

**UNIVERSIDADE FEDERAL DO RIO GRANDE
PÓS-GRADUAÇÃO EM OCEANOGRAFIA BIOLÓGICA**

**DINÂMICA POPULACIONAL DO
CARANGUEJO *HEPATUS PUDIBUNDUS*
HERBST, 1785 (DECAPODA: AETHRIDAE)
NA ENSEADA DE BALNEÁRIO CAMBORIÚ,
SC, BRASIL.**

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

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**RIO GRANDE
DEZEMBRO DE 2012**

AGRADECIMENTOS

Esse trabalho só foi possível ser concretizado com o apoio, incentivo e carinho de muitas pessoas, como professores, amigos, colegas e família. Por isso, aqui vai o meu sincero agradecimento a todos que me ajudaram de alguma forma.

Ao professor Luiz Felipe Cestari Dumont, meu orientador, por ter aturado todo o meu drama e ter adotado o projeto. Os “puxões de orelha” contribuíram muito, me motivando cada vez mais.

Ao pessoal do Laboratório de Crustáceos Decápodes, pela ótima convivência e aprendizado com todos vocês. Agradecimento especial ao Irece Machado, que me disponibilizou os dados da coleta, sendo assim a mola propulsora deste trabalho, e ao amigo Pedro Prata, que me auxiliou e sempre teve paciência me conduzindo nas estatísticas da tese.

Ao meu namorado e amigo, Leandro Ramis, sempre paciente me dando muita força, além, é claro, da ajuda com a formatação das figuras.

Um agradecimento especial aos meus pais pelo amor incondicional e bagagem moral, cultural e intelectual, e as minhas irmãs, Michelle e Thais, por tudo que até hoje já me proporcionaram e pelo incentivo que sempre me deram. Por fim, dedico esta tese única e exclusivamente à minha mãe, que infelizmente não pôde estar aqui para me ver concluir mais esta etapa.

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RESUMO

Nos últimos 20 anos, o arrasto de camarão na plataforma continental brasileira aumentou substancialmente. Evidências sugerem que o caranguejo *Hepatus pudibundus* (Herbst, 1785) é bastante frequente e abundante como captura acessória no arrasto objetivando espécies de camarão. Dessa forma, o objetivo deste trabalho foi determinar aspectos da dinâmica populacional da espécie *H. pudibundus* na costa de Santa Catarina, a fim de subsidiar um plano de manejo adequado para a espécie na costa sul do Brasil. Foram realizados arrastos mensais entre maio de 2008 e abril de 2010, com um barco característico da frota artesanal camaroeira. A embarcação utilizada possui redes com malhas de 3,0 centímetros no corpo e 2,0 centímetros no ensacador. As capturas foram feitas nas profundidades de 7, 14 e 19 metros, onde foram medidos fatores ambientais como temperatura e salinidade de fundo. Em laboratório, foram realizadas a biometria dos indivíduos e a determinação do sexo. Foram coletados 1.882 indivíduos, 1.221 no primeiro ano e 661 no segundo, os picos de abundância no verão e no outono, com os maiores indivíduos encontrando-se na profundidade de 7 metros. Os machos atingiram maiores tamanhos que as fêmeas, e foi observada também uma diferença na média de tamanho de carapaça entre as três profundidades para ambos os sexos e para as fêmeas ovígeras. A razão sexual foi aproximadamente de 1:1, com 1,04 em favor das fêmeas. As relações biométricas entre largura e comprimento de carapaça indicaram alometria negativa para ambos os sexos e a relação entre largura da carapaça e peso também. Os fatores ambientais e a profundidade não evidenciaram influência significativa na abundância desta espécie. Os parâmetros de crescimento estimados foram: $L_{\infty} = 69,00$; $k = 2.19/\text{ano}$; $t_0 = -5,00$, com longevidade de 2,0 anos para fêmeas e $L_{\infty} = 85,89$; $k = 1,82/\text{ano}$; $t_0 = -5,13$, com longevidade de 2,4 anos para machos. Os

coeficientes de mortalidade estimados foram: mortalidade total (Z) de 4,2 e 5,35; mortalidade natural (M) de 2,1 para ambos os sexos; mortalidade por pesca (F) de 2,1 e 3,25; e taxa de exploração (E) de 0,5 e 0,6 – para fêmeas e machos, respectivamente. Assim, estes parâmetros populacionais podem servir como subsídio para a elaboração de planos de manejo que contribuam com a manutenção deste estoque no sul do Brasil. A época do defeso para o camarão sete-barbas, na região de Balneário Camboriú, a qual varia de março a maio, pode estar influenciando negativamente a abundância de *H. Pudibundus*, atuando especialmente sobre as fêmeas ovígeras e recrutas, já que os meses de defeso foram os de maior abundância destes.

ABSTRACT

Over the last 20 years, the shrimp trawling in the Brazil continental shelf has increased substantially. Evidences suggest that the crab *Hepatus pudibundus* (Herbst, 1785) is very frequent and abundant as bycatch in trawling fishery of shrimp species. Thus, the objective of this study was to determine aspects of the species *H. pudibundus* population dynamics off the coast of Santa Catarina, in order to support a management plan appropriate for the species in the southern coast of Brazil. Trawls were performed monthly between May 2008 and April 2010, with a characteristic vessel from the artisanal shrimp fleet. The vessel used has mesh nets with 3.0 cm on the body and 2.0 cm on the bagger. Catches were made at depths of 7, 14 and 19 meters, where environmental factors were measured such as bottom temperature and salinity. Laboratory tests performed biometrics of individuals and sex determination. A total of 1.882 individuals were collected, 1.221 in the first year and 661 in the second, the

abundance peaks occurred in the summer and autumn, with the largest individuals at a depth of 7 meters. Males reached larger sizes than females, and it was also observed a difference in the average size of carapace between the three depths for both sexes and for ovigerous females. The sex ratio was approximately 1:1, with 1.04 in favor of females. The biometric relationship between carapace length and width showed negative allometry for both sexes and the relationship between carapace width and weight also showed negative allometry for both sexes. Environmental factors and depth showed no significant influence on the abundance of this species. The growth parameters estimated were: L_{∞} = 69.00, k = 2.19/year; t_0 = -5.00, with longevity of 2.0 years for females and L_{∞} = 85.89, k = 1.82 /year; t_0 = -5.13, with longevity of 2.4 years for males. The mortality rates estimated were: total mortality (Z) of 4.2 and 5.35, natural mortality (M) of 2.1 for both sexes; fishing mortality (F) of 2.1 and 3.25; and exploitation rate (E) of 0.5 and 0.6 - for females and males, respectively. Thus, these population parameters can serve as input for the preparation of management plans that contribute to the maintenance of this stock in southern Brazil. The closed season for seabob shrimp in the region of Balneário Camboriú, which ranges from March to May, may be influencing negatively the abundance of *H. pudibundus*, acting especially over the ovigerous females and recruits, since the months of closure were the most abundant of these.

INTRODUÇÃO

A fauna acompanhante, também conhecida como “bycatch”, pode ser definida como o conjunto de organismos de outras espécies que são capturados com a espécie-alvo e que, geralmente, são devolvidos ao mar ou rejeitados junto com indivíduos da espécie-alvo que não atingiram tamanho comercial. No Brasil, o camarão é o recurso pesqueiro mais explorado nas Regiões Sudeste e Sul (Paiva, 1997). Nestas regiões, os estoques sofrem alto nível de exploração, principalmente relacionado às atividades dos pescadores artesanais juntamente com as pescarias industriais. A pesca de arrasto direcionada à captura de camarão é, indiscutivelmente, a maior responsável pela grande biomassa de bycatch (Vianna & Almeida, 2005). O desembarque mundial de camarões está estimado em 3,4 milhões de toneladas/ano, o que representa também 1,86 milhões de toneladas do total mundial de descarte (FAO, 2009).

O bycatch é considerado uma das questões mais importantes que afetam o manejo pesqueiro (Hall *et al.*, 2000), assim a caracterização de fauna acompanhante é importante para este manejo e para estabelecer previsões sobre o impacto da atividade pesqueira nos ecossistemas marinhos (Clucas & Teutscher, 1998). A pesca camaroeira com redes de arrasto e a sua conseqüente alta taxa de descarte podem causar impactos sobre as populações do nécton e bentos marinhos, em função da sua característica predatória e não seletiva (Baptista-Metri *et al.*, 2005), além de alterar as teias tróficas destes ambientes (Ye, 2000). Dentre estes efeitos, a mortalidade por pesca normalmente é o mais importante, já que muitas espécies capturadas incidentalmente possuem estratégias de vida bastante diferentes das espécies-alvo. Muitas vezes o esforço necessário para sobre-explorar um estoque de camarão é superior ao nível necessário para sobre-explorar espécies da fauna acompanhante que venham a apresentar um ciclo

de vida mais longo. Apesar disso, somente agora tem havido o reconhecimento da importância da fauna acompanhante, já que constitui uma parcela relevante das pescarias que merece considerações ecológicas e econômicas (Worm *et al.*, 2006). Além disso, já que se consideram os fatores ambientais como determinantes do sucesso de recrutamento de crustáceos (Mantelatto & Fransozo, 1999), faz-se necessária uma investigação detalhada da influência desses parâmetros na variação sazonal e interanual de abundância desta espécie.

A pesca artesanal, efetuada por barcos providos de rede de arrasto com portas, no estado de Santa Catarina, captura incidentalmente grande quantidade de organismos aquáticos que têm hábitos associados ao fundo e que compartilham o ambiente com o camarão sete-barbas *Xiphopenaeus kroyeri* (Heller, 1862). A arte de pesca utilizada atua perturbando mecanicamente os seus habitats, pela movimentação do sedimento (Robert *et al.*, 2007), e provavelmente causando uma grande mortalidade.

Dentre as principais espécies capturadas incidentalmente na pescaria de camarão, o caranguejo *Hepatus pudibundus* é um dos mais abundantes (Keunecke *et al.*, 2007). Este caranguejo é encontrado na Costa Atlântica das Américas (da Flórida ao sul do Brasil) e habita principalmente fundos compostos por lama, areia ou biodetritos em águas rasas, com até 160 metros de profundidade (Melo, 1996). É considerada uma espécie eurihalina, por ser mais capturada em salinidades de até 5 (Abreu, 1980). Com relação a alimentação, segundo Mantelatto & Petracco (1997), a diversidade de itens alimentares consumidos por *H. pudibundus* sugere que esse caranguejo é um predador oportunístico.

Sobre a dinâmica populacional desta espécie são conhecidos, para o Sudeste do Brasil, o crescimento relativo (Mantelatto *et al.*, 1995), o crescimento individual e mortalidade (Keunecke *et al.*, 2007) e a reprodução (Severino-Rodrigues *et al.*, 2002; Fracasso & Branco, 2005). Resultados obtidos para o Sudeste brasileiro (SP) indicam uma reprodução contínua desta espécie (Mantelatto *et al.*, 1995), com maiores abundâncias e predomínio de fêmeas reprodutivas nos meses de setembro e fevereiro (Severino-Rodrigues *et al.*, 2002). No litoral de Ubatuba, as fêmeas ovígeras e em muda foram comuns ao longo do ano, indicando que *H. pudibundus* não apresenta muda terminal, continuando a sofrer ecdise após a maturidade (Fracasso & Branco, 2005). Neste mesmo local, não se verificou relação direta entre a porcentagem de fêmeas ovígeras e a temperatura da água, sugerindo que os fatores ecológicos devem oscilar dentro dos limites de tolerância da espécie, o que favorece a continuidade dos processos fisiológicos, possibilitando a reprodução contínua (Reigada & Negreiros-Fransozo, 1999).

Visando a manutenção de estoques da espécie *H. pudibundus* no Brasil, deve haver o desenvolvimento de ferramentas mais precisas, que auxiliem no manejo da espécie. Para o sul do Brasil, não há estudos referentes às relações morfométricas de *H. pudibundus*, assim torna-se importante a determinação desses padrões, não só para Santa Catarina, mas também para toda a costa brasileira, analisando a relação entre o comprimento da carapaça e o comprimento total e o comprimento da carapaça e o peso dos indivíduos, a fim de se realizar um plano de manejo para esta importante área de pesca do sul do Brasil.

Dois outros parâmetros de grande importância no estudo da dinâmica populacional são o crescimento individual e a mortalidade. Um trabalho acerca desses

parâmetros no sudeste do Brasil revela que *H. pudibundus* é uma espécie de vida curta em que machos e fêmeas têm uma constante de crescimento similar, apesar de os machos serem maiores do que as fêmeas (Keunecke *et al.*, 2007).

Para os crustáceos o crescimento se observa como um processo descontínuo, ocorrendo por saltos, devido à presença de um exoesqueleto rígido, não permitindo um crescimento em tamanho e peso de forma contínua (Petriella *et al.*, 1997). Assim, pela falta de estruturas rígidas para associar à idade, a análise de progressão modal é a técnica utilizada para identificar classes de idade. O tamanho modal de cada classe de idade é empregado para o cálculo dos parâmetros da equação de crescimento de Von Bertalanffy (Ricker, 1975, Sparre & Venema, 1989). Atualmente, têm sido desenvolvidos modelos de avaliação que vão desde os mais simples, como dinâmica de biomassa, até modelos estruturados por idade – ou, no caso de crustáceos, por tamanho (Smith & Addison, 2003). Já as análises sobre a mortalidade mostram que populações de *H. pudibundus* estão sofrendo declínio, principalmente pela mortalidade causada pela pesca, podendo levar à sobrepesca de recrutamento (Keunecke *et al.*, 2007).

Tendo em vista a falta de informação disponível sobre *H. pudibundus* na região de Santa Catarina, já que os estudos realizados nessa área focaram apenas a reprodução, bem como sua alta frequência nas capturas incidentais da pesca de arrasto objetivando o camarão-sete-barbas (*Xyphopenaeus kroyeri*), faz-se necessária uma investigação mais aprofundada do efeito da pesca sobre a dinâmica populacional (abundância, crescimento e mortalidade).

OBJETIVO GERAL

- Investigar a distribuição espaço-temporal e a dinâmica populacional de *H. pudibundus* na Enseada de Balneário Camboriú (SC).

OBJETIVOS ESPECÍFICOS

- Analisar a distribuição e a abundância de *H. pudibundus* (machos e fêmeas; e fêmeas ovígeras), bem como suas variações sazonal, interanual e batimétrica, relacionando com a temperatura e a salinidade de fundo da água.
- Analisar a variação da largura de carapaça (LC) de fêmeas, machos e fêmeas ovígeras, de acordo com a estação do ano e a profundidade;
- Estabelecer relações biométricas para fêmeas e machos;
- Estimar o crescimento de fêmeas e machos através do método de Von Bertalanffy;
- Estimar as mortalidades total, natural e por pesca e a taxa de exploração para fêmeas e machos.

MATERIAL E MÉTODOS

Área de estudo

As amostragens foram feitas na região de Balneário Camboriú ($26^{\circ} 59' 07''$ S - $48^{\circ} 35' 58''$ W), escolhida por ser uma área tradicional de pesca no litoral de Santa Catarina, no sul do Brasil. Além disso, a região é um importante polo turístico, altamente impactado pela ação antrópica, e onde, até agora, não foram realizados estudos neste sentido (Machado *et al.*, 2009).

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.

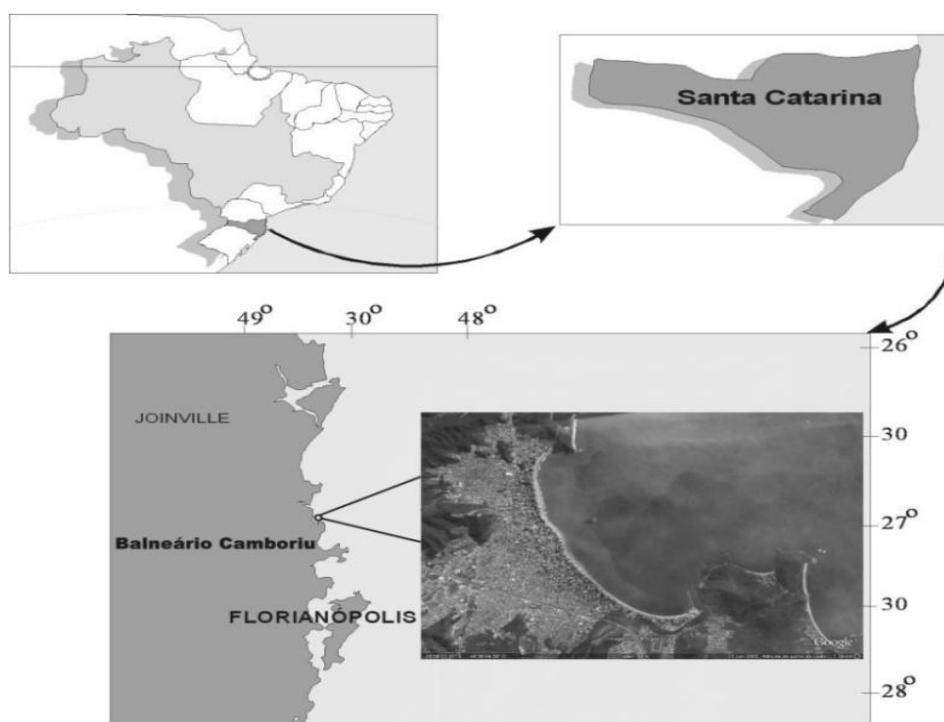


Figura 1: Foto da Região de Balneário Camboriú, Santa Catarina, Brasil.

Amostragem

As coletas foram feitas mensalmente nas profundidades de 7, 14 e 19 metros, durante o período de maio/2008 a abril/2010 na região de Balneário Camboriú, Santa Catarina. 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 *double-rig*). 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 centímetros no corpo e 2,0 centímetros no ensacador. Os arrastos foram realizados a uma velocidade média de 2,0 nós. Foram obtidos os seguintes dados ambientais: temperatura de fundo da água (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 o auxílio de uma garrafa Van-Dohrn.

Processamento amostral

Em laboratório, os caranguejos foram identificados, medidos e o sexo determinado. A biometria consistiu na obtenção da largura da carapaça (LC), do comprimento da carapaça (CC) e do peso total (PT).

Biologia Populacional

As abundâncias médias totais (machos, fêmeas e fêmeas ovígeras) foram comparadas por estrato de profundidade mensalmente e interanualmente através de uma Análise de Variância Fatorial (ANOVA-Fatorial) e um teste *a posteriori* de Fisher (Venables & Dichmont 2004). Foram testados os pré-requisitos de normalidade

(Kolmogorov-Smirnov) e homogeneidade de variâncias (Bartlett). Foi aplicado o teste do χ^2 , ao 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 as faixas de profundidade (Zar, 1984). Uma regressão múltipla foi usada para estabelecer relações entre a abundância da espécie e as variáveis ambientais. As variações das médias de largura de carapaça (LC) de fêmeas, machos e fêmeas ovígeras por estação do ano e por profundidade foram verificadas através de Análise de Variância Fatorial (ANOVA-Fatorial) e um teste *a posteriori* de Fisher (Venables & Ripley 2002). As relações biométricas entre comprimento de carapaça (CC) e largura de carapaça (LC) e entre largura de carapaça (LC) e peso (Pt) foram determinadas separadamente para fêmeas e machos.

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 natural (M) foi determinado pelo método de Taylor (1960). A taxa de exploração do estoque (E) foi feita dividindo a mortalidade por pesca (F) pela mortalidade total (Z).

CAPÍTULO 1

Population Biology of crab box *Hepatus pudibundus* (CRUSTACEA: AETHRIDAE) from the Southern coast of Brazil. Sardá, F.O; Machado, I.F; Prata, P.F.S; Dumont, L.F.C.

Artigo redigido de acordo com as normas para publicação no periódico
Journal of the Marine Biological Association of the United Kingdom

A forma integral desse artigo encontra-se no anexo I.

RESUMO

A pesca direcionada ao camarão sete-barbas (*Xiphopnaeus kroyeri*) no sul do Brasil é realizada com redes de arrasto, afetando populações de algumas espécies bentônicas, como o caranguejo-baú *Hepatus pudibundus*. No sentido de aprimorar o conhecimento sobre esta espécie e fornecer informações relevantes ao manejo ecológico da pesca, o objetivo deste estudo é investigar a influência dos fatores ambientais na abundância e na distribuição espaço-temporal do caranguejo *H. pudibundus*, e sua estrutura populacional. Para obtenção das amostras, foram realizados 2 arrastos de 15 minutos, paralelos à linha de costa, utilizando um barco característico da frota artesanal camaroeira (barco tangoneiro *double-rig*). As amostras foram obtidas mensalmente, de maio de 2008 a abril de 2010, na região de Balneário Camboriú, Santa Catarina, Brasil. Três transectos foram estabelecidos nas profundidades de 7, 14 e 19 metros. Um total de 1.882 indivíduos foi coletado, 1.221 durante o primeiro ano e 661 durante o segundo ano de coleta. A maior densidade foi registrada na profundidade mais rasa (7 m) ($p < 0,05$), a qual apresentou a temperatura mais alta e a salinidade mais baixa. O inverno e a primavera concentraram a maior abundância relativa durante o primeiro ano, enquanto o segundo ano não apresentou uma diferença significativa relacionada à estação do ano. ($p > 0,05$). A maior abundância de fêmeas ovígeras (g/15min) ocorreu de novembro a abril, apresentando uma abundância significativa na profundidade de 7 metros ($p < 0,05$). A razão sexual não foi estatisticamente diferente do equilíbrio (1 macho:1,04 fêmea) – enquanto os machos dominaram as maiores profundidades (14 e 19m), as fêmeas foram mais abundantes em águas rasas (7m). Machos alcançaram maiores tamanhos do que fêmeas, apresentando médias de tamanho de $49,48 \pm 17,55$ mm, variando de 13,5 a 96,67 mm. Já a média de tamanho das fêmeas foi de $47,15 \pm 13,87$ mm, variando de 16,31 a 76,99 mm. As fêmeas ovígeras, por sua vez, apresentaram uma média de tamanho de $56,01 \pm 8,95$, variando de 37,84 a 68,74 mm. Para ambos os sexos e para as fêmeas ovígeras, o valor médio da largura da carapaça (LC) foi maior na profundidade de 7 metros quando comparado com as profundidades de 14 e 19 metros

($p < 0.05$). As maiores fêmeas foram registradas durante a primavera, enquanto os maiores machos, durante o verão. A relação largura da carapaça-peso foi alométrica negativa para fêmeas ($b=2,95$) e machos ($b=2,94$), assim como a relação comprimento e largura da carapaça também foi alométrica negativa para fêmeas ($b=0,72$) e machos ($b=0,68$). O padrão reprodutivo do caranguejo baú se mantém da primavera ao verão e as fêmeas podem estar migrando para águas rasas, atraídas pela alta temperatura da água, para facilitar a incubação dos ovos. Machos escolhem águas mais profundas, evitando assim a competição. A época do defeso para o camarão sete-barbas, a qual varia de março a maio, pode estar influenciando negativamente a abundância de *H. pudibundus*, atuando especialmente sobre as fêmeas ovígeras e recrutas.

CAPÍTULO 2

Growth and Mortality of crab box *Hepatus pudibundus* (DECAPODA: AETHRIDAE) in the State of Santa Catarina, Southern Brazil. Sardá, F.O; Machado, I.F; Prata, P.F.S; Dumont, L.F.C.

Artigo redigido de acordo com as normas para publicação no periódico

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A forma integral desse artigo encontra-se no anexo II.

RESUMO

A pesca de arrasto direcionada ao camarão sete barbas (*Xiphopenaeus kroyeri*) no sul do Brasil afeta populações de algumas espécies bentônicas e *Hepatus pudibundus* é uma espécie acessória comum neste tipo de pescaria. A correta investigação de parâmetros populacionais, tais como crescimento e mortalidade, são relevantes para auxiliar a avaliação pesqueira e o manejo de muitas espécies. O crescimento individual e a mortalidade foram estudados para *Hepatus pudibundus* no estado de Santa Catarina, sul do Brasil. Para obtenção das amostras, foi utilizado um barco típico da pesca camaroeira, equipado com duas redes, perfazendo arrastos de 15 minutos. Coletas mensais foram realizadas de maio/2008 a abril/2010. O modelo de crescimento de Von Bertalanffy (VBGM) foi utilizado para estimar o crescimento da carapaça e os coeficientes de mortalidade, tais como a mortalidade total (Z), a mortalidade natural (M) e a mortalidade por pesca (F) foram determinados para ambos os sexos, a partir da curva de captura baseada na largura da carapaça. A taxa de exploração (E) também foi determinada. O modelo de crescimento descreveu o crescimento de *H. pudibundus* ($K=1,82 \text{ ano}^{-1}$, $CW_{\infty}=85,89 \text{ mm}$; $K=2,19 \text{ ano}^{-1}$, $CW_{\infty}=69,00 \text{ mm}$, para macho e fêmea, respectivamente) resultando em estimativas de comprimentos assintóticos biologicamente coerentes. A estimativa de longevidade está de acordo com valores já obtidos e principalmente com a biologia desta espécie. Os coeficientes instantâneos de mortalidade total, natural e por pesca foram: machos, $Z = 5,35 \text{ ano}^{-1}$ e $M = 2,1 \text{ ano}^{-1}$; $F = 3,25 \text{ ano}^{-1}$; fêmeas, $Z = 4,2 \text{ ano}^{-1}$ e $M = 2,1 \text{ ano}^{-1}$, $F = 2,1 \text{ ano}^{-1}$. A partir destes resultados, foi calculada a taxa de exploração ($E=F/Z$) para ambos os sexos: 0,5 e 0,6 para fêmeas e machos, indicando que o maior tamanho do macho aumenta a vulnerabilidade na rede de arrasto. As análises de composição de comprimentos e de mortalidade sugerem que *H. pudibundus*, na região de Santa Catarina, está no limite da sobrepesca.

CONCLUSÕES

Capítulo 1:

- Houve uma variação interanual de abundância de *H. pudibundus*, entre os dois anos de amostragem, que pode estar relacionado à variação dos fatores ambientais, mais precisamente com a temperatura.
- Durante os dois anos, foram verificados dois picos de abundância, tanto em número quanto em peso, em fevereiro do primeiro ano e em agosto do segundo ano, com as maiores taxas de abundância em águas rasas, onde a temperatura é maior e a salinidade é menor.
- Machos alcançaram maiores tamanhos do que fêmeas. As maiores fêmeas ovígeras foram encontradas durante o verão, na profundidade de 7 metros, possivelmente sendo a profundidade de reprodução.
- A razão sexual foi de 1:1,04 a favor das fêmeas, aproximadamente ao natural de 1:1. As fêmeas foram mais abundantes em águas rasas (7 metros), e os machos, em águas profundas (14 e 19 metros).
- A relação largura da carapaça-peso, assim como a relação comprimento e largura da carapaça, foi alométrica negativa para fêmeas e machos.

Capítulo 2:

- Os parâmetros de crescimento, determinados a partir do modelo de crescimento de Von Bertalanffy, foram de acordo com a biologia da espécie, que apresenta um ciclo de vida curto, apresentando para os machos valores superiores de

longevidade ($t_{\text{máx}}$) e tamanho assintótico (L_{∞}) e um valor inferior de coeficiente de crescimento (k).

- Foram determinados os coeficientes de mortalidade, a partir dos parâmetros de crescimento, estes tiveram índices de mortalidade total e natural altos, e uma taxa de exploração que indica que o estoque está no limite da sobre-exploração, ressaltando a necessidade da elaboração de planos de manejo para espécies que são capturadas acidentalmente, apesar de *Hepatus pudibundus* não apresentar uma aparente importância econômica.

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ANEXO I

Population Biology of the box crab *Hepatus pudibundus*
(CRUSTACEA: AETHRIDAE) in Southern Brazil.

Population Biology of the box crab *Hepatus pudibundus* (CRUSTACEA: AETHRIDAE) off the coast of Santa Catarina State, Southern Brazil.

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Abstract: The fishery for the seabob shrimp (*Xiphopenaeus kroyeri*) in south Brazil is performed by otter trawlers, affecting populations of some benthic species, such as the box crab *Hepatus pudibundus*. In order to improve knowledge about this species and provide information to the ecological management of fisheries, the goal of this study is to investigate the influence of environmental factors on abundance and spatial-temporal distribution of the *H. pudibundus*, and its population structure. To obtain biological samples, a typical shrimp trawler, equipped with double rig nets, performed standardized 15 minutes trawling. Samples were monthly collected, from May 2008 to April 2010 off the Balneário Camboriú coast, Santa Catarina State, Brazil. Three transects were established at mean depths of 7, 14 and 19 m. A total of 1882 individual was collected, 1221 during the first year and 661 during the second year of sampling. Higher densities were recorded in the shallow waters (7 m) ($p < 0.05$), where the temperature is higher and the salinity is lower. Winter and spring concentrated the higher relative abundance index in the first year, while a less oscillating pattern was observed in the second year. The highest abundance index CPUE (g/15min) of ovigerous females was recorded from November to April, presented a significant abundance at depth of 7 meters ($p < 0.05$). The overall sex ratio not was significantly different from the equilibrium (1 male:1.04 female). However, males dominated the deeper isobaths (14 and 19m) and females were more abundant in shallow waters (7m). Males reached larger sizes than females (carapace width), with mean size of $49.48 \pm$

17.55 mm, ranging from 13.5 to 96.67 mm. The females presented a mean size of 47.15 ± 13.87 mm, ranging from 16.31 to 76.99 mm, while the ovigerous females presented a mean size 56.01 ± 8.95 mm, ranging from 37.84 to 68.74 mm. For both sexes and for ovigerous females, the mean value of the carapace width (CW) was higher at 7 m isobath than at the other two isobaths (14 m and 19 m) ($p < 0.05$). Significant larger females were recorded during spring, while larger males were more abundant in summer. The width-weight relationship presented a negative allometry for females ($b = 2.95$) and males ($b = 2.94$). The carapace length and carapace width had a negative allometry for females ($b = 0.72$) and males ($b = 0.68$). The reproductive pattern of the box crab extends from the spring to summer and females migrate to shallower depths, attracted by the higher water temperature, to facilitate egg incubation. Conversely males search for deeper areas, reducing the intraspecific competition. The seabob shrimp closed season, ranges from March to May, may be influencing negatively the *H. pudibundus* abundance, especially, upon ovigerous females and recruits.

Keywords: *Hepatus pudibundus*, distribution and abundance, population biology.

INTRODUCTION

The majority of the commercial fishing activity in Brazil is performed by boats using trawling gear, resulting in a large capture of non-target species, that are mostly discarded (Costa & Di Benedetto, 2009). The worldwide trawling for coastal shrimps is an activity that has resulted in the overexploitation of many stocks (FAO, 2010). The scenario observed throughout the Brazilian coast is not an exception. Over the past 20 years, the shrimp trawling in the Brazilian continental shelf has increased substantially (Batista, 2011), resulting in the overexploitation of the stocks of pink shrimp *Farfantepenaeus brasiliensis* and *F. paulensis* (D’Incao *et al.*, 2002).

Trawlers targeting the seabob shrimp, *Xiphopenaeus kroyeri* Heller, 1862, produce an elevated and diverse incidental catch, mainly composed by fish, crustaceans, molluscs, echinoderms and cnidarians (Branco & Moritz, 2001). However, due to the low economic value of most of these species, they are widely discarded back to the sea resulting in an unknown ecological impact in this ecosystem (Gasalla & Tomás, 1998; Worm, 2006).

Among the discarded catch, one of the most important species is the box crab *Hepatus pudibundus* (Herbst, 1758). This is the most abundant crab of the Aethridae family Dana, 1851 on the seabob shrimp, *X. kroyeri* (Heller, 1862) trawl fishery (Fracasso & Branco, 2005). Its distribution is reported from Georgia's (USA), to Rio Grande do Sul (Brazil). The species is found inhabiting muddy, sandy or biodetritic bottoms, presenting highest abundance in neritic shallow waters, usually between 10 and 15 meters (Klôh & Di Benedetto, 2010), inspite of its occasional occurrences until 160 m deep (Melo, 1996). Despite of not being a commercial valuable species (Fracasso & Branco, 2005), it plays an important role in coastal ecosystems since it represents an important item on the diet of many carnivorous organisms, either in larval stage or adult form (Teixeira & Sá, 1998).

Despite its wide distribution, elevated abundance and ecological role, the population biology of the *H. pudibundus* is poorly understood in the region of Santa Catarina, an area close to the southern limit of its distribution. Conversely, many studies have provided information about relative growth (Mantelatto & Fransozo, 1992, 1994; Reigada *et al.*, 1994), reproduction (Reigada & Negreiros-Fransozo, 2000), natural diet (Mantelatto & Petracco, 1997) and population dynamics (Keunecke *et al.*, 2007). A

limited number of investigations on population structure are available (Mantelatto *et al.*, 1995; Fracasso & Branco, 2005).

Thus, in order to better understand the population biology of the box crab *H. pudibundus* in South Brazil, as well as the possible impact of *X. kroyeri* fishery over this species, the goal differential of this study is to investigate the influence of environmental factors on abundance and spatial-temporal distribution of *H. pudibundus*, and analyze their population structure, including the size structure according to the season and depth, biometric relationships and sex ratio.

MATERIALS AND METHODS

Study area:

The samples were obtained from Camboriú Beach, (26° 59' 07''S – 48° 35' 58'' W), in the State of Santa Catarina, Brazil. This area was chosen since it is a traditional fishing site. This area is influenced by three water masses: the South Atlantic Central Water (SACW), the Tropical Water (TW) and the Coastal Water (CW), which may exert an important influence on population structure of different species, especially through the resulting upwelling, that usually occurs associated to spring and summer atmospheric and oceanographic conditions. During this period, the intense NE winds push the surface coastal waters offshore, resulting in the upwelling of the SACW in the inner shelf.

Sampling strategy and biometry:

Crabs were monthly obtained from May 2008 to April 2010 in the surrounding area of the Balneário Camboriú (Figure 1), using a double rig shrimp trawler with a

mesh size of 30 mm in the body and 20 mm (opposing knots) in the cod end. The first year period was defined from May/08 to April/09, and the second year from May/09 to April/10. Three transects were established at depths of 7, 14 and 19 m, considering that the two nets are operated simultaneously, the two samples were pooled at each station and a second sampling at the same depth, was used as a replicate. The abundance index (CPUE) was composed by a catch unit, either weight (g) or number (n), and a standardized effort of 15 minutes trawling.

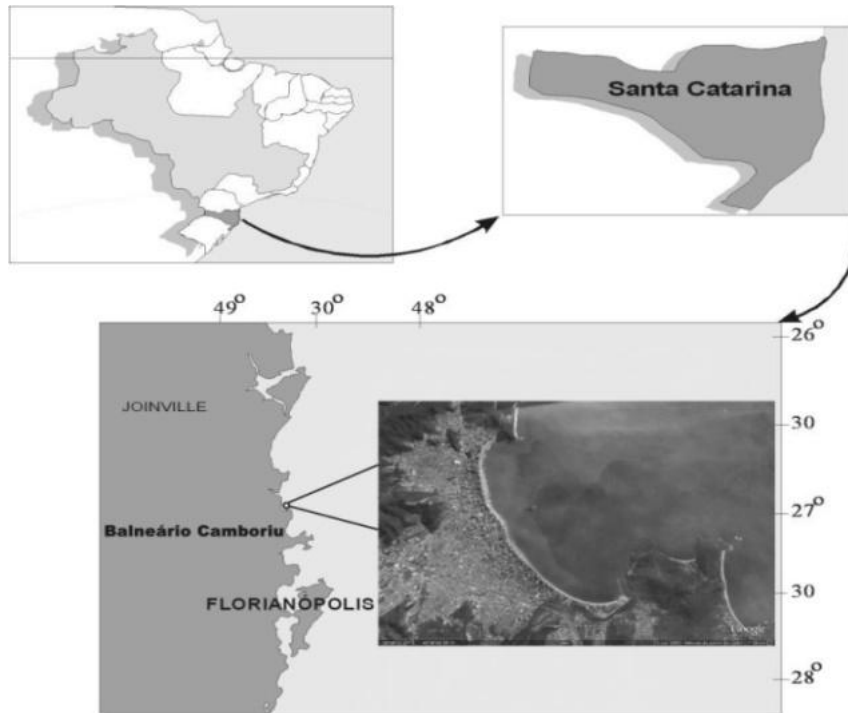


Fig. 1. Map of the region of Balneário Camboriú, State of Santa Catarina, South Brazil.

The crabs were identified, according to sex and determined as young and adults according to the abdomen shape (Williams, 1974). The reproductive condition of females was determined by macroscopic observation of the presence of eggs in the pleopods. The biometry of the specimens consisted of obtaining the carapace width (CW, mm), taken between lateral spines and carapace length (CL, mm), taken between the post-orbital angle to the end of carapace.

Bottom salinity and temperature (°C) were measured by using a thermosalinometer. An ecobathymeter coupled with a GPS (Global Positioning System) was used to record depth at sampling sites.

The possible influence of environmental factors (temperature and salinity) on the CPUE (g/15min; n/15min) of *Hepatus pudibundus* was assessed by a multiple

regression analysis, and the significance level adopted was $p < 0.05$ (Zar, 1999). A Factorial Analysis of Variance (ANOVA) was used to compare the relative abundance (females and males) and abundance of ovigerous females (CPUE – g/15min and n/15min) of the crabs between the two years sampling, seasons and depths (7, 14 and 19 meters). The data was tested for normality and homogeneity of variances (Bartlett) prior to the ANOVA and post-hoc Fisher's test. Normality was achieved for all groups. Similarly, the possible differences in the mean carapace width 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 ($p < 0.05$).

The sex ratio was compared according to year, seasons and depth, by using the χ^2 test ($p < 0.05$). The carapace width-weight relationship was described by the equation $W = aCW^b$ and the carapace width-carapace length relationship by the equation $CW = a + bCL$, where the W is the weight (g), CL the carapace length (mm), CW the carapace width (mm), a is the intercept with dependent variable axis and b is the slope (King, 1995). Both analyzes were performed for each sex separately. Points outside the 95% confidence intervals were automatically excluded since they were considered as an undetected result of a broken or deformed carapace. Differences in slopes were pair wise tested based on confidence intervals, in such way that non-overlapping intervals were considered as statistically.

RESULTS

Enviromental Factors:

A seasonal pattern in temperature trends was observed, with higher values during autumn and summer and lower values during winter and spring. There were not significant differences in the mean bottom temperature between the two years. During the first year, the highest water temperature values were recorded in February ($24.7^{\circ}\text{C} \pm 2.25^{\circ}\text{C}$) and March ($25.3^{\circ}\text{C} \pm 0.76^{\circ}\text{C}$), while the lower values were recorded in May ($18.3^{\circ}\text{C} \pm 1.15^{\circ}\text{C}$) and June ($18.3^{\circ}\text{C} \pm 0.05^{\circ}\text{C}$). In the second year, the highest values were recorded in December ($25.06^{\circ}\text{C} \pm 0.41^{\circ}\text{C}$) and February ($25.16^{\circ}\text{C} \pm 0.61^{\circ}\text{C}$), and the lower values were recorded in August ($17.86^{\circ}\text{C} \pm 0.20^{\circ}\text{C}$) and July ($18.33^{\circ}\text{C} \pm 0.05^{\circ}\text{C}$) (Figure 2). It is also important to stress that a marked stratification was observed during the summer periods in both years, evidenced by the difference between the temperature recorded in shallow (7 m) and deeper waters (14-19 m).

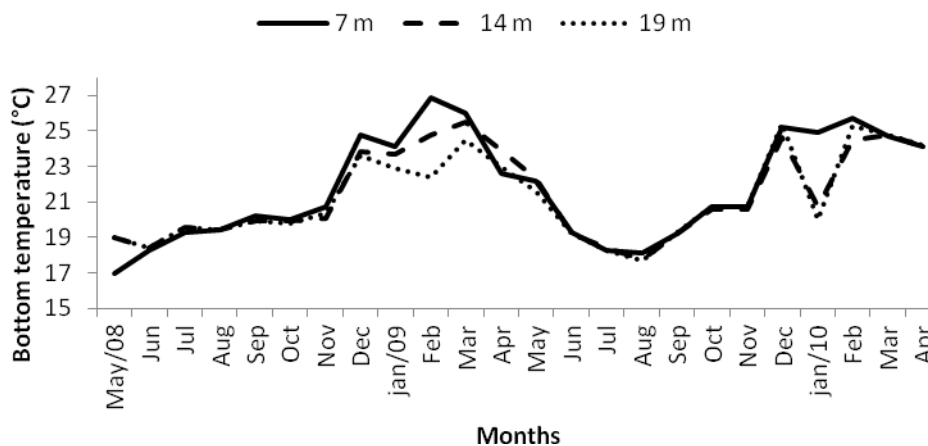


Fig. 2. Variation of the mean monthly $T^{\circ}\text{C}$ for each depth (7, 14 and 19 m) from May 2008 to April 2010, in the region of Balneário Camboriú, Santa Catarina State, Brazil.

The bottom salinity presented remarkable trends during the first year, while a more stable pattern was recorded in the second year (Figure 3). There were significant differences between the two years ($p < 0.05$). In both years, the higher average values occurred in autumn and summer and the lowest during winter and spring. In the first year, the highest values were recorded in March (37.3 ± 0.81) and April (37.5 ± 1.97), while the lower 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).

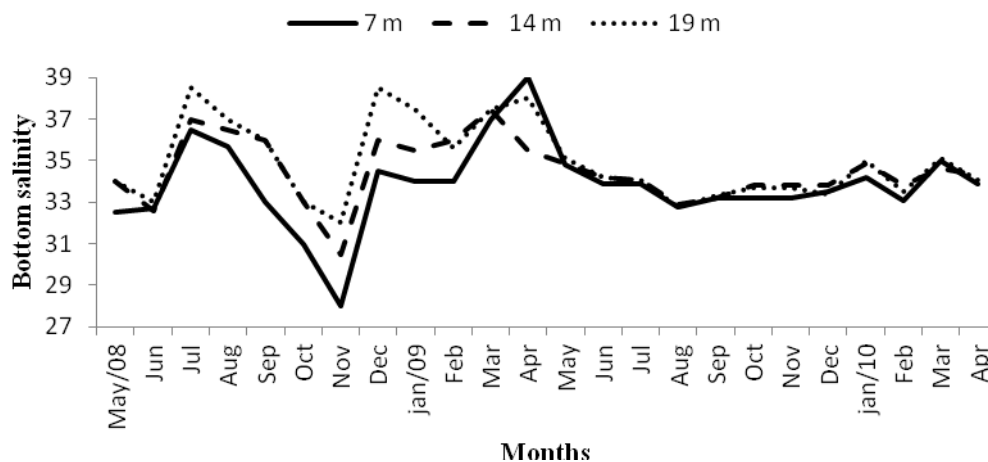


Fig. 3. Variation of the mean monthly bottom salinity for each depth (7, 14 and 19 m) from May 2008 to April 2010, in the region of Balneário Camboriú, Santa Catarina State, Brazil.

Distribution and Abundance:

A total of 1882 individual of *Hepatus pudibundus* was collected, 1221 during the first year and 661 during the second one. The abundance mean (CPUE N/15min) in the

first year was 15.9 ± 21.8 and in the second year was 8.66 ± 11.7 (interannual differences in the mean number per trawling are statistically significant; $F=2.05$, $p<0.01$). Furthermore, the abundance mean in weight (CPUE g/15min) at the first year (459.3 ± 655.9) was significantly higher than the second year (276.8 ± 382.7) ($p<0.05$). The highest average abundance (CPUE g/15min), in the first year, was recorded in February (777.6 ± 419.05), while in the second year highest abundance were recorded in August (646.8 ± 623.5) (Figure 4). During the first year the highest biomass was recorded at the depth of 7 meters (688.8 ± 799.2), when compared to 14 (149.4 ± 212.6) and 19 meters (526.9 ± 686.6), during the winter and spring (Table1), while in the second year it did not present a significant difference related to season or depth.

Considering the abundance in number of individuals, the depth of 14 meters (5.52 ± 6.91) presented significantly lower values ($p<0.01$) than the depths of 7 (15.14 ± 20.23) and 19 meters (16.18 ± 21.05). In the first year, the highest abundance was observed in February at depth of 19 meters (33.83 ± 29.96), and in all seasons the depth of 14 meters was statistically different, being always lower than the depths of 7 and 19 meters ($p<0.01$). On the other hand, the second year presented a different pattern, with the highest abundance was recorded in August at depth of 7 meters (18.66 ± 17.79), in spite of not presenting significant difference according to season or depth ($p>0.05$) (Figure 5) (Table 1).

The highest abundance index CPUE (g/15min), of ovigerous females in the first year, was recorded from November to April, with the highest abundance during November and January. November presented a significant greater biomass concentration at depth of 7 meters (405.64 ± 304.26), when compared to the depths of 19 meters (9.07 ± 12.82) and 14 meters, where no ovigerous females were found

($p < 0.01$). January also presented a higher and significant biomass concentration at depth of 7 meters (432.58 ± 533.32), when compared to the depths of 19 meters (48.46 ± 1.25) and 14 meters, where there was not found any individuals ($p < 0.01$). In the second year the highest CPUE (g/15min) of ovigerous females was recorded in December, without a significant biomass concentration at depth of 7 meters (75.61 ± 106.92), when compared to the depths of 14 (24.72 ± 34.95) and 19 meters (15.52 ± 21.95) ($p > 0.05$) (Figures 6-7).

Table 1. Seasonal variation in the CPUE (a - g/15min; b- N/15min) of *H. pudibundus*, presenting mean and standard deviation, by depth and during the two years sample, of the crab *H. pudibundus* in the region of Balneário Camboriú, state of Santa Catarina, Brazil.

Year 1		Autumn	Winter	Spring	Summer
7	a	457.0±562.1	797.9±1285.2	849.5±814.8	650.6±441.9
	b	17.5±25.4	15.5±18.8	25±28.4	28±25.8
14	a	147.1±202.3	126.5±186.4	61.5±99.2	247.8±308.8
	b	3.8±5.4	5.5±5.6	5.8±6.9	8.1±9.1
19	a	892.3±1151.8	235.8±136.7	265.7±312.6	713.9±583.1
	b	28.5±39	8.6±5.2	11.1±12.7	33.1±31.4
Year 2		Autumn	Winter	Spring	Summer
7	a	249.5±366.8	537.3±722.7	345.6±563.5	200.2±454.7
	b	8±12.5	13.1±17.5	8.8±14.4	5.1±12.1
14	a	117.9±180.8	55.0±106.3	210.2±183.9	249.4±278.1
	b	3±5	1.5±3.2	7.3±5.9	9±11.4
19	a	222.4±210.2	369.8±441.7	386.5±396.1	377.0±340.8
	b	6.1±6.8	10.6±13.4	15±14.7	16.1±15.2

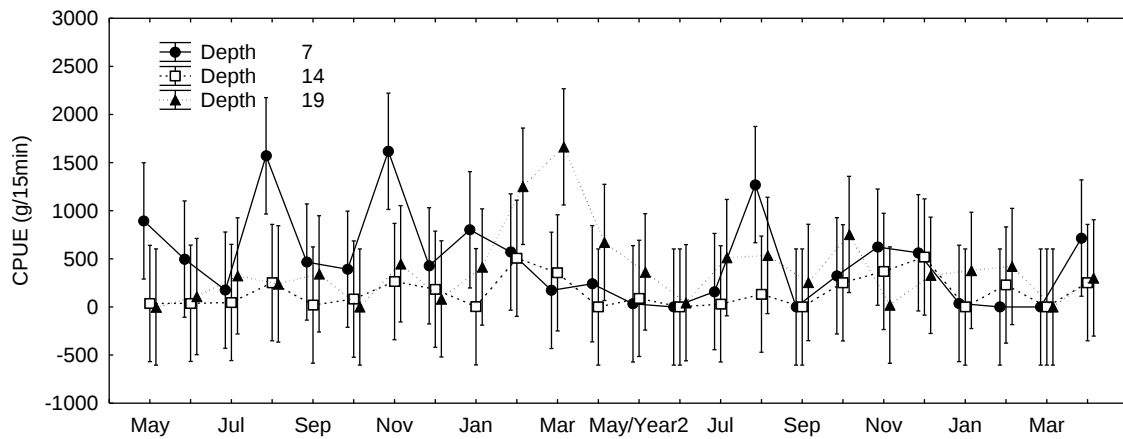


Fig. 4. Variation of the monthly CPUE (g/15min) by depth of the crab *H. pudibundus*, from May 2008 through April 2010. The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values.

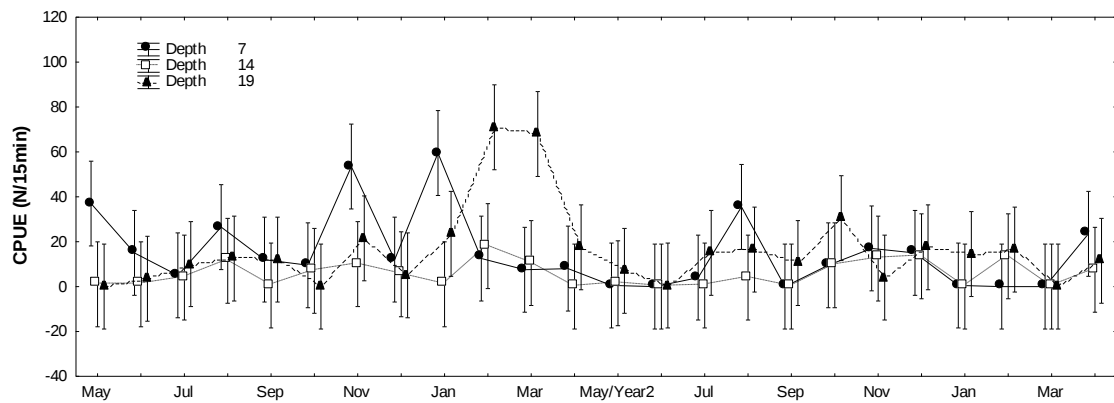


Fig. 5. Monthly variation of the CPUE (N/15min) by depth of the crab *H. pudibundus*, from May 2008 through April 2010. The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values.

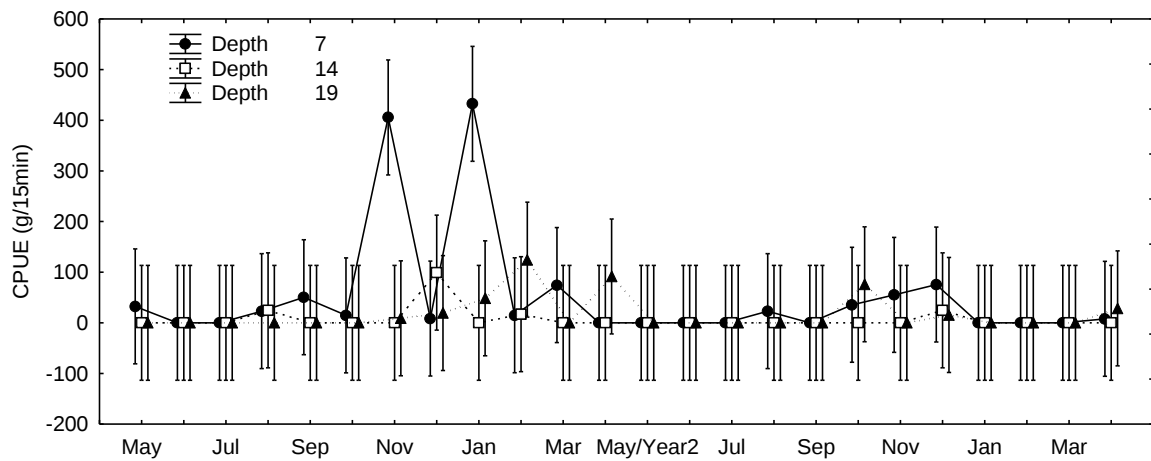


Fig. 6. Monthly variation of the CPUE (g/15min), for ovigerous females of *H. pudibundus*, by depth, from May 2008 through April 2010. The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values.

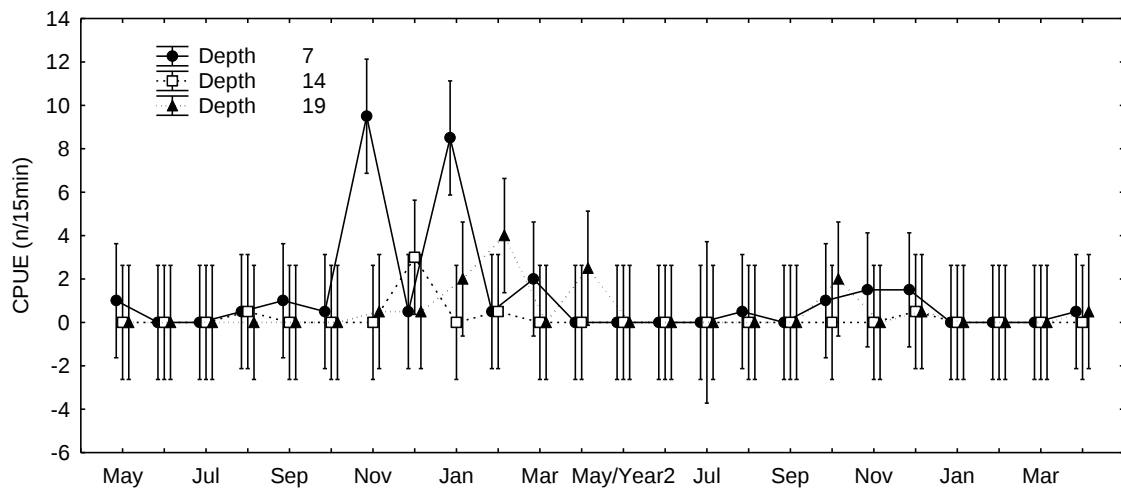


Fig. 7. Monthly variation of the CPUE (N/15min), for ovigerous females of *H. pudibundus*, by depth, from May 2008 through April 2010. The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values.

The multiple regression analysis indicated that both the environmental factors and depth didn't regulated the abundance of *H. pudibundus* ($F=1.20$, $p>0.05$) (Table 2).

Table 2. *Hepatus pudibundus*. The multiple regression analysis, relating the abundance and enviromental variables (bottom salinity and temperature) and depth, measured in the region of Balneário Camboriú ($p < 0.05$).

Enviromental Factor	β	p
Depth	0.07	0.45
Bottom salinity	0.06	0.55
Bottom Temperature	-0.16	0.36

Sex ratio:

The overall sex ratio differs from the expected 1:1 equilibrium ($P > 0.05$, χ^2 test). Considering the 1853 individuals analyzed, 946 (51.05%) were females and 907 (48.95%) were males (1.04:1). During the first year, the monthly pattern indicated significant differences ($P < 0.01$) towards the females in November (72%) and January (65%). Males dominated the samples in July (67%), September (74%) and March (75%). In the second year, the χ^2 test indicated significant differences ($P < 0.01$) toward females in August (65%) and November (67%), and towards males in May (65%) and September (86%). In deeper waters, the M:F presented values of 55% (19m) and 67% (14m), while at a depth of 7 m, the F:M proportion was 2.39:1 (Figure 8).

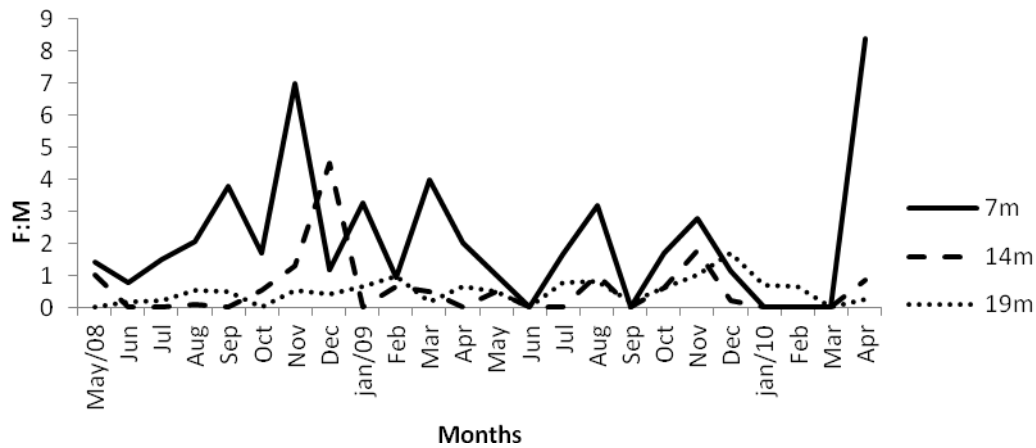


Fig. 8. Monthly proportion of female and male (F: M) of *H. pudibundus*, by depth (7, 14 and 19 m), during the two years of sampling, from May 2008 through April 2010.

Seasonal and Spatial variation in the Carapace width:

The males reached larger sizes than females ($p < 0.05$), presenting mean CW (mm) of 49.48 ± 17.55 mm, ranging from 13.5 to 96.67 mm. On the other hand, the mean size for females was 47.15 ± 13.87 mm, ranging from 16.31 to 76.99 mm. The mean size (CW) of ovigerous females was 56.01 ± 8.95 mm, ranging from 37.84 to 68.74 mm. For both sexes and for ovigerous females, the mean value of the carapace width (CW) was higher at 7 m isobath than at the other two 14 m e 19 m ($p < 0.01$) (Table 3).

Table 3. Variation in the mean carapace width (CW), standard deviation (SD), standard error (SE) and confidence limits (95%) of females, males and ovigerous females of *H. pudibundus* by depth (7, 14 and 19 m), in the region of Balneário Camboriú, Santa Catarina, Brazil, from May 2008 through April 2010.

Values in the same column followed by different letters differ significantly ($p < 0.05$).

Females	Depth	CW (mm)	SD	SE	95%	
	7 ^a	50.77	12.12	9.32	41.76	78.39
	14 ^b	41.83	17.85	1.62	38.60	45.06
	19 ^b	42.01	12.98	14.27	28.16	84.37
Males	Depth	CW (mm)	SD	SE	95%	
	7 ^a	53.26	17.2	1.09	51.10	55.42
	14 ^b	47.47	19.73	1.58	44.35	50.59
	19 ^b	48.23	16.71	0.75	46.75	49.70
Ovigerous Females	Depth	CW (mm)	SD	SE	95%	
	7 ^a	59.28	8.63	1.43	56.36	62.2
	14 ^b	52.78	9.32	3.52	44.16	61.40
	19 ^b	51.86	7.47	1.55	48.63	55.1

The analysis of seasonal trends in the mean carapace width of females showed that in both years, the larger individuals occurred in spring (52.30 ± 12.19) in the 7 m isobaths, while the smaller were recorded during the winter (27.39 ± 26.75) in the 14 m isobaths (seasonal differences are statistically different, $F=4.6$, $P<0.01$) (Figure 9). However, the larger ovigerous females were more abundant in summer (62.45 ± 6.86) and spring (58.34 ± 8.47) seasons, especially in the 7 m isobaths, when compared with others isobaths (seasonal differences are statistically different, $F=3.2$, $P<0.01$).

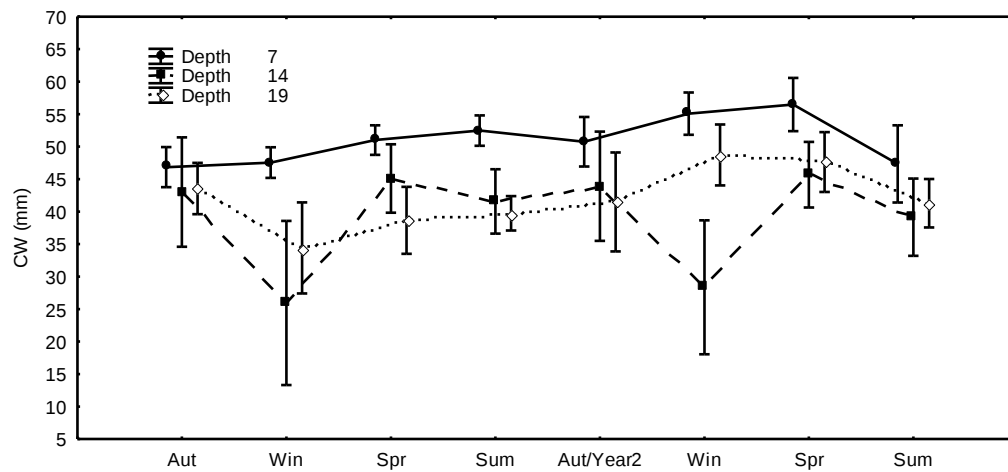


Fig. 9. Seasonal variation of the mean of the carapace width (CW), for females of *H. pudibundus*, by depth, from May 2008 through April 2010. The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values.

On the other hand, the seasonal variation of the carapace width of males showed that in both years, the larger individuals occurred in the summer (58.04 ± 17.17) in the 7 m isobaths, while the smaller were recorded during the winter (41.74 ± 21.69) in the 14 m isobaths (seasonal differences are statistically different, $F=2.94$; $P<0.05$) (Figure 10). In both years, the larger individuals, males and females, remained in shallow areas, while the smaller ones were found in deeper waters.

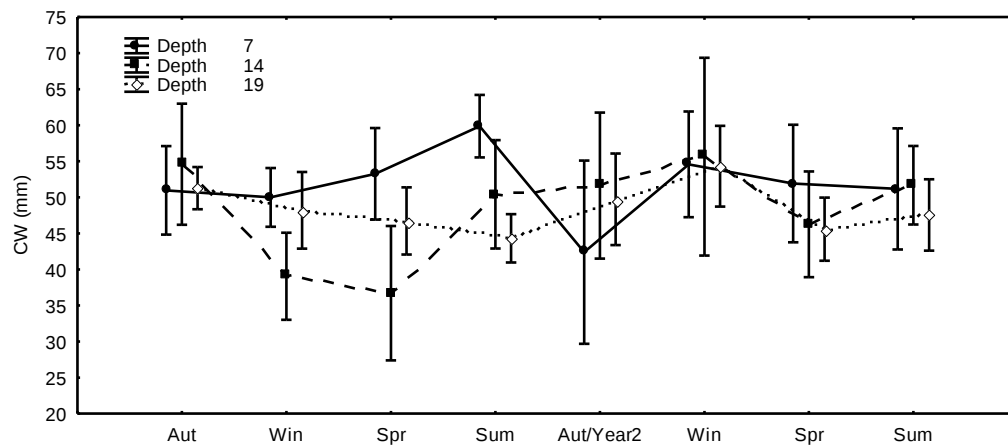


Fig. 10. Seasonal variation of the mean of the carapace width (CW), for males of *H. pudibundus*, by depth, from May 2008 through April 2010. The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values.

Biometric Relationships:

The relationship between carapace width and weight presented a negative allometry for females ($b=2.95$) and males ($b=2.94$) (Figures 11-12), without significant differences between the sexes.

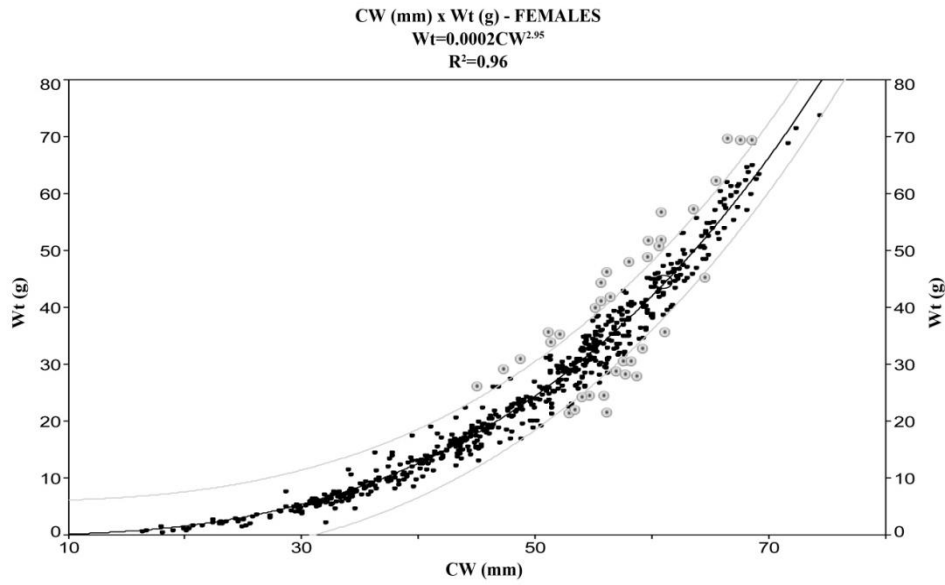


Fig. 11. Size (CW) and weight (Wt) relation for females of the crab *H. pudibundus* estimated for the Balneário Camboriú region, from May 2008 to April 2010.

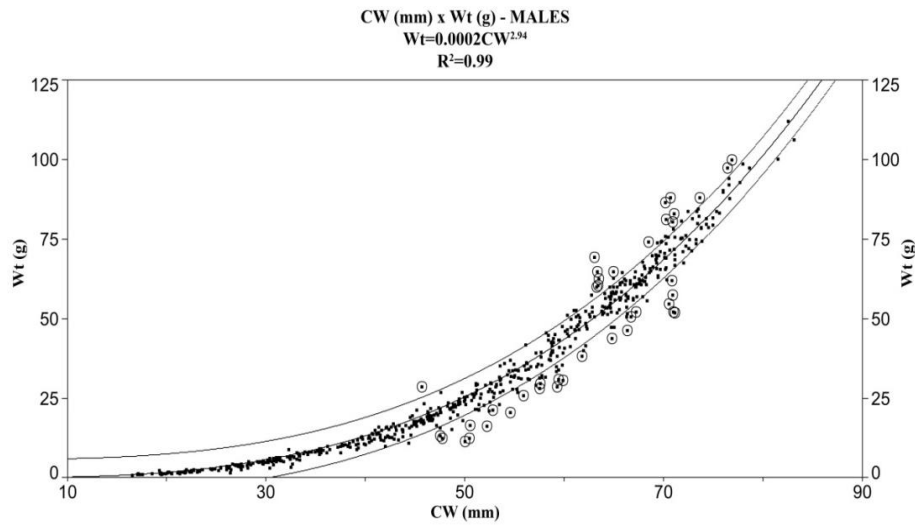


Fig. 12. Size (CW) and weight (Wt) relation for males of the crab *H. pudibundus* estimated for the Balneário Camboriú region, State of Santa Catarina, Brazil, from May 2008 to April 2010.

The relationship between carapace length and carapace width presented a negative allometry for females ($b=0.72$) and males ($b=0.68$) (Figures 13-14), with significant differences between them.

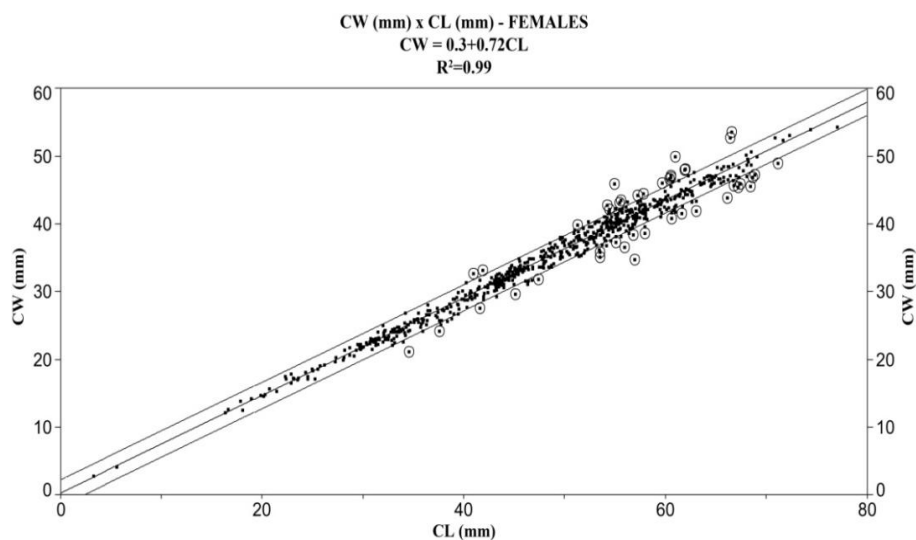


Fig. 13. Size-relation between carapace length (CL) and carapace width (CW) for females of the crab *H. pudibundus* estimated for the Balneário Camboriú region, State of Santa Catarina, Brazil, from May 2008 to April 2010.

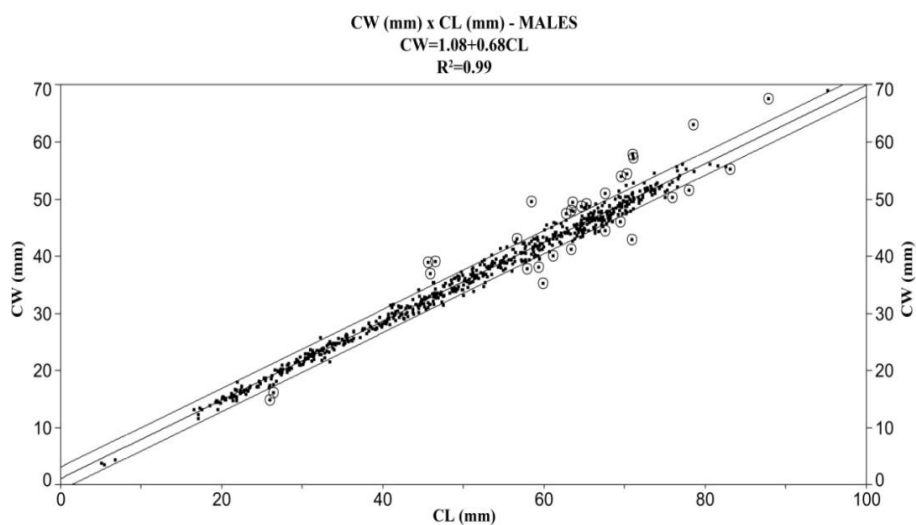


Fig. 14. Size-relation between carapace length (CL) and carapace width (CW) for males of the crab *H. pudibundus* estimated for the Balneário Camboriú region, State of Santa Catarina, Brazil, from May 2008 to April 2010.

DISCUSSION

Enviromental parameters:

During the first sampling year, a greater stratification of the water column was observed from December to March, indicated by lower temperatures and higher salinities in deeper waters. On the other hand, the second year presented a more stable environmental pattern. Probably, this variation in the abiotic factors, in the first sampling year, is due to the influence of a local upwelling. This phenomenon is triggered when there is a predominance of northeast winds, which pushes surface waters away from the coast resulting in the upwelling of cold and salty shelf waters (Acha *et al.*, 2004).

Distribution and Abundance:

Fluctuations in abundance between both years reinforce the idea that the recruitment is influenced by environmental conditions, which directly influences the biomass available each year. It is in agreement with the biology of the brachyurans, since they present important oscillations in CPUE. A marked feature of these populations is with the oscillation between high values of abundance and very subsequent low abundance periods (Fracasso & Branco, 2005), which may be related to the different requirements, during for the various stages of life. In the particular case of *Hepatus pudibundus* such requirements may play an important role on the population structure (Mantelatto *et al.*, 1995), besides providing different patterns of fattening (Mantelatto & Fransozo, 1992). This study supports the data obtained by Fracasso & Branco (2005) that using a six years temporal series sample for Santa Catarina (BR) indicate the occurrence of an interannual fluctuation at catches of *H. pudibundus*,

assigned to the climatic and oceanographic conditions of the studied area, as well as the life cycle events of the species.

Two major peaks of abundance, both in the first year sample, occurred in the spring and summer. These two peaks occurred at an average water temperature of around 20°C, indicating that the species is adapted to a certain range of optimum temperature. Similar results were observed on the coast of state São Paulo (Mantelatto *et al.*, 1995), where the studied population of *H. pudibundus* presented peaks of abundance associated with this temperature range. Additionally, a sudden decrease in the salinity of the water was observed during the transition from spring to summer, which can be related to high rainfall and thus to the transport of nutrients terrigenous fertilizing the coastal area and possibly resulting in a favorable environment for its occurrence. This abundance is reinforced by the fact that this species is considered euryhaline, because it is more captured in salinities of until 5 (Abreu, 1980).

The monthly trends in abundance show two marked peaks of abundance, in August and November, which are likely related to mating, especially during the first year of sampling. This is confirmed by analyzing the abundance in the depth of 7 meters, but also by the larger average carapace width of the individuals. Therefore, the presence of large adult females and males indicates a migration of individuals to shallow waters, possibly for mating. This migratory behavior can be an advantage to the species, as it can avoid competition. In January a peak in the abundance of small individuals and a low abundance in weight and carapace width of individuals, in depth of 7 meters, indicating the presence of recruits. After this period, in February and March, there are two other peaks of abundance, first in numbers then in weight, indicating the end of recruitment. This hypothesis is confirmed by analysis of the

growth curve of this species, which the month of March, after the significant migration to greater depths, presented males with an average of 35 mm CW, representing around 100 days old, and females CW with an average of 28 mm, representing around 85 days old (Sardá *et al.*, unpublished data). Immediately after the abundance peaks, a reduction in abundance of adults (male and female) can be observed, which may be associated to a massive mortality of individuals after the reproduction.

Recently, an investigation performed on the crab *Dilocarcinus pagei* (Taddei & Herrera, 2010) concluded that the abundance of adults was reduced in summer, just after the reproductive season. Only those animals that had no success in reproduction, will possibly survive until the next reproduction season. Also, the estimate of maximum longevity around two years is more common for decapods (Barcelos *et al.*, 2007). The possible death of animals after the reproductive period is an indication that most animals dies until the age of two years. This longevity at to *Hepatus pudibundus* has been observed by Keunecke *et al.*, (2007a); Sardá *et al.*, (unpublished data). Nevertheless, Reigada e Negreiros-Fransozo, 2000 worked with *H. pudibundus* in the Ubatuba estuary (SP) found moult activity in almost all size classes, which indicates that this species does not undergone a terminal anecdysis, but continues moulting even though longer intermoult intervals.

Analyzing the three depths considered in this study, the marked difference in the *Hepatus pudibundus* abundance observed in both years on the Santa Catarina coast can be attributed to the variations in salinity and temperature, where in shallow, warmer and less saline waters; there was a higher abundance of females and ovigerous females. On the other hand, in deeper, colder and more saline waters, there was a higher abundance of males. The highest densities were found in shallow waters, during the months of

August and November. This preference was also observed in another study, performed in the north coast of Rio de Janeiro (Klôh & Di Benedetto, 2010). During the months of February and March, there was also an abundance of males, however, concentrated at the depth 19 m. This may support the idea that mating occurs during these peaks and then immediately afterwards, there is a differential migration between sexes avoiding competition. On the other hand, females may migrate to shallower depths, attracted by the higher water temperature, to facilitate egg incubation (Nagao *et al.*, 1999) and also reducing competition for space. This segregation behavior has also been observed in *Callinectes sapidus* (Rodrigues & D'Incao, 2008). Unlike *H. pudibundus*, after mating, females of *C. sapidus* begin to migrate to more saline areas, where the release and hatching of larvae occurs, with the males remaining in less saline areas and even able to copulate with other females. The juveniles are, therefore, using the 14 meters depth to recruitment, which can be concluded by the lower mean size observed for this depth. This idea can be sustained not only by the fact that the larger carapace width of both males and females, have been found at 7 and 19 meters depths, but also because there is a greater proportion of females at 7m depth and males at 14 and 19 meters depths. The statistical analysis indicated that both the environmental factors, temperature and salinity, didn't regulated the total abundance of *H. pudibundus*, inspite of a clear tendency of habitat selections related to sex. These results corroborate those obtained by Mantelatto *et al.*, (1995) that didn't find, according to the environmental factors of Fortaleza Bay (Ubatuba/SP), no specific pattern of *H. pudibundus* distribution associated with salinity and temperature.

Sex ratio:

Hepatus pudibundus showed a sex ratio around 1:1.04 in favor of females, despite of having months with a significant difference of males over females. This pattern is similar to those found by Fracasso & Branco (2005), also performed in the state of Santa Catarina, despite of the predominance of males in June, differing from that study that found a greater abundance of males in the months of May, July and September. In this study, during the first year sample, there was a significant dominance of females in the months of November and January, in the second year females predominated in November. On the coast of Guarujá (São Paulo), this species showed the predominance of females in the months from September to February (Severino-Rodrigues *et al.*, 2002), while in the Bay of Mucuripe (CE) that predominantly occurred from December to February (Sampaio & Fausto-Filho, 1984). These three studies indicate the dominance of females in the warmer months, which may be related to reproduction.

When the results were analyzed by depth, this predominance of females was not constant over the two years of sampling. A significant difference of males over females was verified at 14 and 19 meters depth, and it can be related to the reproductive migration of females, that moves to shallow waters to spawn. This idea is supported by the high frequency of ovigerous females at a depth of 7 meters, which, despite of having been found in three depths analyzed, showed a greater mean carapace width at shallower depths. The deviation from the expected 1:1 sex ratio is very common in decapods (Wenner, 1972), and may be attributed to spatial segregation (Jesse & Stotz, 2003) and/or temporal variations in sexual composition of the population (Wenner,

1972; Bas *et al.*, 2005). In this particular case of *H. pudibundus*, the reproductive migration seems to explain the trends in sex ratio.

Seasonal and Spatial variation in the Carapace width:

Hepatus pudibundus presents sexual dimorphism related to size, with males larger than females, indicating a different growth rate between the sexes (Keunecke *et al.*, 2007a). Mantelatto & Fransozo (1994) and Reigada *et al.* (1994) point out that the factors that explain this difference in *H. pudibundus* are likely to be: i) the pressure of reproductive selection acts favorably in relation to larger males, which then would leave more descendants, and ii) the female, after sexual maturity, invests more in reproduction metabolism and maturation of the gonads than in its own growth.

The analysis of the mean variation of carapace width of females, males and ovigerous females of *H. pudibundus*, by depth and season, indicated that the largest individuals are concentrated in shallow water (7m) during the summer of first year and autumn of second year, indicating that reproduction takes place in shallow waters. However, the smaller individuals are concentrated in the intermediate depths (14m) during both analyzed years, suggesting that it represents a recruitment zone.

Biometric Relationships:

According to Hartnoll (1982), growth in crustaceans occurs as a consequence of a sequence of phases, and within there are variables that can be explained by allometric models (linear or power). In this study, the relationship between carapace width (CW) and Weight (Wt) of females ($b=2.95$) had a slope close to males ($b=2.94$). For females, the negative allometry indicates that the gain of biomass is reduced when the animal

reaches maturity. For males, it can be related to the need of maximize the size, investing less at weight, in order to assure a successful reproductive strategy, in search for food and territory defense. The same result was obtained by Mantelatto & Fransozo (1992), in a study on the northern coast of São Paulo and Fracasso & Branco (2005) in Santa Catarina. The results by Klôh & Di Benedetto (2010), revealed a isometry on the relation weight and CW of males from this specie, indicating a proportional increase of these variables while the individual is growing. According to these authors, the variations between the studies may reflect the biometric characteristics of the populations of *H. pudibundus* along the distribution areas, or just temporary differences on the individuals ontogeny that compose these populations. The relationship between carapace length (CL) and carapace width (CW) of females had a higher CW slope ($b=0.72$) than males ($b=0.68$), indicating a pattern of higher relative growth in CW for females. This result confronts the results obtained for this species on the coast of São Paulo, since it was observed an isometry on the relation CL and CW, which may be related to latitudinal variations of the areas studied (Bueno *et al.*, 2009). Biometric relationships can provide important on biological events occurring in a population, such as length-weight relationship variation during reproductive season or unfavorable environmental conditions (King, 1995). Additionally, these biometric relationships can provide an easy way of estimating width and weight for missing data, also allowing comparison with previous investigations (Ragonese *et al.*, 1997).

In Brazil the numerical contribution of *Hepatus pudibundus* often does not exceed 10% of total brachyuran recorded in shrimp fishery (Severino-Rodrigues *et al.*, 2002; Branco & Fracasso, 2004; Costa & Di Benedetto, 2009; Klôh & Di Benedetto, 2010). However, a study showed that *H. pudibundus* was the most abundant species

representing 20% of the whole crustacean catch in the pink shrimp trawling fishery (Keunecke *et al.*, 2007b).

Thereby, the continuous action of the shrimp fishery activity in coastal areas can influence the size and structure of the Brachyura populations from the systematic removal of individuals, leading to changes in recruitment rate and population size (Klôh & Di Benedetto, 2010). The closed season for seabob shrimp in the region of Santa Catarina, was established based on the life cycle of the pink shrimp (*Farfantepenaeus paulensis* e *F. brasiliensis*). This period occurs annually during the months of March, April and May, with the largest catches of seabob shrimp occurring on this period (Bail & Branco, 2007) and, consequently the incidental catch of species increases. Given the marked presence of ovigerous females from November to April, this would be the most important time to ensure the preservation of the species, however, the closed season for seabob shrimp covers only two months of this period. Also, another period of interest in preservation of *H. pudibundus* would be the recruitment, which begins in February, just before the start of closed season for seabob shrimp and probably should present an intensive fishing, providing any profit to fishermen during the closed season. Considering that *H. pudibundus*, has a low fecundity, the recovery of the biomass removed by fisheries is slower, if compared with shrimps, for example. Therefore, to overexploit a shrimp stock, would be needed a higher fishing effort if compared to the bycatch. Nowadays there is a international consensus that the bycatch is an important part, and that requires attention from both researchers and fisheries administrators (Worm *et al.*, 2006).

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ANEXO II

Growth and Mortality of crab *Hepatus pudibundus*
(DECAPODA: AETHRIDAE) in the State of Santa
Catarina, Southern Brazil.

Growth and Mortality of the box crab *Hepatus pudibundus* (DECAPODA: AETHRIDAE) in the State of Santa Catarina, Southern Brazil.

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Abstract: The trawling fishery related to the seabob shrimp (*Xiphopenaeus kroyeri*) in the south of Brazil affects populations of some benthic species and *Hepatus pudibundus* is an abundant bycatch in this fishery. The correct determination of population parameters, such as growth and mortality, are mandatory to support the fishery assessment and management of many species. Individual growth and mortality parameters were studied for *Hepatus pudibundus* off the coast of Santa Catarina State, in southern Brazil. To obtain biological samples, a typical shrimp trawler, equipped with double rig nets, performed standardized 15 minutes trawling. Samples were monthly collected, from May 2008 to April 2010. The von Bertalanffy growth model (VBGM) was used to estimate the carapace growth, and the mortality coefficients, such as total mortality (Z), natural mortality (M) and fishing mortality (F) were determined for both sexes, by using a length-based catch curve. The exploitation rate ($E=F/Z$) was estimated for both sexes. The von Bertalanffy growth model properly described the growth of *H. pudibundus* ($k=1.82\text{ y}^{-1}$, $CW_{\infty}=85.89\text{ mm}$; $k=2.19\text{ y}^{-1}$, $CW_{\infty}=69.00\text{ mm}$, for males and females respectively), resulting in biologically coherent estimates. The longevity estimates is in accordance with the previously suggested values and especially with the biology of this species. The instantaneous coefficients of total, natural and fishing mortality were estimated as follows: males, $Z=5.35\text{ y}^{-1}$; $M=2.1\text{ y}^{-1}$; $F=3.25\text{ y}^{-1}$; females, $Z=4.2\text{ y}^{-1}$; $M=2.1\text{ y}^{-1}$; $F=2.1\text{ y}^{-1}$. Based on the mortality coefficients, the exploitation rate ($E=F/Z$) was estimated for both sexes (0.5 and 0.6 for females and males), indicating that the larger length increases the vulnerability of males to the otter trawlers. Growth

and mortality analysis suggest that *H. pudibundus* in the Santa Catarina region is on the limit of overfishing.

Keywords. Box Crab, von Bertalanffy, Modal Progression Analysis, growth.

INTRODUCTION

Most of the commercial fishing activity in Brazil is carried out by boats with trawling gear (Perez & Pezzuto, 2001). The worldwide trawling for coastal shrimps is an activity that has resulted in the overexploitation of many stocks (FAO, 2010). The worldwide scenario is also detected off the Brazilian coast, where many shrimp stocks have been overexploited (D’Incao *et al.*, 2002; Batista, 2011). Regarding that this kind of gear produces a significant bycatch, this predatory fishery may represent an important factor affecting the population dynamics of species caught along with target species (Alverson *et al.*, 1994). Thus, understanding the effects of shrimp trawling on the incidentally caught species is important to elucidate and predict the impact of fishing activities on the population dynamics of this accessory species (Clucas & Teutscher, 1998).

The box crab *Hepatus pudibundus* (Herbst, 1758) is the most caught member of the Aethridae Dana, 1851 family in the trawling for the seabob-shrimp *Xiphopenaeus kroyeri* (Heller, 1862) (Fracasso & Branco, 2005). Its distribution is restricted to the Western Atlantic, from Georgia (USA) to Rio Grande do Sul (Brazil), and can be found in muddy, sandy and biodetritic bottoms from shallow waters up to 160 m deep (Melo, 1996).

Investigation concerning *H. pudibundus* in the Brazilian coast are limited to the relative growth (Mantelatto & Fransozo, 1992, 1994; Reigada *et al.*, 1994),

reproduction (Reigada & Negreiros-Fransozo, 2000) and natural diet (Mantelatto & Petracco, 1997). Conversely, few studies have mentioned the populational dynamics of this species (Mantelatto *et al.*, 1995a, b; Keunecke *et al.*, 2007), such as growth and mortality. Regarding the conspicuous trends in population parameters observed for crustaceans, especially due to short (eg. rainfall) and large scale effects (eg. trends in water temperature due to latitudinal effects), the investigation of local particularities in these parameters are essential for managing the stocks efficiently. In this sense, we report novel results about the individual growth and mortality (total, natural and fishing mortality) of *H. pudibundus* caught in the fishery targeting seabob-shrimp (*Xiphopenaeus kroyeri*) in Balneário Camboriú, SC. The effect of fishing on total mortality is evaluated and possible effects of shrimp fishing in the population of *H. pudibundus* are discussed.

MATERIALS AND METHODS

The samples on this study were obtained monthly, between May/2008 and April/2010, in the Region of Balneário Camboriú (26° 59' 07" S - 48° 35' 58" W), State of Santa Catarina, Brazil (Figure 1). Transects were designed at three depths: 7, 14 and 19 m. The trawling, over a 15 minutes period, was made for a shrimp fishing boat equipped with double rig nets. Sex determination of the specimens was based on secondary sexual characters.

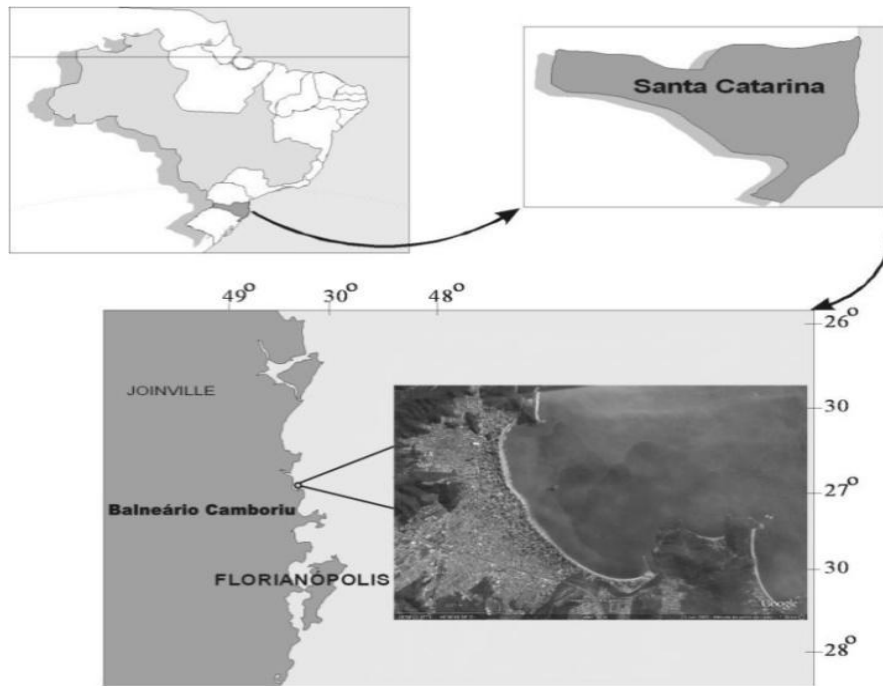


Fig. 1. Map of the region of Camboriú, State of Santa Catarina, South Brazil, where investigation took place between May 2008 and April 2010.

Growth

Based on carapace width (CW) frequency distributions, modal groups were determined and fitted to a normal distribution model. The class interval adopted to perform the CW frequencies analysis – whose distributions were first smoothed (fast Fourier transformation, FFT) – was 1.00 mm. Modal values determined in each CW frequency distribution were tentatively linked to visualize the modal progression, along the sampling period. Individual growth was estimated for females and males following the cohorts, represented by CW modal groups, along the study period (Modal Progression Analysis – MPA) (Dumont & D’Incao, 2004).

Furthermore, model fitting was also tested to a variable value of CW_{∞} – based on the literature (Keunecke, 2007) – and only cohorts which yielded biologically reasonable VBGM parameters were considered. Those parameters are asymptotic

length, coefficient of growth and longevity. To estimate growth parameters all the chosen cohorts were fitted to von Bertalanffy growth model (VBGM) (1938) by an automated least squares fitting procedure. The von Bertalanffy equation is as follows: $CL_t = CL_{\infty} [1 - e^{-k(t-t_0)}]$, where CL_t is the length at the time t , CL_{∞} is the asymptotic length, k is the coefficient of growth and t_0 is the theoretical age at length zero. To estimate longevity (t_{max}) was used the inverted von Bertalanffy (1938) equation, which considers maximum longevity (t_{max}) as reached at 99% of the asymptotic length (D’Incao & Fonseca, 1999). Moreover, F test was applied with the objective to test possible differences between growth parameters of males and females (Cerrato, 1990).

Exploitation rate (E) and total (Z), natural (M) and fishing mortality (F)

Total mortality coefficients (Z/year) were estimated for females and males by using a length-based catch curve (Ricker, 1975). An age-length table was built based on the growth model of von Bertalanffy (1938) (VBGM), taking into account the lower and upper limits of the class intervals. The number of individuals by age, were plotted for each month, which allowed to follow the decreasing abundance of the cohorts during the sampling period. From the recruitment size, the mean numbers of individuals, by age, were linearized and used to estimate the total mortality (Z).

The instantaneous coefficient of natural mortality (M) was estimated according to the method of Taylor (1960) and Pauly (1980). The method of Taylor is originated from the growth equation of Bertalanffy (1938) (VBGM), that considers the connection between longevity and asymptotic length (L_{∞}) and is given by the Taylor’s equation equal to $A_{0.99} = t_0 + 4.60/K$. The method supposes the natural mortality reduces the initial number of the cohort to 1% of this original value, considering a period of time equal to

the longevity. The parameter k of the growth equation is $-k(t_{\max}-t_0)=M=4.60$, so: $M=4.60/A_{0.99}$, it took in this case. On the other hand, the method of Pauly based on the formula: $\log M = -0.0066 - 0.279 \log L_{\infty} + 0.6543 \log K + 0.4634 \log T$, where L_{∞} and K are the growth parameters estimated from the Von Bertalanffy equation and T is the average water temperature. Then was the fishing mortality (F) 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

Growth

A total of 27 cohorts was traced (16 females – 11 males) (Figures 2 and 3) (Table 1 and 2), getting the growth curves shown in figures 4 and 5. The longevity was estimated in 24 months for females, with higher k values, and 29 months for males, that have higher asymptotic length. About the size, which growth parameters estimated are available in table 3, the largest male and female caught had 96.67 e 76.99 mm CW, respectively. Moreover, the growth curves of females and males were different ($F_{\text{calc}}=55.89$; $F_{\text{tab}}= 3.04$), what indicates the relation between sex and growth, in favor of the males.

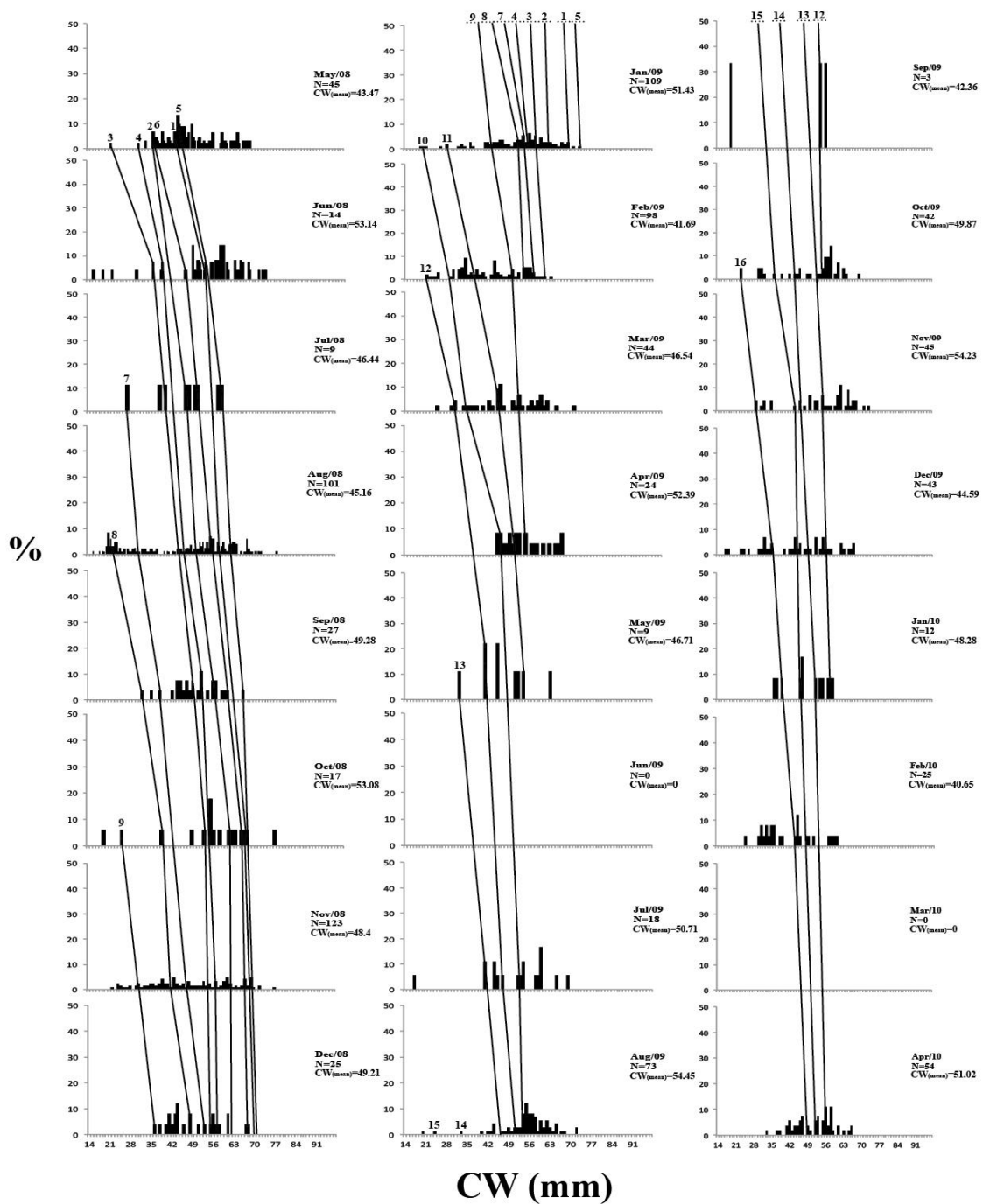


Fig. 2. *H. pudibundus*. Modal progression analysis (MPA) of females cohorts. Bold lines are the cohorts linked along the period of study used to describe the individual growth. N” indicates the number of individuals samples on each month. “CW” indicates the mean carapace width.

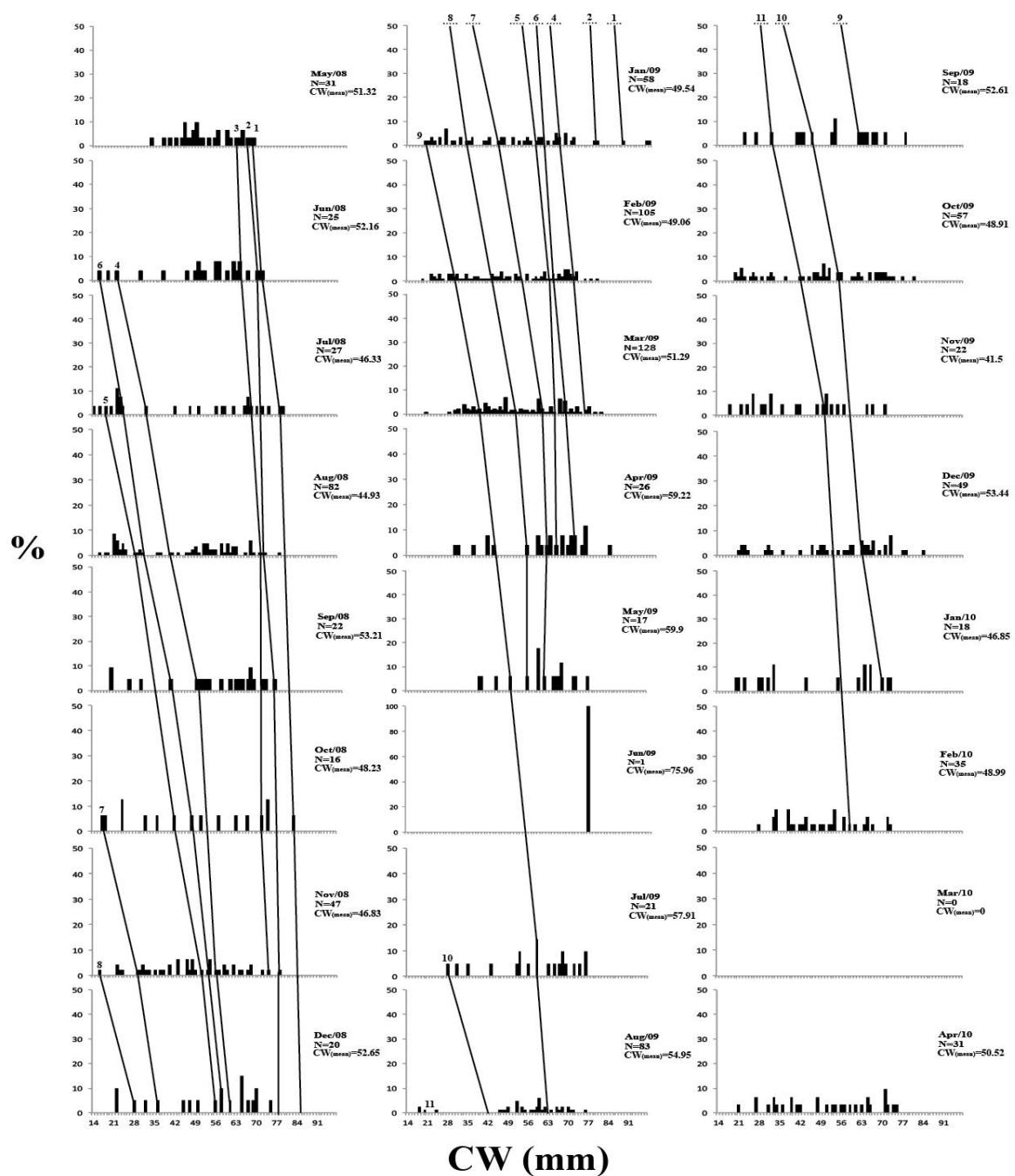


Fig. 3. *H. pudibundus*. Modal progression analysis (MPA) of males cohorts. Bold lines are the linked cohorts used to describe the individual growth. “N” indicates the number of individuals samples on each month. “CW” indicates the mean carapace width.

Table 1. Summary of growth parameters for 16 cohorts of females, indicating asymptotic length (L_{∞}), coefficient of growth (k) and longevity (long). The parameter “k” is presented in years, t_0 in days and the L_{inf} in millimeters.

Parameters ♀				
	L_{∞}	k	t_0	Long. (year)
Cohort 1	72.81	2.92	-102	1.4
Cohort 2	68.23	2.55	-95	1.6
Cohort 3	64.21	2.55	-60	1.6
Cohort 4	67.66	2.19	-85	1.9
Cohort 5	77.22	2.92	-107	1.5
Cohort 6	76.47	2.55	-89	1.7
Cohort 7	73.65	1.82	-88	2.5
Cohort 8	66.89	2.19	-62	1.9
Cohort 9	63.14	2.55	-63	1.6
Cohort10	64.18	2.55	-52	1.7
Cohort11	68.92	2.55	-68	1.6
Cohort12	63.76	2.19	-61	1.5
Cohort13	64.19	2.19	-99	1.8
Cohort14	60.63	2.55	-105	1.7
Cohort15	58.60	2.55	-76	1.8
Cohort16	58.63	2.55	-66	1.6

Table 2. Summary of growth parameters for 11 cohorts of males, indicating asymptotic length (L_{∞}), coefficient of growth (k) and longevity (long). The parameter “ k ” is presented in years, t_0 in days and the L_{∞} in millimeters.

Parameters ♂				
	L_{∞}	k	t_0	Long. (year)
Cohort 1	91.72	2.55	-184	1.8
Cohort 2	81.59	2.55	-224	1.7
Cohort 3	80.45	2.19	-201	1.8
Cohort 4	79.79	2.19	-51	1.8
Cohort 5	76.78	2.19	-44	2.0
Cohort 6	80.65	1.82	-34	2.1
Cohort 7	79.08	2.19	-51	1.8
Cohort 8	73.99	2.19	-39	2.0
Cohort 9	79.66	1.82	-51	2.2
Cohort10	84.57	2.19	-59	1.8
Cohort11	73.74	2.19	-61	1.9

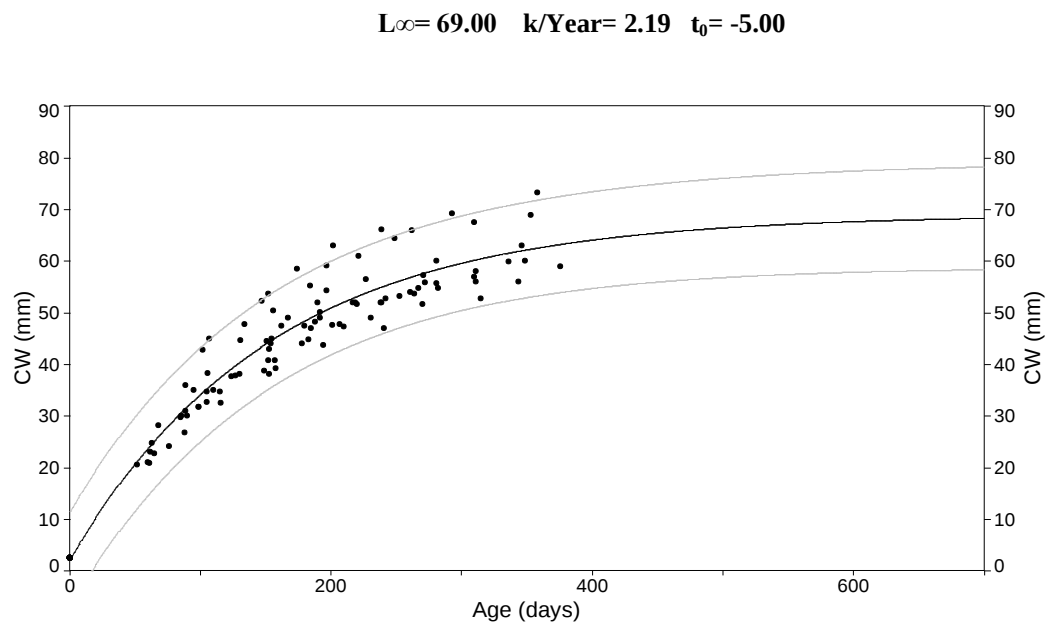


Fig. 4. Females. *H. pudibundus*. Growth curves estimated for the southern population from the Santa Catarina State. The parameter “ k ” is presented in year, t_0 in days and the L_{∞} in millimeters.

$$L_{\infty}=85.89 \quad k/\text{Year}=1.82 \quad t_0=-5.13$$

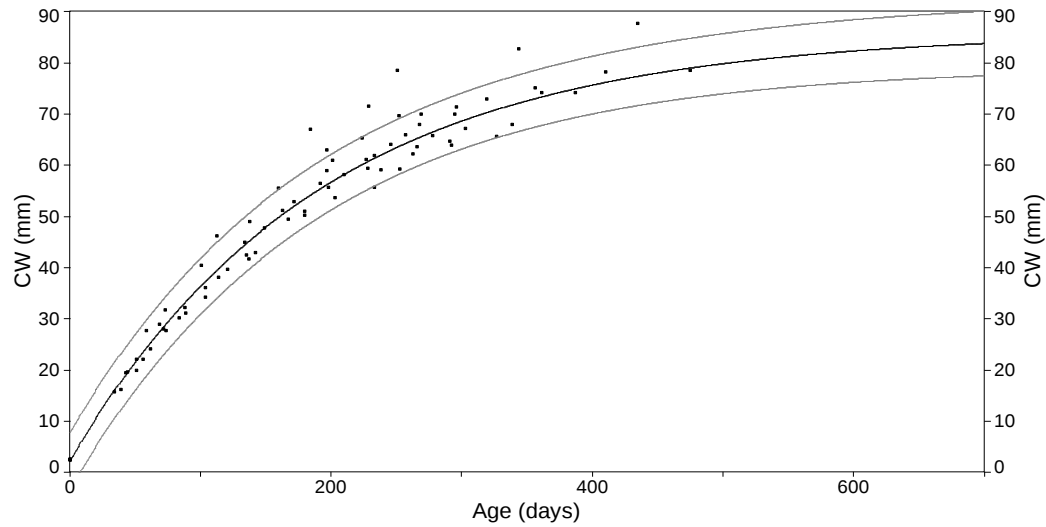


Fig. 5. Males. *H. pudibundus*. Growth curves estimated for the southern population from the Santa Catarina State. The parameter “k” is presented in year, t_0 in days and the L_{∞} in millimeters.

Table 3. Growth parameters of the Von Bertalanffy model, for females and males of *H. pudibundus*, 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	Std Error	t-value	95% Confidence Limits	P> t
L_{∞}	69.00	2.36	29.15	64.31 - 73.69	0,00
k	2.19	0.0005	12.43	0.005 – 0.007	0,00
t_0	-5.00	2.67	-1.87	-10.29 – 0.28	0.06
Parameters ♂	Value	Std Error	t-value	95% Confidence Limits	P> t
L_{∞}	85.89	2.08	41.19	81.74 – 90.05	0,00
k	1.82	0.0002	18.95	0.004 – 0.005	0,00
t_0	-5.13	1.78	-2.87	-8.69 - -1.57	0.05

Exploitation rate (E) and total (Z), natural (M) and fishing mortality (F)

Males and females were completely vulnerable to the fishing gear from 3 and 5 months old, respectively (Figure 6). The instantaneous coefficient of total mortality (Z) was 5.35 y^{-1} and 4.20 y^{-1} , for males and females, respectively. The annual natural mortality rate (M) was 2.1 y^{-1} for males and females. However, the method of Pauly indicated a natural mortality (M) of 1.82 to males and 2.19 to females. The fishing mortality (F) founded was higher than the natural only for males. The difference between total mortality and natural results on the annual value of fishing mortality (F), equal 2.1 for females and 3.25 for males. Therefore, the exploitation rate ($E=F/Z$) was 0.5 for females and 0.6 for males (Table 4).

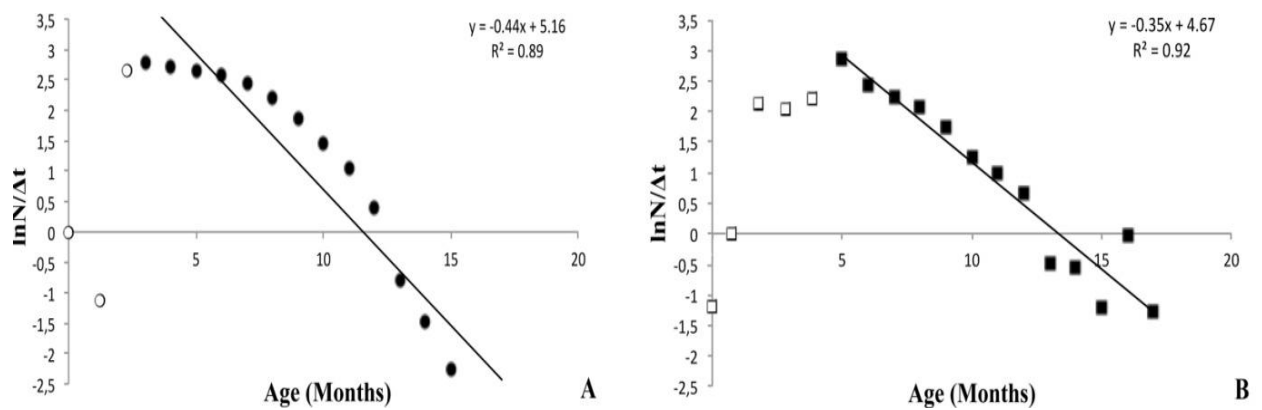


Fig. 6. Length-based catch curves for (A) males and (B) females. Z estimates were 5.35 y^{-1} and 4.2 y^{-1} , respectively.

Table 4. Instantaneous coefficient of total mortality (Z); Natural mortality (M); Fishing mortality (F) and Exploitation rate (E) for females and males of *H. pudibundus* in the region of Balneário Camboriú, SC, Brazil.

	Z	M	F	E
Females	4.2	2.1	2.1	0.5
Males	5.35	2.1	3.25	0.6

DISCUSSION

Growth

The methodology used in this work – about modal progression analysis and VBGM – indicates the longevity (females: 2.0; males: 2.4) and the asymptotic lengths presents coherence with the life cycle of the species, for both sexes. From the results, the curves can be certainly validated through longevity. In *H. pudibundus* case, this parameter is estimated close (+10%) to the maximum length recorded in samples, evoking the biological coherence of the present growth estimates.

There is scarce information about individual growth of *Hepatus pudibundus*. However, a study of the relative growth of this species (Mantelatto *et al.*, 1995a) in southwestern Brazil, found an observed CW of 78.24 mm and 66.48 mm for males and females, respectively, while Keunecke *et al.*, (2007a) for the same region studied found an observed CW of 83.10 mm for males and 67.15 mm for females. These values are close to the maximum CW observed in this study (96.67 for males and 76.99 for females). Larger males may be related to an increased aptitude for mating (Mantelatto &

Franzoso, 1994). This same relation (males larger than females) was observed in a study conducted in Mexico with species of the same genus used in this study, the crab *Hepatus epheliticus* (Hernández *et al.*, 2012). This author found the biggest CW equal to 70.0 mm for males and 60.0 mm for females. However, unlike this study, were found only 5 and 4 cohorts for males and females, respectively.

In this study, the growth curves obtained for *H. pudibundus* result in a longevity around 2.0 years for females and 2.4 years for males. Keunecke *et al.*, (2007a) found a longevity of 1.7 years for both sexes, concluding that this species has short lives. Thus, it is understood that the estimated growth curves are conceivable for this specie. The carapace width (CW) data from Keunecke *et al.*, (2007a) show that males had an increase of CW from October to May, and females had an increase of CW from September to December. Coincidentally on this paper, these were the months with more cohorts plotted. For two species of the genus *Callinectes* were estimated longevity of 2.3 and 2.5 years for males and females of *C. danae*, respectively, and 2.3 and 2.4 years for males and females of *C. ornatus* (Keunecke *et al.*, 2007c). Prior to this study, in a different region, greater values of longevity had already been estimated for *C. danae* and *C. ornatus* (Branco & Masunari, 1992; Branco & Lunardon-Branco, 1993). According to Keunecke *et al.*, 2007c this difference of values may be due to underestimation of the parameter k , which not only result in erroneous values of longevity, but also a negative effect on mortality coefficients.

The growth coefficient (k) and asymptotic length (L_{∞}) are inversely proportionate and, at higher temperatures, tend to increase and decrease, respectively (Pauly *et al.*, 1984). The results about k found in this study (females: 2.19; males: 1.82) was lowest than south-western Brazil's numbers by Keunecke *et al.*, (2007a). 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. In the present study, the asymptotic lengths were 69.00 mm and 85.89 mm for females and males, respectively, while Keunecke *et al.*, (2007a) found the asymptotic lengths of 66.72 mm for females and 82.97 for males. This difference in asymptotic lengths between the two studies may be explained by the values of the growth constant (k), this way the larger sizes found in this study when compared to the study of Keunecke *et al.* (2007a) are related to the lower values of the constant k , since this constant measures the speed in which the animal reaches the L_{∞} , consequently, with a higher value of k , the individual reaches a lower L_{∞} .

Populations of this species can be strongly affected by the shrimp fishery, which selects the largest individuals and, in the long term, acts as a selective force to reduce the average size by age. Fracasso & Branco (2005) determined that females of *H. pudibundus* reached sexual maturity with a CW between 34 and 36 mm, most of the females captured in this study had a CW above this, suggesting that this population of *H. pudibundus* not is subject to recruitment overfishing as a result of shrimp fishery.

Regarding the differences in growth for males and females, a recent study with *Callinectes ornatus* in the state of Rio de Janeiro, there is a difference in the distribution by size class for males and females, with bycatch tending to capture species that have already achieved sexual maturity (Tudesco *et al.*, 2012). This same study found that in the genus *Callinectes*, males are larger than females, which corroborates Hartnoll 1982, who defends the principle that there is a difference in growth between the sexes in crustaceans. The allometric growth in length-weight relationship verified in *H. pudibundus* (Sardá *et al.*, unpublished data) is expected in crustaceans (Hartnoll 1982).

Similar results were reported by Baptista *et al.*, (2003) and Branco & Fracasso (2004) for *C. ornatus* specimens from southern Brazil.

Total, natural and fishing mortality

The ascending curve of capture can result from both the selectivity of fishing art that can facilitate the escape of smaller individuals, or lack of individuals of these specific ages from the fishing area (Ricker, 1975). The age of first capture (3 months for males and 5 months for females) corresponds to CW sizes of 33.9 mm and 44 mm for males and females, respectively. A study performed in south-western Brazil found age of first capture (4 months for males and 6 months for females) corresponds to similar sizes, ~54 mm CW, for males and females and concluded that the influence of mesh selectivity for *H. pudibundus* is clear (Keunecke *et al.*, 2007a).

The substitution of the coefficients of total mortality (Z) and natural (M) in the model generated high values of fishing mortality (F) for both sexes (males = 3.25 y^{-1} and females = 2.1 y^{-1}). The total mortality for males are more related to the fishing activity than for females, once the Z values were equal to 5.35 y^{-1} and 4.2 y^{-1} for males and females, respectively. For females, however, the mortality by fishery (F) equals the natural mortality, showing that it is also relevant for total mortality. This is the additional support for the proposal that *H. pudibundus* in the region is subject to a high impact from fisheries.

In the present study, we used the Taylor's method (1960) for determining the natural mortality rate (M) and found M values of 2.1 for both sexes. However, the method of Pauly (1980), which estimates the natural mortality from the asymptotic length and the average temperature which the stock is located, found values of M equal

to 1.82 and 2.19 for males and females, respectively. This results of Pauly's method, show the highest ratio of natural mortality for females, indicating a higher index of fishing mortality for males, since it showed higher total mortality. However, Sparre *et al.*, (1989) do not indicate the use of formula of Pauly (1984) for crustaceans.

In a study about bycatch in pink shrimp fisheries, in the state of São Paulo, it was observed that *H. pudibundus* represented 29.5% of the entire catch, totaling around 16 tonnes during the study period (Keunecke *et al.*, 2007b). Trawling on shrimp species is undoubtedly the most responsible for the large biomass of bycatch (Vianna & Almeida, 2005). Still, a study conducted in Santa Catarina showed that at least 10 species of crustaceans were identified as bycatch in shrimp fishing, and that about 80% was rejected, only two species were economically valued (Kotas, 1998). In another study on the growth and mortality of *H. pudibundus* indicated that this species might be suffering overfishing recruitment (Keunecke *et al.*, 2007a), since most individuals captured in the study had a smaller size than the size of the first maturation. Still, Mantelatto *et al.*, (1995a) observed ovigerous females with carapace width between 34 mm and 64 mm, in this study the majority of females captured belongs to this size range, suggesting a high impact from fishery on the ovigerous females.

Because all that exposed, added to the fact that many bycatch species have a different life cycle from the target species, which makes the recovery of the bycatch biomass slower and makes management policies needed for the *H. pudibundus* population in southern Brazil.

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