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IDENTIFICAÇÃO DE ESTOQUES E ASPECTOS BIOLÓGICOS E PESQUEIROS DO CAMARÃO-BARBA-RUÇA (*ARTEMESIA LONGINARIS* BATE, 1888 – DECAPODA:PENAEIDAE)

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ÍNDICE

RESUMO

O objetivo desse trabalho foi investigar diferentes aspectos biológicos e pesqueiros do camarão-barba-ruça *Artemesia longinaris* ao longo de sua área de distribuição. A estrutura populacional da espécie foi então investigada através do seqüenciamento de aproximadamente 700pb da zona rica em A+T do DNA mitocondrial. A diversidade nucleotídica (π) variou entre 0,025 e 0,039 e os valores mais baixos foram observados nas populações que habitam zonas próximas aos limites de distribuição da espécie. A diversidade haplotípica foi variou entre 0,90 e 0,95 e seguiu o mesmo padrão de menores valores próximos aos limites de distribuição. As distâncias genéticas estimadas (*Fst*) sugerem maior fluxo genético entre as populações da Argentina e da Zona de Convergência (Rio Grande do Sul e Santa Catarina) (*Fst*= 0,04, p=0,18), enquanto que a população do Rio de Janeiro, localizada no limite norte de distribuição, foi significativamente diferente das demais (*Fst*= 0,07, p= 0,03 quando comparado à Zona de Convergência e *Fst*= 0,11, p= 0,01 quando comparado com a Argentina). Os resultados obtidos são inteiramente corroborados pelas distâncias geográficas e pelo sistema de correntes costeiras no Atlântico Sudoeste, que apresenta expansões e retrações sazonais criando um mecanismo eficiente de dispersão entre as populações do sul. Essas similaridades foram confirmadas por caracteres morfométricos e merísticos que também foram analisados. O padrão reprodutivo de *A. longinaris* também foi analisado, já que essa é uma informação vital para o manejo de espécies exploradas. O esforço reprodutivo se concentra na primavera, entretanto, picos de recrutamento podem ser observados ao longo do ano. Uma migração reprodutiva para profundidades além dos 15 metros foi observada, e o processo de recrutamento ocorre aproximadamente 1 mês após a desova. O tamanho médio de primeira maturação foi estimado em 16,76 mm (CC) e foi atingido à idade de aproximadamente 4 meses. Ajustes significativos aos modelos de estoque-recrutamento foram obtidos apenas durante anos em que as condições ambientais eram desfavoráveis, sugerindo que a redução na biomassa desovante juntamente com condições ambientais adversas pode levar à sobre-pesca de recrutamento. A composição e a abundância da fauna acompanhante foram diferentes para os dois anos avaliados, de modo que as maiores taxas de descartes estiveram associadas a altos índices de pluviosidade e baixa salinidade. A taxa de descarte geral foi de 1:5,6, com valores variando entre 1:11,3 em 2002 e 1:2,5 em 2004. Durante 2004 a salinidade foi alta, associada ao reduzido volume de chuvas, favorecendo a abundância de *A. longinaris* na área de estudo. Durante esse ano de seca, *A. longinaris* foi dominante nas amostras, resultando em níveis de descarte bastante baixos, especialmente no inverno (1:0,97). Através do método de área varrida, um total de 3369 toneladas dessa espécie foi estimada entre os 10 e 20 metros de profundidade. A distribuição de freqüência dos tamanhos permitiu concluir que os maiores comprimentos se encontram especialmente entre 15 e 20 metros de profundidade, mas também que os maiores indivíduos evitam as áreas de menor salinidade, sugerindo que a desova aconteça fora da zona de influência da Lagoa dos Patos. Com relação à pesca de arrasto-duplo, sugere-se a implementação de um período de defeso durante a primavera, preservando a reprodução do estoque. Adicionalmente, uma diminuição no esforço também seria importante, já que o estoque apresenta uma distribuição bastante concentrada em áreas mais favoráveis, tornando-o susceptível à intensa pressão pesqueira.

ABSTRACT

The aim of this work was to investigate different biological and fishery aspects of the Argentinean prawn *Artemesia longinaris* along its distribution area. Stock structure was therefore investigated by sequencing approximately 700bp of the A+T-rich region of mtDNA. Nucleotide diversity (π) ranged from 0.025 to 0.039 and lower values were observed in sites close to the extreme limits of distribution. Haplotype diversity ranged from 0.90 to 0.95 and followed the same pattern of lower values in sites close to distribution limits. The *Fst* distances showed higher genetic flow between Argentina (Mar del Plata) and Convergence Zone (Rio Grande do Sul and Santa Catarina) (*Fst*= 0.04, p=0.18), while Rio de Janeiro population, located at northernmost distribution limit, was significantly different from the others (*Fst*= 0.07, p= 0.03 when compared to Convergence Zone and *Fst*= 0.11, p= 0.01 when compared to Argentina). Results obtained are entirely supported by geographic distances separating populations, as well as oceanographic currents of near shore Southwestern Atlantic, that present seasonal expansions and retractions providing an effective mechanism for dispersal between southern populations. These similarities were also confirmed by morphometric and meristic traits analyzed. Reproductive pattern of *A. longinaris* was also investigated in Southern Brazil, since it is vital information for management. Reproductive effort is concentrated in spring; however, recruitment was observed all year round. A reproductive migration to depths further than 15 meters was observed, and recruitment process starts approximately one month after hatching. Mean length at first maturity (LM) was estimated in 16.76 mm (CL) and is achieved at the age of approximately 4 months. Significant fit of SSR was observed for three models tested under adverse environment conditions, suggesting that reduction of spawning biomass combined with unfavorable environment conditions may lead to recruitment overfishing. The overall discard ratio was 1:5.6, with values ranging from 1:11.3 in 2002 to 1:2.5 in 2004. Conversely, *A. longinaris* production was consistently lower, since this marine species do not tolerate marked reductions in salinity. In 2004, salinity was higher, associated to low rainfall and favoring *A. longinaris* abundance in the area. During this dry year, the species was dominant in samples resulting in very low bycatch ratios, especially in winter (1:0.97). By using a swept area method, a total of 3369 tons of *A. longinaris* was estimated between isobaths of 10 and 20 meters. Size distribution allowed concluding that larger individuals are located especially between 15 and 20 meters, but large individuals of *A. longinaris* clearly avoided the areas of lower salinity, suggesting that spawning takes place outside the direct influence of Patos Lagoon estuary. In terms of double-rig fishery, we suggest a closed season during the spring months, in attempt to preserve the reproduction of the stock. Additionally, a reduction in fishing effort is advisable, since it presents a patchy distribution making it susceptible to intense fishing pressure.

Classificação taxonômica e distribuição do camarão-barba-ruça (argentinean prawn) *Artemesia longinaris*.

Subfilo Crustacea (Pennant, 1777)

Classe Malacostraca (Latreille, 1806)

Subclasse Eumalacostraca (Grobben, 1892)

Superordem Eucarida (Calman, 1904)

Ordem Decapoda (Latreille, 1903)

Subordem Dendrobranchiata (Bate, 1888)

Superfamília Penaeoidea (Rafinesque, 1815)

Família Penaeidae (Rafinesque, 1815)

Gênero *Artemesia*

Espécie *Artemesia longinaris* Bate, 1888

O gênero *Artemesia* é monotípico e endêmico das águas costeiras do oceano Atlântico Sul Ocidental, sendo observados de Atafona (Rio de Janeiro, Brasil, 21°37´S) até Puerto Rawson (Argentina,43°S), totalizando uma extensão de aproximadamente 1300 milhas náuticas (D´Incao, 1999) (Figura 1). A espécie ocorre principalmente entre o limite superior do infralitoral até a isóbata de 30 metros (Boschi, 1969), tendo sido observada em profundidades máximas de até 68 metros (Olivier et al., 1968).

Figura 1. Área de distribuição do camarão-barba-ruça (*A. longinaris*) no Atlântico Sul Ocidental, desde Rawson (Argentina) até Macaé (Rio de Janeiro) (linha preta).

Dois grupos principais de camarões são explorados mundialmente. Os carídeos formam um grupo bastante diverso, somando um total de 2500 espécies que habitam áreas tropicais e temperadas, desde zonas costeiras até águas profundas. Esse grupo representa 18% das capturas mundiais de camarão e a pescaria mais conhecida desse grupo incide sobre a espécie *Pandalus borealis*, realizada na costa da Groelândia (FAO, 2007).

O segundo grupo é formado pelos camarões peneídeos, que possuem menor diversidade, somando um total de 400 espécies (FAO, 2007). Eles habitam principalmente áreas costeiras em regiões tropicais e sub-tropicais, crescem rápido e tipicamente apresentam grandes tamanhos populacionais (Gulland e Rotschild, 1981, Garcia e Le Reste, 1981). No presente trabalho os dois grupos não serão tratados unicamente como camarões, mas a nomenclatura sugerida por King (1997) será adotada. Para evitar confusões com relação aos nomes comuns atribuídos a esse grupo os Caridea (carregam os ovos nos pleópodos) serão tratados como *shrimps*, enquanto que os Dendrobranchiata (liberam os ovos diretamente na água) serão genericamente tratados como *prawns*.

Importância mundial e local da pesca de camarões

Os camarões são recursos marinhos extremamente valiosos, representando 20% de todo o volume de dinheiro negociado no mercado mundial de produtos pesqueiros. No ano 2000 a produção mundial de camarões peneídeos era de 4,2 milhões de toneladas e as capturas oriundas do ambiente representavam 3 milhões de toneladas (EJF, 2003). Dados recentes indicam que a produção vinda da aqüicultura atingiu o valor de 2,4 milhões de toneladas aumentando 28% somente entre 2002 e 2004. Ao contrário, as capturas no ambiente têm se mostrado estáveis ou com pequenos incrementos em torno de 10% (FAO, 2007).

A produção global de camarões é dominada pelas pescarias chinesas, que capturam aproximadamente 1 milhão de toneladas por ano. A Índia é o segundo maior produtor mundial desse grupo, desembarcando um total de 350 mil toneladas, seguida pela Indonésia que desembarca 260 mil toneladas por ano. O Brasil é apenas o décimo quinto país na lista de desembarques mundiais de camarão, com uma produção anual de 31 mil toneladas (FAO, 2007).

Devido à crescente demanda por esse produto, a pressão pesqueira exercida sobre esses estoques também vem crescendo nas últimas décadas. Em geral as espécies de camarão são resilientes à pressão pesqueira (Gulland e Rotschild, 1981). Entretanto, em muitos países onde a exploração é intensa, os limites ecológicos para a exploração sustentável desses recursos já parece ter sido atingido (EJF, 2003). Esse fenômeno é especialmente evidenciado em pescarias tropicais e sub-tropicais onde declínios na abundância relativa das principais espécies pescadas por longos períodos têm se mostrado bastante significativos (Zeller e Pauly, 2005).

Os custos crescentes de operação e manutenção relacionados com a pescaria de camarões, aliados à competição com a produção oriunda da aqüicultura têm colocado os pescadores de camarão sob pressão, especialmente em países em desenvolvimento. Através da produção de tamanhos mais consistentes, maior qualidade, menor preço e menor sazonalidade, relacionados à produção em cativeiro, esse tipo de atividade tem crescido consideravelmente. Para manutenção das atividades pesqueiras os pescadores tendem então a intensificar o esforço de pesca, resultando em excessiva mortalidade por pesca e degradação ambiental gerada pelas redes de arrasto (EJF, 2003).

Entretanto, os rendimentos econômicos aliados à pesca de camarões são extremamente tentadores para muitos países. Por exemplo, a frota de 116 arrasteiros participando da pescaria no norte da Austrália, captura um montante de 8000 toneladas de camarão, resultando em um rendimento econômico de 150 milhões de dólar por ano. A pescaria de camarões também contribui significativamente para o comércio exterior de muitos países, além de gerar oportunidade de empregos e desenvolvimento industrial, todos estes muito importantes para países em desenvolvimento como o Brasil. Entretanto, a geração desses benefícios nem sempre é feita de maneira sustentável e pode resultar em prejuízos econômicos posteriores se não for manejada de maneira responsável (EJF, 2003).

No Brasil a pesca de camarões iniciou na década de 40, após a Segunda Guerra Mundial, principalmente na região SUDESTE/SUL, porém os primeiros dados de captura industrial na região datam de 1965 (Valentini et al, 1991). A frota que tradicionalmente explora esses recursos é formada por arrasteiros duplos e foi considerada como a maior frota comercial do país, com 511 embarcações atuando no Sudeste e Sul do Brasil (Perez et al., 2001).

As principais espécies de camarão exploradas na região SUDESTE/SUL são *Farfantepenaeus paulensis* (camarão-rosa), *Farfantepenaeus brasiliensis* (camarão-rosa), *Xiphopenaeus kroyeri* (camarão-sete-barbas), *Litopenaeus schimitii* (camarão-branco), *Pleoticus muelleri* (camarão-santana) e *Artemesia longinaris* (camarão-barba-ruça). Esse grupo de camarões possui significativo valor econômico, representando aproximadamente 24% da produção pesqueira em termos de valor econômico e 6% em peso de captura no SUDESTE/SUL do Brasil (Perez et al., 2001). Inicialmente essa pesca tinha como espécie alvo o camarão-rosa, que estava entre os principais recursos pesqueiros da região. No ano de 1965 a pesca do camarão-rosa contribuiu com 86% das capturas de camarões na referida área, em 1985 essa fração era de 47,5% e no ano de 1999 caiu para apenas 21% (D´Incao et al, 2002).

Com o declínio das capturas e dos rendimentos industriais do camarão-rosa a partir da década de 80 essa atividade pesqueira transformou-se de mono em multi-específica, buscando espécies alternativas para a manutenção da rentabilidade econômica (Valentini et al, 1991; D´Incao et al, 2002). Com essa situação as outras espécies de camarões ganharam maior importância comercial (Valentini, et al., 1991), destacando-se o camarão sete-barbas (*Xiphopenaeus kroyeri*) com desembarque de 15.580 toneladas em 1981, o camarão-branco (*Litopenaeus schimitii*) com desembarque de 1.291 toneladas em 1984, camarão-santana (*Pleoticus muelleri*) com desembarque de 4.112 toneladas em 1988 e camarão-barba-ruça (*Artemesia longinaris*) com desembarque de 7424 toneladas em 2003. Entre essas espécies, *P. muelerii* e *A. longinaris* foram aquelas que apresentaram maior aumento percentual nas capturas em comparação com o camarão-rosa (*F. paulensis* e *F. brasiliensis*) (D'Incao et al., 2002) (Figura 2).

A exploração comercial de *A. longinaris* no Brasil teve início em 1978, mas no Rio Grande do Sul as estatísticas disponíveis anotaram a presença de desembarques somente em 1982 (D'Incao, et al, 2002). Atualmente essa espécie apresenta os maiores rendimentos por viagem (2192kg/viagem) entre os camarões explorados no Sul do Brasil. Essa espécie ultrapassa até mesmo os rendimentos econômicos por viagem observados para o camarão-rosa, que possui um valor por kilo significativamente maior. Enquanto os desembarques por viagem rendem em média 4380 reais para o desembarque do camarão-rosa, 4428 reais são obtidos a partir dos desembarques de *A. longinaris* (Perez et al., 2001).

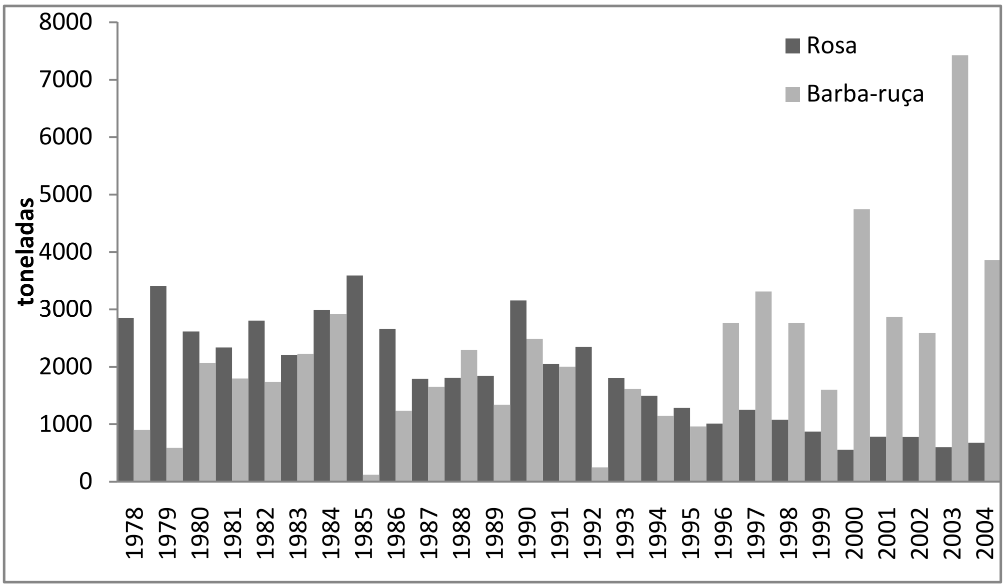

Figura 2. Variações anuais dos desembarques de *F. paulensis* e *F. brasiliensis* (camarão-rosa) em relação aos desembarques de *A. longinaris* até 2004. (Fonte: D´Incao et al 2002, Perez et al, 2001, Baptista-Metri, 2007).

A espécie também está sujeita a uma pesca artesanal que foi descrita pela primeira vez por Dumont (2003). A pesca artesanal acontece com duas diferentes artes de pesca, a rede de "saquinho" e o arrasto de fundo com portas. A rede de saquinho é utilizada por pescadores ao longo da linha de praia, desde o município de São José do Norte até a Barra da Lagoa do Peixe (Dumont 2003). A pesca artesanal de *A. longinaris* realizada na região adjacente à barra de Rio Grande é executada por pequenos barcos de madeira, com baixa capacidade de estocagem e extremamente sujeitos às condições atmosféricas, que utilizam o arrasto de fundo com portas para a captura do camarão-barba-ruça e camarão-santana. Essa pescaria não é regulamentada, o que não impede os pescadores de realizá-la ilegalmente, especialmente durante os meses de defeso dentro da Lagoa dos Patos que se estende de maio a setembro.

Identificação de estoques e a relevância para o manejo pesqueiro

A identificação das populações ou estoques pesqueiros é um componente integral na avaliação pesqueira recente. Entretanto, a importância desses estudos não tem sido relevada, o que se reflete no escasso número de investigações publicadas sobre esse assunto. A maioria dos modelos de avaliação inclui a premissa de que os parâmetros estimados foram baseados em um estoque unitário, com características homogêneas ao longo da sua distribuição (Begg e Waldmann, 1999).

Conseqüentemente, o conceito atual de estoque define grupos semi-discretos com alguns atributos de interesse para os administradores pesqueiros. Booke (1999) discute a evolução do conceito de estoque, argumentando que qualquer conceito utilizado deveria incorporar marcadores que são herdados e podem definir o grupo estudado, assim como o ambiente em que ele vive. No presente trabalho os termos estoque e população foram usados indiscriminadamente e não se referem diretamente ao isolamento genético, ambiental ou comportamental dos grupos analisados.

Variações genéticas entre os estoques podem fornecer, por exemplo, informações diretas sobre a estrutura dos grupos de uma mesma espécie ao longo de uma área de distribuição. Nesse sentido, Benzie (2000) demonstrou algumas aplicações importantes das técnicas moleculares para o estudo pesqueiro. Entre elas pode-se destacar a identificação da variabilidade genética, estrutura populacional e isolamento reprodutivo entre os grupos.

Variações fenotípicas entre estoques também podem ser usadas para identificar estruturas populacionais, embora não forneçam evidências diretas de isolamento genético. Entretanto, esse método pode indicar uma longa de juvenis, larvas ou até mesmo adultos em ambientes discretos. Em muitos casos onde se assumiu que a causa de variação em caracteres morfométricos era genética, o cultivo de indivíduos do mesmo grupo, criados em condições experimentais diferentes, resultou em alometrias no crescimento. Dessa forma, a temperatura a que as larvas, ou até mesmo os embriões estão sujeitos, pode influenciar diretamente nos fenótipos observados na natureza, de maneira que estoques podem mostrar variações morfológicas e merísticas relacionadas a variáveis ambientais, tendo sido comparados a camaleões que mudam sua aparência de acordo com o ambiente (Swain e Foote, 1999).

Variações na bionomia e tamanho de primeira maturação de *A. longinaris* foram previamente atribuídos a diferenças populacionais (Nascimento, 1981; 1983). De acordo com essas investigações duas populações estariam habitando a região da Convergência Subtropical, uma com preferência por águas quentes a salinas e outra com maior afinidade por águas frias e menos salgadas. Dessa forma, a última estaria presente no litoral do Rio Grande do Sul durante os meses mais frios de inverno, se aproveitando do regime de correntes (do sul para o norte) observado nesse período. A hipótese de Nascimento (1981, 1983) sugere que a outra população habitaria o litoral do Rio Grande do Sul durante o verão, se aproveitando da inversão do sistema de correntes, que nessa época do ano flui para o sul.

Entretanto, uma investigação anterior sobre a variação de aloenzimas para essa espécie (Weber et al., 1993) sugere resultados conflitantes com os de Nascimento (1981, 1983). Com base na variação de aloenzimas, Weber et al. (1993) sugere uma população panmítica entre o litoral do Rio Grande do Sul e a Argentina. Portanto, surge a necessidade de se investigar mais profundamente a estrutura dos estoques de *Artemesia longinaris* ao longo de sua área de distribuição, incluindo o limite norte e fornecendo novas informações sobre a estrutura populacional dessa espécie.

Entre os métodos mais recentemente utilizados para investigar a estrutura populacional de peneídeos está o seqüenciamento do DNA mitocondrial (mtDNA) (Benzie, 2000). O mtDNA é uma molécula citoplasmática circular herdada, com aproximadamente 16000-20000 pares de bases. A herança dessa molécula é haplóide e predominantemente maternal. Duas regiões do mtDNA podem ser especialmente úteis para investigar a estrutura populacional de crustáceos, a citocromo oxidase (COI) e a região controle (D-loop) (Caccone et al., 1996). Pouco se sabe sobre a estrutura e evolução da região controle, mas acredita-se que seja dividida em três regiões hipervariáveis, separados por duas regiões de menor variabilidade (Grabowski and Stuck, 1999). Devido a essas características essa região é de extrema utilidade para estudar estrutura populacional de peneídeos ao redor do mundo (Benzie, 2000; Chu et al., 2003, McMillen-Jackson and Bert, 2003, Grabowski et al., 2004).

Reprodução, ciclo de vida e as relações estoque-recrutamento

Diferentemente de outros peneídeos que utilizam baías e estuários como berçário (*Farfantepenaeus paulensis*, *Farfantepenaeus brasiliensis* e *Litopenaeus schmitii*), *A. longinaris* realiza todo o ciclo de vida em ambiente oceânico (Boschi, 1969; D´Incao, 1999). Na Argentina foram reportadas migrações dos adultos para águas de maior profundidade para a desova, enquanto que o recrutamento acontece na região mais próxima a costa (Boschi, 1969). A espécie apresenta (4) fases larvais, divididas em nauplius, protozoea, mysis e pós-larva. As pós-larvas fazem migrações verticais, sendo capturadas com maior facilidade durante a noite (Marlo & Cervellini, 1988).

São camarões de télico fechado, com as fêmeas carregando o espermatóforo introduzido pelo macho com o auxílio do petasma (Bauer & Martin, 1991). São organismos meroplactônicos, que durante as fases larvais habitam a coluna d´água, mas ao tornarem-se juvenis adquirem hábitos bentônicos (Boschi, 1969). Estudos de distribuição e abundância das larvas foram realizados na Argentina por Boschi (1969) e Marlo & Cervellini (1988), já no litoral do Rio Grande do Sul um único estudo foi realizado por Calazans (1992).

Alguns aspectos da reprodução dessa espécie no litoral Brasileiro foram investigados por Nascimento (1981), Dumont e D´Incao, (2004) e mais recentemente por Castillo et al. (2007). Na Argentina a reprodução e o desenvolvimento larval da espécie foram estudados por Boschi (1969), Marlo & Cervellini (1988), Petriella & Bridi (1992) e mais recentemente por Castillo et al. (2007).

Entretanto flutuações interanuais de densidade dos estoques são bastante comuns para esse grupo e normalmente estão relacionadas a parâmetros ambientais e mudanças na biomassa desovante (Gulland e Rotschild, 1981, Crocos & van de Velde, 1995, Vance et al., 1998;). Adicionalmente a identificação e quantificação do estoque desovante, a previsibilidade do recrutamento possui uma importância extrema no manejo de estoques de camarão (Pauly, 1992). Isso é verdade, já que esse grupo possui elevada fecundidade e o recrutamento é altamente dependente das variações ambientais, tais como pluviosidade, salinidade e temperatura (Garcia, 1981; Gulland & Rotschild, 1981). Apesar disso, as relações entre o estoque desovante e o resultante recrutamento têm sido aplicadas com um nível de sucesso considerável para o entendimento do sucesso no recrutamento de peneídeos (Garcia, 1981; Kirkwood, 1981; Pauly, 1992).

Como discutido anteriormente, também existem fortes evidências de que o recrutamento é regulado por fatores ambientais, de maneira que as interações entre o estoque desovante, recrutamento e fatores ambientais devem ser investigados (Garcia, 1981; Kirkwood, 1981; Gulland & Rotschild, 1981; Dall et al., 1990; Pauly. 1992).

Captura acidental associada ao arrasto de camarões

Além do entendimento sobre a dinâmica da biomassa do estoque explorado, informações sobre o impacto do arrasto sobre as comunidades associadas à espécie-alvo têm sido cada vez mais requeridas para um manejo eficaz desses recursos (Zeller e Pauly, 2005). A abordagem ecológica para o manejo pesqueiro tem demonstrado que o nível de esforço requerido para manter a biomassa da espécie-alvo acima do nível sustentável é freqüentemente maior que o valor necessário para manter as capturas incidentais a esses mesmos níveis (Hall, 1999; EJF, 2003).

Tal fato se torna mais evidente quando as pescarias de camarão são consideradas, já que essas espécies são normalmente mais resilientes, possuindo altas taxas de crescimento, alta fecundidade e ciclo de vida curto (Gulland & Rotschild, 1981; King, 1997). Portanto, um ponto importante para o manejo ecológico de uma pescaria é o conhecimento quali-quantitativo da captura incidental associada a essa atividade (Hall, 1999).

A captura incidental de *A. longinaris* no Sul do Brasil foi previamente analisada por Ruffino e Castello (1993), assim como por Haimovici e Mendonça (1996). O primeiro artigo referido trata da variação na composição do bycatch, obtido a partir de arrastos científicos na região adjacente à Barra de Rio Grande, já o segundo relata a captura de peixes desembarcados pela frota arrasteira comercial que objetiva os camarões barba-ruça e santana no Sul do Brasil. Do ponto de vista ecológico, faz-se necessária uma nova avaliação específica do impacto da pesca artesanal de arrasto de camarões na região adjacente a Barra de Rio Grande, considerando diferentes condições ambientais e seus efeitos na produção de camarões e do bycatch associado a essa pescaria. Dessa forma, diferentes aspectos da biologia e da pesca de

A. longinaris necessitam ser investigados, no sentido de gerar novos conhecimentos necessários para o manejo sustentável dessa espécie.

O presente trabalho reúne estudos relativos a diferentes aspectos da biologia e pesca do camarão-barba-ruça *Artemesia longinaris* no Oceano Atlântico Sudoeste, com a intenção de aprimorar o conhecimento sobre sua estrutura populacional, aspectos morfométricos e merísticos, reprodução, captura incidental da pesca artesanal de arrasto e distribuição e abundância durante a temporada de pesca comercial.

Este trabalho está dividido em seis capítulos, cada um deles no formato de artigo científico submetidos para publicação. Os resultados desses artigos encontram-se resumidos nos capítulos de 1 a 6 (escritos em português) e em sua versão completa (escritos em inglês) nos anexos correspondentes (Anexo I a VI). No item metodologia geral encontra-se a descrição da obtenção de amostras utilizadas no presente estudo, enquanto que a metodologia utilizada nas análises foi detalhada em cada um anexos (artigos científicos submetidos para publicação). Os objetivos de cada capítulo são:

CAPÍTULO 1:

Título em português: A região controle do DNA mitocondrial e seu uso potencial como marcador para o estudo da estrutura populacional do camarão-barba-ruça *Artemesia longinaris* (DECAPODA:PENAEIDAE).

Título em inglês: The mtDNA control region of the argentinean prawn *Artemesia longinaris* (DECAPODA:PENAEIDAE) and its potential use as a marker for population structure analysis.

Objetivo geral

Desenvolver um marcador genético capaz de identificar a estrutura populacional de *Artemesia longinaris* ao longo de sua área de distribuição.

Objetivos específicos

a) Obter a seqüência completa da região controle do DNA mitocondrial e compará-la com a de outros peneídeos.

b) Desenvolver *primers* internos à região controle para uso rotineiro no estudo de estrutura populacional da espécie.

c) Comparar o polimorfismo obtido a partir dessas seqüências com outros genes teoricamente mais conservados como citocromo oxidase e 12S.

CAPÍTULO II:

Título em português: Estrutura genética das populações do camarão-barba-ruça *Artemesia longinaris* (DECAPODA:PENAEIDAE) no Atlântico Sudoeste resolvida por análise da região controle do DNA mitocondrial.

Título em inglês: Population genetic structure of the argentinean prawn *Artemesia longinaris* (DECAPODA:PENAEIDAE) in Southwestern Atlantic resolved by mtDNA control region analysis.

Objetivo geral

Estudar a estrutura populacional de *Artemesia longinaris* ao longo de sua área de distribuição, utilizando como marcador a região controle, incluída no DNA mitocondrial.

Objetivos específicos

a) Identificar a estruturação das populações ao longo da área de distribuição.

b) Investigar o fluxo genético entre elas através de cálculos de medidas de distâncias genéticas (*Fst*).

c) Avaliar a variabilidade nucleotídica e haplotípica em cada uma dessas populações.

d) Estimar o grau de estabilidade histórica das populações com base em análise demográfica.

CAPÍTULO III:

Título em português: Relações biométricas do camarão-barba-ruça *Artemesia longinaris* (DECAPODAPENAEIDAE) no Atlântico Sudoeste.

Título em inglês: Biometric relationships of the argentinean prawn *Artemesia longinaris* (DECAPODA:PENAEIDAE) in Southwestern Atlantic.

Objetivo geral

Estudar as relações biométricas em comprimento e peso do camarão-barba-ruça *Artemesia longinaris*, no sentido de fornecer informações biológicas e práticas sobre o crescimento relativo da espécie no Sul do Brasil.

Objetivos específicos

a) Estimar as relações entre comprimento total e comprimento da carapaça para ambos os sexos e a sua variação sazonal e interanual no Sul do Brasil, comparando com relações obtidas a partir de indivíduos coletados nos extremos de distribuição da espécie.
b) Estimar algumas relações morfométricas e merísticas para cada população ao longo da área de distribuição da espécie.
c) Estimar relações entre peso total e comprimento da carapaça, assim como a variação sazonal do fator de condição das fêmeas.

CAPÍTULO IV:

Título em português: Padrão reprodutivo, tamanho de primeira maturação e relações estoque-recrutamento do camarão-barba-ruça (*Artemesia longinaris*, DECAPODA:PENAEIDAE) no Sul do Brasil.

Título em inglês: Reproductive pattern, size at first maturity and stock-recruitment relationships of the argentinean prawn (*Artemesia longinaris*, DECAPODA: PENAEIDAE) in southern Brazil.

Objetivo geral

Investigar a dinâmica reprodutiva de *Artemesia longinaris* no Sul do Brasil, assim como os principais fatores ambientais e populacionais que influenciam no sucesso reprodutivo dessa espécie no sul do Brasil.

Objetivos específicos

a) Investigar a variação sazonal na abundância de fêmeas maduras e de recrutas na região marinha sob influência do deságüe da Lagoa dos Patos.
b) Estimar o tamanho de primeira maturação da população para a região sul do Brasil.
c) Estimar a relação entre estoque desovante e recrutamento, assim como identificar quais os principais fatores atuantes no sucesso reprodutivo dessa espécie no sul do Brasil.

CAPÍTULO V:

Título em português: Análise da captura incidental do camarão-barba-ruça *Artemesia longinaris* (DECAPODAPENAEIDAE), explorado pelo arrasto artesanal na região adjacente à boca do estuário da Lagoa dos Patos, Rio Grande do Sul, Brasil – efeito da pluviosidade na captura incidental.

Título em inglês: Bycatch analysis of the argentinean prawn *Artemesia longinaris* (DECAPODA:PENAEIDAE) exploited by artisanal trawling in surrounding area of Patos Lagoon Estuary mouth, Rio Grande do Sul, Brasil – effects of different rainfall on incidental catch.

Objetivo geral

Investigar a variação sazonal e interanual na captura incidental oriunda da pesca artesanal, assim como a influência de fatores ambientais na quantidade de peixes e crustáceos descartados.

Objetivos específicos

a) Estimar a taxa de descarte oriunda da pesca de arrasto artesanal e suas variações sazonais e interanuais.
b) Examinar a variação de espécies de peixes e crustáceos nas capturas artesanais sazonalmente e anualmente.
c) Estimar parâmetros ecológicos de riqueza de espécies e nível trófico médio das capturas para os anos analisados.
d) Estimar a probabilidade de captura por classe de tamanho para as principais espécies comerciais de peixes e crustáceos capturados incidentalmente na pesca de arrasto e confrontar com os tamanhos de primeira maturação disponíveis na literatura.

CAPÍTULO VI:

Título em português: Distribuição e abundância do camarão-barba-ruça (*Artemesia longinaris* Bate, 1888) e do camarão-santana (*Pleoticus muelleri* Bate, 1888) (DECAPODA:PENAEOIDEA) no sul do Brasil durante a temporada de arrasto duplo comercial.

Título em inglês: Distribution and abundance of the argentinean (*Artemesia longinaris* Bate, 1888) and red prawns (*Pleoticus muelleri* Bate, 1888) (DECAPODA:PENAEOIDEA) in southern Brazil during commercial double-rig trawl commercial fishery season.

Objetivo geral

Investigar a distribuição e a abundância dos principais camarões comerciais capturados ao longo do litoral do Rio Grande do Sul durante a principal época de captura dessas espécies pela pesca comercial.

Objetivos específicos

a) Estimar a captura por unidade de esforço para cada espécie de camarão e compará-las entre as diferentes sub-áreas do litoral gaúcho.
b) Estimar a biomassa total dos estoques de camarão durante o mês de fevereiro/2005 através do método de área varrida.
c) Gerar mapas de contorno dos valores de densidade dos estoques de camarão para identificação das áreas mais produtivas.
d) Relacionar a abundância com parâmetros ambientais que possam explicar esses padrões distribucionais.
e) Comparar os comprimentos médios ao longo das sub-áreas para identificação de possíveis zonas de desova e recrutamento.

Área de estudo

As condições ambientais na área de estudo são principalmente determinadas pelos movimentos de expansão e retração da Água Costeira (AC). Essa massa de água é diretamente influenciada pelos deságües da Lagoa dos Patos (atinge até 60.000 m^3s^{-1}) e do Rio da Prata (atinge até 30.000m^3s^{-1}), que se intensificam principalmente durante os anos de El Niño. A AC se estende por aproximadamente 1.300km de distância, a partir do Rio da Prata até o Sul do Brasil, sempre em baixas profundidades, próxima da costa. Entretanto, durante anos específicos essa massa de água pode atingir o litoral de São Paulo no Sudeste brasileiro (Piola et al., 2004; Piola et al., 2005).

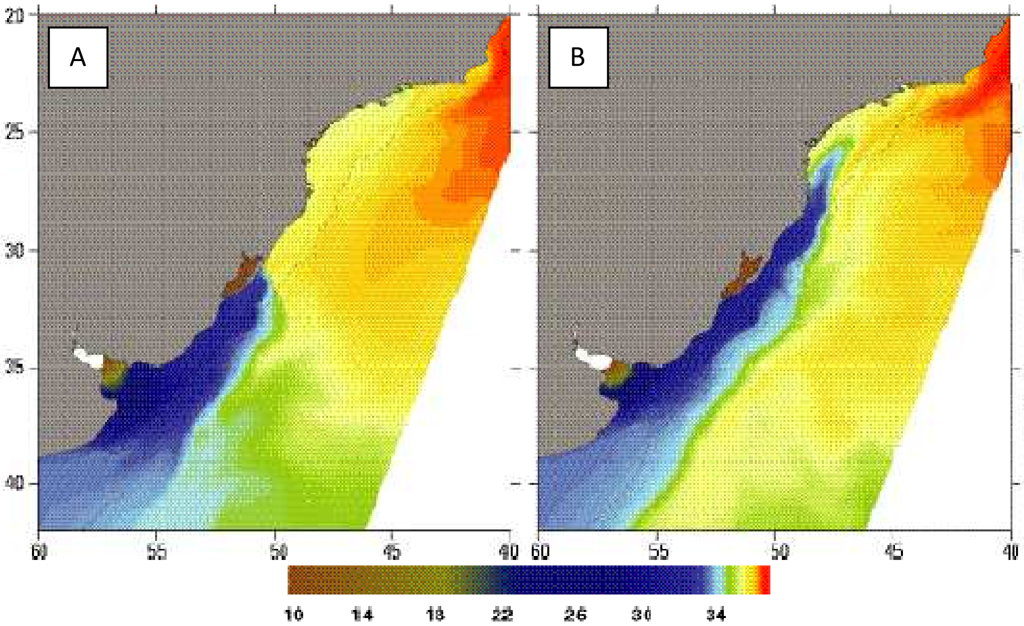

Figura 3. Variação sazonal da salinidade superficial do mar causada pela presença da Água Costeira (AC) no Oceano Atlântico Sudoeste. A figura 3A representa uma situação de verão, quando essa massa de água atinge o litoral do Rio Grande do Sul. A figura 3B ilustra uma situação de inverno, onde a combinação de elevada pluviosidade e ventos do quadrante sul permitem que a AC se expanda até o litoral de Santa Catarina. Fonte: Piola et al. (2004).

O estuário da Lagoa dos Patos está localizado na planície costeira do Rio Grande do Sul, Brasil (32^0S, 49^0W), sendo o maior estuário estrangulado do mundo, cobrindo uma área de 10360km^2 (Asmus, 1996) e a quantidade de chuvas associada à intensidade e direção dos ventos regulam os deslocamentos de água na área de estudo (Piola et al., 2005). O deságüe sazonal oriundo da Lagoa dos Patos apresenta grande variabilidade (30.300 a 47 m^3/s) (Garcia, 1996).

Fontes dos dados

Para a realização dessa tese, foram obtidas amostras de três fontes diferentes no litoral do Rio Grande do Sul, incluindo cruzeiros a bordo da Lancha Oceanográfica Larus (LOc. Larus, Universidade Federal do Rio Grande), Navio Oceanográfico Atlântico Sul (NOc. Atlântico Sul, Universidade Federal do Rio Grande) e frota arrasteira artesanal. Adicionalmente, forma obtidas amostras das frotas comercial de camarão atuante no Rio de Janeiro e semi-artesanal de Mar del Plata. Essas amostras foram obtidas pontualmente durante a primavera de 2004 e utilizados para comparação com a população habitando o litoral sul do Brasil, tanto no que diz respeito a aspectos genéticos quanto morfométricos e merísticos.

Os arrastos com a LOc. Larus foram realizados entre as profundidades de 5 e 20 metros na região adjacente à Barra de Rio Grande durante o ano de 2002. Adicionalmente foram selecionados dados históricos inseridos no Banco de Dados do Laboratório de Crustáceos Decápodes (FURG) para a análise de estoque-recrutamento. Esta embarcação possui um comprimento total de 15,3 metros, calado máximo de 1,4 metros e dois motores centrais de 240 hp´s cada. A rede camaroneira utilizada para a coleta possui tamanho de malha 13 milímetros entre nós opostos. O tempo de arrasto em cada uma das estações foi padronizado em 5 minutos. Foram escolhidos três transects na região adjacente à Barra de Rio Grande, com estações nas isóbatas de 5, 15 e 20 metros de profundidade. Além das amostragens biológicas também foram coletados dados ambientais como temperatura e salinidade.

As coletas realizadas com embarcação da frota artesanal foram obtidas entre as profundidades de 2 e 12 metros, também na região adjacente à Barra de Rio Grande. A embarcação utilizada para as coletas foi um bote de arrasto de fundo com portas, típico da frota artesanal. Essa embarcação possui o comprimento total de 7,60 metros, boca de 2,20 metros e motor de 10 hp´s. A rede camaroneira utilizada para as coletas possui tamanho de malha 16 milímetros entre nós opostos. É importante ressaltar que as embarcações da frota artesanal são extremamente suscetíveis a condições climáticas adversas e, portanto sua atuação está intimamente relacionada com esses fatores. Diferentemente dos pontos amostrais realizados a bordo da LOc. Larus, estes não foram pré-definidos, deixando o mestre da embarcação pescar normalmente. A intenção foi obter dados que refletissem da forma mais fiel possível essa atividade, no que diz respeito à área de atuação, profundidades amostradas e poder de pesca. Também foram coletadas amostras biológicas e dados ambientais, utilizando os mesmos equipamentos usados nas coletas com a LOc. Larus.

As amostras oriundas do NOc. Atlântico Sul foram obtidas durante fevereiro de 2005 em pontos amostrais realizados entre Torres e o Chuí, em profundidades que variaram entre 5 e 29 metros. A rede utilizada possui um arraçal de 20m guarnecido com uma corrente de aço com peso de 1,3kg/m. O tamanho das malhas de rede, entre nós opostos, variou entre 50mm na porção anterior até 22mm no ensacador. Os lances duraram cerca de 30min e a velocidade de arrasto em torno de 5,5km/h. No final de cada lance foram registrados os perfis verticais de temperatura e salinidade através de um CTD. Também foram obtidas amostras do tipo de fundo através de draga van Veen e ecossonda científica.

Processamento das amostragens biológicas

Com exceção das amostras obtidas através do arrasto realizados a bordo do NOc. Atlântico Sul, todas as outras foram levadas integralmente ao laboratório para análise, não necessitando de quarteamento. As medidas tomadas rotineiramente foram comprimento total (CT) em milímetros, comprimento da carapaça (CC) em milímetros, peso total em gramas (PT) e o sexo dos indivíduos. Adicionalmente foram obtidas informações sobre o grau de maturação dos ovários de acordo com Dumont e D'Incao (2004). Para a realização do estudo biométrico também foram tomadas medidas do comprimento do rostro (CR), comprimento do télson (Ctel) e do número de dentes rostrais (ND) (Figura 4).

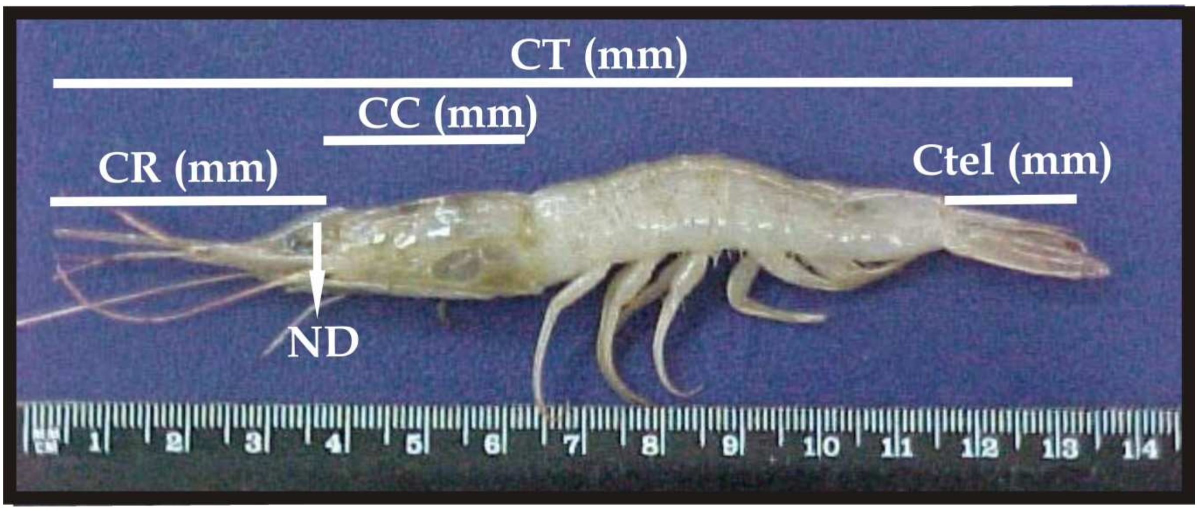

Figura 4. *Artemesia longinaris* e as medidas utilizadas para a análise da estrutura populacional e análises biométricas, incluindo o comprimento total (CT), comprimento da carapaça (CC), comprimento do rostro (CR), comprimento do télson (Ctel) e o número de dentes rostrais (ND).

A REGIÃO CONTROLE DO DNA MITOCONDRIAL E SEU USO POTENCIAL COMO MARCADOR PARA O ESTUDO DA ESTRUTURA POPULACIONAL DO CAMARÃO-BARBA-RUÇA *ARTEMESIA LONGINARIS* (DECAPODA:PENAEIDAE).

Artigo submetido para revista internacional: Dumont, L.F.C., Hwang, G. and Maclean, N. **The mtDNA control region of the argentinean prawn *Artemesia longinaris* (DECAPODA:PENAEIDAE) and its potential use as a marker for population structure analysis**. Journal of Crustacean Biology.

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

RESUMO

O camarão-barba-ruça (*Artemesia longinaris*) é endêmico do Oceano Atlântico Sudoeste, sendo explorado comercialmente ao longo de toda a sua área de distribuição, desde a Puerto Rawson ($43^0$00'S, Argentina) até o Sudeste do Brasil ($21^0$37'S, Rio de Janeiro). Marcadores moleculares têm sido amplamente utilizados para estudar a estrutura populacional de camarões peneídeos ao redor do mundo. A eficiência da região controle do DNA mitocondrial (CR) para estudos a nível populacional foi testada para o camarão-barba-ruça, gerando novos conjuntos de primers capazes de amplificar inteiramente essa região, assim como uma porção hipervariável de aproximadamente 0,8kb. Os primers para amplificar inteiramente a região controle foram posicionados nas regiões mais conservadas que a flanqueiam, sendo elas o gene 12S e o RNA transportador $tRNA^{Ile3}$. A região controle de *A. longinaris* possui uma extensão de 990pb, apresentando duas regiões hipervariáveis nas extremidades 5'e 3', assim como uma região central com menos variabilidade, separada das outras duas por porções mais conservadas. A comparação da região controle com a citocromo oxidase (COI) e o 12S demonstrou que o primeiro gene apresenta maior nível de variabilidade, sendo, portanto, útil nas análises de estrutura populacional de *A. longinaris* no Atlântico Sudoeste. A diversidade nucleotídica estimada para *A. longinaris* foi relativamente baixa (π=0,017), enquanto que a diversidade haplotípica foi alta (*Hd*=0,92), apesar de estar dentro dos limites sugeridos para a família penaeidae. A análise preliminar das distâncias genéticas entre as populações (*Fst*) indicam que os estoques habitando os extremos da área de distribuição da espécie apresentam menor intercâmbio genético e que a população do Sul do Brasil e da Argentina são geneticamente mais próximas.

ESTRUTURA GENÉTICA DAS POPULAÇÕES DO CAMARÃO-BARBA-RUÇA *ARTEMESIA LONGINARIS* (DECAPODA:PENAEIDAE) NO ATLÂNTICO SUDOESTE RESOLVIDA POR ANÁLISE DA REGIÃO CONTROLE DO DNA MITOCONDRIAL.

Artigo submetido para revista internacional: Dumont, L.F.C., Hwang, G. and Maclean, N. **Population genetic structure of the argentinean prawn *Artemesia longinaris* (DECAPODA:PENAEIDAE) in Southwestern Atlantic resolved by mtDNA control region analysis**. Marine Biotechnology.

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

RESUMO

O crescente interesse comercial da frota camaroneira de arrasto-duplo pelo camarão-barba-ruça (*Artemesia longinaris*) gera a necessidade de se investigar a estrutura populacional e identificar os estoques dessa espécie no litoral do Atlântico Sudoeste. *Artemesia longinaris* é uma espécie de peneídeo monotípica e endêmica, que se distribui desde a Argentina (Puerto Rawson - $43^0$00'S) até o Sudeste do Brasil (Rio de Janeiro - $21^0$37'S). A estrutura populacional dessa espécie foi investigada através do seqüenciamento de aproximadamente 0,7kb da região controle do DNA mitocondrial. Sessenta e nove amostras foram obtidas de quatro locais diferentes, incluindo Rio de Janeiro ($21^0$37'S), Rio Grande do Sul ($32^0$00'S), Santa Catarina ($26^0$54'S) e Mar del Plata ($37^0$56'S). A diversidade nucleotídica *(π)* variou entre 0,025 e 0,039 com menores valores sendo observados nas regiões próximas ao limite de distribuição da espécie. A diversidade haplotípica (*Hd*) variou entre 0,90 a 0,95 e seguiu o mesmo padrão observado para a diversidade nucleotídica, com valores mais altos no centro da área de distribuição. Entre as 69 seqüências analisadas, apenas dois haplótipos foram compartilhados por populações diferentes, sendo elas as que habitam o Rio Grande do Sul e Santa Catarina. A análise das seqüências da região controle sugere que existe uma estruturação significativa das populações de *A. longinaris* ao longo de sua área de distribuição. As distâncias genéticas estimadas (*Fst*) demonstram que existe um maior fluxo genético entre as populações que habitam o Sul do Brasil e a Argentina (*Fst*= 0,04, p=0,18), enquanto que a população localizada no extremo norte da distribuição da espécie (Rio de Janeiro) foi significativamente diferente das demais (*Fst*= 0,07, p= 0,03 quando comparada com o Sul do Brasil e *Fst*= 0,11, p= 0,01 quando comparada com a Argentina). Os resultados obtidos são inteiramente corroborados pelas distâncias geográficas separando as populações e pelo sistema de correntes que atua na região costeira do Atlântico Sudoeste, apresentando expansões e retrações sazonais que permitem a dispersão de larvas e/ou adultos dessa espécie

na região. A análise demográfica indicou significante instabilidade para as populações que habitam zonas próximas aos limites de distribuição da espécie, enquanto que a população central apresentou maior grau de estabilidade histórica. Mesmo assim, esse grupo mostrou um padrão oscilatório das diferenças genéticas, indicando que também apresenta variações importantes com relação ao tamanho populacional.

CAPÍTULO 3

RELAÇÕES BIOMÉTRICAS DO CAMARÃO-BARBA-RUÇA *ARTEMESIA LONGINARIS* (DECAPODA:PENAEIDAE) NO ATLÂNTICO SUDOESTE.

Artigo submetido para revista internacional: Dumont, L.F.C. and D'Incao, F. **Biometric relationships of the argentinean prawn *Artemesia longinaris* (DECAPODA:PENAEIDAE) in Southwestern Atlantic.** Journal of Marine Biology Association of United Kingdom.

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

RESUMO

Relações biométricas de tamanho e peso foram estimadas para o camarão-barba-ruça (*Artemesia longinaris* Bate, 1888), uma espécie comercial recentemente explorada de camarão peneídeo. Caracteres merísticos e morfométricos foram utilizados para discutir a estrutura populacional dessa espécie ao longo de sua área de distribuição. As relações de comprimento foram estimadas com base em regressões lineares simples, considerando o comprimento total (CT) como variável dependente do comprimento da carapaça (CC). As relações entre comprimento (CC) e peso total (PT) das fêmeas foram estabelecidas de acordo com um modelo potencial. Os machos que habitam a região da Convergência Sub-tropical no Sul do Brasil apresentaram um incremento em CT ligeiramente menor do que as fêmeas. Uma marcada redução na declividade das retas de regressão foi observada durante o outono e o inverno, se assemelhando com os valores obtidos para os machos na Argentina. Os outros caracteres morfométricos e merísticos utilizados também confirmam essa similaridade, que pode ser atribuída tanto à temperatura da água quanto a migrações de indivíduos do sul se aproveitando do sistema de correntes da região. Além disso, a população que habita o limite norte de distribuição (Rio de Janeiro) parece ser mais diferenciada do resto no que diz respeito a aspectos morfométricos e merísticos, concordando com a análise genética anteriormente realizada. Crescimento alométrico negativo em peso foi estimado para a espécie, refletindo a forma delgada apresentada por essa espécie. As fêmeas apresentam maior incremento em peso durante o período reprodutivo que acontece na primavera, o que está relacionado com a maturação dos ovários e a maior disponibilidade de alimento durante essa época. O fator de condição relativo demonstrou variações sazonais e interanuais, sendo negativamente afetado pelas temperaturas mais elevadas do verão e pelas salinidades menores no inverno.

PADRÃO REPRODUTIVO, TAMANHO DE PRIMEIRA MATURAÇÃO E RELAÇÕES ESTOQUE-RECRUTAMENTO DO CAMARÃO-BARBA-RUÇA (*ARTEMESIA LONGINARIS*, DECAPODA:PENAEIDAE) NO SUL DO BRASIL.

Artigo submetido para revista internacional: Dumont, L.F.C. and D'Incao, F. **Reproductive pattern, size at first maturity and stock-recruitment relationships of the argentinean prawn (*Artemesia longinaris*, DECAPODA: PENAEIDAE) in Southern Brazil.** Scientia Marina.

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

RESUMO

Artemesia longinaris vem sendo explorada pelas frotas comercial e artesanal no Sul do Brasil. Para investigar a biologia reprodutiva e tamanho de primeira maturação dessa espécie na região, amostras mensais foram analisadas entre Fevereiro de 2002 e Janeiro de 2003 em profundidades entre 5 e 20 metros. Adicionalmente foram analisadas nove temporadas reprodutivas e seus conseqüentes resultados em termos de recrutamento. Com base nesses dados, foram desenvolvidas relações de estoque-recrutamento e um modelo preliminar preditivo no sentido de detectar alguns fatores que influenciam o sucesso no recrutamento de *A. longinaris* na região. Concluiu-se que essa espécie concentra o seu esforço reprodutivo na primavera, embora o recrutamento tenha sido observado ao longo de todo o ano. A reprodução durante o outono parece ser mais susceptível a elevadas quantidades de chuva na região que causam uma diminuição da salinidade na área de estudo. Durante o verão a atividade reprodutiva também parece ser reduzida, o que provavelmente reflete a baixa tolerância dessa espécie a temperaturas mais altas. Uma migração reprodutiva para profundidades maiores de 15 metros foi observada e o início do recrutamento acontece aproximadamente um mês após o pico reprodutivo. Esse deslocamento reprodutivo para maiores profundidades é evidenciado por uma maior concentração de fêmeas adultas em áreas mais afastadas da beira, enquanto que os indivíduos menores se concentram mais próximos da costa. O tamanho médio de primeira maturação foi estimado em 16,76 mm (CC) e foi atingido na idade de aproximadamente 4 meses. Ajustes significativos dos dados de estoque-recrutamento foram observados para os três modelos utilizados apenas em anos onde as condições ambientais eram desfavoráveis, sugerindo que a combinação de biomassa desovante reduzida com condições ambientais desfavoráveis pode levar à sobrepesca de recrutamento. O modelo preliminar de previsão preditivo sugere que os principais fatores influenciando o recrutamento são a salinidade na temporada reprodutiva (B=0,96) e a chuva

durante o recrutamento (B=-3,29). O principal fator que influencia o recrutamento durante os anos em que as condições ambientais são adversas é a biomassa desovante (B=1,01), enquanto que em anos onde o recrutamento é elevado o principal fator é a salinidade durante a temporada reprodutiva (B=0,99).

ANÁLISE DA CAPTURA INCIDENTAL DO CAMARÃO-BARBA-RUÇA *ARTEMESIA LONGINARIS* (DECAPODA-PENAEIDAE), EXPLORADO PELO ARRASTO ARTESANAL NA REGIÃO ADJACENTE À BOCA DO ESTUÁRIO DA LAGOA DOS PATOS, RIO GRANDE DO SUL, BRASIL – EFEITO DA PLUVIOSIDADE NA CAPTURA INCIDENTAL.

Artigo submetido para revista internacional: Dumont, L.F.C. and D’Incao, F. **Bycatch analysis of the argentinean prawn *Artemesia longinaris* (DECAPODA:PENAEIDAE) exploited by artisanal trawling in surrounding area of Patos Lagoon Estuary mouth, Rio Grande do Sul, Brasil – effects of different rainfall on incidental catch**. Journal of Marine Biology Association of United Kingdom.

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

RESUMO

Um dos métodos de pesca mais problemáticos em termos de descartes da fauna acompanhante é o arrasto destinado à captura de camarões, com vários estudos tendo identificado e quantificado os tipos e os níveis de descarte em muitas pescarias. O presente trabalho analisou a captura incidental da frota artesanal de arrasto que objetiva a captura de *Artemesia longinaris* na região adjacente à Barra de Rio Grande durante duas temporadas de pesca distintas (2002 e 2004). O assunto desse trabalho foi sugerido pelos pescadores artesanais durante reunião do Fórum da Lagoa dos Patos (órgão consultivo de co-gestão de pesca), na tentativa de se avaliar os impactos, produzir conhecimento e prover informações para uma futura exploração legal desse recurso na região. As amostragens se deram a bordo de uma embarcação pesqueira artesanal durante a principal temporada de pesca, que vai de abril a dezembro. Um pesquisador foi sempre incluído a bordo para evitar a perda de informação devido ao descarte realizado pelos pescadores a bordo. Cinqüenta espécies foram capturadas, sendo 38 de peixes e 12 de crustáceos. O descarte total estimado para os dois anos analisados foi de 1kg de camarão para 5,6kg de peixe, mas os valores variaram entre 1:11,3 em 2002 e 1:2,5 em 2004. As diferenças interanuais mais marcantes foram observadas no outono (1:75 em 2002 e 1:11,30 em 2004) e inverno (1:16 em 2002 e 1:0,97 em 2004), enquanto que durante a primavera os valores se mostraram mais similares (1:8 em 2002 e 1:4 em 2004). Os descartes em termos numéricos mostraram um padrão diferente, variando entre 1:2,24 em 2002 e 1:0,5 em 2004. A maior quantidade de água doce oriunda da Lagoa dos Patos e despejada no mar durante o ano de 2002 pode ter contribuído para o aumento da produtividade na zona costeira, resultando em uma maior biomassa de espécies estuarino-dependentes e estuarino-residentes, sustentando uma maior abundância de espécies que pertencem a níveis tróficos superiores, tais como carnívoros de alto nível e predadores de topo. No entanto, a produção da espécie-alvo (*Artemesia longinaris*) foi consideravelmente

menor já que essa espécie não tolera reduções pronunciadas na salinidade, o que foi causado pela grande quantidade de chuva observada nesse período. Em 2004 a pluviosidade foi marcadamente menor, favorecendo a produção de *A. longinaris* na região. Durante esse ano de seca, a espécie foi dominante nas amostras, o que resultou em uma taxa de descarte bastante menor, especialmente no inverno (1:0,97). Em geral as capturas foram compostas por indivíduos juvenis, já que a pesca é realizada em área de berçário para várias espécies. O esforço pesqueiro aplicado é baixo e altamente dependente da abundância da espécie-alvo, assim como das condições meteorológicas. Assumindo que a pesca de arrasto objetivando o camarão-barba-ruça (*A. longinaris*) na região adjacente à Barra de Rio Grande seja realizada somente em anos de elevada abundância da espécie-alvo, o período mais indicado seria o inverno, resultando em baixos níveis de esforço devido às condições climáticas e aos baixos níveis de captura incidental. Ao contrário, se a pesca for liberada durante anos de elevada pluviosidade, a mortalidade de peixes e crustáceos juvenis seria elevada, já que o descarte de peixes sem valor comercial é elevado.

DISTRIBUIÇÃO E ABUNDÂNCIA DO CAMARÃO-BARBA-RUÇA (*ARTEMESIA LONGINARIS* BATE, 1888) E DO CAMARÃO-SANTANA (*PLEOTICUS MUELLERI* BATE, 1888) (DECAPODA:PENAEOIDEA) NO SUL DO BRASIL DURANTE A TEMPORADA DE ARRASTO DUPLO COMERCIAL.

Artigo submetido para revista nacional: Dumont, L.F.C. and D'Incao, F. **Distribution and abundance of the argentinean (*Artemesia longinaris* Bate, 1888) and red prawns (*Pleoticus muelleri* Bate, 1888) (DECAPODA:PENAEOIDEA) in southern Brazil during commercial double-rig trawl commercial fishery season**. Nauplius.

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

RESUMO

Os declínios das capturas das espécies mais valiosas de camarão, tais como o camarão-rosa (*Farfantepenaeus paulensis* e *F. brasiliensis*), expandiram os alvos da frota comercial de arrasto duplo que passou a objetivar espécies como *Artemesia longinaris* e *Pleoticus muelleri*. Na intenção de aumentar o conhecimento sobre a distribuição e abundância dessas espécies no Sul do Brasil, 64 estações de pesca foram realizadas ao longo do litoral gaúcho durante a principal temporada de pesca comercial. As amostras foram coletadas com o Navio Oceanográfico Atlântico Sul em profundidades eque variaram entre 5 e 29 metros como contribuição ao Projeto SALVAR.. Temperatura, salinidade e o tipo de fundo foram importantes fatores regendo a distribuição de *A. longinaris*, que concentrou maiores abundâncias nas zonas de menor temperatura e maior salinidade associadas à ressurgência de verão e sedimentos mais finos. *Pleoticus muelleri* mostrou uma distribuição mais homogênea, não evitando as areas de menor salinidade sob a influência do deságüe da Lagoa dos Patos. Através do método de área varrida, estimou-se que a biomassa de *A. longinaris* entre as profundidades de 10 e 20 metros foi de 3369 toneladas durante a principal temporada de pesca. *Pleoticus muelleri* apresentou menores densidades, somando um total de 2527 toneladas para a mesma faixa de profundidade. A análise das distribuições de freqüência permite concluir que os maiores indivíduos se concentram em profundidades entre 15 e 20 metros para ambas as espécies. Entretanto, os indivíduos maiores de *A. longinaris* claramente evitaram as áreas sob influência do deságüe da Lagoa dos Patos. Ao contrário, se aproveitou das áreas de menor salinidade, evitadas por *A. longinaris*, para a desova sugerindo que a competição por espaço e recursos é importante entre essas espécies.

CONCLUSÕES GERAIS

CAPÍTULO 1

- ✓ A região controle de *Artemesia longinaris* é similar em tamanho (990pb) e é flanqueada pelos mesmos genes (12S e tRNA^{Ile3}) observados para os outros peneídeos.
- ✓ A comparação interespecífica da região controle de *A. longinaris* com outros peneídeos demonstrou a existência de três regiões hipervariáveis, duas nos extremos e uma central menos polimórfica.
- ✓ A comparação intra-específica da região controle com os genes citocromo oxidase e 12S permitiu concluir que a primeira é mais variável e, portanto, mais eficiente na identificação da estrutura genética de populações para essa espécie.
- ✓ A diversidade nucleotídica estimada com base em 9 amostras foi baixa (π=0,017), enquanto que a diversidade haplotípica foi alta (*Hd*=0,92).

CAPÍTULO 2

- ✓ A população de *Artemesia longinaris* que habita a zona da Convergência Sub-tropical (Santa Catarina e Rio Grande do Sul) e a que habita a Argentina não demonstraram diferenças significativas em termos de distância genética.
- ✓ A população que habita o limite norte de distribuição mostrou ser significativamente diferente das demais, o que pode ser explicado pela distância geográfica e pelo sistema oceanográfico que rege a circulação na área de distribuição da espécie.
- ✓ O grau de variabilidade (diversidade nucleotídica e haplotípica), assim como a estabilidade dessas populações foi menor nos grupos que habitam as áreas próximas aos limites de distribuição para a espécie.

- ✓ A diversidade nucleotídica com base nas 69 amostras foi relativamente baixa, enquanto que a diversidade haplotípica foi alta, sugerindo variações importantes do tamanho populacional para essa espécie.

CAPÍTULO 3

- ✓ Os machos de *Artemesia longinaris*, que habitam a Zona da Convergência, apresentaram um crescimento relativo em comprimento total levemente menor do que as fêmeas dessa espécie.
- ✓ Uma redução bem marcada na declividade das regressões dos machos entre comprimento total e comprimento da carapaça foi detectada durante o outono e o inverno. Tal padrão poderia ser explicado tanto por uma migração de indivíduos ou larvas vindos do sul quanto por um crescimento diferenciado devido à temperatura da água.
- ✓ Os caracteres morfométricos e merísticos utilizados indicaram uma maior similaridade entre as populações que habitam a Zona de Convergência e a Argentina, enquanto que a população que habita o Rio de Janeiro parece ser mais diferenciada do restante.
- ✓ O crescimento alométrico em peso foi observado para ambos os sexos, refletindo o formato alongado que a espécie apresenta.
- ✓ O fator de condição relativo mostrou variações anuais e sazonais, negativamente influenciado pelas altas temperaturas do verão e as baixas salinidades no inverno. Os maiores valores estimados para esse parâmetro foram observados na primavera, concomitantemente com o principal período reprodutivo da espécie.

CAPÍTULO 4

- ✓ O esforço reprodutivo de *Artemesia longinaris* está concentrado na primavera, entretanto, outros picos menores de recrutamento podem ser observados ao longo do ano.
- ✓ Foi observada uma migração reprodutiva para profundidades além dos 15 metros, já que as maiores fêmeas se concentram nessas isóbatas. O recrutamento acontece nas regiões mais próximas da praia e começa na idade de aproximadamente 1 mês.
- ✓ O tamanho médio de primeira maturação sexual foi estimado em 16,76 mm (CC) e é atingido à idade de aproximadamente 4 meses.
- ✓ Ajustes significantes aos modelos de estoque-recrutamento somente foram observados em anos em que as condições ambientais foram desfavoráveis. Esse resultado sugere que a redução da biomassa desovante, combinada a condições ambientais desfavoráveis pode levar à sobrepesca de recrutamento.
- ✓ Os principais fatores que influenciaram o recrutamento dessa espécie foram a salinidade na época reprodutiva (B= 0,96) e a pluviosidade no período de recrutamento (B= -3,29).
- ✓ O principal fator que influenciou o sucesso no recrutamento durante anos de condições ambientais desfavoráveis foi o tamanho do estoque desovante (B=1,01), enquanto que a salinidade na época de reprodução foi o fator preponderante nos anos favoráveis.

CAPÍTULO 5

- ✓ Cinqüenta espécies foram capturadas durante a temporada de pesca artesanal de *Artemesia longinaris*, sendo 38 de peixes e 12 de crustáceos.
- ✓ A composição e a abundância da fauna acompanhante variou sazonal e anualmente, com as taxas mais altas de descarte observadas em períodos de maior pluviosidade.
- ✓ A taxa de descarte total, para os dois anos analisados foi de 1 kg de camarão-barba-ruça para 5,6 kg de bycatch, variando de 1:11,3 em 2002 a 1:1,25 em 2004. As diferenças sazonais mais marcadas foram observadas no outono (1:75 em 2002 e 1:11,30 em 2004), inverno (1:16 em 2002 e 1:0,97 em 2004), enquanto que a primavera mostrou valores mais próximos para os dois anos estudados (1:8 em 2002 e 1:4 em 2004).
- ✓ A maior intensidade de chuva observada durante 2002 acarretou em um maior volume de água doce oriundo da Lagoa dos Patos, diminuindo a salinidade na área de estudo e conseqüentemente a abundância de *A. longinaris*. Adicionalmente, o maior volume de águas continentais despejado sobre a região costeira aumentou a biomassa de espécies estuarino-relacionadas, o que aumentou a taxa de descartes.
- ✓ Assumindo que a pescaria de arrasto artesanal objetivando o camarão-barba-ruça seria realizada apenas em anos onde a abundância da espécie-alvo for alta, a temporada de pesca mais indicada seria durante os meses de inverno.

CAPÍTULO 6

- ✓ Temperatura, salinidade e o tipo de substrato influenciaram a distribuição de *Artemesia longinaris*, que concentra as maiores densidades em áreas de baixa temperatura e elevada salinidade, associadas à ressurgência de verão.
- ✓ *Pleoticus muelleri* apresentou uma distribuição mais homogênea, não evitando as áreas de menor salinidade sob a influência da Lagoa dos Patos.
- ✓ Através do uso do método de área varrida, um total de 3369 toneladas de *A. longinaris* foi estimado entre as profundidades de 10 e 20 metros. *Pleoticus muelleri* apresentou menores abundâncias para a mesma área, somando um total de 2527 toneladas.
- ✓ A distribuição dos comprimentos de carapaça permitiu concluir que os indivíduos maiores se concentram especialmente entre os 15 e 20 metros de profundidade.

CONSIDERAÇÕES FINAIS

A identificação dos estoques de *Artemesia longinaris* ao longo da sua área de distribuição sugere que exista uma estrutura populacional significativa, de maneira que os grupos que habitam as regiões mais ao sul apresentam maiores similaridades em termos genéticos e morfométricos. Dessa forma, futuras avaliações de estoque devem levar em consideração esse fato e, portanto, cada um dos estoques deveria receber uma avaliação individual, especialmente no que diz respeito às populações habitando o litoral brasileiro. Embora o estoque de *A. longinaris* que habita o sul do Brasil apresente maiores similaridades com o que se encontra no litoral argentino, isso não significa que aquela população apresente os mesmos parâmetros populacionais, tais como crescimento, mortalidade e reprodução, mas que provavelmente larvas e/ou adultos migrem da Argentina até a costa do Rio Grande do Sul durante os meses de outono e inverno.

Como discutido anteriormente nesse trabalho, o tamanho médio de primeira maturação apresenta variações latitudinais importantes de maneira que esse parâmetro tende a diminuir com a diminuição da latitude. As variações no tamanho médio de primeira maturação são, muito provavelmente, reflexo das diferenças na temperatura da água em que esses grupos populacionais vivem. A temperatura da água é de grande importância para a distribuição e reprodução da espécie, atuando também no desenvolvimento ontogenético, especialmente dos machos. Além das variáveis morfométricas usadas, o caractere merístico usado (número de dentes no rostro) seguiu o padrão esperado para diferentes faixas de temperatura. O maior número de dentes no rostro foi observado na Argentina, onde a temperatura da água é mais baixa, enquanto que a menor média para essa variável foi estimada na população que habita o limite norte de distribuição (Rio de Janeiro). A temperatura também influenciou diretamente na distribuição da espécie, que procura áreas com águas mais frias, especialmente durante a temporada de pesca comercial. Durante o verão, a espécie apresentou uma distribuição relacionada à ressurgência de plataforma que acontece mais freqüentemente durante esse período.

A salinidade também foi um fator preponderante na biologia da espécie, influenciando o sucesso reprodutivo, a abundância e a distribuição dos indivíduos no sul do Brasil. A salinidade é um dos fatores mais importantes para a reprodução dessa espécie, aumentando o sucesso da reprodução. Em geral, as fêmeas realizam uma migração reprodutiva para as áreas relativamente mais profundas entre 15 e 20 metros, buscando áreas mais afastadas do deságüe da Lagoa dos Patos. No entanto, em anos de baixa salinidade durante a primavera, quando acontece a principal temporada reprodutiva, a biomassa desovante se torna um dos fatores principais no sucesso reprodutivo. A baixa salinidade também diminui a abundância da espécie como um todo, na área sob a influência da Lagoa dos Patos, o que se reflete também nas taxas de captura acidental. O maior deságüe observado durante o ano de maior pluviosidade diminuiu a salinidade na região costeira adjacente, estendendo o habitat de diversas espécies que têm seus ciclos de vida relacionados ao estuário e conseqüentemente aumentando a captura incidental do camarão-barba-ruça. Com base nessa conclusão sugere-se que períodos de defeso deveriam ser implementados para preservar o estoque desovante no sul do Brasil.

Como sugestão de manejo para a pesca comercial de arrasto-duplo propõe-se um período de defeso de no mínimo dois meses entre outubro e novembro, preservando assim o estoque desovante durante a principal temporada reprodutiva. O rendimento máximo sustentável sugerido na literatura parece ser demasiadamente alto, já que os níveis de biomassa estimados durante o verão sugerem que elevadas porcentagens da biomassa total são removidas pela pesca. Dessa forma sugere-se uma diminuição no esforço de pesca aplicado sobre o estoque habitando o litoral do Rio Grande do Sul. O dano causado pelo esforço de pesca elevado se torna ainda mais grave devido ao tipo de distribuição do mesmo, que tende a ser concentrado nos pontos de máxima densidade da espécie-alvo. A espécie apresentou uma distribuição bastante agrupada, concentrando grande parte da biomassa em uma pequena fração da área estudada. Isso a torna mais susceptível ao esforço de pesca dos arrasteiros, que possuem *try nets* e reduzem significativamente o tempo de procura pelas maiores manchas. Adicionalmente, algumas áreas de pesca poderiam ser excluídas, já que concentram altas densidades de fêmeas reprodutivas e, portanto, devem ser áreas de desova.

Com relação ao manejo da pesca artesanal, o esforço de pesca não parece ser excessivo, já que as embarcações são de pequeno porte e com motores de baixa potência. Além disso, a operação desses barcos na zona costeira é altamente dependente das condições climáticas, e a possibilidade de capturar o camarão-barba-ruça se dá apenas em poucos dias após a passagem de frentes frias, às quais eles associam as maiores abundâncias. Dessa forma, sugere-se a permissão do arrasto artesanal para o camarão-barba-ruça durante o inverno, já que durante esse período a abundância da espécie-alvo é alta e a captura incidental baixa, assim como o esforço, que é limitado pelas condições atmosféricas.

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The mtDNA control region of the Argentinean prawn *Artemesia longinaris* (DECAPODA:PENAEIDAE) and its potential use as a marker for population structure analysis

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Abstract

The argentinean prawn (*Artemesia longinaris*) is an endemic penaeid prawn from Southwestern Atlantic, commercially exploited from Argentina (Puerto Rawson - $21^0$37’S) to Southeastern Brazil (Rio de Janeiro - $43^0$00’S). Molecular markers, such as mtDNA control region have been recently used to elucidate population structure of penaeid prawns worldwide. Suitability of mtDNA control region (CR) of the argentinean prawn as a molecular marker at population level was tested and a novel set of primers to amplify this region is provided. Primers were rooted in flanking genes of the control region that showed same order (12S at 5’and $tRNA^{Ile3}$ at 3’) as reported for other penaeid prawns. The CR of *A. longinaris* is 990bp long, presenting two hypervariable regions at the 5’and 3’extremeties (more variable), and a central one that showed less polymorphism. In addition, an internal primer set to amplify approximately 800bp of 5’extreme of CR, including the hypervariable region I, is provided to resolve population structure. Comparison of CR with cytochrome oxydase (COI) and 12S showed that the former gene presents lower polymorphism. Nucleotide diversity estimated for CR was low (π=0.017), and haplotype diversity high (*Hd*=0.92), but within the values suggested for the family. Preliminary *Fst* values suggested that populations inhabiting extremes of distribution show less genetic interchange. Briefly, we managed to confirm the suitability of CR hypervariable regions of *A. longinaris* as a molecular marker to resolve population structure of *A. longinaris*.

KEYWORDS: *Artemesia longinaris*, stock identification, mtDNA, control region, AT-rich region.

Introduction

Artemesia longinaris is an endemic penaeid prawn, distributed from Argentina (Puerto Rawson - 43^{0}00’S) to Southeastern Brazil (Rio de Janeiro - 21^{0}37’S) (D’Incao, 1999). Its life cycle does not demand an estuarine phase, but the recruits migrate to shallower marine waters during grow out phase and females move to deeper waters for spawning (Boschi, 1969; Castillo et al., 2007; Dumont & D`Incao, *submitted*).

Unlike many other penaeid fisheries (*e.g. Farfantepenaeus duorarum*, *F. paulensis*, *F. brasiliensis*), landings of *A. longinaris* have been recently increased (D’Incao et al., 2002; Navarrete et al., 1995), despite of great interannual variability, mainly caused by environment effects. Landings of *A. longinaris* in Brazil have grown since 90’s achieving a maximum value of 7,424 tons in 2003 (Univali, 2004), resulting in the second more profitable prawn fishery in Southern and Southeastern Brazil (Pezzuto, 2001). Thus, molecular investigations would provide relevant information on *A. longinaris* stock structure in Southwestern Atlantic.

The use of mtDNA to identify stock or population structure has proved to be a useful tool for population genetic studies of many terrestrial and aquatic organisms (Avise, 1994). Two portions of mtDNA can be especially useful at population level investigations, the cytochrome oxydase (COI) and control region (CR) (Caccone et al., 1996). The control region, which is also known as the AT-rich region, does not code for a functional gene. Therefore, it is under fewer functional and structural constraints, leading to a high average substitution rate (Saccone et al., 1987). It is usually the fastest evolving region in the mitochondrial genome of either vertebrates or invertebrates, and consequently more sensitive than protein loci as a marker of phylogeographic structuring of many organisms (Caccone et al., 1996; Avise, 2000).

Due to these traits, the CR is of special utility for phylogeographic analysis over extreme microevolutionary time scales, which often shows an exceptionally fast pace of nucleotide substitution and high level of intraspecific polymorphism (McMillan and Palumbi, 1995). The aim of this paper is to explore the potential use of control region of *A. longinaris* as a molecular marker in order to characterize phylogeographic patterns of this species.

Material and Methods

Sampling strategy, preservation and DNA extraction

Samples were collected across the distribution area of *A. longinaris*, from Argentina to Rio de Janeiro in sprin and were arbitrarily divided in three different stocks: Rio de Janeiro (RJ- $21^{0}37$'S), Convergence Zone (CZ- $32^{0}00$'S and $26^{0}54$'S) and Argentina (AR) (Figure1). Three sequences from each region were used to assess the suitability of CR as a molecular marker.

Figure 1. Southwestern Atlantic Ocean and distribution range of *A. longinaris* (black solid line). Black dots indicate sites where samples were obtained, from Mar del Plata (Argentina, AR) Rio Grande do Sul (Brazil, CZ) and Macaé (Brazil, RJ).

Muscle samples from pereiopods and tail were collected, fixed in ethanol 95% and stored at 4°C. DNA was extracted using a phenol-chloroform-isoamyl alcohol (25:24:1) extraction of sodium dodecysulfate (SDS) - proteinase K digested tissue of each individual (Sambrook and Maniatis, 1989). DNA was isolated by 100% ethanol precipitation and visualized by gel electrophoresis to check the quality and amount obtained.

Design of mitochondrial control region primers

Universal control region primers and other primers designed to amplify partial or the entire control region of penaeid prawns were tested with no success (Chu et al., 2003; MacMillen-Jackson and Bert, 2003; Grabowski et al., 2004). Non-amplification or yield of a large number of nonspecific fragments and unsuccessfully optimization of amplification conditions led to the necessity of designing specific primer sets for *A. longinaris*.

First set of oligonucleotide primers were designed on more conserved genes that flank the penaeid prawns control region (Figure 2) and were based on a consensus alignment of *Penaeus monodon* (GenBank accession number NC002184; Wilson et al., 2000), *Marsupenaeus japonicus* (GenBank accession number AP006346; Yamauchi et al., 2005) and *Penaeus notialis* (GenBank accession number X84350; Garcia-Machado et al., 1999). The next primer sets used were designed based on *A. longinaris* sequences.

The forward primer (12Sa-F) was rooted in the beginning (5`end of 12S) of the small subunit ribosomal RNA gene (SSU rRNA – 12S, position 14209 of *P. monodon* mtDNA) and the reverse (ILE3a-R) in the isoleucine transfer RNA (tRNA^{Ile3}, position 7 of *P. monodon* mtDNA) gene (Figure 2). The second set of primers (12Sb-F and ILE3b-R) was positioned in the middle of 12S gene (position 14596 of *P. monodon* mtDNA) and inside the CR (position 15945 of *P. monodon* mtDNA). Third set of primers (12Sc-F and ILE3c-R) was positioned in the 5` flank of CR (position 14988 of *P. monodon* mtDNA) and inside the CR (position 15310 of *P. monodon* mtDNA. Primer-dimmer, secondary structure and G+C percentage were checked by using PRIMER3 software online (Rozen and Skaletsky, 2000) (Figure 2).

The first set of primers managed to amplify a fragment of 1.8 kb, including approximately 90% of the 12S gene and the entire CR. Two more primer walking steps have been performed to obtain more reliable sequences from the entire fragment. In order to establish a variation reference point, we amplified a 0.7kb fragment from COI region (HCO/LCO) (Folmer et al., 1994). Additionally, an interspecific comparison of 12S was also performed to test suitability of this gene for phylogenetic analysis in penaeid prawns. Primer oligonucleotides and their position in *P. monodon* mtDNA entire genome (GenBank accession number NC002184; Wilson et al., 2000) are provided in table I.

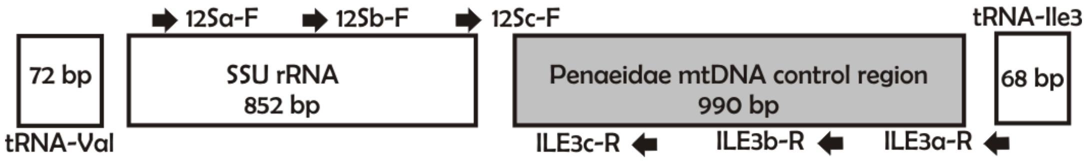

Figure 2. Primer positions used for partial amplification of 12S mtDNA and the entire control region of *A. longinaris*. Diagram also shows the position of flanking genes surrounding control region.

Table I. Primer sets used for *A. longinaris* mtDNA amplification, including oligonucleotide sequences, gene location and primer position based on *P. monodon* sequences. *nr= position not reported

Primer name	***Oligonucleotide sequences***	***Gene location***	***Primer position (bp)***
12Sa-F	5`-AGCGACGGGCGATGTGTTACAT- 3`	SSU rRNA	14209
ILE3a-R	5`-GATAATCCTTTTTCAGGCAGN- 3`	tRNA-Ile	7
12Sb-F	5` -GTGTAACAGGGTATCTAATC- 3`	SSU rRNA	14596
ILE3b-R	5`-GAGGGGTCGCCAGAAACAAA- 3`	CR	15945
12Sc-F	5` -GAATCAAGCCAGAATAAAAC- 3`	SSU rRNA	14988
ILE3c-R	5`-GTTGTATGCATTTAGTTAATT- 3`	CR	15310
HCO	5`-TAAACTTCAGGGTGACCAAAA-3`	COI	nr
LCO	5`-GTCAACAAATCAGGGTGACCAAAA- 3`	COI	nr

Amplification, purification of PCR products and sequencing

Amplification reactions were conducted using an Applied Biosystems PCR machine and each 20 µl of PCR contained 1µl of DNA template, 3.5 µl of 10x buffer (with 15 mM of $MgCl_2$), 0.2 µl of dNTP (20 mM), 0.5 µl of $MgCl_2$ (15 mM), 3.0 µl of Q-solution (Qiagen), 0.2 µl of each primer (100 pM), 0.5 µl of Taq DNA polymerase (5U/µl) and sterile HPLC-grade water. The cycle conditions were 1x94^{0}C for 1 minute, 94^{0}C for 10 seconds, 56^{0}C for 1 minute (12Sa-F/ILE3a-R), 68^{0}C for 1:50 minutes and finally 5 minutes at 68^0 (10x). Twenty five cycles more were carried out under the same conditions, except by the 10 seconds added after extension time at each cycle. This strategy was adopted to compensate the loss of synthesizing ability of polymerase through the cycles, when amplifying long products.

Annealing temperature used to amplify 1.3 kb with the second primer set (12Sb-F/ILE3b-R), was 48.5^{0}C for 1 minute and an elongation time of 1:30 minutes at 68^{0}C, also adding 10 seconds of extension time at each cycle. Last primer walking step amplified approximately 0.3kb at the 5` extremity of CR (annealing temperature 62^{0}C), in such a way that the entire CR was entirely covered.

Internal primers (12Sc-F/ILE3b-R) were used to amplify approximately 0.8kb (709bp were effectively analyzed) of CR, including the hypervariable region at 5`extreme, in attempt to test the suitability of CR as a genetic marker for *A. longinaris*. Annealing temperature used with this set of primers was 67^{0}C. A total of nine individuals were sequenced for intraspecific comparison of CR polymorphism and confronted to sequences obtained from cytochrome oxydase gene (700bp fragment length, 544bp were effectively analyzed) (Table I). Annealing temperature used to amplify COI region was 60^{0}C.

The PCR products were checked for correct size and amount of DNA on 1.0% agarose gel. Products were then purified by using PCR purification kit (Qiaquick™ PCR Purification Kit, Qiagen, Inc.) to remove excess nucleotides and primers as well as concentrate PCR products. The purified double-stranded amplification products were used as template DNA in sequencing reactions. Cycle-sequencing was performed using the ABI Prism BigDye Ready Mix (Applied Biosystems) and all PCR products were sequenced in both forward and reverse directions.

Sequence alignment, phylogenetic and phylogeographic analysis

Homologous nucleotide sequences from all samples were aligned using the program CLUSTAL W included in BIOEDIT (Hall, 1999) and refined when necessary. All the sequences are reported for the first time for *A. longinaris* and were submitted to GenBank database (National Center of Biotechnology Information). Estimates of nucleotide diversity (*π*), haplotype diversity (*Hd*) and preliminary *Fst* distances between CR sequences were estimated by using Arlequim 3.1 (Schneider et al., 2006). Kimura 2-parameter, used in interspecific comparison of 12S, substitution rates as well as nucleotide composition was estimated through the software MEGA (Tamura et al., 2007).

Results

Interespecific comparison of 12S

We were able to sequence approximately 90% of the 3` extremity of 12S gene (764 of 852bp, 400bp were effectively analyzed) as well as the entire CR (990bp). Comparison of *A. longinaris* 12S with *P. mondon* and *M. japonicus* resulted in 2.5% (10/400bp) of polymorphic sites (*S%*), an average number of differences (*k*) of 7.66 (±2.55) and nucleotide diversity (*π*) of 0.0196 (±0.00004).

Nucleotide composition in 12S gene was 36.43% (A), 35.44% (T), 17.84% (C) and 10.30% (G). Kimura 2-parameter, based on 12S alignment between three different *Penaeidae* genera (*Penaeus*, *Marsupenaeus* and *Artemesia*), varied from 0.197 (*Marsupenaeus* and *Penaeus*) to 0.256 (*Artemesia* and *Penaeus*).

Interspecific alignment of the entire CR sequence with *P. monodon* and *M. japonicus* showed three hypervariable regions, two at extremes and one central. The hypervariable region (I) extends from the 5` extremity for approximately 300bp. The hypervariable region I is followed by a more conserved region, that stretches for approximately 100bp. This conserved area is followed by a central hypervariable domain (II), which presents lower variation rates. The central domain is followed by another short conserved stretch. At the end of this conserved region, one more hypervariable region is present (III), similar to the hypervariable region I in terms of variation rates, that ends concurrently with the control region (Figure 3).

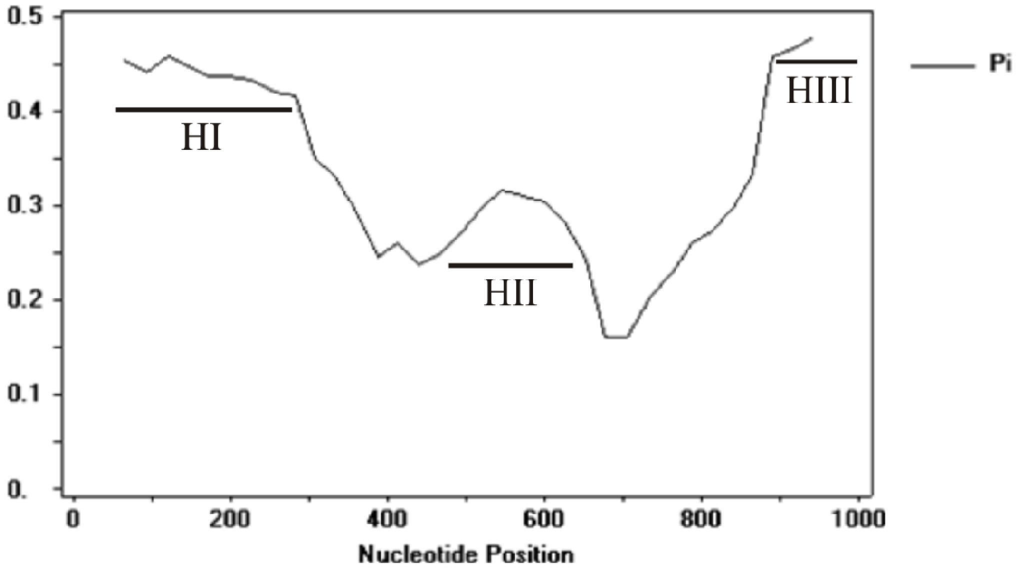

Figure 3. Variation in nucleotide diversity (*Pi*) along the 990bp of penaeid control region. Three hypervariable regions were observed (HI, HII and HIII), agreeing with previous penaeid prawns CR sequenced. Comparison was made between three different *Penaeid* genera (*Penaeus, Artemesia* and *Marsupenaeus*).

Intraspecific comparison of control region (CR) and cytochrome oxydase (COI)

Intra-population analysis showed that percentage of polymorphic sites (*S%*) estimated for CR was 6.9% (49/709bp), haplotype diversity (*Hd*) found was 0.83<0.92>0.98, nucleotide diversity (*π*) 0.017 (±0.0009) and average number of differences (*k*) 12.09 (±0.367). The nucleotide composition was 42.49% (A), 45.61% (T), 7.79% (C) and 4.11% (G).

The COI gene showed lower percentage of polymorphic sites (1.28% or 7/544bp), haplotype diversity (*Hd*=0.38<0.77>0.94), nucleotide diversity (*π*=0.006±0.000001) as well as lower average number of differences (k= 3.55±0.83) than CR (Table II).The nucleotide composition was 28.31% (A), 30.51% (T), 22.06% (C) and 19.12% (G).

Table II. Summary of intra-population comparison between control region (CR) and cytochrome oxydase (COI) and gene, containing fragment length (bp), percentage of polymorphic sites (*S%*), haplotype diversity (*Hd*), nucleotide diversity (*π*) and A+T composition obtained from *Artemesia longinaris*. Estimates were based on nine individuals sampled along distribution area.

Amplified fragment	CR	COI
Fragment length (bp)	709	544
Percentage of polymorphic sites (*S%*)	6.91	1.28
Haplotype diversity (*Hd*)	0.92	0.77
Nucleotide diversity (*π*)	0.017	0.006
Nucleotide composition (A+T%)	88.1	58.82

Since CR showed more suitability to resolve population structure than 12S and COI, preliminary *Fst* distances were estimated based on these gene. Results revealed that populations inhabiting the Convergence Zone (*CZ*) and Argentinean waters are more closely related (*Fst*=-0.02). Highest *Fst* value was observed between the populations inhabiting the extremes of distribution area (*Fst*= 0.043). Additionally, the *Fst* distance between CZ and RJ population was 0.023.

Discussion

Interespecific comparison of 12S

The metazoan mitochondrial genome is a circular, double-stranded DNA molecule that is highly variable in DNA sequence but conservative in gene content and order (Wolstenholme 1992). Sequencing of CR and part of adjacent flanking genes confirmed this hypothesis, since gene size and order are identical to reported for *P. monodon* (Wilson et al., 2000), *P. notialis* (Garcia-Machado et al., 1999) and *M. japonicus* (Yamauchi et al., 2005). Same gene order was also observed for the lobster *Panulirus argus* (Diniz et al., 2005).

The nucleotide composition, observed in partial sequence from 12S gene of *A. longinaris,* was in agreement with values observed for other penaeid mtDNA, such as giant tiger prawn *P. monodon* (A+T= 70.6%; G+C= 29%) (Wilson et al., 2000). The bias in favor of A+T has also been observed for other arthropodan mtDNA sequences (Simon et al., 1994), which is in accordance with data obtained.

Comparison between 12S and CR sequences polymorphism clearly demonstrates that the second gene greatly increases the number of informative characters and the resolution power in population analysis (Chu et al., 2003). On the other hand, 12S gene shows a good potential to be used in phylogenetic analysis, at family and species level, as suggested by previous investigations (Taylor et al., 1996). Similar Kimura 2-distances were observed when using 16S and COI genes to elucidate penaeids phylogeny (Lavery et al., 2004). For instance, distance estimated between *Litopenaeus* and *Melicertus* was 0.135, while the average distance estimated within the subgenus was 0.111 (Lavery et al., 2004). Similar distances observed in comparison with previous results (*e.g.* Lavery et al., 2004) and reduced polymorphism suggest the potential use of 12S sequences to elucidate phylogenetic relationships in crustaceans. It is important to point out that *A. longinaris* is an endemic species from Southwestern Atlantic and has never been included in penaeid prawn phylogenetic analysis.

Therefore, the information regarded on suitable genes for this kind of investigation is important to help resolving phylogeny of penaeid group, which is still controversial to date (Lavery et al., 2004).

Intraspecific comparison of control region and cytochrome oxydase

The mtDNA is widely known as a polymorphic marker (Avise, 1994); however, control region can be even more variable and therefore, has been successfully used to detect population structure in most different phyla, from mammals (Lau et al., 1998; Nagata et al., 1998) to invertebrates (Duran et al., 2004). Sequencing of AT-rich region has also been widely used as an effective marker for population studies in crustaceans as whole (Diniz et al., 2005), but especially in prawn studies (see Benzie, 2000 for a review; Chu et al., 2003, McMillen-Jackson and Bert, 2003, Grabowski et al., 2004).

The amount of polymorphic sites observed among nine specimens (three different populations) of *A. longinaris* alignment was 6.91%, which is close to lower limit values suggested by Benzie (2000) for penaeid prawns ranging from 2.2% to 33%. It is important to point out that low sampling numbers may have affected this estimate, but nevertheless very low percentage of polymorphic sites is occurring in *A. longinaris*. Nucleotide diversity was also low (π=0.017) and subject to sampling numbers, but within values suggested for the group, that range from 0.058 in *P. monodon* from Indonesia to 0.002 in Western Australia (Benzie, 2000). Conversely, haplotype diversity was high (0.83<0.92>0.98) but within the estimated in recent investigations on mtDNA control region for penaeid prawns (McMillen-Jackson and Bert, 2003). Low nucleotide diversity combined to high haplotype diversity has frequently been attributed to expansion after a period of small effective population size, retaining new mutations (Avise et al., 1984).

The A+T composition is known to be high in CR, as observed for *A. longinaris* (87.1% A+T) and other penaeid prawns such as *P. monodon* (81.5% A+T). The A+T percentage values observed for *A. longinaris* control region were within values observed in insect genomes (86% - 96% A+T), but higher than those in some crustaceans such as *Artemia fransiscana* (68% A+T) and *Daphnia pullex* (67.1%) (Wilson et al., 2000).

The COI region showed lower polymorphism than CR when intraspecific comparison was performed. This observation is in agreement with previous investigations concerning variation levels comparison between these two genes in penaeids (Chu et al., 2003). Despite of lower polymorphic levels observed in COI gene, it is still may be used to elucidate *A. longinaris* phylogeography, since variation observed was not remarkably lower than CR.

In conclusion, present investigation provides novel sets of primers to amplify the entire CR of *A. longinaris*, as well as internal primers capable of resolving population structure of this species. Additionally, preliminary *Fst* distances showed that AR and CZ populations are more closely related, which is supported by shorter geographical distance separating them, as well as circulation pattern in near shore Southwestern Atlantic (Piola et al., 2004).

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Population genetic structure of the argentinean prawn *Artemesia longinaris* (DECAPODA:PENAEIDAE) in Southwestern Atlantic resolved by mtDNA control region analysis.

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Abstract

Growing interest of commercial double-rig trawlers in the argentinean prawn (*Artemesia longinaris*), due to recent remarkable landings, create a need for new investigations on stock structure of this species. *Artemesia longinaris* is an endemic penaeid prawn, distributed from Argentina (Puerto Rawson - $21^0$37'S) to Southeastern Brazil (Rio de Janeiro - $43^0$00'S) and its population structure was investigated by sequencing approximately 700bp of the A+T-rich region of mtDNA. Sixty nine sequences from four different sites were analyzed, including Rio de Janeiro ($21^0$37'S), Rio Grande do Sul ($32^0$00'S), Santa Catarina ($26^0$54'S) and Mar del Plata ($37^0$56'S). Nucleotide diversity (π) ranged from 0.025 to 0.039 and lower values were observed in sites close to the extreme limits of distribution. Haplotype diversity ranged from 0.90 to 0.95 and followed the same pattern of lower values in sites close to distribution limits. Only two haplotypes were shared between different sites and were found in nearest populations (Rio Grande do Sul and Santa Catarina). Investigation based on control region sequencing suggests significant population structuring for *A. longinaris*. The *Fst* distances showed higher genetic flow between Argentina (Mar del Plata) and Convergence Zone (Rio Grande do Sul and Santa Catarina) (*Fst*= 0.04, p=0.18), while Rio de Janeiro population, located at northernmost distribution limit, was significantly different from the others (*Fst*= 0.07, p= 0.03 when compared with Convergence Zone and *Fst*= 0.11, p= 0.01 when compared with Argentina). Results obtained are entirely supported by geographic distances separating populations, as well as oceanographic currents of near shore Southwestern Atlantic, that present seasonal expansions and retractions providing an effective mechanism for dispersal between southern populations. Mismatch analysis indicated significant lack of stability for populations close to distribution limits. Population inhabiting the Convergence Zone did not differ significantly from normal the distribution, but presented

a wavy pattern in the distribution of pairwise genetic differences, also indicating frequent oscillation in size.

Introduction

Artemesia longinaris is an endemic penaeid prawn, distributed from Argentina (Puerto Rawson - $43^0$00S) to Southeastern Brazil (Rio de Janeiro - $21^0$37S). With decreasing yields of traditional pink prawn (*Farfantepenaeus paulensis* and *Farfantepenaeus brasiliensis*) fishery, alternative species became attractive for fishermen, who diverted the fishing effort to species such as *A. longinaris*, *Litopeaeus schmitti*, *Xiphopenaeus kroyeri* and *Pleoticus muelleri* (D`Incao et al., 2002). Its life cycle do not demand an estuarine phase, but the recruits migrate to shallow marine waters during grow out phase and females move to deeper waters for spawning (Boschi, 1969; Castillo et al., 2007).

Stock identification has been previously performed by using morphological traits (Nascimento, 1981, 1983; Dumont and D'Incao *manuscript*) and allozyme variation (Weber et al., 1993). However, conflicting results were obtained from previous population structure analysis, which may be related to the low resolution of both methods applied (Begg and Waldman, 1999; Benzie, 2000). Besides, both investigations were restricted to Southern Brazil (Nascimento, 1981; 1983) or to Southern Brazil and Argentina, not including population inhabiting northern limit of distribution.

The existence of genetically differentiated subpopulations presents problems from the scientific and fishery management points of view, since different gene pools should be treated separately in research as well as management policy (Lester, 1979; Begg and Waldman, 1999). Additionally, population depletion, caused by overfishing, may result in loss of total genetic pool of a species (Smith et al., 1991). Therefore, the importance of understanding population structure of exploited stocks, including penaeid prawns (Benzie, 2000; Chu et al., 2003, McMillen-Jackson and Bert, 2003, Grabowski et al., 2004; Ward et al., 2006), has been extensively discussed in literature (Begg et al., 1999; Waldman, 1999; Stephenson, 1999).

Penaeid prawns are outbreeders with very high fecundity (Gulland and Rotschild, 1981) and larvae take advantage of the currents to migrate to nursery grounds, which are usually represented by estuaries, bays and marine shallow waters (Dall et al., 1990). The expected pattern is therefore, that species with high dispersal potential (*e.g.* planktotrophic larvae) have little genetic structuring and high gene flow in the absence of significant geographical barriers (Palumbi and Wilson, 1990; Lacson, 1992; Benzie, 2000, Palumbi, 2003).

The use of mtDNA to identify stock or population structure has proved to be a useful tool for population genetic studies of many terrestrial and aquatic organisms (Avise, 1994). Two portions of mtDNA can be especially useful at population level investigations, the cytochrome oxydase I (COI) and control region (Caccone et al., 1996). Little is known about the structure and evolution of marine invertebrates mitochondrial control region, but in prawns it is believed to be divided into 3 polymorphic domains, set apart by two stretches with lower intraspecific variability (Grabowski and Stuck, 1999).

The peripheral segments, adjacent to flanking coding regions, are highly polymorphic, presenting a higher base substitution rate than the central domain and therefore named hypervariable region, used as genetic marker for population studies (Grabowski & Stuck, 1999; Grabowski et al., 2004). Due to these traits, the control region sequencing is of special utility for phylogeographic analysis, and has been extensively used to resolve population structuring of penaeid prawns worldwide (Benzie, 2000; Chu et al., 2003, McMillen-Jackson and Bert, 2003, Grabowski et al., 2004).

Present investigation aims to elucidate population structure of *A. longinaris* in Southwestern Atlantic Ocean by using mtDNA control region sequencing, in order to provide novel information on genetic interchange between stocks, as well as to generate knowledge capable of helping in management of this species.

Material and Methods

Sampling strategy, preservation and DNA extraction

Sixty nine samples were collected from four sites along distribution area of *A. longinaris*, from Argentina to Southeastern Brazil and were initially divided in four different stocks: Rio de Janeiro (RJ, n= 21), Rio Grande do Sul (RS, n= 15), Santa Catarina (SC, n= 15) and Argentina (AR, n= 18) (Figure1). Prawn samples from Rio de Janeiro were obtained from otter-trawl fishery off the coast of Macaé ($21^0$37'S) at northern limit of distribution. (D'Incao, 1999). Sampling of population inhabiting southern limit was also based on prawn fishery, performed off Mar del Plata ($37^0$56'S) and Bahia Blanca ($38^0$44'S). Samples from Rio Grande do Sul ($32^0$00'S) were obtained during scientific cruises onboard of LOc. Larus (University of Rio Grande) and from Santa Catarina onboard of the vessel N.P. Soloncy Moura (IBAMA-CEPSUL) off the coast of Itajaí ($26^0$54'S).

Sampling regime was designed to test broad and fine genetic interchange across the distribution range of *A. longinaris*. Significant differences between populations were tested by using two grouping patterns. Initially, comparison was performed between the four sites sampled. Additionally, sites located in southern Brazil (RS and SC) were pooled together and treated as a single group named Convergence Zone (CZ).

Figure 1. Southwestern Atlantic Ocean, highlighting distribution range of *A. longinaris* (black line) from Rio de Janeiro to Argentina. Samples were taken from Mar de Plata (Argentina-AR), Rio Grande (Brazil-RS), Itajaí (Brazil-SC) and Macaé (Brazil-RJ).

Muscle samples from pereiopods and tail were collected, fixed in ethanol 95% and stored at 4°C. DNA was extracted using a phenol-chloroform-isoamyl alcohol (25:24:1) extraction of sodium dodecysulfate (SDS) - proteinase K digested tissue of each individual (Sambrook and Maniatis, 1989). DNA was isolated by 100% ethanol precipitation and visualized by gel electrophoresis to check the quality and amount obtained.

Control region amplification, purification of PCR products and sequencing

Amplification reactions were conducted using an Applied Biosystems PCR machine and each 20 µl of PCR contained 1µl of DNA template, 3.5 µl of 10x buffer (with 15 mM of $MgCl_2$), 0.2 µl of dNTP (20 mM), 0.5 µl of $MgCl_2$ (15 mM), 3.0 µl of Q-solution (Qiagen®), 0.2 µl of each primer (100 pM), 0.5 µl of Taq DNA polymerase (5U/µl) and sterile HPLC-grade water. Internal primers (12Sc-F/ILE3b-R) were used to amplify approximately 0.8kb of CR (709bp were effectively analyzed), including the hypervariable region at 5` extremity of control region. Forward oligonucleotide primer sequence used was (12Sc-F): 5`-GAATCAAGCCAGAATAAAAC-3` and reverse (ILE3b-R) 5`-GAGGGGTCGCCAGAAACAAA- 3` (Dumont et al., *manuscript*).

The cycle conditions were 1 minute at 94^0C, 94^0C for 10 seconds, 67^0C for 1 minute, 68^0C for 1:50 minutes (35x) and finally 5 minutes at 68^0. The PCR products were checked for correct size and amount of DNA on 1.0% agarose gel. Products were then purified by using PCR purification kit (Qiaquick™ PCR Purification Kit, Qiagen, Inc.) to remove excess nucleotides and primers as well as concentrate PCR products. The purified double-stranded amplification products were used as template DNA in sequencing reactions. Cycle-sequencing was performed using the ABI Prism BigDye Ready Mix (Applied Biosystems) and all PCR products were sequenced in both forward and reverse directions.

Sequence alignment and phylogeographic analysis

Homologous nucleotide sequences from all samples were aligned using the program CLUSTAL W included in BIOEDIT (Hall, 1999) and refined when necessary. Most frequent haplotype sequences were submitted to GenBank database (National Center of for Biotechnology Information).

Analyses were performed in Arlequin 3.1 software (Excoffier et al., 2006). Nucleotide composition and estimates of sequence diversity, such as nucleotide diversity (*Pi*), haplotype diversity (*Hd*), number of transversions and transitions and number of polymorphic sites were obtained. Tajima's D (Tajima, 1989) was calculated to test for selective neutrality of samples. Measures of genetic distance (standard *Fst* and Slatkin linearized *Fst*) were used to test significant differences between populations and to perform Mantel's test of isolation by distance (Mantel, 1967). This analysis was used to estimate the significance of correlation between pairwise genetic distance among sample sites using Slatkin's linearized *Fst* and the $\log_{10}$ straight line of geographic distance among sites. Leas squared procedure was used to fit genetic differences to geographical distances. Pattern of isolation by distance is accepted when significant correlation between genetic differentiation and geographical distance is obtained (Hurwood et al., 2005). Mismatch, or demographic analysis, was used to assess stability of populations over time. This method can differentiate from populations that have remained stable and those that have experienced recent expansions or retractions (Rogers, 1995).

Results

A total of 69 argentinean prawns were sequenced for 709 nucleotides. The A+T composition ranged from 87.7% in Rio de Janeiro (RJ) to 87.56% in Rio Grande do Sul (RS). The transition/transversion rate was similar in populations from SC, RS and AR, while RJ presented a different pattern. Haplotype diversity (*Hd*), nucleotide diversity (π), average number of differences (*k*) and percentage of polymorphic sites (*S*) were higher in SC and RS, with both limits of distribution for the species (RJ and AR) presenting lower values for this parameter (Table I). Only populations from SC and RS shared common haplotypes (2 haplotypes), while all the others were population-specific (Table II).

Table I. Summary of genetic diversity of *A. longinaris* control region sequences obtained across its distribution area, including number of transitions and transversions, number of polymorphic sites (*S*), percentage of A+T nucleotides, haplotype diversity (*Hd*), nucleotide diversity (π) and average number of pairwise differences (*k*). RJ= Rio de Janeiro, SC= Santa Catarina, RS= Rio Grande do Sul, AR= Argentina. Numbers within brackets represent sample sizes at each site.

	RJ (21)	SC (15)	RS (15)	AR (18)
Number of transitions	39	37	40	31
Number of transversions	9	14	13	15
Number of polymorphic sites (*S*)	44	48	50	42
A+T %	87.70	87.57	87.56	87.59
Haplotype diversity (*Hd*)	0.88	0.93	0.96	0.91
Nucleotide diversity (π)	0.019	0.028	0.023	0.020
Average number of differences (*k*)	13.79	20.00	16.47	14.70

Table II. Frequency distribution of control region haplotypes among *A. longinaris* populations from four different sites sampled for population structure analysis in Southwestern Atlantic. RJ= Rio de Janeiro, SC= Santa Catarina, RS= Rio Grande do Sul, AR= Argentina. Numbers within brackets represent sample sizes at each site.

Haplotype	RJ (21)	AR (18)	RS (15)	SC (15)	Haplotype	RJ (21)	AR (18)	RS (15)	SC (15)
1	4.76	0.00	0.00	0.00	28	9.52	0.00	0.00	0.00
2	4.76	0.00	0.00	0.00	29	9.52	0.00	0.00	0.00
3	4.76	0.00	0.00	0.00	30	4.76	0.00	0.00	0.00
4	4.76	0.00	0.00	0.00	31	4.76	0.00	0.00	0.00
5	9.52	0.00	0.00	0.00	32	4.76	0.00	0.00	0.00
6	9.52	0.00	0.00	0.00	33	0.00	5.56	0.00	0.00
7	4.76	0.00	0.00	0.00	34	0.00	5.56	0.00	0.00
8	4.76	0.00	0.00	0.00	35	0.00	11.11	0.00	0.00
9	4.76	0.00	0.00	0.00	36	0.00	11.11	0.00	0.00
10	0.00	5.56	0.00	0.00	37	0.00	5.56	0.00	0.00
11	0.00	5.56	0.00	0.00	38	0.00	0.00	0.00	6.67
12	0.00	11.11	0.00	0.00	39	0.00	0.00	6.67	0.00
13	0.00	11.11	0.00	0.00	40	0.00	0.00	6.67	0.00
14	0.00	5.56	0.00	0.00	41	0.00	0.00	6.67	0.00
15	0.00	5.56	6.67	0.00	42	0.00	0.00	6.67	0.00
16	0.00	0.00	6.67	0.00	43	0.00	0.00	6.67	0.00
17	0.00	0.00	6.67	0.00	44	0.00	5.56	0.00	0.00
18	0.00	0.00	0.00	0.00	45	0.00	0.00	6.67	0.00
19	0.00	0.00	0.00	6.67	46	0.00	0.00	6.67	0.00
20	0.00	0.00	0.00	6.67	47	0.00	11.11	0.00	0.00
21	0.00	0.00	***6.67***	***6.67***	48	0.00	0.00	6.67	0.00
22	0.00	0.00	0.00	13.33	49	0.00	0.00	6.67	0.00
23	0.00	0.00	6.67	0.00	50	0.00	0.00	0.00	6.67
24	0.00	0.00	***6.67***	***13.33***	51	0.00	0.00	0.00	6.67
25	4.76	0.00	0.00	0.00	52	0.00	0.00	0.00	13.33
26	4.76	0.00	0.00	0.00	53	0.00	0.00	0.00	6.67
27	4.76	0.00	0.00	0.00	54	0.00	0.00	0.00	13.33
					55	0.00	0.00	0.00	6.67

Estimated *Fst* distances, based on fine scale sampling design, do not support significant (p>0.05) population structure for *A. longinaris* in Southwestern Atlantic coast. However, p-values observed between AR and RJ (p=0.08), as well as RJ and populations from Convergence Zone (CZ) (p=0.09) showed marginal probabilities (p<0.05), suggesting that RJ stock is more isolated. Populations inhabiting the Convergence Zone (SC and RS) showed highest level of similarity (*Fst*=-0.25) and negative values suggest intense genetic interchange (Table III).

Table III. Fine scale pairwise *Fst* distances and levels of significance (*within brackets*) estimated from *A. longinaris* control region sequences between four sites sampled. RJ= Rio de Janeiro, SC= Santa Catarina, RS= Rio Grande do Sul, AR= Argentina. Numbers within brackets represent sample sizes at each site.

site	RJ (21)	SC (15)	RS (15)	AR (18)
RJ		0.065 (*0.09*)	0.065 (*0.09*)	0.062 (*0.08*)
SC	0.065 (*0.09*)		-0.25 (*0.99*)	0.031 (*0.19*)
RS	0.065 (*0.09*)	-0.25 (*0.99*)		0.031 (*0.19*)
AR	0.062 (*0.08*)	0.031 (*0.19*)	0.031 (*0.19*)	

Conversely, when most similar populations (SC and RS) are grouped as a single Convergence Zone (CZ) stock a clear pattern of genetic structure can be noticed. The southern populations, formed by AR and CZ, are significantly ($p<0.05$) different from the group inhabiting the northernmost limit of distribution (Table IV). Relatively small number of samples obtained, when SC and RS were considered as distinct groups, may have influenced statistical analysis, resulting in non-significant differences between populations, in spite of showing spatial structuring for genetic distances and p-values close to critical value.

According to Mantel's test, genetic distances showed positive relationship with geographic distance ($r=0.97$, $p=0.007$) only for broad scale sampling design, indicating isolation by distance. Conversely, elevated similarity between RS and SC populations within a considerable geographic distance, have influenced linear regression resulting in a non-significant fit for fine scale design.

Table IV. Broad scale pairwise *Fst* distances and levels of significance (*within brackets*) estimated from *A. longinaris* control region sequences between four sites sampled. RJ= Rio de Janeiro, SC= Santa Catarina, RS= Rio Grande do Sul, AR= Argentina. Numbers within brackets represent sample sizes at each site.

site	RJ	CZ	AR
RJ		0.071 (*0.03*)	0.111 (*0.01*)
CZ	0.071 (*0.03*)		0.043 (*0.18*)
AR	0.111 (*0.01*)	0.043 (*0.18*)	

Mismatch analysis, used to detect sudden population expansion, resulted in a normal distribution of pairwise differences for CZ (p=0.25) and critical p-value for AR (p= 0.05). Stock inhabiting RJ did not fit the sudden expansion model (p<0.001) (Rogers and Harpending, 1992) (Table V). Despite of showing significant fit to sudden population model, population of CZ showed a wavy pattern in distribution of pairwise differences, also suggesting a certain level of demographic unstability (Rogers, 1995) (Figure 2). The Tajima's D values were negative but not significant (p=0.52) (Table V).

Table V. Neutrality tests for *A. longinaris* pooled grouped in Argentina (AR), Convergence Zone (CZ) and Rio de Janeiro (RJ) populations. Parameters of sudden expansion are presented, as well as goodness of fit test of the model, sum of squared deviations (SSD), p-values for rejection of sudden expansion model and Tajima's test its p-values.

Parameters	RJ	CZ	AR	mean	std. dev.
Tau	15.13	20.3	22.9	19.44	3.96
$Teta_0$	0	4.5	0	1.50	2.60
$Teta_1$	162	721	87	323.33	346.43
Goodness of fit test					
SSD	0.08	0.02	0.21	0.10	0.10
p-value	0.00	0.25	0.05	0.10	0.13
Tajima's D-test	-0.06	-0.5	-0.02	-0.19	0.27
p-value	0.48	0.29	0.52	0.43	0.12

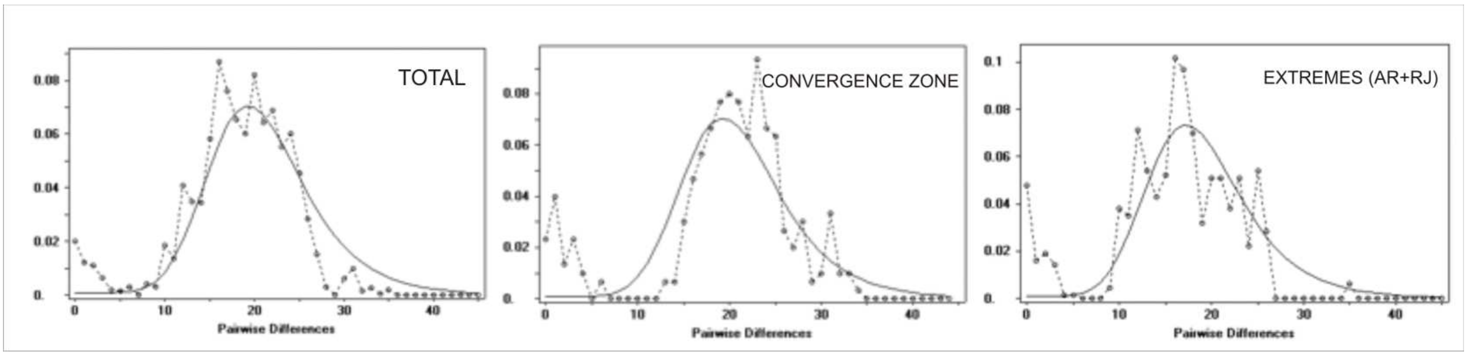

Figure 2. Distribution of pairwise differences, between mtDNA control region haplotypes of *A. longinaris* in Convergence Zone (CZ), distribution extremes (AR+RJ) and total estimate, fitted to a normal model. The solid line depicts the mismatch distributions expected from a sudden expansion. Dashed line describes the observed distribution. Parameters estimated for each population are provided in Table V.

Discussion

Genetic diversity and population structure

The mtDNA is widely known as a polymorphic marker (Avise, 1994). Nevertheless, control region can be even more variable and therefore, has been successfully used to detect population structure in most different phyla, from mammals (Lau et al., 1998; Nagata et al., 1998) to invertebrates (Duran et al., 2004, Hurwood et al., 2005). Sequencing of the AT-rich region has also been widely used as an effective marker for population studies in crustaceans (*e.g.* Diniz et al., 2005), but especially in prawn studies (see Benzie, 2000 for a review; Chu et al., 2003, McMillen-Jackson and Bert, 2003, McMillen-Jackson and Bert, 2004; Grabowski et al., 2004).

Genetic diversity in penaeid prawns, estimated from mtDNA, shows marked variation within and between species. Values of nucleotide diversity (π), suggested in literature, range from 0.002 to 0.058 and main factors affecting variation are historical events, life cycle strategy and geographical isolation (Klinbunga et al., 1998; Benzie, 2000). For instance, populations of giant tiger prawn (*Penaeus monodon*) from Indonesia, Thailand and Malasia present nucleotide diversity values that range from 0.040 to 0.058, while those sampled in Philippines averages 0.009. Even less variation was observed in populations living close to species range of distribution, such as those from Western Australia (π= 0.002) (Klinbunga et al., 1998). Nucleotide diversity (π) ranged from 0.019 to 0.028 and can be considered low for the group.

Pattern of reduced nucleotide diversity at extreme limits of distribution observed in present investigation have also been previously reported for penaeid prawns (Klinbunga et al., 1998; Benzie et al., 2000). However, decreasing in this parameter obtained in present investigation was not marked as observed by other authors, but also indicates reduction of genetic variability in these areas.

The haplotype diversity was high, ranging from 0.88 to 0.96 and followed same variation pattern as nucleotide diversity, with higher values in populations inhabiting central areas. Combination of high haplotype diversity with low nucleotide diversity in marine organisms has been frequently attributed to expansion after a period of small effective population size (Avise et al., 1984), which may explain the pattern observed for *A. longinaris*.

Reduced variation in populations inhabiting limits of distribution may reflect bottleneck effects occurred in the past or reinvasion after extinction of these peripheral populations (Benzie, 2000). Bottleneck effect is not likely to be occurring in *A. longinaris* populations experiencing present levels of fishing effort, since much lower levels of nucleotide diversity have been reported in literature for other penaeid prawns (Klinbunga et al., 1998, Benzie, 2000). However, population inhabiting northern limit of distribution is more likely to experience bottleneck effects if fishing effort is increased.

The *Fst* values were low, but significant between southern and northern populations. The genetic distances estimated showed linear relationship with geographic distances when using the broad sampling design. Examination of isolation by distance, in which, close population are more similar than distant ones, has the potential to increase confidence in the significance of slight genetic differentiation. Analysis of population structure as a function of the distance between samples has many advantages over estimation of a single *Fst*. According to Palumbi (2003), there is little association between *Fst* and geographic distance if the error in estimating *Fst* outstrips the differences among populations. Moreover, only if the geography of genetic differentiation of marine species is examined, low but significant *Fst* can be distinguished from zero (Waples, 1998).

The *Fst* values, based on control region sequences from four different sites sampled in Southwestern Atlantic, did not show significant differences between populations, in spite of showing marginal values between northern populations. Populations from CZ and AR showed reduced genetic distances, while RJ was more isolated. Populations from SC and RS showed extremely high similarities, since 99% of variance observed was due to variation within population. This observation do not support previous hypothesis suggested by Nascimento (1983), who based on size at first maturity, suggested that the exploited stock of *A. longinaris* in southern Brazil was composed by two different populations, with particular environment preferences.

When SC and RS samples were grouped as a single site, a clearer population structure emerged. Pattern of panmitic populations of *A. longinaris* inhabiting CZ and AR was maintained under the new data arrangement, reinforcing that a unit genetic stock is exploited from Argentina to southern Brazil. The *Fst* distance estimated by using allozyme variation was considerably lower (*Fst*=0.008) (Weber et al., 1993) than present estimates, reflecting lower resolution of the method applied. When broad sampling design was adopted, the stock inhabiting RJ was significantly different from the others, which is likely owned to greater mean number of individuals per population obtained by using this approach (Hurwood et al., 2005; McMillen-Jackson and Bert, 2003). Present data supports previous investigations stating that penaeid populations show considerable movements of individual prawns from hundreds to thousands of kilometers over few months, resulting in little genetic structuring over long distances (Weber et al., 1993; Benzie, 2000), if geographic or oceanographic barriers are absent (Palumbi, 2003).

Furthermore, genetic flow between AR and CZ populations is supported by oceanographic systems and reproductive strategy of this species. *Artemesia longinaris* is a high fecundity prawn, releasing eggs that hatch in to larvae and inhabit meroplankton community during first stages of its life cycle (Scelzo and Christiansen, 1971), increasing its dispersal potential. Additionally to great potential for larval dispersion and stock mixing, coastal circulation in Southwestern Atlantic supports the population structure obtained from genetic distances.

As a neritic species (more abundant from 0-30 meters), its life cycle is highly dependent on near shore currents (D'Incao, 1999). Main oceanographic system regulating water movements in near shore zones is the Coastal Water (CW) (Piola et al., 2005). The CW is mainly influenced by freshwater discharge from La Plata river (discharges up to 60,000 m^3/s^{-1}) and Patos Lagoon estuary (discharges up to 30,000 m^3/s^{-1}). This water mass flows northwards from La Plata river to the latitude of Florianópolis (27^0S), but under specific conditions may reach São Paulo coast (23^0S) (Piola et al., 2004). The CW is observed in CZ latitudes all year round; however its presence is much more noticeable during winter periods, associated to southwesterly winds (Piola et al, 2004, 2005).

Additionally, preliminary tagging experiment performed in Argentinean waters reported a recapture of a single prawn, released in November and found 40 km northwards (Boschi and Scelzo, 1971). Thus, genetic flow between CZ and AR populations is supported by expansions and retractions of SACW in Southwestern Atlantic coast and by reduced geographical distance separating them, which may allow adult and/or larval interchange. The unit stock structure observed between CZ and AR was also suggested by earlier allozyme investigation performed (Weber et al., 1993), confirming that, despite of lower resolution of the method, results are in accordance with those obtained by using more polymorphic markers, such as mtDNA (Benzie, 2000).According to a review of population structure in penaeid prawns performed by Benzie (2000), in the few cases for which joint information of mtDNA and allozymes is available, the former method tended to confirm patterns of variation detected by allozymes. Morphometric and meristic analysis also detected similar morphotypes in AR and CZ populations, especially during winter (Dumont and D´Incao, *manuscript*), which may be attributed to environment-induced relative growth or genetic interchange (Begg et al., 1999, Begg and Waldman, 1999).

Population inhabiting northern limit of distribution (RJ) showed higher and significant genetic distance from southern stocks. Genetic distances are also supported by geographical distance and oceanographic systems in Southwestern Atlantic. As previously discussed, even under maximum expansion conditions, of wind stress and rainfall, the CW does not reach the RJ region (Piola et al, 2004), preventing these two stocks from genetic interchange. Previous investigations, on distribution and abundance of this species, suggest that greater densities are connected to the presence of lower temperatures associated to CW, even at further north latitudes (Costa et al., 2005). Thus, higher genetic isolation of RJ stock, coupled with lower genetic variation and higher water temperatures (Beisl et al., 2001), may represent a reduction of population fitness, making this stock more susceptible to overfishing.

Demographic structure

Results obtained from mismatch analysis suggests lower stability of RJ stock, since adjust was highly different from normal expansion model (Rogers and Harpending, 1992). A population that is relatively stable can retain genetic signature of a sudden population expansion for a long time, despite of more recent or more gradual expansions and minor short-term population reductions (Rogers, 1995; Lavery et al., 1996). However, a population that fluctuates greatly in size will tend to erase evidence of prior population expansions or retractions, resulting in a wavy pattern of pairwise differences (Rogers, 1995). Hence, lack of fit to normal model observed for RJ population may be explained by higher demographic instability of this population. Mismatch analysis of two sympatric penaeid species (*Farfantepenaeus aztecus* and *Litopenaeus setiferus*) from eastern United States, suggest that the white prawn (*L. setiferus*) was more susceptible to cold water-induced mortality events (DeLancey et al., 1994) and expansion events were progressively deleted from contro region, resulting in significant rejection of sudden population expansion model (McMillen-Jackson and Bert, 2003).

It is also important to point out that population from AR showed a critical value for rejecting the sudden expansion model. This population is also close to distribution limit, where it is heavily exploited along with red prawn (*Pleoticus muelleri*) (Boschi, 1969). Fishery statistics point out greater abundance of *A. longinaris* in CZ when compared to *P. muelleri*. Conversely, statistics from AR show that *P. muelleri* dominates catches by far, which may suggest that *A. longinaris* takes more adapted to this environment (Dumont, 2005).

Nevertheless, the more stable population of *A. longinaris* seems to inhabit CZ in Southern Brazil. Densities of *A. longinaris* in this region are high, reaching values up to 260kg/h (Dumont, 2005), in spite of great interannual variability also reported for this area (Univali, 2004). Genetic data obtained in this investigation reinforces the relatively higher stability of CZ population, in spite of marked recruitment variation, intrinsic to penaeid prawns (Gulland and Rotschild, 1981).

Implications for management

An understanding of stock structure and mixing is a fundamental requirement for the effective assessment and management of fisheries resources. Serious errors can be introduced into assessments of stock status when populations are distributed outside of their management units or landings include unknown contributions from other populations. Fisheries removals from stock mixtures can result in overexploitation of less productive stocks and the erosion of genetic diversity (Begg and Waldman, 1999).

Our results suggest that genetic interchange is occurring between *A. longinaris* populations, from Convergence Zone to Argentinean coast, which may have been caused by northwards migration of adults and/or larvae carried by CW. Similarly, other fish stocks (*e.g. Sardinella brasiliensis* and *Pomatomus saltatrix*) take advantage of CW to migrate northwards in Southwestern Atlantic. Therefore, further investigations must be carried out to effectively understand seasonality trends in control region haplotypes inhabiting Southern Brazil, providing a more detailed scenario about the time and amount of prawn exchanged between these two countries.

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Biometric relationships *Artemesia longinaris*

Biometric relationships of the Argentinean prawn *Artemesia longinaris* (DECAPODA:PENAEIDAE) in Southwestern Atlantic

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ABSTRACT

Biometric relationships of size and weight were estimated for the Argentinean prawn (*Artemesia longinaris* Bate, 1888), a new commercial penaeid prawn exploited in Southwestern Altlantic. Morfometric and meristic traits were used to elucidate population structuring of *A. longinaris* along its distribution area. Length relationships were estimated by simple linear regression, considering total length (TL) as dependent variable. Length-weight relationships of females were estimated by a power curve. Males inhabiting Convergence Zone (CZ) presented a slightly lower total length (TL) increment than females. A marked reduction in slopes of males from CZ was observed in autumn and winter. Relative growth in length of males from Argentina is similar to observed during autumn and winter in CZ. The other morphometric and meristic variables used also indicated higher similarities between CZ and Argentina (AR), which may be explained by relative growth associated to water temperatures or migration during winter taking advantage of the oceanographic systems connecting both sites. Moreover, population from Rio de Janeiro (RJ) seems more differentiated from the others, which is in agreement with previous genetic analysis. Negative allometric growth in weight was estimated for both genders, reflecting stretched shape of this species. Females present higher increment in weight due to ovary maturation during reproductive season that takes place in spring. Relative condition index (RCI) showed seasonal and interannual variations, negatively affected by higher temperatures of summer and lower salinities during winter. Highest RCI values were observed in spring, concurrently with main reproductive season reported in literature.

Keywords: *Artemesia longinaris*, stock identification, morphometric relationships, meristic traits, relative growth.

INTRODUCTION

The Argentinean prawn *Artemesia longinaris* is an endemic species from Southwestern Atlantic, occurring from Rio de Janeiro (Brazil -21^{0}37’S) to Puerto Rawson (Argentina-43^{0}00’S). This species belongs to penaeid family, which includes other commercially important species, such as *Farfantepenaeus paulensis* (Pérez-Farfante,1967); *F. brasiliensis* (Latreille, 1817); *Litopenaeus schimitti* (Burkenroad, 1936) and *Xiphopenaeus kroyeri* Heller, 1862 (D’Incao, 1999; D’Incao *et al*., 2002).

Artemesia longinaris has a preference for muddy and sandy soft bottoms (Boschi, 1969, Costa et al, 2005) and higher densities are observed between 11 and 20 meters depth (Boschi, 1969; Nascimento, 1981; D’Incao, 1999). Unlike most penaeid prawns, *A. longinaris* has a strictly marine life cycle, not demanding an estuarine nursery phase (D’Incao, 1999).

Due to its high abundance in shallow coastal waters, *A. longinaris* is an important link in food-web of this ecosystem in Southwestern Atlantic. Analysis of feeding habits and trophic interactions showed that this species accounts for 30% in diet of coastal fishes (Capitoli *et al*., 1994). Since the argentinean prawn is a valuable species for artisanal and commercial fleet, there is a growing interest on this resource, especially after the decreasing yields observed for most traditional prawn species exploited in Brazilian waters (D’Incao *et al*., 2002).

Biometric relationships can provide important information on biological events occurring in a population, such as length-weight relationship variation during reproductive season or unfavorable environmental conditions (King, 1997). Additionally, these biometric relationships can provide an easy way of estimating length and weight for missing data, also allowing comparison with previous investigations (Ragonese *et al*., 1997). It is especially important when analyzing total length, since this measure is often lost during biometry due to high frequency of animals with broken rostrum. Although size is usually measured as length, weight measures are often required for fisheries assessment models, such as yield per recruit (Sparre & Venema, 1991).

Morphometric and meristic traits also provide an important tool for delineating stocks either of fishes (Swain et al., 2001; Pinheiro et al., 2005) or crustaceans (Tzeng & Yeh, 2002), since very often different meristic and morphometric relationships may reflect reproduction isolation or environment influence (Gulland, 1971; Begg & Waldman, 1999; Begg et al., 1999). Stock identification is of primary interest in fisheries management, since population replenishing and reducing effects of recruitment and mortality operate independently on the individual stocks (Waldman, 1999).

Previous investigation on *A. longinaris* biometry was performed in Argentina (Boschi, 1969) and the Brazilian coast (Nascimento, 1983), however inclusion of individuals from northern limit of distribution and analysis of seasonal and interannual trends in length relationships have never been developed. The aim of this study is to estimate biometric relationships as well as use morphometric and meristic traits to identify population structure of *A. longinaris* along its entire distribution area, in attempt to provide practical and biological information about this species.

MATERIAL & METHODS

Sampling took place in shallow marine waters adjacent to Patos Lagoon estuary mouth (Figure 1). This area is located under the influence of Coastal Water (CW), which is highly influenced by freshwater discharge from La Plata river (can reach up to 60,000 m^3s^{-1} during El Niño) and Patos Lagoon estuary (can reach up to 30,000 m^3s^{-1} during El Niño). This water mass stretches northwards from La Plata for about 1300 km, but during specific years may reach São

Paulo coast. Coastal Water presents seasonal and annual variations in strength and shape, highly dependent on a combination of rainfall and wind stress (Piola et al., 2004; Piola et al., 2005).

Patos Lagoon estuary is located at costal plain of Rio Grande do Sul State, Brazil (32^0S, 49^0W) and is the largest choked lagoon in the world, covering an area of 10,360 km^2. Drainage basin covers 201,626 km^2 (Asmus, 1996) and pluvial intensity as well as wind direction regulate the water movements in study area (Piola et al., 2005). Seasonal freshwater discharge presents great variability (30,300 - 47 m^3s^{-1}) and during ENSO runoff is significantly higher than mean values estimated (Garcia, 1996).

Samples were monthly collected from surrounding area of Patos Lagoon estuary, in two different years (2002 and 2004), on board of short-range artisanal trawlers in depths varying from 2 to 15 meters (Figure 1). To establish possible morphometric and meristic differences between *A. longinaris* populations, over its distribution area, samples from Argentina (Mar del Plata, $37^0$56'S) and Southeastern Brazil (Macaé, $21^0$37'S, Brazil) were obtained from fishery activity during spring and compared to individuals from Rio Grande do Sul. To perform this analysis 50 individuals from each population were randomly chosen.

Carapace length (CL-mm) was measured as the distance from the postorbital margin to the mid-dorsal posterior edge of carapace. Total length (TL-mm) was considered as the distance from the tip of the rostrum to the end of the telson. Rostrum length (RL-mm) was measured from the tip of rostrum to postorbital margin of carapace. Telson length (TsL) was taken from the base to the tip of this structure. The number of rostral teeth (RT) was also counted and used as a meristic trait to identify possible population structuring. Wet weight was measured to the nearest 0.001g and size measures were taken to the nearest 0.01mm.

Assumptions of normality and homogeneity of variances were tested by Lilliefor's and Levene's routines, respectively (Zar, 1984). Raw length and weight data showed normal distribution (Lilliefor's $p<0.2$) but did not show homogeneity of variances (Levene's $p>0.05$). However, log transformation and *Loess* smoothing procedure were applied to reduce noise without arbitrarily determine which points should be excluded from analysis due to measuring errors. Pattern observed using smoothing procedure was compared to log transformed data, in an attempt to check whether slopes would keep same pattern when noise was removed.

Figure 1. Distribution of *A. longinaris* in Southwestern Atlantic Ocean (black line). Samples were seasonally obtained in Rio Grande do Sul and compared to a single sampling in Mar del Plata and Rio de Janeiro.

Length-length relationships were seasonally estimated by using log transformed data through simple linear regression, considering TL as dependent variable. The equation of linear regression is given by $TL = a + bCL$, where TL is total length, a is the intercept with dependent variable axis, b is the slope and CL is the carapace length. Points outside 95% confidence intervals were automatically excluded since were considered as undetected broken or regenerating rostrum as well as deformed carapace. Data were also log transformed and smoothed *a posteriori* according to a *Loess* algorithm (Cleveland, 1979). This procedure was adopted to remove noise from analysis with minimum intervention, providing a way of comparison with original data to confirm that differences in slopes were not associated to excessive noise, but with biological process, such as migration or allometric growth (Cleveland, 1979). Since linear regression may be influenced by different adjust qualities, a correction procedure was applied by using coefficients of correlation values. Only smoothed data is showed but a summary of linear regression based on log transformed data is also provided. Differences in slopes were pairwise tested based on confidence intervals, in such a way that non-overlapping intervals were considered as statistically different.

In an attempt to elucidate population structuring 50 males were randomly selected from each population to test significant ($p<0.05$) differences in relationships between variables (TL/CL, CL/RL, CL/TsL and RT) by One-Way ANOVA and post-hoc Tukey’s test. Since samples obtained from fishery may not represent the entire size composition of a population, the influence of size composition on relationships previously mentioned (TL/CL, CL/RL, CL/TsL and RT) was tested by using a linear model. Only the variable CL/TsL showed significant relationship with CL ($p=0.000$, $r=0.95$), therefore results obtained must be carefully analyzed due to effect of different CL composition of samples. The other variables did not show significant correlation with size (CL/RL - $p=0.58$, $r=0.07$, TL/CL – $p=0.15$, $r=0.03$, RT – $p=0.46$, r=0.1). Euclidean distances were estimated and cluster analysis was performed to elucidate population structure based on morphometric variables previously selected.

Length-weight relationships were concentrated on females since this gender tends to show more striking differences due to ovary maturation (King, 1997). Length-weight relationships were estimated by a power curve, which equation is given by: $TW= aCL^b$, where TW is the total weight, a is the condition factor, CL is the carapace length and b is the exponent of power curve. Points outside 95% confidence intervals were automatically excluded from analysis, since they were considered as measuring errors. All data were fitted to power and linear models by an automated least square procedure.

When considering an individual prawn, the values obtained by power equation can be transformed to be used as an index of "well-being", known as relative condition index (RCI). The more a prawn weights for a given CL, the greater will be its relative condition index (King, 1997). To estimate RCI, an overall length-weight relationship was estimated as a reference point. To compute the condition index (CI_i) for each individual in sample, the following equation was used: $CI_i=TW_i/CL_i^b$. Equation used to estimate normalized RCI_i was given by: $RCI_i= (CI_i$ - mean CI)/Standard Deviation of CI). Mean RCI were compared between seasons and years by Factorial ANOVA.

RESULTS

Abiotic parameters showed seasonal and interannual variations, with 2002 showing lower values of salinity and higher values of temperature and rainfall, when compared to equivalent season in 2004 (Figure 2). Rainfall statistics allowed concluding that exceptionally high precipitation was recorded in 2002, surpassing values observed for intense El Niño Southern Oscillation (ENSO) events, such as 1997-1998. Total volume of rainfall registered in 2002 for the city of Rio Grande was 1915 mm^3 while volume observed in 2004 (969 mm^3) was considerably below mean values for the region (1215 mm^3) (Figure 2).

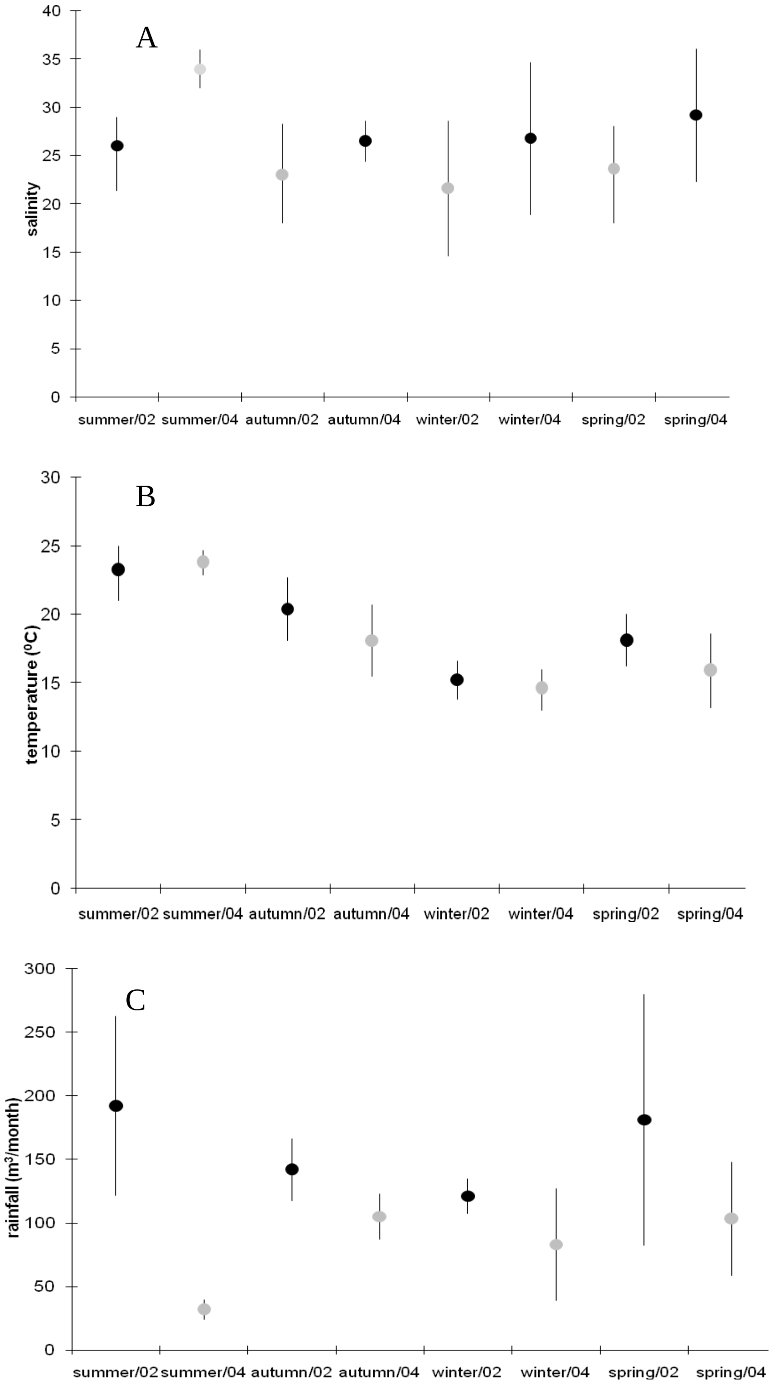

Figure 2. A- Trends in mean salinity in surrounding area of Patos Lagoon estuarine mouth. B- Trends of water temperature (^{0}C) in marine waters surrounding Patos Lagoon estuarine mouth.

C- Trends in mean rainfall (mm^3/month) registered for the city of Rio Grande during 2002 and 2004. Circles represent mean values and bars the standard deviation of means. Black dots represent the estimates obtained during 2002, while 2004 is represented by the grey ones.

A total of 5368 individuals was used in regression analysis (Table I, Table II), being 2971 males and 2116 females. Moreover, 139 individuals from Argentina and 142 individuals from Rio de Janeiro were analyzed. Deviation from 1:1 sex ratio (Ruffino & Castello, 1992) resulted from higher number of females discarded due to broken or regenerating rostrums.

Males inhabiting southern Brazil have a slightly lower TL slope (*b*=5.25) than females (*b*=5.35) (Table I). Smoothed and log transformed data showed same pattern of higher relative growth in TL for females, showing values close to expected for isometry (b=1) in length relationships (Table II, Figure 3). Linear regression estimated for males inhabiting Rio de Janeiro was 0.95 for log transformed and 0.97 for smoothed data. Slopes estimated for males inhabiting Argentina were consistently lower (0.59 and 0.56 for log transformed and smoothed data, respectively) than overall pattern observed for the other two populations sampled (Table I, Table II).

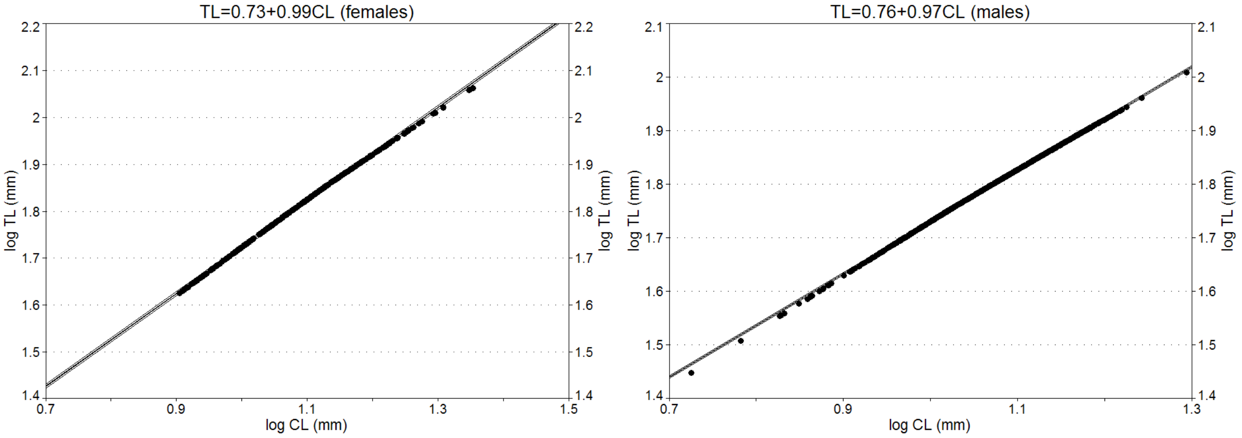

Figure 3. Linear regression between TL and CL for *A. longinaris* in southern Brazil pooled by sex. Data was log transformed and smoothed by using *Loess* algorithm.

Seasonal analysis of linear regression slope showed different patterns for both sexes. Slopes of linear regression, estimated for females inhabiting Southern Brazil, ranged from 0.92 (autumn/02) to 1.01 (spring/02) without a clear pattern of seasonal variation (Table I, Table II, Figure 4).

Table I. Linear regression summary obtained from *A. longinaris* total (TL) and carapace length (CL) data for different sexes, sites and seasons, containing estimates of intercept (a ± confidence interval at 95%), slope (b ± confidence interval at 95%), coefficient of correlation (r) and number of individuals used (n). CZ = Convergence Zone. All linear regressions presented significance level of fit ($p<0.05$). Due to different R values, slopes were corrected based on different coefficient of correlation values (b_{corr}). * indicates predictive regression parameters obtained from raw data.

site	**(a ± CI 95%)**	**(b ± CI 95%)**	**b_{corr}**	**r**	**n**
CZ-overall (females)*	0.67<0.18>1.03	5.3<5.35>5.40	-	0.94	2116
CZ-overall (males)*	0.46<1.49>2.53	5.17<5.25>5.33	-	0.91	2971
CZ-overall (females)	0.71<0.73>0.73	0.99<1.00>1.1	1.03	0.95	2116
CZ-overall (males)	0.73<0.74>0.75	0.96<0.97>0.99	1.02	0.90	2971
Argentina (males)	1.03<1.16>1.29	0.49<0.59>0.69	0.69	0.73	139
Rio de Janeiro (males)	0.66<0.78>0.89	0.85<0.95>1.05	1.04	0.84	142
CZ-Summer/02 (males)	0.62<0.65>0.67	1.05<1.07>1.10	1.09	0.96	251
CZ-Summer/04 (males)	0.67<0.73>0.80	0.93<0.99>1.05	1.06	0.87	191
CZ-Autumn/02 (males)	0.85<0.90>0.95	0.79<0.84>0.89	0.93	0.82	324
CZ-Autumn/04 (males)	0.87<0.93>0.99	0.73<0.83>0.88	0.92	0.82	248
CZ-Winter/02 (males)	0.92<0.96>1.0	0.75<0.79>0.82	0.85	0.86	918
CZ-Winter/04 (males)	1.02<1.08>1.14	0.65<0.70>0.75	0.78	0.80	207
CZ-Spring/02 (males)	0.70<0.72>0.75	0.99<1.01>1.03	1.05	0.93	636
CZ-Spring/04 (males)	0.69<0.73>0.77	0.97<0.99>1.04	1.02	0.94	196
CZ-Summer (females)	0.69<0.72>0.75	0.98<1.00>1.03	1.03	0.94	423
CZ-Autumn (females)	0.77<0.80>0.84	0.89<0.93>0.96	0.97	0.91	346
CZ-Winter (females)	0.75<0.78>0.82	0.92<0.95>0.98	1.04	0.84	824
CZ-Spring (females)	0.75<0.78>0.81	0.93<0.96>0.98	1.03	0.87	523

Table II. Linear regression summary obtained from log transformed and smoothed (*Loess*) data of *A. longinaris* total (TL) and carapace length (CL) for different sexes, sites and seasons, containing estimates of intercept (a ± confidence interval at 95%), slope (b ± confidence interval at 95%), coefficient of correlation (r) and number of individuals used (n). CZ = Rio Grande do Sul State. All linear regressions presented significant level of fit (p<0.05).

site	**(a ± CI 95%)**	**(b ± CI 95%)**	**r**	**n**
Argentina (males)	1.15<1.16>1.17	0.55<0.56>0.57	0.99	139
Rio de Janeiro (males)	0.74<0.75>0.76	0.96<0.97>0.98	0.99	142
CZ-overall (females)	0.72<0.73>0.74	0.99<1.00>1.01	0.99	2116
CZ-overall (males)	0.76<0.77>0.78	0.95<0.96>0.97	0.99	2971
CZ-Summer/02 (males)	0.61<0.63>0.65	1.05<1.07>1.10	0.99	251
CZ-Summer/04 (males)	0.75<0.76>0.77	0.96<0.97>0.98	0.99	191
CZ-Autumn/02 (males)	0.84<0.85>0.86	0.87<0.88>0.89	0.99	324
CZ-Autumn/04 (males)	0.94<0.95>0.96	0.80<0.81>0.82	0.99	248
CZ-Winter/02 (males)	0.94<0.95>0.96	0.88<0.79>0.80	0.99	918
CZ-Winter/04 (males)	1.03<1.04>1.05	0.72<0.73>0.74	0.99	207
CZ-Spring/02 (males)	0.70<0.71>0.72	1.00<1.01>1.02	0.99	636
CZ-Spring/04 (males)	0.68<0.69>0.70	1.02<1.03>1.04	0.99	196
CZ-Summer (females)	0.72<0.73>0.74	0.98<0.99>1.00	0.99	423
CZ-Autumn (females)	0.80<0.81>0.82	0.94<0.92>0.93	0.99	346
CZ-Winter (females)	0.78<0.79>0.80	0.94<0.95>0.96	0.99	824
CZ-Spring (females)	0.70<0.71>0.72	1.00<1.01>1.02	0.99	523

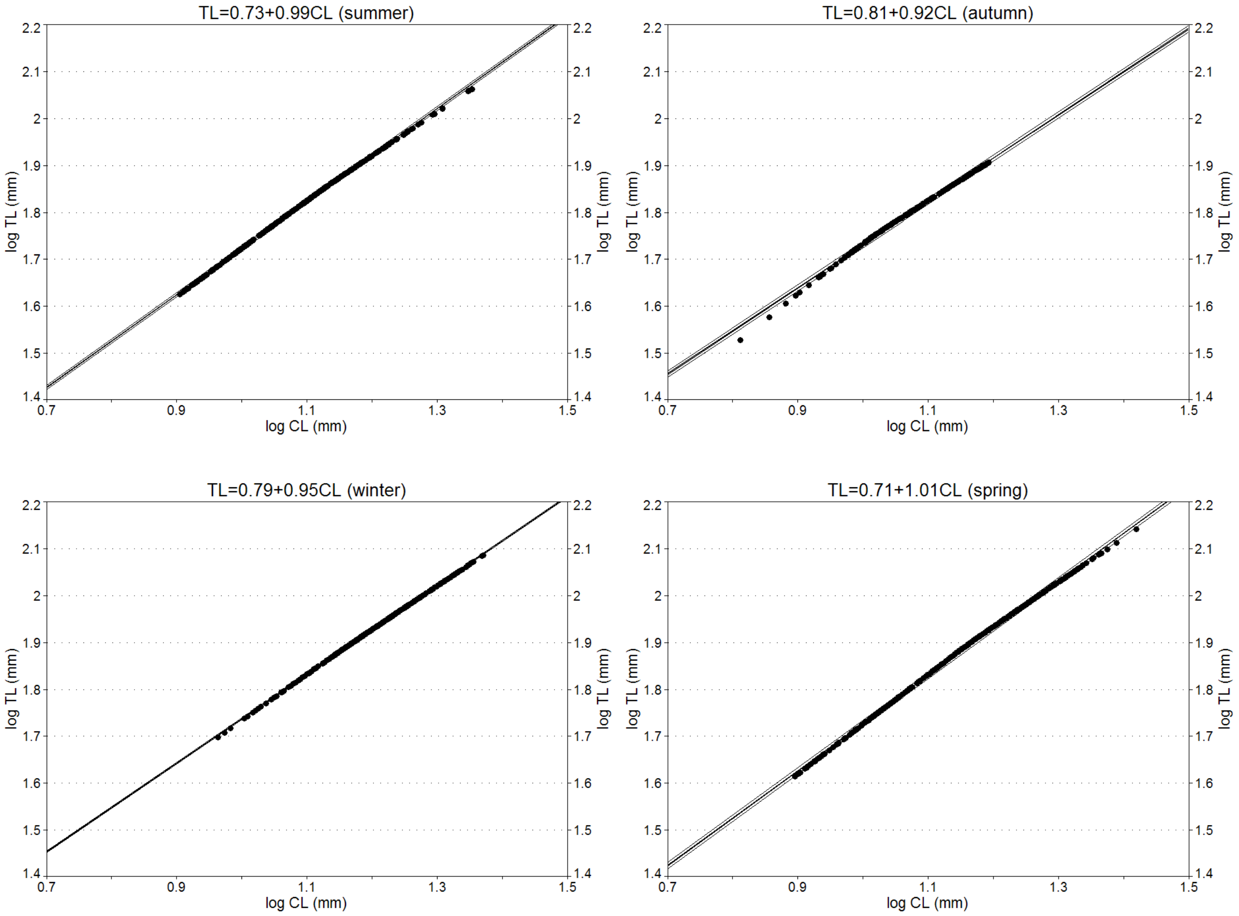

Figure 4. Seasonal variation in length relationship (TL *vs* CL) of *A. longinaris* females in Southern Brazil pooled by season. Data was log transformed and smoothed by *Loess* algorithm.

Wider range of slopes was observed in males linear regression, ranging from 0.73 (winter/04) to 1.07 (summer/02). Unlike females, slopes of males showed marked seasonal trends, with higher values observed in summer and spring, and lower values observed from autumn to winter. Autumn and winter slopes presented lower TL increment suggesting that increment of carapace (CL) is higher than total length (TL), or that contribution of cephalotorax to total length is relatively more important. Same pattern of negative isometry during autumn and winter was observed in both years analyzed. Nevertheless, 2004 showed a more marked reduction in slopes during autumn and winter (Figure 5).

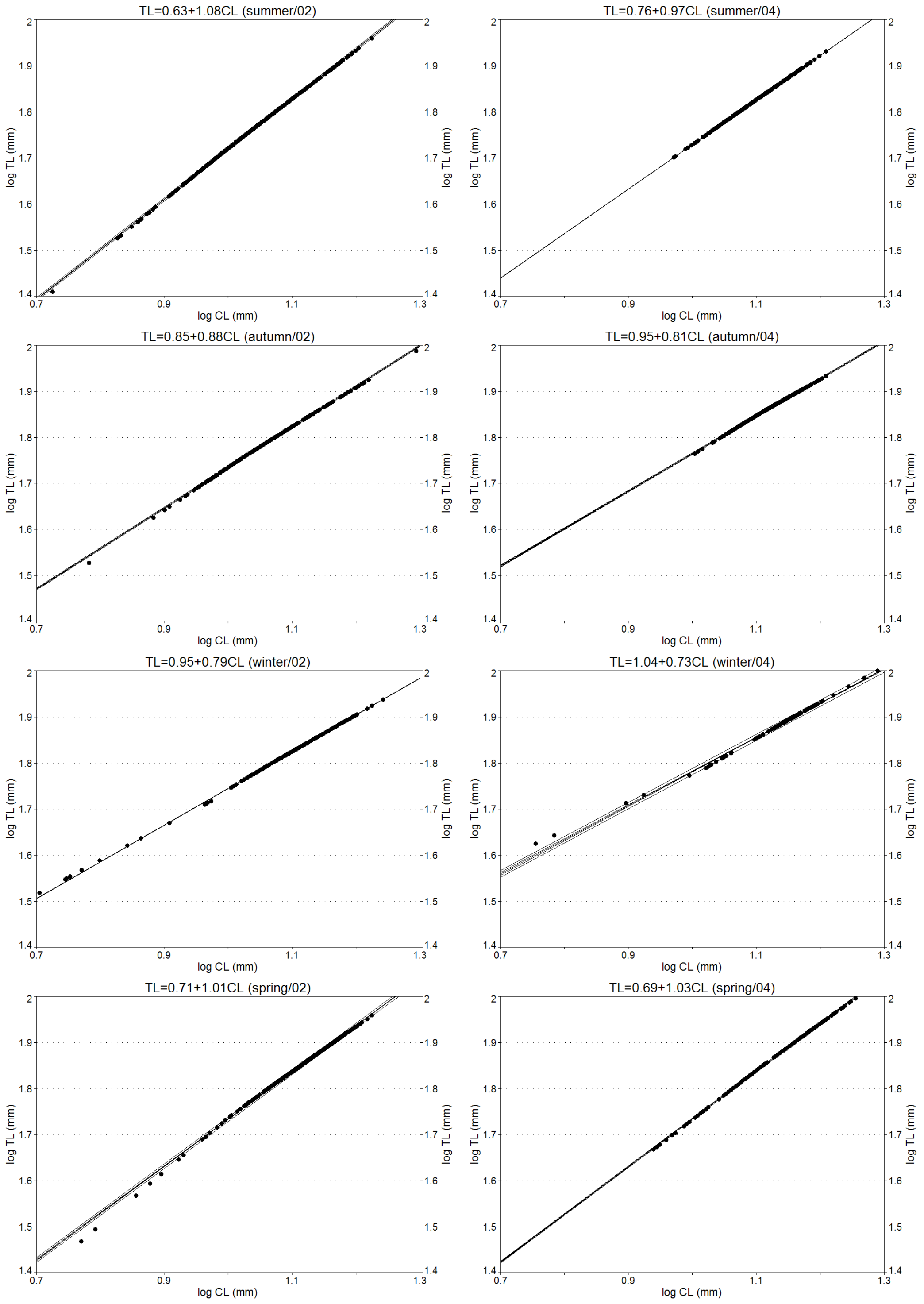

Figure 5. Interannual (2002/2004) and seasonal variation in length relationships (TL *vs* CL) for *A. longinaris* males in Southern Brazil.

Since most striking trends in slopes were observed in males, morphometric and meristic analysis included only male data obtained from Southwestern Atlantic. Mean CL/RL was significantly different between populations inhabiting southern areas (Argentina and Convergence Zone) and RJ (Table III). The variable TL/CL also suggested significant differences between southern stocks (Argentina and Convergence Zone) and population inhabiting RJ (Table IV). Since seasonal trends in TL/CL regression analysis pattern was observed, summer and winter individuals sampled in Southern Brazil were compared by One-Way ANOVA to males from distribution extremes (Rio de Janeiro and Argentina). The ANOVA results suggest that individuals from AR and those inhabiting CZ during winter have similar values for this variable. The other groups were statistically different (Table V).

Table III. Descriptive statistics of carapace (CL) and rostrum length (RL) ratio, obtained from *A. longinaris* males in different sampling sites, containing number of individuals sampled (n), mean CL/RL values, standard deviation (s.d.), standard error (s.e.) and confidence intervals (CI95%). RJ= Rio de Janeiro, AR= Argentina and CZ= Convergence Zone. Superscript letters indicate groups separated by One-Way ANOVA ($p<0.05$).

CL/RL	n	mean	s.d.	s.e.	CI (95%)	
overall	150	0.809	0.084	0.007	0.796	0.823
AR(a)	50	0.804	0.064	0.008	0.788	0.819
CZ (a)	50	0.793	0.110	0.016	0.762	0.825
RJ (b)	50	0.846	0.063	0.011	0.823	0.869

Table IV. Descriptive statistics obtained from total (TL) and carapace length (CL) ratio of *A. longinaris* males in different sampling sites, containing number of individuals sampled (n), mean TL/CL values, standard deviation (s.d), standard error (s.e.) and confidence intervals (CI 95%). RJ= Rio de Janeiro, AR= Argentina and CZ= Convergence Zone. Superscript letters indicate groups separated by One-Way ANOVA ($p<0.05$).

TL/CL	n	mean	s.d.	s.e.	CI (95%)	
RJ $^{(a)}$	50	5.405	0.048	0.010	5.384	5.427
AR$^{(b)}$	50	4.409	0.207	0.045	4.315	4.503
CZ $^{(b)}$	50	4.980	0.447	0.050	4.881	5.079

Table V. Descriptive statistics from total and carapace length ratio (TL/CL) obtained from *A. longinaris* males in different sampling sites, containing number of individuals sampled (n), mean number of rostral teeth (RT), standard deviation (s.d.), standard error (s.e.) and confidence intervals (CI95%). RJ= Rio de Janeiro, AR= Argentina, CZ (w)= Convergence Zone in winter and CZ (s)= Convergence Zone in summer. Superscript letters indicate groups separated by One-Way ANOVA.

TL/CL	n	mean	s.d.	s.e.	CI (95%)	
overall	200	4.96	0.47	0.04	4.87	5.04
RJ^{c}	50	5.41	0.05	0.01	5.38	5.43
AR^{b}	50	4.41	0.21	0.05	4.31	4.50
CZ (w)^{b}	50	4.53	0.29	0.06	4.41	4.66
CZ (s)^{a}	50	5.15	0.38	0.05	5.05	5.24

The analysis of number of rostral teeth (RT) showed significant differences between groups located at extremes of distribution area. Mean number of RT decreases with latitude, varying from 11.16 in Argentina to 10.56 in Rio de Janeiro (Table VI). In population inhabiting AR and CZ, frequency of RT was concentrated between 10 (29% and 33.3%, respectively) and

11 (42% and 46.66%) (Figure 6). A different pattern was observed in males from Rio de Janeiro population, with 48% presenting 10 teeth and 40% 11 teeth.

Table VI. Descriptive statistics from number of rostral teeth (RT) of *A. longinaris* males in different sampling sites, containing number of individuals sampled (n), mean number of rostral teeth (RT), standard deviation (s.d.), standard error (s.e.) and confidence intervals (CI95%). RJ= Rio de Janeiro, AR= Argentina, CZ= Convergence Zone. Superscript letters indicate groups separated by One-Way ANOVA and Tukey's test.

RT	n	mean	s.d.	s.e.	CI (95%)	
overall	150	10.901	0.973	0.116	10.671	11.132
AR $^{(a)}$	50	11.161	1.068	0.192	10.770	11.553
RJ $^{(b)}$	50	10.560	0.821	0.164	10.221	10.899
CZ $^{(a,b)}$	50	10.933	0.884	0.228	10.444	11.423

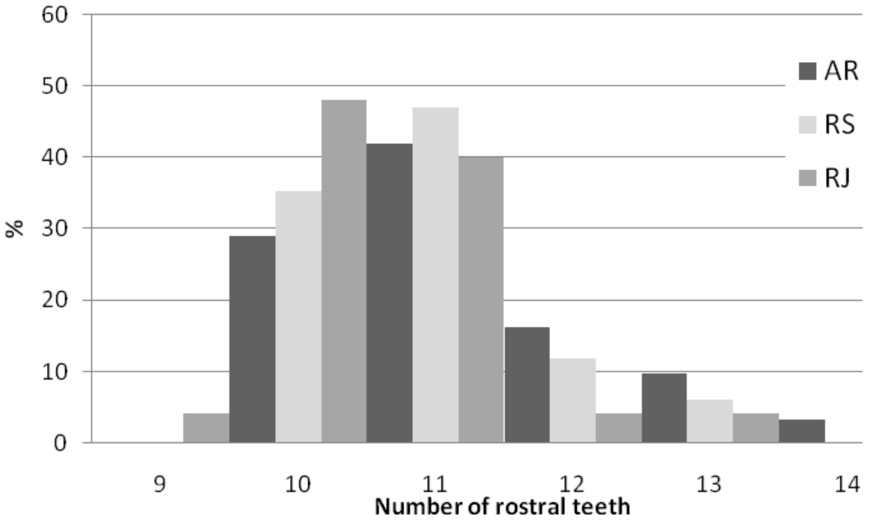

Figure 6. Relative frequency of number of rostral teeth (RT) in males of *A. longinaris* inhabiting Argentina (AR), Convergence Zone (CZ) and Rio de Janeiro (RJ).

The same clustering pattern was observed for both variables analyzed (TL/CL and CL/RL), grouping southern stocks (AR and CZ) in the same cluster. Lower distances were recorded between Argentina (AR) and Convergence Zone in winter ($CZ_{(w)}$). Males inhabiting CZ in summer ($CZ_{(s)}$) also clustered together with southern populations, but showing slightly higher distance from winter and Argentina (Figure 8).

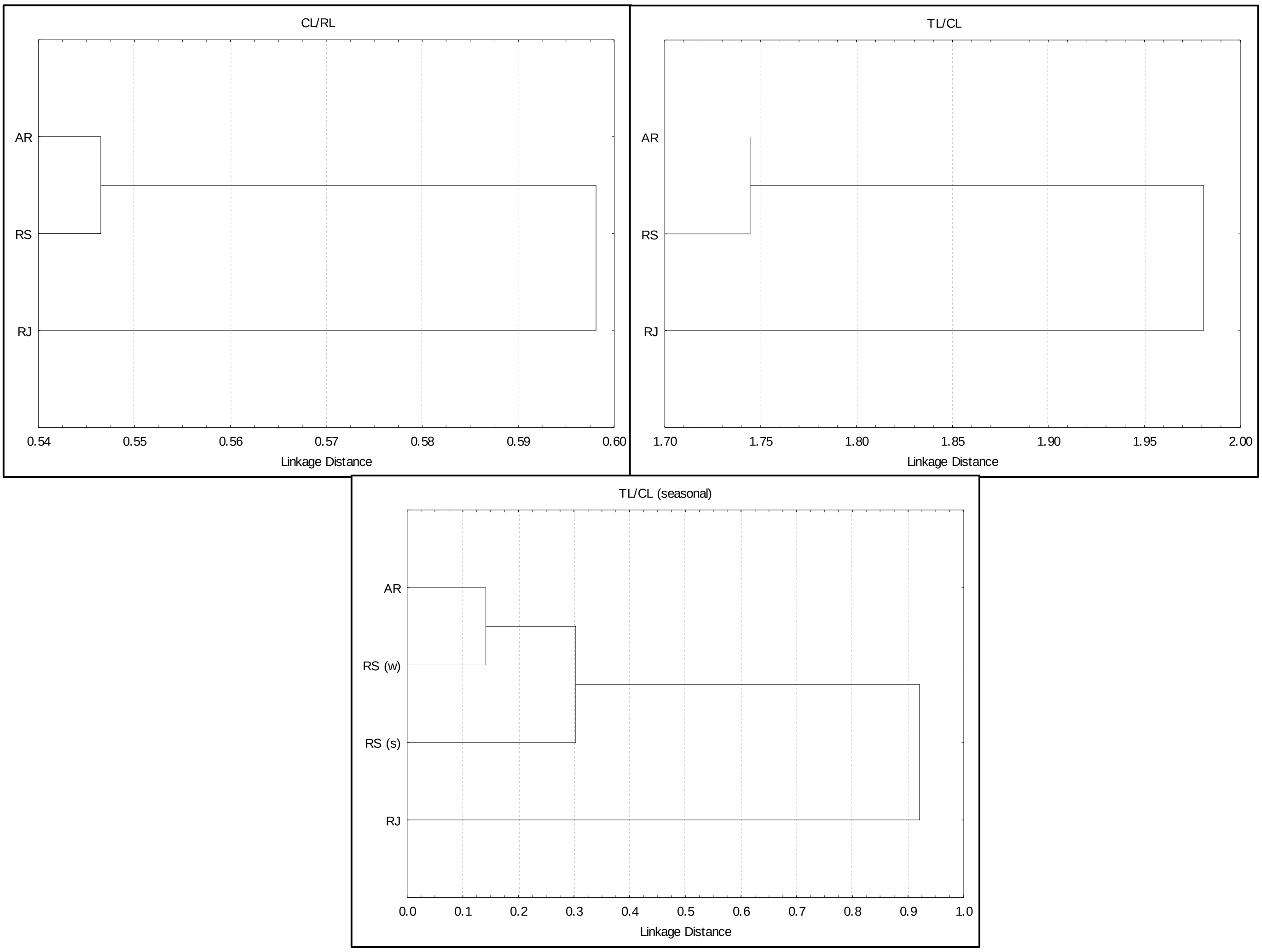

Figure 8. Cluster analysis estimated for males of *A. longinaris* from CL/RL and TL/CL variables. AR= Argentina, RJ= Rio de Janeiro, CZ (w)= Convergence Zone in winter and CZ (s)= Convergence zone in summer.

Relative growth in weight was negative allometric for both sexes, since confidence intervals did not reach the isometric value (*b*=3) (Figure 9). Females have a slightly higher *b* value (2.87) than males (2.83), but significant differences (CI 95%) were not found (Table VIII).

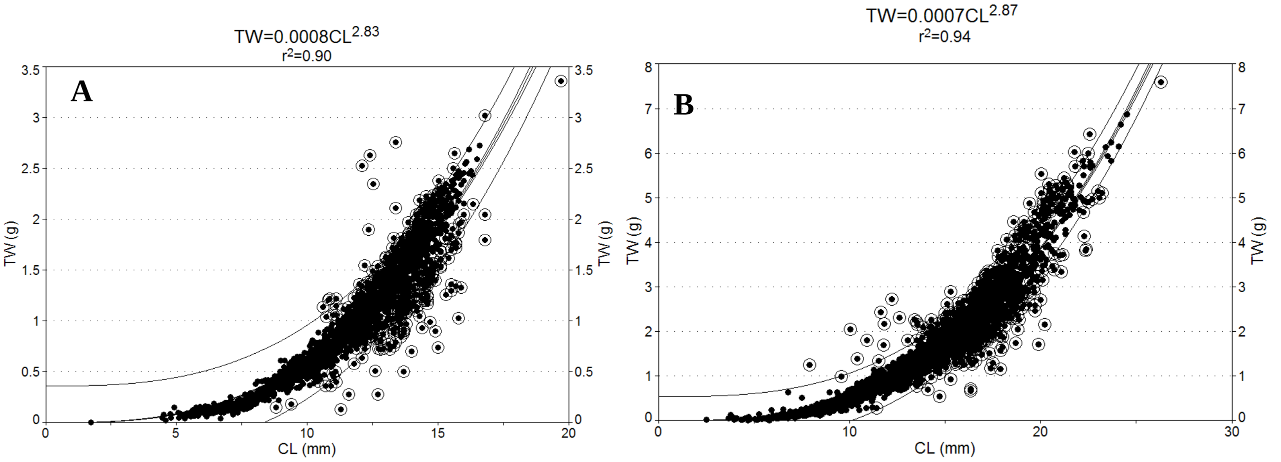

Figure 9. Length-weight relationship estimated for each sex of *A. longinaris* in Southern Brazil. A-females; B- males. Circled points were automatically excluded from analysis since they were located outside 95% confidence interval and therefore assumed as measuring errors.

Table VII. Statistic summary of length-weight relationships estimated for *A. longinaris* males and females in Southern Brazil, containing of intercept (a), slope (b), coefficient of determination (R^2) and significance level (p).

	a(±IC95%)	b (±IC95%)	R^2	p
males	0.0007<0.0009>0.001	2.78<2.83>2.89	0.89	0.000
females	0.0006<0.0007>0.0008	2.85<2.87>2.89	0.96	0.000

Relative condition index showed seasonal variation, with lower values observed in summer for both years analyzed (Table VIII). This index (RCI) was statistically lower in summer for both years, but especially in 2002 when the lowest value (-0.030) for this parameter was recorded. Conversely, spring the highest RCI was recorded in spring, reaching values up to 0.823 in 2004. In 2004 the estimates were not significantly different from autumn to spring, while in 2002 autumn and winter formed a discrete intermediate group differing from spring mean value (Table VIII).

Table VIII. Statistic summary of relative condition index (RCI) estimated for *A. longinaris* females in Southern Brazil during the years of 2002 and 2004, including number sampled, (n), mean values, standard deviation (s.d.), standard error (s.e) and confidence intervals at 95% level (CI95%). Letters within brackets indicate similar groups estimated by ANOVA.

RCI	n	mean	s.d	s.e	CI 95%	
overall	4036	0.506	1.632	0.027	0.453	0.559
summer/02 (a)	516	-0.030	1.814	0.080	-0.187	0.127
summer/04 (d)	115	0.033	2.077	0.194	-0.351	0.417
autumn/02 (b)	466	0.449	1.314	0.061	0.329	0.568
autumn/04 (e)	444	0.768	1.596	0.076	0.619	0.917
winter/02 (b)	590	0.231	2.017	0.083	0.068	0.394
winter/04 (e)	300	0.733	1.625	0.094	0.548	0.917
spring/02 (c)	1185	0.777	1.318	0.038	0.702	0.852
spring/04 (e)	420	0.823	0.811	0.125	0.571	1.076

DISCUSSION

Overall pattern of relative growth in size was similar for both sexes, with values close to expected isometry for size relationships. However, slightly higher TL growth was observed for females. Similar pattern was previously observed for other penaeid prawns such as *Penaeus aztecus* (Parrack, 1979), *Penaeus indicus* (Devi, 1986), *Penaeus longystilus* (Dredge, 1990), *Litopenaeus vannamei* (Chow & Sandifer, 1991), *Metapenaeus endeavouri* (Buckworth, 1992) and *Penaeus monodon* (Primavera et al., 1998). Previous investigation on length-length relationships for *A. longinaris* describes a slightly higher relative growth of TL in males (Boschi, 1969; Nascimento, 1983), which may be explained by higher frequency of regenerating and broken rostrum of females, directly influencing TL measurements. In the present study, percentage of excluded females surpassed males (5.21% of females and 3.0% of males were located outside 95% CI), which is likely related to larger rostrum of females and consequent higher probability of breakdown. We hypothesize that slightly higher relative growth observed in previous investigations (Boschi, 1969; Nascimento, 1983) was due to inclusion in the linear regression of individuals, of both sexes, with undetected broken or regenerating rostrum.

None of the linear regressions presented intercept passing through the origin which may be explained by significant trends occurred in morphology during larval stages of *A. longinaris*. Previous analysis of length-length relationships in penaeids prawns, such as *P. monodon* and *F. paulensis*, showed the same pattern observed in present investigation, with intercepts differing from zero (Primavera et al., 1998, Albertoni et al., 2003). Primavera et al. (1998) investigated length-length relationships along different life stages of *P. monodon*, from nursery to grow out phases, in wild and captive stocks, always estimating intercept values different from zero. Since variables used in the current investigation did not show significant influence of size composition within the range analyzed, it is likely that these trends are occurring at first stages of development or in pre-recruitment phase.

Results obtained from morphometric traits analyzed suggest that the population inhabiting RJ is discrete from the rest. Additionally, significant similarity between southern populations from Argentina and Convergence Zone, was detected. However, the exact causes of variation in exploited stocks are not easily distinguishable (Waldman, 1999). Phenotypic differences have been widely discussed and used as an important tool for stock identification of populations (Begg et al., 1999; Swain & Foote, 1999; Waldman, 1999, Begg & Waldman, 1999; Swain et al., 2001; Pinheiro et al., 2005). Morphometric characters are phenotipically expressed and represent both genetic and environment information, but lacks from the absence of information on their respective contributions (Waldman, 1999).

Nascimento (1983) analyzed changes in size relationships for *A. longinaris* along the CZ suggesting, without a definite conclusion, that these trends may be attributed to environment-induced different growth patterns, allometry caused by interactions between different populations or the presence of a puberty molt. Primavera et al. (1998) suggest that the presence of old, slow growing individuals may force the slope down in linear regressions of length relationships of *P. monodon*. However, the analysis of size composition does not support this hypothesis since small recruits can also be observed during autumn and winter and larger males were mainly observed in spring. Previous investigations on allozymes (Weber et al., 1993) and mtDNA (Dumont et al., manuscript) confirm significant similarity between CZ and AR populations and isolation of the group inhabiting RJ coast (Dumont et al., manuscript).

Although phenotypic differences do not provide direct evidence of genetic isolation between stocks, they can indicate the prolonged separation in different environmental regimes (Campana & Thorrold, 2001). Morphometric characters typically show ontogenetic changes associated with allometric growth and may be attributed to environmental influences through life (Swain & Foote, 1999). Body shape be easily modified by several environment and ecological factors such as rearing temperature (Beacham, 1990) as well as quantity and quality of diet (Currens et al., 1989).

Mean water temperature registered for Macaé (RJ) is 24^0C, except in summer when temperature decreases due to a coastal upwelling process (20-22^0C) (Beisl et al., 2001). Conversely, water temperatures in Mar del Plata (AR) are consistently lower, ranging from 10^0C to 20.5^0C (Ciemchomski & Vigo, 1971). Hence, lower temperatures recorded in southern area, where AR and CZ populations live may explain significant differences in relative growth observed in present investigation. Cluster analysis including summer and winter individuals showed reduced distances between individuals from AR and CZ (w), which may also suggest that temperature is an important factor influencing morphometric traits of *A. longinaris*. Additionally, lower slopes observed during 2004 may also indicate the influence of temperature on relative growth for this species.

However, oceanographic features of the studied region may also imply genetic interchange between AR and CZ populations as well as isolation of RJ population. Changes in morphometrical, namely TL/CL ratio and slope of TL/CL regression (males), traits observed during colder periods of autumn and winter may be linked to the presence of morphotypes from AR, brought to Southern Brazil by Coastal Water (CW). The CW is a colder water mass that is mainly influenced by the La Plata river freshwater outflow and is displaced northwards when southwesterly winds are frequent and intense. This water mass stretches northwards reaching the coast of Rio Grande do Sul ($32^0$00’) all year round but its presence is more noticeable in autumn and winter (Piola et al., 2004; Piola et al., 2005). This “diluted” water is therefore, the dispersion vector by which prawns and/or larvae from southern stocks, with relative larger carapace and rostrum lengths, can be transported to Rio Grande do Sul coast, especially during winter. Assuming that individuals from AR are carried by CW in autumn and winter and that the main reproductive event takes place in spring (Calazans, 2002; Ruffino & Castello, 1992; Dumont & D’Incao, manuscript), it is likely that genetic interchange occurs between these two stocks (Dumont et al., manuscript).

It is also important to highlight that sampling was performed during two contrasting years in terms of amount of rainfall, salinity and water temperature. During 2002, the total volume of rain recorded was the highest in the last thirty years, overcoming elevated values observed in intense El Niño events (ENSO), such as 1997-1998 (NOAA, 2007). On the other hand, 2004 was considered as a dry year, presenting lower rainfall values, higher salinity and lower temperature. Therefore, reduction of slopes during 2004 may be linked to larger amount of CW in the coast of Rio Grande do Sul (CZ). This water mass is quite variable in terms of salinity and temperature, showing latitudinal displacements regulated by rainfall and wind stress along the coast (Piola et al., 2004; Piola et al., 2005).

Theoretical arguments indicate that high river discharges should lead to increased penetration of La Plata plume northwards (Garvine, 1999). Surprisingly, and in spite of significant discharge variations, low salinities are observed near the river mouth or displaced offshore (35^0S). The meridional penetration of the river plume is therefore largely controlled by the magnitude and direction of southwesterly winds predominant during winter (Kourafalou et al., 1996). During ENSO events, southwest winds are weakened and northeast wind predominates in Southwestern Atlantic, reducing northwards penetration of CW (Piola et al., 2005). Thus, it may explain lower abundances of morphotypes from Argentina in the CZ during 2002. Conversely, during years of intense southwest winds and moderate rainfall, the influence of CW on South and Southeastern Brazil is more intense, reaching the latitude $23^0$32'S (São Paulo) (Piola et al., 2004) (e.g. 2003, when maximum landings of *A. longinaris* were recorded in Southern Brazil). The isolation of RJ population is therefore also explained by the maximum expansion of CW that does not reach this region even during favorable combinations of wind and rainfall (Piola et al., 2005).

Relative growth of rostrum also allowed identification of significant similarities between males from Argentina and Rio Grande do Sul. Populations inhabiting southern areas (CZ and AR) tend to have a relative longer rostrum, which does not occur in northern limit of distribution (Rio de Janeiro). Previous investigation of relative growth of *A. longinaris* (Nascimento, 1981) also suggested that individuals inhabiting latitudes higher than $32^0$05' presented relative larger rostrums. However, the refereed investigation was restricted to Convergence Zone and did not analyze the extremes of *A. longinaris* distribution.

Power of morphometric characters to identify stocks has been widely discussed (Gulland, 1971; Begg & Waldman, 1999; Begg *et al.*, 1999). An argument against this tool is that morphometric characters are easily influenced by environment changes, such as temperature and salinity. On the other hand, if these differences are maintained through time it may be an indicative of reproductive isolation (Cushing, 1981), which does not hold true for *A. longinaris*, since prawns from AR may reproduce with individuals from CZ population, as indicated by molecular analysis (Weber et al., 1993). The basic premise behind the modern concepts of stocks is whether there is a marker, genetic or phenotypic, that will remain the same without much variation for all identification applications over time (Booke, 1999). It is also important to highlight that morphometry is only a single tool for identifying stocks and must be combined with other techniques to improve reliability of stocks differentiation. According to modern theories about stock identification a holistic approach (*e.g.* genetic information plus morphometry and meristics) must be addressed to increase confidence in stock structure analysis (Begg & Waldman, 1999; Begg, *et al.*, 1999).

Additionally to molecular (Weber et al., 1993; Dumont et al., manuscript) and morphometric analysis, meristic counts of number of rostral teeth (RT) also showed a certain level of population structuring for *A. longinaris* in Southwestern Atlantic. According to D’Incao (1999) *A. longinaris* presents great variability in number of RT, showing values that range from 7 to 14. In present investigation, the number of rostral teeth varied from 9 to 14, which may have been caused by exclusion of females from analysis or due to low sampling numbers. A latitudinal pattern in mean number of RT was observed, since reductions in mean values were recorded as latitude decreases. Mean comparison tests indicated that only populations inhabiting distributions extremes (AR and RJ) showed significant differences in mean number of RT. However, modal value of population inhabiting RJ was located at interval of 10, while the most frequent number of rostral teeth in other two populations (AR and CZ) was 11. Therefore, the analysis of this variable reinforces similarity between stocks located at southern regions and the isolation of northern population (RJ), caused either by environment-induced or migration phenomenon.

Meristic characters such as the number of vertebrae or fin rays have a long history of use in the delineation, especially, of fish stocks (e.g. Swain & Foote, 1999). Variation in these characters was assumed to reflect genetic differentiation, but some authors state that the number of parts formed in an individual can be strongly influenced by the environment, in particular temperature (Lindsey, 1988; Shepherd, 1991; Kinsey et al., 1994), usually before or immediately after hatching and is normally unaffected by subsequent environmental variation (Lindsey, 1988) This suggestion is reinforced by studies that demonstrate morphological differences between groups of fish that appear genetically homogeneous (Leslie & Grant, 1990; Kinsey et al., 1994).

Even though meristic differences may be environmentally-induced rather than genetically-based, consistent morphological differences among areas may indicate the existence of ‘‘phenotypic stocks’’ with sufficient distinctness to warrant separate management (Shepherd, 1991). The phenotipic (Nascimento, 1981, 1983) and genetic (Weber et al., 1993; Dumont et al., manuscript) traits analyzed allowed to conclude that stocks of *A. longinaris* inhabiting southern regions (CZ and AR) show higher level of similarity when compared to the northernmost stock. These evidences are supported by geographical distance, differences of water temperature and oceanographic systems observed in species’ distribution the area.

To manage a fishery effectively, it is important to understand the stock structure and how fishing effort and mortality are distributed (Grimes *et al*., 1987). An understanding of stock structure is vital for designing appropriate management regulations in fisheries. It is especially important when multiple stocks are sharing similar areas and being exposed to different exploitation patterns (Ricker, 1981). Knowledge of stocks composition permits to obtain specific maximum yields and therefore protect the less productive ones (Begg *et al*., 1999). Consequently, the understanding of stock structure of *A. longinaris* is quite important for management strategies, especially because this resource is shared between two different countries.

Artemesia longinaris presents the lowest values for the allometric coefficient of relative growth in weight among commercial penaeid prawns from Southwestern Atlantic. For instance, *Farfantepenaeus paulensis* has a positive allometric growth, presenting *b* values for both sexes above the isometric value (3.65 and 3.40 for females and males, respectively). Previous studies concerning relative growth of *Farfantepenaeus brasiliensis* showed an approximated isometric weight increment, with females presenting slightly higher *b* (3.09) than males (2.95) (Rebelo-Neto, 1985). Lower values estimated for *A. longinaris* reflect the body shape of investigated species that has a thinner abdomen and a stretched shape when compared to species previously cited.

Higher exponent of females is influenced by ovarian maturation, increasing the relative growth in weight during reproductive season (King, 1997). Different results were obtained for *A. longinaris* length-weight relationships in Argentina. Males from Argentina have positively allometric growth (b= 3.20), while females have similar growth pattern in weight (b= 2.84) (Boschi, 1969) when compared to present results. Comparison of results from the present investigations with those obtained for Argentinean stock is difficult, since independent variable used was TL and not CL as in present investigation. Nevertheless, expected *b* values for penaeid females are supposed to be higher than males since ovarian development tends to increase the increment in weight (King, 1997).

Seasonal analysis of relative condition factor confirms previous biological information available for the species in Southern Brazil (Nascimento, 1983, Ruffino & Castello, 1992, Dumont & D’Incao, manuscript). Highest RCI observed during spring is related to availability of food and favorable salinity and temperature in studied area. During spring high availability of nutrients in water column results in phytoplankton blooms (Ciotti et al., 1995), providing good environment conditions for growth and reproduction of several species. Reproductive season of *A. longinaris* is also connected to this seasonal cycle (Nascimento, 1983; Ruffino & Castello, 1992; Calazans, 2002; Dumont & D’Incao, manuscript) which is reflected in RCI. Lowest values of RCI observed during summer are related to higher water temperature, since mortality rate for this species is high (89%) in temperatures around 26 °C (Haran *et al.*, 1992). Thus, environment stress due to high temperatures recorded in summer may reduce increment in weight for *A. longinaris*.

An abrupt decrease in RCI was observed in winter/02 coinciding with intense rainfall accumulated since summer, reducing salinity in the area. Changes in salinity can affect feeding activity as well as growth of crustaceans, altering metabolic pathways and developmental processes (Anger, 2003). The negative effect of brackish water on euryaline coastal species, such as *A. longinaris*, is that under suboptimal salinity concentration the energetic requirements are increased due to hyper-osmoregulation (Kinne, 1971). Allocation of the energy initially designated to reproduction is diverted to osmotic regulation and may inhibit ovary maturation of prawns, since it is a high energy demanding process (Dall *et al.*, 1990), explaining lower RCI values of *A. longinaris* during elevated rainfall periods.

In summary, the main result of this investigation was the indication of a high similarity in morphometric and meristic traits of populations occurring in Convergence Zone and Argentina, caused either by genetic or environment-induced factors. Moreover, seasonal trends in RCI showed interannual and seasonal variations, negatively affected by high temperatures of summer and low salinities.

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Reproductive pattern, size at first maturity and stock-recruitment relationships of the Argentinean prawn (*Artemesia longinaris*, DECAPODA: PENAEIDAE) in Southern Brazil

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Reproductive pattern *A. longinaris…*

Keywords: *Artemesia longinaris*, reproductive pattern, size at first maturity, stock-recruitment relationships, stock assessment.

SUMMARY

Artemesia longinaris has been recently exploited by commercial and artisanal fisheries in Southern Brazil. To investigate the reproductive biology of this species in Southern Brazil, monthly samples were analyzed between February/2002 and January/2003. Stock-recruitment relationships (SSR) were estimated, as well as a preliminary predictive model for recruit biomass. Reproductive effort is concentrated in spring; however, recruitment was observed all year round. Reproduction in autumn is more variable and susceptive to intense rainfall and consequent low salinity observed the in studied area. A reproductive migration to depths higher than 15 meters was observed, and recruitment process starts approximately one month after hatching. Mean length at first maturity was estimated in 16.76 mm and is achieved at approximately 4 months. Significant fit of SSR was observed for three models tested under adverse environment conditions, suggesting that the reduction of spawning biomass combined with unfavorable environment conditions may lead to recruitment overfishing. A preliminary predictive model was developed and the main factors influencing recruitment of the species are salinity in spawning season and rain in recruitment. The main factor influencing recruitment success under adverse environment conditions is the biomass of spawning stock, while under favorable conditions salinity in spawning season plays a significant role.

INTRODUCTION

Artemesia longinaris Bate, 1888 is a penaeid prawn commercially exploited along its entire distribution area, from Rio de Janeiro ($21^0$37S), Brazil to Puerto Rawson ($43^0$00S), Argentina. The Argentinean prawn usually used as food for human consumption as well as for bait in amateur fishery. The species is caught along with *Pleoticus muelleri*, which is also a valuable fishery resource in Southern Brazil and Argentina (Boschi, 1969; D`Incao *et al.*, 2002).

Commercial landings in Brazilian coast date from 1978; however, landing statistics were only available after 1982, presenting remarkable increasing in last decades (Univali, 2004). The growing interest and increasing fishing effort over the Argentinean prawn, especially after the collapse of pink prawn fishery (D´Incao *et al*., 2002) require new investigations about its population dynamics.

Although prawn stocks throughout the world support highly profitable fisheries (FAO, 2007), little is known about the biology of several species (Cha et al., 2002). Out of population parameters, one of the most important is the size or age at first maturity, which is widely used as a biological reference point for managing exploited stocks (Gulland and Rotschild, 1981; Cha et al., 2002; López-Martinez, 2005; Frisch, 2007) since preservation of individuals smaller than mean size at first maturity increases the chance of success of the next offspring (Garcia and Le Reste, 1981; King, 1997).

Previous investigations concerned on reproduction and ovary maturation of *A. longinaris* are scarce, especially in Southern Brazil (Nascimento, 1981; Dumont & D´Incao, 2004; Castillo et al., 2007). Using variation of size at first maturity, in southern Brazil, a hypothesis of two different populations was stated for this species (Nascimento, 1981). However, the trait used to define morphological maturity was the presence of spermatophore, which is now known as a no informative feature to identify ovary development for this species, since females can carry spermatophores without being fully mature (Scelzo, 1991). Dumont & D´Incao (2004) established a chromatic scale, based on ovarian microscopic traits, to identify stages of gonadal development of *A. longinaris* more accurately, providing a routine method to classify the ovaries. Recently, Castillo et al. (2007) investigated trends in size at first maturity in populations inhabiting distribution limits of the species.

Furthermore, investigations on penaeid prawns biology suggest conspicous trends in reproductive dynamics for this group, highly dependent on environment conditions (Staples et al., 1995; Vance et al., 1998; Crocos et al., 2001). Recruitment of juveniles and larval abundance of *A. longinaris* has been previously assessed and marked oscillations in time and intensity of reproduction were reported, even tough the main breeding season in Southern Brazil is accepted as taking place in spring (Calazans, 2002; Ruffino & Castello, 1992; Nascimento, 1981). Previous studies suggest that main reproductive season in Argentina takes place in summer and that endogenous and environment factors may affect reproduction of this species in that area (Boschi, 1969; Christiansen & Scelzo, 1971; Scelzo, 1991; Petriella & Bridi, 1992). In Northeastern Brazil reproduction was reported to take place in summer, associated to colder water resurgence

Prediction of recruitment is also of special interest for penaeid fisheries management (Pauly, 1992). Forecasting of recruit abundances in prawn populations has been considered a hard task due to their high fecundity and susceptibility to environment shifts, such as those caused by rainfall and wind stress (Garcia, 1981; Gulland & Rotschild, 1981, Crocos et al., 2001). Despite of that, stock-recruitment relationships (SRR) have been applied to estimate recruitment of penaeid prawns with considerable level of success (Garcia, 1981; Kirkwood, 1981; Pauly, 1992).

There are evidences that level of recruitment is at least partly governed by environment conditions and interactions between spawning stock, recruitment and environment conditions must be investigated to properly manage and predict future abundances. There are therefore many aspects of interaction between prawn biology and environment that must be carefully considered, especially under low spawning biomass levels (Garcia, 1981; Kirkwood, 1981; Gulland & Rotschild, 1981; Dall *et al*., 1990; Pauly. 1992).

The aim of this paper is to investigate the mean size at first maturity, reproductive dynamics, stock-recruitment relationships as well as develop a preliminary model to predict the abundance of *A. longinaris* recruits in commercial fishery of extreme Southern Brazil.

MATERIAL AND METHODS

Study area

Sampling took place in surrounding area of Barra de Rio Grande, which links the estuary to marine coastal waters through a four kilometers channel (Figure 1). This area is significantly influenced by freshwater discharge from Patos Lagoon Estuary (Ciotti et al., 1995) and discharge values of 30,300m^3/s^{-1} have been reported (Garcia, 1996). The estuary is located at coastal plain of Rio Grande do Sul State, Brazil (32^0S, $49^{'}$W) and is the largest choked lagoon in the world, accounting for an area of 10,360km^2. Drainage basin covers 201,626 km^2 (Asmus, 1996) and rainfall as well as wind stress regulate the water movements in study area (Garcia, 1996, Piola et al., 2004, 2005). Seasonal freshwater discharge presents great variability (30,300 - 47m^3/s^{-1}) and during El Niño Southern Oscillation (ENSO) events runoff is usually higher than mean values estimated (Garcia, 1996).

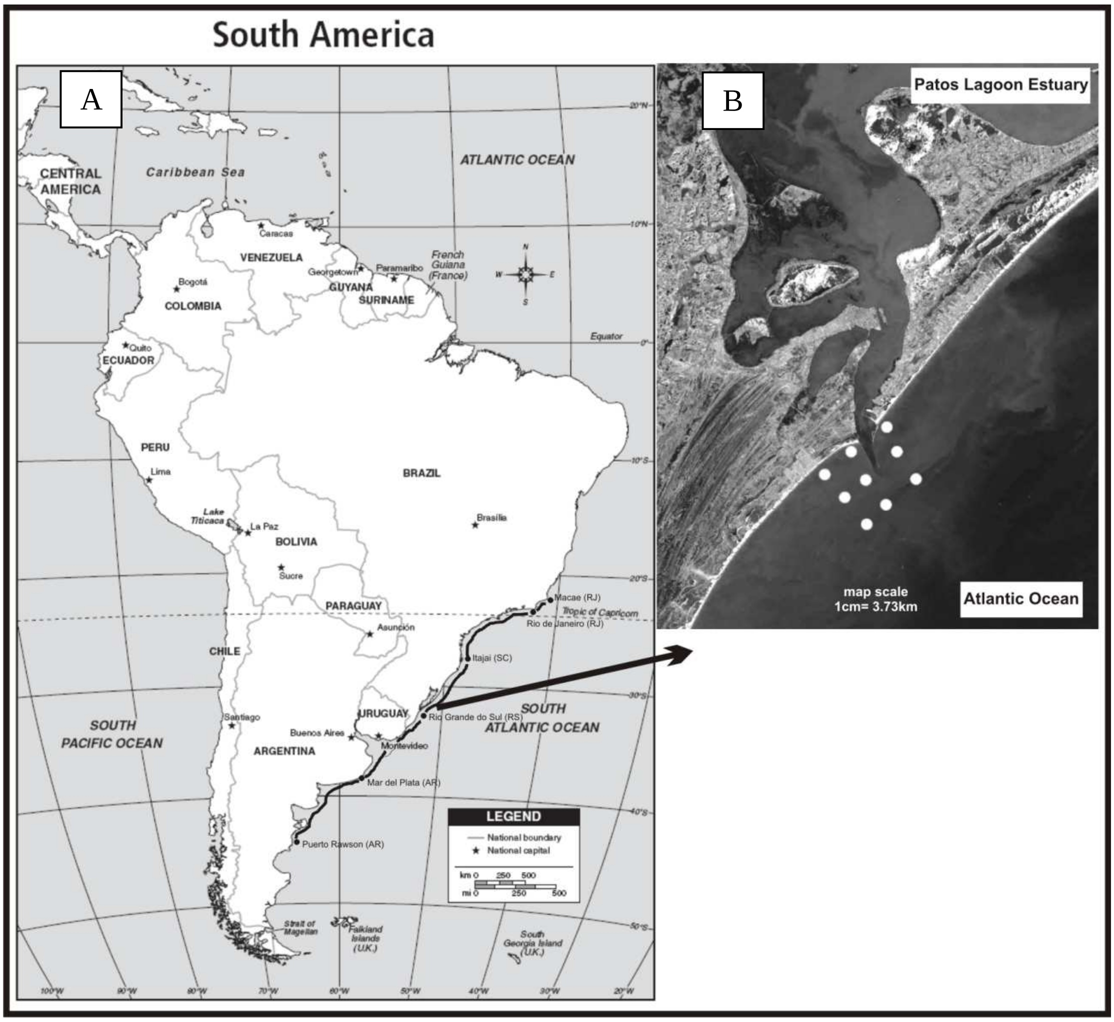

Figure 1. A- Southwestern Atlantic Ocean and distribution of *A. longinaris* in coastal waters (black line). B- Closer view of Southern Brazilian coast, highlighting the surrounding area of Patos Lagoon Estuary and nine sampling stations (white dots) positioned at depths varying from 5 to 25 meters.

Data sources

Standardized data used in this paper were obtained during oceanographic cruises (L.Oc. Larus) from 1982 to 2003, in depths varying from 5 to 20 meters. To investigate reproductive pattern only data obtained during 2002/2003 were analyzed, since during previous research cruises, ovary classification has not been performed. To estimate stock-recruitment relationship

(SRR), data between 1982 and 2003 were selected based on availability of information from spawning biomass and subsequent recruitment and only nine, out of twenty one years, were used. Discard of twelve years was due to gaps in collections during spawning or recruitment periods. Spawning season was considered as spring (October, November, December) and recruitment as summer (January, February, March). It is important to stress that main reproductive event takes place in spring and commercial trawling for *A. longinaris* concentrates maximum fishing effort during summer (Univali, 2004). Therefore, commercial fishery depends on recruitment originated from cohorts hatched during previous spring spawning season.

Reproductive dynamics and size at first maturity

To establish relative abundance index (CPUE) the catch unit adopted was number of individuals and effort unit used was five minutes trawling. Mean relative abundances were statistically compared by One-Way ANOVA and subsequent *post-hoc* Tukey test (3 or more means compared) or *t* test (2 means compared), with confidence level of 95%. Assumptions of normality (Kolmogorov-Smirnov) and homogeneity of variances (Levene) were tested prior to perform ANOVA.

Carapace length (CL) was used to describe the size structure of population, been measured from post-orbital angle to the end of mid-dorsal carapace. Size-class interval used was 0.5mm (CL). Ovary development was classified based on color and shape traits, previously established by using histological sections. Three ovarian development stages were adopted (I-immature, II-developing, III-ripe) (Dumont & D´Incao, 2004).

Recruitment patterns were obtained using ELEFAN II routine (Pauly, 1987), included in FISAT program (Gayanilo *et al.*, 1995). Growth parameters used to estimate peaks of recruitment were obtained from von Bertalanffy growth model (VBGM). Monthly relative frequency of ripe (stage III) females was compared to the recruitment pattern generated by

ELEFAN II to validate the pattern obtained. Modal groups of females were tentatively linked to visualize modal progression along the sampling period. 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 given by:

$$CLt = CL_{\infty} [\ 1 - e -k\ (\ t - to\ )],$$

where CLt is length at the time t, CL_{∞} is asymptotic length, k the coefficient of growth and to the theoretical age at zero length. Longevity (t_{max}) was estimated by inverted von Bertalanffy (1938) equation, considering maximum longevity (t_{max}) as reached at 99% of the asymptotic length (D’Incao & Fonseca, 2000).

Mean size at first maturity (LM) was considered as the size class interval (1mm interval) in which frequency of ripe females is 50% (King, 1997). Frequency of ripe females was fitted to the logistic model by an automated least square procedure, in such a way that:

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

where P is the percentage of ripe females in a given length class, r is the logistic curve slope, CL_1 is the upper limit of carapace size interval and LM is the mean length at first maturity.

Stock-recruitment relationships (SRR) and multiple regression analysis

Standardized data obtained from oceanographic cruises (L.Oc. Larus) were used to estimate spawning (females larger than LM caught during spring) and recruitment (females smaller than LM caught during summer) abundance index (g/30 minutes of trawling).

According to Gulland & Rotschild (1981) a single spawning-recruitment (SRR) curve can not entirely describe the changes in stock biomass of an exploited prawn population. Besides spawning biomass, environment factors play an important role in recruitment success and therefore must be considered in stock assessment (Garcia, 1981; Kirkwood, 1981; Gulland & Rotschild, 1981; Dall *et al*., 1990). Thus, two different SSR were visually established and their respective environmental parameters investigated, in such a way that one curve was estimated for favorable environment conditions (1988, 1989, 2000, 2002) and another for adverse years, where same spawning stock resulted in smaller recruitment biomass (1982, 1983, 1984, 1996, 2001).

Stock-recruitment relationships (SRR) were obtained by using three different models. The Beverton & Holt (1957 *apud* King, 1997) model assumes that recruitment achieves an asymptotic value of biomass at high spawning stock abundances and the equation that describes it is given by:

$$R=S/(a+bS)$$

where R is the abundance of recruits in the next year, S is the spawning biomass and a and b are the parameters of the model.

The Ricker (1975 *apud* King, 1997) equation describes a stock-recruitment relationship where recruitment achieves a maximum and decreases afterwards at high spawning biomass levels. The equation is given by:

$$R=aS\ exp(-bS)$$

where R is the abundance of recruits in the next year, S is the spawning biomass and a and b are the parameters of the model.

The last model fitted was created by Shepherd (1982 *apud* King, 1997).

$$R=aS/[1+(S/K)^b]$$

The parameters R and S have the same meaning as in other equations. The parameter a is the initial slope at the origin and reflects the potential stock-recruitment relationship without the density-dependent effects. The parameter K represents the threshold spawning biomass above which density-dependent effects dominate density-independent effects. Specifically, K is the stock size at which recruitment is reduced to one half the level it would have been under density-independent process only (King, 1997). Spawning stock and recruitment abundances were fitted to SRR models by an automated least square procedure. Mean salinity and rainfall during spring were grouped according to good and bad recruitment years (visually determined according to SRR) and than compared by a *t* test at 5% significance level.

Multiple regression analysis was performed to elucidate main environmental and biological factors affecting reproductive successes of *A. longinaris* in surrounding area of Patos Lagoon estuary. Predictors used were: total rainfall in spawning (RSS) (spring) and recruitment seasons (RRC) (summer), salinity in spawning season (SALS) (spring), salinity in recruitment (SALR) and spawning biomass (SS). Recruitment abundance in subsequent summer (RC) was considered as the dependent variable. A forward stepwise method was chosen, in such a way that most important predictors were progressively included in regression equation. Salinity data was measured with a termosalinometer after each fishing station. Daily rainfall (mm^3) data was obtained from Estação Agrometeorológica da Universidade Federal de Pelotas, and seasonally grouped as previously mentioned.

RESULTS

Environmental data

Rainfall data collected for the city of Rio Grande was chosen due to higher correlation with salinity in surrounding area of Patos Lagoon (r=0.73, b=0.049). Conversely, polled rainfall data from all drainage basin did not show a close relationship with salinity. Lack of correlation may be owned to complex interactions between pluviosity and wind stress (Garcia, 1996), resulting in a larger gap between rainfall and freshwater runoff.

Mean annual rainfall, between 1913 and 2002, in the city of Rio Grande is 1215mm^3. Total rainfall recorded in 2002 was the highest since 1915, reaching the value of 1915mm^3. Values recorded in 2002 were consistently above main values for the area, except in July, when slightly lower rainfall was observed. Four main peaks of rainfall were observed in January (241.7mm^3), March (224.2mm^3), October (195.8mm^3) and December (272.7 mm^3) (Figure 2).

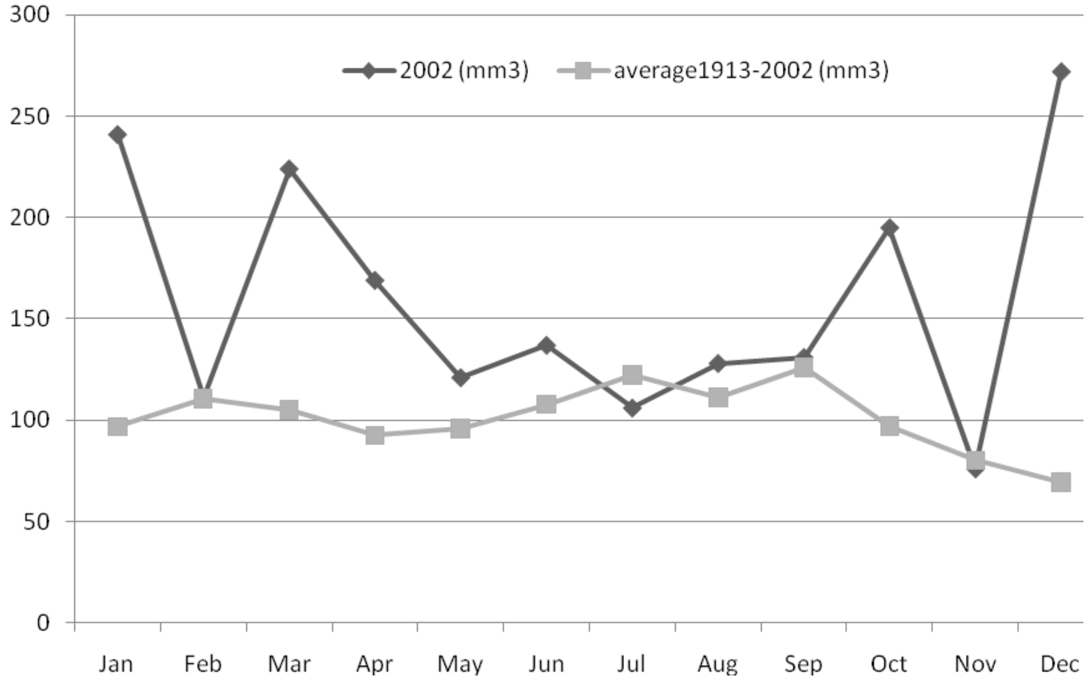

Figure 2. Trends in rainfall (mm^3)observed during 2002 for the city of Rio Grande (Southern Brazil), compared to average values from 1913 to 2002.

Higher values of salinity were observed in summer (February= 30.2±0.39), despite of a striking reduction of values in March (24.4±1.8), as a consequence of intense rainfall during this month. Salinity tended to decrease towards winter when lowest value were recorded (September= 19.07±5.37). After winter, salinity increased again towards December (23.1±5.83), when another reduction, associated to high rainfall, was noticed (Figures 2, 3).

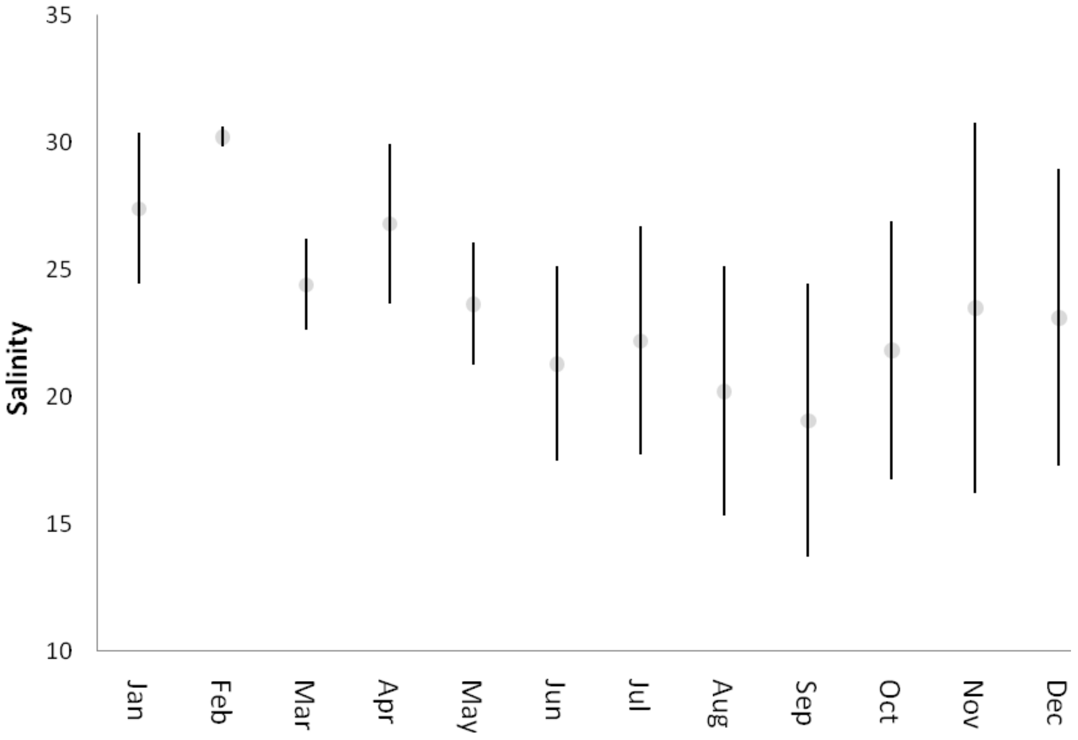

Figure 3. Trends in mean salinity in surrounding area of Barra do Rio Grande, Southern Brazil. Black dots represent mean values and vertical bars represent the range in sampled values.

As expected, temperatures were higher in summer (January= 25.64±0.78) and lower in winter (August= 13.7±0.6). From September (15.75±0.5) onwards, temperatures increased again and a stabilized between November (21.4±0.3) and December (21.4±05) (Figure 4).

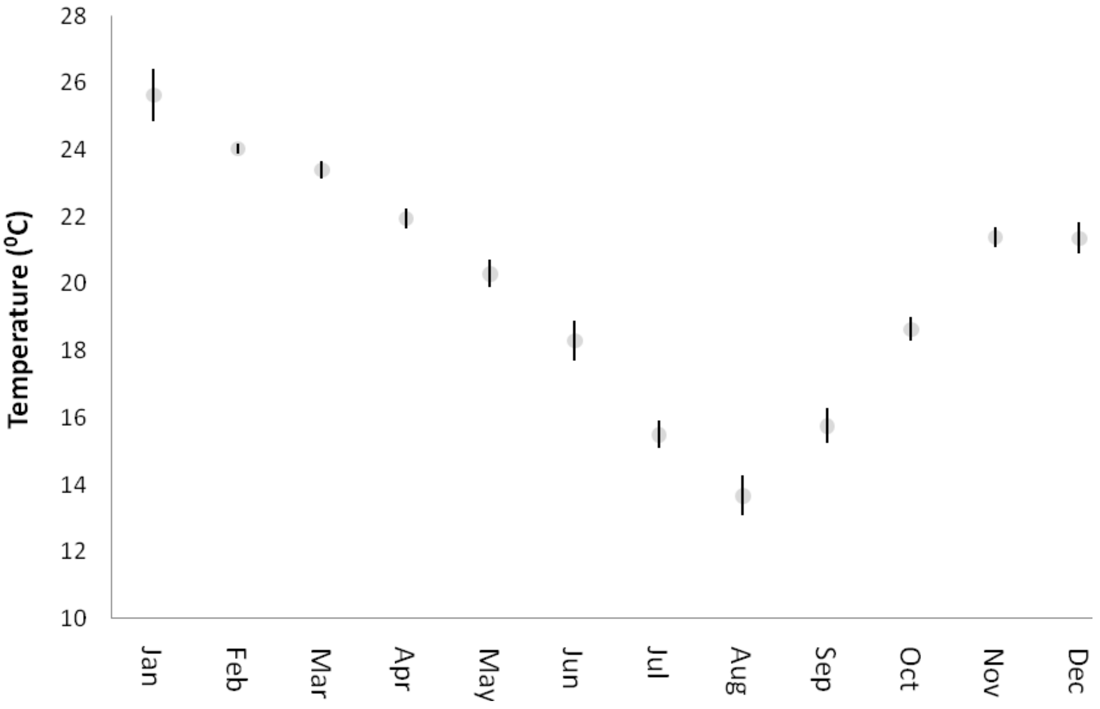

Figure 4. Trends in mean water temperature (^{0}C) in surrounding area of Barra do Rio Grande, southern Brazil. Black dots represent mean values and vertical bars represent the range in sampled values.

Seasonal reproductive dynamics and size at first maturity

A total of 2623 females was analyzed between January/2002 and January/2003 for reproductive pattern and size at first maturity estimates. Ripe, vitelogenic and adult females were recorded all year round, but mainly from July to October. Conversely, very low frequencies of ripe females were recorded in May and January/2002 (Figure 5, 6).

Three peaks of adult females and proportion o ripe ovaries were observed along the year (Figures 6, 7). Highest density of adult females took place in October, and during this month 38.86% of females presented ripe ovaries (Figure 5). In May, another important mean relative abundance of adult females was recorded (Figure 5). However, a very low proportion of females presented ripe ovaries during this month (Figure 4). In January, the smallest abundance peak of

A. longinaris females was observed, also with very low percentage of mature ovaries (Figures 5, 6).

Trends in relative abundance of recruits coincide with pattern estimated by ELEFAN II routine, which resulted in three peaks along the year (Figure 6). Recruitment peaks presented one month delay after maximum values of adult females and proportion of ripe females (Figures 5, 6, 7, 8). Main recruitment event takes place in November, as indicated by high percentage (Figure 7) and relative abundance (Figure 8) of individuals smaller than P_{50}. The other two recruitment events are less important in magnitude and took place in February and June (Figures 7, 8).

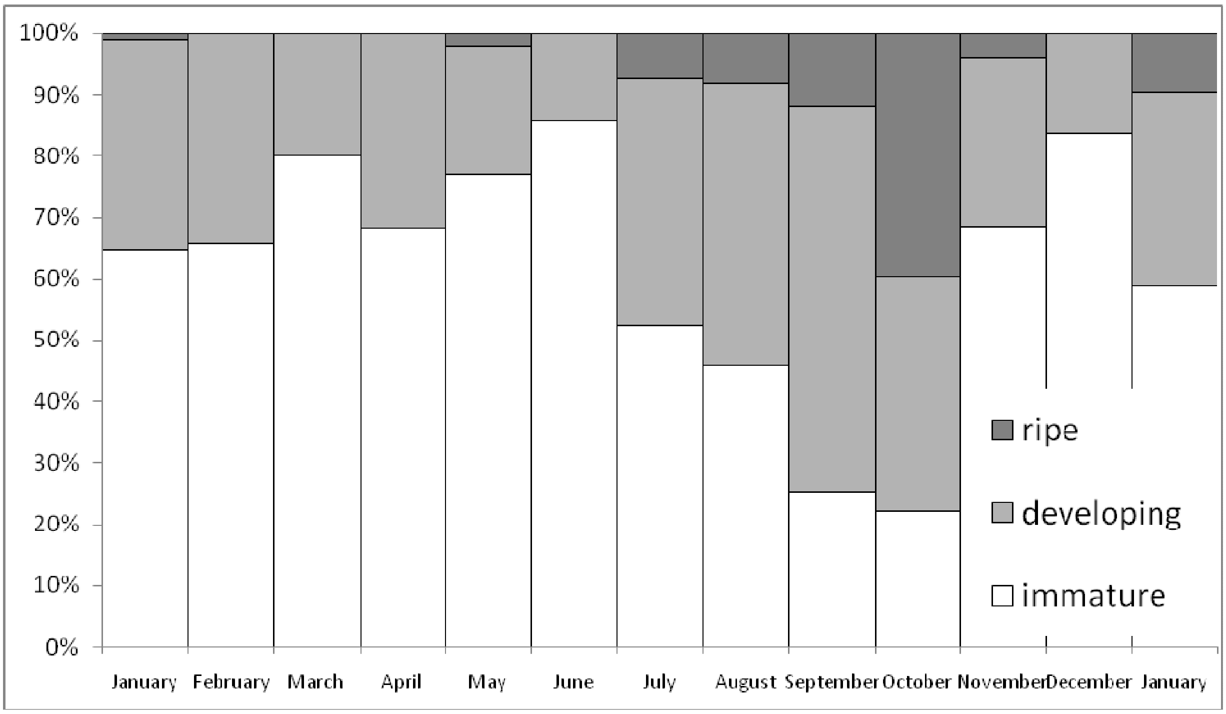

Figure 5. Frequency of immature, developing and ripe females of *A. longinaris* between January 2002 and January 2003.

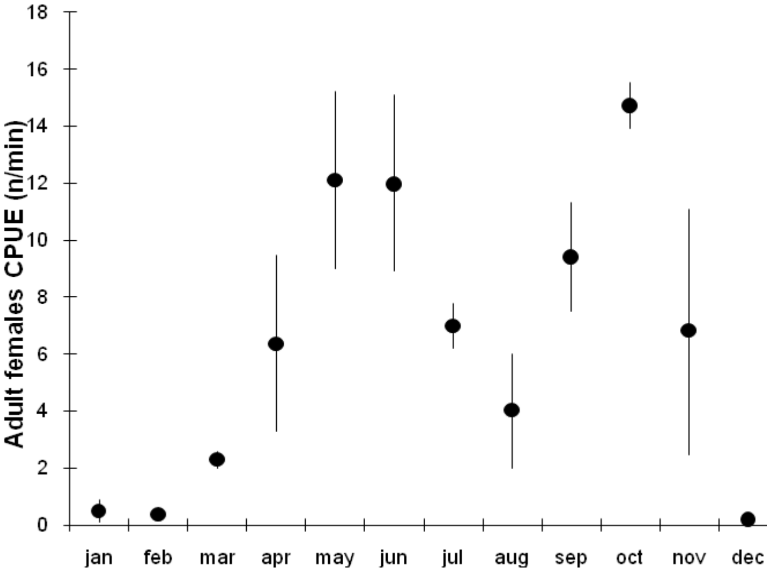

Figure 6. Monthly relative abundance (CPUE in numbers/minute) of *A. longinaris* adult females in Southern Brazil. Vertical bars represent standard deviation of means.

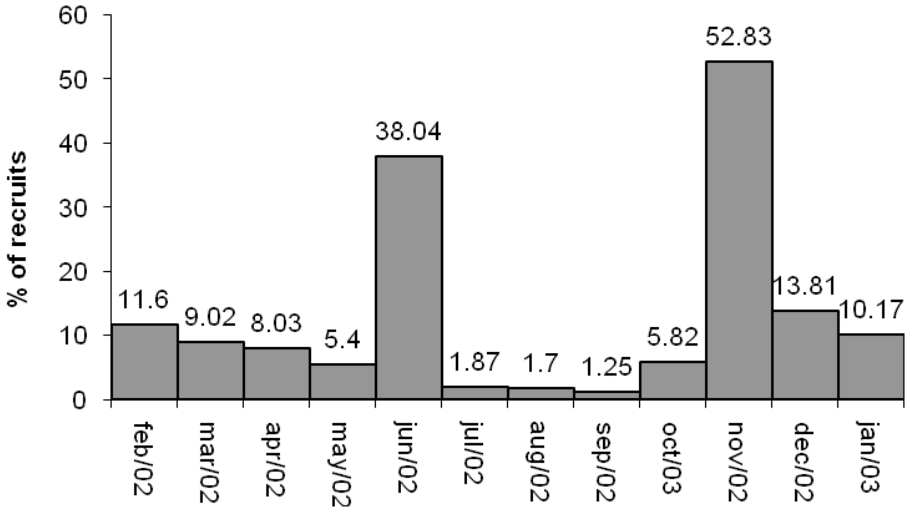

Figure 7. Monthly recruitment pattern estimated by ELEFAN II routine for *A. longinaris* females in Southern Brazil. Values above grey bars indicate frequency of recruits in samples.

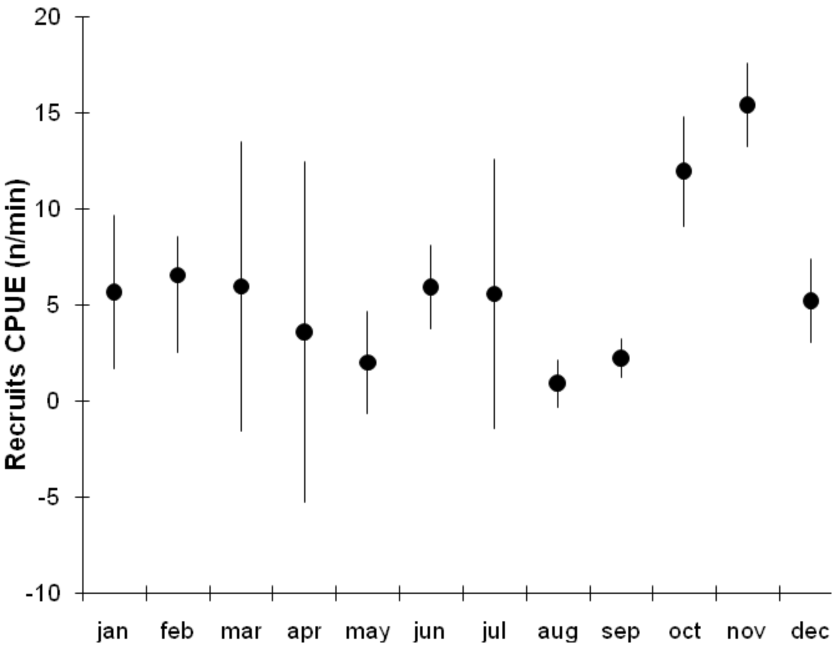

Figure 8. Monthly relative abundance (CPUE in numbers/minute) of *A. longinaris* recruits (females) in Southern Brazil. Vertical bars represent standard deviation of means.

Smallest ripe female measured was 13.3mm (CL) and the largest 30.49mm (CL). Estimated mean length at first maturity (LM) was 16.76mm (CL) (Figure 9, Table I) and based on length-age table, obtained from VBGM, the LM estimated corresponded to the age of approximately 4 months. The lenght at which 100% of females were mature was 25.0 mm (CL), corresponding to the age of 8 months (Figure 9).

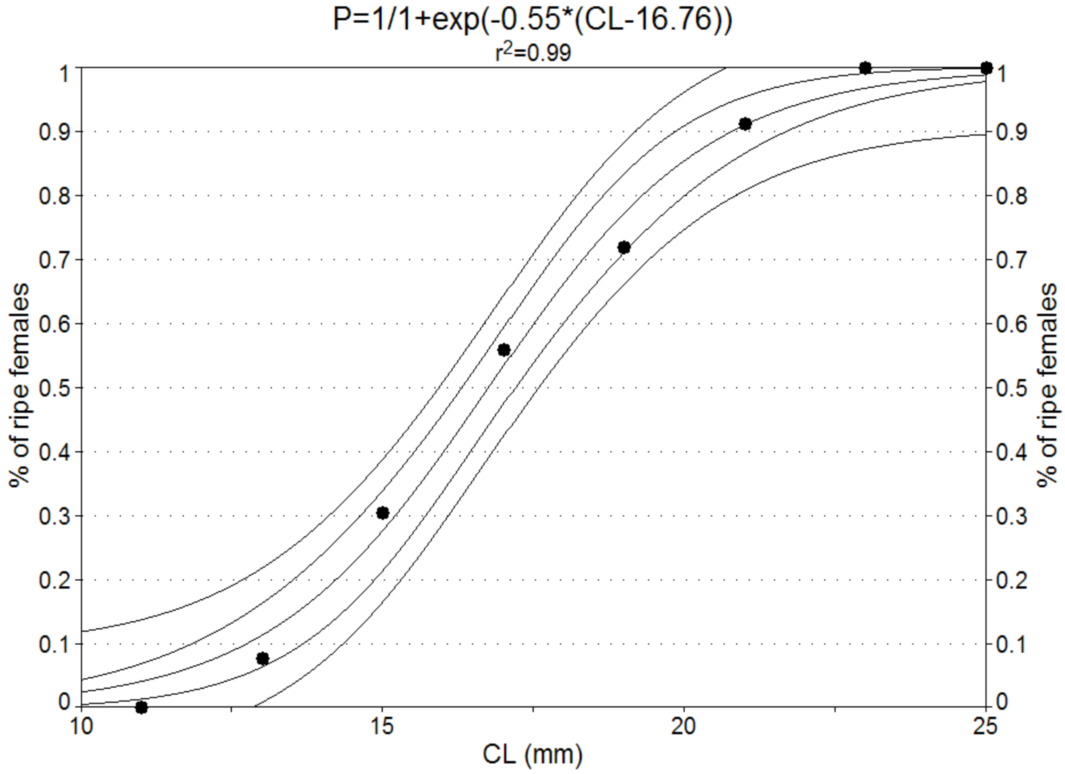

Figure 9. Logistic curve of ovary maturation for *A. longinaris*. Carapace length (CL mm) that corresponds to frequency of 50% is 16.76mm. Length at which 100% of females presented ripe ovaries is 25mm. External lines represent the confidence interval of estimate (95%) and internal bands the prediction interval (95%).

Table I. Summary of estimates obtained from least square procedure that fitted the frequency of *A. longinaris* ripe females to a logistic model, containing slope (r), length at first maturity (LM), t-values, confidence limits (CI95%) and p-values.

Parameter	value	CI (95%)		p
r	0.55	0.43	0.66	0.000
LM	16.76	16.33	17.19	0.000

Size frequency and VBGM analysis

Carapace lengths (CL) ranged from 3.1mm to 30.49mm and larger females were observed from winter to spring (July, August, September and October). During March (10.35mm), May (11.70mm), November (10.72mm) and December (10.81mm) lowest mean CL values were recorded (Figure 10).

Analysis of CL data showed that differential length distribution of females occurred in studied area. Statistical comparison of mean length between isobaths (5-15m and 16-20m) suggests that significantly larger females (p=0.0009) inhabited deeper grounds, in isobaths further than 15 meters (CL= 13.9 ± 3.94 mm). Conversely, smaller females (CL= 9.89 ± 3.71 mm) presented a preference for shallower waters near the beach (Table II).

Table II. Trends in length (CLmm) composition grouped in two categories, from 5-15 and 16 to 20 meters. Summary of *t* test results, including mean carapace length (CLmm), standard deviation of mean (std. dev.) and confidence intervals (95%). Test showed significant differences between groups (p=0.0009).

depth	n	CLmm	std. dev.	CI (95%)	
overall	1006	12.61	4.24	12.35	12.87
5-15	328	9.89	3.95	9.46	10.32
16-20	678	13.93	3.72	13.65	14.21

The VBGM parameters, estimated by a least square procedure, are summarized in Figure 8. Longevity estimated by using inverted VBGM was 17.7 months and is in agreement with modal progression analysis. Asymptotic length (LC_∞= 29.6mm) estimated was close to largest size observed in the wild (30.49mm) (Figure 11).

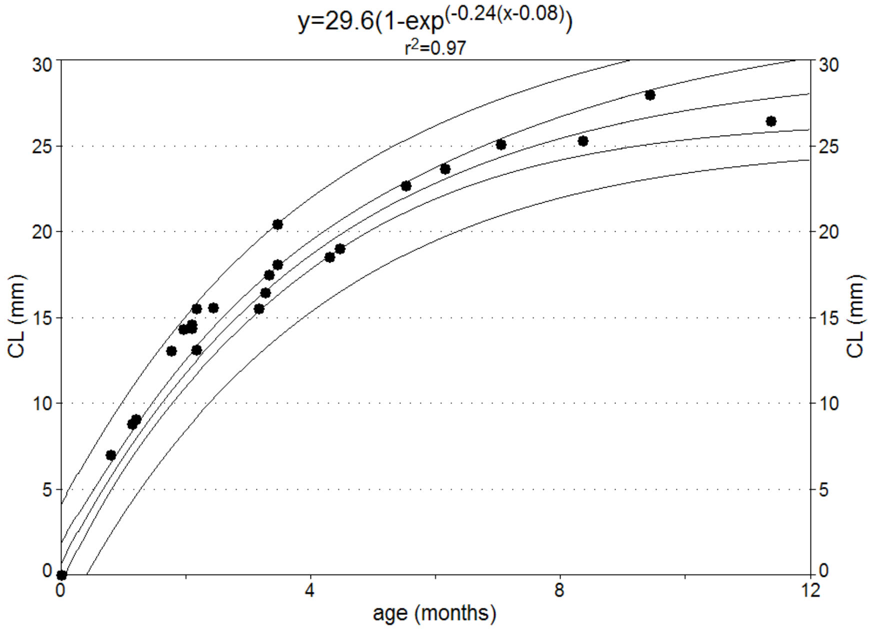

Figure 11. Growth curve estimated for *A. longinaris* females by using the VBGM, containing the following growth parameters: asymptotic length (CL_∞= 29.6 mm), coefficient of growth (k= 0.24 month^{-1}) and age at zero length (t_0= -0.08 month^{-1}).

Reproductive females observed during summer were likely hatched in previous spring and ranged from 4 to 6 months old. Autumn also presented a limited number of adult age classes (4 to 6 months old) as well as reduced frequency of ripe females and CPUE of adult females.

No recruitment peak was recorded during early winter months, despite of the presence of large (4 to 10 months old) and ripe females in the area. During late winter (September), a marked increase in recruitment density was observed, suggesting that spawning season starts during previous month with younger females. However, spawning reaches a maximum intensity in October when cohort hatched in previous spring reaches one year old. Late winter spawning is also confirmed by the presence of very small recruits in October, suggesting spawning activity during previous month. Nevertheless, spring presented highest relative abundance of adult females, percentage of ovary maturation as well as larger females contributing to recruitment (4 to 12 months) (Figure 10). The importance of recruitment originated from October spawning is confirmed by high abundance of recruits during the following month (November), especially in class interval of 7mm (CL) or the equivalent age of approximately 1 month (Figure 10).

In October, the highest CL mean value was verified, even with significant frequency of juveniles in length classes between 4 and 15 millimeters. The smaller (CL= 4mm) were probably hatched in October and the largest (CL= 15mm) in August. A marked decrease in mean CL was observed in November. This reduction in mean CL is explained by high frequency of small individuals (peak at 7mm), originated from October spawning (Figure 10).

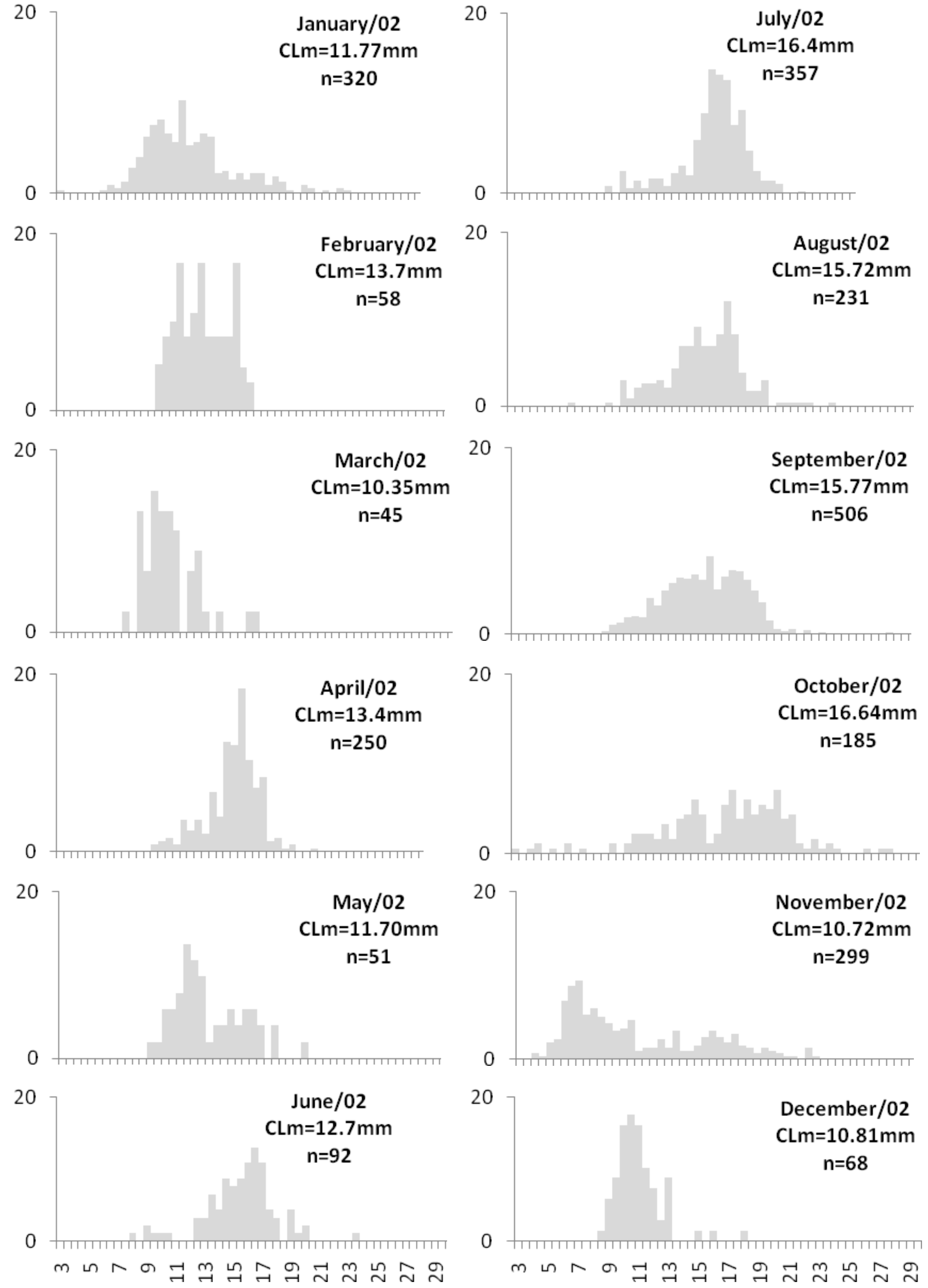

Figure 10. Monthly variation in size structure (carapace length-CL) of females, containing number of individuals measured (n) and mean carapace length (CL_m).

Stock-recruitment relationships (SRR) and multiple linear regression

A total of 8699 female prawns were used for stock-recruitment analysis. Significant differences (p= 0.01 and p=0.04) in mean salinity and amount of rainfall during the spawning season between good (mean salinity= 28.9 ± 3.3 and total rainfall= 487±55 mm^3) and bad years (mean salinity=23.3 ± 6.9 and total rainfall= 577 ±14.88mm^3) were observed. Thus, these results provided the first insight on environment factors influencing reproductive success of *A. longinaris* in Southern Brazil.

Among three stock-recruitment models tested, only the Beverton & Holt showed significant fit under overall, bad and good environment conditions. However, all three models presented significant fit for bad environment conditions, suggesting that the spawning biomass is even more important when the environment conditions are adverse (Table III).

Table III. Statistic summary of *A. longinaris* stock-recruitment data fitted to the models, containing the estimated parameters with standard deviations (within brackets) and coefficient of determination (R^2). Significant adjusts are indicated by * and non significant by ns. Overall p-values (p(ov)) are also provided. B&H= Beverton and Holt model, OV= overall, GE= good environment and BE= bad environment.

	a	**b**	**K**	**R^2**	**p (ov)**
Ricker (OV)	16.1(6.37)*	0.01 (0.004)*	-	0.44	0.03
Ricker (GE)	19.9 (8.13)^{ns}	0.01 (0.004)^{ns}	-	0.54	0.15
Ricker (BE)	10.4 (2.31)*	0.01 (0.003)*	-	0.95	0.01
B & H (OV)	0.026 (0.02)^{ns*}	0.002 (0.0006)*	-	0.48	0.02
B & H (GE)	0.005 (0.002)^{ns}	0.002(0.00008)*	-	0.98	0.001
B & H (BE)	0.07(0.03)*	0.003(0.0005)*	-	0.91	0.002
Shepherd (OV)	7.99(16.9)^{ns}	0.97(5.7)^{ns}	74.3(933)^{ns}	0.20	0.45
Shepherd (GE)	19.99(40.1)^{ns}	0.93(3.0)^{ns}	33.2(353)^{ns}	0.30	0.41
Shepherd (BE)	9.0(4.6)*	1.49(0.24)*	74.6 (29.8)*	0.95	0.01

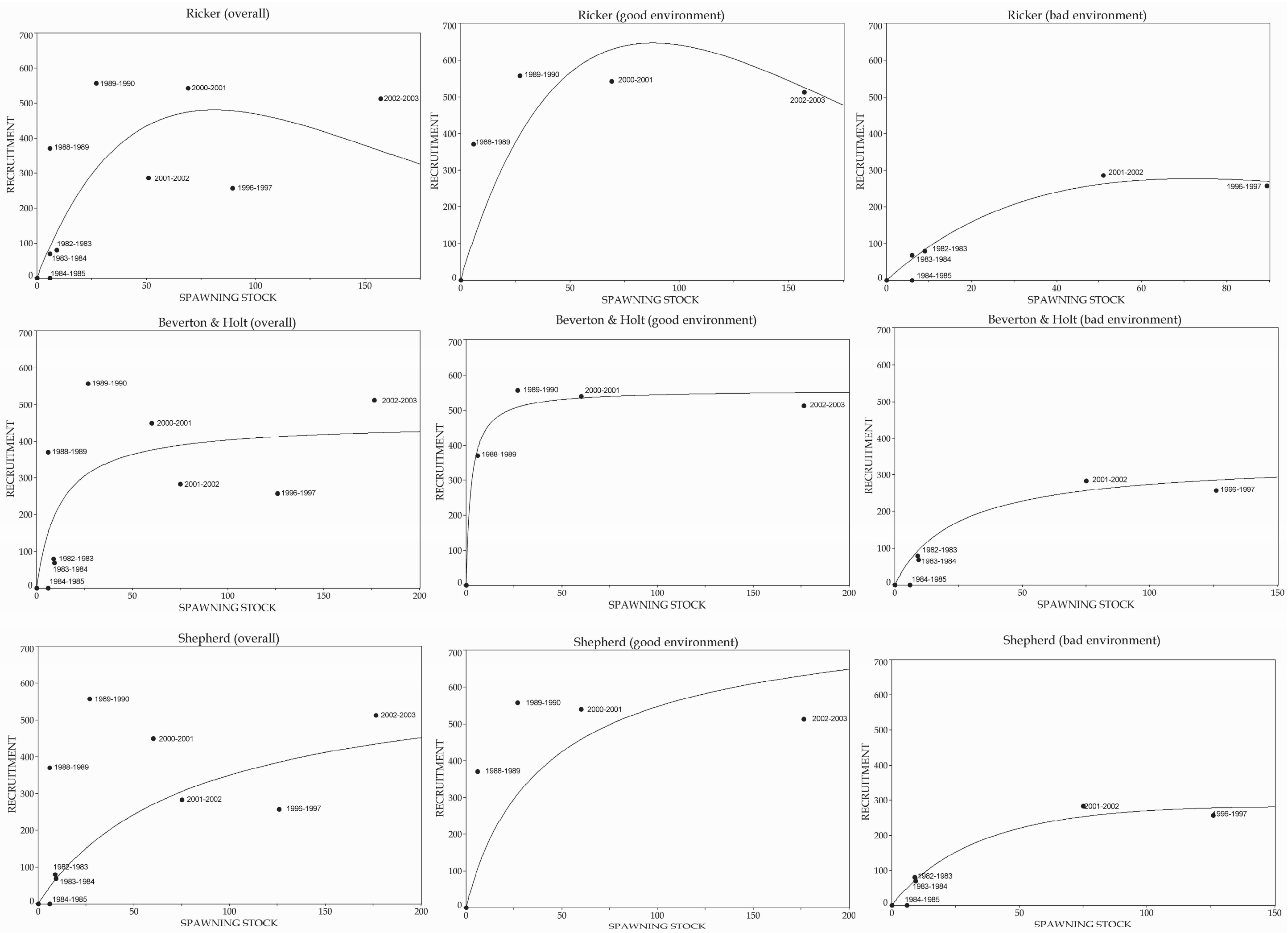

Figure 8. Different stock-recruitment models fitted to *A. longinaris* spawning-stock and recruitment biomass, for overall, good and bad environment conditions.

Results obtained from overall multiple linear regression suggested that main factors influencing recruitment of *A. longinaris* in southern Brazil are salinity in spring (B= 0.96; p= 0.05) and rainfall during recruitment (B= -3.29; p= 0.05), which indirectly results in lower salinity during recruitment. When the favorable environment years were analyzed separately, main factor affecting recruitment was salinity during spawning season (B= 0.99; p= 0.00). During adverse environment years the main factor regulating recruitment biomass was the abundance of spawning stock (B= 1.01; p= 0.03). Total amount of rain in spawning year was not included in the model, since no significant p-value was obtained. Significant p-values were considered as those lower than 0.05 and only factors included within this range were considered in regression equation (Table IV).

Table VI. Summary of multiple regression analysis estimated for *A. longinaris* in Southern Brazil, containing. Three different models were obtained and significant p-values included are *highlighted*. SALS= salinity during spring (spawning season), RRC= rain during recruitment to commercial fishery, TRAIN= total rain during the spawning year and SS= spawning stock biomass.

			overall				
	Beta	Std. Err.	B	Std. Err.	t	p	R^2_{adj}
SALS	0.96	0.41	12.29	5.23	2.35	*0.05*	0.90
RRC	-3.29	1.41	-1.25	0.53	-2.34	*0.05*	
TRAIN	3.15	1.69	0.75	0.40	1.87	0.10	
			bad years				
SS	1.01	0.18	3.13	0.55	5.72	*0.03*	0.88
TRAIN	0.24	0.18	0.12	0.08	1.39	0.30	
			good years				
SALS	0.99	0.10	15.92	1.54	10.32	*0.00*	0.88

DISCUSSION

Seasonal reproductive dynamics and size at first maturity

Artemesia longinaris clearly shows a year round spawning pattern, with main peak taking place in early spring (October). Preparation for main spawning event starts in winter, when increasing frequency of developing and ripe females were observed in surrounding area of Patos Lagoon Estuary. Furthermore, larger females, hatched during previous spring (12 months) participate in this reproductive event, which also increases the chances of successful recruitment (Vance et al., 1998).

Penaeid prawns usually present strong relationship between fecundity and size (Penn, 1980). For instance, reared individuals of *A. longinaris* weighting 5g produce more than 78000 eggs. Conversely, a female weighting 2g produces only 1150 eggs (Scelzo, 1991). Therefore, the presence of larger, as well as greater abundance of ripe females during October, explains the higher success of coohort hatched during spring.

The two other reproductive events, in autumn and summer, are clearly less important for population renewal and seem more variable in intensity and time (Calazans, 2002; Ruffino and Castello, 1992). Calazans (2002) reported autumn and spring as the seasons that concentrate similar high densities of *A. longinaris* post-larvae. Conversely, during studied year, a much lower frequency and abundance of large and ripe females was recorded during autumn. Smaller females, hatched in summer and spring participate in this event, which was evidenced by size frequency and growth analysis. As stated by several authors (Gulland & Rotschild, 1981; Vance et al., 1998) penaeid prawns inhabiting tropical and sub-tropical regions usually present two recruitment peaks, one in spring and a secondary in autumn, always connected to phytoplankton blooms. However, a marked interannual variation in strenght, area and time of secondary reproductive events is very often observed in prawn populations and is usually explained by unfavorable environment conditions (Vance *et al*., 1998).

It is important to stress out that during autumn/2002 and winter/2002, the Southern Brazilian coast was under the influence of El Niño Southern Oscillation (ENSO) (Wolter and Timlin, 1993, 1998), increasing rainfall and consequently reducing salt concentration in surrounding area of Patos Lagoon Estuary (Garcia *et al*., 1996). Dumont (2005), observed that *A. longinaris* tends to avoid lower salinity areas, under the influence of freshwater outflow from Patos Lagoon, which may have caused recruitment failure during this period.

The summer reproductive event is recognized as the less important for population replenishing, since very low densities of post-larvae (Calazans, 2002), adult and ripe females are reported. Females participating in this event are younger and originated from spring spawning (4 to 6 months) reaching final maturation during summer. Higher water temperature seems to have a negative effect on summer reproduction. Growth of *A. longinaris* reared at 26 ºC is very low and mortality rate is high (89%), suggesting that this temperature is close to lethal for this species (Haran *et al*., 1992). During summer, mean water temperature reached 25.64 ºC, approaching to lethal value reported for this species (Haran *et al*., 1992). Therefore, reproduction of *A. longinaris* in the coast of Rio Grande do Sul seems to be constrained during summer, since under relatively high temperatures larval production and survival of cohort hatched in this period is reduced (Haran *et al*., 1992).

Previous investigation performed in argentinean coast concluded that reproductive activity is closely related to water temperature (Petriella & Bridi, 1992, Castillo et al., 2007). These investigations stress that ovary development is interrupted in autumn, synchronized with decreasing temperature. Spawning in Argentina is observed again only in December, when water temperature achieves 17^0C (Petriella & Bridi, 1992). Therefore, population of *A. longinaris* inhabiting Southern Brazil presents an extended reproductive season, which is linked to the latitude and consequently the temperature regime of the region. Several penaeid prawn species distributed in higher latitudes tend to present well defined reproductive seasons, reduced to few months (Dall *et al*., 1990). Conversely, those species that live in warmer latitudes tend to present ripe ovaries and spawning activity all year round (Gulland and Rotschild, 1981; Buckworth, 1985; Crocos, 1987).Briefly, reproductive cycle of *A. longinaris* coincides with pattern suggested to other penaeid prawns, presenting a more stable spawning season in spring and secondary events more susceptible to environment variation (Vance *et al*., 1998).

Besides the influence in time and range of reproductive cicle, temperature also plays an important role on size at first maturity, in such a way that populations distributed in higher latitudes have later gonadal development and therefore reach larger LM (Courtney & Massel, 1997). Comparison of mean length at first maturity of population inhabiting Southern Brazil to investigations performed in northern and southern limits of distribution confirms this pattern. The LM estimated for population inhabiting 23^0S was 13.6mm (CL), while the estimate for southern limit ($37^0$59'S) was 22.1mm (CL) (Castillo et al., 2007). In fact, prawn populations inhabiting higher latitudes tend to present slower growth rates and consequently delaying size at first maturity (Gulland & Rotschild, 1981).

Differential length composition by depth, suggests a reproductive migration of this species to deeper waters. Thus, is likely that females move away from shallow waters to deeper fishing grounds (16-20m) to complete ovary maturation (Boschi, 1969), avoiding areas under the influence of estuarine outflow (Dumont, 2005). Spawning seems to occur in similar depths, since highest larval abundance was observed between 10 e 30 isobaths, decreasing from 30 to 60m (Calazans, 2002).

Displacement of adult females to deeper waters was also observed in Argentina. During main reproductive season (summer) there is an absence of mature females in artisanal fishing grounds (0-10 meters), suggesting a reproductive movement to further out depths (Boschi, 1969; Castillo et al. 2007). Reproductive migrations were verified for several penaeid prawns and as a general rule, juvenile prawns move away from shallow to spawning grounds in deeper oceanic waters where salinity tends to be higher (Dall *et al.*, 1990).

Stock-recruitment and multiple regression analysis

Stock-recruitment analysis (SRR) showed considerable interannual variations, which are not connected to any obvious trends in spawning stock biomass. It is quite clear that whatever the relationship between spawning stock and recruitment biomass, it is also influenced by environment factors. Therefore, it is convenient to describe stock-recruitment relationship by a family of curves, each corresponding to an environment condition (Gulland & Rotschild, 1981). In the present paper we suggest the use of two different groups of SRR, one for favorable environment conditions (*good year*), with higher recruit biomass ratio and another curve for lower recruitment ratio (*bad year*). Visual classification of spawning/recruit data was supported by significant differences in salinity during spawning season, in such a way that *good years* presented higher salinity and reduced rainfall. Salinity has been reported as the main factor influencing the recruitment success of penaeid prawns (Garcia, 1981) and it is especially true for penaeid species that do not tolerate low salt concentrations, where life cycle does not depend on an estuarine life stage (Anger, 2003).

Changes in salinity can affect feeding activity as well as growth of crustaceans, altering metabolic pathways and developmental processes (Dall et al., 1990). This becomes especially conspicuous on yolk utilization during embryonic development, which may eventually cause significant intraspecific variation in the size and biomass of late eggs and early larvae (Giménez & Anger, 2001). Such mechanisms should therefore, affect viability and, in particular, the nutritional vulnerability of planktotrophic larvae, thus playing a significant role for chance of larval survival in species living under variable salinity regimes (Giménez, 2002; Giménez and Anger, 2003).

Concern was expressed that management decisions in the past had mostly been made on the basis that recruitment numbers are independent of parental stock abundance at levels of exploitations being experienced, in such a way that only environment aspects regulate the recruitment success (Gulland and Rotschild, 1981). However, this statement may not hold true for all prawn fisheries (D'Incao et al., 2002), since high exploitation rates combined with unfavorable environment conditions can cause dangerous reductions in spawning biomass. This is clearly true for *A. longinaris*, since highly significant fits to SRR models were observed under bad environment conditions.

The Beverton and Holt model showed the best fit to spawning and recruitment biomass and as previously stated describes a relationship where an asymptotic density of spawning biomass is achieved, stabilized by density-dependent factors. The best fit of Beverton & Holt model to prawn data was also observed in other prawn fisheries worldwide (*e.g.* Cheng, 1981), agreeing with results obtained in this investigation. Despite of problems reported for stock-recruitment relationships, this model can be used to detect recruitment overfishing, especially under very low spawning biomass levels, as well as to understand the resilience of studied population (Maury, 1996).

The preliminary predictive model developed permits to conclude that salinity at spawning season and rain at recruitment explain 90% of recruitment success of *A. longinaris* in surrounding area of Patos Lagoon when all years are pooled together. Salinity is widely known as a limiting factor for penaeid prawn reproduction and most of species depend on higher salinity to maturate the ovaries (Dall *et al*., 1990). The amount of rainfall during recruitment season is clearly linked to reductions in salinity of studied area (Garcia, 1996), resulting in a negative effect on cohort survival. Since in this group, most metabolic and physiological processes (*e.g.* reproduction) require a stable osmotic and ionic environment, salinity is generally considered an ecological key factor in coastal and estuarine areas (Anger, 2003).

The negative effect of brackish water on euryaline coastal species, such as *A. longinaris*, is that under suboptimal salinity concentration the energetic requirements are increased due to hyper-osmoregulation (Kinne, 1971). Allocation of the energy initially designated to reproduction is diverted to osmotic regulation and may inhibit ovary maturation of prawns, since it is a high energy demanding process (Dall *et al.*, 1990).

Suboptimal salt concentrations also play a negative role on decapod crustaceans larvae. Brackish water can slow down the molt interval and reduce growth, delaying larval development (Anger, 2003). Even a slight delay in larval development may further reduce the chance of survival in plankton where slowly developing larvae are exposed for longer period to potentially harmful factors, such as physical stress, food limitation and pelagic predation (Lalli and Parsons, 2006).

Results obtained from *bad year* regression reinforce those estimated through SSR. As previously mentioned, dangerous spawning biomass levels can be achieved under unfavorable environment conditions, and preservation of biomass during these periods is vital to keep the stock healthy. Conversely, salinity is the main factor during those years considered as favorable. Even under low spawning biomass, the high fecundity (Scelzo, 1991), growth rate (Ruffino and Castello, 1992) and continuous spawning along the year allow recruitment success for this species.

Results obtained from multiple regressions must be carefully interpreted and only provide a preliminary idea about main factors affecting SRR, since a reduced number of seasons were analyzed. Therefore, further investigation must be developed using more variables and a greater number of years to identify new environment factors causing trends in stock biomass. Nevertheless, results obtained in this investigation confirm salinity as key factor for reproductive success of *A. longinaris* in surrounding area of Patos Lagoon.

Once reproductive seasons analyzed in present investigation showed marked differences in terms of importance to population replenishing, future analysis can be refined assuming heterogenic reproductive performances along the year and differential depth distribution according to size. The evident susceptibility to environment factors and high natural mortality rates (Ruffino and Castello, 1992) combined with excessive fishing effort may cause a serious damage to the stock of *A. longinaris* in southern Brazil.

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Running title: Bycatch of *A. longinaris* in Southern Brazil

Bycatch analysis of Argentinean prawn *Artemesia longinaris* (DECAPODA:PENAEIDAE) in surrounding area of Patos Lagoon, Southern Brazil: effects of different rainfall

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ABSTRACT

One of the most problematic fishing methods in terms of by-catch and discarding is the prawn-trawling, with numerous studies having identified and quantified the types and levels of by-catch in several fisheries. This paper analyses the incidental catch of artisanal trawl fleet during two discrete *Artemesia longinaris* fishery seasons (2002 and 2004). The subject of this paper was suggested by the local artisanal fishermen, during a F.L.P. (Lagoa dos Patos Forum) meeting, in attempt to evaluate the impacts of trawl nets on bycatch species and provide base knowledge to permit a future legal exploration of this resource. Fishing took place in the Barra do Rio Grande surrounding area on monthly basis. Sampling was carried out during the fishing season (April - December) always on the same artisanal trawl boat. An observer was included on board to avoid lost of information due to discards made by the fishermen at sea. Fifty species were caught, being 38 fishes and 12 crustaceans. Discrete fauna abundance and composition were recorded in analyzed years, with higher bycatch ratio associated to elevated rainfall and low salinity. The overall discard ratio was 1:5.6, with values ranging from 1:11.3 in 2002 to 1:2.5 in 2004. Most striking differences between both years analyzed were observed during autumn (1:75 in 2002 and 1:11.30 in 2004) and winter (1:16 in 2002 and 1:0.97 in 2004), while spring presented more similar values (1:8 in 2002 and 1:4 in 2004). The discard ratio estimated in terms of number showed a different pattern, presenting overall values of 1:2.24 in 2002 and 1:0.5 in 2004. Higher estuarine runoff increased biomass production in surrounding area of Patos Lagoon during 2002, sustaining higher abundance of estuarine related and marine species in the area, as well as higher mean trophic level and abundance of top-predators. Conversely, *A. longinaris* production was consistently lower, since this marine species do not tolerate marked reductions in salinity. In 2004, salinity was higher, associated to low rainfall and favoring *A. longinaris* abundance in the area. During this dry year, the species was dominant in samples resulting in very low

bycatch ratios, especially in winter (1:0.97). Catch was composed mainly by juvenile fishes, since fishery is performed in nursery grounds. Fishing effort is low and depends on the density of prawns as well as on the weather conditions. Assuming that artisanal fishermen will trawl for *A. longinaris* in surrounding area of Patos Lagoon only when this resource is abundant, the most indicated fishery season is the winter. Conversely, if trawling for prawns is allowed during wet years, the mortality of juvenile fish and crustaceans will be elevated, killing unmarketable fish that are discarded dead back to the sea.

INTRODUCTION

Penaeid prawns are highly prized seafood harvested from coastal tropical and subtropical waters throughout the world (Gulland & Rotschild, 1981), accounting for 20% of internationally traded fishery products (FAO, 2007). One of the most common problems related to prawn trawling is the associated discard, with numerous studies having identified and quantified the types and levels of bycatch in several fisheries worldwide (Gulland & Rotschild, 1981; Alverson et al., 1994; Hall, 1999; EJF, 2003; Eyars, 2007). Damage caused by prawn trawling has been previously compared to clear-cutting forests, disrupting trophic interactions and reducing diversity in marine environment (EJF, 2003). However, unlike deforestation, the impacts of prawn fisheries are only beginning to receive international attention (Eayrs, 2007), and the use of satellite images has developed the scale of disturbance caused by prawn-trawling (Van Houtan and Pauly, 2007).

Artemesia longinaris Bate, 1888 is a penaeid prawn, commercially exploited along its distribution area, being used for human feeding as well as bait in recreational fishery (Boschi, 1969). In Southern Brazil the species is also target of an artisanal fishery that operates with two different fishing gears, the stationary and trawl nets. The former fishing gear is used by fishermen in shallow waters (1-2 meters) along the shore line of Rio Grande do Sul State. The artisanal trawl fishery is restricted to the surrounding area of Barra de Rio Grande (Rio

Grande do Sul, Brazil), being performed in shallow waters (2-15 meters) close to the beach. This depth limitation is due to small size of wooden boats and the fact that the fleet is not equipped with mechanical tows, which would allow deeper trawling (Dumont, *personal observation*).

The incidental catch of argentinean prawn in Southern Brazil region was previously investigated by Ruffino & Castello (1993) and by Haimovici & Mendonça (1996a,b). The former paper described the variation in bycatch composition during trawls performed on board of a research vessel (Lancha Oceanográfica Larus – LOc. Larus), while the second paper analyzed the bycatch from double-rig commercial fleet. However, the incidental catch originated from artisanal prawn trawling, targeting mainly the argentinean prawn (*Artemesia longinaris*), but also the red prawn (*Pleoticus muelleri*), in surrounding area of Patos Lagoon estuary has never been investigated. This fishery is performed in nursery as well as spawning areas for several fish (Vieira et al., 1998) and crustacean (D'Incao, 1999) species, demanding new information on the effects of trawling in the ecosystem.

Major problems related to bycatch are conflicts between fishermen catching juvenile fishes in shrimp trawl and fishermen targeting mature fishes that are bycatch in other fishery (Kennelly et al., 1998). Moreover, ecosystem simplification and trophic structure changes also play an important role on fishery management of prawns (Jones, 1992). Recently, much interest has been shown to ecosystem-based management, in attempt to evaluate the effects of fishing on the entire community and not only on the target species (Vasconcellos & Gasalla, 2001; Hall & Mainprize, 2005; Zeller & Pauly, 2005, Worm et al., 2006).

The eco-based management approach has shown that fishing effort required to keep target species biomass above the sustainable level is often higher than the value needed to maintain bycatch species in a sustainable level (Hall, 1999; EJF, 2003). It is more evident when considering prawn species, since they are thought to be resilient to fishing pressure, presenting high growth rate, egg production and short lifespan (Gulland & Rotschild, 1981; King, 1997). Thus, an important issue to manage a fishery ecologically is to obtain quantitative and qualitative description of the species caught incidentally (Hall, 1999). In this sense, this paper aims to analyze the incidental catch of artisanal trawling for *A. longinaris* in two discrete fishing seasons, comparing bycatch during a wet (2002) to a dry year (2004). The subject of this paper was suggested by the local artisanal fishermen, during a F.L.P. meeting (Fórum da Lagoa dos Patos, a co-management institution) (D´Incao & Reis, 2002), in attempt to evaluate the impacts of trawl nets on bycatch species and to provide base knowledge to permit a future legal exploration of this resource.

MATERIAL & METHODS

Study area

Surrounding area of Barra de Rio Grande is highly influenced by freshwater discharge from Patos Lagoon estuary (Ciotti et al., 1995). This estuary is located at costal plain of Rio Grande do Sul State, Brazil (32^0S, 490W) and is the largest choked lagoon in the world, encompassing an area of 10,360 km^2. Drainage basin covers an area of 201,626 km^2 (Asmus, 1996) and pluvial intensity as well as wind direction play an important role on water circulation. Seasonal freshwater discharge presents great variability (30,300 - 47 m3s^{-1}) and during El Niño Southern Oscillation events (ENSO) runoff is significantly higher than mean values estimated (Garcia, 1996) (Figure 1).

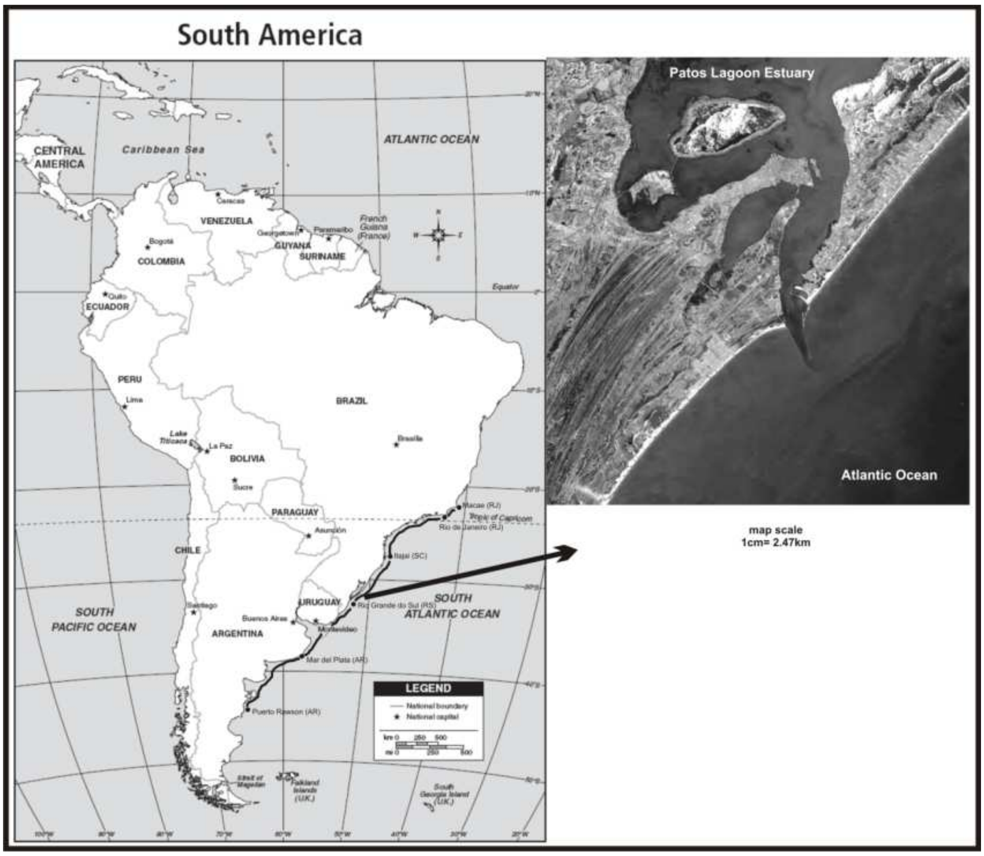

Figure 1. A-Southwestern Atlantic Ocean including distribution area of *A. longinaris*. B-Closer view of estuarine and surrounding area of Patos Lagoon, where sampling took place.

Field sampling and laboratory procedures

Fishing took place in surrounding area of Barra do Rio Grande on a monthly basis. Sampling was carried out during the fishing season (April - December) always onboard of the same artisanal trawl boat in two discrete years, 2002 and 2004. Boat chosen was a typical artisanal otter trawler, a wooden boat, 7.6 meters long, 2.20 meters wide with a 24 hp central engine. The net used was also typical of this fleet, with 16 mm mesh size (opposing knots). Tow time ranges from few minutes to 1 hour, but duration of most of trawls was approximately 30 minutes. A researcher was included on board to avoid loss of information due to discards made by the fishermen. After each fishing station, salinity and temperature of water were recorded using a thermosalinometer. Fishermen were not influenced by researchers to operate in a determined fishing site, neither to determine the duration of trawling, in order to describe the fishery bycatch as close as possible to the actual fishing activity. Samples from trawl net were taken to the laboratory for analysis, which included sorting fishes and crustaceans to species level as well as measuring both to the nearest 0.1 mm and weighting to the nearest 0.001g. Daily rainfall (mm^3) data was obtained from Estação Agrometeorológica da Universidade Federal de Pelotas.

Data analysis

Organisms were classified according to taxonomic and life history criteria. Life history classification was also performed to compare community composition during the analyzed years. Classification was based on Garcia et al. (2003):

-Marine: species that live in marine environment and do not depend on estuarine region neither for grow out nor reproduction;

-Estuarine dependent: species that live in marine environment but depend on estuarine region whether during grow out phase or reproduction;

-Estuarine resident: species that live inside the estuary but present a marine phase (e.g., for spawning).

To estimate discard ratios the method proposed by Andrew et al. (1995) was applied, where all catch values (in weight and number) of all the species were transformed in relative abundance values (CPUE), and a seasonal mean CPUE was calculated for each species. The effort unity adopted was 30 minutes of trawling. Overall discard ratio was obtained dividing the total amount of bycatch by the amount of target species in the year. Catch in numbers was only used to estimate total discard ratios and was seasonally analyzed.

Data were pooled by season, considering autumn (April, May, June), winter (July, August, September) and spring (October, November, December) as the fishery season. Normality and homogeneity of variance were tested prior to perform mean CPUE comparison (*t-test*) of estuarine related species (resident and dependent) between both years analyzed. Since normality was not attained, a Kruskall-Wallis test was performed to compare pairwise median CPUE's, but only mean and standard error values are presented in the text.

Ecological parameters

Number of species caught per season was analyzed and considered as a direct measure of richness. Species caught were also categorized according to trophic level, based on Vasconcelos & Gasalla (2001): herbivores, detritivores and omnivores (2-3); mid-level carnivores (3.1-3.7); and high-level carnivores and top predators (3.8-4.3). Weighted mean trophic level (TrLm) was estimated for each year analyzed, multiplying the relative abundance of each species by its trophic level and dividing for the total amount of catch obtained during this period (Milessi et al., 2005).

Catch probability and size composition of catches (P_{50})

Cumulative length frequencies of most important commercial fishes and crustaceans were fitted to a logistic model to estimate the length at which probability of catch is 50%

(P_{50}). The P_{50} obtained was compared to length at first maturity (LM) available in literature for these species, in attempt to evaluate possible effects of artisanal trawling on juvenile fishes and crustaceans, since an elevated capture of these organisms could lead to a growth overfishing of commercial bycatch species (EJF, 2003).

RESULTS

Environmental parameters

Anomalies in MEI rank (Wolter & Timlin, 1993, 1998) allowed the identification of discrete situations among studied years, since 2002 presented values above the neutral limit during approximately all fishing season (April-October). Conversely, 2004 was considered as a neutral to moderate ENSO year, presenting lower or threshold MEI rank values (NOAA, 2007).

As a likely consequence of a more intense ENSO, significantly higher rainfall ($p=0.001$) was observed during 2002 (monthly mean= 159.2 mm^3/day), exceeding by far the mean for 2004 (monthly mean = 80.7 mm^3/day) and the 1913-2006 average for the city of Rio Grande (monthly mean= 101.2 mm^3/day). Influence of freshwater discharge from Patos Lagoon Estuary on sampling area during 2002 is clearly marked, since salinity values were permanently lower, especially in winter (Figure 3).

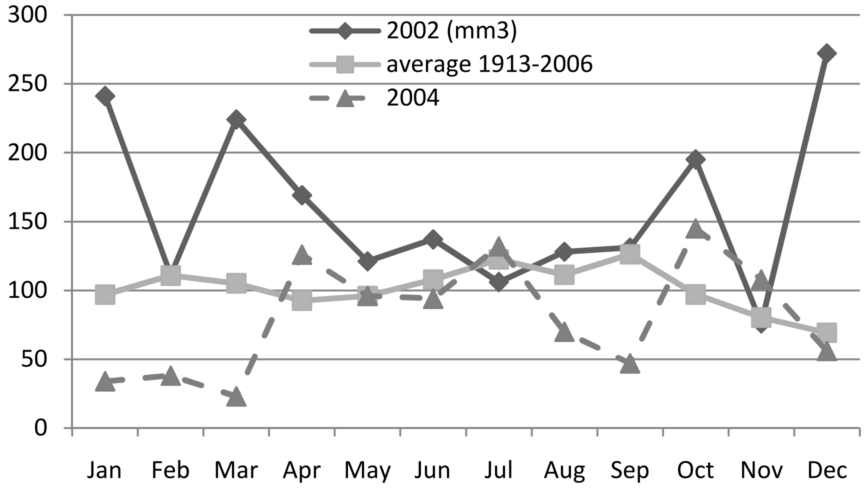

Figure 2. Monthly rainfall (mm^3) for the city of Rio Grande, RS, Brazil, containing the values recorded in 2002, 2004 and the mean values between 1913 and 2006.

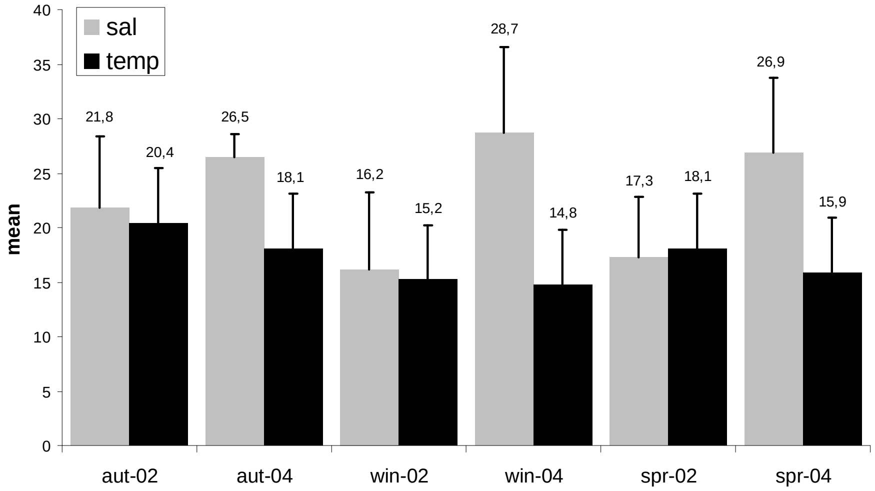

Figure 3. Seasonal variation of salinity and temperature in surrounding area of Patos lagoon for both years analyzed (2002-2004). Mean ± standard error are shown.

Discard composition and seasonal variation of catches

A total of 84 trawls was performed on board of the artisanal trawl fleet, resulting in 50 different species caught, being 38 species of fishes and 12 of crustaceans (Table I). A greater number of species was caught in autumn (2002= 25; 2004= 36) while the lowest values were obtained in winter (2002= 17; 2004= 22). Number of species caught in spring varied from 20 in the wet year (2002) to 27 in the dry year (2004).

The overall discard ratio estimated in weight was 1:5.3 (target species:bycatch) when both years were grouped. During wet fishery season (2002) discard ratio was 1:13, contrasting with 2004 when a much lower ratio (1:2.6) was recorded. Bycatch ratio was remarkably variable, presenting highest values during autumn (2002= 1:74; 2004= 1:11.3), while most striking difference was recorded in winter, when the lowest discard was recorded (2002= 1:10.85 and 2004= 1:0.97). Spring presented most similar values when the two years were compared (2002= 1:7.94; 2004= 1:3.33) (Figure 4). The overall discard ratio estimated in terms of number was 1:1.3, ranging from 1:2.24 in 2002 to 1:0.5 in 2004.

Crustaceans accounted for approximately 17% of incidental catch and the blue crab *C. sapidus* was the third most abundant species in the catches (8% of total discard). Five species comprised 50% of the bycatch, as follows: banded croaker (*P. brasiliensis*= 18%), followed by salmon sea catfish (*G. barbus*= 14.22%), the blue crab (*C. sapidus*= 8.19%), the withemouth croaker (*M. furnieri*= 8%) and the cangoá (*S. brasiliensis*= 7%).

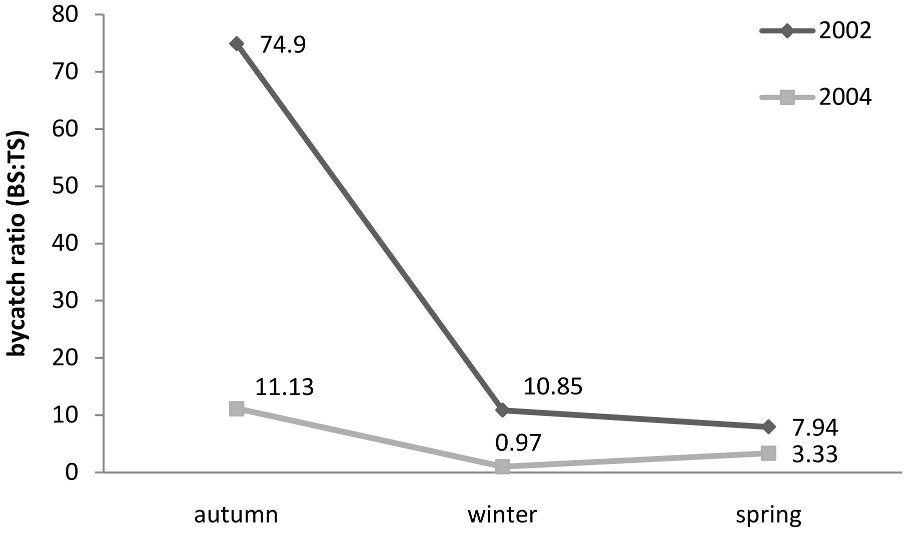

Figure 4. Seasonal trends in discard ratio in weight (bycatch (BS):target species (TS)) from artisanal trawling for marine prawns in surrounding area of Patos Lagoon (RS, Brazil) for both years analyzed (2002-2004).

Table I. List of species caught in trawling for marine prawns in surrounding area of Patos Lagoon, containing life history classification (marine, estuarine dependent and estuarine resident) and trophic level suggested (Vasconcellos & Gasalla, 2001).

Species	Life history	Trophic level
Anchoa marinii Hildebrand, 1943 (Anchovy)	marine	3
Arenaeus cribarius Lamarck, 1818 (Spotted crab)	marine	2.6
Artemesia longinaris Bate, 1888 (Argentinean prawn)	marine	2.3
Balistes capriscus Gmelin, 1789 (Gray triggerfish)	marine	3.4
Brevoortia pectinata Jenyns, 1842 (Menhaden)	estuarine dependent	3.2
Callinectes danae Smith, 1869 (Blue crab)	estuarine dependent	2.6
Callinectes ornatus Ordway, 1863 (Blue crab)	marine	2.6
Callinectes sapidus Rathbun, 1895 (Blue crab)	estuarine resident	2.6
Catathyridium garmani (Jordan & Gloss, 1889) (Sole)	marine	3.5
Chloroscombrus chrysurus Linnaeus, 1776 (Atlantic bumper)	marine	3.5
Conodon nobilis (Linnaeus, 1758) (Barred grunt)	marine	3.5
Cynoscion guatucupa (Cuvier, 1819) (Weakfish)	marine	4
Eucinostomus argenteus Baird and Girard, 1855 (Silver mojarra)	marine	3.5
Exhippolysmata oplophoroides (Holthuis, 1948) (Shrimp)	marine	2.3
Farfantepenaeus paulensis (Perez-Farfante, 1967) (Pink prawn)	estuarine dependent	2.3
Genidens genidens (Valenciennes, 1839) (Sea catfish)	estuarine resident	3.5
Genidens planifrons Higuchi, Reis & Araujo, 1982 (Sea catfish)	estuarine dependent	3.5
Hepatus pudibundus (Herbst, 1785) (Crab)	marine	2.6
Lagocephalus laevigatus (Linnaeus, 1766) (Smooth puffer)	marine	3.5
Libinia spinosa H. Milne Edwards, 1834 (Spiny crab)	marine	2.6
Litopenaeus schmitti (Burkenroad, 1936) (White prawn)	estuarine dependent	2.3
Loxopagurus loxochelis (Moreira, 1901) (Hermit crab)	marine	2.6
Lycengraulis grossidens Agassiz, 1829 (Toothed anchovy)	estuarine dependent	3
Macrodon ancylodon (Bloch & Schneider, 1801) (King weakfish)	marine	4.3
Menticirrhus americanus (Linnaeus, 1758) (Southern kingfish)	estuarine dependent	3.5
Menticirrhus litorallis (Holbrook, 1855) (Gulf kingfish)	marine	3.5
Micropogonias furnieri (Desmarest, 1823) (Whitemouth croaker)	estuarine dependent	3.5
Mugil platanus Gunther, 1880 (Mullet)	estuarine dependent	3.8
Genidens barbus (Lacepede, 1803) (Salmon sea catfish)	estuarine dependent	3.5
Paralichthys orbgnyanus (Valenciennes, 1839) (Flounder)	estuarine dependent	3.5
Paralonchurus brasiliensis (Steindachner, 1801) (Banded croaker)	marine	3.5
Peprilus paru (Linnaeus, 1758) (American harvestfish)	marine	3.5
Pleoticus muelleri (Bate, 1888) (Red shrimp)	marine	2.3
Pogonias cromis (Linnaeus, 1766) (Black drum)	marine	3.5
Pomatomus saltatrix (Linnaeus, 1766) (Bluefish)	estuarine dependent	4.2
Porichthys porosissimus (Valenciennes, 1837) (Midshipman)	marine	3.4
Portunus spinimanus (Latreille, 1819) (Crab)	marine	2.6
Prionotus punctatus (Bloch, 1797) (Bluewing searobin)	marine	3.5
Selene setappinis (Mitchill, 1815) (Atlantic moonfish)	estuarine dependent	3.3
Squatina argentina (Marini, 1930) (Skate)	marine	3.8
Squatina guggenhein Marini, 1936 (Skate)	marine	3.8
Stellifer brasiliensis (Schultz, 1945) (Cangoa)	estuarine dependent	3.3
Stellifer rastrifer (Jordan, 1889) (Rake stardrum)	estuarine dependent	3.3
Stephanolepis setifer (Bennett, 1830) (Pigmy filefish)	marine	3.4
Symphurus jenynsii Evermann & Kendall, 1907 (Tonguefish)	marine	3.5
Sympterigia acuta Garman, 1877 (Skate)	marine	3.8
Sympterigia bonapartii Muller and Henle, 1841 (Skate)	marine	3.8
Trachinotus carolinus (Pampo)	marine	3.3
Trachinotus marginatus Cuvier, 1832 (Stripped pampo)	marine	3.5
Urophycis brasiliensis (Kaup, 1858) (Squirrel hake)	marine	3.5

Relative abundance (g/30 min) and percentage of incidental catch was greatly influenced by estuarine dependent and estuarine resident species during 2002 (Figures 5, 6). The Kruskal-Wallis test performed to compare abundance of estuarine related species during both years analyzed, showed that CPUE of these species was significantly higher in the catches during the wet year (2002= 240±125; 2004= 37.55±31.45; p=0.03) as well as its relative frequency (Figure 5). Conversely, when the mean CPUE of marine species was compared between 2002 and 2004, a higher, but not significantly different, was observed in the dry year (2002= 140±136; 2004= 220.3±220; p=0.70), which was also confirmed by the relative frequency of this category (40% in 2002 and 49% in 2004) (Figure 5). This result suggests that the higher abundance of fishes in catch was mainly influenced by the elevated biomass of estuarine related species is surrounding area of Patos Lagoon mouth.

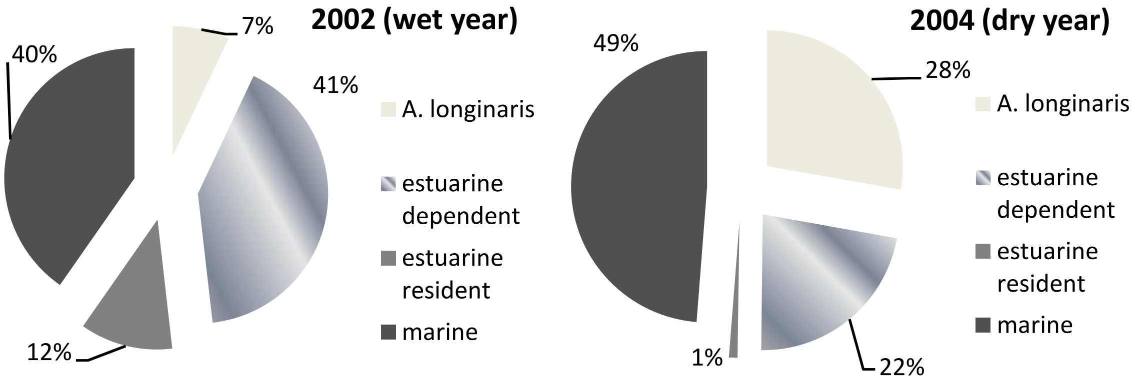

Figure 5. Relative frequency of species with three categories of life history caught in trawling for marine prawns in surrounding area of Patos Lagoon estuary (Rio Grande do Sul, Brazil).

Among the estuarine dependent fish species during autumn, the most abundant in weight were the sea catfish (*G. planifrons* 1,549±895), salmon sea catfish (*G. barbus* 930±747) and whitemouth croaker (*M. furnieri* 638±210). Estuarine resident species were mainly represented by the blue crab (*C. sapidus* 1,733±740), the second most abundant species in samples during autumn, after the banded croaker (*P. brasiliensis* 2,702±1,470), which is a marine species. The argentinean prawn (*A. longinaris*) showed very low abundance (152±47) and red prawn (*P. muelleri*) was not even collected during this period (Figure 6).

A similar scenario was observed in winter/2002. However, the cangoa (*S. brasiliensis* 3,312±2890), an estuarine dependent species, was the most abundant fish in surrounding area of Patos Lagoon, followed by salmon sea catfish (*G. barbus* 1,550±1,182) and whitemouth croaker (*M. furnieri* 803±561). The blue crab (*C. sapidus* 357±348) was the most abundant estuarine resident species, in spite of its reduced abundance when compared to the previous season. Banded croaker (*P. brasiliensis* 1,028± 267) showed a decreasing abundance during winter; but it was still the most abundant marine species. Relative abundance of *A. longinaris* (863±26) was even smaller during winter and *P. muelleri* (13±8) showed a slight increase in CPUE during this season (Figure 6).

Argentinean prawn (*A. longinaris* 1,420±931) and red prawn (*P. muelleri* 301±227) presented an abundance increase only in spring/2002. The blue crab (*C. sapidus* 1,675±1,129) also showed an increasing CPUE after winter, being the most abundant estuarine resident species. An elevated CPUE was estimated for *G. barbus* (3,557± 2,397) during this period, being markedly the most abundant estuarine dependent species in samples. The banded croaker (*P. brasiliensis* 1,861±626) was the most abundant marine species during spring/2002, followed by bluewing robin (*P. punctatus* 1,180±544) and the gulf kingfish (*M. littoralis* 856±531). It is worth noticing that ray species, such as *S. bonapartii* (425±380) and *S. acuta* (158±94), were not caught along the year, except in spring when very low abundance of these species was observed (Figure 6).

Bycatch composition and abundance showed different pattern in the dry year. Lower abundances of fishes and crustaceans were observed in autumn. During this season, relative abundance index estimated for *A. longinaris* (707±304) was considerably higher than in previous autumn (2002). No estuarine resident species was observed, moreover, the abundance of estuarine dependent species was also very low (*G. barbus* 97±7 and *M. furnieri* 72±8) (Figure 6). The presence of marine crustaceans in samples was noticed, represented by crabs such as *C. danae*, *C. ornatus* and *H. pudibundus*, as well as the shrimp *E. oplophoroides* and prawns such as *L. schmitti*. A marked increase in CPUE of *A. longinaris* (4,476±1,470) was recorded in winter/2004, when a maximum CPUE was observed. The red prawn (*P. muelleri* 467±317) also presented an increase in abundance during winter. Among the estuarine dependent species, pink prawn (*F. paulensis* 212±179) was the most abundant, followed by the toothed anchovy (*Lycengraulis grossidens* 198±125) and whitemouth croaker (*M. furnieri* 159±145). Marine species were mainly represented by the banded croaker (*P. brasilensis* 1,094±952), gulf kingfish (*M. littoralis* 740±203), the squirrel hake (*Urophycis brasiliensis* 523±271) and the ray *Sympterygia acuta* (489±337). No estuarine resident species was caught during this period (Figure 6). During spring (2004), a decrease in *A. longinaris* (1,659±495) CPUE was observed; on the other hand, *P. muelleri* (556±80) presented its highest abundance index. As in the other seasons during this year, marine species predominated in samples (*P. brasiliensis* 1,190±614, *P. punctatus*, 457±265 and *M. littoralis*, 394±165), while few estuarine dependent species were caught and no estuarine resident species were observed (Figure 6).

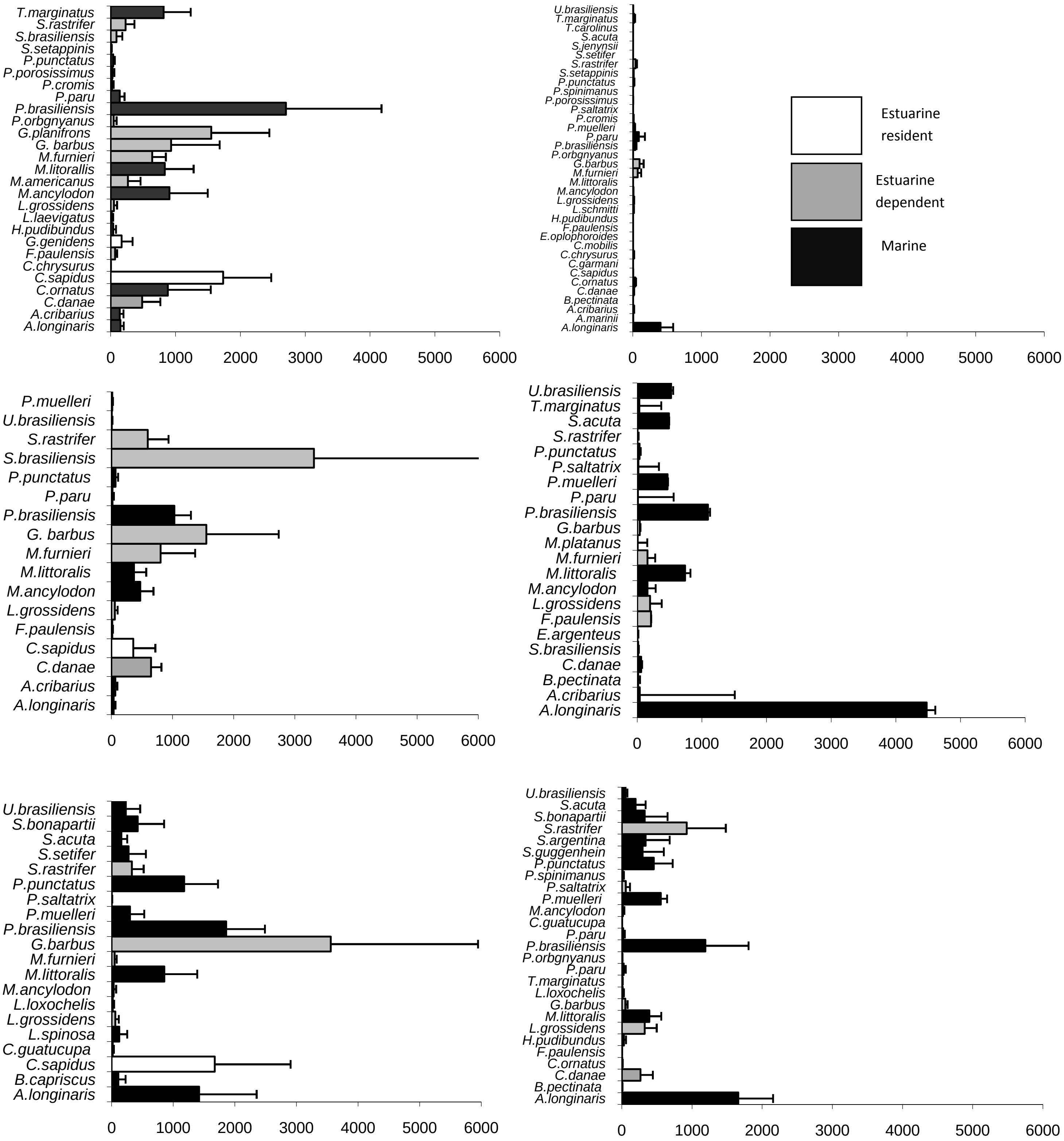

Figure 6. Seasonal trends in relative abundance (g/30min) of species caught in trawling for marine prawns in surrounding area of Patos Lagoon Estuary, Rio Grande, Brazil.

Ecological parameters

The mean trophic level of catches (TrLm) was negatively affected by the abundance of marine prawns (*A. longinaris* and *P. muelleri*), being consistently lower during the dry fishery season (2004) (Figure 7). During 2004, a higher percentage of trophic level I (herbivores, detritivores and omnivores) and level II species (mid-level carnivores) was observed. Conversely, 2002 showed a more even distribution of catches among trophic levels, presenting a higher percentage and abundance of top-predators (trophic level III). Pairwise comparison between both years showed significant differences in mean relative abundance of top-predators (g/30 min), with higher values obtained during wet fishery season (2002= 381±203.44; 2004= 143±47.03, p=0.03). The mean relative abundance of level I species in the catch was higher in 2004, but no significant differences were observed (2002= 437±98.9; 2004= 533±99.9; p=0.50). As well as observed for top-predators, mean biomass per trawl of trophic level II species was significantly higher in wet fishery season (2002=604±112.6 2004=300±74.4; p=0.02).

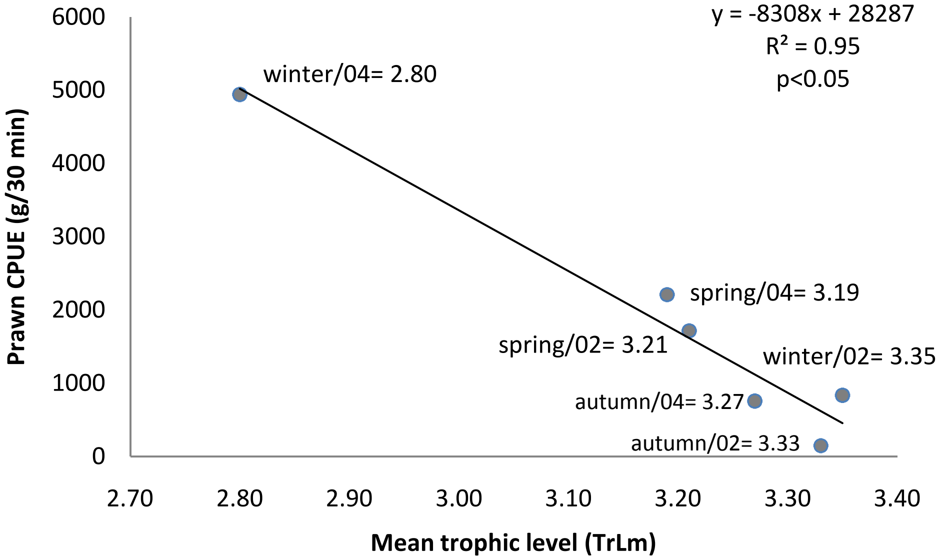

Figure 7. Linear regression obtained from prawn CPUE (g/30min) and mean trophic level estimated from prawn trawling in surrounding area of Patos Lagoon estuary (Rio Grande, Brazil) for each season and year analyzed.

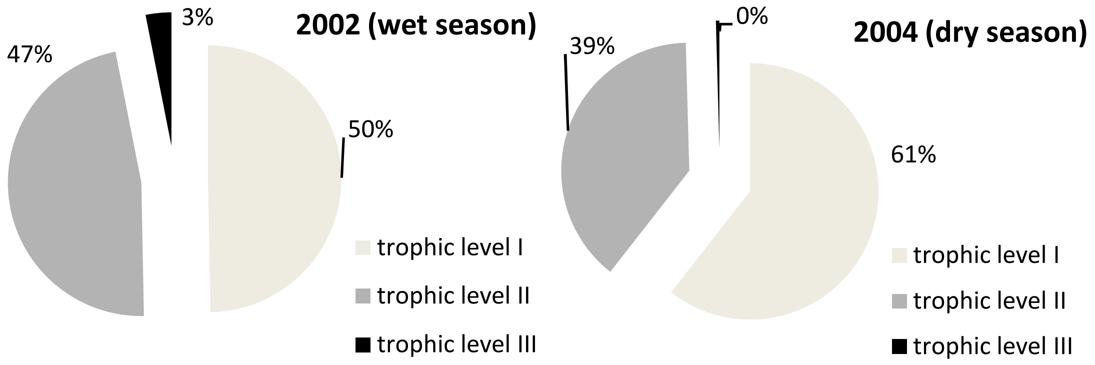

Figure 8. Relative frequency of each trophic level previously established to classify catches obtained from prawn trawling in surrounding area of Patos Lagoon, Rio Grande, Brazil. Trophic level I= herbivores, detritivores and omnivores; Trophic level II= mid-level carnivores; Trophic level III= top-predators.

Catch probability and size structure of commercial bycatch species

The probability of catch per length class was estimated for the four main commercial fish (*P.brasiliensis, G. barbus, M. littoralis, M. furnieri*), as well as for main crustacean species (*C. sapidus, P.muelleri, C. danae* and *F. paulensis*). Total length (TL) of whitemouth croaker (*M. furnieri*) varied between 4 and 27cm, with polymodal distribution and higher frequencies among 4 and 6 cm. Probability of catch (P_{50}=8.49 cm) estimated was much lower than the size at first maturity (LM) suggested in literature (20.5cm) for estuarine region (Castello, 1986), meaning that catches are mainly composed by immature juveniles. Same scenario was observed for the gulf kingfish (*M. littoralis*), with sizes ranging between 5-33cm and P_{50} (13.9 cm) lower than the LM suggested in literature (43cm) (Vazzoler et al., 1973) (Figures 9, 10).

The length frequency of salmon sea catfish (*G. barbus*) presented a well marked peak around 10 cm with another modal value around 15 cm. All individuals caught were smaller than LM (43 cm) estimated in literature (Reis, 1986a) and consequently lower than P_{50} (9.29 cm). Among the fish species, only the banded croaker (*P. brasiliensis*) presented similar P_{50}

(13.86 cm) and LM (16.7 cm) values (Vazzoler et al., 1973). The length of *P. brasiliensis* varied between 7-26 cm and was composed mostly by juveniles (Figure 8).

Length probability of catch (P_{50}) estimated for *C. danae* (71.98 mm) was relatively close to LM (90.36 mm) suggested in literature (Baptista-Metri et al., 2005), and size of individuals varied from 30-120 mm, with polimodal distribution. Similar pattern was observed for *C. sapidus*, presenting a P_{50} value slightly higher (85.18 mm) than the size at first maturity (84.5 mm) (Oliveira, 2003). Pink prawn presented a wide range of size distribution with polimodal shape, varying from 30 to 120 mm with higher frequencies between 50-80 mm. As one may expect, no mature prawns were observed in the area. The red shrimp (*P. muelleri*) size ranged from 40 to 150 mm, however P_{50} estimated (76.65 mm) was lower than the LM (108 mm) (Dumont & D'Incao, *unpublished data*). It is important to stress that this species presents a marked sexual dimorphism related to size and LM was estimated only for females (Figure 9).

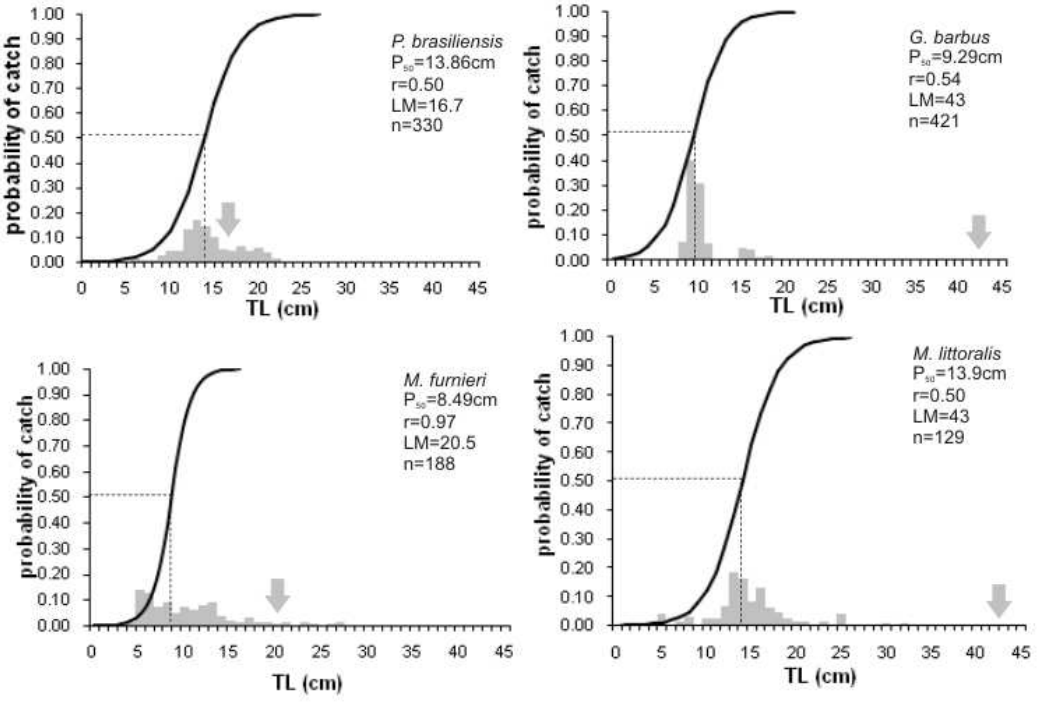

Figure 9. Probability of catch estimated for the main commercial fish species caught in artisanal trawling for prawns in surrounding area of Patos Lagoon estuary (Southern Brazil).

Dashed line indicates the length at which probability of catch is 50% (P_{50}), the grey arrows indicate the length at first maturity (LM) estimated for females, *r* is the slope of logistic curve and *n* is the number of individuals measured.

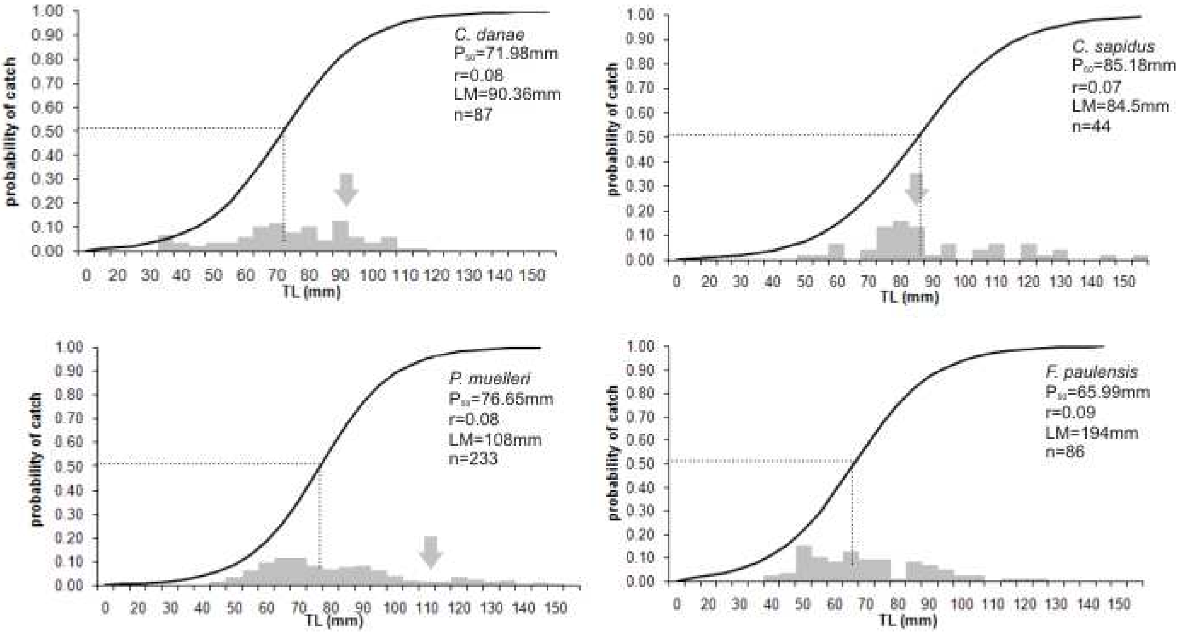

Figure 10. Probability of catch estimated for the main commercial crustacean species caught in artisanal trawling for prawns in surrounding area of Patos Lagoon estuary (Southern Brazil). Dashed line indicates the length at which probability of catch is 50% (P_{50}), the grey arrows indicate the length at first maturity (LM) estimated for females, *r* is the slope of logistic curve and *n* is the number of individuals measured.

DISCUSSION

Environment parameters

Discrete environmental conditions were observed during both years analyzed. The 2002/03 El Niño was considered as a moderate event, comparable to other years such as 1951/52, 1976/77 and 1963/64 (NOAA, 2007). During 2004, MEI ranks indicate a neutral to weak El Niño year. Despite of being a neutral year, 2004 presented very low precipitation ratio, which was a result of a northwards displacement of Convergence Zone of Atlantic, reducing rainfall in the south and increasing in rainfall in southeast (CPTEC, 2004).

Rainfall exceeded the monthly mean value for the region during 2002, increasing estuarine runoff and lowering salinity in coastal area. Similar effects of increased discharges from Patos Lagoon have been reported during periods of ENSO (Lima et al., 1996; Garcia et al., 2003). Consequently, hydrological processes that are responsible for regulate water exchange between estuarine and coastal zones (Lima et al., 1996), as well as transporting organisms were markedly discrete in analyzed fishery seasons, influencing salinity, temperature and causing marked changes in bycatch abundance and composition.

Discard composition and seasonal variation of catches

Main factors affecting bycatch ratios are recruitment of target species, changes in fishery practices as well as environment parameters; and can vary significantly even within same geographic area (Hall, 1999). For instance, discards recorded for Caribbean prawn fisheries range from 1:3 to 1:20 (Alverson et al., 1994). Bycatch ratio suggested for prawn trawling in Brazil is 1:9.5, however the composition and the amount of species caught incidentally varies according to oceanographic conditions, season and latitude (Alverson et al., 1994).

Remarkable variation in bycatch rates have also been reported for prawn-trawling in Brazil. Branco (2001) observed that the incidental catch of *Xiphopenaeus kroyeri* fishery in Southern Brazil was 1:17 (kg), while Damasceno & Evangelista, *apud* (Isaac, 1999) studied the incidental catch of *Penaeus subtilis* fishery in the northern region of Brazil and verified a discard ratio of 1:15 (kg). A lower discard ratio of 1:10 has also been reported for pink prawn commercial fishery is southeastern Brazil (Vianna & Almeida, 2005). Lowest discard reported for commercial prawn trawling is 1:0.31, resulting from *A. longinaris* fishery in Southern Brazil (Haimovici & Mendonça, 1996b).

It is important to stress that bycatch quantified by Haimovici and Mendonça (1996b) was restricted to catch landed and therefore, a higher ratio would be expected, since part of the catch (e.g. some crustaceans) is discarded back to the sea and part is landed along with prawns. Since this fishery demands high operational costs, trawlers operate only in those years when abundance of prawns is high, which explains the very low discards estimated. Additionally, these species present a very patchy distribution (Dumont, 2005) resulting in very low discards during years of elevated abundance.

Macrodon ancylodon, U. brasiliensis and *P. brasiliensis* were the most discarded fishes by commercial double-rig trawlers (Haimovici and Mendonça, 1996b), while the most discarded fishes recorded in present investigation were *P. brasiliensis*, *G. barbus* and *M. furnieri*. Commercial trawlers for *A. longinaris* and *P. muelleri* operate in shallow marine waters, mainly from 5 to 40 meters in depths outside surf zone (2-10 m), where artisanal trawling takes place. The surf zone of sandy beaches can be considered as semi-closed ecosystems, and therefore may present slightly different fishes and crustaceans assemblages (Borzone & Gianuca, 1990), resulting in different incidental catch composition and ratio. Commercial trawling for marine prawns takes place in mainly in summer, which is also reflected in catch composition. Skates for instance, gather in shallow waters during summer for breeding (Vooren & Klippel, 2005) and therefore, represent a considerably higher fraction of catches in commercial trawling (1.6%) (Haimovici & Mendonça, 1996b) than in artisanal fishery (0.18% in 2002 and 0.40% in 2004).

Previous investigation performed during scientific cruises, in similar fishing grounds, estimated a discard ratio for three year round analysis of 1:4.5 in 1979, 1:12.7 in 1980 and

1:0.5 in 1990 (Ruffino & Castello, 1993). However, when the same authors standardized bycatch ratios for the periods sampled during the three years investigated (autumn and winter), this values rise to 1:40 in 1979, 1:34 in 1980 and 1:2.39 in 1990. In the present investigation, the highest discard ratios were also observed in autumn, especially in wet year (1:75). Conversely, during winter/2004 the lowest discard ratio (1:0.97) was recorded which is likely related to the combined factors of high abundance of *A. longinaris* and low abundance of estuarine related fishes and crustaceans in the surrounding area of Patos Lagoon Estuary.

The overall discard pattern observed for both years (1:5.6) is inferior to the value suggested by Alverson et al. (1994) for prawn fishery in Brazilian coast (1:9) and very close to the value suggested by Andrew & Pepperel (1992) to worldwide prawn fishery in temperate and sub-tropical zones (1:5). Therefore, the first conclusion is that bycatch of artisanal trawling for *A. longinaris* is extremely variable and highly dependent on recruitment patterns and oceanographic conditions in studied area. Thus, it is important to stress that interannual comparison of bycatch composition in prawn fisheries must be performed in long-term basis, providing a better understanding of the complex interactions regulating discards (Ambrose et al, 2005).

The presence of an observer during sampling in artisanal fishing cruises, avoided the selection effect usually performed by fishermen at sea. Nevertheless, it was possible to assess the relative importance of the crustaceans, as well as the quantitative and qualitative information concerned to partial use of bycatch. In accordance with previous investigations developed for artisanal fishery in third world countries (Hall et al., 2000), the utilization of fishes incidentally caught is despicable, being selected just few large individuals (usually around 30 cm) of traditionally marketable species (*M. furnieri*, *M. littoralis* and *U. brasiliensis*) for subsistence of fishermen and their families. Due to very low importance of bycatch utilization, the quantification of this category can be considered as inexistent.

Conversely, landings from commercial trawling for marine prawns in Southern Brazil include some fish species, such as scianids and flat fishes that account for 2.5% of total catch (Haimovici & Mendonca, 1996b).

The bycatch ratio, in terms of numbers, showed a different pattern when compared to estimates obtained in weight. High relative abundance in numbers can be explained by the wide reproduction period and fast growth pattern, resulting in high numeric abundance and small size of individuals (Ruffino & Castello, 1992). Even in nursery areas, where small and numerous fishes and crustaceans were expected to occur (Garcia & Gianuca, 1998), the numeric abundance of *A. longinaris* was higher then bycatch during the dry year. The results confirm that, under favorable environment conditions, this is one of the dominant species of coastal waters and can provide 30% of biomass predated by fishes inhabiting marine shallow waters in Southern Brazil (Capitoli et al., 1994).

Our observations are in agreement with empirical knowledge of artisanal fishermen, who perform this fishery only during those years of successful recruitment of prawns. Due to reduced commercial value of marine prawns (when compared to pink prawns, for instance), no fishing is performed during low recruitment years, since trawling is usually not profitable under this condition, which was also reported for commercial fishery (Haimovici & Mendonca, 1996a). This regime tends to preserve the stock since it provides an opportunity for biomass recovery in subsequent years. Conversely, during elevated rainfall periods, the abundance of prawns is reduced in the area, reflecting the reduction in salinity values. In this case, alternative species such as whitemouth croaker (*M. furnieri*), squirrel hake (*U. brasiliensis*) and more recently the blue crab (*C. sapidus*), are targeted by this fleet with different fishing gears (*personal observation*).

Fish abundance tends to be higher in the Patos Lagoon surrounding area during elevated rainfall, highly influenced by a significant increase of estuarine dependent and estuarine resident species. High precipitation occurring on drainage basin increases the freshwater flow outside the estuary, resulting in higher transport of nutrients and causing environment eutrophization of the coastal zone (Ciotti et al., 1995). Thus, coastal water enrichment, due to high nutrient and primary production outflow, sustains an elevated production of estuary related and marine fishes in the area, explaining the greater amount of bycatch observed during 2002, while the abundance of marine prawns is reduced.

Ecological facilitation due to habitat expansion plays an important role in abundance of eurihaline species, since salinity in surrounding area of Patos Lagoon estuary is markedly changed during high precipitation periods. Similar pattern was observed during 1997-1998 El Niño inside the estuary, when freshwater species took advantage of reduced salinity to expand their habitat. Besides geographic habitat extension occurred during elevated rainfall, many estuarine dependent or resident species are involuntarily transported outside Patos Lagoon estuary, increasing biomass of fishes (Garcia et al., 2003) and crustaceans in coastal zone.

Ecological parameters

Recent experiments showed that ecosystems presenting higher diversity have more ability to withstand with environment disturbances and to recover from unfavorable events (Worm et al., 2006). In general terms, sub-tropical and temperate trawling for prawns, are less damaging to the ecosystem then tropical ones (Hall, 1999). Temperate seas tend to support large numbers of comparatively few species, while tropical seas contain many species in smaller numbers (Lalli & Parsons, 2006).

Despite of prawn trawling for *A. longinaris* has been performed in nursery areas, where diversity is high (Garcia & Gianuca, 1998), a lower number of species (38 fish and 12 crustacean species) was found when compared to previous investigations in the same area (47 fish species) (Ruffino & Castello, 1993). It may be explained by slightly different sampling depths, different fishing gears used and to the inclusion of summer months in the analysis. Lower richness of fish in incidental catch was recorded in a higher latitude (San Jorge Gulf, 46^0S, Argentina) trawling for red prawn (*P. muelleri*), summing 32 species (Pettovello, 1999). Conversely, the number of species discarded in tropical fisheries (e.g. Northern Prawn Fishery in Australia), are remarkably high, catching hundreds of species along with prawns (Gulland & Rotschild, 1981).

Coupled analysis of richness (number of species) and mean trophic level of catches allowed concluding that higher estuarine runoff may have increased the concentration of nutrients in surrounding area of Patos Lagoon, resulting in higher trophic level of catches as well as supporting a greater abundance of top-predators and a lower number of species. Conversely, in the dry year, mean trophic level was reduced, significantly influenced by elevated abundances of marine prawns in the area. The greater number of species caught is explained by the presence of more diverse marine fauna, such as strictly marine crustaceans (*C. ornatus*, *C. danae, E. oplophoroides*).

During high estuarine runoff, lower salinity water was found in surrounding area of Patos Lagoon, disrupting the entrance of larvae and juveniles, involuntarily transporting estuarine dependent or resident species outside the estuary (Garcia et al., 2003) and increasing nutrient outflow (Ciotti et al., 1995). As a result, higher abundance indices were estimated, influenced by estuarine dependent (*G. barbus, G. planifrons, M. furnieri*), estuarine resident (*C. sapidus*, *G. genidens*) as well as the expected marine species (*P. brasiliensis, T. marginatus*).

The whitemouth croaker (*M. furnieri*) was more abundant during the wet year. This scianid species spawns in coastal areas under the influence of freshwater outflow, explaining higher biomass recorded in 2002. The stripped pampo (*T. marginatus*) is also a marine species that tolerates changes in salinity and inhabits the surf zone surrounding estuarine mouth (Vieira et al., 1998). Despite of being more frequent during the dry year, higher biomass recorded during wet year (2002) suggests that food availability can be quite important, especially for euryhaline species that are capable of tolerate trends in salinity.

Additionally, *P. brasiliensis*, a marine species, also showed higher biomass values in wet year taking advantage of nutrient-rich water outflow. The king weakfish (*M. ancylodon*) was also more abundant in this period and associations of this species with *P. brasiliensis* have been previously reported (Araujo, 1984). These associations are mainly explained by predation, since adults of *M. ancylodon* have the juveniles of *P. brasiliensis* as one of their main food items. Juveniles of catfish (*G. barbus*) start to gather in surrounding area of Patos Lagoon estuary in late summer, where they feed on *C. sapidus* pereiopods (Araujo, 1984). During 2002, the abundance of *G. barbus* juveniles was associated with *C. sapidus* reproductive season that extends from spring to early autumn (Oliveira, 2003).

Therefore, while high rainfall has been reported as playing a negative effect on production inside the estuary (Garcia et al., 2003), the adjacent zone takes advantage of greater nutrient volume flushed out, resulting in higher biomass production, sustaining a higher mean trophic level, higher biomass of top-predators and resulting in a lower number of species. Estuarine discharge has been previously reported as a key factor regulating communities and food-web structure (Livingston et al., 1997), which is likely to be occurring in studied area.

Probability of catch (P_{50}) and size composition

The analysis of catch probability and the size composition of the most important fishes showed that the trawl net caught mainly individuals that did not reach the mean length at first maturity. An exception is *P. brasiliensis* (banded croaker) and the blue crabs (*C. danae* and *C. sapidus*) that presented similar LM and P_{50} values. Hence, it is not recommended to manage this fishery simply by estimating intraspecific parameters, such as MSY. Ecological degradation, caused by trawling in elevated rainfall seasons, will probably occur, since many species of fish and crustaceans are discarded dead back to the sea and most of catch is composed by juveniles.

In some areas where prawn trawling has been occurring for several decades, high bycatch levels have had very obvious effects (EJF, 2003). In the Gulf of Mexico, for instance, bycatch ratio has actually been declining since the 1970. Rather than being a sign that the ecological impacts of trawling are decreasing, it shows that bycatch species have been significantly depleted. Croakers (Sciaenidae) are about 40% less abundant than they were twenty years ago, which is a result of high fishing pressure (Eyars, 2007).

Similar phenomenon seems to be occurring in Southern Brazil, caused not only by prawn trawling, but by a combination of different fishing gears catching individuals in different phases of their life cycle (Haimovici et al., 1993; Haimovici & Mendonça, 1996b; Vieira et al., 1996). Ruffino & Castello (1993) observed that whitemouth croaker (*M. furnieri*) was the dominant species in catches during late 70`s. However, a new scenario was observed in 90's, when abundance of *P. brasiliensis* surpassed the former species (Haimovici et al., 1993; Ruffino & Castello, 1993). The present study verified that *M. furnieri* accounted for 8% of the captures in weight in 2002, being just the fourth more important species in catches.

Previous assessment estimated that 199.8 t/year of *M. furnieri* and 82.5 t/year of *G. barbus* are caught incidentally in pink prawn (*F. paulensis*) trap fishery inside the estuary. In numbers, values estimated are around 4.2 millions of *M. furnieri* and 2.7 millions of *G. barbus* caught. Moreover, it was noticed that the fishing pressure was quite accentuated on the individuals that did not reach the mean length at sexual maturity (Vieira et al., 1996), which was also confirmed by the present study for surrounding area of Patos Lagoon estuary.

The incidence of fishing mortality is even more harmful for *K*-strategist species (Alverson, et al., 1994), such as sea catfish (*G. barbus*) and skates (*S. bonapartii, S. acuta, S. argentina* and *S. guggenhein*). The sea catfish is also a long-lived species (can reach 23 years old) presenting slow growth, late sexual maturity (reached with 7 years old) and low fecundity (32-272 oocytes per female) (Reis, 1986a,b), making it more susceptible to recruitment and growth overfishing.

Whereas prawns tend to fall towards the *r* end of the spectrum, many of the other species caught alongside it are *K* species (Gulland & Rotschild, 1981; EJF, 2003). Because prawn fisheries capture such a broad range of species, it is impossible to hold fishing pressure at different levels for different species. Fishing pressure is therefore set high to get maximum productivity from shrimp stocks, to the disadvantage of those *K* species caught as bycatch (EJF, 2003; Vooren & Klippel, 2005; Eyears, 2007).

Among *K*-strategist species, skates seem to be the most threatened ones (Vooren & Klippel, 2005). Four ray species were captured in the present study (*S. bonapartii, S. acuta, S. argentina* and *S. guggenhein*) while in the study developed by Ruffino & Castello (1993) five species were caught. It is important to point out these authors performed a year round sampling and higher concentrations of skates in coastal area for spawning are reported during summer. Several authors suggest that elasmobranchii species migrate to shallow waters for reproduction (*e.g.* Vooren & Klippel, 2005), where they are explored by different fishing gears, other than the prawn otter-trawling. Nevertheless, relative abundance of rays was markedly low, and decreasing densities have been previously reported (Ruffino & Castello, 1993; Vooren & Kliepel, 2005). In the early 80`s high densities of these resources were recorded (*e.g.* in 1981 *S. guggenhein* was caught in 90% of fishing stations), showing first signs of declining in early 90`s until some of rays species be considered as at extinction risk in 00`s (Vooren & Kliepel, 2005).

While the effects of trawling on fishes have been extensively discussed, the crustacean composition in trawling for prawns is poorly understood, since some are of low commercial value or inedible as well as of low densities (EJF, 2003). The main crustacean species caught was *C. sapidus,* followed by *C. danae* and *P. muellerii*. Size composition of blue crab (*C. sapidus*) in samples reflects the reproductive biology of this species, since mature females migrate to surrounding area of Patos Lagoon for spawning (Oliveira, 2003). Therefore, similar values of P_{50} and LM observed for *C.sapidus* do not reduce the impact of prawn fishery over this species, since recruitment overfishing may occur, resulting from an excessive fishing effort selectively driven to the spawning area.

On the other hand, CPUE of blue crab was reduced and concentrated in summer during the dry year (*data not showed*), minimizing the impact of trawling activity over this species. One factor that contributes to high mortality levels of the crustaceans and skates captured incidentally is the selection method performed on board. The amount of dead blue crabs and skates could be reduced if the fishermen returned the individuals back to the sea while they are still alive. Many individuals stay in the deck during the whole day of fishing, being discarded dead back to the sea. Studies showed that survival rate of crabs (Hill & Wassemberg, 1990) and skates (Cedrola et al., 2005) is high if they are immediately returned to the sea.

Trawling for prawns has been considered as a low selective as well as damaging activity, compared to bulldozing a forest to catch song birds (EJF, 2003). The Magnuson–Stevens Fisheries Conservation and Management Act of 1996, aims to reduce impacts of fishery on ecosystem, suggesting that conservation and management measures shall minimize bycatch and, to the extent bycatch cannot be avoided, minimize the mortality of such bycatch (NOAA Fisheries, 2007). Educate fishermen to release crabs and skates back to the water shortly could significantly reduce mortality, especially of spawning females of *C. sapidus*.

As previously discussed, trawling for prawns in surrounding area of Patos Lagoon, during high rainfall years results in low prawn production as well as high byctach ratio, mainly composed by juvenile fishes and crustaceans. Therefore, trawling for prawns in the surf zone, during low salinity years, must not be sustained. On the other hand, during dry years, high salinity favors marine prawns, especially in winter; and therefore, relative abundance of bycatch species are reduced. However, a combination of low biomass of incidental catch, resulting from oligotrophic waters, combined to excessive fishing effort may cause irreversible damage to ecosystem, especially to K-strategist species caught along with prawns. Reduction in bycatch ratios has been extensively discussed (Eayrs, 2007; Brewer et al., 2006; Hannah & Jones, 2007) and solutions such as increase mesh size and adoption of bycatch reduction devices (BRD`s) have been proposed. Increase mesh size, to reduce catch of juveniles in prawn fishery, has been previously reported as non-viable, since yields can be dramatically reduced, resulting in fishing effort increments to compensate it (Haimovici & Mendonça, 1996a). On the other hand, BRD`s could provide a profit increase and an easier operation on the deck as well as to improve product quality and consequently its price (Eayrs, 2007). According to FAO Code of Conduct for Responsible Fisheries (1995), BRD`s must be implemented in prawn fisheries, reducing bycatch ratio as a whole, but especially the catch of more susceptible species such as rays, catfishes and turtles. Nevertheless, trawling for marine prawns in surrounding area of Patos Lagoon represents an important economic yield for local fishermen communities, especially during closed season inside the estuary from April to July. Therefore, is important to create regulations to optimize artisanal exploitation of this resource (*e.g.* implementation of BRD`s and allow fishing only during winter), since intensity of fishing effort seems to be low (dependent on the weather) and self-regulated by prawn abundance in the area.

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Distribution and abundance of the argentinean (*Artemesia longinaris*) and red (*Pleoticus muelleri*) prawns (DECAPODA:PENAEOIDEA) in Southern Brazil during commercial double-rig trawl commercial fishery season

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Distribution and abundance of marine prawns

ABSTRACT

Declining in landings of more valuable prawn species, such as pink prawns (*Farfantepenaeus paulensis* and *F. brasiliensis*), expanded the targets of double-rig otter-trawlers to other species such as *Artemesia longinaris* and *Pleoticus muelleri*. In attempt to increase information on distribution and abundance of these prawns, 64 samples were analyzed in summer/2005 during commercial trawling fishery season off Rio Grande do Sul coast. Samples were collected from a research vessel (NOc. Atlântico Sul- FURG) in depths varying from 5 to 29 meters as a contribution to SALVAR project. Temperature, salinity and substrate play an important role on distribution of *A. longinaris*, concentrating greater densities in areas of low temperature and high salinity, associated to summer ressurgence. *Pleoticus muelleri* showed a more homogenous distribution and did not avoid areas of lower salinity under the influence of estuarine runoff. By using a swept area method, a total of 3369 tons of *A. longinaris* was estimated between isobaths of 10 and 20 meters. *Pleoticus muelleri* presented lower abundances and a total of 2527 tons was estimated by using swept area method. Size distribution allowed concluding that larger individuals are located especially between 15 and 20 meters for both species. However, large individuals of *A. longinaris* clearly avoided the areas of lower salinity, suggesting that spawning takes place outside the direct influence of Patos Lagoon estuary. Conversely, *P. muelleri* takes advantage of lower salinity areas, avoided by *A. longinaris*, for spawning.

Keywords: *Artemesia longinaris*, *Pleoticus muelleri*, distribution, abundance, , environment factors, Southern Brazil

INTRODUCTION

The argentinean (*Artemesia longinaris* Bate, 1888) and the red (*Pleoticus muelleri* (Bate, 1888) prawns are monotypic and endemic species inhabiting shallow waters of southwestern Atlantic. The argentinean prawn is found from Atafona (Rio de Janeiro, Brazil, $21^0$37'S) to Puerto Rawson (Argentina, $43^0$00'S), while red prawn presents a further south distribution, reaching the Santa Cruz Province (Argentina, $50^0$00'S) (D´Incao, 1999). These species are mainly distributed from littoral zone to 30 m isobaths, however, further occurrences (68 m) have been reported (Olivier *et al*., 1968; Iwai, 1973a,b).

Both species play an important role on the trophic-web of coastal marine waters of Southern Brazil, as they are intensively predated by fishes (Capitoli *et al*., 1994). Additionally to ecological relevance, both species have been recently exploited by commercial and artisanal fisheries along their entire distribution area (Boschi, 1969; Valentini, *et al*., 1991; D´Incao, *et al.*, 2002). Declining in landings of more valuable prawn species, such as pink prawns (*Farfantepenaeus paulensis* Pérez-Farfante, 1967 and *F. brasiliensis* Latreille, 1817), expanded the targets of double-rig otter-trawlers to other species such as *A. longinaris* and *P. muelleri* (D'Incao *et al*., 2002). This commercial fishery takes place mainly in summer, when higher landing values are usually recorded (Haimovici and Mendonça, 1996a; Pérez *et al*., 2001).

Lack of information on distribution and abundance of these prawn species have been reported (Costa *et al*., 2004; Costa *et al*., 2005), especially in Southern Brazil (Nascimento, 1981; 1983, Pérez *et al*., 2001; Dumont, 2005; Baptista-Metri, 2007). Lack of information on *P. muelleri* biology in Southern Brazil is even more noticeable, since investigations are restricted to geographical distribution (D'Incao, 1999) and landings reports (Haimovici and Mendonça, 1996b). No significant relationship between fishing effort and catches has been reported for both species, indicating that abundance is mainly regulated by environment factors (Haimovici and Mendonça, 1996b; Pérez *et al*., 2001). Therefore, information on the main factors regulating distribution and abundance of *A. longinaris* and *P. muelleri* during commercial fishery season must be investigated, as well as main concentration areas for these species.

MATERIAL and METHODS

Samples were collected during a scientific cruise, performed from February 13th to February 28th of 2005, onboard of the research vessel Atlântico Sul as part of SALVAR project. The sampled area covered the entire Rio Grande do Sul coast, from Santa Marta Grande Cape (28^{0}36’S) to Chui Stream (33^{0}45’S) in depths that ranged between 5 to 29m, summing a total of 64 fishing stations (Figure 1). Sampling design was initially performed by separating the total area in 15 equidistant and perpendicular to coast line layers. Each of the 15 sectors received a number of stations proportional to its area.

To perform biological analysis of distribution and abundance, three main areas were adopted. The northern area was comprised between 29^{0}18’S and 31^{0}13’S, the central area from 30^{0}58’S and 32^{0}14’S and the southern area from 32^{0}01’S to 33^{0}51’S (Vooren *et al*., 2005). Additionally, each of the areas was subdivided in two smaller zones according to depth, which ranged from 5-15 and 16-20 meters. Consequently, a total of six sectors were created to perform distribution and abundance analysis of main prawn species inhabiting commercial trawling area during summer.

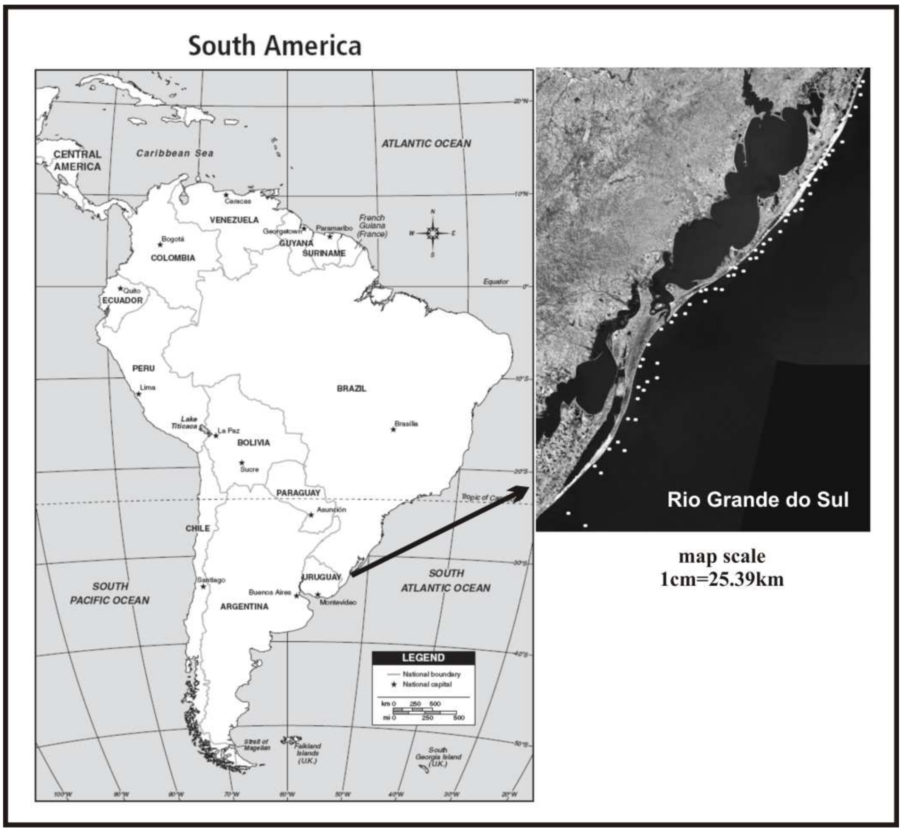

Figure 1. Southwestern Atlantic Ocean, highlighting Rio Grande do Sul State (Southern Brazil) where investigation took place during summer/2005. White dots represent the fishing stations performed between 5 and 29 meters depth.

Motivation to sub-divide each of three main areas in two groups came from previous investigation on *A. longinaris* that suggest differential size-composition according to depth (Dumont and D'Incao, *manuscript*). Area 1 represents the shallow waters from southern region (5-15m), while area 2 is located at further depths (16-20m) also in southern region. Area 3 was located at central shore and it comprised the stations performed in depths varying from 5-15m. Area 4 was also located in central shore, but includes only the stations performed in deeper waters (16-20m). Areas 5 and 6 were positioned at northern shore and were also determined according to depth, in such a way that area 5 comprises shallow water stations (5-15m) and area 6 deeper region (16-20m) covered by the investigation cruise.

Biological samples were collected by using a prawn otter-trawl net. The footrope of the trawl net was 20 meters long, with a steel chain (1.3 kg/m) attached in attempt to increase vulnerability of prawns to the net. Mesh size (opposing knots) varied from 50 mm in wings to 22 mm in the codend. A standardized time of trawling was adopted (30 minutes). Trawling speed was always around 5.5 km/h and distance between otterboards around 28 meters (Table I).

Total weight obtained in a determined fishing station was recorded for each species of prawn and sub-samples were taken to perform size-frequency analysis, and to estimate abundance in numbers. Relative abundance in weight and number was given by total amount of catch divided by the standardized 30 minutes tows. To describe oceanographic features of shallow waters in Southern Brazil, a CTD Ocean Seven 316 (Idronaut-Italy) was used, registering temperature (^{0}C), salinity (PPS-78) and depth of water column, always after each fishing station. The sediment type was classified according to samples obtained by using a Van Veen dredge and Scientific Ecosound SIMRAD EK-500 and classified as silt, mud and sand.

Carapace length (CLmm) was used to describe size structure of prawn stocks exploited by commercial trawlers and measured from postorbital angle to the end of posterior carapace margin. Gender of prawns was determined through secondary sexual traits and proportion of megaspawners in each area was analyzed. Only females larger than the size class in which probability of been ripe is 100% (LM_{100}) were considered as megaspawners. To estimate LM_{100} a logistic model was adjusted to frequency of ripe females and values obtained were 22mm (CL) and 26mm (CL) for *A. longinaris* and *P. muelleri*, respectively (data not showed).

Table I. Summary of fishing stations performed during summer/2005 off the coast of Rio Grande do Sul (Southern Brazil), containing position of trawl, environment parameters and net properties used to estimate total biomass through swept area method.

latitude	longitude	depth	surface temperature (^{0}C)	bottom temperature (^{0}C)	surface salinity	bottom salinity	net oppening (m)	trawl distance (m)	swept area (m^2)
33 51.402	52 54.624	29	22.9	22.9	34.0	34.1	19.36	4221.13	81707.50
33 45.511	53 05.567	23	23.1	23.6	34.4	35.0	17.46	3162.83	55233.15
33 25.365	52 46.994	17	23.5	23.7	33.9	34.0	15.52	4050.12	62845.66
33 21.803	52 50.218	10	24.1	23.7	33.6	33.7	13.31	2834.17	37716.62
33 13.064	52 41.246	10	24	23.8	33.8	33.9	13.31	2284.62	30403.24
33 09.812	52 34.276	13	23.4	23.5	34.2	34.2	14.25	3286.63	46849.65
33 13.247	52 30.505	15	23.5	23.5	33.6	33.6	12.83	2739.39	35158.36
32 58.581	52 29.581	12	23.5	23.4	34.2	34.2	17.04	4452.16	75875.42
32 58.647	52 25.520	16	23.4	23.3	33.9	33.9	15.20	4296.04	65305.77
32 48.475	52 23.518	13	23.7	23.6	33.6	33.8	14.25	4238.28	60414.92
32 42.200	52 22.552	10	23.4	23.5	34.2	34.2	16.53	3327.08	54986.39
32 43.562	52 19.700	13	23.5	23.5	34.1	34.2	8.63	2970.30	25623.04
32 38.841	52 16.339	14	23.6	23.5	34.3	34.3	21.04	2694.25	56687.08
32 36.996	52 12.223	17	23.9	23.3	34.3	34.3	17.57	3392.77	59605.47
32 31.612	52 21.795	8	24.3	23.8	34.3	34.4	12.68	3578.55	45363.89
32 27.399	52 19.881	8	24.1	24.1	34.2	34.3	12.68	1523.19	19308.88
32 29.725	52 11.585	17	23.5	23.4	34.3	34.3	15.52	2790.83	43305.24
32 20.712	52 16.581	9	24.4	23.9	34.5	34.4	13.26	2903.36	38484.61
32 12.378	52 09.175	7	24.6	23.8	34.5	34.5	9.05	3003.40	27172.40
32 04.704	51 54.658	13	24.3	23.5	34.5	34.6	15.52	3273.42	50793.64
32 04.282	51 59.069	8	24.2	24.2	34.5	34.5	12.68	3276.81	41538.77
32 07.822	52 01.616	9	23.9	23.9	35.9	35.9	3.88	3317.50	12878.13
30 58.335	50 39.646	12	23.9	22.7	36.2	36.0	14.41	3200.28	46123.77
30 50.819	50 33.936	11	23.8	23.1	36.2	36.2	14.41	3961.99	57101.80
30 46.312	50 30.248	10	23.8	23.7	36.1	36.0	18.15	3565.17	64697.23
30 47.590	50 29.508	14	24	21.8	36.2	36.2	14.41	3679.01	53023.30
30 44.770	50 28.920	12	24.4	22.5	36.0	36.1	14.41	3666.38	52841.40
29 24.074	49 44.343	18	22.1	20.5	36.1	36.1	15.99	3384.71	54122.86
29 27.896	49 48.401	9	21.5	20.9	35.6	36.1	11.78	3321.70	39137.57
29 36.304	49 54.376	8	23	20.7	36.2	36.1	10.73	3294.12	35347.19
29 41.381	49 56.697	19	21.8	20.4	36.0	36.1	12.83	3607.26	46296.97
29 47.961	50 01.161	12	23.3	20.6	36.0	36.1	14.41	3452.28	49755.60
29 56.114	50 05.130	10	23.3	20.5	35.3	36.2	12.31	3224.68	39690.60
30 05.373	50 08.233	19	21.6	20.4	36.1	36.2	17.04	3599.75	61348.31
30 07.832	50 10.054	12	21.4	20.6	36.1	36.3	13.36	3459.05	46214.26

30 11.902	50 09.711	20	22.2	20.9	36.0	36.2	14.41	3489.35	50289.93
30 18.499	50 12.590	18	22.3	21.6	36.0	36.2	13.36	3520.07	47029.56
30 22.826	50 15.800	10	22.7	21.8	36.1	36.2	14.41	3407.84	49115.21
30 36.045	50 20.125	17	23.3	22.9	36.0	36.2	14.41	3769.34	54325.28
30 40.426	50 25.709	12	23.9	22.3	35.9	36.3	14.41	3259.35	46975.00
30 55.603	50 35.494	17	22.7	20.4	36.2	36.3	17.57	3737.26	65657.71
31 02.403	50 38.770	18	23.3	19.9	36.0	36.2	17.57	3691.20	64848.49
31 05.986	50 43.473	15	21.4	20.3	36.2	36.3	15.99	5063.88	80973.49
31 10.436	50 44.316	18	23.1	19.6	35.8	36.2	14.41	3907.69	56319.25
31 11.279	50 47.540	16	22.4	20.8	36.1	36.2	17.57	3414.12	59980.58
31 13.409	50 51.570	12	22.6	20.5	35.3	36.1	14.94	3435.91	51326.97
31 18.128	50 54.888	17	22.7	20.6	35.9	36.1	16.04	4695.07	75322.99
31 22.155	50 56.364	20	22.4	20.7	35.9	35.9	16.04	3414.56	54779.79
31 26.138	51 02.602	19	22.7	21.9	35.8	35.8	16.04	3012.26	48325.75
31 28.321	51 06.235	15	23.6	23.6	35.8	35.8	14.94	3282.87	49040.87
31 31.398	51 11.046	9	24.2	24	35.9	35.9	14.41	3211.62	46287.09
31 32.370	51 07.309	19	23.3	23.1	35.8	35.8	15.99	2919.03	46676.45
31 35.916	51 10.244	17	23.9	23.6	35.4	35.7	14.94	3203.73	47858.67
31 35.830	51 14.125	15	24.2	24.2	35.7	35.7	15.99	3129.66	50044.46
31 42.103	51 17.888	18	24.2	23.7	35.5	35.6	17.04	3725.43	63490.24
31 40.804	51 22.835	12	24.7	24.4	35.6	35.6	14.41	3264.29	47046.26
31 44.276	51 23.872	16	24.7	24.3	35.5	35.5	15.46	3320.97	51356.73
31 44.813	51 27.375	14	25	24.4	35.2	35.5	14.41	2788.86	40194.10
31 51.658	51 31.206	20	24.7	23.9	35.2	35.5	14.94	3033.55	45316.45
31 51.784	51 34.606	17	24.7	24.6	35.3	35.5	14.41	3235.35	46629.14
31 51.795	51 40.700	15	25	24.8	35.2	35.3	15.46	2986.74	46188.12
31 53.317	51 45.486	13	25.1	24.9	34.8	35.2	15.46	3596.27	55614.12
31 57.377	51 41.011	17	24.6	24.5	35.3	35.6	17.04	3419.32	58273.40
31 58.791	51 50.383	13	24.9	25.2	35.7	35.8	17.04	3662.37	62415.49

Relative abundance (CPUE) data was tested for normality (Lilliefor’s<0.2) and homogeneity of variances (Levene’s>0.05) prior to perform ANOVA and post-hoc Tukey’s test (0.05). Normality was achieved for all groups, while homogeneity of variance was not. Differences in mean relative abundances and sizes were tested by using 6 areas previously described. The influence of environment parameters on the CPUE (kg/30min) of *A. longinaris* and *P. muelleri* was assessed by a multiple regression analysis.

Swept area method was applied to estimate a total stock biomass available during the commercial fishery season. The swept area was estimated by the following equation:

$$a = W*TV*D,$$

where W is the effective width of the trawl net, TV is the towing velocity and D is the duration of the tow. Once swept area is estimated, total biomass in the fishing ground was given by:

$$B = Cw/v*(A/a),$$

where Cw is the catch per unit of effort, v is the vulnerability of prawns to the net, A is the total area and a is the swept area. Since high dispersion of CPUE values were noticed, total biomass was estimated for each of the six areas previously described and total biomass was obtained by summing each of these values.

Vulnerability of prawns and fish to trawling nets is difficult to estimate (King, 1997). Values suggested range from 0.5 to 1.0 and a value of 0.75 was adopted, since it represented the most coherent results among all the values tested (0.5-1.0 data not showed). Total area of each of the 6 sectors was obtained from Weigert *et al*., 2005 and values ranged from 3110 km^2 (area 2) to 332km^2 (area 5). Geographic Information System (GIS) was used to perform interpolation (natural neighbor) of biomass/km^2 data that was mapped to create visual representation of stock densities and confronted to interpolations created by using environmental parameters. Parameters used in environment data interpolation were bottom salinity and temperature, as well as sediment type. This analysis was performed in attempt to identify main fishing grounds, for argentinean and red prawns in Southern Brazil as well as the main factors influencing species distribution during commercial fishing season.

RESULTS

Environmental parameters

Overall distribution of water temperature showed a trend of warmer waters in near shore areas, except in region 5 and 6, where bottom temperature in shallow waters (5-15) was lower then in further depths (15-20m) (Figure 2). Lower mean bottom salinity values were recorded in shallower waters, while saltier water was found in stations positioned at deeper isobaths.

Lower salinities and higher temperatures were observed in regions 1 and 2, located at southern shore of Rio Grande do Sul State (Figure 2, 3). The regions 3 and 4 represent a transitional area, where salinity increases and temperature decreases, evidenced by wide confidence intervals observed. Central and northern shores were under the influence of Tropical Water (TW) explaining higher salinity values recorded. In addition, intrusions of colder oceanic water, in central and northern shores were clearly detected when analyzing bottom water temperature and salinity contour maps (Figure 3a, 3b). Larger continuous areas of fine sediments (silt and mud) were observed in southern regions, while central and northern areas presented sparse distribution of these bottom types. In central shore, fine sediments grounds stretch from 20 meters isobaths to littoral zone as well as in southern area. Conversely, in northern shore fine sediments are distributed in deeper areas away from the coast (Figure 3c).

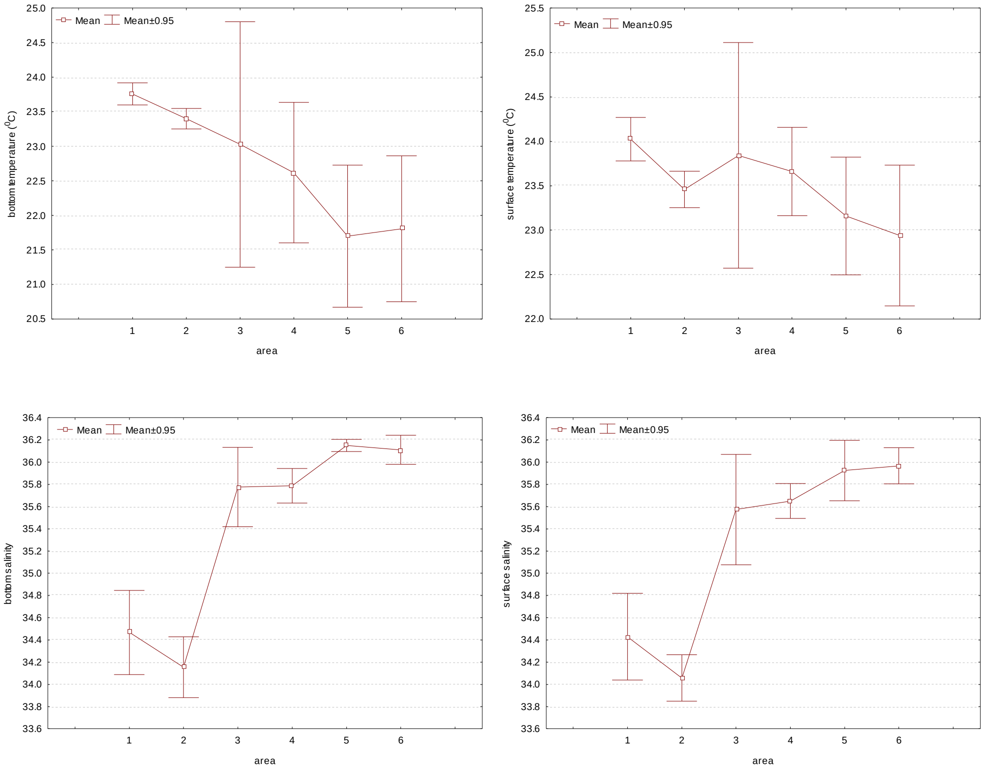

Figure 2. Trends in mean salinity and temperature (bottom and surface), recorded in Southern Brazil during summer/2005, for each of the six areas previously determined. Squares represent mean values and parallel bands the confidence intervals (95%).

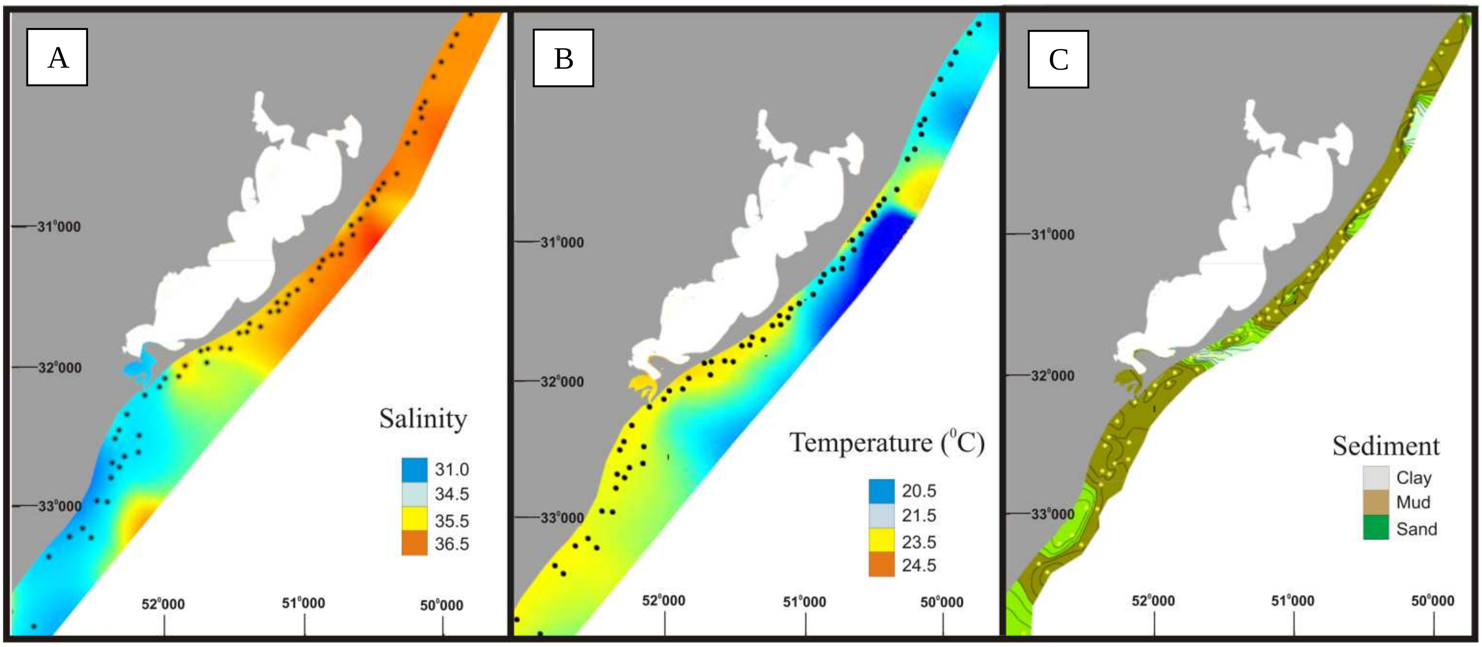

Figure 3. Contour maps of environmental parameters (A- salinity, B- temperature and C- sediment type) interpolation performed by using data collected during summer/2005 in the coast of Rio Grande do Sul, in Southern Brazil. Dots represent fishing stations where information was collected.

Distribution and abundance of the argentinean and red prawn

Artemesia longinaris and *P. muelleri* were the most abundant prawn species caught during summer, either in weight or number. Both species were captured in 86% of tows and occurred at approximately same fishing stations. A total of 513.2 kg of *A. longinaris* and 282.2 kg de *P. muelleri* were sampled during present investigation.

Mean CPUE (kg/30min) values of the argentinean prawn ranged from 0.7 in area 5 to 21.8 in area 4. Elevated densities were recorded in central shore (both areas 3 and 4) as well as in deeper areas of northern shore (area 6), composing a distinct group in post-hoc Tukey's test. Conversely, lower abundances were observed in southern region (both areas 1 and 2) as well as in shallow waters of northern region (area 5) (Table II).

Unlike *A. longinaris*, the red prawn *P. muelleri* showed a more homogenous distribution in commercial fishing grounds during summer. Mean CPUE values ranged from 1.0 in area 5 to 6.9 in area 4. Significantly higher CPUE values were observed for *P. muelleri* only in area 4, while all the other five areas were not significantly different (Table III).

Table II. *A. longinaris*. Summary of descriptive statistics obtained from mean CPUE values, containing number of stations (n), mean CPUE (kg/30min), standard deviation (s.d.), standard error (s.e.) as well as 95% confidence intervals of means. Superscript letters within brackets indicate non-significant differences between groups, estimated trough Tukey's test.

area	n	CPUE (kg/30min)	s. d.	s. e.	CI (95%)	
overall	64	8.6	20.6	2.6	3.4	13.7
$1^{(a)}$	12	0.9	0.6	0.2	0.4	1.3
$2^{(a)}$	10	3.2	2.9	0.9	1.1	5.2
$3^{(b)}$	7	8.1	14.6	5.5	-5.5	21.6
$4^{(b)}$	15	21.8	36.8	9.5	1.5	42.2
$5^{(a)}$	8	0.7	0.9	0.3	-0.1	1.4
$6^{(b)}$	12	9.7	14.7	4.3	0.4	19.1

Table III. *P. muelleri*. Summary of descriptive statistics obtained from mean CPUE values, containing number of stations (n), mean CPUE (kg/30min), standard deviation (s.d.), standard error (s.e.) as well as 95% confidence intervals of means. Superscript letters within brackets indicate non-significant differences between groups, estimated trough Tukey's test.

area	n	CPUE (kg/30min)	s. d.	s. e.	CI (95%)	
overall	64	4.3	6.0	0.8	2.8	5.8
$1^{(a)}$	12	4.7	5.6	1.6	1.1	8.2
$2^{(a)}$	10	4.5	3.2	1.0	2.2	6.8
$3^{(a)}$	7	3.7	3.3	1.2	0.7	6.7
$4^{(b)}$	15	6.9	9.5	2.4	1.7	12.2
$5^{(a)}$	8	1.0	1.9	0.7	-0.6	2.6
$6^{(a)}$	12	3.2	5.1	1.5	0.0	6.4

Multiple linear regression indicated bottom temperature as the main variable affecting relative abundance in weight (CPUE) of *A. longinaris* (B=-0.32, p=0.01, R^2=0.39), in such a way that higher densities were observed in lower temperatures. Conversely, no significant factors were estimated to explain *P. muelleri* abundance, reflecting a more homogeneous distribution of this species.

According to swept area method, and considering vulnerability of prawns to the net as 75%, an amount of 3369 tons of *A. longinaris* was estimated to be available between the isobaths of 10 and 20 meters. Assuming similar distribution of the stock in the adjacent areas (<10 and from 20 to 30), extrapolation of the values obtained, to an area stretching from 0 to 30 meters resulted in a total of 6069.02 tons for the entire fishing area covered by commercial fleet (17349.46 km^2). Area 4 yielded a total of 2421 tons presenting the highest biomass recorded during the scientific cruise. Conversely, lowest biomass was recorded in area 5 (1.9 tons) which is represented by shallow waters of northern shore (Figure 4, Table IV).

Table IV. *A. longinaris*. Summary of swept area method estimates for each of six areas in the coast of Southern Brazil, containing number of fishing stations (n), mean density (ton/km^2) and confidence intervals (CI±95%), swept area (km^2), total area (km^2) and biomass estimates (ton). Bold value at bottom right corner represents the sum of biomass obtained from six areas.

area	n	mean ton/km^2	CI (±95%)		swept area (km^2)	total area (km^2)	biomass (ton)
1	12	0.072	0.048	0.096	624.10	2292.40	165.05
2	10	0.123	0.072	0.175	403.16	3110.72	382.62
3	7	0.165	-0.107	0.438	406.18	816.51	134.72
4	15	1.149	0.026	2.271	777.28	2107.12	2421.08
5	8	0.006	0.000	0.011	533.90	332.54	2.00
6	12	0.244	0.017	0.471	490.04	884.53	215.83
sum							**3368.97**

Lower biomass of *P. muelleri* was estimated, summing a total of 2527 tons from 10 to 20m range. Extrapolation of biomass estimated to total fishing area (17349 km^2) resulted in an estimate of 4594 tons. Highest biomass was observed in area 4 (842 tons) and lower in area 5 (6.65 tons) (Table V). Unlike *A. longinaris*, this species showed elevated biomass even in the areas influenced by estuarine runoff, positioned southwards to latitude 32^{0}S (Figure 5).

Table V. *P. muelleri*. Summary of swept area method estimates for each of six areas in the coast of Southern Brazil, containing number of fishing stations (n), mean density (ton/km^2) and confidence intervals (CI±95%), swept area (km^2), total area (km^2) and biomass estimates (ton). Bold value at bottom right corner represents the sum of biomass obtained from six areas.

area	n	mean ton/km^2	CI (95%)		swept area (km^2)	total area (km^2)	Biomass (ton)
1	12	0.364	0.171	0.557	624.10	2292.40	834.87
2	10	0.227	0.118	0.336	403.16	3110.72	705.79
3	7	0.071	0.004	0.138	406.18	816.51	58.03
4	15	0.404	0.093	0.716	777.28	2107.12	851.69
5	8	0.020	-0.011	0.051	533.90	332.54	6.63
6	12	0.079	0.002	0.157	490.04	884.53	70.23
sum							**2527.23**

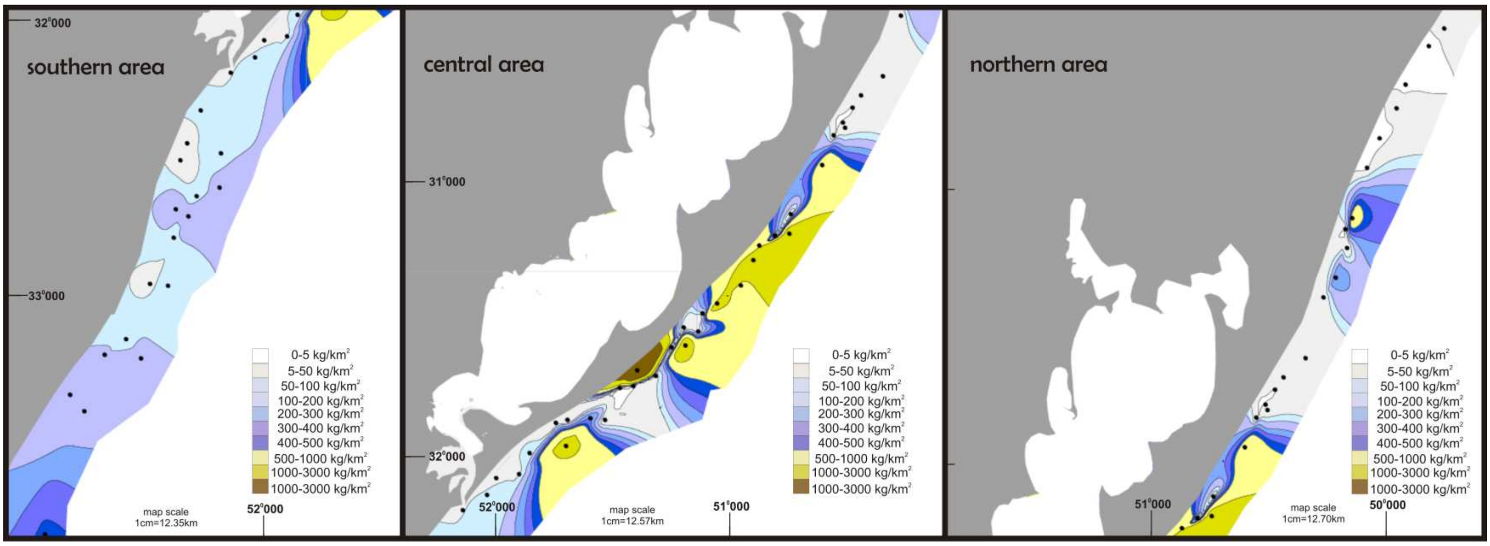

Figure 4. *A. longinaris*. Contour map showing densities of the argentinean prawn (kg/30min) in Southern Brazil during summer/2005, estimated by swept area method and considering vulnerability as 75%. Three main areas are showed (southern, central and northern) and extremes of each are overlapped.

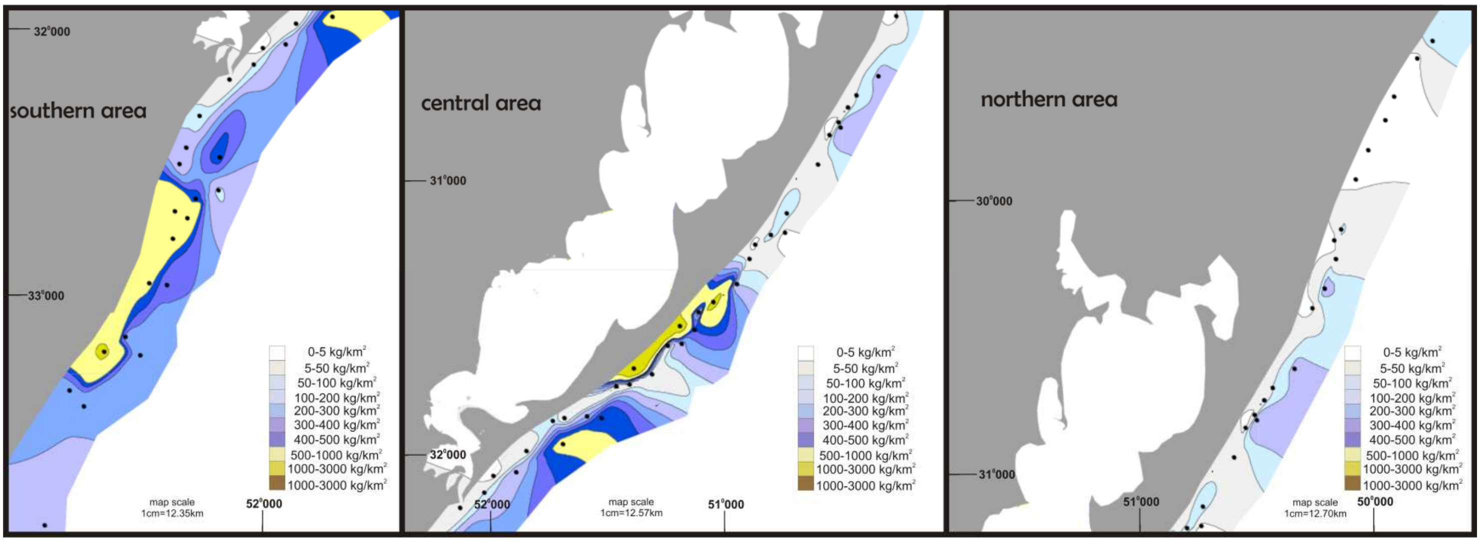

Figure 5. *P. muelleri*. Contour map showing densities of the argentinean prawn (kg/30min) in Southern Brazil during summer/2005, estimated by swept area method and considering vulnerability as 75%. Three main areas are showed (southern, central and northern) and extremes are overlapped.

Size-frequency analysis

Carapace length of argentinean prawn females ranged from 2 to 30 mm, while in males ranged from 1 to 22 mm. The red prawn, presented carapace length values that varied from 1 to 41 mm for females and males from 1 to 26 mm. Mean CL comparison pooled by sex showed significant differences ($p<0.05$), suggesting size dimorphism related to sex, that is, females are larger for both species analyzed.

Largest females of *A. longinaris* inhabit the area 6, located at deeper isobaths at northern shore of Rio Grande do Sul State. Zones 3 and 4 also showed high mean CL values, but these figures were not significantly different from the other areas (Table VI). Smallest males were found mainly in the southern region, forming a significant different group from the other regions. Accordingly to females, highest mean CL value of females was recorded in northern shore at the deeper area (area 6), but of non-significant differences was found compared to areas 5, 4 and 3 (Table VII).

Table VI. *A. longinaris* - females. Summary of descriptive statistics obtained from mean carapace length (CL), containing number of prawns measured (n), mean carapace length (CLmm), standard deviation (s.d.), standard error (s.e.) as well as 95% confidence intervals of means. Superscript letters within brackets indicate non-significant differences between groups, estimated trough Tukey's test.

area	n	mean CL (mm)	s.d.	s.e.	CI (±95%)	
overall	1763	15.07	3.63	0.09	14.90	15.24
$1^{(a)}$	264	13.09	1.62	0.10	12.89	13.29
$2^{(a)}$	30	13.17	1.34	0.24	12.67	13.67
$3^{(a)}$	344	15.36	3.42	0.18	14.99	15.72
$4^{(a)}$	606	15.13	3.68	0.15	14.83	15.42
$5^{(a)}$	192	14.34	3.83	0.28	13.80	14.89
$6^{(b)}$	327	16.86	3.98	0.22	16.42	17.29

Table VII. *A. longinaris* - males. Summary of descriptive statistics obtained from mean CPUE values, containing number of prawns measured (n), mean carapace length (CLmm), standard deviation (s.d.), standard error (s.e.) as well as 95% confidence intervals of means. Superscript letters within brackets indicate non-significant differences between groups, estimated trough Tukey's test.

area	n	mean CL (mm)	s.d	s.e	CI (±95%)	
overall	1049	13.07	2.26	0.07	12.93	13.21
$1^{(a)}$	123	11.69	1.13	0.10	11.49	11.89
$2^{(a)}$	32	11.74	0.98	0.17	11.39	12.09
$3^{(b)}$	170	12.98	2.19	0.17	12.65	13.31
$4^{(b)}$	533	13.46	2.21	0.10	13.27	13.64
$5^{(b)}$	93	12.89	2.89	0.30	12.29	13.49
$6^{(b)}$	98	13.48	2.46	0.25	12.99	13.98

Significant larger mean sizes of the red prawn females were detected in zones 2 and 6, while smaller ones were located at zone 3, corresponding to shallower waters in central shore. (Table VIII). Males from area 4 were significantly larger than the rest of regions, followed by those from area 2 (Table IX). Except by the pattern of higher mean CL recorded in shallower waters of central region observed for *A. longinaris* females, all the other regions that presented larger individuals, of both sexes and species, were concentrated in deeper areas.

Table VIII. *P. muelleri* - females. Summary of descriptive statistics obtained from mean CPUE values, containing number of prawns measured (n), mean carapace length (CLmm), standard deviation (s.d.), standard error (s.e.) as well as 95% confidence intervals of means. Superscript letters within brackets indicate non-significant differences between groups, estimated trough Tukey's test.

area	n	mean CL (mm)	s.d.	s.e.	CI (±95%)	
overall	1443	17.75	5.07	0.13	17.49	18.01
1$^{(a)}$	291	17.11	3.76	0.22	16.68	17.55
2$^{(b)}$	66	18.37	3.04	0.37	17.62	19.11
3$^{(c)}$	209	15.20	2.77	0.19	14.82	15.58
4$^{(a)}$	395	17.52	4.51	0.23	17.08	17.97
5$^{(a)}$	114	17.21	3.32	0.31	16.59	17.82
6$^{(b)}$	368	20.01	7.03	0.37	19.29	20.73

Table IX. *P. muelleri* - males. Summary of descriptive statistics obtained from mean CPUE values, containing number of prawns measured (n), mean carapace length (CLmm), standard deviation (s.d), standard error (s.e.) as well as 95% confidence intervals of means. Superscript letters within brackets indicate non-significant differences between groups, estimated trough Tukey's test.

area	n	mean CL (mm)	s.d	s.e	CI (±95%)	
overall	781	15.53	2.75	0.10	15.34	15.72
1(a)	204	15.10	2.56	0.18	14.75	15.46
2(a)	60	15.89	2.45	0.32	15.26	16.52
3(a)	114	14.44	1.97	0.18	14.07	14.81
4(b)	192	16.64	2.67	0.19	16.26	17.02
5(a)	42	15.43	3.13	0.48	14.45	16.40
6(a)	169	15.43	3.07	0.24	14.96	15.89

Comparison of percentage of *A. longinaris* megaspawners, between six areas analyzed, also showed higher frequency in deeper areas, suggesting spawning activity. Frequency of megaspawners, was higher in area 6, and showed an increasing pattern from southern to northern region. Conversely, *P. muelleri* presented higher percentage of megaspawners in southern region, under the influence of estuarine runoff. This species also showed a high frequency of megaspawners in region six as well as *A. longinaris* (Figure 5).

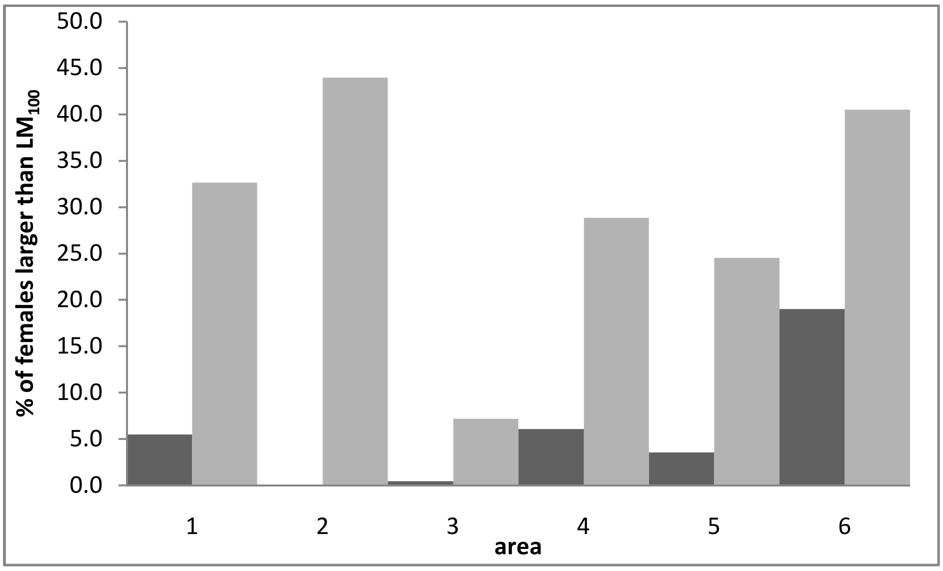

Figure 5. Relative frequency of *A. longinaris* (dark bars) and *P. muelleri* (light bars) megaspawners (females larger than LM_{100}) per area in southern coast of Brazil.

DISCUSSION

Environmental parameters

Trends in temperature and salinity followed the same pattern as observed in other coastal areas where *A. longinaris* and *P. muelleri* were investigated (Boschi, 1969; Costa *et al*., 2005), with lower temperatures in deeper waters and lower salinities nearshore. It is also possible to observe that the southern region is influenced by Coastal Water (CW) (Vooren *et al*., 2005), highly affected by Patos Lagoon and La Plata River runoff (Piola *et al*., 2004, 2005), resulting in higher temperatures and lower salinities.

Another important oceanographic feature observed was the intrusion of colder waters from depths further than 30 m, influencing deeper areas in central and northern shores of Rio Grande do Sul coast. The occurrence of this phenomenon is linked to summer resurgences over the Southern Brazil continental shelf. Upcoming of oceanic water during summer is explained by predominant northeast wind that pushes surface water offshore resulting in resurgence of colder and saltier oceanic waters (Garcia, 1996).

Distribution and abundance

Environment factors determine to a large extent the abundance and distribution of prawn populations (Gulland and Rotschild, 1981). Both prawn species analyzed showed same general environmental requirements (Costa *et al*., 2004; *Costa et al*., 2005), since they occurred at approximately same fishing stations. In spite of that, *P. muelleri* showed a more homogeneous distribution than *A. longinaris*, tolerating areas of lower salinities and higher temperatures in southern shore of Rio Grande do Sul. High level of scattering around mean abundance values suggests patchy distribution for both species, concentrating elevated abundances in areas where environmental conditions are favorable.

The abundance of *A. longinaris* was partially explained by water temperature, presenting a clear preference for areas where lower values for this parameter were recorded. Same pattern was observed by Costa *et al*. (2005) in Southeastern Brazil (São Paulo), with higher abundances linked to intrusion of colder and saltier oceanic waters. This species has a life cycle where adult females migrate to further depths for spawning (Boschi, 1969; Dumont and D'Incao, manuscript) and ontogenetic development is entirely completed in marine waters (Dall *et al*., 1990), explaining the affinity for deeper areas.

Additionally to the influence of temperature and salinity, the distribution pattern was also influenced by sediment type, in such a way that fine granulometry sites provide suitable grounds for this species (Costa *et al*., 2005), which is also verified for other penaeid species in literature (Gulland and Rotschild, 1981; Somers, 1987). The importance of sediment type for distribution of both species is more clearly noticed when analyzing the abundance in shallow waters of northern shore. Salinity and temperature are favorable in this area, however the relative abundance of both species was the lowest. A likely explanation for this observation is the consolidated sandy bottom registered in this region, which may prevent prawns from entering this area.

Baptista-Metri (2007) analyzed relative abundance of *A. longinaris* and *P. muelleri* in the coast of Rio Grande do Sul, identifying two main areas where densities of these species are the highest. The first area coincides with a soft bottom (mud) observed in southern shore (areas 1 and 2), where *P. muelleri* was very abundant. High densities of prawns were also associated to soft bottoms (mud and clay) in central and northern shores, especially in areas between 15 and 20 meters, agreeing with previous reports on distribution of these species during commercial fishery season (Baptista-Metri, 2007).

Maximum sustainable yields (MSY) suggested for *A. longinaris* is 3579 ton/year (Baptista-Metri, 2007). This volume of catch represents 77% of biomass estimated during the investigation cruise analyzed, which may represent an excessive fishing mortality for the stock even if trends in biomass occurs along the main fishing season. Mean annual catches of this species is 2700 tons (Valentini, 2005), however, reductions in landings during the last few years may indicate first signs of excessive fishing effort. The combination of elevated fishing mortality with adverse environment conditions may lead to recruitment overfishing if spawning stock is drastically reduced (Dumont and D'Incao, manuscript).

Additionally, patchy distribution of the stock results in intense fishing effort extremely concentrated in areas where abundance is high. During present scientific cruise a great concentration of prawn trawlers was observed in areas 3 and 4 (Dumont, *personal observation*), coinciding with most abundant areas. As a result of that, fishing effort can remove great amounts of prawn in a short time period. Similarly, maximum sustainable yield suggested for *P. muelleri* (4447 ton/year) (Baptista-Metri, 2007) may be excessive, especially during seasons of adverse environment conditions. Assuming that stable biomass is maintained during commercial fishing season, the MSY reported would remove approximately 97% of biomass estimated resulting in total depletion of the stock. It is important to point out that this resource is also fished in Santa Catarina state and biomass estimates comprise only the stock inhabiting Rio Grande do Sul coast, resulting in an underestimated biomass of prawns. However, most of the catch is obtained from Rio Grande do Sul Coast and only landed in Santa Catarina (Baptista-Metri, 2007), indicating that for stock assessment purposes, biomass sustaining the fishery is located at Rio Grande do Sul coast.

It is also important to point out that vulnerability adopted may not exactly reflect the real value. Additionally, different species may present distinct catchability to prawn nets, related to behavior (e.g. burrowing or swimming habits) and environment parameters (e.g. turbidity and temperature) (Garcia and Le Reste, 1981). Therefore, values obtained must be taken as rough approximations, since vulnerability coefficient to trawl nets adopted was an intermediate value suggested by King (1997) that range from 50% to 100%. Vulnerability suggested for other crustaceans such as hermit crabs is 51% (Reiss *et al*., 2005) and therefore, vulnerability adopted may represent a coherent value for prawns.

Length distribution obtained from catches of *A. longinaris* indicate that smaller prawns of both sexes tend to inhabit lower salinity areas, under the influence of estuarine runoff, while largest females were mainly found in deeper areas where salinity is higher and temperature is lower. As previously discussed, marine prawns (life cycle type III according to Dall *et al*., 1990) tend to migrate offshore for complete ovarian development and spawning (Garcia and Le Reste, 1981). Mating also seems to occur in spawning areas, since larger males were found concurrently with larger females. Percentage of megaspawners also suggests a more intense spawning activity in deeper areas, mainly in northern shore where the salinity was higher.

Conversely, *P. muelleri* also presented an important density of large females and males inhabiting the southern areas under the influence of estuarine runoff. Greater tolerance to lower salinity of this species was confirmed by the important abundance of large individuals and frequency of megaspawners in southern areas. Nevertheless, the deeper area in central region concentrated higher densities of this species. If on one hand both prawn species analyzed presented similar environment requirements, on the other, competition seems to play an important role on distribution, which may explain the more homogenous distribution of *P. muelleri*, searching for alternative spawning areas.

Briefly, distribution of both species analyzed is patchy and related to environmental variations such as those caused by summer ressurgence, making fishing effort intense and concentrated on relatively small areas. For instance, 77% of total biomass estimated for *A. longinaris* was restricted to 12% of total area available for prawn trawling, demanding a regulation in fishing effort applied. The use of try nets aggravates this problem since cost for searching for schools is reduced and main fishing grounds do not show remarkable yearly variations (Baptista-Metri, 2007), which was confirmed by the large number of boats observed in fishing in areas of highest abundance during the present investigation.

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