American zoogeographic provinces. *Revista de Investigación y Desarrollo Pesquero*. 13, 1-64.

Castilho A.L. (2004). *Dinâmica Populacional do camarão Artemesia longinaris Bate, 1888 (Decapoda: Penaeidae) no litoral norte do Estado de São Paulo*. PhD Thesis. Universidade Estadual Paulista, Botucatu, Brazil.

Castilho A.L; Gavio M.A; Costa R.C; Boschi E.E; Bauer R.T & Fransozo A. (2007). Latitudinal Variatin in Population Structure and reproductive pattern of the endemic South American shrimp *Artemesia longinaris* (Decapoda: Penaeoidea). *Journal of Crustacean Biology* 27, 548-552.

Castilho A.L; Costa R.C; Fransozo A; Fransozo M.L.N. (2008) Reproduction and recruitment of the South American red shrimp, *Pleoticus muelleri* (Crustacea: Solenoceridae), from southeastern coast of Brazil. *Marine Biology Research* 4, 361-368

Costa R.C; Fransozo A; Mantelatto F.L & Castro R.H (2000). Occurrence of shrimp species (Crustacea: Decapoda: Natantia: Penaeidea and Caridea), in Ubatuba Bay Ubatuba, SP, Brazil. *Proceeding of the Biological Society of Washington* 113, 776-781.

Costa R.C & Fransozo A. (2004). Abundace and ecological distribution of the shrimp *Rimapenaues constrictus* (Crustacea: Penaeidae) in the northern coast of São Paulo, Brazil. *Journal of Natural History* 38: 901-912.

Costa R.C; Fransozo A; & Pinheiro A.P. (2004). Ecologic 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 &Freire F.A.M. (2005) Annual, seasonal and spacial variation of abundance of the shrimp *Artemesia longinaris* (Decapoda: Penaeoidea) in south-eastern Brazil. *Journal of the Marine Biological Association of the United Kingdom*, 85(1): 107-112.

Dall W., Hill B.J., Rothlisberg P.C. & Staples D.J. (1990). The Biology of the Penaeidae. *Advances in Marine Biology*, Academic Press, London, UK. 489 pp.

De la Garza, J. (2003). Relaciones morfométricas del langostino patagónico (*Pleoticus muelleri*). *Informe Técnico Interno Inidep* 101, 1-9.

De la Garza, J. & Fischbach C. (2009). Obtención de índices de mortalidad y tasas de explotación Del langostino (*Pleoticus muelleri*) em lãs temporadas de pesca 1992-2008 a partir de dados de producción y desembarque. *Informe de Investigación, INIDEP*, N°63, 18pp.

D'Incao F; H Valentini & Rodrigues L.R. (2002). Avaliação da pesca de camarões nas regiões sudeste e sul do Brasil. *Atlântica* 24, 103–116.

Dumont L.F.C; F D`incao. (2008). 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. *Nauplius***,** pp. 1-12.

FAO. (2010). The State of World Fisheries and Aquaculture. Rome.

Fernández M; Macchi, G; De la Garza J. (2003). Análisis reproductivo de las concentraciones de langostino (*Pleoticus muelleri*) localizadas en la exploración llevada a cabo en el Golfo San Jorge (provincia de Santa Cruz) con el Arbumasa XIV. *Informe Tecnico INIDEP* 184, 1-12.

Fernandez M. (2005). Localización de las concentraciones reproductivas del langostino em El litoral patagônico. Periodo analizado: Diciembre de 2000 a enero de 2005. *Informe Técnico Interno INIDEP* 77, 1-13.

Garcia S; & Le Reste L. (1981). Life cycles, dynamics, exploitation, and management of coastal penaeid shrimp stocks. *FAO Fisheries Technical Papers* 203, 1-215.

Gavio M.A; E.E Boschi. (2004). Biology of the shrimp *Artemesia longinaris* Bate, 1888 (Crustacea: Decapoda: Penaeidae) from Mar del Plata Coast. *Nauplius* 12, 83-94.

Gep.(2010). *Grupo de Estudos Pesqueiros*. Disponível em http://siaiacad04.univali.br/consulta/.

Gillet R. *Global study of shrimp fisheries* (2008). FAO fisheries technical paper 475. Fiji, FAO.

Haimovici M. & J.T Mendonça.(1996). 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.

Hartnoll R. (1982). ‘’Growth’’. The Biology of Crustacea, n°. 2, 111-196.

Macchi G.J; Iorio M.I; &Christiansen H. (1992). Aspectos del desove y fecundidad Del lagostino *Pleoticus muelleri* (Bate, 1888) (Crustacea, Decapoda, Solenoceridae). *Revista de Biologia Marina* 27, 43-58.

Mathews C.P. (1994). Fisheries Management: the Kwait Experience. *Marine Fisheries Review* 56, 23-30

Odum E.P. (1988). Ecologia (Guanabara). 434pp.

Parsons T.R. & Lalli C.M. (2006). Biological Oceanography: An introduction. Pergamon Press. University of British Columbia, 301 pp.

Sluczanowski P.R. (1984). Modeling and optimal control: a case study based on the Spencer Gulf Prawn fishery for *Penaeus latisulcatus. Journal du conseil international pour l' exploration de la mer*. 41, 211-225.

Ye Y & Mohammed H.M.A. (1999). An Analysis of Variation in Catchability of Green Tiger Prawn, *Penaues semisulcatus,* in Waters of Kwait. *Fishery Bulletin,* n°.3, 97pp

Zar T.H. (1999). *Biostatistical analysis*. Fourth Editio., Prentice Hall. 663p.

Capítulo 2

Ovarian development and length at first maturity of the red shrimp *Pleoticus muelleri* based on histological analysis in the northern coast of Santa Catarina state, Brazil. Prata, P.F.S; Machado, I.F; Dumont, L.F.C.

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Ovarian development and length at first maturity of the red shrimp *Pleoticus muelleri* based on histological analysis in the northern coast of Santa Catarina state, Brazil

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ABSTRACT: The stages of ovary development for the females of red shrimp (*Pleoticus muelleri,* (Bate, 1888*))* were characterized based on histological analysis. Three stages (immature, developing, and ripe) were determined according to the structure and arrangement of ovary cells. The color of the fresh ovary was compared with a standardized chromatic scale to establish a macroscopic classification of the gonads. Analysis of the histological sections allowed the determination of the main morphological characteristics of the gonads, including size and frequency of the different oocyte types. The mean size of cells was 53.97 µm (±11.81) (stage I), 149.30 µm (±20.89) (stage II) and 153.68 µm (± 57.66) (stage III). The size frequency of cells was polymodal, and different cell stages were observed in the ripe ovaries, suggesting the occurrence of multiple spawning for this species. The smallest ripe female measured 50 mm and the largest 140 mm of the total length. Estimated mean length at first maturity was 82 mm for total length and 19 mm for carapace length. The length at which 100% of females are mature is 140 mm.

KEY WORDS. First maturity, shrimp, histology, ovary.

RESUMO. Desenvolvimento dos ovários e tamanho de primeira maturação do camarão vermelho *Pleoticus muelleri* baseado em análises histológicas no litoral norte de Santa Catarina, Brasil. Os estágios de desenvolvimento dos ovários de fêmeas do camarão vermelho (*Pleoticus muelleri* (Bate, 1888)) foram caracterizados com base em uma análise histológica. Três estágios (imaturo, em desenvolvimento e maduro) foram determinados de acordo com a estrutura e arranjo das células do ovário. A cor do ovário fresco foi comparada com uma escala cromática padronizada para estabelecer uma classificação macroscópica das gônadas. As análises dos cortes histológicos permitiu a determinação das principais características morfológicas das gônadas, incluindo o tamanho e a freqüência dos diferentes tipos de oócitos. O tamanho médio das células foi de 53,97 µm (±11,81) (estágio I), 149,30 µm (±20,89) (estágio II) e 153,68 µm (±57,66) (estágio III). A frequência dos tamanhos das células teve um padrão polimodal, e diferentes estágios da célula foram observados nos ovários maduros, indicando a ocorrência de desova múltipla para a espécie. A menor fêmea medida foi de 50 mm e a maior foi de 140 mm de comprimento total. O tamanho médio de primeira maturação foi de 82 mm de comprimento total e de 19 mm para tamanho da carapaça. O tamanho no qual 100 % das fêmeas estão maturas foi de 140 mm de comprimento total.

Palavras chaves: *Pleoticus muelleri*, camarão, histologia, ovário.

The distribution of the shrimp *Pleoticus muelleri* (Bate, 1888) (Decapoda: Solenoceridae) is restricted to the Western Atlantic, from Rio de Janeiro (23° S), Brazil, to Santa Cruz (50° S), Argentina. This species remains in the marine environment throughout its life cycle (BOSCHI, 1997) and plays an important role in thophic-web of costal marine waters of Southern Brazil, as they are intensively predated by fishes (CAPITOLI *et al;* 1994).

P. muelleri has been exploited by artisanal and industrial fisheries throughout their distribution area. (D`INCAO *et al;* 2002; DUMONT *et al*; 2007; MACHADO *et al*; 2009), and became more intensively caught due to the landings declining of more valuable prawn species, such as the pink shrimp species (*Farfantepenaeus paulensis* Pérez Farfante, 1967 and *F. brasiliensis.* Latreille (1817).

Therefore, the stock management needs to deal with the reproduction process of the species, because the reproductive patterns can differ according to the environment variations according to the latitude (CASTILHO *et al;* 2007).

The knowledge on ovary maturation and length at first maturity is essential to determine the minimum catch size (VAZZOLER, 1996; KING, 1997). Therefore, the main objective of this study was to determine the size of first maturity of *Pleoticus muelleri* in southern Brazil, based on the relationship between histological sections and macroscopic features using a chromatic scale, with the size of the specimens collected at sea.

MATERIALS AND METHODS

The samples were collected in Babitonga Bay (26° 16’ 63’’ S – 48° 41’ 20’’W) northern coast of Santa Catarina state, southern Brazil. There were conducted 76 trawl fishing operations, of 30 minutes each, in depths ranging from 10 to 100 meters (Fig. 1). Each fishing station was held during the day and night considering that spawning occurs mainly at dusk and night (DUMONT *et al;* 2007).

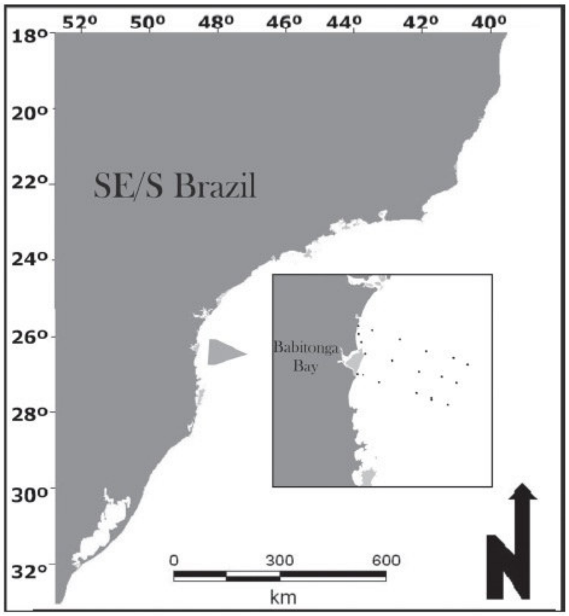


Figure 1: Coastal Region of Southeastern and Southern Brazil, where the *P. muelleri* fishing takes place, highlighting the sampling area of Babitonga Bay. Black dots indicate sampling stations, in depths varying from 10-100 meters.

The *P. muelleri* ovaries were initially classified according to a standard Pantone’s color catalog (PANTONE Inc. 1999) to establish a chromatic reference point (PEIXOTO *et al;* 2003*;* DUMONT & D`INCAO, 2004; DUMONT *et al;* 2007, MACHADO *et al*; 2009).

To cover the range of ovarian development, a sample of thirty females from stage I, thirty two from stage II and fifty from stage III was used to establish a chromatic scale to classify the ovaries of *P. muelleri*.

The ovarian tissue (middle portion) was fixed with Davidson solution for 24 h, embedded in paraffin and sectioned (6µ*m*) (BELL & LIGHTNER, 1988). The haematoxylin-eosin staining technique was used, which indicates basophilic or acidophilic reaction by the cell parts stained with blue or red color, respectively used. To define the ovary color accurately, an automated tool was used to match the predominant ovary color to Pantone's reference table (Fig. 2). This tool samples a square of 12 x 12 pixels and provides the mean reference color obtained within this area.

To test for significant differences among mean oocyte size grouped according to development stage, an ANOVA ($p<0.05$) and a *posteriori* Tukey's test were performed (ZAR, 1984). Length at first maturity was estimated by fitting the frequency of mature females to a logistic model, described by the following equation:

$$P=1/[1+\exp^{(-r(CL1 - LM))}]$$

Where P is the expected proportion of mature individuals, r is the slope, *CL* is the carapace length and *LM* the size at first maturity.

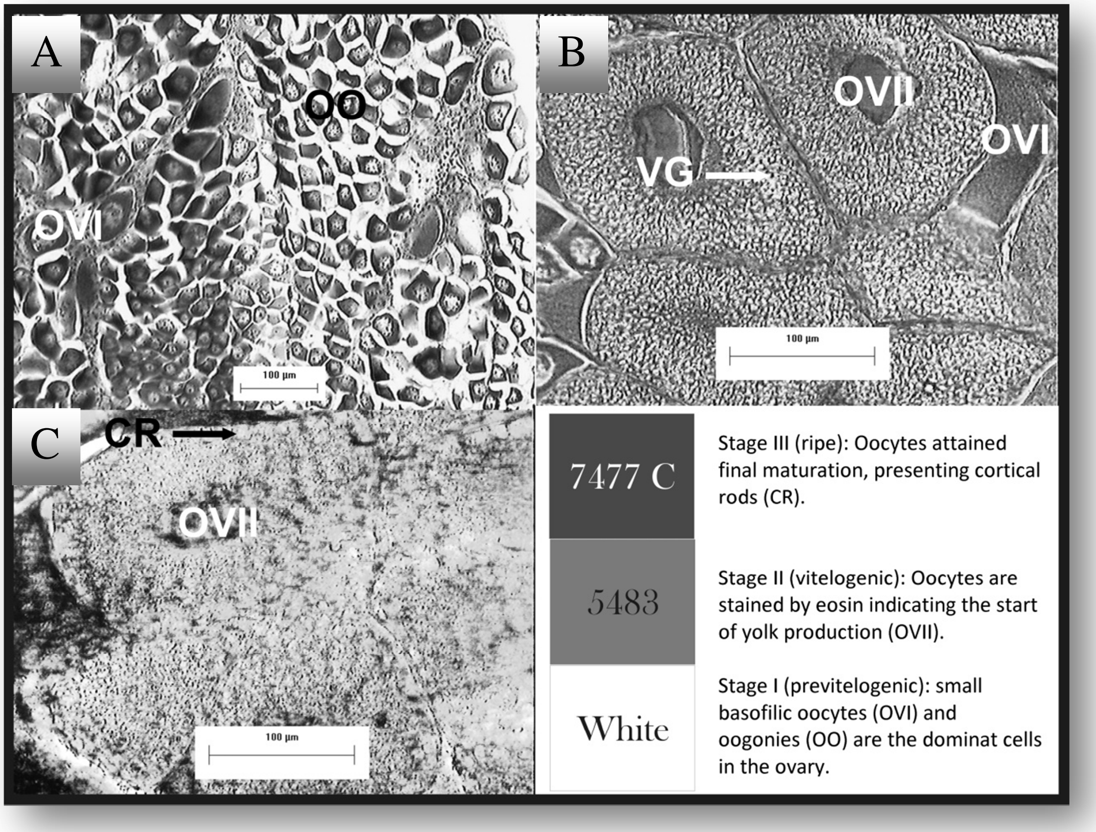
RESULTS

According to histological sections (Fig. 2) we defined three different ovary maturation stages, which are described as follows:

Stage I (Pre-vitelogenic or Immature): Most frequent cells observed are the previtelogenic oocytes and the oogonies, which form the germinative epithelium. The cells are basophilic (stained by hematoxilin) indicating lack of yolk production during this stage. Macroscopically, the ovaries vary from white-translucent to light grey, occupying a reduced portion of the abdomen cavity. Mean oocyte diameter is 53.97 µm (±11.81).

Stage II (Vitelogenic): The cells are acidophilic and stained by eosin. The start of vitellogenesis is observed with small yolk granules in the cytoplasm. Mean cell diameter during this stage is 149.30 µm (±20.89). The ovary is clearly palpable through the exoskeleton due to a considerable increase in its size and consistency. A light green colour (catalogue 5483 PC) prevails at this stage.

Stage III (Ripe): Acidophilic oocytes with cortical rods (CR) in the periphery of the cytoplasm are typical of this stage, as well as the increase in mean cell diameter 153.68 µm (± 57.66). The ovary is large and turgid and occupies all the available spaces in the body cavity. The light green colour of the previous stage turns into an olive-brown colour (catalogue 5747 PC) as development proceeds.



Stage III (ripe): Oocytes attained final maturation, presenting cortical rods (CR).

Stage II (vitelogenic): Oocytes are stained by eosin indicating the start of yolk production (OVII).

Stage I (previtelogenic): small basofilic oocytes (OVI) and oogonies (OO) are the dominat cells in the ovary.

Figure 2: Histological sections (100x) and representative color of each ovarian maturation stage for *Pleoticus muelleri.* (A) Stage I (immature): small basophilic oocytes (OVI) color ranged from white-translucent to light gray (white); (B) stage II (developing): acidophilic oocytes with yolk granules in the cytoplasm (OVII), light to neutral green color (5483C); (C) stage III (ripe): acidophilic oocytes (OVIII) with cortical rods (CR), dark green to pale black color (7477C).

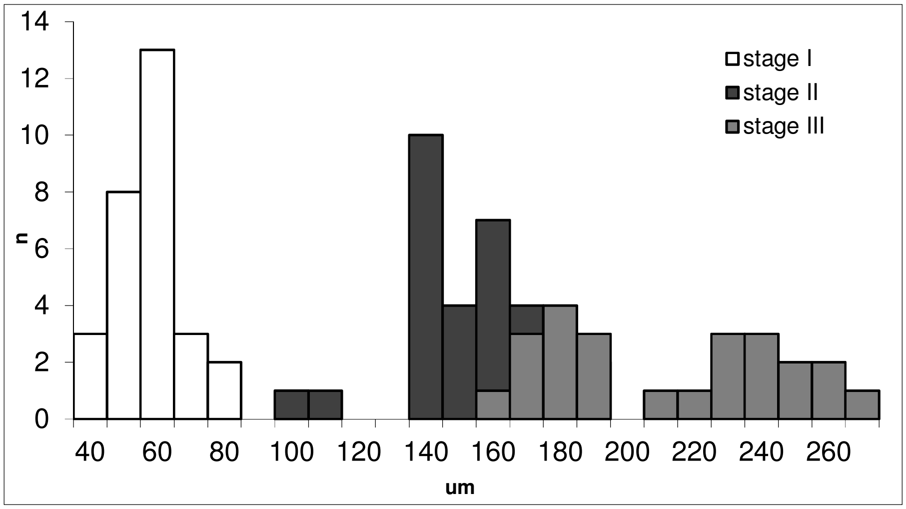


Figure 3: Relative frequency of size distribution of oocytes (μm) pooled by development stage obtained from histological sections of *P.muelleri* ovaries.

Size overlapping of oocytes was recorded between different developing stages (Fig. 3), however significant differences ($p < 0.005$) related to mean oocyte diameter were observed (Tab. I). The size frequency of oocytes showed a polymodal pattern for immature and developing oocytes, with one peak for immature oocytes and two for developing ones (Fig. 3).

The length at first maturity estimated for females was 82 mm (TL). (Fig.4). The length at which 100% of females are mature is 140 mm, and the parameters of the logistic curve is showed in Tab.II.

Table I: Statistic summary of oocyte size analysis, containing number of oocytes measured (N) for each development stage, mean size of the cells (X), confidence intervals of means (CI 95%) and standard error (SE).

N	Mean	CI (±95%)		Min	Max	SE
30	53.97	49.55	58.38	36.83	93.19	11.81
32	149.30	141.76	156.83	95.95	188.58	20,89
50	153.68	137.29	170.06	83.74	263.78	57.66

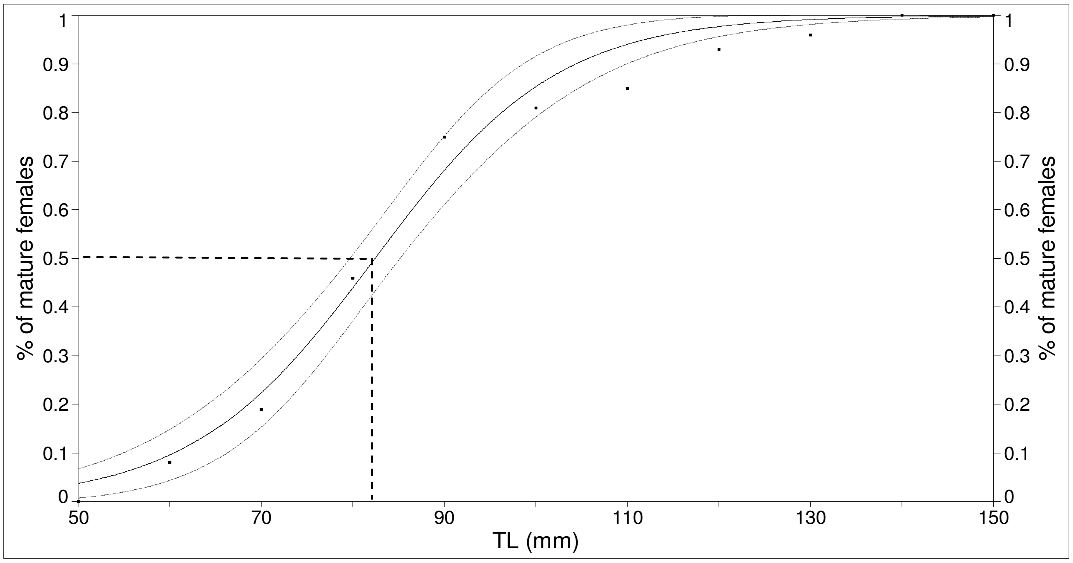


Figure 4: Logistic curve of sexual maturity estimated for *Pleoticus muelleri* females in Babitonga Bay, SC. The solid lines represent the confidence interval where the probability of being mature is 50% and 100% (TL). R^2= 0.98

Table II: Summary of fit obtained from logistic model, containing the parameter fit (Parm), the value estimated (Value), the standard error (SE), the t value, the confidence limits to 95% of significance as well the p value (limit of significance adopted was p< 0,005).

Parm	Value	SE	T	CL (95%)		P>|t|
r	0.02	7.72	0.10	0.19	0.00006	0.14
LM	1.01	80.39	79.37	84.06	0.00000	81.71

DISCUSSION

Although the classification of penaeoidea ovarian maturation in different stages is subjective, this process is characterized by microscopic and macroscopic changes that allow it to be conveniently divided into stages (DALL *et al.* 1990). Macroscopic classification based on color and shape of ovaries, showed a close relationship with cell development and ovary structure, obtained from histological sections. Ovarian maturation of several species has been described according to histological features (KING, 1948; TAN-FERMIN & PUDADERA, 1989; QUINITIO *et al;* 1993; MEDINA *et al.* 1996) or the external appearance of the ovary (KING, 1948; LAUBIER-BONICHON, 1978; CROCOS & KERR, 1983).

Many previous investigations suggested at least five development stages for penaeid prawns (QUINITIO & MILLAMENA, 1992; MEDINA *et al.* 1996; PALÁCIOS *et al.,* 1999). These stages are usually named as immature (I), initial developing (II), incipient maturity (III), mature (IV) and spent (V) and determined through macroscopic features of the ovaries.

However, most of the authors have not found significant histological differences between stage I and II related to cell diameter and only three different oocytes types were observed (WORSMANN *et al.,* 1971; WORSMANN &SESSO, 1977; QUINTERO AND GARCIA, 1998; PEIXOTO *et al.* 2003, MACHADO, *et al.* 2009).

The present study could not identify any histological evidence in the cell arrangement, which suggests the existence of more than three clear ovarian maturation stages.

For instance, in a similar study done by MACCHI *et al.* (1998), in Puerto Rawson, Argentina, which is one of the most important reproductive areas of *P.muelleri* and also have the highest catch rates, results showed mainly two types of oocytes: previtelogenic and vitelogenic. The previtelogenic oocytes are small, with a strongly basophilic cytoplasm, while the vitelogenic elements presented diameters between 140 and 260 µm, and the cytoplasm is acidophilic due to accumulation of yolk globules. The mean diameters of oocytes from *P.muelleri* of the present study showed high similarity with other results obtained for the species elsewhere, as well as for other penaeids, including the overlapping of the two last maturation stages (GUITART & QUINTANA, 1978; RAMOS & TORRAS, 1986).

Our results of length at first maturity, altogether with studies done southwards, suggests a paradigm of latitudinal pressure: In Argentina, FERNANDEZ *et al.* (1993) found reproductive females with carapace larger than 31 mm, which is much larger than the value (11.1 mm) found by CASTILHO *et al.* (2008) off the coast of São Paulo. In that study, the length at first maturity based on carapace length was 19 mm. According to

BOSCHI *et al.* (1989), on the Patagonian Coast, the growth and molting of *P.muelleri* is influenced by water temperature, mainly in winter (7-8°C), having a longevity of 20 months. However, the increase of temperature in other seasons allows for faster growth of the juvenile cohort at the end of spring and summer, up to the beginning of autumn. According to the study done by CASTILHO *et al.* (2008), off the Brazilian Coast, the size-class distribution is influenced temporally by the water-temperature cycle, and spatially by the differences in regions off the southeastern Brazilian coast, in terms of oceanographic conditions. In the region of Santa Catarina, variations in temperature and salinity are well marked because the penetration of the mass of the South Atlantic Central Water (SACW) in the bottom layer of the continental shelf during summer, forming a thermocline at a depth of approximately 10 to 15 m. With the retreat of SACW in winter, the temperature distribution in the coastal zones becomes homogeneous with temperatures between 20 and 23°C and average salinity of 35 (MATSUURA, 1986). So, these results allows us to infer that this species is suited for different environmental conditions according to migration toward lower latitudes, and is probable that there are different populations of *P. muelleri* between Rio de Janeiro and Argentina, but, it's still necessary to do further studies to learn how this species is distributed over the Western Atlantic.

REFERENCES

BELL T.A. & LIGHTNER D.V. 1988. A Handbook of Normal Penaeid Shrimp Histology (Special Publication).World Aquaculture Society, Baton Rouge, USA. 114 pp.

BOSCHI EE. 1997. Las pesquerías de crustáceos decápodos en El litoral de la Repú blica Argentina. **Investigaciones Marinas** 25: 19-40.

CROCOS P.J. & KERR J.D.1983. Maturation and spawning of the banana prawn Penaeus merguiensis in the Gulf of Carpentaria, Australia. **Journal of Experimental Marine Biology and Ecology 122**: 557-570.

CAPITOLI, R. R.; BAGER, A. & 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.

CASTILHO A.L, GAVIO M.A, COSTA, R.C; BOSCHI, E.E; BAUER, R.T, FRANSOZO, A. 2007. Latitudinal variation in population structure and reproduction pattern of the endemic South American shrimp *Artemesia longinaris* (Decapoda: Penaeoidea). **Journal of Crustacean Biology 27**: 548-52.

CASTILHO, A.L; COSTA, R.C; FRANSOZO, A; FRANSOZO, M.L.N. 2008. Reproduction and recruitment of the South American red shrimp, *Pleoticus muelleri* (Crustacea: Solenoceridae), from southeastern coast of Brazil. **Marine Biology Research**, **4**: 361-368.

DALL W., HILL B.J., ROTHLISBERG P.C. & STAPLES D.J. 1990. The Biology of the Penaeidae. **Advances in Marine Biology**, 489 pp. Academic Press, London, UK.

D'INCAO, F.; VALENTINI, H. & RODRIGUES, L. F. 2002. Avaliação da pesca de camarões nas regiões Sudeste e Sul do Brasil; 1965-1999. **Atlântica**, Rio Grande, **24** (2): 49-62.

DUMONT, L.F.C. & D'INCAO F. 2004. Estágios de desenvolvimento gonadal de fêmeas do camarão-barbaruça (*Artemesia longinaris* – Decapoda:Peneidae). **Iheringia**. **94** (4), 389-393.

DUMONT, L.F.C; D'INCAO, F; SANTOS, R; MALUCHE, S; RODRIGUES, F.L. 2007. Ovarian devolopment of wild pink prawn Farfantepenaeus paulensis in the northern shore of Santa Catarina State. **Nauplius, 15**: 65-71

FERNÁNDEZ, M; MACCHI, G; DE LA GARZA, J. 2003. Análisis reproductivo de las concentraciones de langostino (*Pleoticus muelleri*) localizadas en la exploración llevada a cabo en el Golfo San Jorge (provincia de Santa Cruz) con el Arbumasa XIV.
Informe Tecnico INIDEP 184:1-12.

GUITART, B. & QUINTANA, M. 1978. Estadios de maduración gonadal en las especies importantes del género *Penaeus* em el Banco del Campeche. **Revista Cubana de Investigaciones Pesqueras**, Havana, **3**: 82-126.

KING J.E. 1948. A study of the reproductive organs of the common marine shrimp, Penaeus setiferus (Linnaeus). **Biology Bulletin 94**: 244-262.

KING, M.G. 1997. Fisheries biology, assesment and management. **Fishing news books. Osney Mead, Oxford**, England., pp. 341.

LAUBIER-BONICHON A.1978. Ecophysiologie de la reproduction chez la crevette Penaeus japonicus: trois annes d'éxperience en millieu contrôle. **Oceanologica Acta 1**: 135-150.

MACCHI, G.J; IORIO, M.I; AUBONE, A. 1998. Estimación de La fecundidad Del langostino argentino *Pleoticus muelleri* Bate, 1888 de Patagonia (sur de Argentina). **Boletín del Instituto Español de Oceanografía 14**(1/2): 19-29

MATSUURA, Y. 1986. Contribuição ao estudo da estrutura oceanográfica da Região Sudeste entre Cabo Frio (RJ) e Cabo de Santa Marta Grande (SC). **Ciênc. Cult**., *38* (8):1439-1450.

MEDINA, A.; VILA, Y.; MOURENTE, G. AND RODRÍGUEZ, A. 1996. A comparative study of the ovarian development in wild and pond-reared shrimp, *Penaeus kerathurus* (Förskal, 1775). **Aquaculture, 148**: 63-75.

MACHADO, I. F; DUMONT, LFC; D`INCAO, F. 2009. Stages of Gonadal Development and mean length at first maturity of wild females of white shrimp (*Litopenaeus schimitti* – DECAPODA, PEANEIDAE) in Southern Brazil. **Atlântica Rio Grande**, **31(2):** 169-175.

PANTONE. 1999. **Pantone Professional Color System**. 14th ed. New Jersey, Carlstad. 260p.

PALACIOS E., RODRÍGUEZ-JARAMILLO C. & RACOTTA I.S. 1999. Comparison of ovary histology between di!erent-sized wild and pond-reared shrimp *Litopenaeus vannamei* (*Penaeus vannamei*). **Invertebrate Reproduction and Development 35**: 251-259.

PEIXOTO, S., CAVALLI, O. R., D'INCAO, F., MILACH, A. M. & WASIELESKY, W. 2003. Ovarian maturation of wild *Farfantepenaeus paulensis* in relation to histological and visual changes. **Aquaculture Research**, 34: 1255-1260.

QUINITIO, E. T. & MILLAMENA, O. M. 1992. Ovarian changes and female-specific protein levels during sexual maturation of the white shrimp *Penaeus indicus.* **The Israeli Journal of Aquaculture, 44(1)**: 7-12.

QUINITIO E.T., CABALLERO R.M. & GUSTILO L. 1993. Ovarian development in relation to changes in the external genitalia in captive Penaeus monodon. **Aquaculture 114**: 71-81.

QUINTERO M.E.S. & GARCIA A. 1998. Stages of gonadal development in the spotted pink shrimp *Penaeus brasiliensis.* **Journal of Crustacean Biology 18**: 680-685.

RAMOS, L. & TORRAS, E. 1986. Histologia del ovário maduro del camarón rosado *Penaeus notialis* com ablacion del pedúnculos oculares. **Revista de Investigaciones Marinas**, Havana, **7**: 53-61.

TAN-FERMIN J.D. & PUDADERA R.A. 1989. Ovarian maturation stages of the wild giant tiger prawn Penaeus monodon Fabricius. **Aquaculture 77**: 229-242.

VAZZOLER, A.E.A. DE M. 1996. Biologia da reprodução de peixes teleósteos: teoria e prática. Maringá: **EDUEM**, pp. 169.

WORSMANN T.U., NEIVA G.S., OLIVEIRA M.T. & VALENTINI H. 1971. Contribuição ao estudo da maturação da gônada feminina do 'camarão-rosa' (*Penaeus paulensis* Perez Farfante, 1967)**. Boletim do Instituto de Pesca 1**: 23-28.

WORSMANN T.U. & SESSO A. 1977. Observations ultrastructurales sur la maturation des cellules germinales de l'ovaire de *Penaeus paulensis*. **Archives D'Anatomie D'Histologie D'Embryologie Normales et Expérimentales 60**: 175-188.

ZAR, T. H. 1984. **Biostatistical analysis**. New Jersey, Prentice Hall. 718p.

Capítulo 3

Reproduction and recruitment of the red shrimp *Pleoticus muelleri* (DECAPODA:Solenoceridae) from the southern coast of Brazil. Prata, P.F.S; Machado, I.F; Sarda, F.O; Dumont, L.F.C.

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Reproduction and recruitment of the red shrimp *Pleoticus muelleri* (Bate, 1888) (DECAPODA: Solenoceridae), from the Southern coast of Brazil

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Abstract: Reproductive dynamics and recruitment period were examined for the red shrimp *P.muelleri* in the region of Balneário Camboriú, State of Santa Catarina, Brazil. Monthly samples were taken from May 2008 to April 2010, at depths between 7 and 19 m. The reproductive period was determined comparing the mean CPUE (g/15min) of reproductive females (developed and ripe gonads) by month, season and depth. The size at recruitment was estimated based on the catch curve, in such a way that age classes include in the ascending part of the curve were considered as recruits. The relative abundance (number/15 minutes) of recruits was compared by month and season. A total of 15.153 individuals were analyzed (9866 females and 5287 males). Over the two years of sampling, females with ripe ovaries were collected in every season, with the highest CPUE values in summer and spring months in the first year and in all seasons in the second year. Recruits were found in lower numbers in the first year, with peaks in September and October. However, in the second year, the recruits were found in all seasons, with peaks of abundance in March and September. These results suggest that *P. muelleri* presents continuous reproduction under favorable environmental conditions of lower water temperature.

key words: *Pleoticus muelleri,* reproduction, recruitment, spawning.

RESUMO

A dinâmica reprodutiva e o período de recrutamento foram examinados para o camarão santana *Pleoticus muelleri* na região de Balneário Camboriú, Estado de Santa Catarina, Brasil. Coletas mensais foram realizadas entre maio de 2008 a abril de 2010, em profundidades entre 7 e 19 m. O período reprodutivo da população foi estimado como a média da CPUE (g/15min) de fêmeas reprodutivas (ovário desenvolvido e maduro) em cada mês, estação do ano e profundidade. O tamanho dos recrutas foi estimado com base na curva de captura, de tal forma que as classes de idade incluídas na parte ascendente da curva foram considerados como recrutas. A abundância relativa (number/15 minutos) de recrutas foi comparada por mês e estação do ano. Um total de 15.153 indivíduos foram analisados (9.866 fêmeas e 5.287 machos). Ao longo dos dois anos de amostragem, as fêmeas com ovários maduros foram encontradas em todas estações do ano, com as maiores abundâncias relativas no verão e na primavera. Os recrutas foram encontrados em menor número no primeiro ano, com picos em setembro e outubro. No entanto, no segundo ano, os recrutas foram encontrados em todas as estações, com picos de abundância em março e setembro. Estes resultados sugerem que *P.muelleri* apresenta uma reprodução contínua, com a salinidade, profundidade, e consequentemente a temperatura exercendo uma influência neste padrão.

Palavras chaves: *Pleoticus muelleri*, reprodução, recrutamento, desova.

INTRODUCTION

The increase of the fishing fleet and the decrease of landings of commonly exploited species have contributed to the expansion of the *Pleoticus muelleri* (Bate, 1888) fishery. The landings of *P. muelleri* in the state of Santa Catarina, Southern Brazi, according to the statistical bulletins of industrial fishing, in the last 11 years averages approximately 713.53 kg, with a maximum of 1.577 kg in 2008 (GEP, 2010).

The understanding of reproductive dynamics is essential for assessing the the spawning stock, as well as the recruitment period in any fishery resource. These studies provide support for the development of sustainable management strategies, since the pattern of reproduction of most species can vary according to the local oceanographic conditions, as well as influenced by a latitudinal pattern (Bauer, 1992; Castilho *et al.*, 2007).

The geographical distribution of *Pleoticus muelleri* is restricted to the western Atlantic, from Rio de Janeiro (23°S) to Argentina (43°S). This species remains in the marine environment throughout its life cycle (Boschi, 1989). In Argentina, the breeding activity of the species occurs from October to April, with maximum intensity between November and January (Iorio *et al.,* 2000; Fernandez *et al.,* 2002, 2005). Little is known about the reproductive dynamic of *P.muelleri* off the Brazilian Coast. Some reproductive aspects of reproduction and recruitment were investigated in the coast of São Paulo (Castilho *et al.* (2008), where there is a rising fishery for *P.muelleri* (Costa *et al.,* 2005).

The goal of this study is to analyse the interannual and seasonal variations of reproductive female's abundance and recruits of *P.muelleri* during two years off the coast of Santa Catarina, and relate with the variations of the bottom water temperature and salinity.

MATERIALS AND METHODS

Shrimp were monthly collected from May 2008 to April 2010 along the region of Camboriú, state of Santa Catarina, Brazil (26º 59' 07''S – 48º 35' 58'' W).Three transects were established at mean depths of 7, 14 and 19 m. A shrimp fishing boat, equipped with a double rig net (mesh size 30 mm and 20 mm in the cod end) was used for trawling. The transects were trawled for a period of 15 min. Since this species inhabits benthic environments, we adopted the bottom temperature and salinity measurements for analysis, which were monitored at each depth.

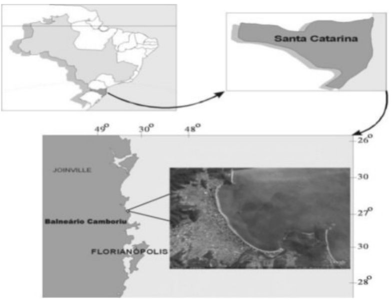

Fig.1. Map of the region of Camboriu, State of Santa Catarina, Southern Brazil, where investigation took place between May 2008 and April 2010.

The individuals were sexed (presence of the petasma in males and thelycum in females), and measured. Carapace length (CL, mm) was measured as the distance from the postorbital margin to the mid-dorsal posterior edge of carapace. Total length (TL, mm) was considered as the distance from the tip of the rostrum to the end of the telson. The total weight (TW, g) of each specimen was measured to the nearest 0.01 g. The length-frequency distributions were constructed separately for each sex, using 1.0 mm CL size intervals.

The reproductive condition of females was determined by macroscopic observation of the degree of ovarian development (color and volume occupied by the gonad), being: immature, almost mature and ripe, according to Prata (*unpublished data*). Sexual maturity of males in penaeoids was indicated by the fusion of the petasmal lobes (Castilho *et al.*, 2007).

Spawning intensity of the population was estimated as the CPUE (g/15min) of reproductive females (developed and ripe gonads) in each month, season and depth. Recruit abundance was defined as the number of individual smaller than 14 mm of carapace length (CL). (caught in a 15 min (2 nets x 15 min) trawling. Recruits size classes were defined equally for males and females, through the catch curve, with only one peak for both sexes.

RESULTS

A total of 15.153 individuals was analyzed (9.866 females and 5.287 males). For females, the mean size recorded was 16.74 ± 4.78 mm CL, ranging from 4.78 to 35.5 mm. The mean size of the carapace length of reproductive females was 21.65± 4.01 mm CL (Figure 2). The mean size of males was 13.87±2.68 CL, ranging from 4 to 31.58 mm. Males were more abundant in length classes between 11 to 16 mm CL, and females from 12 to 20 mm CL. The size at recruitment was defined as 14 mm of carapace length, being estimated based on the catch curve (Figure 2), in such a way that age classes include in the rising part of the curve were considered as recruits.

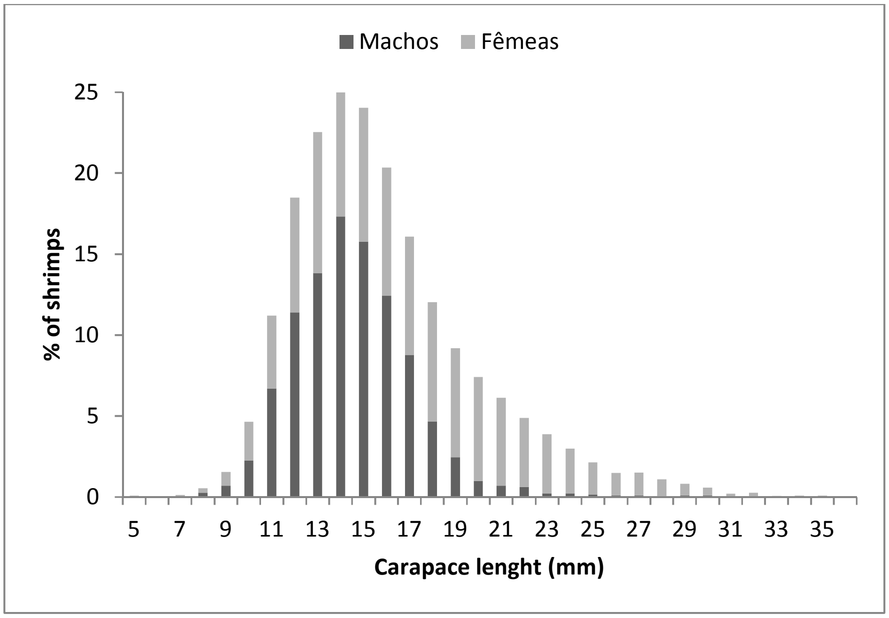

Fig.2. Size-frequency distributions for females and males of *P.muelleri* collected in the region of Balneário Camboriú, Santa Catarina, Brazil, from May 2008 through April 2010.

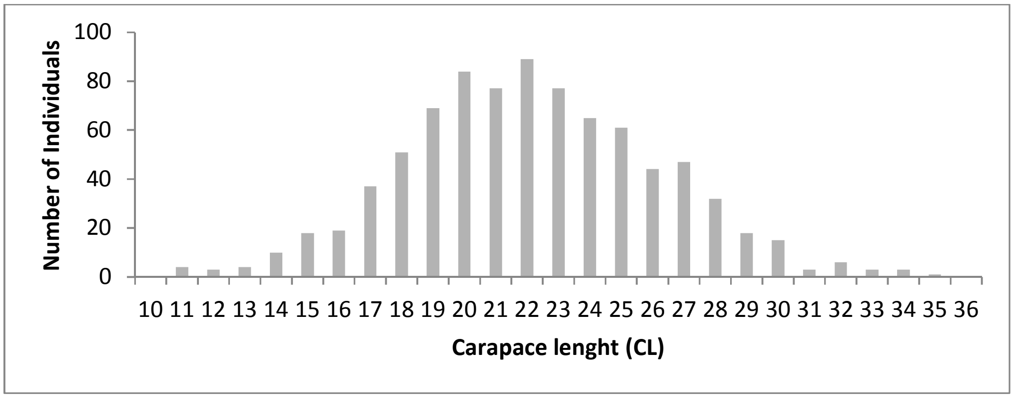

Fig.3. Size-Frequency distributions for reproductive females of *P.muelleri* in the region of Balneário Camboriú, from May 2008 through April 2010.

The variation of the average monthly CPUE (g/15min) of reproductive females is showed in Figure 4. In the first year of study, the presence of reproductive females was restricted to two main peaks, one during spring (26.01±56.96) and another on summer (14.42±43.26). However, in the second year, the presence of reproductive females was all year round noticed, with the highest CPUE values in June, September, October and April. Overall, according to table 1, the highest CPUE average of reproductive females occurred in deeper waters (19 m) (171.52±326.44) (P<0.005) (Anova). Besides, according to figure 5, we can see a clear pattern of increase in mean CPUE of reproductive females in deeper waters from autumn to spring and summer in both years.

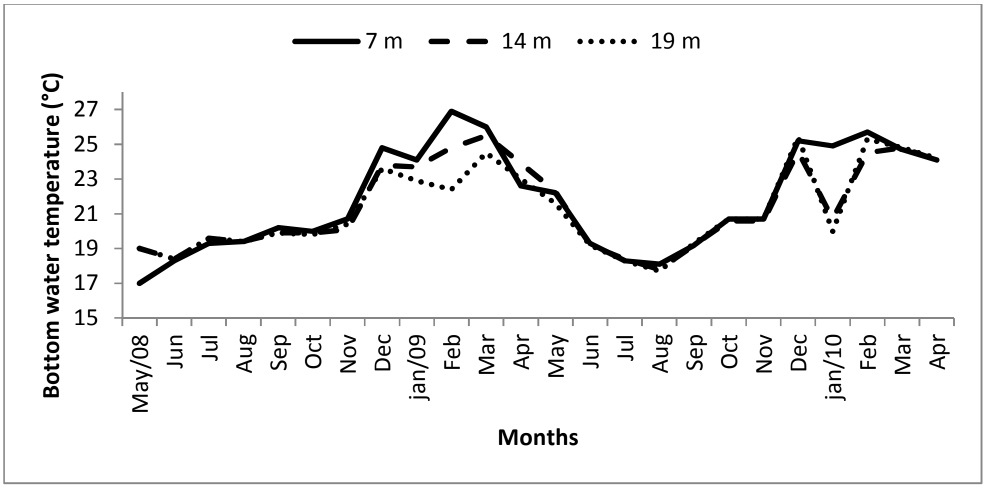

Fig.4. Variation of the mean monthly bottom water temperature for each depth (7, 14 and 19 m), from May 2008 to April 2010, in the region of Camboriú, Santa Catarina State, Brazil.

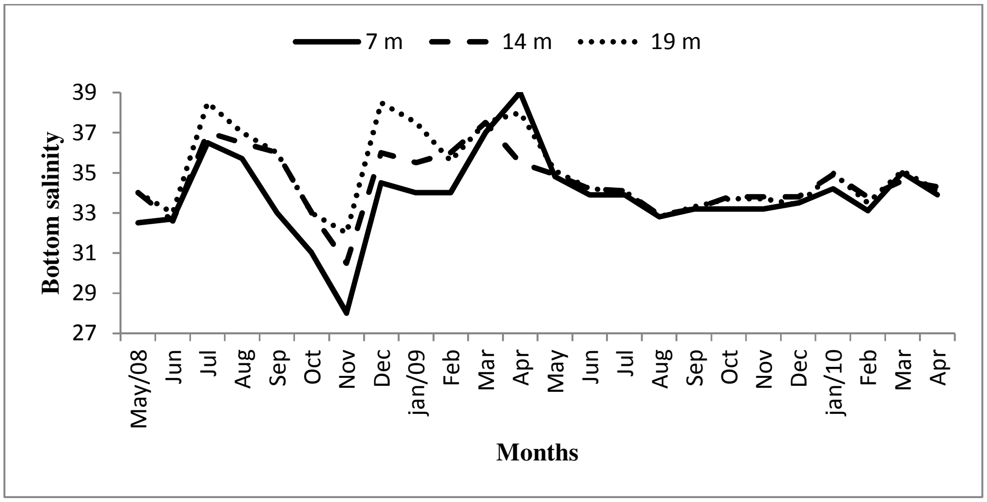

Fig.5. Variation of the mean monthly bottom water salinity for each depth (7, 14 and 19 m), from May 2008 to April 2010, in the region of Balneário Camboriú, Santa Catarina State, Brazil.

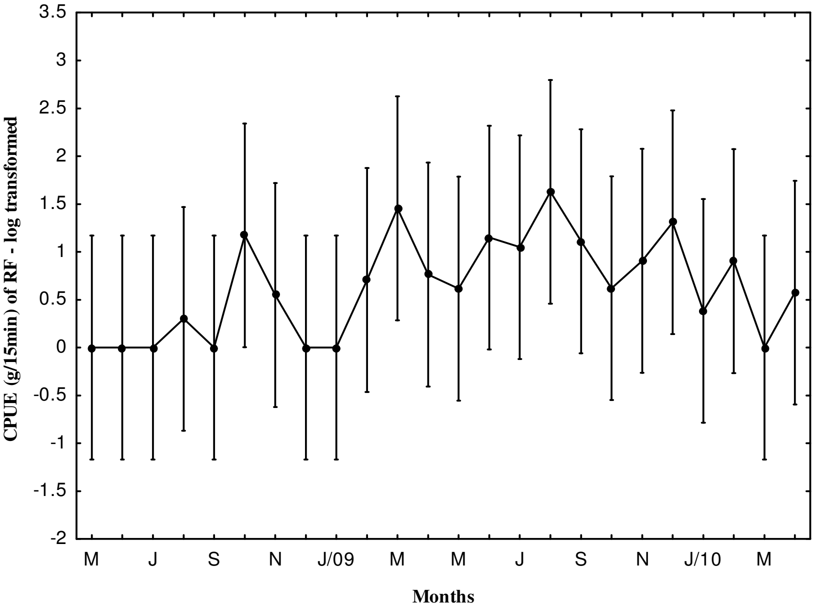

Fig.6. Monthly Variation in the CPUE (log transformed) of reproductive females of *P.muelleri,* from May 2008 through April 2010, in the region of Balneário Camboriú, state of Santa Catarina, Brazil.

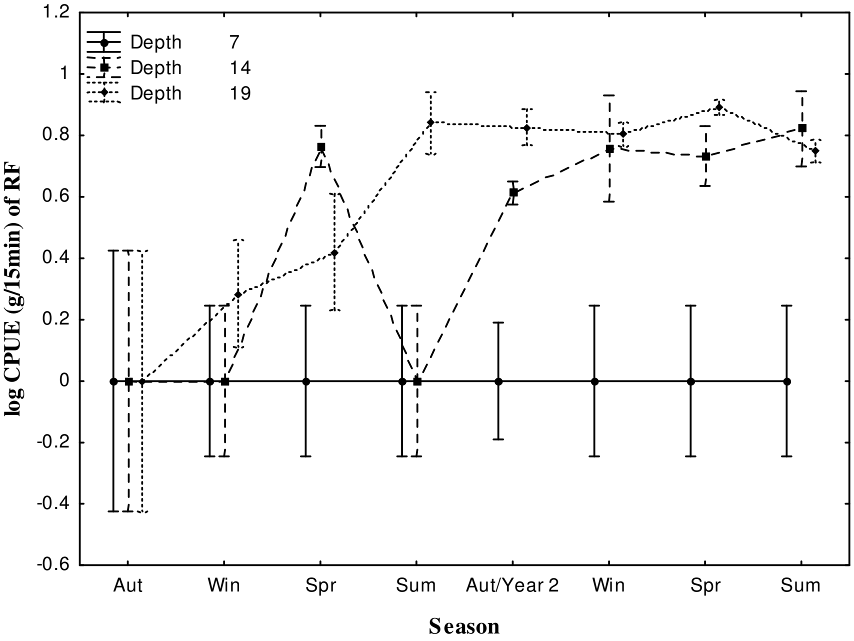

Fig. 7. Seasonal pattern of CPUE (log transformed) of reproductive females of *P.muelleri* by depth (7, 14 and 19 m), from May 2008 through April 2010, in the region of Balneário Camboriú, state of Santa Catarina, Brazil.

Table1. Mean CPUE (log transformed) of reproductive females of *P.muelleri* by depth, with standard deviation (SD), and confidence intervals CI(±95%).

Depth	Mean	SD	CI (±95%)
7	0	0	0
14	0.64	0.24	0.61 0.68
19	0.82	0.24	0.80 0.84

The recruits were recorded throughout all seasons over the entire study period. (Figure 6). In the first year, the main recruitment peak (CPUE) occurred in spring (142.84±115.67). However, in the second year, the peaks of recruits were more evenly distributed through the year, with peaks recorded in spring (569.29±757.67) and winter (391.25±261.14).

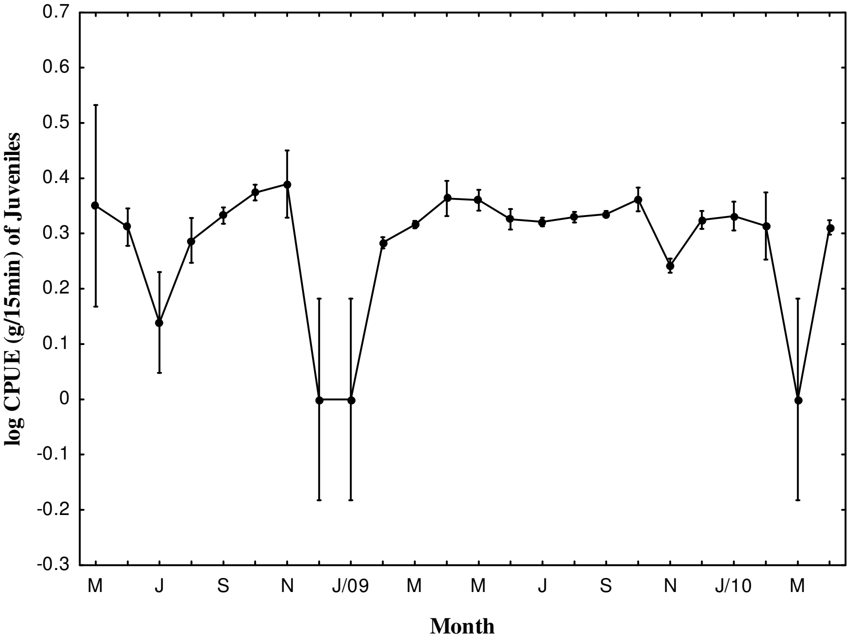

Fig.8. Monthly pattern of *P.muelleri* recruits distribution, showing the catch per unit effort (CPUE) – log transformed, collected for 15 min (two nets x 15 min), in each month, over the 2 year study period, from May 2008 to April 2010.

DISCUSSION

Sexual dimorphism related to size was observed for *P. muelleri*, in such a way that females grow larger than males, indicating differential growths rates between sexes (Boschi, 1989; Prata *et al*., 2012 unpublished data). According to Boschi (1989), these differences between males and females are a general rule among penaeoid shrimps. Sex-related body-length differences, according to Gab-Alla *et al.* (1990) and Yamada *et* *al.* (2007), can be attributed to the fecundity of females increase exponentially with body size and the large body size of females may be an adaption to increase egg production.

In the present study, we found a variation in the average CPUE of reproductive females, according to the season, increasing with the arrival of spring and summer, with greatest abundance in deeper waters (19m), in both years, which shows that there is a reproductive migration toward colder and saline waters. The highest average CPUE of reproductive females in spring, in both years, is probably a result of the intrusion of the SACW into the region during upwelling events, which increases the phytoplankton production and causes the decreasing of the bottom temperature (Vega-Pérez, 1993). Off the coast of São Paulo, the highest percentages of reproductive females were found in spring and summer (Castilho *et al.,* 2008). In Argentina, the distribution of reproductive females in the Patagonian coast is related to the latitudinal evolution of the environmental processes, especially the increasing of the water temperature (Fernandez, 2005). Besides temperature, according to other studies, viability of food and photoperiod influence the growth and maturation of the ovary, as well as in the process of spawning (Fernandez *et al*., 2002, 2005).

The mean size of reproductive females is affected by the latitude that the population inhabits (Castilho *et al.,* 2007), with the values increasing toward higher latitudes. In the present study, mean carapace length values were between 11 and 34 mm, while off the coast of São Paulo, Castilho *et al.* (2008) found mean values between 11.1 and 35 mm. In contrast, Iorio *et al.* (2000) found reproductive females along the Argentinean coast reaching 55 mm of carapace length. These differences in size between different locations match with the parameters of growth of the species. Prata *et* *al.* (unpublished data) found asymptotic lenghts (L∞) of 34.20 mm and 28.34 mm for females and males, respectively. In the Argentinean coast, De La Garza (2007) found L∞ of 57 mm and 45 mm for females and males, respectively. Probably, those variations in parameters such as carapace lenght between sexes and reproductive females, and growth parameters, are a reflection of different habitat conditions, correlated with latitude, mainly with differences of the mean water temperature, which was demonstrated with the present study. The season of highest abundance of reproductive females in both years (spring) coincides with the period of abundance of nutrient supply, resultant of the primary productivity that forms the basis of the larval food supply (Vega-Pérez, 1993).

The presence of recruits and reproductive females, especially in the second year of study, suggests that this species breeds continuously. However, there is evidence of a more intense reproductive activity in summer and spring in comparison to other seasons. Otherwise, there were no seasonal trends in recruitment of juveniles, which coincides with the results found by Castilho *et al.* (2008) off the coast of São Paulo. Boschi (1989) also found no relationship, and this can be a result of the conditions of the environmental factors and food supply of each breeding season exert a selective pressure on the offspring (larval development). In Argentina, the main spawning period occurs in the Patagonian coast, from spring to late summer, and another period in the winter. The main breeding areas coincide with areas of coastal fronts, which determine a high yield. Besides, the natural mortality of these small organisms is very high, especially in the first months of life, so any changes in the determinants of primary production, predators and environmental changes may be largely responsible for a high or low recruitment (Boschi, 1989).

Our data suggest that *P.muelleri* adjust it`s reproductive behavior to variations in bottom water temperature, particularly during the spring and summer, just like in the southeastern coast (according to Castilho *et al.* 2007 , 2008). Thus, future studies about the migration of *P.muelleri* populations off the Brazilian coast, or genetic differentiation may reveal the principal stocks of spawning individuals, larvae and recruitment of juveniles.

REFERENCES

Bauer R.T. (1992). Testing generalizations about latitudinal variation in reproduction and recruitment patterns with sicyoniid species (Decapoda:Penaeoidea) from a tropical seagrass habitat. *Journal of Experimental Marine Biology and Ecology*. 161:223-240.

Bauer R.T & Vega L.W.R. (1992). Pattern of reproduction and recruitment in two sicyioniid shrimp species (Decapoda: Penaeoidea) from a tropical seagrass habitat. *J.Exp.Mar.Biol.Ecol*. 161: 223-240.

Boschi, E.E. (1969). Crecimiento, emigración y ecologia del camarón comercial *Artemesia longinaris .FAO Fish. Rep*., 57(3): 833-846.

Boschi E.E. (1989). Biologia pesquera Del lagostino Del patagonico de Argentina (*Pleoticus muelleri*). *Contribución Instituto Nacional y Desarrollo Pesquero* 646: 5-71

Castilho A.L; Gavio M.A; Costa R.C; Boschi E.E; Bauer R.T & Fransozo A. (2007). Latitudinal Variatin in Population Structure and reproductive pattern of the endemic South American shrimp *Artemesia longinaris* (Decapoda: Penaeoidea). *Journal of Crustacean Biology* 27, 548-552.

Castilho A.L; Costa R.C; Fransozo A; Fransozo M.L.N. (2008) Reproduction and recruitment of the South American red shrimp, *Pleoticus muelleri* (Crustacea: Solenoceridae), from southeastern coast of Brazil. *Marine Biology Research* 4, 361-368

Costa R.C & Fransozo A. (2004). Abundace and ecological distribution of the shrimp *Rimapenaeus constrictus* (Crustacea: Penaeidae) in the northern coast of São Paulo, Brazil. *Journal of Natural History* 38: 901-912.

Costa R.C; Fransozo A; Castilho A.L & Freire F.A.M. (2005) Annual, seasonal and spacial variation of abundance of the shrimp *Artemesia longinaris* (Decapoda: Penaeoidea) in south-eastern Brazil. *Journal of the Marine Biological Association of the United Kingdom*, 85(1): 107-112.

Fernández M, J de la Garza & G Macchi. (2002). Estimación de la fecundidad potencial y fecundidad relativa Del langostino del Golfo San Jorge y litoral de la provincia Del Chubut. Periodo analizado: Septiembre 2001 a febrero de 2002. *Informe Técnico Interno INIDEP* 36: 1-34.

Fernandez M. (2005). Localización de las concentraciones reproductivas del langostino em El litoral patagônico. Periodo analizado: Diciembre de 2000 a enero de 2005. *Informe Técnico Interno INIDEP* 77, 1-13.

Iorio M.I; G.J Macchi & D Hernández. (2000). Estimación de La talla de primera madurez y fecundidad Del langostino patagônico. Caracterización Del desarrollo Del ovário y el estádio de impregnación. *Informe Técnico Interno INIDEP*. 61:1-14

Kuhlmann M.L & R.E Walker. (1999). Geographic variation in size structure and size at maturity in the crab *Pilummus sayi* (Crustacea:Decapoda:Xantidae) in the northern Gulf of Mexico. *Bulletin of Marine Science* 64: 535-541.

Matsuura Y. (1995). Exploração pesqueira: ambiente marinho no litoral brasileiro. *In:* MMA. *Ecossistemas brasileiros e os principais macrovetores de desenvolvimento: subsídeos ao planejamento da gestão ambienta*l. Brasília. Ministério do Meio Ambiente, 40-46.

Sokal R.R; Rohlf F.J. (1995). Biometry. New York: W.H. Freeman and Company. p 887.

Vega-Pérez L.A. (1993). Estudo do zooplâncton da região de Ubatuba, Estado de São Paulo. *Publicação especial do Instituto Oceanográfico*. 10: 65-84

Yamada R; Kodama K; Yamakawa T; Horiguchi T; Aoki I. (2007). Growth and reproductive biology of the small penaeid shrimp *Trachylasambria curvirostris* in Tokyo Bay. *Marine Biology*. 151: 961-971.

Capítulo 4

Growth and Mortality of the red shrimp *Pleoticus muelleri* (DECAPODA: Solenoceridae) in the State of Santa Catarina, Southern Brazil. Prata, P.F.S; Machado, I.F; Sarda, F.O; Dumont, L.F.C.

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Growth and Mortality of the red shrimp *Pleoticus muelleri* (DECAPODA: Solenoceridae) in Southern Brazil.

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Abstract: Estimating growth and mortality in Crustacea is usually tricky, provided that the moulting process results in the absence of hard structures capable of indicate the individual age. Therefore, the management of penaeid shrimp stocks is particularly hard, since the short lifespan turns the age determination even harder to be obtained. The inappropriate assessment of many shrimp stocks have led to several cases of fishery collapse, including the sub-tropical fisheries in Brazil. Declining in landings of more valuable prawn species, such as the pink shrimps (*Farfantepenaeus paulensis* and *F.brasiliensis*), expanded the targets of double-rig otter trawlers to alternative species, such as *Pleoticus muelleri*. Therefore, the investigation of population parameters, such as growth and mortality, are mandatory to support the fishery assessment and management of this recently exploited resource. In this sense, the length-frequency data were analyzed, during two subsequent years, in order to estimate growth and mortality parameters for *P.muelleri* in the state of Santa Catarina, southern Brazil. Monthly samples were collected from May/2008 to April/2010, in the region of Balneário Camboriú, state of Santa Catarina, Brazil. The carapace growth was estimated by using the von Bertalanffy growth model (VBGM), and the mortality coefficients were determined for both sexes. The three mortality coefficients were estimated, named:

total mortality (Z), natural mortality (M) and fishing mortality (F). The exploitation rate (E) was also determined. The VBGM parameters differed significantly between sexes and were estimated as follows: L_∞= 34.20; k=2.55/year; t_0=-0.53 for females and L_∞= 28.34; k= 2.92/year; t_0=-0.03 for males. Based on the inverted VBGM, the maximum longevity ($t_{máx}$) estimated was 1.80 years for females and 1.58 years for males. The mortality coefficients estimated were: total mortality (Z) of 4.56 and 4.68, natural mortality (M) of 1.57 and 1.80, fishing mortality (F) of 2.99 and 2.88 and exploitation rate (E) of 0.65 and 0.61, for females and males, respectively. Comparison of growth and morality parameters with stocks occurring further south (Argentina) suggests that higher temperature experienced by the stock inhabiting the Brazilian coast is reflected in the faster growth and higher natural mortality.

Key words: *Pleoticus muelleri*, growth, von Bertalanffy, mortality

RESUMO

Estimar o crescimento e a mortalidade em Crustacea é geralmente complicado, já que com o processo de muda, há a ausência de estruturas rígidas capazes de indicar a idade individual. Portanto, o manejo de estoques de camarões peneídeos é particularmente difícil, uma vez que o ciclo de vida curto torna a determinação da idade ainda mais difícil de ser obtida. A avaliação inadequada de muitos estoques de camarão levaram a diversos casos de colapso pesqueiro, incluindo os da pesca sub-tropical no Brasil. O declínio dos desembarques de espécies mais rentáveis de camarão, como os camarões rosa (*Farfantepenaeus paulensis* e *F.brasiliensis*), ampliou os alvos de pesca de arrasto para espécies alternativas, como *Pleoticus muelleri*. Portanto, a investigação de parâmetros populacionais, como o crescimento e mortalidade, são essenciais para apoiar a avaliação e a gestão das pescarias deste recurso recentemente explorado. Neste sentido, os dados de frequências de comprimento foram analisados, durante dois anos subseqüentes, a fim de estimar parâmetros de crescimento e de mortalidade para *P.muelleri* no estado de Santa Catarina, sul do Brasil. Coletas mensais foram realizadas de maio/2008 a abril/2010, na região de Balneário Camboriú, Estado de Santa Catarina, Brasil. O crescimento da carapaça foi estimado usando o modelo de crescimento de Von Bertalanffy, e os coeficientes de mortalidade foram determinados para ambos os sexos. Os três coeficientes de mortalidade foram estimados: mortalidade total (Z); mortalidade natural (M) e de mortalidade por pesca (F). A taxa de explotação (E) foi também determinada. Os parâmetros de crescimento diferiram significativamente entre os sexos: $L\infty = 34,20$; $k = 2,55$/ano e $t0 = -0,53$ para as fêmeas e $L\infty = 28,34$; $k = 2,92$/ano e $t0 = -0,03$ para os machos. Com base no modelo inverso de crescimento de Von Bertallanfy, a longevidade máxima (t_{max}) foi estimada em 1,80 anos para as fêmeas e 1,58 anos para os machos. Os coeficientes de mortalidade estimados foram: mortalidade total (Z) de 4,56 e 4,68, mortalidade natural (M) de 1,57 e 1,80, de mortalidade (F) por pesca de 2,99 e 2,88 e taxa de exploração (E) de 0,65 e 0,61, para as fêmeas e machos, respectivamente. A comparação dos parâmetros de crescimento e mortalidade com os estoques que ocorrem na Argentina sugere que o estoque na costa brasileira, por estar sujeito a uma maior temperatura média, tenha um crescimento mais rápido e maior mortalidade natural.

Palavras chave: *Pleoticus muelleri*, crescimento, Von Bertalanffy, mortalidade, sul do Brasil.

INTRODUCTION

The red shrimp *Pleoticus muelleri* is an endemic species with the geographic distribution restricted to the Southwestern Atlantic Coast, occurring from Rio de Janeiro (23º S), Brazil, to Santa Cruz (50º S), Argentina (D`Incao, 1999).

Pleoticus muelleri has a strictly marine life cycle, not depending on an estuarine growth phase to complete its life cycle. This species has a short lifespan, fast growth and high natural mortality indicating that, for fisheries purposes, the stock biomass is replenished every year (Petriella *et al.,*1997; Dumont, 2005). These features, combined with a large annual fluctuation in recruitment, generate a large variability (and uncertainty in the quantification) of biomass available for the fishing fleet, causing a risk of overfishing and also an economic loss (Bertuche, 2006).

Therefore, population parameters such as growth and mortality must be investigated to support the use of age-structured models, which are more effective in stock assessment. Despite of the recently increased commercial importance, population parameters of *P. muelleri*, such as growth and mortality have never been estimated for the stocks inhabiting the Brazilian coast. Conversely, a number of studies on growth and mortality parameters along the Argentinean coast have provided information in this sense (De la Garza, 2006; De la Garza & Fischbach, 2007, 2009). The effects of fishing on total mortality is assessed, and possible effects of the shrimp fishery on the population of *P.muelleri* in southern Brazil will be discussed.

Provided that crustaceans do not have a rigid structure capable of directly indicate the age (since molting process prevents the direct age estimation), the age estimation is indirect and usually based on size structure. Therefore, the age estimation based on lengths must be carefully employed, since it may result in biologically incoherent results (D'Incao & Fonseca, 1999).

The von Bertalanffy growth model (VBGM) appropriately describes the growth of crustaceans and it has been widely used to represent the growth of penaeids worldwide (Garcia & Le Reste, 1981; Rothlisberg, 1998; D'Incao & Fonseca, 1999). Usually, the age groups are determined by Modal Progression Analysis (MPA), since it represents a simple approach to identify cohorts based on size. However, the validation of growth parameters estimated has to be made by checking the biological coherence of the estimates, especially when no previous studies were performed for the species, in this particular case, *P.muelleri* (D'Incao & Fonseca, 1999; Dumont & D'Incao, 2004).

Total mortality estimates largely depend on the growth curve, since the reliability of the age estimation depends on the age-length tables. Additionally, the natural mortality (M) is usually tricky to estimate, provided that some methods were developed for fish stocks and are not adequate to shrimp populations.

Therefore, the aim of this investigation is to provide the first information on the growth and mortality parameters of *Pleoticus muelleri* in Brazil, providing relevant information to support future management strategies in southern Brazil.

MATERIAL AND METHODS

Samples were monthly obtained from May/2008 to April/2010 in the Region of Camboriú (26º 59' 07" S - 48º 35' 58" W), State of Santa Catarina, Brazil. Three transects were established at mean depths of 7, 14 and 19 m. A shrimp fishing boat equipped with double rig nets (mesh size 30 mm and 20 mm in the cod end) was used for trawling. The transects were trawled during 15 min.

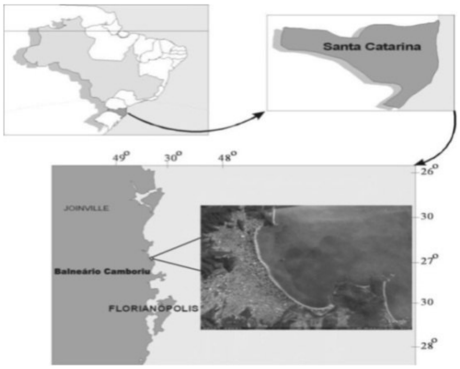

Fig.1. Map of the region of Camboriú, State of Santa Catarina, South Brazil, where investigation took place between May 2008 and April 2010

The shrimp were sexed (presence of the petasma in males and absence in females. Carapace length (CL-mm) was used to analyze the size structure of the stock and it was measured as the distance from the postorbital margin to the mid-dorsal posterior edge of carapace.

Modal groups were determined on CL frequency distributions and fitted to a normal model, using Peakfit v.4 (SPSS Inc., Chicago, Illinois). The class interval adopted to perform the length frequencies analysis was 1.00 mm. Total length frequency distributions were first smoothed (Fast Fourier Transformation, FFT) and the normal models were then fitted to the smoothed distribution by an automated least squares fitting procedure. Age groups were tentatively linked through time in attempt to visualize the growth pace for males and females. (Modal Progression Analysis – MPA). Modal values determined in each CL frequency distribution. Moreover, model fitting was also constrained to a variable value of CL_{∞}, based on the literature for the species in the Brazilian coast. Only cohorts which yielded biologically reasonable VBGM parameters, such as asymptotic length with a value of 10 to 15% smaller or larger than the maximum value that the samples had, and longevity of up to 2 years for females and 1 year and eight months for males were considered. Thereafer, cohorts data were pooled and the growth parameters were estimated for each sex. The VBGM is given as follows: $CL_{t=} CL_{\infty}[1\text{-}e^{-k(t\text{-}to)}]$, where CL_t is the carapace length at the time t, CL_{∞} is asymptotic length, K the coefficient growth and t_0 the theoretical age at length zero. Longevity (t_{max}) was estimated by the inverted von Bertalanffy (1938) model, considering maximum longevity (t_{max}) as reached at 99% of the asymptotic length (D´Incao & Fonseca, 2000). To test possible differences between growth parameters of males and females, a F test was applied (Cerrato, 1990).

The total coefficient of mortality (Z/year) was estimated for females and males by using a catch curve based on size (Ricker, 1975). The VBGM provided a size-age table, in order to assign the age in months to each of these size classes. The abundance by age class was log transformed and fitted to a linear model y=ax + b, where a is the value of the instantaneous coefficient of total mortality.

The instantaneous coefficient of natural mortality (M) was estimated according to the methods of Taylor (1960) and Pauly (1980). The first one originates from the growth equation of Bertallanfy (1938) (VBGM), and consequently from the relationship between longevity and asymptotic length (CC∞) and is given by the equation: $A_{0.99}=t_{0+}4.60/K$. It assumes that the natural mortality reduces the initial number of the cohort to 1% of this original value in a period of time equal to the longevity. For this relation, it took in consideration the parameter K of the growth equation, so $-k(t_{max}\text{-}t_0)=M=4.60$, so: $M=4.60/A_{0.99.}$ The method of Pauly uses the empirical formula: log M=

-0.0066 - 0.279 log L_∞ + 0,6543 log K + 0,4634 log T where L∞ and K are the growth parameters estimated from the Von Bertallanfy equation and T is the average water temperature which the stock is located.

The Fishing mortality (F) was calculated by the difference between total (Z) and natural (M) mortality and the exploitation rate (E) by the division of fishing mortality by the total mortality.

RESULTS

Were measured 7535 females and 6765 males**.** Females reached larger sizes than males, in such a way that the mean size estimated for females was 16.74± 4.78 mm, ranging from 4.78 to 35.5 mm and the mean size for males was 13.87±2.68, ranging from 4 to 31.58 mm. Carapace length frequency histograms were clearly polymodal during the period of study. Based on these histograms, fifteen modal progressions, for females and males, were determined during the sampling period (Figs 2,3), which resulted in the growth curves shown in figures 4 and 5. The cohorts chosen for females and males, and the growth parameters generated by them are shown in tables 1 and 2 respectively. Growth parameters ± 99% CL estimated for females were K=2.55 y^{-1} and CL_∞=34.20 mm ± 0.94 and for males were K= 2.92 y^{-1} and CL_∞= 28.34 mm ± 1.02. Maximum longevity for females and males was 1.80 years and 1.58 years respectively.

A detailed numeric summary of the growth parameters estimated is available in table 3. The growth curves of females and males were significantly different (Fcalc=48593; Ftab= 2.71), pointing out the sexual dimorphism related to growth.

Cohorts hatched in all reproductive seasons were accompanied, mainly in spring months.

Table 1. Asymptotic length (CL_∞), growth coefficient (K) and longevity of the females cohorts.

	Parameters ♀			
	L∞	**k**	**t_0**	**Long (year)**
Cohort 1	37.48	4.01	-12.02	1.91
Cohort 2	40.31	2.19	-35.95	1.91
Cohort 3	37.73	2.19	-40.31	1.89
Cohort 4	36.29	2.55	-90.79	1.78
Cohort 5	35.32	2.55	-55.89	1.70
Cohort 6	33.15	2.55	-67.46	1.65
Cohort 7	30.32	2.92	-31.94	1.50
Cohort 8	30.06	2.92	-40.05	1.53
Cohort 9	30.76	2.55	-69.88	1.78
Cohort 10	29.02	2.55	-52.08	1.62

Tab. 2. Asymptotic length (CL_∞), coefficient of growth (K) and longevity of the males cohorts.

	Parameters ♂			
	L∞	**k**	**t_0**	**Long. (year)**
Cohort 1	31.70	2.92	48.04	1.47
Cohort 2	31.61	2.19	-53.97	1.84
Cohort 3	27.93	2.55	-25.29	1.66
Cohort 4	27.24	2.55	-45.07	1.63
Cohort 5	28.31	2.19	-29.31	1.11

Table 3. Growth parameters of the Von Bertallanfy model, for females and males of *P.muelleri*, showing the asymptotic length (L_∞), the growth coefficient (k) and the hypothetical age when the length should be nil (t_0), with the respective standard error, t-value, the confidence limits (95%) and the level of significance.

Parameters ♀	**Value**	**SD**	**t-value**	**95% CL**		**$P>\lvert t \rvert$**
L_∞	34.20	0.94	36.01	32.30	36.10	0.00000
k	0.007	0.0004	14.74	0.006	0.008	0.00000
t_0	-0.53	2.14	-0.24	-4.82	3.75	0.80
Parameters ♂	**Value**	**Std Error**	**t-value**	**95% Confidence Limits**		**$P>\lvert t \rvert$**
L_∞	28.34	1.02	27.52	26.23	30.45	0.00000
k	0.008	0.0008	10.11	0.007	0.01	0.00000
t_0	-0.03	2.92	-0.01	-6.01	5.94	0.99

From the growth parameters calculated, it was estimated the total mortality coefficient (Z) for females and males through the catch curve (Fig. 6). The estimated value of Z was 4.51 for females and 4.68 for males. Age of first capture was defined as 3 months for both sexes.

The annual natural mortality rate (M) was 1.57 for females and 1.80 for males. The method of Pauly indicated a natural mortality (M) of 1.31 fo females and 1.33 for males.

The fishing mortality (F) was higher than the natural for both sexes. Subtracting the total mortality of natural, the annual value of F was 2.99 for females and 2.88 for males. From these results, it was calculated the exploitation rate (E=F/Z) for both sexes: 0.65 and 0.61 for females and males, respectively.

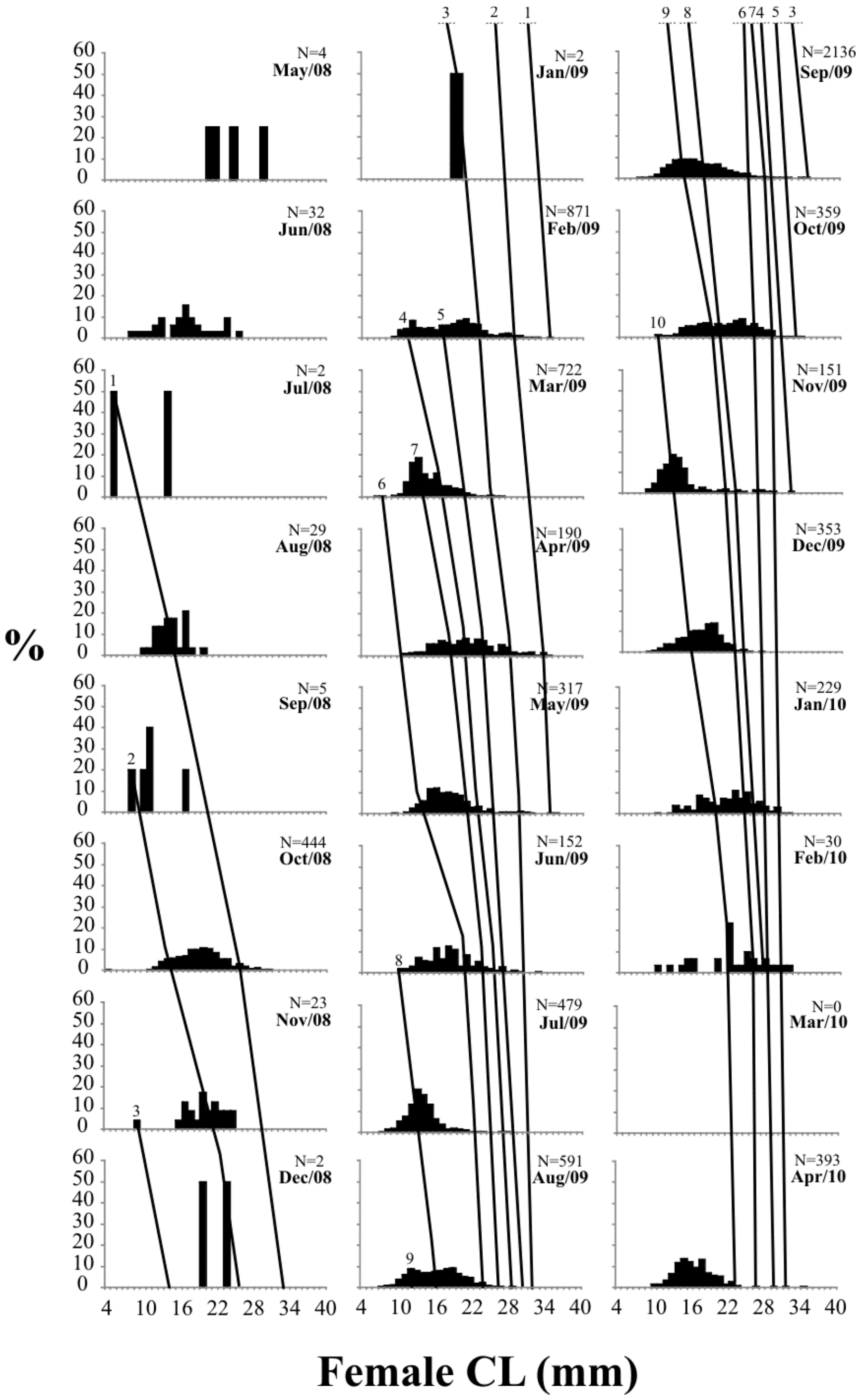

Fig.2. *P.muelleri*. Modal progression analysis (MPA) of females cohorts. Solid lines are the linked cohorts used to describe the individual growth

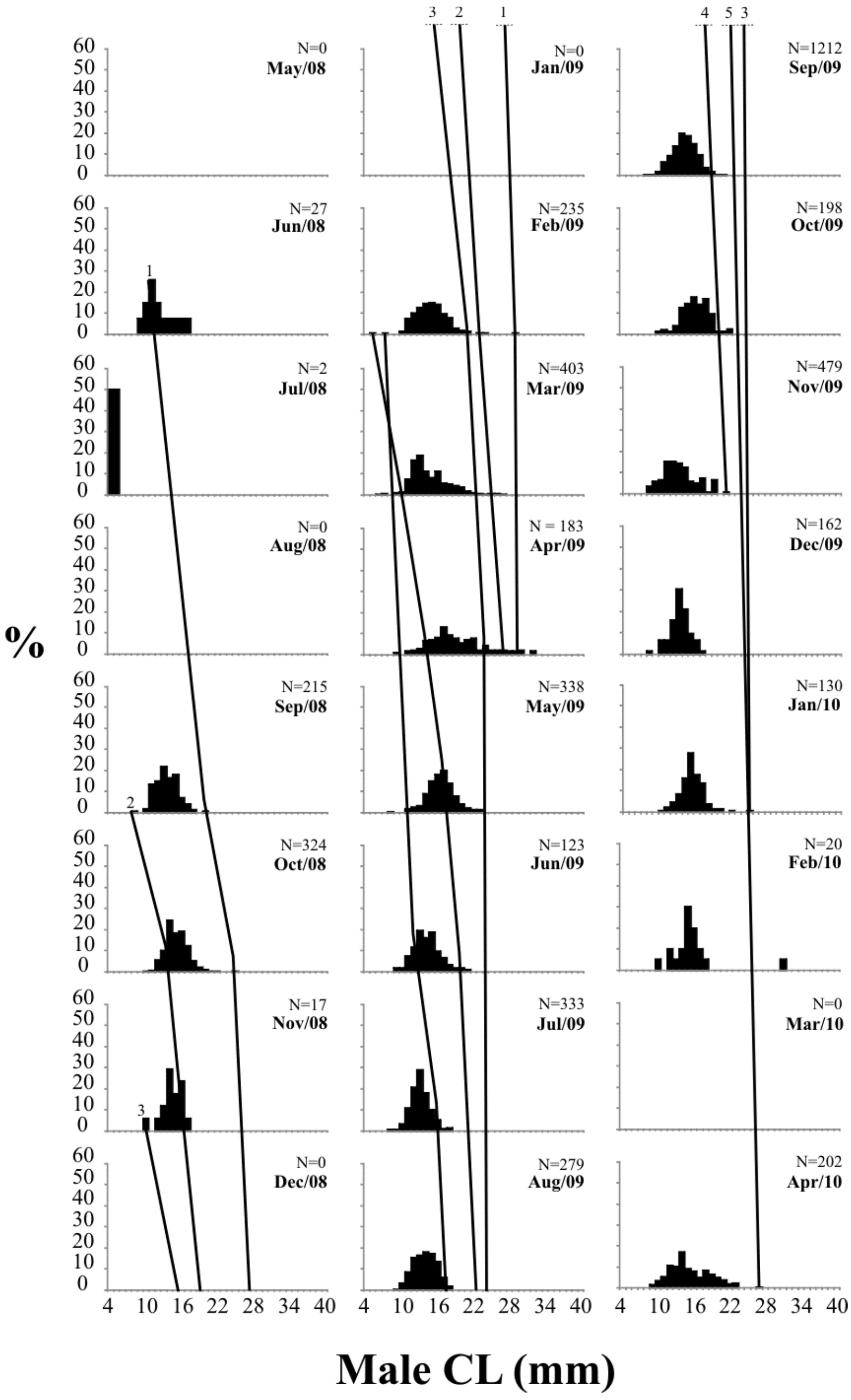

Fig. 3. *P.muelleri*. Modal progression analysis (MPA) of males cohorts. Solid lines are the cohorts linked along the period of study used to describe the individual growth

L∞= 34.20 k= 2.55 t_0= -0.53

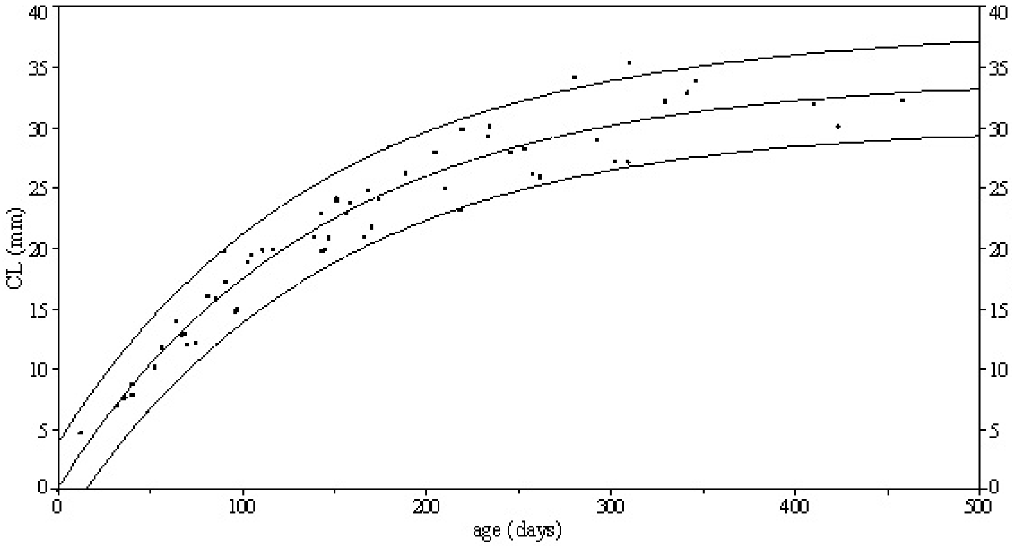

Fig. 4. *P.muelleri*. Growth curves estimated for the female population from the Santa Catarina State.

L∞= 28.34 k= 2.92 t_0= -0.03

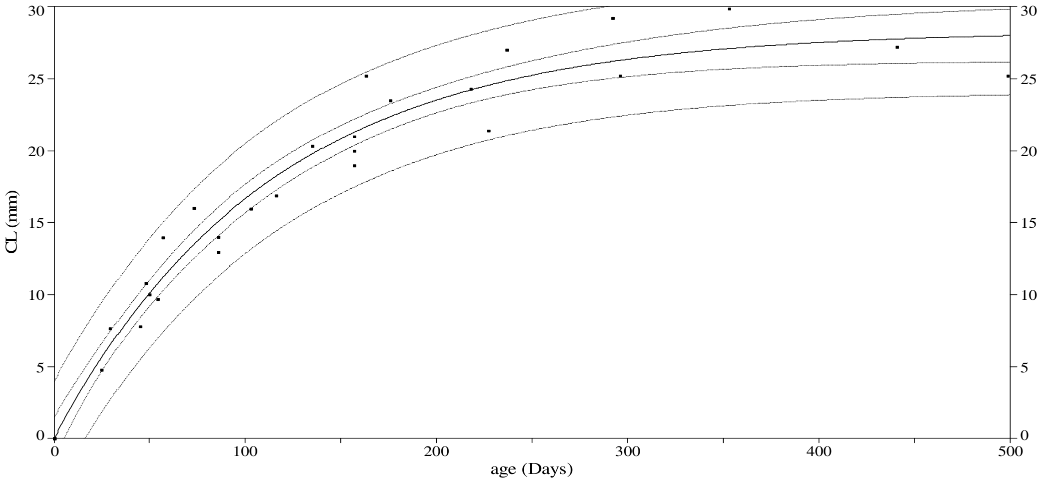

Fig. 5. .*P.muelleri*. growth curves estimated for the male population from the Santa Catarina State.

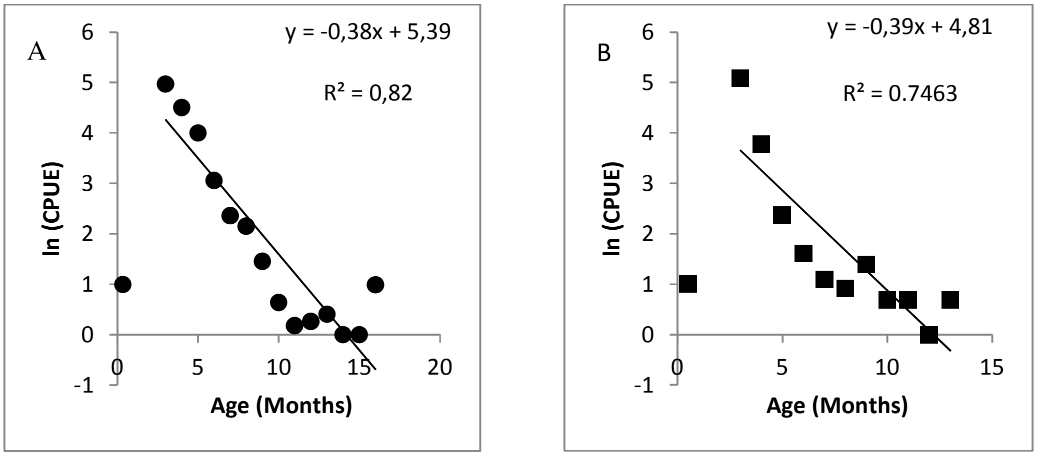

Fig. 6. Length -converted catch curves for (A) females and (B) males of *P. muelleri* in the Region of Camboriú, SC, Brazil.

Table.3. Instantaneous rate of total mortality (Z); Natural mortality (M); Fishing mortality (F) and Exploitation rate (E) for females and males of *P.muelleri* in the region of Balneário Camboriú, SC, Brazil.

	Z	M	F	E
Females	4.56	1.80	2.99	0.65
Males	4.68	1.57	2.88	0.61

DISCUSSION

Until now, growth studies for *P.muelleri* have never been done for the Brazilian coast. The modal progression analysis and the VBGM used in this study allow us to say that the longevity (females: 1.80; males: 1.58) presents coherence with the life cycle of the species, and thus could be validated. The asymptotic lengths are also in accordance with what was observed in the field for both sexes, and were also used for the validation of the curves. Thus, according to this study, the validation of the growth curves can be made through longevity, considering it as 99% of L_∞ considering that the obtaining estimates adjusted to the characteristics of the life cycle of the species is favored by this methodology, providing a better identification of possible distortions in parameter estimates.

The results showed that estimates of growth parameters for *P.muelleri* are in agreement with the short longevity of most of the penaeid shrimps (Pauly *et al.,* 1984), provided that cohorts could not be followed for more than 1.5 year. Additionally, the parameter of asymptotic length is often neglected biologically and is usually fixed, not estimated. The parameter estimated for *P. muelleri* is from 10 to 15% to the maximum length recorded in samples, indicating the biological coherence of the present growth estimates.

The asymptotic lengths (L_∞) were consistent with the observed data in the field, for both sexes, and were also used for the validation of the curves. In the present study, the asymptotic lengths were 34.20 mm and 28.34 mm for females and males, respectively. Besides, in penaeids, males exhibit lower L_∞ and higher K (Garcia & Le Reste, 1981; Dall *et al.*, 1990). In Brazil, a review of the growth of penaieds made by D'Incao & Fonseca (1999) showed a variation of 0.24 to 7.38 years of longevity, considering t_{max} as 99% of asymptotic lenght. The estimates of the coefficient of growth (K) per year, showed a variation of 0.62 to 18.8. According to Pauly, should be considered k values between 0.25 and 2.25, while Le & Garcia Reste suggest values between 1.8 and 3.6. In the present study, longevity was estimated at 1.80 and 1.58 between age and K 2.50 and 2.92 for females and males respectively.

Theoretically, at higher temperatures, the growth coefficient (K) and asymptotic length (L_∞) tend to increase and decrease, respectively (Pauly *et al.,* 1984). Comparing the results found in this study (females: 2.55; males: 2.92) with those obtained in Argentina by Bertuche (2006), we found higher values of K. This can be explained by the low water temperature in the living population located in the south, which slows growth and increases the asymptotic length (Pauly, 1984). The growth coefficient estimated for the Argentine population were 1.05 and 1.11 for females and males respectively. Besides, De la Garza (2007) analysed the interannual variations in growth and size of *P.muelleri* in Argentina, from 1992 to 2003, and found the k values ranging from 0.37 in the 2001-2002 season and 1.06 in the 2002-2003 season. Thus, higher values of k found in southern Brazil were expected, indicating faster growth, probably due to higher water temperature.

As expected, in the present study, there were found asymptotic lengths $CL\infty$ lower (females: 34.20; males: 28.34) than those found in the Argentinean coast (females: 57; males: 45), reaching a maximum of 60 mm in the 2001 season (De la Garza, 2007). For the sympatric species *Artemesia longinaris,* there were also found a lower difference in $CL\infty$ between the sexes (females: 28.86; males: 21.01) (Dumont, 2004), with females reaching larger sizes than males, as well as a pattern of latitudinal variation, with significant differences between the distribution limits of the species. Therefore, these results allow us to infer that there is a latitudinal variation in growth parameters of *P.muelleri,* which are mainly influenced by environmental conditions, being the water temperature one of the main factor.

Mortality is the most variable and difficult population parameter to estimate (Neal & Maris, 1985). Shrimps are not long lived crustaceans, and the short life spans imply high mortality rates. The total mortality (Z) found in the present study were 4.56 and 4.68 for females and males, respectively. The higher value of Z for males can be explained by the higher coefficient of growth they have, generating a higher natural mortality. According to Le Reste & Garcia (1981), higher values of k shown by Penaeoidea, lead to higher natural mortality rates. Another factor that may explain this difference is the presence of a greater number of females in the samples. Values found are within the range estimated for population inhabiting the Argentinean coast, where the Z values ranged from 2.02 in the 2001-2002 season to 6.32 in the 1996-1997 season. (De la Garza & Fischbach, 2009).

The direct evaluation of the coefficient of natural mortality has proven to be extremely difficult and is usually assumed to be constant and specific for each stock. This, somehow, also occurs for the analysis of commercial shrimp stocks, which typically require estimates of M for age stock-recruitment (Vetter, 1988). Among the methods used for determining the natural mortality rate (M), in the present study, we used the Taylor`s method (1960). This method is based on the premise that mortality and the coefficient of growth (K) are inversely related, and therefore, that the populations with older individuals will be those with a lower rate of natural mortality (M). So, we found M values of 1.17 and 1.57 for females and males, respectively, which was acceptable for the species, since there are no published studies with natural mortality calculated by the method of Taylor (1960) for *P.muelleri* in the Brazilian coast. Another method used to determine the natural mortality is the method of Pauly (1980), which estimates the natural mortality from the asymptotic length and the average temperature of the environment. De la Garza and Fischbach (2009) suggests that the M values obtained from this method in the Argentinean coast are valid, with values ranging between 0.50 to 1.51 from 1992 to 2008, as it is closer to the values reported for other Penaeoidea. In this study, we found values of M through the method of Pauly of 1.31 and 1.33 for females and males respectively. These results are within the range of results found in Argentina. However, its empirical formula to estimate M is based on studies with 175 species of fishes, and the use for crustaceans is not advisable. Sparre *et al.* (1989) advise against the use of empirical formula of Pauly (1984) for crustaceans. So, the Taylor`s method was more effective for use in crustaceans, in this case more specifically for Penaeoidea shrimps, since it takes into account the difference in coefficient of growth between the sexes, that generates a natural mortality rate more coherent for this group.

As was expected, in the present study, the fishing mortality rate (F) was higher for females, which can be explained by the higher asymptotic length, and, thus, greater vulnerability to fishing gear. Besides, there was found a fishing mortality rate higher than the natural mortality, and it can be explained This resource presents a very patchy distribution, concentrating 77% of the biomass in only 12% of the fishing area, resulting in a high vulnerability to fishing effort (Dumont & D'Incao, 2008). The F values found in the present study were lower than those estimated for Argentinean population by De la Garza (2009) where the results reached 5.59 in 1997. Probably, it occurs due to higher attention for this species in Argentina, and consequently one of the most important products exported in the country, different from Brazil, where the main target fishing species still are *Farfantepenaues paulensis, F. brasiliensis* and *Xiphopenaeus kroyeri.*

The exploitation rate (E) allows an evaluation of the exploitation conditions of the stocks, assuming that the optimum value of E is approximately 0.5. (Pauly, 1984). In this study, we found exploitation rates (E) higher than 0.5, indicating that the stock in southern Brazil is in reasonable conditions of exploitation. In Argentina, the average E over the last years had an average value of 0.74 (De la Garza & Fischbach, 2009), indicating that the resource is highly exploited, and it is appropriate to manage policies for the maintenance of a minimal level of biomass for the maintenance of the stocks.

Briefly, this investigation demonstrated that *P.muelleri* is a short-lived species in which females are larger than males, and management policies should be adopted for the *P.muelleri* population in southern Brazil.

REFERENCES

Bertuche D. (2006). Estimación de los parâmetros de crecimiento Del langostino patagônico utilizando frecuencia de tallas paera lãs temporadas 2004 a 2006. *Informe técnico INIDEP* N°078/06. 12pp.

Cerrato R.M. (1990). Interpretable statistical tests for growth comparisons using parameters in the von Bertalanffy equation. *Can. J. Fish. Aquat. Sci. 47*: 1416-1426.

Dall W., Hill B.J., Rothlisberg P.C. & Staples D.J. (1990). The Biology of the Penaeidae. *Advances in Marine Biology*, Academic Press, London, UK. 489 pp.

D`Incao F & Duane D.B. (1999). Performance of the Von Bertallanfy growth curve in penaied shrimps: A critical approach. In *Proceedings of the fourth international crustacean congress, Amsterdan, The Netherlands, 20-24 July 1998. The biodiversity crisis and crustacea* (ed.J.C.V. Klein and F.R.Schram), pp. 733-737. Rotterdam: A.A.Balkema.

D`Incao F. (1999). Subordem Dendobrachiata (camarões marinhos). In: Buckup L. & BondBuckup G. (eds.). *Os camarões do Rio Grande do Sul*. Editora da Universidade, Porto Alegre. PP: 271-299.

De la Garza J. & Fischbach C. (2007). Variaciones internanuales en el crecimiento y la talla Del langostino (*Pleoticus muelleri*) em El período 1992-2003, a partir de datos de producción. *Informe técnico INIDEP* N°014/07: 31pp.

De la Garza, J. & Fischbach C. (2009). Obtención de índices de mortalidad y tasas de explotación Del langostino (*Pleoticus muelleri*) em lãs temporadas de pesca 1992-2008 a partir de dados de producción y desembarque. *Informe de Investigación, INIDEP*, N°63, 18pp.

Dumont L.F.C & D`incao F. (2004). Growth and reproductive of the caridean shrimp *Paleomontes argentines* Nobili, 1901 (Decapoda: Palaemonidae) in the south of Rio Grande do Sul, Brazil. *Nauplius.* 12(2), 151-163.

Garcia S; & Le Reste L. (1981). Life cycles, dynamics, exploitation, and management of coastal penaeid shrimp stocks. *FAO Fisheries Technical Papers* 203, 1-215.

Neal R.A & R.C Maris. (1985). Fisheries biology of shrimps and shrimplike animals. In: *The biology of Crustacea*: 1-110.

Pauly D. (1980). On the interrelationships between natural mortality, growth parameters, and mean enviromental temperature in 175 fish stocks. *Journal.Cons.Int.Explor.Mer*. 39(2): 175-192.

Pauly D; Ingles J; & Neals R. (1984). Aplicattion to shrimp stocks of objective methods for estimation of growth, mortality and recruitment-related parameters from lengt-frequency data (ELEFAN I and II). In Gulland J.A & Rothschild B.J. Penaeid shrimps: their biology and management. Fishing new books. Farnham. Surrey. England. 220-234p

Petriella A.M; & Boschi E.E (1997). Crecimiento en crustáceos decápodos: resultados de investigaciones realizadas em Argentina. *Invest. Mar. Valparaiso*, 25: 135-157

Ricker W.E (1975). Computation and interpretation of biological statistics of fish populations. *Bulletin of the fisheries research board of Canada*. 191, 1-382.

Rothlisberg P.C. (1998). Aspects of penaeid biology and ecology of relevance to aquaculture: a review. *Aquaculture*, 164: 49-65.

Sparre P; Ursin E. & Venema S.C. (1989). Introduction to tropical fish stock assessment. Part 1: manual. *FAO Fisheries Technical paper* N°306.1. Rome, Italy, 337p.

Taylor C.C. (1960). Temperature, growth and mortality; the Pacific cockle. *J. Cons. perm.int. Explor. Mer,* Copenhague, 26(1): 117-124.

Vetter E.F. (1988). Estimation of natural mortality in fish stocks: *Fisheries Bulletin.* 86(1): 25-43.

CONSIDERAÇÕES FINAIS

O estudo da dinâmica populacional da espécie *Pleoticus muelleri* na costa de Santa Catarina revelou parâmetros importantes, que eram desconhecidos na costa sul do Brasil, e que podem ser levados em conta em futuras avaliações para o manejo do estoque.

Como discutido anteriormente no trabalho, houve uma variação interanual de abundância de *P.muelleri*, entre os dois anos de amostragem, o que é comum para os penaeoidea, devido, principalmente, à variação dos fatores ambientais, sendo o principal deles, no presente estudo, a salinidade de fundo. Durante os dois anos, foram verificados dois picos de abundância, sendo no outono no primeiro ano e na primavera no segundo ano, com as maiores taxas de abundância em águas profundas, onde a temperatura é menor e a salinidade é maior. A salinidade teve um papel muito importante nos padrões de distribuição e abundância da espécie. Além disso, foi um dos fatores mais importantes para o sucesso reprodutivo, uma vez que as maiores abundâncias de fêmeas maduras ocorreram na primavera, em águas profundas (19 m). Entretanto, foi verificada uma reprodução contínua ao longo do ano, uma vez que foram encontradas fêmeas maduras em todas as estações. As análises histológicas corroboram estes resultados, já que através da determinação do tamanho e freqüência dos diferentes tipos de oócitos, em que diferentes estágios foram observados nos ovários maduros, foi verificada a ocorrência de desova múltipla para a espécie.

Através da determinação do tamanho de primeira maturação e comprimento assintótico, foi verificado um padrão de variação latitudinal, em que estes parâmetros tendem a diminuir com a diminuição da latitude. Essa variação, provavelmente, ocorre devido às diferenças de habitats em que as populações encontram-se, sendo a diferença na temperatura da água entre os limites de distribuição um dos principais fatores. Dessa forma, essas informações podem subsidiar planos de manejo específicos para cada localidade.

Os parâmetros de crescimento, determinados a partir do modelo de crescimento de Von Bertallanfy, foram coerentes com a biologia da espécie, que tem um ciclo de vida curto, apresentando para as fêmeas valores superiores de longevidade ($t_{máx}$) e tamanho assintótico (L_∞) e um valor inferior de coeficiente de crescimento (k), o que já era esperado. A partir dos parâmetros de crescimento, foram determinados os coeficientes de mortalidade, os quais tiveram índices de mortalidade total e natural altos, e uma taxa de explotação que indica que o estoque está sobreexplotado, o que gera a necessidade da elaboração de planos de manejo que visem a sustentabilidade do estoque.