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DINÂMICA POPULACIONAL DO SIRI AZUL *Callinectes ornatus* Ordway, 1863 (DECAPODA: PORTUNIDAE) NA ENSEADA DE BALNEÁRIO CAMBORIÚ, SC, BRASIL

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Resumo

O siri azul *Callinectes ornatus* Ordway, 1863 é frequentemente capturado nas pescas de camarão do Atântico Oeste. A espécie distribui-se continuamente desde a Carolina do Norte (EUA) ao Rio Grande do Sul (BR) e está geralmente associada a fundos de lama ou areia entre a zona de arrebentação e os 75 m de profundidade. *C. ornatus* possui importante papel na cadeia trófica do ecossistema que ocupa, atuando como predadores e comedores de detritos. Devido à sua abundância e voracidade possui importante papel no controle das espécies que fazem parte de sua dieta, além de também serem presas de diversas outras espécies marinhas. Apesar da importância da espécie para os ecossistemas costeiros e seu potencial como recurso econômico, pouca informações sobre seu ciclo e estratégias de vida encontram-se disponíveis. O presente estudo teve por objetivo descrever a dinâmica populacional de *C. ornatus* na enseada de Balneário Camboriú, avaliando sua distribuição e abundância, parâmetros de crescimento e mortalidade. As amostras foram coletadas mensalmente entre Maio/2008 e Abril/2010, na região de Balneário Camboriú, utilizando uma embarcação característica da frota pesqueira artesanal (tangoneiro / *double-rig*), equipada com redes de malha de 3,0 cm no corpo e 2,0 cm no ensacador. As coletas foram realizadas em três profundidades (7, 14, 19 m), sempre em paralelo à costa. Durante o período de coleta, foram capturados 6182 espécimes, sendo 2931 no primeiro ano e 3251 no segundo. A espécie apresentou preferência por regiões mais rasas, com maior concentração nos 7 m de profundidade. Foi observada também a maior abundância de machos sobre fêmeas nos dois anos, com uma razão sexual média de (M) 1,7:1 (F). As relações biométricas entre largura de carapaça e peso apresentaram uma relação alométrica positiva para fêmeas e uma tendência isométrica para machos. Indivíduos maturos concentraram-se nos 7 m, enquanto as isóbatas de 14 e 19 m apresentaram maior concentração de indivíduos imaturos. O crescimento para a espécie foi analisado através do método proposto por von Bertalanffy (VBGM). Os parâmetros de crescimento ± 95% IC estimados para fêmeas foram K=1,82 y^{-1} e CW=120 mm (fixado). Para os machos foi encontrado K=1,89 y-1 e CW∞=103,19 mm ± 2,98. A longevidade máxima estimada para fêmeas e machos foi de 2,5 anos e 2,4 anos, respectivamente. O coeficiente de mortalidade total (Z) apresentou valor mais alto para fêmeas (7,36) que para machos (2,46). O coeficiente de mortalidade natural (M) apresentou valores similares para machos e fêmeas (4.83), enquanto a mortalidade por pesca (F) apresentou maiores valores para fêmeas (4,83) que para machos (0,058). O presente estudo descreveu pela primeira vez a distribuição e abundância de *Callinectes ornatus* com suas relações biométricas, padrões de distribuição, crescimento e mortalidade em uma região próxima ao limite sul de distribuição da espécie.

Palavras chave: Biologia populacional, decapoda, portunidae, *Callinectes ornatus*, razão sexual, distribuição, crescimento, von Bertalanffy, mortalidade

Abstract

The blue crab *Callinectes ornatus* Ordway, 1863 is frequently caught in double-rig trawling for shrimps in Western Atlantic. The species has a continuous distribution since the North Caroline (USA) to the Rio Grande do Sul (BR) and is usually associated to muddy and sandy bottoms, between the intertidal and the 75 m isobath. *C. ornatus* plays an important role in inner shelf ecosystems, acting as predators and scavengers. Due to its voracity and abundance, the species has important rule in the control of other species included in its diet. Besides, *C. ornatus* serves as pray to marine species. Despite its importance for the coast ecosystems and its potential as fishery resource, few information about its life cycle and strategies are available. The present study has as objective describe the populational dynamic of *C. ornatus* at Balneário Camboriú bay, including its distribution, abundance, growth parameters and mortality. Samples were monthly obtained between May/2008 and April/2010, by using a typical boat of the local artisanal fishing fleet (double-rig trawlers), equipped with nets of 3.0 centimeters mesh at body and 2.0 centimeters at cod. The trawlings were performed on one transect at three depths (7, 14 and 19m), parallel to the shoreline. During the two years of sampling a total of 6182 specimens were caught, being 2931 during the first year an 3251 during the second. The species presents a clear preference for shallower regions, with higher abundance at 7m isobath. During the two years it was observed a dominance of males over females with a mean sex ratio of (M) 1.7:1 (F). Width-weight biometric relationship shows an alometric positive growth for females and a isometric trend for males. Mature individuals concentrated at 7 meters, while the 14 and 19 meters samples had higher abundance of immature ones. The species' growth parameters ± 95% CL were determined using the von Bertalanffy growth model (VBGM). Females presented K=1.82 y^{-1} e CW=120 mm (fixed). Males had K=1.89 y^{-1} e CW∞=103.19 mm ± 2.98. Longevity was estimated in 2.5 and 2.4 years for females and males respectively. The coefficient of total mortality (Z') presented higher values for females (7.36) than males (2.46).The coefficient of natural mortality (M) had similar values for females and males (2.53 and 2.41, respectively), while fisheries mortality (F) had higher values for females (4.83) and lower for males (0.058). The present study described for the first time the distribution and abundance of *Callinectes ornatus* with its biometrical relations, distributional patterns, growth and mortality at a region close to de South limit of the species distribution.

Key words: Populational Biology, Decapoda, Portunidae, *Callinectes ornatus*, sex ratio, distribution, growth, von Bertalanffy, mortality

Introdução

A população de determinada espécie consiste em um grupo de indivíduos que compartilham suas características genéticas, ocupam uma área territorial determinada e possuem a capacidade de procriar (Chakraborty, 2001; Begon *et al.*, 2006). Populações animais são naturalmente dinâmicas, apresentando variações sazonais, anuais, padrões de distribuição, entre outras características. O estudo da dinâmica populacional nos permite, por exemplo, responder questões relativas à variação espaço-temporal da abundância de uma espécie em determinado local com base em estimativas de abundância, tais como número de indivíduos ou captura por unidade de esforço (CPUE). No entanto, estes fatores considerados isoladamente podem guiar a pesquisa para conclusões errôneas. Um registro meramente numérico está fadado a ignorar informações vitais sobre a dinâmica da espécie, deixando de observar questões como idade dos indivíduos e estágios de maturação. Duas populações numericamente semelhantes podem apresentar características bastante distintas. Caso uma delas seja formada apenas por indivíduos velhos e a outra por indivíduos de variadas classes de idade, uma pode vir à extinção em menos tempo do que a outra. Para que tais perguntas possam ser respondidas satisfatoriamente faz-se necessário um estudo que abranja além da abundância da espécie, seu ciclo de vida, variações de estágios de maturação, reprodução, crescimento, mortalidade e as condições ambientais às quais a mesma está submetida (Townsend *et al.*, 2010). As condições físico-químicas do ambiente podem revelar preferências e padrões, além de clarificar questões sobre diferenças de abundância e dinâmica de uma mesma espécie em regiões distintas (Townsend *et al.*, 2010).

A utilização de relações biométricas na avaliação dos parâmetros populacionais permite observar eventos que possam ocorrer dentro de uma população, tais como variações na relação comprimento-peso durante o período reprodutivo ou sob estresse ambiental (King, 2007). Esta ferramenta possibilita ainda o uso de relações matemáticas estabelecidas entre os parâmetros investigados para, a partir de um dos parâmetros, estimar dados que possam ter sido perdidos durante o processo investigativo (Rangonese *et al.*, 1997). Através de tais relações também é possível estabelecer diferenças entre estoques, visto que as relações morfométricas podem refletir um isolamento reprodutivo (Begg *et al.*, 1999).

A importância dos oceanos como fonte de alimento tem sido subestimada, pois apesar de corresponder a 71% da superfície terrestre é responsável por apenas 17% da proteína animal consumida no mundo, enquanto o ambiente terrestre, 29% da superfície, gera 83% da proteína animal consumida no mundo. Grande parte da proteína animal continental é obtida através de sistemas de cultivo, tais sistemas apresentam maior eficiência e menor custo que a extração de recursos pesqueiros. As dificuldades impostas pelo ambiente marinho tornam a pesca a única atividade econômica envolvida com a produção de alimentos que é essencialmente extrativista, portanto não existe um controle direto do explorador sobre o recurso, tornando-o menos eficiente que outros como a agricultura e a pecuária. Parte da baixa eficiência da pesca como produção de alimento dá-se pelo fato de que os dois primeiros níveis da cadeia trófica marinha estão praticamente indisponíveis ao consumo direto por seres humanos, com exceção ao *krill*, explorado em regiões como Japão, Coréia do Sul, Ucrânia e Polônia (Fonteles-Filho, 2011).

Devido ao caráter extrativista da pesca, faz-se necessário o conhecimento da dinâmica populacional das espécies exploradas para que se possam determinar padrões espaço-temporais de agregação dos recursos pesqueiros e melhores metodologias de captura com vista a maximizar a produção e a desenvolver medidas que ajudem a conservar o estoque de modo que este não venha a colapsar devido à sobrepesca (Fonteles-Filho, 2011). Assim sendo, a dinâmica populacional atua como importante ferramenta da biologia pesqueira afim de reunir conhecimento que leve à administração dos recursos pesqueiros (D'incao, 1984).

A pesca de camarões na região Sudesde e Sul do Brasil apresenta como principais espécies alvo o camarão-rosa (*Farfantepenaeus brasiliensis e F. paulensis*) e o camarão-sete-barbas (*Xiphopenaeus kroyeri*). Outras espécies como o camarão-barba-russa (*Artemesia longinaris*), o camarão-santana (*Pleoticus muelleri*) e o camarão-branco (*Litopenaeus schmitti*) têm ganhado espaço na pesca industrial (D'incao *et al.* 2002). Assim como acontece em todo mundo um dos grandes problemas da pesca de camarão no Brasil é a captura incidental (*bycatch*). Define-se por *bycatch* a captura de indivíduos através de uma arte de pesca que objetiva outra espécie (Keunecke, 2007). A ocorrência de fauna acompanhante em pescas marinhas está bem documentada por estudos no Brasil e em todo mundo (Alverson *et al.*, 1996; Probert *et al.,* 1997; Lopes *et al.*, 2002; Graça- Bail & Branco, 2003; Branco & Fracasso, 2004; Branco & Verani, 2006; Keunecke *et al.*, 2007). Segundo Earys (2007), aproximadamente sete milhões de toneladas de peixes são descartados por pescadores todo ano, o equivalente a 8% da captura de peixes marinhos em todo mundo. Dentre as artes de pesca, o arrasto de camarão encontra-se entre os que apresentam maior *bycatch*, contribuindo com cerca de 27% do descarte mundial.

A quantidade de crustáceos decápodos associados à pesca do camarão supera consideravelmente o volume de camarão em condições de comercialização. O material descartado possui pouca chance de sobrevivência e é composto por diversos grupos entre eles peixes, crustáceos, tartarugas, mamíferos, corais, algas e por vezes aves marinhas (Earys, 2007). Além das espécies capturadas incidentalmente a pesca de arrasto também é responsável pela perturbação do substrato marinho, do qual dependem diversas espécies. Devido à sobreposição de hábitat com algumas espécies de interesse comercial, a pesca incidental (*bycatch*) de *Callinectes ornatus* é bastante recorrente (Branco & Verani, 2006). De acordo com Branco & Fracasso (2004), a família Portunidae aparenta ser a mais abundante família de crustáceos na pesca de arrasto com portas em toda costa brasileira, apresentando como espécies dominantes *C. ornatus e C. danae.*

A família Portunidae é composta por cerca de 300 espécies (Norse, 1977), 13 das quais são integrantes do gênero *Callinectes* Stimpson (Robles *et al.*, 2007). Espécies do gênero são economicamente exploradas em todo o mundo, com destaque para o siri-azul *Callinectes sapidus*, que apresenta grande importância na economia de regiões do Atlântico noroeste, Golfo do México e Mar do Caribe (Williams, 1974). Por sua importância econômica, a espécie possui um ciclo de vida bastante conhecido, com estudos e séries temporais capazes de representar ciclo e estratégias de vida satisfatoriamente. Entretanto, outras espécies do mesmo gênero, com potencial para exploração econômica como *Callinectes ornatus*, carecem de informações que possibilitem o desenvolvimento de estratégias de exploração e conservação.

O siri azul *Callinectes ornatus* apresenta distribuição restrita ao atlântico oeste e contínua desde a Carolina do Norte (Estados Unidos) ao Rio Grande do Sul (Brasil), incluindo as ilhas da América Central. Habita preferencialmente substratos não consolidados, lamosos ou arenosos. Possui preferência por águas rasas, mas pode ser encontrado desde o entre-marés até os 75m de profundidade (Melo, 1996). A presença da espécie pode estar associada a massas de água costeiras, com maior salinidade que as interiores, realizando incursões a regiões estuarinas associadas às marés e à zona de influencia da cunha salina (Norse, 1977; Buchanan & Stoner, 1988).

A espécie desempenha um importante papel na cadeia trófica marinha. Assim como outros portunídeos, costuma ingerir o sedimento a fim de digerir as bactérias presentes nos grãos, porém apresenta uma dieta predominantemente carnívora, alimentando-se principalmente de animais predados ou em decomposição (Pinheiro *et al.,* 1997). Devido à sua abundância, voracidade e capacidade predatória, atua tanto como regulador de diversas outras espécies quanto na reciclagem de nutrientes, por ser um importante consumidor de detritos orgânicos (Haefner, 1990).

Apesar de sua importância ecológica e potencial econômico, poucos estudos foram desenvolvidos acerca dos parâmetros de crescimento e mortalidade de *C. ornatus*. A ausência de estruturas corporais rígidas impede o uso de medidas diretas para estimar o crescimento em crustáceos, já que durante a muda a carapaça antiga é abandonada e o incremento durante a fase de crescimento é variável, sofrendo influencia inclusive das variáveis ambientais. Devido à impossibilidade da medição direta, outros métodos foram utilizados para a avaliação do crescimento em crustáceos, geralmente baseados na estrutura de tamanhos e parâmetros de crescimento da população. O método de crescimento proposto por von Bertalanffy (1938) (VBGM) é capaz de descrever de forma eficiente o crescimento em crustáceos e é comumente usado no estudo de espécies marinhas (King, 2007). Em crustáceos, 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 correta estimativa dos parâmetros de crescimento permite que se estimem os coeficientes de mortalidade da população, uma informação de grande importância para o manejo de espécies comerciais (Keunecke *et al*., 2008).

Alguns trabalhos foram desenvolvidos sobre distribuição e abundância da espécie (Branco & Lunardon-Branco, 1993; Negreiros-Fransozo *et al.* 1999; Baptista *et al.* 2003; Branco & Fracasso 2004; Fernandes *et al.* 2006; Pereira *et al.*, 2009; Golodne *et al.* 2010; Keunecke *et al.* 2011; Tedesco *et al*. 2012;), porém pouca informação sobre seu ciclo de vida encontra-se publicada, tornando necessária a pesquisa a fim de disponibilizar informações que possibilitem uma melhor compreensão de questões como crescimento, dinâmica populacional e estratégias de vida da espécie.

Objetivo Geral

Este trabalho tem por objetivo descrever a dinâmica populacional de *C. ornatus* na enseada de Balneário Camboriú (SC).

Objetivos Específicos

- Determinar a distribuição e abundância de *C. ornatus*, sua variação sazonal e possíveis relações com os parâmetros ambientais (temperatura, salinidade, tipo de fundo e profundidade).
- Estimar o tamanho médio de primeira maturação
- Identificar o período reprodutivo e a composição etária dos indivíduos que contribuem em cada evento.
- Estimar o crescimento individual para ambos os sexos
- Estimar os coeficientes de mortalidade total (Z), natural (M) e por pesca (F) para ambos os sexos

A dissertação foi dividida em dois capítulos. O primeiro abrange as análises relativas à distribuição e abundância da espécie, cumprindo os três primeiros objetivos específicos. O segundo capítulo trata do crescimento e mortalidade, relativos aos dois últimos objetivos específicos.

Metodologia Geral

Área de estudo

As amostras analisadas provem da região de Balneário Camboriú (26º 59' 07'' S - 48º 35' 58”W) (Figura 1), Santa Catarina, conhecida como uma tradicional área de pesca do litoral Catarinense. A região recebe um grande aporte de turístico todos os anos, apresenta alta urbanização e consequentemente forte impacto antrópico. Este consiste no primeiro estudo realizado para a espécie na região.

A área é influenciada por 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 das espécies locais.

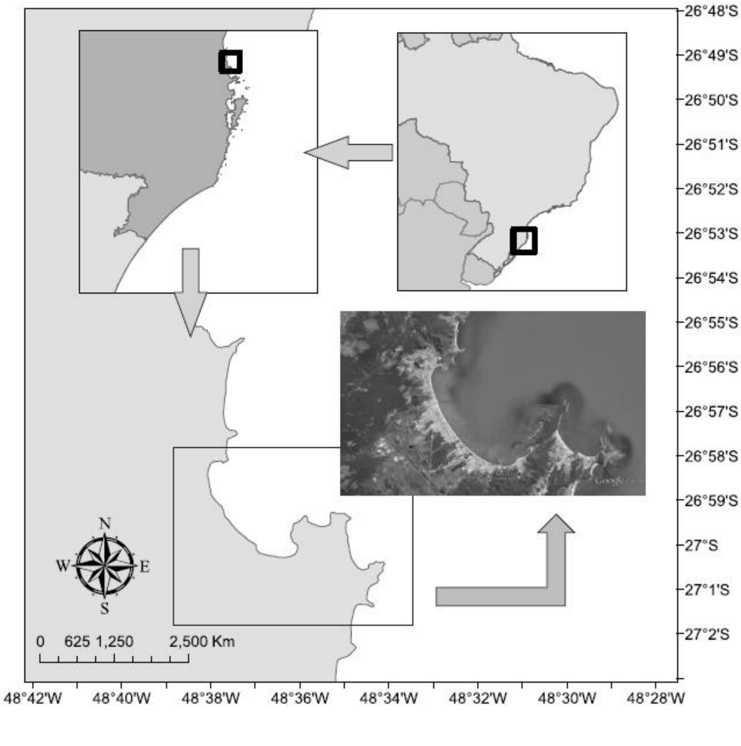

Figura 1: Mapa da região de Balneário Camboriú (SC), Brasil.

Amostragem

O material analisado foi coletado mensalmente entre Maio/2008 e Abril/2010 na região de Balneário Camboriú, Santa Catarina. Perpendicular a praia foi delimitado um transecto com três profundidades, 7, 14 e 19 metros. Em cada isóbata foram realizados 2 arrastos de 15 minutos, a uma velocidade média de 2 nós, em paralelo à costa, utilizando um barco característico da frota artesanal camaroneira (tangoneiro / double-rig). Considerando que a embarcação opera duas redes em cada arrasto, o material obtido em cada um foi considerado como pertencente à mesma amostra. A embarcação encontrava-se equipada com redes de 3,0 centímetros de malha no corpo e 2,0 centímetros no ensacador. Em cada ponto de coleta foram mensurados os seguintes parâmetros ambientais: temperatura de fundo (termômetro – 0,1ºC), transparência da água (disco de Secchi), salinidade de fundo (refratômetro) e profundidade (eco-sonda da embarcação). A água de fundo foi coletada utilizando uma garrafa de Van-Dorn.

Processamento amostral

Todo o material coletado foi refrigerado em campo e trazido para o Laboratório de Crustáceos Decapódos (FURG). Em laboratório os siris foram medidos e identificados quanto ao sexo e estágio de maturação através da observação de caracteres secundários. As medidas tomadas em laboratório foram: largura da carapaça incluindo espinho lateral (CW1), largura da carapaça sem o espinho lateral (CW2) e peso total (Wt) (Figura 2).

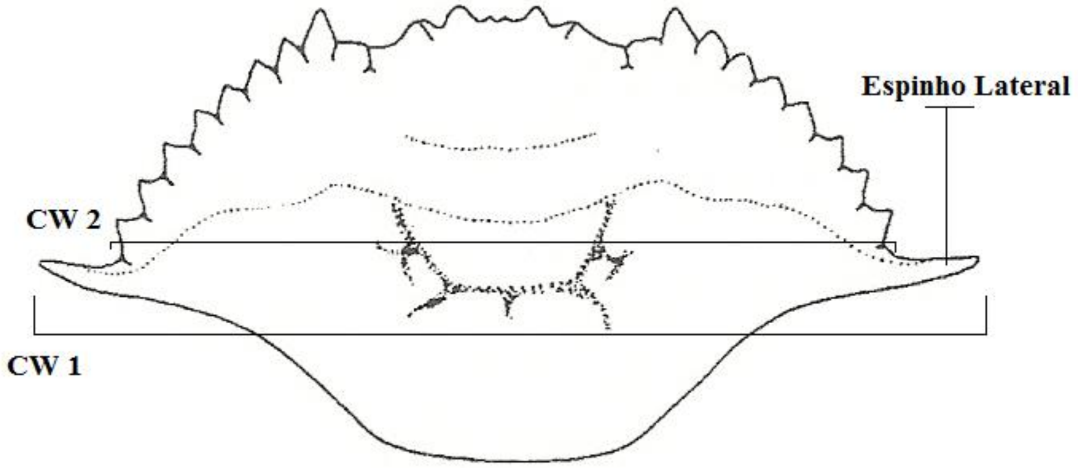

Figura 2: Ilustração da carapaça de *Callinectes ornatus* indicando as medidas tomadas em laboratório e o espinho lateral.

Biologia Populacional

A abundância de indivíduos foi analisada separadamente para machos e fêmeas levando em consideração o estrato de profundidade e a sazonalidade através de uma Análise de Variância Fatorial (Two-way-ANOVA) e um teste *a posteriori* de Tukey (Venables & Dichmond, 2004). Foram respeitados os pré-requisitos de normalidade e homogeneidade de variância para todas as análises. A razão sexual foi analisada de acordo com um teste de Qui², com nível de significância 5% e n-1 graus de liberdade (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 (Lc1) 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 largura de carapaça com espinho (CW1) e largura de carapaça sem espinho

(CW2) e peso (Wt), foram determinadas separadamente para fêmeas e machos.

Reprodução e Recrutamento

O período reprodutivo da população foi estimado com a média da CPUE (g/15min) de fêmeas ovígeras (ovário desenvolvido e maduro) em cada mês e/ ou estação do ano e profundidade. O período de recrutamento foi determinado através de uma curva de captura utilizando a CPUE (captura por unidade de esforço =CPUE), considerando como fase de recrutamento o pico de juvenis capturados. Foram considerados juvenis todos os indivíduos imaturos.

Crescimento e Mortalidade

Para a estimativa dos padrões de crescimento foi utilizada a análise de progressão modal (MPA) com grupos etários ajustados de acordo com o modelo proposto por von Bertalanffy (1938) (VBGM). 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). 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).

Os anexos que se seguem são fruto da pesquisa realizada durante os dois anos de mestrado. Ambos apresentam estrutura de artigos independentes e foram formatados de acordo com as normas exigidas pelas revistas para os quais foram submetidos.

Considerações Gerais

As informações geradas por este estudo permitiram observar a dinâmica populacional de *Callinectes ornatus* na costa de Santa Catarina e comparar com estudos realizados em outras regiões a fim de identificar padrões latitudinais de distribuição e estratégias de vida. Os parâmetros populacionais obtidos podem também ser utilizados para o desenvolvimento de estratégias de manejo pesqueiro levando em consideração espécies capturadas no *bycatch.*

A observação da distribuição de indivíduos adultos e juvenis por profundidade evidenciou o uso de áreas de menor profundidade como área de reprodução, concentrando maior número de indivíduos adultos, enquanto as maiores profundidades eram dominadas por jovens, caracterizando uma área de crescimento. O estudo da relação biométrica entre peso e largura de carapaça evidenciou a existência de uma variação nas estratégias de vida entre populações em regiões distintas. Tais diferenças podem estar associadas à variação latitudinal e, consequentemente, à variação nas condições ambientais. Quanto à razão sexual, os resultados encontrados apresentam uma dominância numérica de machos sobre fêmeas, que corrobora com outros estudos realizados para a espécie. Fêmeas ovígeras foram encontradas em todas as estações do ano, sugerindo uma reprodução contínua, que já foi observada por outros autores. A constante presença de juvenis também é um indicador de uma reprodução continua. Os parâmetros de crescimento e mortalidade apresentados por esse trabalho para a população de Balneário Camboriú apresentaram coerência biológica com a ecologia da espécie.

C. ornatus corresponde a uma das principais espécies capturadas no bycatch das pescas de camarão no litoral brasileiro, sofrendo impacto direto das pescarias industriais e artesanais. Entretanto, o defeso das pescarias de camarão em Santa Catarina compreende o período entre 1 de Março e 31 de Maio, período correspondente ao outono, estação de maior reprodução das espécies de camarão. Considerando o ciclo de vida do *Callinectes ornatus* apresentado por esse estudo, o período de reprodução não coincide com o das principais espécies exploradas, portanto a espécie sofre alta pressão de pesca durante sua fase reprodutiva. Soluções que poderiam atenuar o impacto das pescarias sobre *C. ornatus* poderiam incluir orientações aos pescadores para que estes devolvessem ao mar os indivíduos capturados, visto que de acordo com estudos realizados mostram que crustáceos apresentam alta resiliência ao tempo passado no convés das embarcações.

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Anexo 1

Distribution and abundance of a population of the blue crab *Callinectes ornatus*, Ordway 1863 (DECAPODA: PORTUNIDAE) inhabiting an area close to its southern limit distribution.

Distribution and abundance of a population of the blue crab *Callinectes ornatus*, Ordway 1863 (DECAPODA: PORTUNIDAE) inhabiting an area close to its southern limit distribution.

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Abstract

The blue crab Callinectes ornatus *Ordway, 1863 is frequently caught in double-rig trawling for shrimps in Western Atlantic, where its distribution stretches from North Carolina (USA) to Rio Grande do Sul (BR). It is usually found in muddy and sandy bottoms, from intertidal zone to the 75m isobath. It plays an important role in inner shelf ecosystems but in spite of that, scarce information on its life-history is available. Since the ecosystem approach in fisheries is a mandatory strategy, the present study intends to investigate the ecological distribution of the blue crab* Callinectes ornatus *off the coast of Santa Catarina state, an area considered as near the southern distribution limit of this species. Samples were monthly obtained between May/2008 and April/2010, by using a typical boat of the local artisanal fishing fleet (double-rig trawlers), equipped with nets of 3.0 centimeters mesh at body and 2.0 centimeters at codend. The trawlings were performed on one transect at three depths (7, 14 and 19m), parallel to the shoreline. During the two years of sampling a total of 6182 specimens were caught, being 2931 during the first year an 3251 during the second. The species presents a clear preference for shallower regions, with higher abundance at 7m isobath. During the two years it was observed a dominance of males over females with a mean sex ratio* *of 1.7:1 (M:F). Width-weight biometric relationship shows an alometric positive growth for females and a isometric trend for males. Mature individuals concentrated at 7 meters, while the 14 and 19 meters samples had higher abundance of immature ones. Ovigerous females presented higher abundance at first year, with higher catch at February/2010. The present study described for the first time the population dynamic of* Callinectes ornatus *with biometric relations and distribution patterns at the southern limit of distribution, comparing with other populations and analyzing latitudinal differences at life patterns*.

Keywords: Bycatch, Population biology, Decapoda, Portunidae, *Callinectes ornatus*, sex-ratio, allometry, reproduction, distribution, abundance.

INTRODUCTION

The genus *Callinectes* Stimpson, 1860 is composed of 14 species, most of which are inhabitants of shallow coastal waters. A total of eleven species are found in the Atlantic Ocean and three at the Pacific (Williams, 1974). The blue crab *Callinectes ornatus*, Ordway 1863 is restricted to the Western Atlantic Ocean, and presents a continuous distribution from the United States, to Southern Brazil. This species is mostly associated to sandy or muddy bottoms, from the intertidal zone to the 75m isobath (Melo, 1996). Studies by Norse (1977) and Buchanan & Stoner (1988) characterize the preference of the species for marine habitats, with very low occurrence inside estuarine lagoons or regions with elevated fresh water influence. The species from the *Callinectes* genus plays an important role in neritic environments acting as scavengers, predators and food resource for other aquatic organisms (Haefner, 1990).

Callinectes ornatus presents variations in the use of habitat throughout its life cycle. Ovigerous females migrate to deeper areas, where the higher salinity provides a better environment for the hatching of eggs and the zooplanktonic larvae (Fernandes *et al.* 2006). Still according to Fernandes *et al.* (2006), studying at Ilha do Frade (ES), individuals of smaller size classes have a preference for shallow and coastal areas, with moderate salinity and high concentration of organic material. This habitat selection favors the protection of juveniles because prevents intraspecific competition between young and adult individuals (Tudesco *et al.* 2012).

Callinectes ornatus is found at the Brazilian coast throughout the year in all growth stages. The abundance of this species may change according to environmental factors as salinity, temperature and depth. Norse (1977) describes a higher abundance of *C. ornatus* at high salinity regions. The preference of the species for saline waters is evidenced by the work of Carvalho & Couto (2011) at Cachoeira River estuary (Bahia, Brazil). Studies on brachyuran have cited an important influence of temperature over distribution and life patterns (Buchanan & Stoner, 1988; Chacur & Negreiros-Fransozo, 2001; Rome *et al.*, 2005). Laboratorial experiments performed by Rome *et al.* (2005) with specimens of *Callinectes sapidus*, collected at Chesapeake Bay, tested its tolerance to temperature variations, and registered a lower mortality rate between 14º C and 30.5 ºC. This study also revealed that low temperature and salinity reduces the osmotic efficiency and raises the energetic demand (to keep the body functions and osmoregulation), leading the crabs to a higher mortality during winter periods.

Studies on latitudinal variation over the structure of populations and reproduction are of high importance for enlightening the differences of life patterns once populations under environmental variations may adjust the biological process and ecological events (Sastry, 1983). To this date, there are no studies on latitudinal variations at life patterns for *Callinectes ornatus*.

Therefore, this investigation aims to provide novel information on population biology of this blue crab species, highlighting the possible particularities showed by a population inhabiting an area close to de distribution limits.

MATERIALS AND METHODS

The sampling area comprises the Balneário Camboriú bay (26º59'07" S - 48º35'58" W), located at the Santa Catarina State, Brazil (Fig. 1), an area considered close to the southern distribution limit for the studied species. The region is a traditional fishing area in southern Brazil (Machado *et al*., 2009).

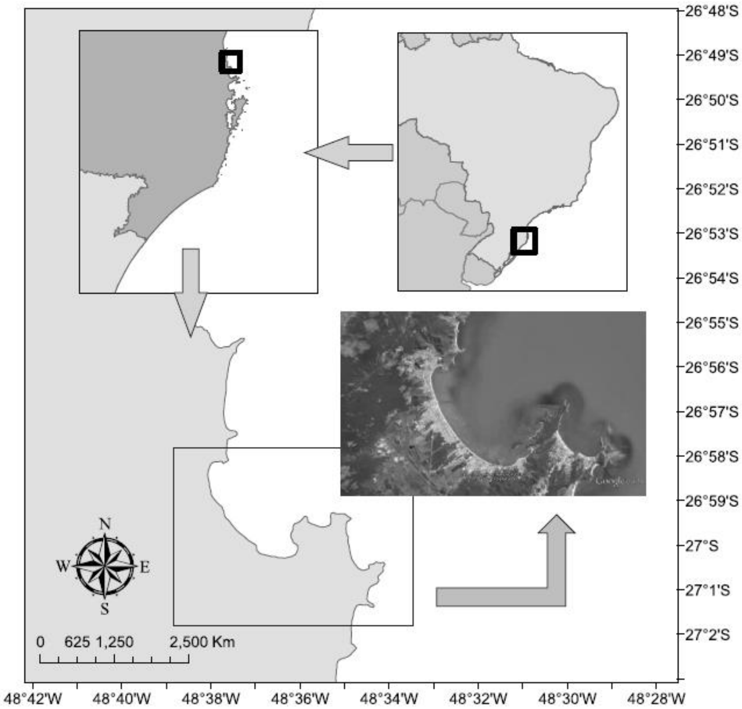

Fig. 1: Spatial view of Balneário Camboriú bay (SC), Brazil.

The biological samples were monthly collected, during two years, from May/2008 to April/2010, at Balneário Camboriú. The sampling area was delimited by one transect perpendicular to the coast line with three isobaths (7, 14 and 19 m depth). Each isobath was trawled twice during 15 minutes at an average speed of 2 knots parallel to the coastline using an artisanal shrimp fishing boat (double rig), trawling two nets, that were grouped as a single sample (Machado *et al., 2010*).

Environmental information of bottom temperature (ºC) and bottom water salinity were obtained *in situ*, by using a thermosalinometer. An echobathymeter coupled with a GPS (Global Positioning System) was used to record depth at sampling sites.

After sampling, *Callinectes ornatus* individuals were identified, sexed and classified according to maturation stage (Williams, 1974). The crabs were measured considering carapace width including antherolateral spine (CW1-mm), carapace width excluding antherolateral spine (CW2-mm) and wet weight (Wt-g) (Williams, 1974).

The average realtive abundance (CPUE – g/15min) of males and females were compared for depth and season through a Two-Way Analysis of Variance (Two-Way ANOVA) followed of a Tukey test with 5% of significance. Data were tested for the assumptions of normality (Komolgorov-Smirnov) and homogeneity (Bartlett) (Zar, 2004). The sex ratio was calculated based on the monthly frequencies of male (M):female (F) and differences at the 1:1 proportion were tested by the χ^2 test, being considered as significant when $p<0.05$. The biometric relationships of CW1 versus CW2 (width-width) was estimated by simple linear regression given by $CW1=a+b(CW2)$, where “a” is the intercept with the dependent variable axis and “b” is the slope. This analysis allows recovering information of those individuals with broken lateral spines. The CW1 versus Wt relation (width-weight) was described by the power model $Wt=a(CW1^b)$, where “a” is the intercept and “b” is the coefficient of allometry. Points outside the 95% confidence interval were automatically excluded based on Dumont and D’Incao (2010). Both models were fit for the two sexes separately. The size of fishing recruitment was estimated based on the curve of capture. Data were log transformed according to a Poisson distribution, and the relation between numeric abundance and environmental variables was tested by using a generalized linear model (GLM) and a Poisson (log link) distribution was adopted for the data (Xiao, 2004; Venables & Dichmont, 2004). The GLM analysis was made using the software R. Significant influences were accepted when $p<0.05$. The most adequate model was chosen according the lower AIC value (Lai & Helser, 2004). The analysis was performed considering four categories: immature males, mature males, immature females and mature females.

RESULTS

Enviromental Parameters

It is possible to identify a seasonal pattern in the temperature, with higher values recorded during summer and autumn and lower ones recorded during winter and spring. In the first year, the highest values were registered in summer (February/2009 (24.7°C ± 2.25°C) and March/2009 (25.3°C ± 0.76°C)) and the lower for the winter (May/2009 (18.3°C ± 1.15°C) mand June/2009 (18.3°C ± 0.05°C)). In the second year, the highest temperatures were registered in summer (December/2009 (25.06°C ± 0.41°C) and February/2010 (25.16°C ± 0.61°C)) and lower in winter (August/2009 (17.86°C ± 0.20°C) and July/2009 (18.33°C ± 0.05°C)) (Fig. 2). Statistical analysis shows no significant difference in bottom temperature between years and depth.

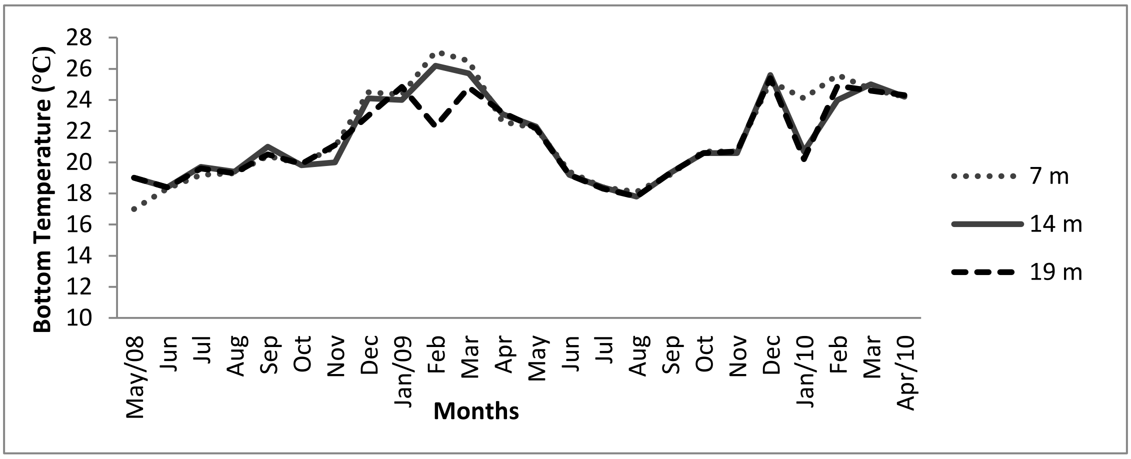

Fig. 2: Bottom temperature variation for each isobath (7, 14 and 19 m) in the region of Balneário Camboriú bay (SC), Brazil, from May/2008 to April/2010.

Salinity showed an oscillating pattern for the first year and a more stable pattern for the second one. The highest values of salinity were registered in summer and autumn and lowest during winter and spring, for both years. The highest values were registered in March/09 (spring - 37.3± 0.81) and April/09 (autumn - 37.5 ± 1.97) for the first year and May/09 (autumn - 34.9± 0.13) and March/10 (spring - 34.9±0.31) for the second. The lowest values for the first year were observed at June/08 (winter - 32.8±0.23) and November/08 (spring - 26±1.43). The low values of salinity at November may be consequence of an atypical pluviometric event. For the second year the lowest values were registered at August/09 (winter - 32.8±0.13) and September/09 (spring - 33.2±0.19) (Fig. 3). Statistical analysis shows no significant difference in bottom salinity between years and depth.

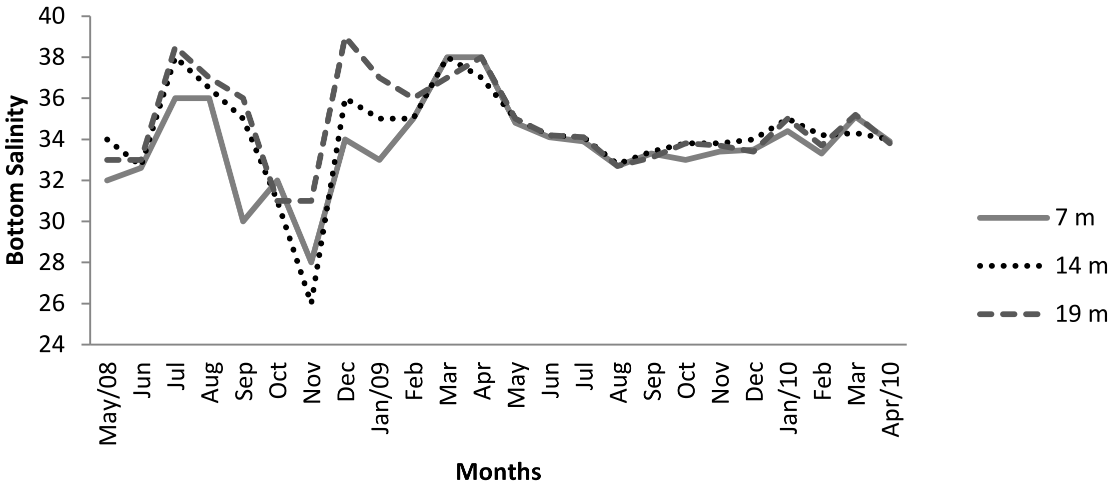

Fig. 3: Bottom salinity variation for each isobath (7, 14 and 19 m) in the region of Balneário Camboriú bay (SC), Brazil, from May/2008 to April/2010.

Catch per unit of effort (CPUE):

A total of 6182 individuals were caught during the two years of sampling, 2931 at the first year and 3251 at the second. As general pattern, *C. ornatus* abundance seems to be associated to depths and seasons. A statistical analysis showed a significant difference between the two years ($p<0,005$). The depths of 7 meters (N=3247) showed significantly higher abundance than the 14 (N=1384) and 19 (N=1551) meters. Seasonal trends indicated higher abundances in May/08 (N=440), November/2008 (N=468) and February/2009 (N=580). The second year (May/2009 to April/2010) showed few variations between months, with an isolated abundance peak in April/2010 (N=822). The sample of September/2008 had no individuals of the species.

For the first year, both genders had higher values of numeric abundace at 7 meters (M=1223; F=850), a decrease at 14 meters (M=168; F=70) and a rise at 19 (M=273; F=139). However, in the second year there was a different pattern, with a decrease for males in higher depths and the opposite occurring with the females (Fig. 4). Statistical analysis shows significant differences ($p<0.05$) of abundance for the 7 meters depth when compared to 14 and 19 meters.

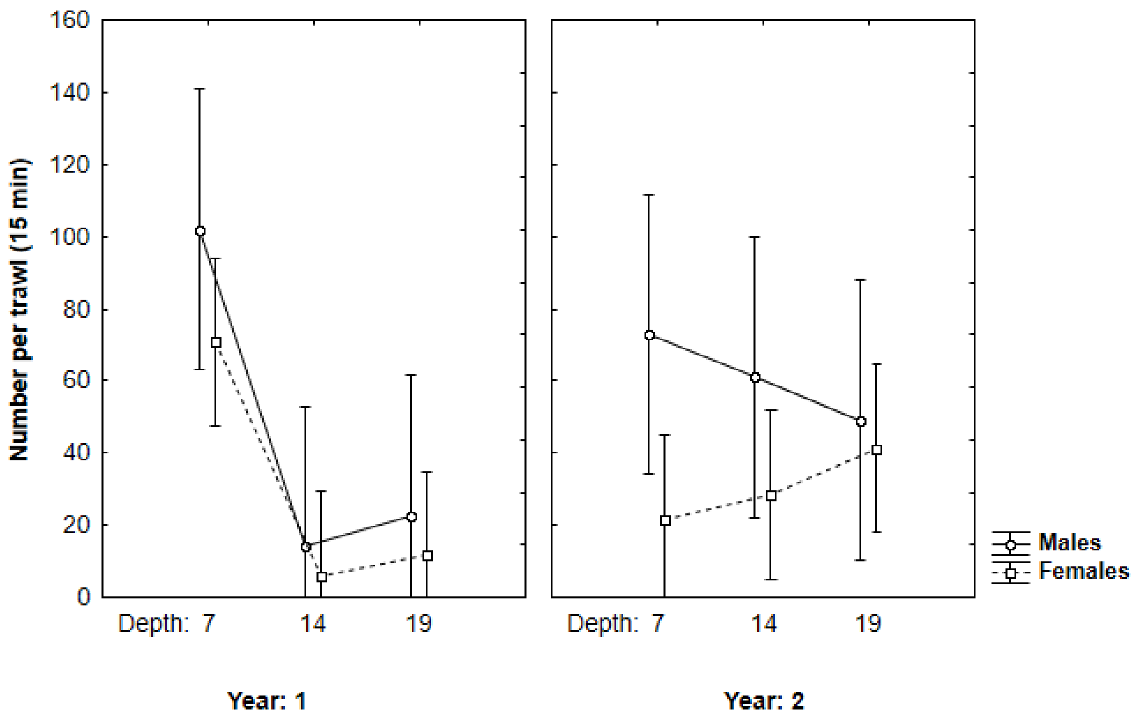

Fig. 4: Abundance mean variation for males and females between years and isobath (7, 14 and 19 m) in the region of Balneário Camboriú bay (SC), Brazil, from may/2008 to april/2010.

Callinectes ornatus also presented differences in mean CPUE (g/15min) according to depth. The CPUE (Fig. 5) and showed great variation, especially for the 7 meters isobath. Higher mean values were observed at autumn of 2010 (3,653.58 g/15min). Conversely, the lower mean values were recorded in summer of 2010 (313.35 g/15min). The 14 meters isobath had a constant low abundance mean, with higher value at summer 2010 (476.25 g/15min). At 19 meters, the mean abundance had a high variation, with no catch at autumn and winter of 2008 and higher means at autumn 2009(1,012.89 g/15min) and autumn 2010(1,127.98 g/15min).

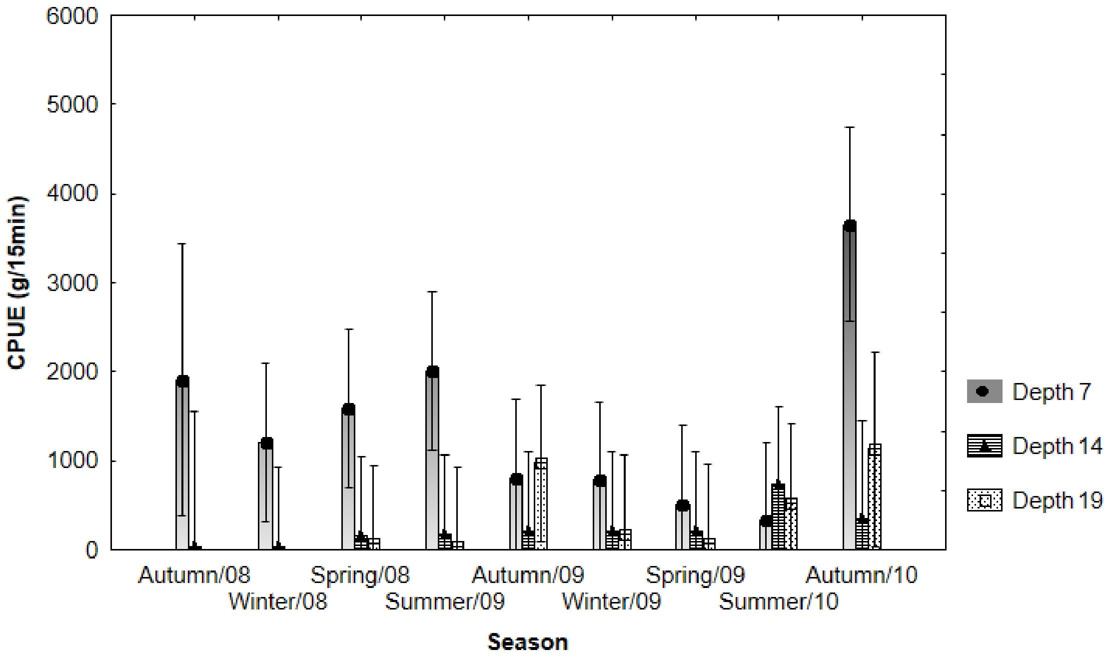

Fig. 5: CPUE mean variation between seasons and isobath (7, 14 and 19 m) for the years of sample in the region of Balneário Camboriú bay (SC), Brazil.

The GLM analysis showed significant influence of temperature, depth and salinity on the abundance. Mature males and females presented an inverse relation between depth and abundance, with higher catch at 7m depth. Immature females had a trend to be positive influenced by depth while immature males had a negative trend (Table 1).

Table 1: GLM analysis of depth, salinity and temperature influence over the abundance with respective AIC. Values of β for each variable with respective significance (‘***’ = p<0,001/ ‘**’ = p<0,01 / ‘*’= p <0,05 / ‘ ’= p >0,05)

	Depth	**Salinity**	**Temperature**	**AIC**
Immature Males	-0,098***	-0,691***	0,236***	2667,8
Mature Males	-0,580***	-0,723***	0,496***	1937
Immature Females	0,134***	-0,601***	0,138**	1590.7
Mature Females	-0,718***	-1,067***	0,109*	1271

Seasonal and Spatial variation in the Carapace Width (CW):

Size structure based on carapace width for males (Fig. 6) presented the highest and lowest mean values in the second (69.65 ± 19.36 mm) and first autumn (33.94 ± 22.66 mm), respectively. The seasons were statistically significant ($p<0.05$) as a factor influencing the size composition.

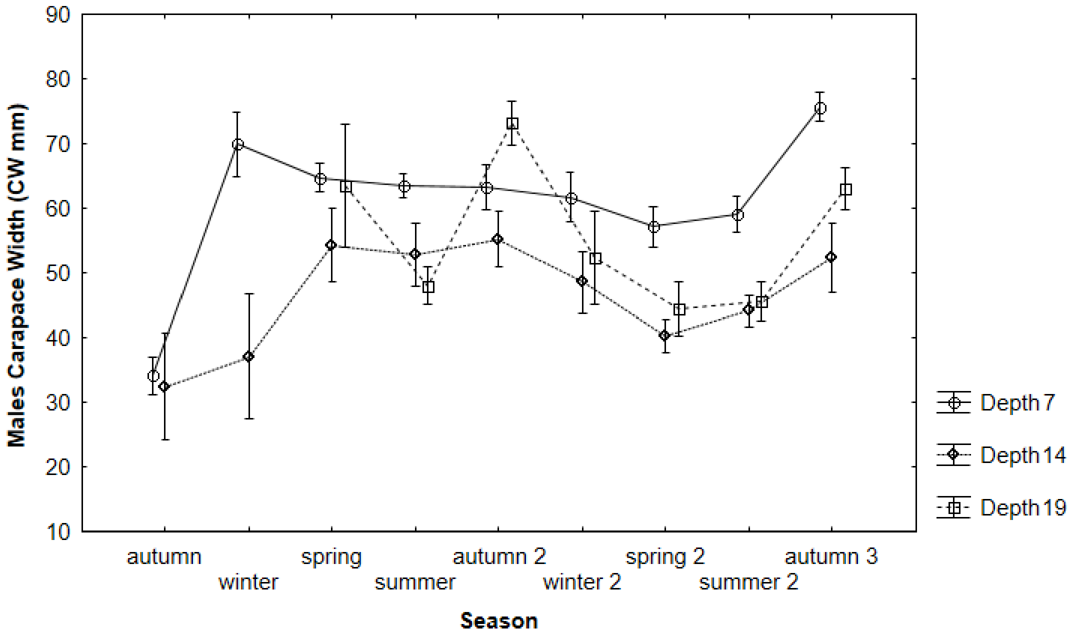

Fig. 6: Variation of the mean of the carapace width (CW), for *Callinectes ornatus* males in the region of Balneário Camboriu (SC). The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values.

The analisys of carapace width indicate that of *C. ornatus* females (Fig. 7) presents significant ($p<0.05$) annual ($F=55.11$), seasonal ($F=43.33$) and bathymetric ($F=33.95$) differences. The first year showed an average of 48 ± 1.30 mm, while the second had 42 ± 1.20 mm. The higher average values were found in winter of the first year (7m isobath – 60.23 ± 13.24 mm) and spring (14m isobath – 65.20 ± 14.87 mm) and second year's autumn (7m isobath – 56.14 ± 17.47 mm) and winter (7m isobath – 57.44 ± 22.76 mm). The lower values of carapace width were registered for the first year's winter (14m isobath – 37.19 ± 7.40 mm) and second year's spring (19m isobath – 30.03 ± 10.72 mm).

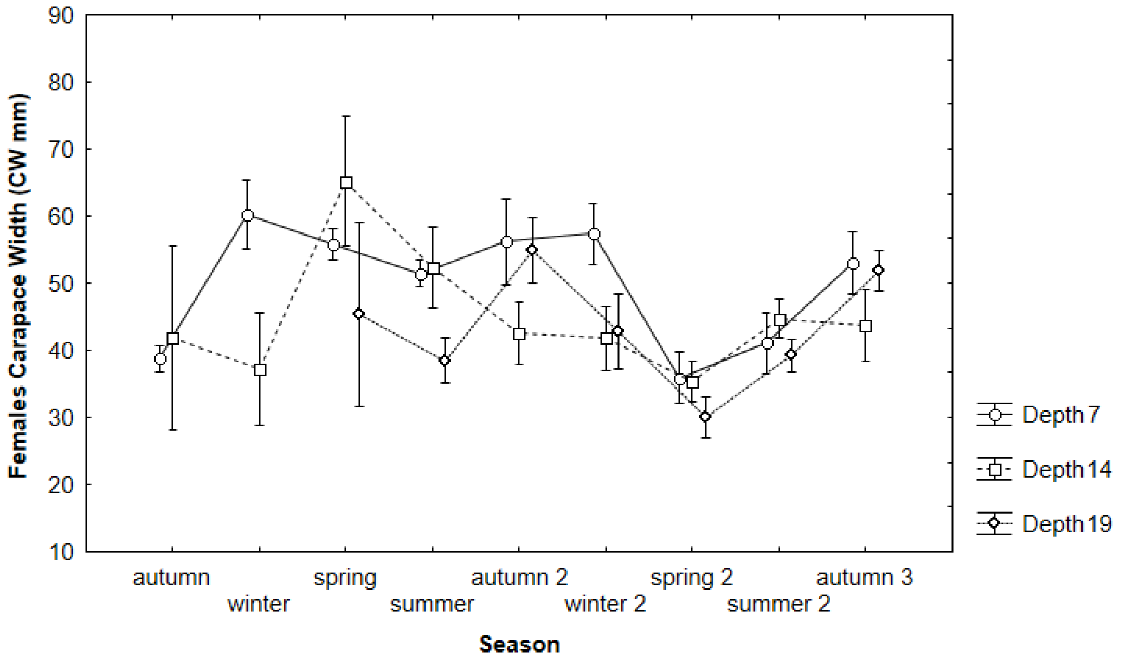

Fig. 7: Variation of the mean of the carapace width (CW), for *Callinectes ornatus* females in the region of Balneário Camboriu, (SC). The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values.

Width- Weight Biometric Relationship (CW1xWt):

The relationship between carapace width (CW1) and weight (g) had a pattern of negative alometry with isometric tendency for males (b=2.95) (Fig. 8) and a positive allometric for females (b=3.12) (Fig. 9).

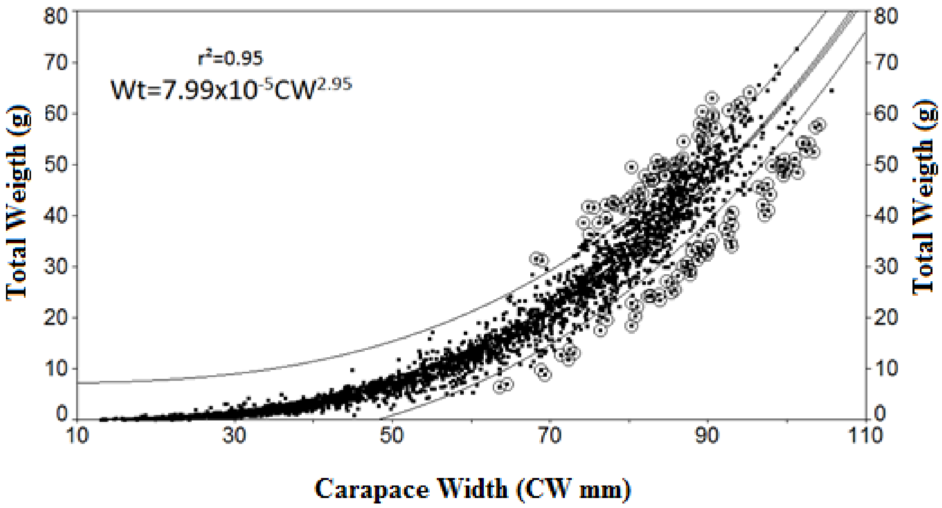

Fig. 8: Biometric relationship between carapace width (CW1) and total weigth (Wt) for *Callinectes ornatus* males in the region of Balneário Camboriu (SC). Circled points were removed from the analysis, being considered outliers.

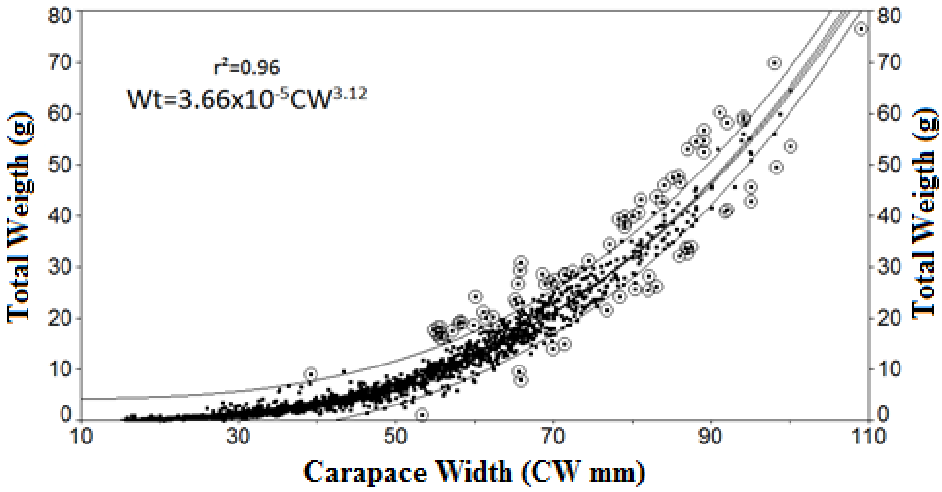

Fig. 9: Biometric relationship between carapace width (CW1) and total weigth (Wt) for *Callinectes ornatus* females in the region of Balneário Camboriu (SC). Circled points were removed from the analysis, being considered outliers.

Sex ratio:

A total of 5871 specimens were analyzed, being 3675 males (62.59%) and 2196 females (37.41%), resulting in average sex ratio of 1.7:1 (M:F). The sex ratio at first year was variable, with significant values of χ^2 for May, August, November, December, February and April (Table 2). There was predominance of males over females, except for June/08 (0,7:1).

Table 2: Sex ratio of *Callinectes ornatus* at Balneário Camboriú between May/08 and Apr/09. Values of χ^2 calculated with gl=1 and critical value >3.84.

Month	Number of Males	Number of Females	Total	% Males	% Females	χ^2
May/08	233	204	437	53.32	46.68	**6.453**
Jun/08	86	96	182	47.25	52.75	0.302
Jul/08	16	13	29	55.17	44.83	1.070
Aug/08	80	46	126	63.49	36.51	**7.281**
Sep/08	0	0	0	---	---	---
Oct/08	23	28	51	45.10	54.90	0.961
Nov/08	299	170	469	63.75	36.25	**7.565**
Dec/08	49	122	171	28.65	71.35	**18.224**
Jan/09	151	153	304	49.67	50.33	0.004
Feb/09	329	219	548	60.04	39.96	**4.029**
Mar/09	78	62	140	55.71	44.29	1.306
Apr/09	126	68	194	64.95	35.05	**8.938**

The second year (May 08 – April 09) also showed a pattern of male dominance over females. Values of χ^2 were significant at all months, except for July, August and January (Table 3).

Table 3: Sex ratio of *Callinectes ornatus* at Balneário Camboriú between May/09 and Apr/10. Values of $\chi 2$ calculated with gl=1 and critical value >3.84.

Month	Number of Males	Number of Females	Total	% Males	% Females	χ^2
May/09	143	42	185	77.30	22.70	**29.806**
Jun/09	79	19	98	80.61	19.39	**37.484**
Jul/09	90	65	155	58.06	41.94	2.601
Aug/09	87	62	149	58.39	41.61	2.815
Sep/09	32	16	48	66.67	33.33	**11.111**
Oct/09	47	18	65	72.31	27.69	**19.905**
Nov/09	96	26	122	78.69	21.31	**32.921**
Dec/09	342	183	525	65.14	34.86	**9.172**
Jan/10	180	180	360	50.00	50.00	0
Feb/10	313	185	498	62.85	37.15	**6.606**
Mar/10	264	8	272	97.06	2.94	**88.581**
Apr/10	530	209	739	71.72	28.28	**18.868**

At the 7 meters isobath, no individuals were caught during the months of October and February. The other months showed dominance of males (except for December). The 14 meters depth had no individuals at March. June, January and April had no significant difference. Sex ratio per depth analysis showed no significant differences during the first year. The second year had differences at 7 and 14 meters at second year (Table 4). Sex ratio doesn’t seem to be influenced by depth.

Table 4: Sex ratio of *Callinectes ornatus* at Balneário Camboriú per depth. Values of $\chi 2$ calculated with gl=1 and critical value >3.84.

Year 1					
Depth	**Number of Males**	**Number of Females**	**% Males**	**% Females**	χ^2
7 m	1059	850	55.47	44.53	1.199
14 m	166	184	47.43	52.57	0.264
19m	128	138	48.12	51.88	0.141
Year 2					
Depth	**Number of Males**	**Number of Females**	**% Males**	**% Females**	χ^2
7 m	857	248	77.56	22.44	**30.375**
14 m	662	281	70.20	29.80	**16.324**
19m	684	484	58.56	41.44	2.932

Seasonal patterns weren't found at the present study, this may be due the influence of the temperature and salinity variation between the two years.

Reproduction and Recruitment:

A statistical analysis (ANOVA) shows a significant difference of mature individual abundance per depth, with higher values at 7m. Ovigerous females were present with higher abundance in the first year at 7m depth (Fig. 10). The second year had few ovigerous females with higher catch at February/10.

The estimated size of fishing recruitment was 35mm. Recruits were found all year long with higher concentration at summer (Fig. 11). The second summer presents a higher abundance of small individuals, characterizing the season with best recruitment success. Immature individuals had no significant differences in distribution per depth.

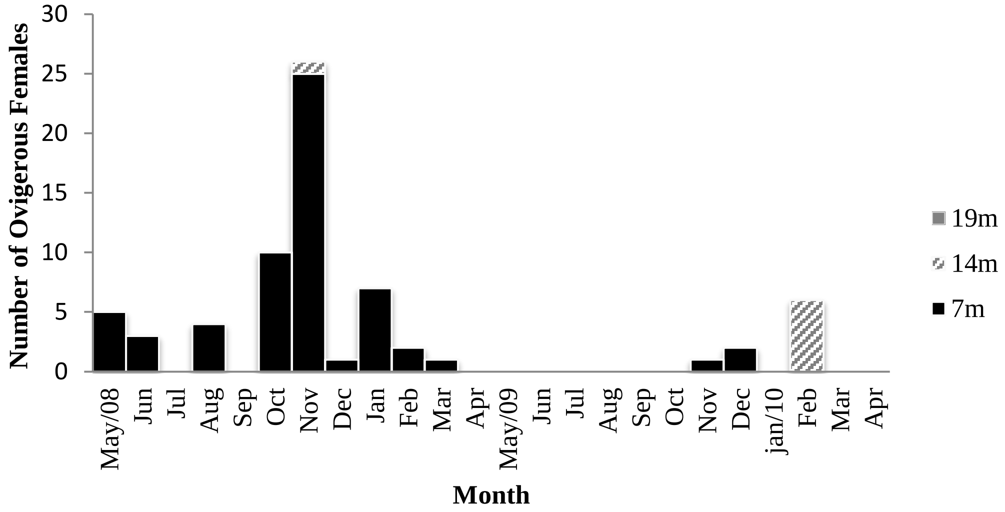

Fig. 10: Number of ovigerous females of *C. ornatus*, by depth (7, 14 and 19 m) in the region of Balneário Camboriú, State of Santa Catarina, from May 2008 through April 2010.

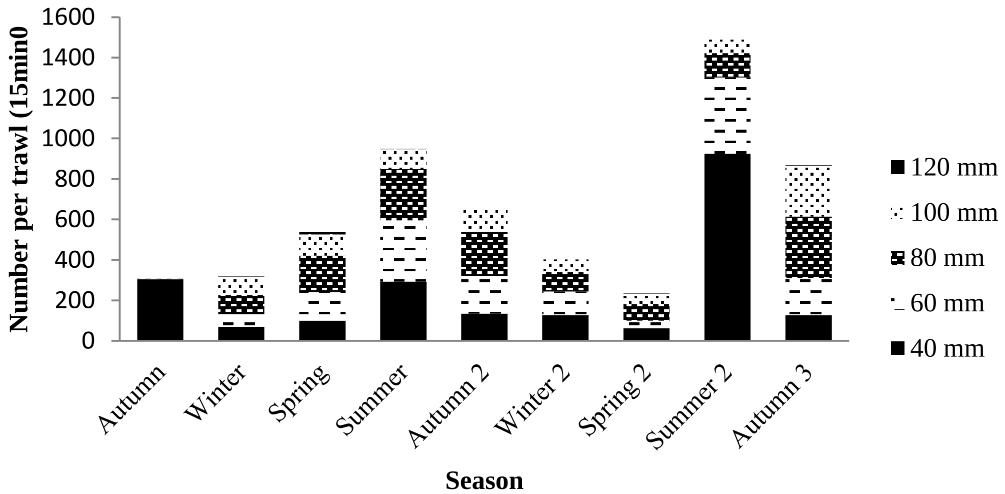

Fig. 11: Number of *C. ornatus* per size class by season in the region of Balneário Camboriú, State of Santa Catarina, from May 2008 through April 2010.

DISCUSSION

Seasonal and spatial variation in the Carapace Width (CW), abundance and catch per effort unit (CPUE):

Branco & Lunardon-Branco (1993) studying *Callinectes ornatus* at Matinhos (PR) determinate a size of first maturity of 61mm for females and 67mm for males and observed a predominance of individuals smaller than the size at first maturity (Lm). At Balneário Camboriú were found a total of 60.66% of males and 70.11% of females under the Lm determined by Branco & Lunardon-Branco (1993). Fernandes *et al.* (2006), studding a *C. ornatus* population at Ilha do Frande (Vitória-ES), also found a dominance of young individuals over mature, result that leaded him to the conclusion that the crabs used the area as a nursery. On the other hand, at Balneário Camoboriú the smaller size crabs occurs at 14 meters, while the larger size crabs are more concentrated at shallow waters (7m depth), concentrating also the greater number of mature individuals, which may indicate that this population uses areas closer to the coast as the reproduction area and higher depths as growth area. Latitudinal variations on distribution and reproductive patterns on crustacean populations are well-documented (Hines, 1989; Berkenbusch & Rowden, 2000). The differences found between the two populations distribution may be due the temperature variations during the year. According to Norse (1977), the patterns of distribution of *Callinectes* seems to be limited by the effects of summer temperature on larvae, rather than winter temperatures. The lower water temperature found at south limit distribution has a direct influence over the life pattern of the population. Mature crabs uses the coastal waters, which are warmer than higher depths, as reproductive and spawning area, while juveniles occupy deeper areas. Another factor that may influence the distribution patterns of the population is the influence of a cold water mass during the summer that pulls down the bottom temperature and push the crabs to shallower and hotter areas. This influence may be associate to the South Atlantic Central Water (SACW) and the coastal upwelling of Santa Marta, with cold water masses that advance over the continental shelf during the summer months (Pereira *et al.* 2009; Domingos-Nunes & Resgalla, 2012).

Although the species has a preference for higher salinity areas (Buchanan & Stoner, 1968), at Balneário Camboriú bay higher abundances were found with the decrease of the salinity. This fact may be due the discharge of continental water enriched by urban rainwater and domestic sewer that decreases the salinity of the bay and increases the primary production and availability of food (Schettini & Carvalho, 1998). Although the negative relation with abundance and the presence of a lower value of 26, the salinity at the sample area presents in mean values of sea water salinity.

Width - Weight Biometric Relationship (CW1xWt):

Golodne *et al.* (2010) sampling at Guanabara Bay found an allometric positive relation between CW1 and Wt for males and females, Branco & Lunardon-Branco (1993), at Matinhos (PR), encountered a positive allometric relation for males and negative for females. The present study shows a negative allometry for males and positive for females at Balneário Camboriú population. At Matinhos (PR) there weren't found mature females, what could have decreased the "b" value, that is used to determinate the correlation between width and weight. The females' gonad weight represents a significant proportion at total weight. The absence of this information can lead the analysis to values lower than the real. The differences between the populations may be due to the environmental parameters that can affect the growth. Latitudinal variances are expect to exert influence on animal life patterns so that different populations of the same species, at different latitudes and, consequently, environmental conditions, have differences in growth patterns and life strategy. According to Hartnoll (2001), the increase of temperature almost universally increases the growth rate of crustaceans, usually without evidence of optimal temperature. It increases and accelerate the growth rate by shortening the intermoult period or increasing the moult increment (or both). Because of the proximity of the south limit distribution of the species and the influence of the low temperature predominant at south Brazil limits, the population of *C. ornatus* at Balneário Camboriú bay presents a life strategy that favors the gain of weight of the females instead of the males.

After the maturation size males and females invest on different patterns of growth. At the onset of reproduction females focus on the energetic resources to gonad development and breeding (Charnov *et al.,* 2001). Considering the effect of temperature on growth is possible to infer that females closer to the south limit distribution will achieve sexual maturity (and stops the investment on size growth) at smaller sizes than the ones of tropical regions. The concentration of growth on the gonadal development is evidenced by the observation of a positive allometric growth. This fact was also observed by Leme (2005) studying the growth of females *Sesarma rectum*, that observed the occurrence of a marked positively allometry in the transitional phases of immature to mature.

Regarding the males, the investment on growth in size instead weight has a direct relation to the size of seminal ducts, the capability of semen storage and capability of handle the female during the mate. Recent research on crustacean reproduction reveals that two of the most important factors of influence over the ejaculate size and quality are male size and mating history (Kendall *et al.*, 2002). Higher size males will be able to mate and fertilize more females. The relation between size and sperm storage capability was also observed at the king crab *Paralithodes camtschaticus* (Kendall *et al.*, 2002). Small crabs had reduced reproductive success after seven consecutive matings, while larger ones had no such reduction until nine consecutive mates (Powell *et al.*, 1974). The investment on size growth will grant a higher production of sperm and capability to more mates, increasing the reproductive success. Males with larger size of carapace will also have more capability of hold the females during the mate and defend the couple against predators.

Sex ratio:

The sex ratio found at Balneário Camboriú corroborates with Negreiros-Fransozo *et al.* (1999), Carvalho & Couto (2010) and Golodne (2010), were the number of males dominate over females. This pattern may be explained by the fact that females may copulate with several males during the reproductive season (Negreiros-Fransozo *et al.*, 1999). Males had a limited stock of sperm that trend to end as it copulate with different females. Females that mates with such males may receive less sperm and seminal fluid than if they had mated with a fully recovered one (Kendall *et al.* 2002). The divert of the sexual ratio in favor of males increases the quality of mates and consequently the reproductive success. According to Wenner (1972), few species of crabs and swimming crabs obeys the 1:1 sex ratio. The decrease of females' abundance at second year seems to be related to the lower temperatures presented in relation to the first. This observation emphasizes the importance of temperature on the distributional patterns of the species. Tudesco (2012) at Rio de Janeiro found a mean value of sex ratio of 2:1 (M:F) and Baptista (2003), studying at Pontal do Paraná, found a value of 1.5:1. The present study found a mean value of sex ratio of 1.66:1, suggesting that the sex ratio had no direct relation with latitudinal variation. Studies about *C. ornatus* abundance should be realized at lower latitudes to obtain a more accurate result.

Reproduction and Recruitment:

The constant presence of ovigerous females observed during the first year corroborates with Negreiros-Fransozo *et al.* (1999) that suggests a continuous reproductive pattern for *C. ornatus*. Also, at Balneário Camboriú, the species reproduction presented a first peak of ovigerous females at first year spring, followed by a smaller peak at summer, a pattern similar to the found by Negreiros-Fransozo *et al.* (1999) at Ubatuba (SP). The second year had a low incidence of ovigerous females. This low abundance may be associated to the influence of a cold water mass that triggered a migratory behavior on these females to regions with higher temperatures and salinity, conditions that favor the spawning.

GLM analysis shows significant ($p<0.005$) influence of depth and salinity over the presence of ovigerous females. Previous studies related a migration of females to higher depths in search of better spawning conditions to the eggs (Pitta *et al.*, 1985; Negreiros-Fransozo, 1995; Branco & Masunari, 2000; Mantelato, 2000; Carvalho & Couto, 2010), but at Balneário Camboriú population ovigerous females had higher concentration at 7m isobath. At lower latitudes the temperature range required for reproduction is present during all the year, including the deeper regions. But at south limit of distribution, it may be restricted to the shallow waters.

The constant presence of individuals at smaller size classes confirms the continuous reproduction of the species. Observing the distribution of ovigerous females and the recruitment is possible to conclude that the higher abundance of ovigerous females doesn't mean necessarily a higher success at recruitment. The first year had a higher abundance of females than the second during the reproductive period, but a lower peak of juvenile abundance. The abundance of juveniles during the second year may had be affected by the low regional temperatures during the larval stage, that reduce the larval growth and survival (Torres *et al.* 2002). The success at recruitment is directly influenced by the environmental conditions and the survival rate of larvae.

CONCLUSION

The information provided by this study allows affirming that the species have an influence of the latitudinal variation and, close to the south distribution limit, presented differences from the populations at lower latitudes on distribution and life patterns. Mature individuals dominate at 7m depth, where probably occurs the copulation during the autumn. The ovigerous females select regions where the environmental conditions such as temperature and salinity favor the hatching off the eggs, liberating the larvae during the spring. The juvenile crabs are pushed to shallower regions by marine flow or cold fronts and settle during the summer. For the *C. ornatus* of Balneário Camboriú, immature individuals concentrate at 14m depth region until reach the first maturation size and join the mature group at 7m depth. Distribution patterns of *Callinectes ornatus* have direct influence of environmental conditions as temperature, salinity and depth.

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Anexo 2

Growth and mortality of the swimming crab *Callinectes ornatus*, Ordway 1863 (DECAPODA: PORTUNIDAE) from Balneário Camboriú bay, Santa Catarina (Brasil).

Growth and mortality of the swimming crab *Callinectes ornatus*, Ordway 1863 (DECAPODA: PORTUNIDAE) from Balneário Camboriú bay, Santa Catarina (Brasil).

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Abstract

The species of the genus Callinectes *play an important role in the food chain of coastal marine ecosystems acting as predators, scavengers and prey. The group is also present as an important fishery resource in North America, Europe and Asia. Despite of its ecological importance and economic potential, few studies about the individual growth and mortality of* Callinectes ornatus *were developed. In this sense, was measured the width-frequency data of* C. ornatus *during two subsequent years in order to estimate the growth and mortality parameters for the species at Santa Catarina, (Brazil), region close to the south limit of the species distribution. The samples were collected monthly from May/2008 to April/2010, in the region of Balneário Camboriú. The absence of rigid structures doesn't allow a direct measurement of growth in crustacea, making necessary the use of indirect age estimative, usually based on the population size structure. The von Bertalanffy growth model (VBGM) is capable of describing the growth of crustaceans and has been used to represent the growth of several species worldwide. From the correct estimation of growth biological parameters is possible to achieve reliable mortality coefficients, widely used by fishery stakeholders for management of commercial species. Growth parameters ± 95% CL estimated for females were K=1.82 y-1 and CW_∞=120 mm (fixed) and for males were*

K= 1.89 y-1 and CW∞= 103.19 mm ± 2.98. Maximum longevity for females and males was 2.5 years and 2.4 years respectively. The coefficient of total mortality (Z') presented higher values for females (7.36) than males (2.46).The coefficient of natural mortality (M) had similar values for females and males (2.53 and 2.41, respectively), while fisheries mortality (F) had higher values for females (4.83) and lower for males (0.058). Mortality coefficients suggest a difference on habitat selection, with females occupying areas more susceptible to the fisheries effort.

Key words: Callinectes ornatus, growth, von Bertallanfy, mortality

INTRODUCTION

The brachyuran family Portunidae is composed of approximately 300 species (Norse, 1977). In Americas, the Portunidae fauna encompasses approximately 45 species, 13 of which belonging to genus *Callinectes* Stimpson (Robles *et al*, 2007). The blue crab *Callinectes ornatus* Ordway, 1863 occurs at Western Atlantic coast, from North Carolina (United States) to Rio Grande do Sul (Brazil). The species is mostly found associated to soft bottoms of sand or mud, between the littoral and the 75m depth isobath (Melo, 1996).

The species of this genus play an important role in coastal marine ecosystems, controlling the pray populations, eating debris as well as serve of pray for numerous other species (Hines *et al*, 1987). The economic exploration of blue crabs is practiced in North-America, Europe and Japan (Branco & Fracasso, 2004). In Brazil, this resource is explored only by small-scale fisheries, with reports of 57 tons/year on average yield for the state of Alagoas at the decade of 1960's and a catch of 1,545 tons at the year of 1970 at Santa Catarina (Severino-Rodrigues *et al*, 2001; Mendonça *et al*, 2010).

Despite of its ecological and economic relevance, few studies about the individual growth of *C. ornatus* were developed. The absence of rigid structures doesn't allow a direct measurement of age in crustaceans, since during the molt, the old carapace is abandoned and the increment on width of the new carapace may be influenced by the environmental conditions. Therefore, the age estimation is usually indirect and based on the population size structure. The growth model proposed by von Bertalanffy (1938) (VBGM) is capable of describing the growth of crustaceans and has been used to represent the growth of several species worldwide (Garcia & Le Reste, 1981; D'Incao & Fonseca, 1999). The age groups were determined by Modal Progression Analysis (MPA), which makes possible an approach to identify cohorts based on size. This estimative can only be validate if presents biological coherence with the nature patterns of the species, especially when no previous studies were performed about it (D'Incao & Fonseca, 1999; Dumont & D'Incao, 2004). Several studies developed for crustaceans and other groups validates the von Bertalanffy method efficiency in the determination of growth parameters (Strong & Daborn, 1979; D'Incao & Fonseca, 1999b; Barcelos *et al.*, 2007; Martínez-Jerónimo, 2012).

The correct estimation of growth biological parameters leads to reliable mortality coefficients, widely used by fishery stakeholders for management of commercial species (Keunecke *et al.*, 2008). The total mortality coefficient (Z) of a species is given by the sum of the coefficients of natural mortality (M) and fisheries mortality (F) (Z=M+F) (Fonteles-Filho, 2011). It is also possible to use the inverse mathematical relation to find one of the terms, since you have the others (M=Z-F or

F=Z-M). These parameters must be studied to evaluate the population characteristics and observe the impact of fisheries over the species.

Latitudinal variations in benthic communities may be brought on by the hydrographic differences, such as temperature, salinity, oxygen concentration and other characteristics of the environments, such as water mixing, primary production, geological processes that affects terrestrial runoff, as well as an array of other abiotic and biotic factors (Castilho *et al.*, 2007). According to Hines (1989), intra-specific variations in growth and life histories are well documented for many crustaceans groups and at least five species from four brachyuran families (including Portunidae) exhibit geographic variation on life patterns.

This study aims to investigate the growth rates and mortality coefficients of *Callinectes ornatus* at Balneário Camboriú and evaluate the existence of latitudinal variations in growth, comparing the results with the available literature.

MATERIAL AND METHODS

The sampling area comprise the Balneário Camboriú bay (26º59'07" S - 48º35'58” W), located at the Santa Catarina, Brazil. The region consists of one of the most traditional fisheries areas of the state (Andrade, 1998; Machado *et al*., 2009). The seasons were divided in summer (January, February and March), autumn (April, May and June), winter (July, August and September) and spring (October, November and December).

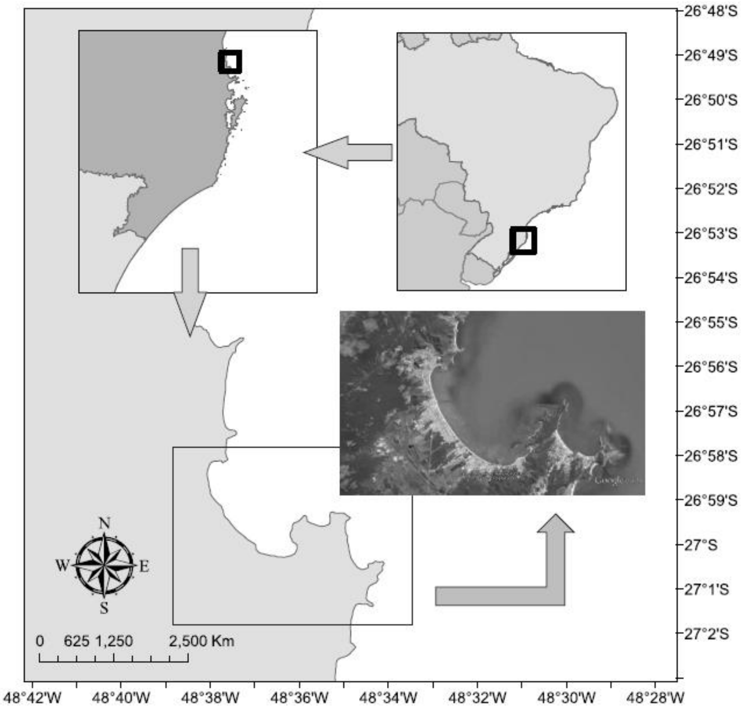

Fig. 1: Spatial view of Balneário Camboriú bay (SC), Brazil.

The biological sampling was monthly performed, during two years, between May/2008 and April/2010 (May/2008 – April/2009 as first year and May/2009 – April/2010 as second year). Two trawlings were performed through three pre-established isobaths (7, 14 and 19 meters). The depths of trawling were defined based on the areas with higher concentration of fishing effort. Each isobath was trawled twice during 15 minutes at average speed of 2 knots parallel to the coastal line using a traditional boat of artisanal shrimp fishing fleet (double rig), trawling two nets. The material of the tow nets were grouped and repeated the trawl to (Machado *et al., 2010*).

Environmental information of bottom temperature (ºC) and bottom salinity were obtained *in situ*, collected with a thermosalinometer. An ecobathymeter coupled with a GPS (Global Positioning System) was used to record depth at sampling sites.

The collected specimens were identified, sexed and classified according to maturation stage (Williams, 1974). The crabs were measured considering carapace width including epistomial spine (CW1-mm), carapace width excluding epistomial spine (CW2-mm) and wet weight (Wt-g) (Williams, 1974).

Modal groups were determined using the distribution of CW frequency fitted to a normal model at a spreadsheet software. The analysis of width frequencies were made considering the interval of 1,00 mm between modal classes. The total width frequency distributions were smoothed (Fast Fourier Transformation) and the normal models were fitted to the smoothed distribution using an automated least squares fitting method. The cohorts were chosen tentatively in order to find VBGM parameters coherent to the biology of the species. After chose the cohorts, the growth parameters were estimated for males and females separately. The equation of von Bertalanffy growth method is given by "$CWt= CW\infty[1-e^{-k(t-t_0)}]$", where "CWt" is the carapace width at the time "t", "$CW\infty$" is asymptotic width, "k" the coefficient growth and "t_0" the theoretical age at width 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 width (D´Incao & Fonseca, 2000). To test possible differences on growth parameters between males and females was applied a F test (Cerrato, 1990). The $CW\infty$ for females was fixed due the absence of individuals at higher size classes. The value was estimated based on the higher carapace width value found for the female. The VBGM allows to fix the asymptotic width of females in 120 mm since it consists in a theoretical higher carapace width possible if the species lives indefinitely. The value used is coherent with the available bibliography and the results obtained by this study at the studded area.

The coefficient of total mortality (Z) was estimated for males and females using a catch curve based on size (Ricker, 1975). The method consists in use the VBGM size-age table information to estimate the mortality. 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 using the methods of Taylor (1960). Taylor (1960) is based on the growth equation of von Bertallanfy (1938) (VBGM) and the relationship between longevity and asymptotic width (CW∞) that is given by the equation: $A_{0.99}=t_{0+}4.60/K$. It assumes that the initial number of the cohort reduces the natural mortality by 1% of the original value in a period of time equal to the longevity. For this relation the analysis takes the parameter K of growth equation in consideration, so $-k(t_{max}-t_0)=M=4.60$, so: $M=4.60/A_{0.99.}$ The Fishing mortality (F) was calculated by the difference between total (Z) and natural (M) mortality.

RESULTS

A total of 5714 individuals were measured and sexed (2127 females and 3587 males). The carapace size for females ranged between 10.93 and 109 mm with a modal value of 32 mm and for males between 12 and 105.58 mm with two modal values, at 32 and 84 mm. Estimate mean size was 44.93 ± 18.95 mm for females and 56.57 ± 23.23 mm for males. The carapace width frequency was analyzed by histograms and presented a polymodal distribution along the sample period (Fig. 2, 3).

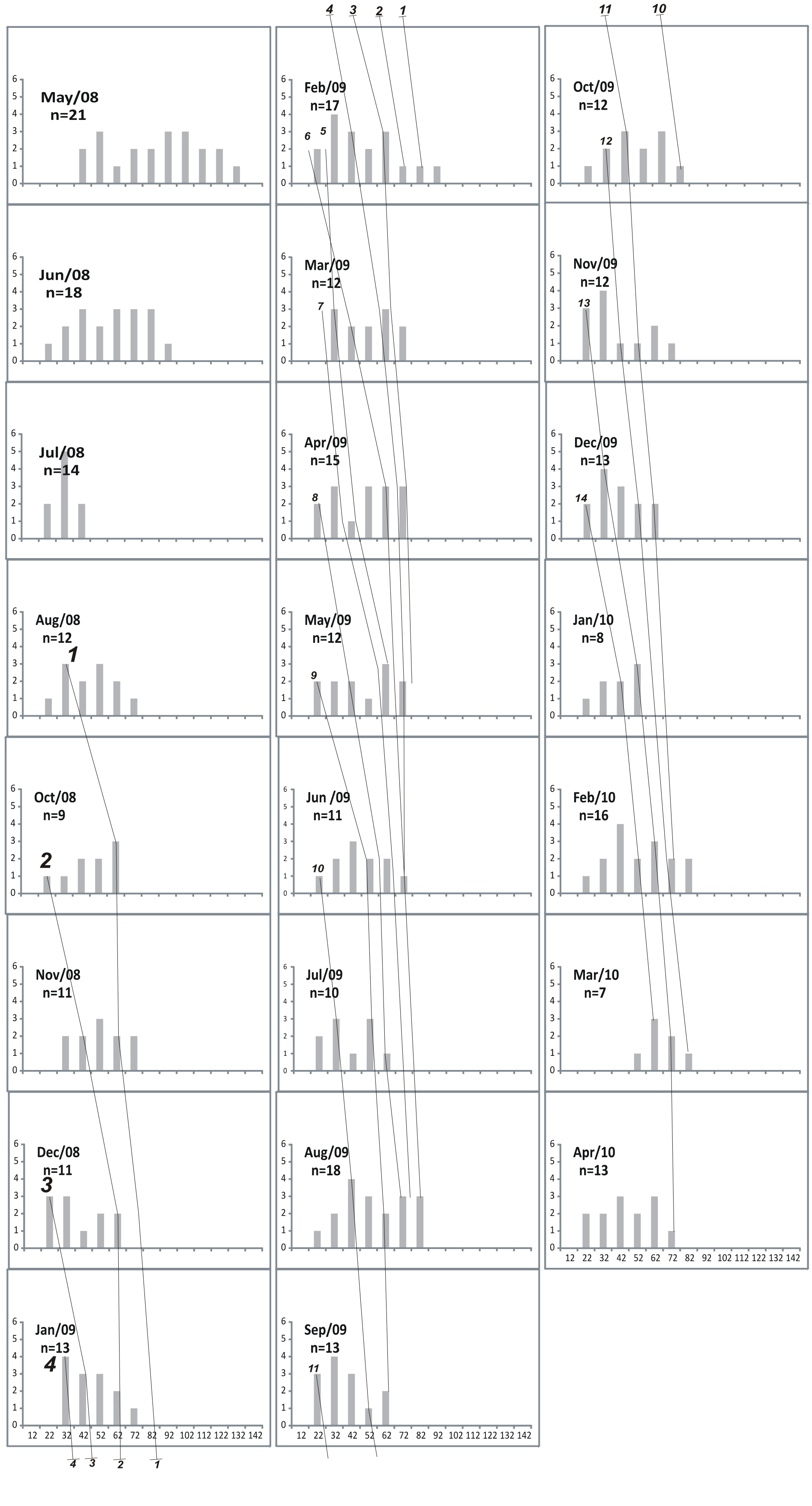

Fig. 2: Modal progression analysis (MPA) of *C. ornatus* females cohorts. Solid lines are the linked cohorts used to describe the individual growth

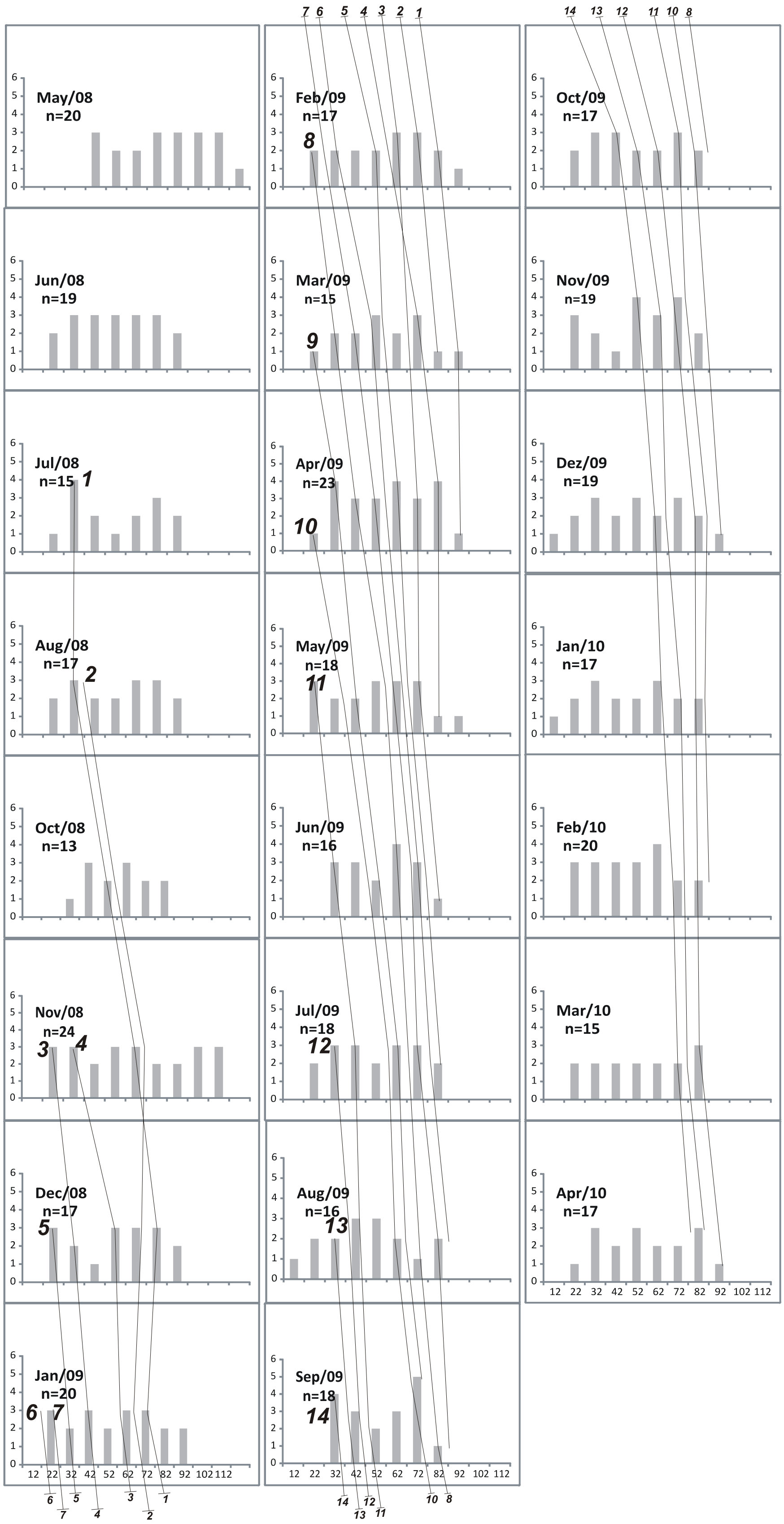

Fig. 3: Modal progression analysis (MPA) of *C. ornatus* males cohorts. Solid lines are the linked cohorts used to describe the individual growth

These histograms were used to determinate fourteen modal progressions for females and males and resulted in the growth curves represented by figures 4 and 5. Tables 1 and 2 represents the cohorts chosen for females and males respectively, and the growth parameters generated by them. Growth parameters ± 95% CL estimated for females were $K=1.82\ y^{-1}$ and $CL\infty=120mm$ (fixed) and for males were $K= 1.89\ y^{-1}$ and $CL\infty= 103.19$ mm ± 2.98. Maximum longevity for females and males was 2.5 years and 2.4 years respectively.

The table 3 presents a estimated numeric summary of the growth parameters for both genders. The growth curves of females and males were significantly different (Fcalc=43.4182; Ftab= 3.0403), result that points to a sexual dimorphism related to growth.

Table 1. Asymptotic width (L_∞), coefficient of growth (K) and longevity of the males cohorts.

	Parameters ♀			
	L∞	**k**	**t_0**	**Long (year)**
Cohort 1	120	0.0054	-53.93	2.31
Cohort 2	120	0.0053	-43.16	2.34
Cohort 3	120	0.0051	-42.99	2.45
Cohort 4	120	0.0055	-39.12	2.28
Cohort 5	120	0.0056	-38.91	2.25
Cohort 6	120	0.005	-30.01	2.51
Cohort 7	120	0.0056	-43.95	2.23
Cohort 8	120	0.0045	-48.2	2.77
Cohort 9	120	0.0043	-51.23	2.87
Cohort 10	120	0.0046	-37.04	2.74
Cohort 11	120	0.0045	-33.64	2.78
Cohort 12	120	0.0054	-40.46	2.31
Cohort 13	120	0.0048	-35.68	2.61
Cohort 14	120	0.0047	-34.7	2.69

Table 2. Asymptotic width (L_∞), coefficient of growth (K) and longevity of the males cohorts.

Parameters ♂				
	$L\infty$	k	t_0	Long (year)
Cohort 1	96.76	0.0062	-31.61	2.03
Cohort 2	99.4	0.0066	-31.35	2.11
Cohort 3	115.16	0.0042	-41.31	2.99
Cohort 4	106.54	0.0047	-38.34	2.65
Cohort 5	110.43	0.0045	-39.52	2.77
Cohort 6	95.47	0.0058	-25.22	2.16
Cohort 7	112.08	0.0049	-65.5	2.58
Cohort 8	113.75	0.0041	-35.95	3.09
Cohort 9	113.69	0.0043	-44.55	2.88
Cohort 10	101.58	0.0053	-66.86	2.35
Cohort 11	97	0.0058	-51.93	2.13
Cohort 12	95.58	0.0058	-59.24	2.18
Cohort 13	104.37	0.0057	-49.58	2.2
Cohort 14	95.92	0.0061	-61.59	2.07

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

Parameters ♀	Value	SD	t-value	95% CL		P>│t│
L∞ (mm)	120	--	--	--	--	--
k	0.00499	0.0001	47.55	0.0048	0.0052	0.000
t_0	-1.01	1.61	-0.63	-4.23	2.19	0.5299

Parameters ♂	Value	Std Error	t-value	95% Confidence Limits		P>│t│
L∞ (mm)	103.19	2.98	34.56	97.28	109.10	0.0000
k	0.0052	0.0002	18.11	0.0046	0.0058	0.000
t_0	-0.03	1.43	-0.019	-2.866	2.810	0.984

The mortality coefficients were calculated based on the growth parameters. The Figure 6 represents the graphic of total mortality (Z) estimate for females and males. The estimate value of annual total mortality (Z) was 7.36 for females and 2.46 for males. The annual natural mortality coefficient (M) was 2.53 for females and 2.41 for males. The values of M obtained by Pauly's method were 1.63 and 1.76 for females and males respectively. The fishing mortality (F) was higher than natural mortality (M) for females and lower for males, the annual value of F was 4.83 for females and 0.058 for males. The table 4 presents the instantaneous mortality coefficients for males and females of *C. ornatus* at Balneário Camboriú.

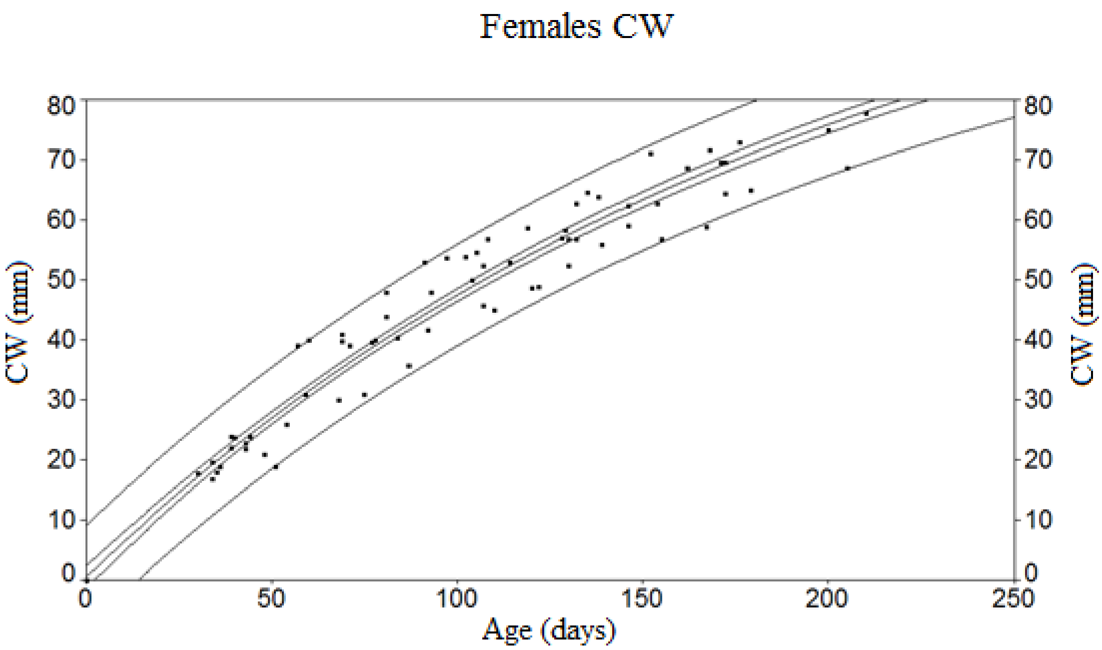

Fig. 4. *C. ornatus*. Growth curves estimated for the females from the Santa Catarina State. Inner lines correspond to confidence interval (95%) and extern lines to prediction interval (95%).

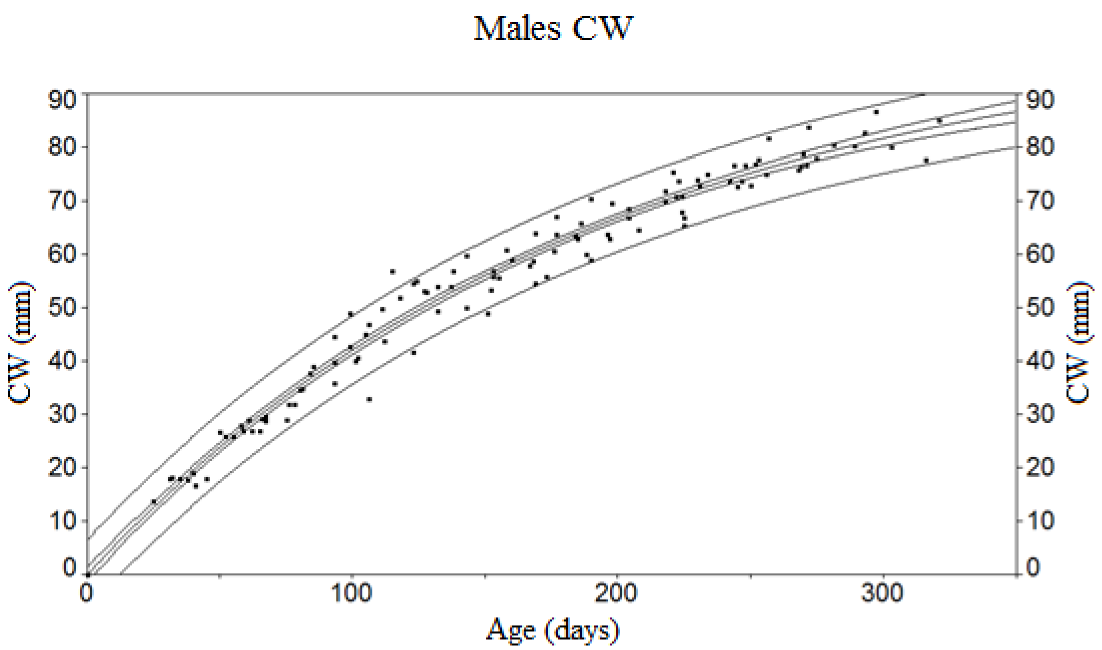

Fig. 5. *C. ornatus*. Growth curves estimated for the males from the Santa Catarina State. Inner lines correspond to confidence interval (95%) and extern lines to prediction interval (95%).

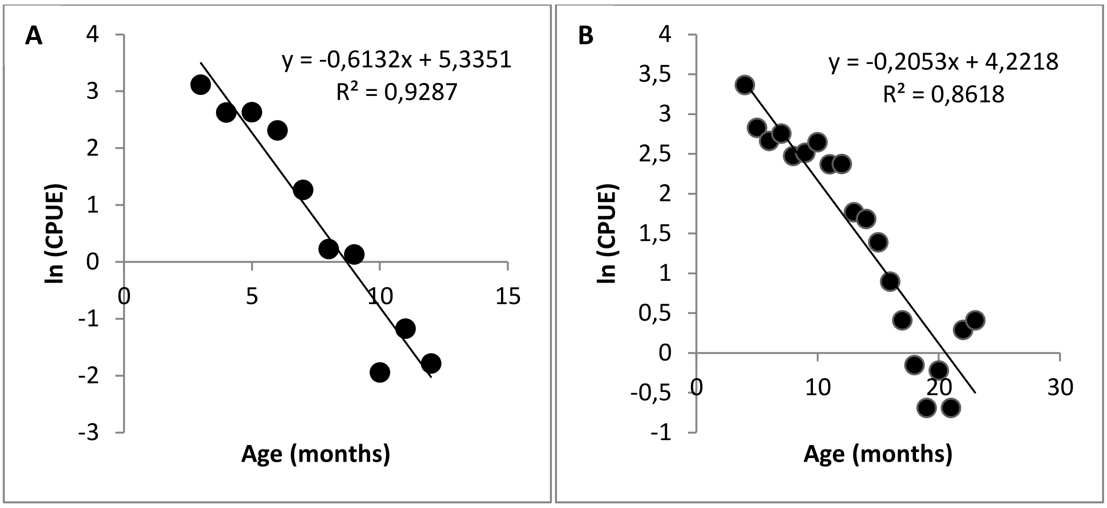

Fig. 6. Width - converted catch curves for (A) females and (B) males of *C. ornatus* in the Region of Camboriú, SC, Brazil.

Table 4. Instantaneous coefficient of total mortality (Z); Natural mortality (M); Fishing mortality (F) for females and males of *C. ornatus* in the region of Balneário Camboriú, SC, Brazil using the method of Taylor (1960).

	Z	M	F
Females	7.36	2.53	4.83
Males	2.46	2.41	0.058

DISCUSSION

Longevity and growth constant (k) have an inverse correlation, in which low values of k are correlated with high longevity and high k with low longevity. Branco & Masunari (1992) and Branco & Lunardon-Branco (1993), studing the growth for two *Callinectes* species, *C. danae* e *C. ornatus*, respectively, found very low values for k and higher for longevity (*C. danae* k males = 0.6975, k females = 0.6555, long. = 3.5 years) (*C. ornatus* k males = 0.5160, k females = 0.6552, long. = approx. 3 years). The discrepancy of results showed by these studies is probably because of methodological problems or variations at environmental factors (Keunecke, 2008). The Ford-Walford growth estimative method used ignores the variations on growth parameters of the animal's different life stages and assumes a continuous growth, fact that is not coherent with the observed at the species ecology. The use of least-squares method allows a more accurate estimative of the growth parameters and a correct observation of growth variation with age.

The values of k and longevity found for the species by this study had no significant difference of those found by Keunecke *et al.* (2008) at Baía de Guanabara (k = aprox. 2 for both sexes and longevity of 2.4 years for females and 2.3 for males). Both studies present ecological coherence and fit with the life cycle observed for the species and other correlates. The little differences found may be due the temperature variation influence on growth of populations from different latitudes. According to Hartnoll (2001), the temperature has a direct influence over the growth in crustacean. Growth rates trends to increase with the increase of temperature.

The observation of higher means sizes of carapace in males than females presents coherence with the *Callinectes ornatus* ecology. Higher size males have more chance to submit the female and protect her against predators and other males during the mate. The values of carapace width found for the species by this study are lower than the presented by Golodne *et al.* (2010) (26.74 ~ 109.3 mm for females and 26.96 ~ 99.13 for males). The difference is probably linked to the latitudinal variation

The asymptotic width proposed by this study of higher carapace width for females than males agrees with Keunecke *et al.* (2008) (110 mm for females and 94 for males) but disagrees with Branco & Lunardon-Branco (1993) (91 mm for females and

124 mm for males), that using a different methodology, found higher values for males than females (124 mm and 91 mm respectively).

The observation and comparison of females and males growth curves of the present study allow to affirm that the genders have distinct growth patterns, which makes necessary two curves to explain the grow pattern of the species. Keunecke *at al.* (2008) found that one curve can describe the growth for the species independently of gender, but affirm that the expected result was two curves. According the study, the sampled area is used for young individuals, including females that didn't reach the puberty molt, presenting growth patterns similar to the males. The need of two growth curves to explain the species growth is explain by the difference on growth strategies after the puberty molt. Females decrease the investment on somatic growth and invest on gonadal development, while males continue with the somatic growth.

Mortality in crustaceans is a subject that lacks information. The coefficient of natural mortality (M) had similar values for females and males (2.53 and 2.41, respectively), while fisheries mortality (F) had higher values for females (4.83) and lower for males (0.058). Keunecke (2006) found the same pattern for *C. ornatus* at Guanabara Bay, Rio de Janeiro. The sum of the values of "M" and "F" coefficients presents a higher total mortality coefficient (Z') for females (7.36) than males (2.46). The difference showed by this study may be due the a difference of habitat selection between males and females, with females occupying regions with higher fishing effort, and males at more protected areas.

CONCLUSION

The present study did not found latitudinal variation on growth parameters between the data obtained and the available bibliography, but the species have a large gap of information on lower latitudes, that must be studded to achieve more reliable results. Males and females presents different strategies of growth after reach the maturity, with males reaching higher size growth than females investing on gonadal development after the puberty molt. The fisheries mortality coefficients (F) present higher values for females than males, which may indicate a difference on distribution between genders. The results found for *C. ornatus* growth and mortality parameters generated by this study were coherent with the patterns found for the species and others of same genus.

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