

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

**ESTRUTURA DA ASSEMBLEIA DE PEIXES DA
ZONA DE ARREBENTANÇA DAS PRAIAS
ARENOSAS ADJACENTES AO ESTUÁRIO DA
LAGOA DOS PATOS (RS): EFEITOS
AMBIENTAIS E DO AMOSTRADOR.**

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

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**RIO GRANDE
Dezembro, 2012**

Para minha família.

AGRADECIMENTOS

Ao Prof. Dr. João P. Veira por todos os ensinamentos passados ao longo de todos estes anos (que são muitos!), pela amizade e compreensão.

Aos membros da banca de acompanhamento (Dr. José H. Muelbert, Dr. Lauro J. Calliari, Dr. Carlos E. Bemvenuti e por último e não menos importante Dr. Leonardo E. Moraes), que com suas críticas e sugestões, engrandeceram esta Tese e foram fundamentais nesta jornada.

Ao Prof. Dr. Henrique N. Cabral, pela disponibilidade em me receber em Lisboa e pelos ensinamentos passados ao longo da minha estadia em Portugal.

Ao Prof. Dr. Cassiano Monteiro-Neto, por mais uma vez colaborar para o meu crescimento profissional.

A CAPES pelo financiamento (bolsa de doutoramento e estágio no exterior).

A “Verinha” e ao Prof. Eduardo R. Secchi pela atenção durante as minhas necessidades junto a CORCUR.

A todos os amigos do Laboratório de Ictiologia pelos inúmeros momentos de discussão e descontração.

A todos os demais amigos espalhados pela Base Oceanográfica!

Aos demais professores que participaram desta etapa da minha vida profissional, seja ministrando disciplinas ou durante as muitas discussões sobre ciência.

Aos motoristas da FURG que também participaram de forma ativa, desta empreitada.

Aos meus amigos fora do eixo-FURG.

A “equipa” de Portugal que muito me ajudou em *terras além mar*.

Aos peixes.

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RESUMO

O objetivo desta Tese foi estudar a assembleia de peixes da zona de arrebenção de duas praias arenosas, adjacentes aos molhes da barra da Lagoa dos Patos, com relação: i) a variabilidade espacial na riqueza e na abundância da assembleia de peixes; ii) a influência dos molhes sobre a abundância e diversidade de peixes; iii) o uso de diferentes amostradores para avaliar a influência na composição de espécies, riqueza e estrutura de tamanhos; e iv) possíveis variações interanuais na composição e abundância da assembleia de peixes destas praias. Para tanto, analisou-se um banco de dados de coletas mensais contínuas, para um período de 12 meses (Maio 2001 a Maio 2002) e um segundo período de 24 meses (Julho 2009 a Junho 2011), usando diversos petrechos de pesca. Os principais resultados obtidos indicam um forte padrão sazonal influenciando no aumento da abundância e da riqueza de espécies presentes na zona de arrebenção durante os meses mais quentes, e que os molhes da barra da Lagoa dos Patos não promove mudanças espaciais na composição de espécies, em ambas as praias. A diferença entre as praias está mais relacionada à abundância de algumas espécies, como por exemplo, a tainha *Mugil liza*, que é significativamente mais abundante na praia do Cassino, associada, fundamentalmente à dispersão da pluma estuarina que é mais intensa no lado oeste dos molhes. Com relação à comparação entre redes de arrasto de praia, observou-se que ambas as redes utilizadas (9 e 30 m) podem ser consideradas complementares em relação a distribuição de tamanhos, pois capturam a mesma composição de espécies dominantes, mas com a rede maior capturando uma grande parcela de indivíduos maiores que 60 mm de comprimento total. A rede de espera (feiticeira) não foi considerada um bom amostrador para o uso na zona de arrebenção, mas pode ser usada como um amostrador complementar para capturar indivíduos com tamanhos maiores. A variabilidade na riqueza de espécies foi explicada por um conjunto de sete variáveis, sendo que a sazonalidade e o tipo de rede de arrasto de praia usada foram às variáveis que detiveram a maior parcela de variabilidade (19,2%). Dentre as espécies dominantes nos dois períodos analisados, *M. liza*, *Trachinotus marginatus*, *Menticirrhus littoralis* e *M. americanus* registraram uma significativa queda na abundância média ao longo dos períodos, sendo esta atribuída principalmente à variabilidade natural no recrutamento destas espécies e/ou a forte pressão de pesca

exercida sobre estas espécies ao longo dos últimos anos. No entanto, com relação à última parte desta Tese, análise mais criteriosa deve ser realizada.

Palavras-chave: sazonalidade, diferentes amostradores, modelos lineares generalizados, mudança interanual, Atlântico sudoeste

ABSTRACT

The aim of this Thesis was to study the surf zone fish assemblage from two sandy beaches adjacent to the Patos Lagoon jetties (Cassino in the west side and Mar Grosso in the east side), with respect to: i) the variability of fish assemblages richness and abundance; ii) the influence of the jetties on fish abundance and diversity; iii) the influence of the use of different sampling gears to assess fish species composition, richness and size structure; and, iv) possible interannual changes in fish assemblage composition and abundance between those two beaches. Thus, we analyzed a dataset of monthly collections for period of 12 months (May 2001 to May 2002) and 24 months (July 2009 to June 2011), using a diverse set of sampling gear. The main results indicate a strong seasonal pattern influencing the increase of fish abundance and species richness during the warmer months, and that there is no direct influence of Patos Lagoon jetties on species composition, at both beaches. Nevertheless, the difference between the beaches is more related to the abundance of some species, such as the mullet *Mugil liza*, which is significantly more abundant in Cassino Beach and, mainly associated with the estuarine plume that is more intense on the west side of the jetties. In relation with beach seine net comparison, we observed that both gears used (9 to 30 m) can be viewed as complementary, once they capture the same dominant species, with the largest net capturing more individuals greater than 60 mm total length. The other sampling gear tested (trammel net) was not considered a good sampler for surf zone area, but can be used as a complementary sampler to capture additional individuals with larger sizes. The variability in species richness was explained by a set of seven variables, and seasonality and type of beach seine used were the variables accounting for the largest share of variability (19.2%). Among the dominant species caught in both periods analyzed, *M. liza*, *Trachinotus marginatus*, *Menticirrhus littoralis* and *M. americanus* showed a significant decrease in average abundance over the periods. This drop in abundance may be attributed to natural variability in the recruitment of these species and/or the increase in fishing pressure over the last few years. However, with respect to the last part of this Thesis, more careful analysis should be done.

Key words: seasonality, different sampling gears, generalized linear models, interannual changes, southwest Atlantic

Prefácio

Esta Tese de Doutorado foi estruturada conforme o modelo alternativo, proposto pelo Programa de Pós-Graduação em Oceanografia Biológica. Na primeira parte do trabalho, redigida em português, são apresentados aspectos gerais da introdução, metodologia, resultados e conclusões. A segunda parte consta de quatro manuscritos, três em inglês (um aceito para publicação, um submetido conforme parecer interno da banca avaliadora e outro inédito) e um quarto, também inédito, em português. Cada manuscrito possui objetivos específicos e está estruturado de forma independente, conforme modelo proposto pelo periódico onde ele foi ou será submetido. O conteúdo destes manuscritos é complementar, e em conjunto, atendem aos objetivos científicos desta Tese.

1. INTRODUÇÃO GERAL

As praias arenosas marinhas são encontradas ao longo da linha de costa de regiões tropicais, subtropicais e temperadas, constituindo uma importante área de recreação, além de abrigar uma grande variedade de recursos naturais, tais como moluscos, crustáceos e peixes. Este habitat ocupa uma posição de interface entre o continente e o oceano, e devido a sua capacidade de absorver a energia de onda, constitui-se em um dos ambientes mais dinâmicos da linha de costa. A zona de arrebentação destas praias é considerada um ecossistema semifechado e auto-sustentável, onde existe uma contínua, porém variável troca de água e nutrientes entre a parte rasa (zona de arrebentação) e as águas mais profundas (*offshore*) (McLachlan e Brown 2006).

Os principais parâmetros físicos atuantes nas praias arenosas são a ação das ondas e do vento, das correntes marinhas costeiras (*longshore currents*, *rip currents*, *undertow* e *set up*), e das marés (Calliari et al. 2003, Veloso e Neves 2009); sendo que cada um destes fatores influencia de forma direta a morfodinâmica da praia. As praias arenosas podem ser classificadas em três tipos (dissipativas, intermediárias e refletivas) com características distintas, e que de certa forma ditam a estrutura e composição de espécies presentes nestes ambientes (Short 1999). Praias dissipativas como as da área de estudo, apresentam uma zona de arrebentação larga e com um baixo gradiente topográfico, onde a energia de onda é transformada em “*set up*” (subida do nível médio do mar) e fluxos de correntes de retorno (*rip currents*), os quais podem ocorrer devido a variações espaciais na altura da arrebentação (Calliari et al. 2003).

Embora considerados ambientes com uma baixa complexidade de habitats e elevada hidrodinâmica, a zona de arrebentação é tida como uma importante área de criação, alimentação e recrutamento para inúmeras espécies de peixes, atuando como rota de passagem e/ou habitat para larvas e juvenis de algumas espécies (p. ex. Harris et al. 1999, Patrick e Strydom 2008, Sato et al. 2008). No entanto, se comparada com outros ambientes marinhos e costeiros (p. ex. estuários, manguezais e recifes de corais) a zona de arrebentação de praias arenosas apresenta uma menor diversidade de peixes, com poucas espécies dominantes e aptas a viverem parte do seu ciclo de vida neste ambiente (McLachlan e Brown 2006).

Os fatores físicos são os principais controladores da abundância e da distribuição da fauna presente na zona de arrebentação (Schoeman et al. 2000); no entanto, as interações bióticas (p. ex. disponibilidade alimentar, predação, competição, áreas de desova) também exercem uma forte influência sobre o uso da zona de

arrebentação, pelas espécies de peixes (Vasconcellos et al. 2010). Neste sentido, a grande maioria dos estudos relacionados à assembleia de peixes da zona de arrebentação de praias arenosas têm concentrado seus esforços em abordar variações diárias e sazonais na estrutura da assembleia (p. ex. Monteiro-Neto et al. 2003, Pessanha et al. 2003, Nanami e Endo 2007, Gaelzer e Zalmon 2008, Vasconcellos et al. 2011,), variações espaço-temporais (p. ex. Clark et al. 1996, Lima e Vieira 2009, Hackradt et al. 2011, Jarrin e Shanks 2011), estrutura trófica (p. ex. Monteiro-Neto e Cunha 1990, Rodrigues e Vieira 2010, Niang et al. 2010, Bergamino et al. 2011) e a influência de variáveis físicas (p. ex. Gibson et al. 1993, Layman et al. 2000, Beyst et al. 2002, Vasconcellos 2007, Inoue et al. 2008, Inui et al. 2010). No entanto, estudos abordando a reação da ictiofauna em razão de obstruções físicas dispostas no ambiente praiial (p. ex. quebra-mar, molhes; ver Cenci et al. 2011, Mikami et al. 2012), e a comparação do uso de diferentes amostradores (ver Prestelo & Monteiro-Neto *in press*), como forma de obter uma ampla visão do comportamento e da estrutura da assembleia de peixes presente neste ambiente tão dinâmico, ainda são escassos.

De fato, a grande maioria dos trabalhos realizados na zona de arrebentação de praias arenosas utiliza somente um tipo de rede de arrasto de praia (amostrador) para coletar a assembleia de peixes presente neste ambiente, porém com variados comprimentos e tamanhos de malha (p. ex. Clark 1997, Layman 2000, Wilber et al. 2003). Neste sentido, pode-se estar observando somente uma parcela da estrutura da assembleia de peixes, assim, informações a respeito de outras espécies e outros papéis ecológicos, podem estar sendo perdidas. Além do mais, pode-se estar subestimando a real estrutura de tamanhos da assembleia de peixes da zona de arrebentação, visto que redes pequenas e com malhas de menor tamanho, capturam na sua grande maioria,

(Rodrigues e Vieira 2012), podem não estar capturando indivíduos maiores e de natação mais rápida (Říha et al. 2008).

Por ser área de criação e rota de passagem de algumas espécies que buscam o estuário para o seu desenvolvimento, este ambiente pode estar sendo frequentado esporadicamente por indivíduos maiores e que seriam favorecidos pela rica fonte de presas, tais como a elevada abundância de peixes juvenis (p. ex. Monteiro-Neto et al. 2003, Lima e Vieira 2009, Rodrigues e Vieira 2012) e de macroinvertebrados bentônicos (Neves et al. 2008). De fato, sabe-se que a zona de arrebentação não é frequentada somente por peixes juvenis de menores tamanhos, visto que exemplares subadultos e adultos de determinadas espécies são pescados em determinadas épocas do ano, ao longo de todo o litoral do Rio Grande do Sul, sustentando uma considerável pesca amadora e artesanal (Peres & Klippel 2005; Klippel et al. 2005).

Com base neste contexto, estão fundamentados os três primeiros capítulos desta Tese, que de uma forma geral, visam: i) avaliar a influência dos molhes da barra do estuário da Lagoa dos Patos, na composição e abundância da assembleia de peixes das praias do Cassino e do Mar Grosso (ANEXO I); ii) comparar a eficácia do uso de três diferentes tipos de amostradores, em obter um retrato fidedigno da assembleia de peixes da zona de arrebentação destas praias (ANEXO II); e iii) avaliar a variabilidade da assembleia de peixes das praias do Cassino e do Mar Grosso, frente a um conjunto de variáveis explanatórias, além de comparar a estrutura de tamanhos e abundância relativa dos juvenis das duas espécies dominantes em ambas as praias, a tainha *M. liza* e o pampo *Trachinotus marginatus* (ANEXO III).

Por outro lado, além da análise da relação causa/efeito entre as variáveis abióticas e bióticas na estruturação da assembleia de peixes da zona de arrebentação,

recentemente, grande atenção tem sido dada para os impactos antrópicos diretos (aumento da poluição orgânica, obras costeiras, uso recreativo, aumento da pressão de pesca) e indiretos (mudanças climáticas) nas praias arenosas (Defeo et al. 2009). Neste sentido, tem-se buscado analisar séries de dados composta por mais de um ano de dados coletados (séries temporais), a fim de se identificar padrões e tendências, que poderiam estar sendo detectados quando estudados somente períodos curtos (p. ex. 12 meses). Sendo assim, e considerando a importância da zona de arrebentação como área de criação e alimentação (McLachlan e Brown 2006), assim como rota de passagem para muitas espécies de peixes marinhos costeiros em conexão com sistemas estuarinos (Able et al. 2011), e que apresentam uma considerável importância econômica para a região (p. ex. *M. liza*, *T. marginatus*, *Menticirrhus americanus* e *M. littoralis*), buscou-se avaliar possíveis variações interanuais na composição e abundância da assembleia de peixes da zona de arrebentação das praias em estudo, além de identificar os fatores que podem estar influenciando nestas possíveis variações (ANEXO IV).

1.1. Objetivo geral

Analisar a estrutura da assembleia de peixes da zona de arrebentação das praias arenosas adjacentes ao estuário da Lagoa dos Patos, a fim de identificar influências de variáveis ambientais e de uso de diferentes amostradores sobre a ictiofauna, bem como identificar mudanças na composição de espécies e abundância, ao longo dos anos.

1.1.1 Objetivos específicos

Objetivo 1 (ANEXO I):

1) Testar a hipótese de que a presença dos molhes da barra da Lagoa dos Patos, impõe diferenças na composição de espécies e na abundância da ictiofauna entre as praias do Cassino (abrigada) e Mar Grosso (exposta);

2) Descrever e comparar a estrutura da comunidade de ambas as praias, identificando possíveis correlações entre a temperatura e a salinidade da água em superfície, e transparência da coluna d'água, na estrutura da assembleia de peixes.

Objetivo 2 (ANEXO II)

1) Comparar a eficácia de três amostradores distintos, para o julgamento prévio, da composição de espécies presente na zona de arrebentação das praias arenosas adjacentes ao estuário da Lagoa dos Patos;

2) Testar a hipótese de que o uso de diferentes amostradores, em estudos de ecologia de peixes da zona de arrebentação de praias arenosas, pode apresentar diferentes resultados dos padrões observados.

Objetivo 3 (ANEXO III)

1) Avaliar os padrões de variabilidade da assembleia de peixes de duas praias arenosas, usando um conjunto de variáveis ambientais para explicar os padrões encontrados;

2) Comparar a abundância relativa e a estrutura de tamanhos de *Mugil liza* e *Trachinotus marginatus*, na zona de arrebentação de ambas as praias.

Objetivo 4 (ANEXO IV)

- 1) Testar a hipótese de que a pressão de fatores naturais e/ou antrópicos podem estar afetando a composição de espécies e abundância da ictiofauna da zona de arrebenção das praias em estudo;
- 2) Identificar as variáveis que influenciam nas variações interanuais da assembleia de peixes da zona de arrebenção.

2. MATERIAL E MÉTODOS

2.1. Área de estudo

A área de estudo compreendeu um trecho de aproximadamente 24 km de cada lado dos molhes do Estuário da Lagoa dos Patos (ELP), representados pelas praias do Cassino e do Mar Grosso, localizadas na porção sul do Rio Grande do Sul (RS) (Figura 1). A região é fortemente influenciada pela ação de ondas e as praias possuem sedimentos variando de muito fino a médio (Siegle e Calliari 2008), com ambos os trechos estudados, classificados como praias dissipativas (Pereira et al. 2010). Com relação à morfologia, a porção submersa apresenta múltiplos bancos arenosos paralelos à linha de praia (Pereira et al. 2011), o que possibilita a quebra das ondas com diferentes alturas e energia, na medida em que a ondulação se desloca em direção a costa.

O principal fator regulador da hidrodinâmica na região costeira e na zona de arrebenção do RS é o vento. O vento tem forte influência no transporte de areia na região costeira (das dunas para a parte submersa da zona de arrebenção e vice-versa), influencia na ascensão e abaixamento do nível do mar na linha de praia, e na formação e intensidade das ondas que quebram na zona de arrebenção, além de influenciar no transporte de sedimentos muito finos para a zona de arrebenção. Como exemplo, os ventos predominantes de nordeste (NE) direcionam a pluma do ELP para a direção sul

(Cassino) e em consequência disto, sedimentos muito finos são transportados para o sul e depositados na zona de arrebentação externa, na forma de lama fluída (Calliari et al. 2000). Durante fortes tempestades (p. ex. passagem de frentes frias) e elevada incidência de ventos do quadrante sul (principalmente sudoeste), esta lama fluída pode ser retrabalhada e transportada para a zona de arrebentação, atenuando a energia de onda (Calliari et al. 2007). Embora na praia do Mar Grosso não haja registros de depósito de lama na zona de arrebentação, sedimentos lamosos ocorrem em ambos os lados dos molhes (Calliari et al. 2000).

2.2. Amostragem

O banco de dados analisado neste trabalho provém de amostragens biológicas realizadas durante três períodos distintos. O período-I compreendeu amostragens pretéritas (Maio-2001 a Maio-2002), em dois pontos situados na praia do Cassino (P2-P3) e no Mar Grosso (P4-P5), enquanto que no período-II (Julho-2009 a Junho-2010) e III (Julho-2010 a Junho-2011), as amostragens foram realizadas nos mesmos pontos previamente amostrados no passado, porém foram adicionados mais dois pontos extremos, um em cada praia (P1 no Cassino e P6 no Mar Grosso) (Figura 1). Em todos os períodos, as saídas de campo ocorreram mensalmente, onde eram realizadas amostragens biológicas (coleta de peixes) e registro de dados abióticos (variáveis ambientais) explicitados em cada um dos anexos. Em cada um dos estudos, a metodologia de coleta está descrita de forma completa e reflete o objetivo de cada estudo, no entanto, uma descrição geral dos materiais usados, é feita a seguir.

Para a coleta dos peixes foram utilizados três petrechos de pesca distintos, onde a rede “picaré” foi utilizada em todos os estudos, a rede “cerco” foi utilizada nos

estudos II e III, e a rede de espera foi utilizada somente no estudo II. As redes de arrasto de praia são amostradores ativos (vão ao encontro dos peixes), enquanto que a rede de espera é um amostrador passivo (fica parada a espera que o peixe a encontre e seja capturado). A seguir há uma descrição dos petrechos de pesca utilizados.

Rede “picaré” (denominada de BS-9m; *beach seine*): é uma rede de arrasto de praia com 9 m de comprimento por 1,5 m de altura e confeccionada com malha multifilamento de 13 mm nas asas (3 m cada) e 5 mm no pano central (3 m). A rede era operada por duas pessoas e cada arrasto era feito perpendicular a linha de praia, em profundidade inferior a 1,5 m.

Rede “cerco” (denominada de BS-30m; *beach seine*): é uma rede de arrasto de praia, porém com 30 m de comprimento por 1,8 m de altura, confeccionada em nylon monofilamento com malha uniforme de 12 mm entrenós opostos. No entanto, ao longo de toda a porção inferior da rede (entre o pano principal e a tralha inferior) costurou-se uma barra de 30 cm de altura com malha 12 mm multifilamento, cuja finalidade era dar mais resistência à rede e evitar que a captura de crustáceos (principalmente siris do gênero *Callinectes*) danificasse as malhas da rede e interferisse na operação de arrasto, causando um vício no resultado final. A rede era operada por duas pessoas e cada arrasto era feito na forma de um semicírculo (cerco) em profundidade inferior a 1,5 m. Uma pessoa ficava com um calão em profundidade entre 0,5 – 1,0 m, enquanto que a outra pessoa entrava mar adentro com o outro calão e soltava a rede aos poucos, fazendo um semicírculo e arrastando até a praia.

Rede “feiticeira” (denominada de TN-25m; *trammel net*): é uma rede de espera toda confeccionada com nylon monofilamento e com 25 m de comprimento por 2,5 m de altura e possui três painéis, sendo o painel central com malha 35 mm e os

dois painéis externos com malha 150 mm, entrenós opostos. Em cada um dos pontos de coleta era usado um conjunto de três redes, que eram colocadas em posição perpendicular a linha de praia (operando contra a corrente) e com uma distância de aproximadamente 100 m entre si. Cada rede era fixada na zona de arrebentação por meio de um sistema de cabos e estacas (calões) cravadas na areia, onde uma das extremidades era presa por um cabo a uma estaca fixada na beira da praia, enquanto que a outra extremidade era fixada em outra estaca mar adentro, em profundidade de até 2,0 m, dependendo da variação de mar. Como é um amostrador passivo, que conta com a probabilidade do peixe encontrar a rede e ficar retido. O tempo de permanência da rede operando era de até 6 horas.

Todos os peixes capturados com as redes de arrasto eram colocados em sacos plásticos contendo formalina 10%, enquanto que os peixes capturados com a rede de espera eram colocados em caixas térmicas contendo gelo. No Laboratório de Ictiologia (IO/FURG) todos os exemplares capturados eram identificados ao menor nível taxonômico possível com o auxílio de guias de identificação, medidos (comprimento total em mm) e pesados (g).

As variáveis ambientais utilizadas nas análises foram obtidas simultaneamente as amostragens biológicas e detalhadas em cada estudo. As variáveis registradas foram: temperatura da água em superfície com um termômetro (°C); transparência obtida com disco de Secchi (m); salinidade em superfície com refratômetro; velocidade do vento (medida com um anemômetro digital portátil Instrutherm AD-250); direção do vento (registrada com o auxílio de um GPS Garmin *eTrex*); número de linhas de arrebentação (medida de forma visual e com uma escala de 0 a 6 linhas); altura da onda antes de

quebrar (medida de forma visual) e a direção da corrente litorânea (medida de forma visual).

2.3. *Análise de dados*

A análise de dados empregada neste estudo segue em linhas gerais, o objetivo de cada estudo, sendo descritas as principais análises empregadas na obtenção dos resultados.

Inicialmente, para todos os estudos, procurou-se identificar as espécies frequentes e abundantes, por meio da sua importância relativa (Garcia et al. 2001, Artioli et al. 2009, Mont'Alverne et al. 2012). Esta abordagem permite identificar o comportamento das espécies no ambiente, com relação à ocorrência e a abundância. Neste caso, a importância das espécies dominantes foi calculada com base na média das frequências numérica (N%) e de ocorrência (FO%). Desta forma, as espécies foram classificadas em: frequente e abundante (quando N% e FO% de cada espécie estiveram acima da média), não frequente e abundante (quando apenas N% de cada espécie esteve acima da média), frequente e pouco abundante (quando apenas FO% de cada espécie esteve acima da média), presente (quando N% e FO% estiveram abaixo da média) e ausente (quando a espécie não foi capturada). Com exceção do Anexo II, os dados de abundância e CPUE foram transformados [$\text{Log}_{10}(X+1)$], para atingir os pressupostos das análises propostas.

A similaridade na composição de espécies (quer entre praias – Anexo I; quer entre amostradores – Anexo II) foi avaliada com base na razão presença/ausência das espécies, por meio do coeficiente de Jaccard (S_j) (Magurran 2004) e por meio da abundância relativa usando-se o Percentual de Similaridade Mínima (%Min) (Krebs

1999). Curvas acumuladas de espécies por amostra foram construídas para determinar a eficiência do esforço amostral em registrar a riqueza de espécies da assembleia de peixes da zona de arrebentação (Anexo I), e para expressar a riqueza de espécies coletadas pelos diferentes amostradores (Anexo II) (Ugland et al. 2003).

A captura por unidade de esforço por classe de comprimento (CPUE-CC; Vieira 2006) foi calculada para se obter a variação da abundância média por classe de comprimento, sendo obtida pela razão entre a soma do fator de ponderação FP ($FP = N/n$, onde N é o número de indivíduos capturados na amostra e n o número de indivíduos medidos) e o esforço, i.e., $[\sum FP(CC)/\text{esforço}]$. Esta abordagem foi utilizada nos Anexos II e III.

Um conjunto de Análises Multivariadas foi usado com a finalidade de reconhecer fontes de variação nos dados (variáveis) e identificar tendências. De um modo geral, o objetivo de cada análise multivariada utilizada, é descrito abaixo.

Análise de Correspondência Canônica (CCA): no Anexo I foi usado um *triplot* para avaliar a influência das variáveis ambientais sobre a assembleia de peixes. No Anexo IV foi usada para identificar uma estruturação das espécies em relação aos períodos estudados, e avaliar a influência das variáveis ambientais nesta estrutura (*triplot*). Nestas análises foram incluídas apenas as espécies frequentes e abundantes, e somente as variáveis ambientais significativas, que foram avaliadas usando o teste de permutação de Monte Carlo ($n = 9.999$; $p < 0,05$) (Lepš e Šmilauer, 2003).

Análise de Variância com Permutação (PERMANOVA⁺ para o PRIMER) (Anderson et al. 2008): análise usada no Anexo I, para testar os efeitos dos diferentes fatores (pontos de coleta, praias e estações do ano) sobre a composição da assembleia. Usou-se a distância de Bray-Curtis como medida de semelhança e os valores de P foram

calculados usando 9.999 permutações. Conforme Anderson (2001), este método analisa a variância de dados multivariados explicada por um conjunto de variáveis explanatórias (categóricas ou numéricas) e é usado para criar uma distribuição F e obter um valor de P .

Análise de Coordenadas Principais (ACP; PCO em inglês): é um método de ordenação que analisa a dispersão multivariada nos dados, inferindo uma medida de variabilidade. A grande vantagem da ACP é de poder ser baseada em qualquer métrica de semelhança (Anderson et al. 2008). Esta análise foi aplicada no Anexo II, usando Jaccard como métrica de semelhança. Além da ACP, utilizou-se a Análise de Dispersão Multivariada (PERMDISP) para testar os desvios nas distâncias dentro do grupo, dos seus respectivos centróides. As diferenças entre os grupos eram identificadas com o uso de um teste *post-hoc*, calculado com a finalidade de identificar onde estavam representadas as diferenças. Assim como na PERMANOVA⁺, testes de significância usando o teste de Monte Carlo foram calculados com base em 9.999 permutações e um valor de P e um pseudo- F estatístico foi gerado.

Modelos Lineares Generalizados (MLG) foram utilizados no Anexo III, para modelar o conjunto de dados (variáveis bióticas x abióticas) permitindo que relações ecológicas sejam modeladas de forma precisa (Austin 2002). Antes da modelagem, o conjunto de variáveis preditoras foi analisado de forma exploratória, para identificar colinearidade entre as variáveis independentes, visto que a colinearidade pode reduzir a precisão da variável em estimar coeficientes e sua significância (Beger e Possingham 2008). Quando colinearidade entre variáveis era detectada, a variável com maior importância ecológica era mantida na análise, enquanto que a outra variável (ou variáveis) era retirada da análise.

As análises foram conduzidas no software R (R Development Core Team 2005), em três etapas. Primeiro, modelou-se a variação da riqueza de espécies entre cada praia, em resposta a um conjunto de variáveis preditoras (descritores). Para isto, usou-se a distribuição de Poisson com *log* como a função de ligação (em inglês: *log link function*) (Hastie e Tibshirani 1990). Contrário ao modelo Gamma, o modelo Poisson permite que valores iguais a zero sejam usados na análise (Ye et al. 2005). Em segundo, modelou-se a probabilidade de presença das duas espécies dominantes no ambiente (a tainha *Mugil liza* e o pampo *Trachinotus marginatus*), usando o modelo de regressão logística, com *logit* como função de ligação (em inglês: *logit link function*) (Hosmer e Lemeshow 1989). Regressões logísticas representam a probabilidade de ocorrência da variável de interesse, *P*, como função de uma combinação linear de preditores. Por último, modelou-se a abundância das duas espécies dominantes, usando-se um modelo de distribuição Gamma somente para valores positivos (sem zeros) (França et al. 2011).

Os MLG foram executados conforme o procedimento de seleção *stepwise* (passo a passo), com um corte de $p = 0,05$ para determinar as variáveis significativas e que ficariam retidas no modelo. Adicionalmente o comando *drop1* do software R foi usado para comparar o modelo completo, com o modelo mais parcimonioso, onde as variáveis não significativas foram retiradas (*dropped*). Esta comparação foi feita usando o teste Chi-quadrado. Desta forma, assim que a análise era executada, o comando retirava cada variável explanatória, calculando para cada vez, a diferença entre as “deviancias” e comparava as diferenças usando uma distribuição Chi-quadrado (Zuur et al. 2007). Quando vários descritores são usados simultaneamente, o método seleciona somente os significativos. Não foi identificada “sobredispersão” nos dados para o modelo de Poisson. Todos os modelos finais foram ajustados somente com as variáveis

significativas e a porcentagem da “deviância” total explicada e a relativa contribuição de cada fator foi avaliada para cada modelo independentemente.

3. SÍNTESE DOS RESULTADOS

Embora exista um efeito de sombra dos molhes sobre a praia do Cassino, o qual se dilui na media que se afasta dos molhes, não foi observada diferença significativa na estrutura na assembleia de peixes entre as praias do Cassino e do Mar Grosso. No entanto, um forte efeito sazonal local foi identificado, influenciando diretamente na abundância e na diversidade dos peixes que habitam ambas as praias (ANEXO I). Foi observada uma variabilidade natural nos valores médios das variáveis ambientais durante o período de estudo, no entanto estes valores não foram significativamente diferentes entre os pontos de coleta de uma mesma praia e entre as praias do Cassino e do Mar Grosso. Com apenas a rede picaré (9 m) foi observada uma alta similaridade entre as praias (18 espécies em comum; $S_j = 62,1\%$), porém a diversidade foi baixa, com alta dominância de poucas espécies (ver Tabela 1, Anexo I). A praia do Cassino registrou mais espécies ($S = 25$) do que a praia do Mar Grosso ($S = 22$), sendo que diferença significativa na riqueza de espécies entre as praias foi observada somente na primavera e no verão. Duas espécies (*Trachinotus marginatus* e *Mugil liza*) foram responsáveis por mais de 60% das capturas em ambas as praias, com *M. liza* sendo significativamente mais abundante ($p = 0,0001$) na praia do Cassino, enquanto que para *T. marginatus* não foi registrada diferença significativa na abundância entre as praias ($p = 0,08$). *Trachinotus marginatus* mostrou um claro padrão sazonal, aumentando sua abundância durante o verão, enquanto que *M. liza* não mostrou um

padrão definido, sendo capturada em maior abundância principalmente nos meses mais frios (ver Figura 4, Anexo I).

O experimento de comparação entre amostradores (rede de arrasto de praia de 9 m – BS-9 m e rede de arrasto de praia de 30 m – BS-30 m) não mostrou diferenças na composição de espécies entre as duas redes de arrasto de praia, porém ambos amostradores apresentam diferente composição da rede de espera (TN-25 m). No entanto, o principal resultado deste experimento foi identificar que as três redes são complementares em relação aos tamanhos capturados (Anexo II). As redes de arrasto de praia são similares entre si ($S_j = 70,3\%$) com relação às espécies capturadas, enquanto que a similaridade entre as duas redes de arrasto de praia e a rede de espera foi considerada baixa ($S_j < 45,0\%$ para as duas comparações). Este resultado é corroborado pela análise de ordenação (ver Figura 3, Anexo II), que evidencia uma clara separação ($p < 0,001$) entre as duas redes de arrasto de praia e a rede de espera, e pela não diferença ($p = 0,09$) em composição entre as duas redes de arrasto de praia. Embora a adição de dois novos amostradores tenha resultado em um total de 41 espécies capturadas, a composição de espécies não variou muito em relação ao Anexo I, com as espécies dominantes permanecendo as mesmas (comparar Tabela 1 dos Anexo I e II). Cada amostrador capturou grupos distintos de tamanhos, porém com sobreposição em algumas classes (ver Figura 5, Anexo II). No geral, a maioria dos indivíduos capturados pela rede BS-9 m apresentou tamanhos ≤ 60 mm CT (78,6%), enquanto que a rede BS-30 m capturou a maioria dos indivíduos com tamanhos ≤ 120 mm CT (73,0%). A rede de espera capturou a maior amplitude de tamanhos, embora tenha capturado o menor número de indivíduos em comparação com as redes de arrasto de praia.

A utilização de modelos lineares generalizados permitiu identificar as variáveis significativas e consideradas importantes descritores da riqueza de espécies, e da probabilidade de ocorrência e da abundância de *M. liza* e *T. marginatus*, as duas espécies dominantes na área de estudo (Anexo III). Conforme mostrou o experimento de comparação entre amostradores, as duas redes de arrasto de praia são consideradas complementares, e capturam praticamente as mesmas espécies, no entanto, BS-30 m capturou mais espécies ocasionais (ver Tabela 1, Anexo III). Com relação à riqueza de espécies não foi observada diferença significativa entre as praias (conforme já observado no Anexo I), e sete variáveis explanatórias foram consideradas preditores significativos, com o modelo explicando 25,0% da deviência total, sendo 16,2% explicado pela sazonalidade (ver Tabela 3 e Figura 2, Anexo III). Duas espécies dominaram a área de estudo, *M. liza* e *T. marginatus*, e devido a sua importância foram escolhidas para serem modeladas em separado (ocorrência e abundância). O modelo de ocorrência para *M. liza* explicou 25,1% da deviência total (20,4% explicado pelo amostrador), enquanto que o modelo de abundância explicou 32,8%, com 21,2% sendo explicado pela combinação de amostrador e praia (ver Tabela 4 e Figura 4, Anexo III). O modelo de ocorrência para *T. marginatus*, explicou 22,7% da deviência total (18,6% explicado pela estação do ano), enquanto a sazonalidade foi o principal fator do modelo que explicou a variabilidade (22,3%), com a espécie sendo mais abundante durante o verão (ver Tabela 4 e Figura 5, Anexo III). Com relação aos tamanhos, as redes foram um fator significativo na modelagem da abundância para *M. liza*, sendo esta espécie capturada principalmente pela rede BS-9 m e com tamanhos entre 20 e 30 mm CT. Já *T. marginatus* não mostrou diferença significativa nas capturas entre redes, no entanto, a rede BS-9 m capturou mais indivíduos com tamanhos ≤ 60 mm CT e a rede BS-30 m

capturou mais indivíduos com tamanhos > que 60 mm CT. Tal fato evidencia a complementaridade entre ambas as redes.

Por fim, analisando-se os dois bancos de dados estudados (passado x presente), observa-se que houve uma elevação na temperatura média da água durante o verão, e uma queda significativa na abundância total, abundância média de algumas espécies e diversidade, no presente em relação ao passado. A temperatura da água, a vazão e as componentes meridional e zonal do vento em superfície foram importantes para explicar, em parte, as tendências encontradas (Anexo IV). Ao longo dos três períodos analisados nove espécies foram dominantes, e padrões claros de queda na abundância média de algumas espécies foram registrados (ver Tabela 3 e Figura 2, Anexo IV). Com base na análise entre períodos, foi possível identificar que quatro espécies (*M. liza*, *T. marginatus*, *Menticirrhus americanus* e *M. littoralis*) apresentaram queda significativa na abundância média no presente, em relação ao passado (ver Tabela 3 e Figura 3, Anexo IV). Os resultados obtidos neste estudo, aliados a importância econômica destas espécies para a região, nos permitem levantar a hipótese de que um possível aumento no esforço de pesca pode ser o principal fator que explica a queda na abundância destas espécies.

4. CONCLUSÕES

Anexo I

A abundância e a diversidade da assembleia de peixes que habita as praias do Cassino (Rio Grande) e do Mar Grosso (São José do Norte) não são influenciadas pela presença dos longos molhes que separam as duas praias arenosas. Isto ocorre, mesmo com as praias apresentando padrões diferenciados de exposição às ondas (Cassino

abrigado e Mar Grosso exposto) e hidrodinâmica (p.ex., predominância da pluma estuarina na praia do Cassino). Além do mais, ambas as praias apresentaram baixa diversidade, com uma composição de espécies similar em ambas as praias, sendo formada principalmente por indivíduos juvenis, com tamanhos ≤ 60 mm CT.

Marcado padrão sazonal foi identificado, onde podemos observar uma baixa abundância e diversidade durante os meses mais frios (inverno e outono), e uma alta abundância e diversidade durante os meses mais quentes (primavera e verão).

Anexo II

A principal fonte de diferenças encontrada entre o três amostradores comparados, esteve relacionada à variação de tamanhos capturados. A rede de arrasto de praia com o maior tamanho (BS-30m) capturou mais indivíduos e mais espécies, no entanto, não houve diferença em termos de composição das espécies dominantes, em relação a rede de arrasto de praia de menor tamanho (BS-9m). Para efeito de amostragens científicas, a BS-9m é considerada um amostrador mais eficaz do que a BS-30m, visto que ela fornece boas informações a cerca da composição de espécies do ambiente onde ela é usada, além de ser extremamente fácil de ser operada em relação aos demais amostradores usados.

A adição de um novo amostrador (TN-25m) ao conjunto de amostradores utilizados na zona de arrebentação, trouxe uma informação complementar a cerca da estrutura de tamanhos e fornece uma visão mais completa a respeito da assembleia de peixes da zona de arrebentação de ambas as praias.

Anexo III

A utilização de modelos lineares generalizados permitiu identificar as variáveis significativas e consideradas importantes descritores para a riqueza de espécies, e a ocorrência e abundância das duas espécies dominantes na zona de arrebentação, *M. liza* e *T. marginatus*. A sazonalidade é a principal variável que explica a variação na riqueza de espécies, mas tipo de amostrador, salinidade, transparência, direção do vento e da corrente litorânea e número de linhas de arrebentação contribuem significativamente e com baixo poder de explicação.

Duas espécies dominaram o ambiente, *M. liza* e *T. marginatus*. A ocorrência de *M. liza* esteve principalmente relacionada ao amostrador usado (BS-9 m) e a sua abundância esteve principalmente relacionada a praia do Cassino. O amostrador usado foi um fator significativo para a abundância de *M. liza*, e a espécie foi capturada principalmente com a rede BS-9 m e com tamanhos entre 20 e 30 mm CT. No entanto, outras variáveis também foram significativas no modelo (p. ex. local, estação do ano, direção do vento), porém apresentaram baixo poder de explicação. A ocorrência e abundância de *T. marginatus* esteve diretamente relacionada à estação do ano (verão), sendo que o tipo de rede usada não foi um fator significativo, no entanto, a rede menor (BS-9 m) capturou principalmente indivíduos com tamanhos ≤ 60 mm CT e a rede maior (BS-30 m) capturou mais indivíduos com tamanhos $>$ que 60 mm CT.

Anexo IV

A análise do banco de dados usado neste estudo (passado, Junho-2001 a Maio-2002 x presente, Julho-2009 a Junho-2011) possibilitou identificar um aumento na temperatura média da água em superfície, principalmente durante os verões. Este resultado é corroborado por dados obtidos junto a NOAA, que indicam, para o Atlântico sul, um aumento na temperatura média da água em superfície durante os verões. No

entanto, qualquer inferência a respeito de mudanças climáticas é extremamente precipitada, devido a curta série temporal analisada. Além da temperatura da água, a vazão do estuário e a componente zonal (leste-oeste) e meridional (norte-sul) do vento foram variáveis significativas no modelo, porém com baixo poder de explicação, evidenciando o forte efeito sazonal existente na região sul do Brasil.

Observou-se um queda na abundância total ao longo dos períodos, com uma significativa diferença entre o presente em relação ao passado. *Mugil liza*, *T. marginatus*, *M. americanus* e *M. littoralis* registraram uma significativa tendência de queda na abundância média no presente em relação ao passado. Além de estarem diretamente relacionadas com a zona de arrebentação, possuindo um importante papel ecológico, estas espécies também possuem uma forte importância econômica para a região. Sendo assim, devem ser tomadas medidas de conservação e exploração sustentável destas espécies.

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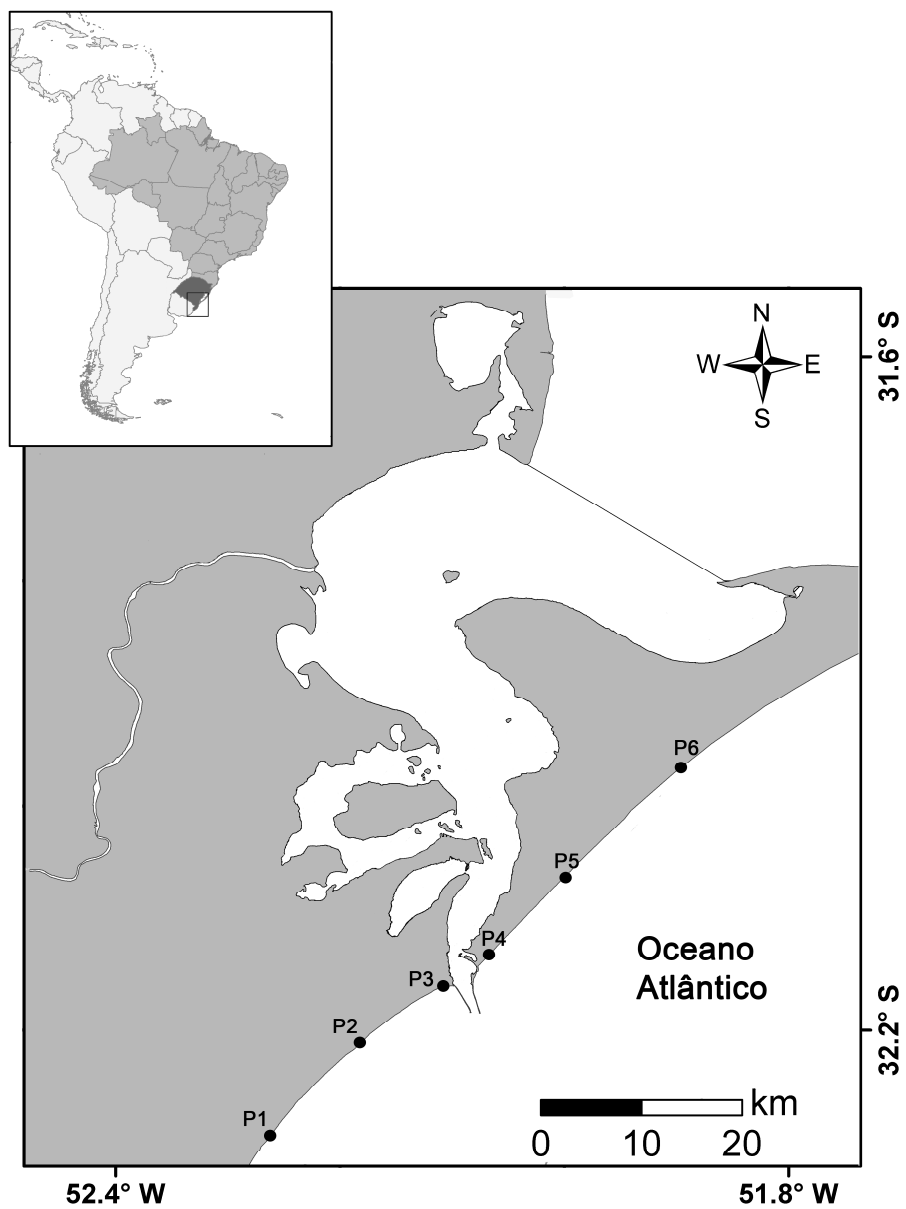


Figura 1. Área de estudo com a localização dos pontos de coleta na praia do Cassino (P1-P3) e Mar Grosso (P4-P6).

ANEXO I

Surf zone fish abundance and diversity at two sandy beaches separated by long rocky
jetties

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(Publicado no periódico *Journal of the Marine Biological of the United Kingdom*)

Surf zone fish abundance and diversity at two sandy beaches separated by a long rocky jetties

SURF ZONE FISH ABUNDANCE AND DIVERSITY

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ABSTRACT

In this work, we evaluated the influence of long rocky jetties (~ 5 km) on fish abundance and diversity between sheltered and exposed marine sandy beaches. We also described and compared the fish community structure and investigated the relationships between environmental variables and fish assemblages. Fish were collected monthly with a beach seine net from May 2001 to May 2002 at the Cassino and Mar Grosso beaches. Twenty-nine taxa were caught and the fish assemblage showed similar composition between beaches ($S_j = 62.1\%$; %Min = 52.3%), with 18 species in common. Most of the fish were juveniles, mainly young-of-the-year with sizes ≤ 60 mm TL. Eight species (Trachinotus marginatus, Mugil liza, Brevoortia pectinata, Menticirrhus littoralis, Menticirrhus americanus, Atherinella brasiliensis, Odontesthes argentinensis, and Oncopterus darwini) were the most abundant, accounting for 95.6% of the total catch. At both beaches, only T. marginatus, M. liza and M. littoralis were frequent and abundant, but with some differences in their relative abundance. The CCA results showed that temperature had the highest correlation with fish abundance. Seasonal changes in fish assemblage structure were evident, with greater species diversity and abundance in the spring and summer. The overall results indicate that the presence of jetties had no effect on fish assemblages of adjacent sandy beaches. Moreover, differences between beaches were related to some species abundance and not to differences in the number and composition of species between beaches.

Keywords: fish nurseries, wave exposure, man-made structures, beach seine net, multivariate analysis, fish assemblage

INTRODUCTION

Shallow marine waters constitute crucial environments for a diversity of fish species (Valesini *et al.*, 2004). Although the surf zones of sandy beaches are considered habitats of low complexity and high dynamics, several authors have also found them to be important recruitment and nursery zones (Ayvazian & Hydes, 1995; Harris *et al.*, 2001; Strydom, 2003), as well as migratory paths to other nearshore habitats (Monteiro-Neto *et al.*, 2003; McLachlan & Brown, 2006; Nanami & Endo, 2007; Inoue *et al.*, 2008). Other possible reasons for fish to use the surf zones are the abundant supply of potential prey and shelter from predators (Beyst *et al.*, 2002; Silva *et al.*, 2004; Sato *et al.*, 2008). These reasons suggest that the surf zones of sandy beaches play an important role as coastal habitats, mainly those located near estuaries (Beck *et al.*, 2001; Bell *et al.*, 2001; Beck *et al.*, 2003; Able *et al.*, 2011; Moraes *et al.*, 2012).

The littoral zone in the southernmost state in Brazil is characterized by a 620 km long, straight coastline with a NE-SW orientation, and is located between 29°-34° S latitude. This sandy beaches are completely exposed to wave action, have a microtidal regime and semidiurnal tides with a mean range of 0.3 m (Figueiredo *et al.*, 2007; Pereira *et al.*, 2010). This coastline is interrupted by five estuaries (Vieira & Rangel, 1988; Ramos & Vieira, 2001) and is wave-dominated with significant wave heights of 1.5 m H_s (Calliari & Klein, 1993). A major feature in this region is a ~ 5 km-long rocky jetties, connecting the Patos Lagoon (PL) estuary with the Atlantic Ocean. Sandy beaches adjacent to each side of these jetties have different hydrological dynamic. The east side has beaches that are exposed to predominant winds from NE (Tomazelli, 1993) and predominant waves from E-SE (Calliari & Klein, 1993), whereas sandy beaches

located on the west side are more sheltered from prevailing winds and waves, creating a shadow zone with less intensity of wind, waves and longshore currents from E-NE.

The structure and dynamic of the fish assemblage from the surf zone of the west jetty (Cassino Beach, hereafter CB) is relatively well known, being composed mainly by juveniles of approximately 37 species (with nine dominant species) with sizes ranging from 15 to 150 mm total length (e.g. Monteiro-Neto *et al.*, 2003; Lima & Vieira, 2009). Since the jetties may influence the fish fauna inhabiting the sandy beaches near the PL estuary (Lima & Vieira, 2009), and there is no information on the fish assemblage of the east jetty sandy beach (Mar Grosso Beach, hereafter MGB), it is necessary to investigate if fish assemblages inhabiting the surf zone of these two sandy beaches, with different degrees of wave exposure (sheltered *vs.* exposed) and separated by a long rocky jetties, have differences in terms of fish abundance and diversity patterns.

In this paper, we evaluated the null hypothesis that there are no significant differences in fish abundance and diversity between sheltered (CB) and exposed (MGB) marine sandy beaches. We also described and compared the fish community structure on sandy beaches adjacent to the PL jetties and identify the relationships between environmental variables and fish assemblages at each side of the jetties.

MATERIALS AND METHODS

Study area and field sampling

The coastline of the southernmost in Brazil is characterised by extensive wave-dominated, straight sandy beaches, with sediments ranging from very fine to medium sand (Siegle & Calliari, 2008). The sandy beaches near the mouth of PL estuary are

classified as dissipative (Pereira *et al.*, 2010) and are associated with one or two longshore sandbars (Calliari & Klein, 1993). The pattern of coastal water circulation along this coastline undergoes strong seasonal influences. During the winter, south-westerly (SW) winds force the Rio de La Plata waters with low salinities and temperatures to lower latitudes ($\sim 28^\circ$ S); while in the summer, dominant north-easterly (NE) winds bring tropical waters with high salinities and temperatures to $\sim 32^\circ$ S (Möller *et al.*, 2008). The predominant pattern in the NE winds directs the plume of the PL estuary in a southern direction. Fine sediments provided by this plume are transported to the south and deposited offshore as fluid mud. Stormy conditions, such as cold front passages, can rework and transport the fluid mud from the inshore to the surf zone and offshore of CB, attenuating the wave energy (Calliari *et al.* 2007). MGB is different from CB because there is no record of fluid mud deposits on the former, which is located northward of the jetties.

Samplings were performed from two beaches, CB on the west and MGB on the east side of the jetties, with two fixed sampling sites at each beach (Figure 1). Fish were collected monthly from May 2001 to May 2002 from the early morning until noon. A beach seine net (9 m long; 1.5 m high) with a 13 mm stretch mesh in the wings and a 5 mm stretch mesh in the centre 3 m section was pulled perpendicular to the beach at depths less than 1.5 m, covering an area of approximately 120 m² per haul. At each sampling site, three hauls were performed, always avoiding the previously swept areas. Surface water temperature ($^\circ$ C), salinity and transparency (Secchi depth) were recorded before sampling. Fish were preserved in 10% formalin and later identified and counted. The total length (TL) of each fish was measured to the nearest 1 mm, and the total wet weight (g) of each species in each sample was recorded.

Data analysis

Fish were considered abundant when the numeric percentage (N%) was greater than or equal to $100/S$, where S is the total number of species captured on each beach. Fish were considered frequent when the percentage of frequency of occurrence (FO%) was greater than or equal to $\sum\%FO/S$ on each beach. Based on this classification, fish species were grouped into the following categories: frequent and abundant ($\%FO \geq \sum\%FO/S$; $\%N \geq 100/S$), frequent but not abundant ($\%FO \geq \sum\%FO/S$; $\%N < 100/S$), not frequent but abundant ($\%FO < \sum\%FO/S$; $\%N \geq 100/S$), present ($\%FO < \sum\%FO/S$; $\%N < 100/S$) and absent (no fish captured) (Garcia & Vieira, 2001).

Similarity of fish composition between beaches was based on the ratio of the presence/absence of species calculated by the Jaccard coefficient (S_j) (Magurran, 2004) and on Percent Similarity (%Min) (Krebs, 1999). The diversity was evaluated using Fisher's α because its value is relatively easy to calculate for communities that contain a comparatively large number of species that are rare (Magurran, 2004). Fisher's α was calculated as: $\alpha = \frac{N(1-x)}{x}$, where α is the diversity index from a logarithmic series, N is the total number of individuals in the sample and x is a parameter of a logarithmic series. The large-sample variance of the diversity index α was calculated as: $\text{Var}(\alpha)$

$$= \frac{0.693147 \times \alpha}{\left[\ln\left(\frac{x}{(1-x)-1}\right) \right]^2}$$

. For each beach, we constructed species accumulation curves to

determine the efficiency of the sampling effort in assessing the species richness of fish assemblage.

Environmental variables and fish abundance data (number) were transformed [$\text{Log}_{10}(x + 1)$] to meet assumptions of normality and homoscedasticity for statistical

tests (Analysis of Variance (ANOVAs), Permutational Analysis of Variance (PERMANOVA) and Canonical Correspondence Analysis (CCA)). One-way ANOVA was performed to test differences in environmental variables among sites and differences in abundance for the three frequent and abundant species, between beaches. Two-way ANOVA was employed to test differences in total fish abundance between beaches (two levels) and seasons (five levels). Previously, the 13 months were grouped in seasons as follows: autumn 1 = May and June; winter = July to September; spring = October to December; summer = January to March; autumn 2 = April and May. Permutational analysis of variance (PERMANOVA+ for PRIMER; Anderson *et al.*, 2008) was used to test the effects of different factors (sites, beaches and season) on the fish assemblage composition. A PERMANOVA analysis was done using Bray–Curtis distance as a resemblance measure and *P* values were calculated using 9,999 permutations. This method analyzes the variance of multivariate data explained by a set of explanatory variables (categorical or numeric) and is used to create a distribution of *F* and obtain a *P* values (Anderson, 2001).

Canonical Correspondence Analysis (CCA) was applied to environmental variables, species abundance and beaches (triplet) to assess environmental influence on fish assemblages. Only environmental variables that were significant were included in the analysis. Only species with occurrences > 1% were included in the CCA to reduce the importance of rare species. The significant variables were assessed using a Monte Carlo permutation test ($n = 9,999$; $p < 0.05$) (Lepš & Šmilauer, 2003).

RESULTS

Environmental variables

The mean values of seawater surface temperature did not differ among the four sampling sites, but showed seasonal fluctuations with a clear annual cycle (Figure 2a). No significant differences were observed among sampling sites at CB (ANOVA, $F = 0.09$; $p = 0.76$) or at MGB (ANOVA, $F = 0.24$; $p = 0.63$); however, MGB presented higher temperatures compared with CB. For both beaches, the highest temperature values were recorded from November to April and the lowest values from May to October (Figure 2a).

Salinity showed no seasonal pattern, ranging from 10 to 30 (Figure 2b). No significant differences occurred between sampling sites at the same beach (CB: ANOVA, $F = 0.07$, $p = 0.79$ and MGB: ANOVA, $F = 0.32$, $p = 0.58$). The lowest salinity values were registered in July and November-2001 (MGB) and in September 2001 (CB). The highest salinities were found at CB in November 2001 and at MGB in May 2002.

Water transparency values were low, ranging from 0 to 1 m, with sampling sites at CB showing the highest water transparency values (Figure 2c). No significant differences were observed among sampling sites at both beaches (CB: ANOVA, $F = 1.13$, $p = 0.30$ and MGB: ANOVA, $F = 0.94$, $p = 0.34$). The highest transparency values were registered in November and May 2002 for sampling sites at CB.

Because no differences were found with regard to the environmental variables measured at the two sampling sites at each of the two beaches, we grouped sampling sites from the same beach to compare fish abundance and diversity between beaches (CB *vs.* MGB).

Spatial and seasonal variations in fish assemblage structure

A total of 20,331 fish from 29 taxa, representing 14 families, were caught in 260 beach-seine hauls during the study period. Only Clupeidae (n = 12) had a group of individuals not identified at the species level. Most fish were juveniles, mainly young-of-the-year with sizes ≤ 60 mm TL (95.6%). However, individuals of a wide range of sizes (12 to 410 mm TL) were collected (Table 1). Eight species were abundant and comprised 95.6% of the total catch. They were the La Plata pompano *Trachinotus marginatus*, the striped mullet *Mugil liza*, the Argentine menhaden *Brevoortia pectinata*, the Gulf kingfish *Menticirrhus littoralis*, the Southern kingfish *Menticirrhus americanus*, the Brazilian silversides *Atherinella brasiliensis* and *Odontesthes argentinensis*, and the Remo flounder *Oncopterus darwinii*.

Although the highest captures were registered at CB, no significant difference for total abundance was found between CB and MGB (ANOVA, $F = 2.28$, $p = 0.13$). Nevertheless, there was a seasonal difference in the overall number of individuals for both beaches (ANOVA, $F = 4.14$, $p = 0.003$), and when seasons were analyzed separately, differences between the beaches were found only in the second autumn 2 (Figure 3). The PERMANOVA results performed on the complete fish abundance data set showed a significant effect of season and there were no significant interactions between beaches, seasons and sites between beaches (Table 2). These results are in accordance with one-way ANOVA performed with environmental variables between sites and corroborate the previous choice of grouping sites of the same beach, and analyze CB vs. MGB.

Despite of no differences in overall fish abundance between CB and MGB, the analysis showed that *B. pectinata* and *A. brasiliensis* were frequent and abundant only at

CB, whereas *M. americanus*, *O. darwinii* and *O. argentinensis* were frequent and abundant only at MGB, showing a spatial difference in the structure of fish assemblage (Table 1). *Trachinotus marginatus*, *M. liza* and *M. littoralis* were frequent and abundant at both beaches. The white mullet *Mugil curema* was considered frequent/not-abundant at both beaches, whereas the remaining species were recorded seasonally or occasionally.

Mugil liza represented 43.5% of the total catch at CB and 18.1% at MGB, with significant differences between beaches (ANOVA, $F = 10.42$, $p = 0.001$). *Trachinotus marginatus* showed an inverse pattern of abundance, with higher values at MGB (47.9%) and lower values at CB (18.8%) but no significant differences between beaches (ANOVA, $F = 3.17$, $p = 0.08$). *Menticirrhus littoralis* showed clear differences in overall abundance (ANOVA, $F = 39.17$, $p < 0.01$) and represented 70.4% of the total catch at CB and 29.6% at MGB, confirming the spatial difference in the structure of the ichthyofauna. For these three species, it seems that the mean size of *T. marginatus* and *M. littoralis* were larger at MGB than at CB, whereas the mean size of *M. liza* were the same for both beaches (see Table 1).

Seasonal differences in relative abundance of the three dominant species were also found for each beach (Figure 4). *Menticirrhus littoralis* showed the lowest relative abundance in the coldest months (May to November), with an increase in relative abundance during warm months (December to March) (Figure 4a). *Trachinotus marginatus* displayed the same seasonal pattern (Figure 4b) as *M. littoralis*, whereas *M. liza* did not show a clear seasonal pattern of distribution during the study period and was caught all year-round (Figure 4c). Furthermore, *M. liza*, which relative abundance was

higher at CB (N = 4726) than MGB (N = 1716), presented peak of abundance occurring in July, November, February and May.

The species composition between beaches revealed 18 common species among 29 taxa captured (%Min = 52.3% and S_j = 62.1%). The number of species at CB (S = 25) was higher than at MGB (S = 22), and there was a seasonal and spatial trend in diversity estimated by Fisher's α (Figure 5). Differences in diversity between both beaches were observed only during spring and summer. The species accumulation curve did not stabilise towards asymptotic values for either beach (Figure 6), indicating that more species may be found with an increase in fish sampling effort.

The CCA revealed that the most significant environmental variables related to fish abundance were water temperature and transparency. Species-environmental correlations from CCA were higher for the first (0.83) and second (0.72) axes. Environmental variables explain 30.0% of the fish abundance, and the axis 1 explains 60.0% of the explained variability (Figure 7). Species such as *T. marginatus*, *M. littoralis*, *M. americanus*, *M. curema*, *Mugil cf. hospes*, *B. pectinata* and *O. argentinensis* seems to be more associated with the warmer season (on the left), whereas *M. liza* and *O. darwinii* were associated with the colder season (on the right). *Atherinella brasiliensis* was associated with higher transparency waters related mainly with to the colder season (autumn and winter) and sampling sites at CB.

DISCUSSION

This work analyzed the influence of long rocky jetties (~ 5 km) in the surf zone fish assemblage structure of two sandy beaches that differ in terms of wave exposure and dynamics: Cassino Beach (CB) more sheltered and Mar Grosso Beach (MGB) more

exposed. The structure and dynamics of the fish community from CB is relatively well known (e.g., Monteiro-Neto *et al.*, 2003; Lima & Vieira, 2009), but there is no information on MGB, and we expected differences between both fish assemblages in terms of fish abundance and diversity. Our results demonstrated that there is no difference in total fish abundance and diversity between more sheltered and more exposed sandy beaches. Both beaches presented a low diversity of fish species, with a very similar fish composition, consisting mainly of small-sized juveniles (95.6% \leq 60 mm TL), and only eight species were numerically dominant. This pattern seems to be similar with several other surf zones around the world (Robertson & Lenanton, 1984; Gibson *et al.*, 1993; Suda *et al.*, 2002; Inoue *et al.*, 2008; Selleslagh & Amara, 2008). In fact, surf zones are considered nursery area, transit routes, and feeding grounds for several species (Lasiak, 1986; Santos & Nash, 1995; Layman, 2000; McLachlan & Brown, 2006; Nakane *et al.*, 2011), and dominated mainly by small-sized juveniles fishes (Nanami & Endo, 2007; Lima & Vieira, 2009; Mont'Alverne *et al.*, 2012).

Three species (*Trachinotus marginatus*, *Mugil liza* and *Menticirrhus littoralis*) were frequent and abundant at both beaches, but with distinct abundance patterns between beaches. *Trachinotus marginatus* and *M. littoralis* showed higher abundance during early spring/summer, but *M. liza* show no seasonal pattern in peak abundance. Juveniles of *T. marginatus* and *M. littoralis* are typically found at the surf zones of southern Brazil (Rodrigues & Vieira, 2010; Lemos *et al.*, 2011), whereas the juveniles of *M. liza* use the surf zones during their recruitment from the ocean towards shallow areas (Vieira, 1991) and probably as a transient habitats before recruitment into PL estuary (Monteiro-Neto *et al.*, 2003).

Man-made structures like rocky jetties could affect the water circulation (Roberts, 1997), modify surf zone conditions (Martin *et al.*, 2005) and enhanced connectivity between different environments (Cenci *et al.*, 2011). In spite of that, species composition and densities of fish assemblages at sandy beaches adjacent to the PL jetties seems to be not affected by this man-made structure. However, there are some effects on the relative abundance of some species at each side of the jetties, which could be related with differences on physical conditions. For instance, the presence of the PL plume, intensified by the PL jetties, favours a more estuarine condition at CB than at MGB (Möller *et al.*, 2009), which allows a greater concentration of estuarine-dependent species at this beach (Lima & Vieira, 2009). This situation is intensified during El Niño Southern Oscillation (ENSO) episodes, when estuarine fishes are frequent at the coastal marine sites adjacent to the PL estuary (Garcia *et al.*, 2001; Garcia *et al.*, 2012). Even in non-ENSO years the flooding of the PL occurs after different levels of precipitation (Vieira *et al.*, 2008), which could also explain the high catches of *A. brasiliensis* and *B. pectinata* at CB in the present study. In contrast, MGB is more exposed to wave energy and less influenced by the PL plume than CB (de Oliveira & Calliari, 2006; Pereira *et al.*, 2010), which apparently favours those fishes associated with more exposed sandy beaches, like members of Carangidae and Sciaenidae families (Vasconcellos *et al.*, 2007).

The wave exposure (wave energy) is considered an important environmental variable influencing surf zone fish assemblages and there is strong evidence in the literature of an inverse relationship between wave action, coastal currents and species abundance (Romer, 1990; Clark, 1997; Félix *et al.*, 2007; Vasconcellos *et al.*, 2007; Inui *et al.*, 2010). On MGB, four of the six dominant species (*T. marginatus*, *M. littoralis*,

Menticirrhus americanus and *Oncopterus darwinii*) are directly associated with moderate to high wave energy sandy beaches (Lima & Vieira, 2009; Rodrigues & Vieira, 2010). Although wave energy was not measured in this study, we believe that high catches of abovementioned species, at MGB, can be an indicator of wave energy conditions.

The surf zone fish community structure in southern Brazil seems to be spatially homogenous along the 620 km straight coastline (Ramos & Vieira, 2001). Thus, the jetties that connect the PL estuary with the Atlantic Ocean are one of the few obstacles that could create distinct environmental conditions along this littoral zone. On the east side of the jetties, MGB is more influenced by the predominant NE wind and wave patterns, whereas on the west side, CB experiences lesser wave action, and it is more influenced by the plume of the PL estuary, which passes through spaces among the granite rock boulders used to built the jetties. These two contrasted conditions may occur at both sides according to wind conditions (Lima & Vieira 2009; Mont'Alverne *et al.*, 2012) resulting in no overall differences in fish assemblage structure in both sides of the jetties. In fact, some recent studies have suggested that surf zone fish assemblage is not particularly affected by the presence of jetties or breakwaters (Cenci *et al.*, 2011; Mikami *et al.* 2012).

We found a pattern of lower fish abundance associated with colder months (winter and autumn) and higher abundance in warmer months (spring and summer), with no differences between beaches. The only exception was autumn2 when the large abundance of *M. liza*, *Atheriella brasiliensis* and *Brevoortia pectinata* at CB remained similar with the previous winter, but the abundance level at MGB dropped significantly. Like in others subtropical zones, our results show that seasonality plays a role in

structuring the fish assemblage near PL jetties. Patterns of species abundance are predominantly cyclical, as observed by Lima & Vieira (2009), and temperature appeared to be the primary factor regulating species abundance after breeding season, which occurs in early spring to summer (Young *et al.*, 1997; Beyst *et al.*, 2001; Wilber *et al.*, 2003; Amara, 2003; Moraes *et al.* 2012).

In summary, our results suggests that (1) fish abundance and diversity are not influenced by long rocky jetties, although the two beaches differ in terms of wave exposure and dynamic, and (2) fish assemblage descriptors (mainly abundance and diversity) showed marked seasonal pattern. Future studies, including additional environmental variables (e.g., wave energy, wind, coastal current) and the use of other complementary sampling gears (e.g., larger beach seine nets, trammel nets, gill nets) are needed in order to advance the current knowledge on the structure and dynamic of fish assemblage at sandy beaches in southern Brazil.

ACKNOWLEDGEMENTS

The authors would like to thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), the Ichthyology Laboratory staff, the Institute of Oceanography (FURG), and the anonymous reviewers of this manuscript. We also thank to L.G. Fisher for the fish drawings.

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TABLES

Table 1. Total species composition of fishes caught at both beaches (number of individuals, percentage of abundance, weight and size ranges) and at each individual beach between May 2001 and May 2002. TL = total length, SD = standard deviation, n = number of individuals.

(Footnote) * indicates total number of individuals was more than 1%.

Table 2. PERMANOVA results for fish abundance considering the whole species data set.

(Footnote) d.f., degrees of freedom; SS, sum of squares; MS, mean squares; Pseudo-F, Pseudo-f ratio; *P* (perm), permutation *P* value; Bold value denote significant difference at $p < 0.0001$.

FIGURES

Fig. 1. Location of the study areas with the four sampling sites: 1 and 2 at Cassino Beach (CB) and 3 and 4 at Mar Grosso Beach (MGB), Rio Grande do Sul state, Brazil.

Fig. 2. Temporal fluctuations in environmental variables between May 2001 and May 2002: (a) surface water temperature, (b) salinity and (c) transparency of each of the sampling sites. Legend: 1-2 = Cassino Beach and 3-4 = Mar Grosso Beach.

Fig. 3. Spatio-temporal variation in total abundance between beaches.

Fig. 4. Mean abundance of three dominant species in both beaches, between May 2001 and May 2002. (a) *Menticirrhus littoralis*, (b) *Trachinotus marginatus* and (c) *Mugil liza*.

Fig. 5. Seasonal Fisher's α index of diversity with standard deviation for both beaches.

Fig. 6. Species accumulation curves for Cassino and Mar Grosso beaches.

Fig. 7. CCA ordination diagram of two environmental variables (represented by vectors), 10 species (represented by symbol Δ) and two beaches (\bullet = Cassino Beach and \square = Mar Grosso Beach). Legend: Temp. = Temperature and Transp. = Transparency; Species codes *A. bra* = *Atherinella brasiliensis*, *B. pec* = *Brevoortia pectinata*, *M. ame* = *Menticirrhus americanus*, *M. lit* = *Menticirrhus littoralis*, *M. cur* = *Mugil curema*, *M. liz* = *Mugil liza*, *M. hos* = *Mugil cf. hospes*, *O. arg* = *Odontesthes argentinensis*, *O. dar* = *Oncopterus darwinii* and *T. mar* = *Trachinotus marginatus*.

Table 1.

| Species | Total Number | Percent (%) | Weight (g) | Cassino Beach | | | | | Mar Grosso Beach | | | | |
|--|--------------|-------------|------------|---------------|-------|--------------|-------|-------|------------------|-------|--------------|-------|-------|
| | | | | (n) | % | Size (TL mm) | | | (n) | % | Size (TL mm) | | |
| | | | | | | Min-Max | Mean | SD | | | Min-Max | Mean | SD |
| <i>Trachinotus marginatus</i> Cuvier, 1832 * | 6577 | 32.35 | 7,414.6 | 2040 | 18.78 | 18-112 | 37.0 | 15.3 | 4537 | 47.92 | 15-129 | 40.8 | 23.8 |
| <i>Mugil liza</i> Valenciennes, 1836 * | 6442 | 31.69 | 1,899.2 | 4726 | 43.51 | 20-290 | 27.5 | 9.0 | 1716 | 18.12 | 20-128 | 26.9 | 4.5 |
| <i>Brevoortia pectinata</i> (Jenyns, 1842) * | 1613 | 7.93 | 731.9 | 1295 | 11.92 | 20-132 | 32.3 | 8.9 | 318 | 3.36 | 21-55 | 31.8 | 5.7 |
| <i>Menticirrhus littoralis</i> (Holbrook, 1847) * | 1599 | 7.86 | 1,543.1 | 1125 | 10.36 | 22-105 | 42.2 | 10.3 | 474 | 5.01 | 13-145 | 45.1 | 19.5 |
| <i>Menticirrhus americanus</i> (Linnaeus, 1758) * | 1208 | 5.94 | 207.7 | 393 | 3.62 | 14-49 | 32.3 | 6.1 | 815 | 8.61 | 12-44 | 22.5 | 4.6 |
| <i>Oncopterus darwinii</i> Steindachner, 1874 * | 898 | 4.42 | 707.1 | 93 | 0.86 | 15-87 | 39.3 | 16.7 | 805 | 8.50 | 18-95 | 38.1 | 12.5 |
| <i>Atherinella brasiliensis</i> (Quoy & Gaimard, 1825) * | 652 | 3.21 | 802.7 | 573 | 5.27 | 25-123 | 55.6 | 12.1 | 79 | 0.83 | 36-102 | 58.7 | 14.0 |
| <i>Odontesthes argentinensis</i> (Valenciennes, 1835) * | 532 | 2.62 | 1,406.2 | 66 | 0.61 | 20-175 | 107.5 | 49.8 | 466 | 4.92 | 22-290 | 46.2 | 24.9 |
| <i>Mugil cf. hospes</i> * | 312 | 1.53 | 196.6 | 245 | 2.26 | 24-108 | 37.7 | 11.1 | 67 | 0.71 | 25-58 | 33.9 | 5.4 |
| <i>Mugil curema</i> Valenciennes, 1836 * | 256 | 1.26 | 355.6 | 190 | 1.75 | 23-118 | 43.8 | 19.5 | 66 | 0.70 | 21-127 | 34.5 | 21.7 |
| <i>Anchoa marinii</i> Hildebrand, 1943 | 94 | 0.46 | 8.6 | 4 | 0.04 | 27-30 | 29.0 | 1.41 | 90 | 0.95 | 20-33 | 26.8 | 2.8 |
| <i>Harengula clupeiola</i> (Cuvier, 1829) | 64 | 0.31 | 38.2 | 63 | 0.58 | 25-57 | 37.4 | 9.4 | 1 | 0.01 | 56 | 56.0 | - |
| <i>Stellifer rastrifer</i> (Jordan, 1889) | 20 | 0.10 | 5.4 | 7 | 0.06 | 19-39 | 28.3 | 7.7 | 13 | 0.14 | 17-31 | 24.2 | 3.4 |
| <i>Platanichthys platana</i> (Regan, 1917) | 15 | 0.07 | 13.9 | 14 | 0.13 | 25-72 | 47.2 | 15.3 | 1 | 0.01 | 37 | 37.0 | - |
| Clupeidae not identified | 12 | 0.06 | 0.8 | 6 | 0.06 | 20-27 | 23.8 | 2.7 | 6 | 0.06 | 19-23 | 21.2 | 1.5 |
| <i>Lycengraulis grossidens</i> (Spix & Agassiz, 1829) | 9 | 0.04 | 14.9 | 5 | 0.05 | 24-125 | 59.2 | 42.1 | 4 | 0.04 | 29-36 | 31.2 | 3.2 |
| <i>Micropogonias furnieri</i> (Desmarest, 1823) | 8 | 0.04 | 148.6 | 4 | 0.04 | 37-121 | 60.2 | 40.6 | 4 | 0.04 | 21-202 | 120.7 | 75.1 |
| <i>Trachurus lathami</i> Nichols, 1920 | 4 | 0.02 | 9.6 | 4 | 0.04 | 67-78 | 72.5 | 4.5 | 0 | - | - | - | - |
| <i>Jenynsia multidentata</i> (Jenyns, 1842) | 3 | 0.01 | 0.9 | 3 | 0.03 | 28-31 | 29.6 | 1.5 | 0 | - | - | - | - |
| <i>Pomatomus saltatrix</i> (Linnaeus, 1766) | 3 | 0.01 | 27.0 | 1 | 0.01 | 90 | 90.0 | - | 2 | 0.02 | 95-123 | 109.0 | 19.8 |
| <i>Trichiurus lepturus</i> Linnaeus, 1758 | 2 | 0.01 | 63.2 | 2 | 0.02 | 43-410 | 226.5 | 259.5 | 0 | - | - | - | - |
| <i>Parapimelodus nigribarbis</i> (Boulenger, 1889) | 1 | < 0.01 | 0.2 | 1 | 0.01 | 34 | 34.0 | - | 0 | - | - | - | - |
| <i>Trachinotus goodei</i> Jordan & Evermann, 1896 | 1 | < 0.01 | 0.7 | 1 | 0.01 | 41 | 41.0 | - | 0 | - | - | - | - |
| <i>Stellifer brasiliensis</i> (Schultz, 1945) | 1 | < 0.01 | 0.4 | 1 | 0.01 | 33 | 33.0 | - | 0 | - | - | - | - |
| <i>Paralichthys orbignyanus</i> (Valenciennes, 1839) | 1 | < 0.01 | 64.1 | 1 | 0.01 | 188 | 188.0 | - | 0 | - | - | - | - |
| <i>Ramnogaster arcuata</i> (Jenyns, 1842) | 1 | < 0.01 | 0.2 | 0 | - | - | - | - | 1 | 0.01 | 30 | 30.0 | 30.0 |
| <i>Hippocampus reidi</i> Ginsburg, 1933 | 1 | < 0.01 | 1.0 | 0 | - | - | - | - | 1 | 0.01 | 50 | 50.0 | - |
| <i>Selene vomer</i> (Linnaeus, 1758) | 1 | < 0.01 | 23.2 | 0 | - | - | - | - | 1 | 0.01 | 120 | 120.0 | 120.0 |
| <i>Ctenogobius shufeldti</i> (Jordan & Eigenmann, 1887) | 1 | < 0.01 | 0.1 | 0 | - | - | - | - | 1 | 0.01 | 18 | 18.0 | - |

Total n°. of Individuals

20331

15,685.7 10863

9468




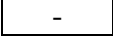
| | |
|---|-----------------------|
|  | Frequent/Abundant |
|  | Frequent/Not-Abundant |
|  | Present |
|  | Absent |

Table 2.

| Source of variation | d.f. | SS | MS | Pseudo-F | <i>P</i> (perm) | Unique perms |
|-----------------------|------|--------|--------|----------|-----------------|--------------|
| Beach | 1 | 2863.6 | 2863.6 | 1.8548 | 0.0828 | 9934 |
| Season | 4 | 30817 | 7704.2 | 4.9901 | 0.0001 | 9916 |
| Site (Beach) | 2 | 1562.9 | 781.4 | 0.5061 | 0.9184 | 9931 |
| Beach x Season | 4 | 8482.2 | 2120.6 | 1.3735 | 0.1136 | 9895 |
| Site (Beach) x Season | 8 | 5207.1 | 650.9 | 0.4216 | 0.9936 | 9874 |
| Residual | 32 | 49405 | 1543.9 | | | |
| Total | 51 | 98574 | | | | |

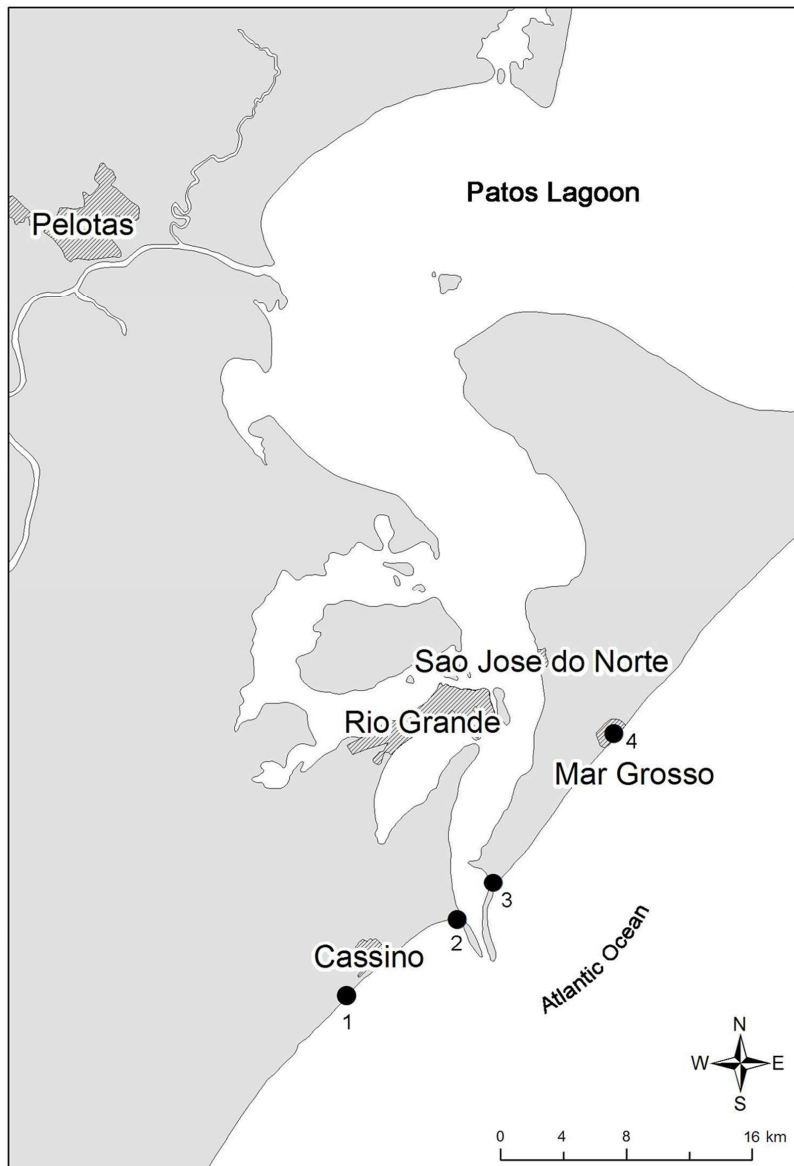


Fig. 1.

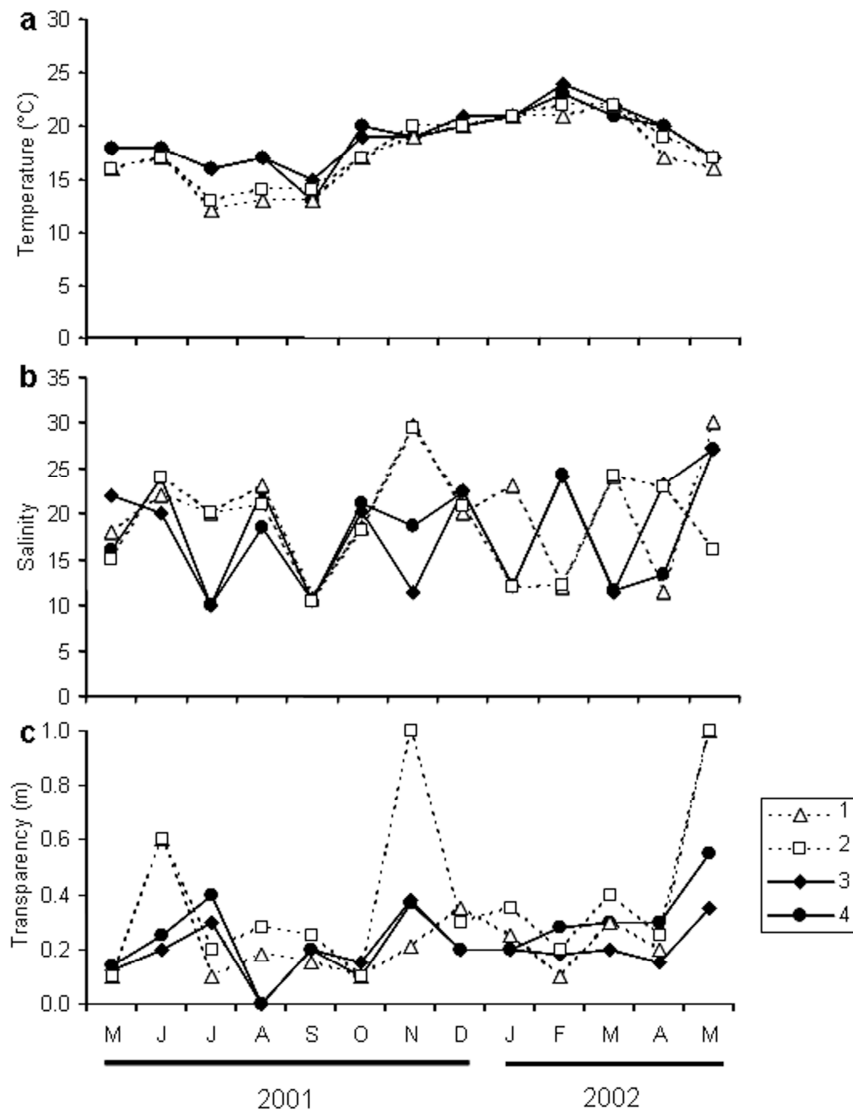
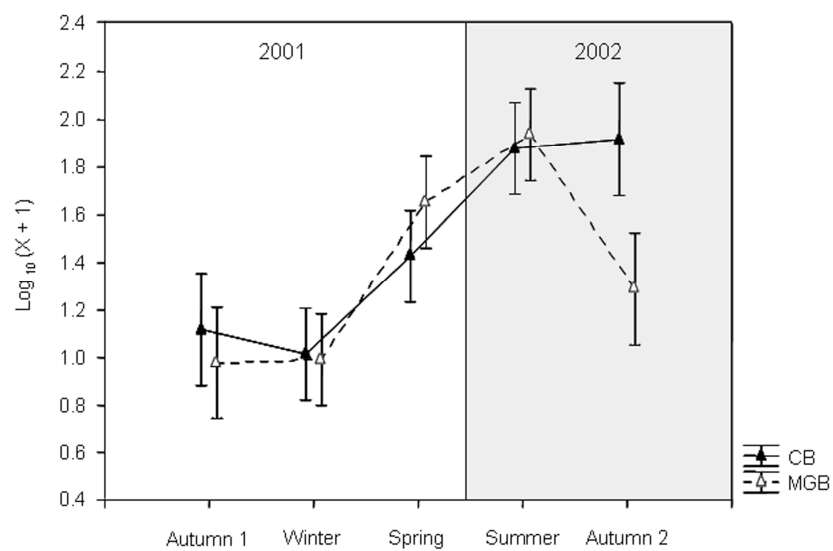


Fig. 2.

**Fig. 3.**

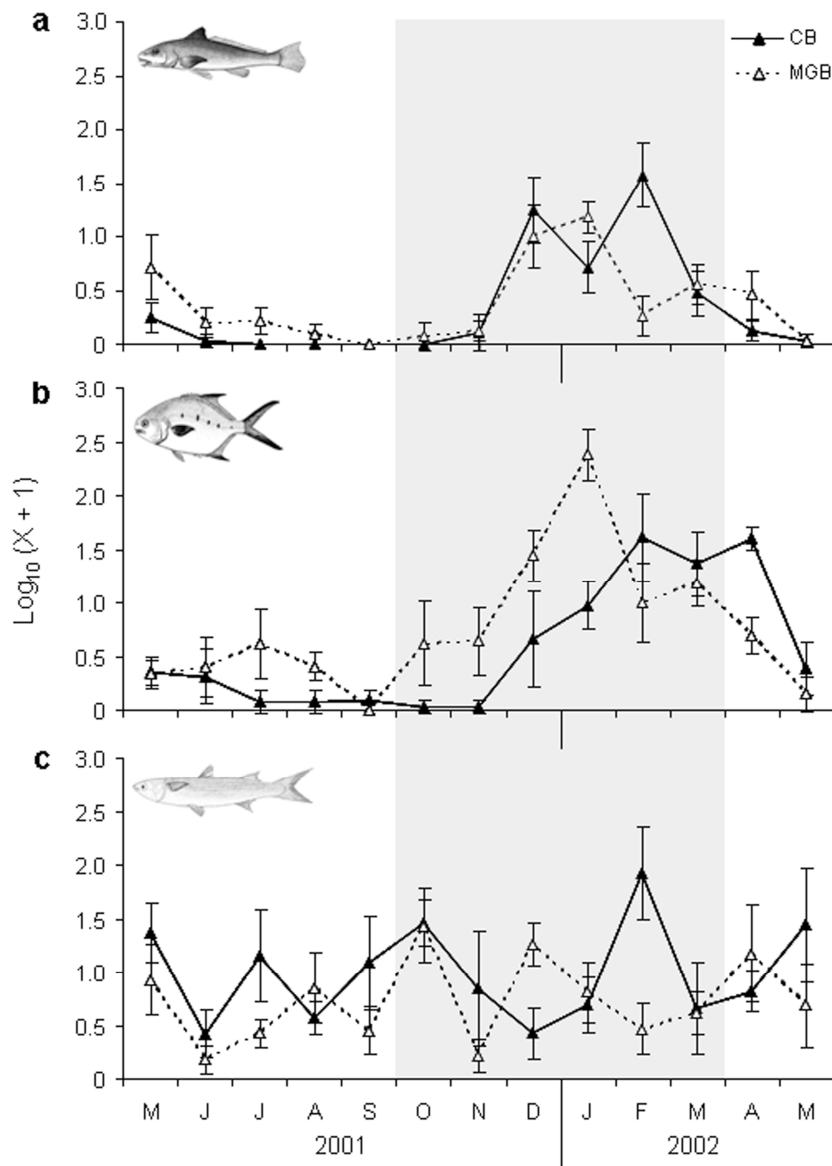


Fig. 4.

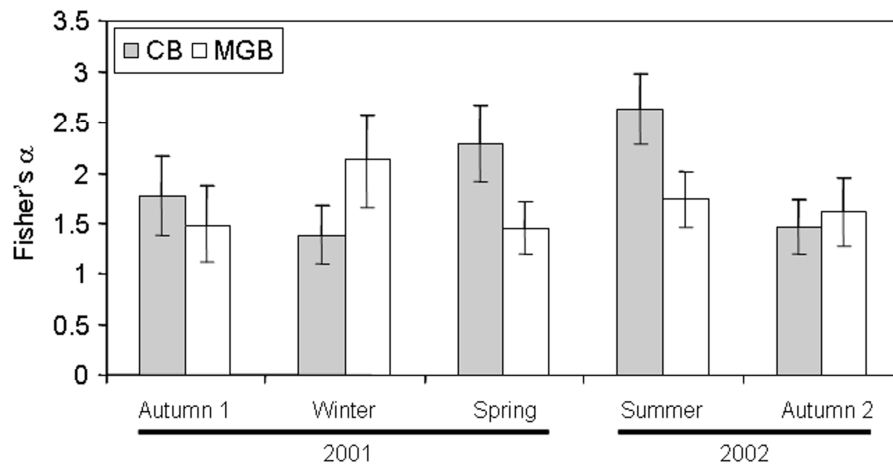


Fig. 5.

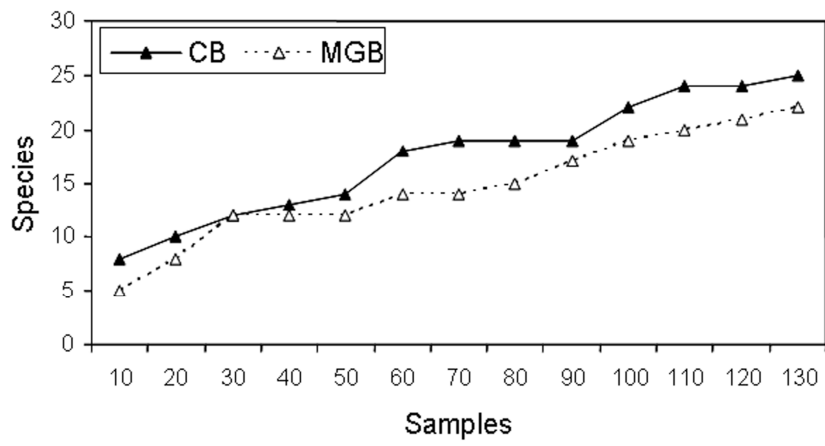


Fig. 6.

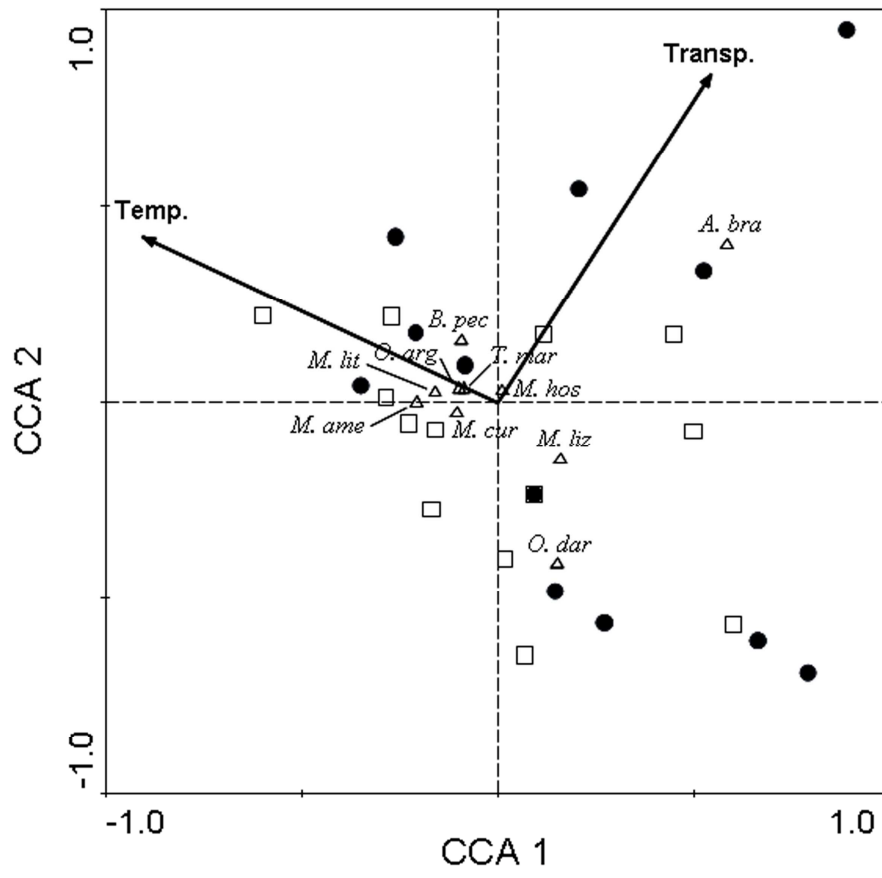


Fig. 7.

ANEXO II

The effects of different sampling gears on the assessment of surf zone fish assemblages:
Community structure and size distribution.

Rodrigues, Fábio Lameiro; Vieira, João Paes

(Submetido ao periódico *Fisheries Research*)

The effects of different sampling gears on the assessment of surf zone fish assemblages:
Community structure and size distribution.

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ABSTRACT

This work simultaneously compared three distinct types of sampling gears (two beach seines of different sizes and one set of trammel nets) to assess the species composition, richness and size structure of a surf zone fish assemblage. Furthermore, we tested the hypothesis that the sampling gears would catch fish of a similar fauna but with a different size distribution. For each type of sampling gear, we assessed the relative importance of the fish species and the size distribution of the catch. A Principal Coordinates Analysis (PCO) and Permutational Analysis of Multivariate Dispersions (PERMDISP) were performed to provide a measure of the variability between the sampling gears, and cumulative species curves calculated using a Bootstrap method were used to express the species richness. A total of 41 species were caught, and the number of species varied among the nets, with the large beach seine catching more species ($S = 35$) than the small beach seine ($S = 30$) and the trammel net ($S = 20$). PCO clearly separated the sampling gears, and PERMDISP showed significant differences between the trammel net and the beach seines ($P < 0.001$), but not between the beach seines ($P = 0.09$). The fish size also varied between the gears, with the small beach seine catching 78.6% of fish < 60 mm TL and the large beach seine catching 68.4% of fish between 60 and ≤ 120 mm TL. The trammel net showed a bimodal size distribution, with peak abundance at 150 mm TL. In conclusion, the catches of both beach seines were similar in species composition and complementary in relation to the size distribution. The trammel net was not considered a good sampling gear for use in the surf zone, but it may be used as a complementary gear to catch larger fish.

Keywords: Shallow habitats, net comparison, beach seine, trammel net, species composition, multivariate analysis

1. Introduction

Coastal environments are regarded as highly important sites for fish. The surf zone of sandy beaches is an environment characterized by harsh conditions and composed of different fish species, with low fish diversity and a high dominance of a few species (Beck et al., 2003; McLachlan and Brown, 2006). In general, small fish (≤ 60 mm total length) are caught with different sampling gears (e.g., Félix et al., 2007; Nanami and Endo, 2007; Gaelzer and Zalmon, 2008), and any conclusions about the structure of the fish assemblage that inhabit the surf zone are misleading. Using a large beach seine net (with larger mesh size), Lima and Vieira (2009) reported catches of fish with sizes above 60 mm, increasing the range of sizes caught and the knowledge about the structure of the fish community of a dissipative sandy beach in southern Brazil.

When conducting fish assemblage surveys, the choice of the sampling method depends on the particular objective of a project, the ease of handling, cost and familiarity with a specific method (Carter and Resh, 2001; Bonar and Hubert, 2002). Many studies use a range of sampling gears to provide accurate measurements relative to the occurrence, abundance and fish size distribution of a particular community in coastal marine habitats (Queirolo et al., 2009; Scharf et al., 2009). Based on these assumptions, the choice of the survey design and the sampling gear must provide adequate spatial and temporal resolution to enable field samples to reveal habitat-related ecological processes (Pepin and Shears, 1997).

The beach seine net is the most common and effective type of fishing gear to sample shallow marine areas (King, 2007). Nevertheless, other types of sampling gear, such as gill nets (with several mesh sizes) and trammel nets (Acosta and Appeldoorn, 1995; Moth-Poulsen, 2003; Stergiou et al., 2006, Hickford and Schiel, 2008), have been used

to collect fish in shallow waters worldwide. Both types of gear may be size- and species-selective (Hamley, 1975). However, the trammel net may be more effective than the gill net because two different mesh sizes are incorporated into the trammel net (i.e., one large and one small), making it possible to catch fish in pockets (Lloyd and Mounsey, 1998). In general, beach seining catches smaller fishes (Monteiro-Neto et al., 2003; Lima and Vieira 2009) whereas trammel nets tend to be selective for larger sizes (Fabi et al., 2002; Erzini et al., 2006). In this sense, it would be interesting to compare the fish composition of these three types of fishing gear to better understand the structure of the fish assemblage in the surf zone of dissipative sandy beaches.

Trammel nets are used along the entire southern Brazilian coast by artisanal fisheries to catch fish within or just beyond the surf zone (Klippel et al., 2005). The surf zone fish assemblages in this area were studied based on beach seine samples collected over a long period (Monteiro-neto et al., 2003; Lima and Vieira, 2009; Mont'Alverne et al., 2012; Rodrigues and Vieira, 2012). However, these studies are scattered in time and space, and the use of information from the fisheries' trammel nets can significantly enhance our understanding of surf zone fish ecology. To advance this knowledge, it is necessary to evaluate the performance of these different nets.

In this study, we test the hypothesis that three different types of sampling gears (two beach seines of different sizes and a set of trammel nets), provide similar fish-fauna composition and richness, but different size structures of the fish associations in the surf zones of sandy beaches.

2. Materials and methods

2.1. Study area

The sampling was conducted at six sampling sites that were evenly distributed at two beaches (Cassino and Mar Grosso) located along the southern Brazilian coast. The beaches are located adjacent to the south and north of the Patos Lagoon jetties (Fig. 1). The most distant sampling sites on each side were approximately 24 km apart from each jetty. Both beaches have similar morphodynamic behavior, are dissipative (Pereira et al., 2010) and the sediment size in the limit between beachface and swash is characterized as very fine sand (Siegle and Calliari, 2008). Although similar to Cassino, the Mar Grosso beach is likely to receive more wave energy from the east/southeast and is more exposed to northeast winds (Calliari and Klein, 1993; Tomazelli, 1993). Despite this difference, previous comparative studies on the fish fauna revealed no ecological differences between the Cassino and Mar Grosso beaches (Rodrigues and Vieira, 2012).

2.2. Field sampling

The sampling was conducted monthly from July 2009 to June 2010 using two different sets of beach seines and a set of three trammel nets. All fish caught were euthanized, stored in plastic bags and transported on ice to the laboratory. Subsequently, each individual was identified at the species level, counted and measured (total length with 1 mm precision; mm TL).

2.2.1. Beach seine design

The beach seine 9 m (BS-9 m) is a straight bagless net of 9 m length x 1.5 m height made of a 12-mm stretch mesh in the wings and a 5-mm stretch mesh in the 3 m center section. The beach seine 30 m (BS-30 m) is also a straight bagless net measuring 30 m long x 1.8 m height made of a 12-mm nylon uniform stretched mesh. Between the body

of the net and the lead line, a 30-cm strip (manufactured with multifilament line) was sewn to give strength to the net. These sampling gears were used at all six sampling sites. At each site, a beach seine haul was replicated five times (5 hauls per beach seine/per site/per month), with a total of 720 samples (360 for each beach seine).

2.2.2. Trammel net design

Each trammel net (TN-25 m) consists of three net panels attached together to the float and the lead lines (Lloyd and Mounsey, 1998). The two external panels are made of a larger mesh size, and between them lies a single loosely sewn smaller mesh panel. When a fish swims through the outer large mesh panels, it pushes against the small mesh panel forming a pocket, trapping the fish between the net panels.

For this experiment, we used a set of three trammel nets, each one separated by approximately 100 m, and we used each net at only two sampling sites (S1 and S6; Fig. 1). Each net was 25 m long x 2.5 m high. All panels were made of monofilament nylon, the outer panels had a mesh size of 150-mm stretched mesh, and the internal panel had a 35-mm stretched mesh. The TN-25 m operates in a position perpendicular to the beach from 1 to 2 m deep. Each net was fixed to two “1.8 m iron stakes”, one spiked at approximately 1.5 m deep and the other near the swash zone. The nets were set early in the morning (approximately 08:00 h) and retrieved six hours later.

2.3. Data Analysis

To assess the relative importance of the fish species caught with each type of sampling gear, the frequency of occurrence (FO%) and the numeric percent abundance (%N) were compared to their respective means (\bar{X} FO%; \bar{X} %N). A species was

considered abundant when $\%N \geq 100/S$ (S = the total number of species captured in each sampling gear), and it was considered frequent when $FO\% \geq \sum\%FO/S$ in each sampling gear. Based on this classification, the species were grouped into the following categories: frequent and abundant ($\%FO \geq \sum\%FO/S$; $\%N \geq 100/S$), frequent but not abundant ($\%FO \geq \sum\%FO/S$; $\%N < 100/S$), not frequent but abundant ($\%FO < \sum\%FO/S$; $\%N \geq 100/S$), present ($\%FO < \sum\%FO/S$; $\%N < 100/S$) and absent (no fish captured). Abundant and frequent species were considered as dominant (Garcia and Vieira, 2001).

The size structure was analyzed for each sampling gear using 30-mm total length classes (TL). Fishes that were dominant in at least two fishing gears simultaneously were selected to analyze the contribution by size class. The percentage of catch per unit effort based on the size class (CPUE-SC) of each species (Garcia and Vieira, 2001; Vieira, 2006) was used to compare the size class distributions between the types of sampling gears tested.

Multivariate dispersion analyses of the species presence/absence data (only with first 16 species on Table 1) were performed using the Principal Coordinates Analysis (PCO) ordination method and Permutational Analysis of Multivariate Dispersions (PERMDISP) to provide a measure of the variability between the sampling gears. PCO and PERMDISP were performed on a resemblance matrix using the Jaccard distances (Anderson et al., 2008). PERMDISP is a distance-based test for the homogeneity of multivariate dispersions based on any resemblance measure. PERMDISP results were reported as the average within-group distance deviations of each group from the respective centroids. If differences between groups were found, a post-hoc pair-wise test was calculated with the finality to identify where these differences were represented.

Permutation tests for significance using the Monte Carlo test were also performed with 9,999 permutations, generating P -values of the pseudo- F statistic.

The cumulative curve of species per sample, pooled by month was used to express the richness of species collected by each sampling gear (Ugland et al., 2003). To assess the randomness or non-randomness associated with each richness value, non-parametric confidence intervals were calculated using the Bootstrap method (based on 9,999 resamplings) (Tirasin and Jørgensen, 1999).

With the aim to compare the fish species composition between the different sampling gears, a faunal similarity analysis was performed based on the species presence/absence relationship, using the Jaccard coefficient (S_j) (Magurran, 2004) and the Percent Similarity (%Min) based on the relative species abundance (Krebs, 1999).

3. Results

A total of 23,892 individuals and 41 species were caught. The beach seines sampled more individuals (BS-9 m, $n = 11,008$; BS-30 m, $n = 12,661$) and species ($S = 28$ and 35 , respectively) compared to the trammel nets (TN-25 m, $n = 223$ and $S = 20$; Table 1). The six dominant species in BS-9 m were *Trachinotus marginatus*, *Mugil liza*, *Odontesthes argentinensis*, *Brevoortia pectinata*, *Mugil curema* and *Lycengraulis grossidens*, and they accounted for 92.4% of the total catch. With the BS-30 m, the six dominant species (89.7% of the total catch) were *T. marginatus*, *O. argentinensis*, *B. pectinata*, *Menticirrhus littoralis*, *Menticirrhus americanus* and *Oncopterus darwinii*. Two species (*T. marginatus* and *M. liza*) were dominant in the TN-25 m, and they accounted for 50.7% of the total catch. *Trachinotus carolinus* and *Stephanolepis*

hispidus made up another 22.9% of the catch, but they were only abundant and not frequent.

Based on the cumulative curves of the species caught by month, it was possible to compare the number of species caught using each type of sampling gear (Fig. 2a) and the estimated number of species collected using a resampling method (Fig. 2b). For the beach seines, the estimated cumulative curves stabilized after 10 months of sampling, and there is no significant difference in terms of species richness, whereas the TN-25 m cumulative curve did not stabilize, indicating that this sampler may catch more species.

PCO analyses showed that the first two axes accounted for 54.4% of the total variation in the data dispersion, evidencing a clear separation between the sampling gears (Fig. 3a). TN-25 m presented higher data dispersion in comparison with the other two sampling gears (Fig. 3a-b). In fact, the PERMDISP analysis showed significant differences ($F = 20.116$, $P = 0.0001$) in the multivariate dispersion between the sampling gears. A pair-wise test showed significant differences among the TN-25 m and the other two sampling gears (BS-9 m and BS-30 m; $P < 0.001$), but not between the BS-9 m and the BS-30 m ($P = 0.09$).

The overall faunal similarity between the BS-9 m and the BS-30 m was high ($S_j = 70.3$, %Min = 60.5). The Jaccard index between the two beach seines ranged from $S_j = 53.1$ in the summer to $S_j = 71.4$ in the winter. Lower percent similarities were observed in the winter (%Min = 37.1) and higher values in the summer (%Min = 67.0) (Fig. 4a). The overall similarity between the BS-9 m and the TN-25 m ($S_j = 29.7$, %Min = 44.1) and between the BS-30 m and the TN-25 m ($S_j = 41.0$, %Min = 27.0) were low. Both indices showed low values throughout the year (Fig. 4b-c).

The fish size varied between the sampling gears (Table 1; Fig. 5a). Each sampling gear showed a tendency to capture fishes of distinct size groups, but with some size-classes overlapping between gears. The BS-9 m showed a skewed size distribution with 78.6% of the individuals ≤ 30 mm TL and 19.5% between 60 and 120 mm TL. The BS-30 m showed a normal size distribution with 73.0% of the fish ≤ 120 mm TL. The TN-25 m showed a bimodal size distribution, with a peak abundance at lengths smaller than 240 mm TL, overlapping with both beach seines. The second mode peak occurred at lengths larger than 240 mm TL, and it only overlapped with the BS-30 m.

Four fish species (*T. marginatus*, *M. liza*, *O. argentinensis* and *B. pectinata*) were dominant in the catches of at least two sampling gears simultaneously (Table 1; Fig. 5b-d). With the BS-9 m (Fig. 5b), individuals < 30 mm TL were represented mainly by *M. liza* (50.6%), whereas individuals between 30 and 120 mm TL were represented mainly by *T. marginatus* and *O. argentinensis*, which dominated the size-classes between 120 mm and ≤ 210 mm TL. With the BS-30 m (Fig. 5c), individuals with size-classes < 60 mm TL were represented mainly by *T. marginatus*, *B. pectinata* and *M. liza*. The 60 mm TL individuals were represented by *T. marginatus* (55.2%) and *B. pectinata* (16.4%), and the 90 mm TL by *T. marginatus* (35.5%). *Odontesthes argentinensis* was caught between 120 and 270 mm TL, and the size-classes ≥ 300 mm TL were composed mainly of low numbers of *M. liza*. For the TN-25 m (Fig. 5c), the size-classes between 120 and 210 mm TL were composed mainly of *T. marginatus* and *B. pectinata* and represented the first mode in the size distribution (mean = 170 mm TL). The size-classes above 240 mm TL were composed by large individuals of *M. liza*, which represented the second mode in the size distribution (mean = 340 mm TL).

4. Discussion

A broad variety of sampling strategies and types of fishing gears have been developed to scientifically collect and record the presence and abundance of different fish species in coastal marine habitats (Van Marlen, 2003; Rotherham et al., 2007; Queirolo et al., 2009). Several authors (Monteiro-Neto and Musick, 1994; Vieira et al., 2006; King, 2007) have suggested that the beach seine is the most effective type of fishing gear for sampling in shallow non-vegetated surf zone areas. Furthermore, the beach seine is easy to operate compared to other types of sampling gears (Rozas and Minello, 1997). The surf zone is a nursery for both fish and crustaceans, and sampling gears that are able to catch small size fish, such as the beach seine, are the most efficient in this habitat (Gibson et al., 1993; Monteiro-Neto et al., 2003; Félix et al., 2007; Vasconcellos et al., 2007). Large individuals also occur in the surf zone area but are not easily caught by beach seining (Lemos and Vieira, 2011). However, these large size specimens are often present in catches of gill nets, trammel nets, or both (Acosta and Appeldoorn, 1995; Moth-Poulsen, 2003; Rotherham et al., 2006; Stergiou et al., 2006; Hickford and Schiel, 2008).

Our study analyzed the use of three different types of fishing gears to sample the surf zone fish assemblages of dissipative sandy beaches, testing the hypothesis that these gears would catch similar fish-fauna but with different size structures. Both of the beach seines used in this study have been used in southern Brazilian surf zones to assess juvenile fish composition and abundance (Chao et al., 1982; Monteiro-Neto et al., 2003; Lima and Vieira, 2009). According to our expectations, the BS-9 m and the BS-30 m did not differ from each other in terms of species composition. Nevertheless, the smaller BS-9 m net, made of a fine mesh (5- and 12-mm), caught smaller fish than the larger

beach seine (BS-30 m; mesh = 12-mm). On the other hand, trammel nets have been used to catch adult fishes in the southern Brazilian surf zone (Klippel et al., 2005), and the TN-25 m differed significantly from both beach seines in terms of the species composition of the catch.

Different samplers are usually needed to fully characterize the fish assemblage in a given environment (Gibson et al., 1993), and some studies have shown that different nets consistently underestimate the abundance and biomass of fish (Pierce et al., 1990; Allen et al., 1992) due to their size selectivity. Furthermore, large fish are more capable of out-swimming beach seine nets and are more under sampled compared with smaller fish (Jacobsen and Kushlan, 1987). Another source of bias may be related to the patchy distribution of schooling small fishes (e.g., *B. pectinata*, *M. liza*), which may be present in great abundance in a single haul but then may not occur even as a single individual in the next several hauls (Guest et al., 2003).

The three sampling gears used in this study collected a total of 41 species, which is similar to the species list composed by other studies conducted in this area (Chao et al., 1982; Monteiro-Neto et al., 2003; Lima and Vieira, 2009). The number of species expected based on the literature, using both beach seines, suggests that these sampling gears are efficient for estimating the species richness of the surf zone. The addition of a new sampler (TN-25 m) resulted in the collection of only four new species compared to the beach seines, and these species are usually found in deeper areas (> 10 m), using shallow waters for feeding and/or shelter. The observed richness of TN-25 m ($S = 20$) and the expected richness based on the literature suggested that the TN-25 m was not a good estimator of the species richness of the area. Nevertheless, it captured a wider range of fish sizes not observed in beach seine samples.

The high similarity ($> 70\%$) between both beach seines contrasted with lower similarity between each beach seines and the TN-25 m ($< 50\%$). Although the BS-30 m was larger than the BS-9 m, which would result in an increase in the swept area, both gears nets were pulled in the same location and at the same range of depth (≤ 1.5 m). The high similarities observed in the colder months were the most likely related to the low diversity and abundance during this period (Monteiro-neto et al., 2003; Rodrigues and Vieira, 2012), thus increasing the probability of both beach seines collecting the same or no species (i.e., the more likely record of double-zeros during lower-abundance periods favors the higher similarity). During warmer seasons (spring and summer), the similarity between the beach seines decreased, most likely because the BS-30 m collected more species than the BS-9 m due to its larger size. Indeed, longer nets may provide a more representative picture of the fish community than smaller nets, especially with respect to the occurrence of large, active swimming fishes in the surf zone (Říha et al., 2008). Between both beach seines and the TN-25 m, the similarity indices were low, most likely due to differences in net operation. The use of the different sampling gears with different sampling strategies can result in a different fish community structure (Gray et al., 2005; Monteiro-Neto and Prestrelo, *in press*).

The most outstanding pattern of difference among those three different fishing gears was related to the fish size distributions considering that all three samplers were complementary to each other. The BS-9 m showed a skewed size distribution pattern composed mainly of individuals ≤ 60 mm TL. The BS-30 m showed a greater size spread, between 60-120 mm TL, included larger active swimming fishes, and provided a more representative picture of the size distribution within fish community of the sampled surf zone. Nevertheless, the BS-30 m was not efficient for catching the

dominant *M. liza* with sizes ≤ 30 mm TL. The TN-25 m caught fewer individuals and species than the beach seines, but the catch was mostly represented by individuals > 120 mm TL. According to Scharf et al. (2009), the use of a single method to collect fish may not be sufficient for drawing a complete picture of the population size structure. As the fishes grow in the surf zone, they tend to swim faster and avoid nets with smaller mesh sizes, and they become more susceptible to capture by nets with larger mesh sizes (Allen et al., 1992).

Bimodal patterns are relatively common for trammel nets (Erzini et al., 2006). The TN-25 m showed a bimodal size distribution, with one peak in 170 mm TL and the other at 340 mm TL. For passive fishing gear, the number of fishes expected to be captured is dependent on the probability of a net encounter, the net contact after the encounter and the likeliness of being retained after contact (Anderson, 1998), and the differences in abundance between the catches with the beach seines and the trammel nets can be accounted for by these characteristics. Additionally, the catches of the trammel nets depend on the mesh size and the vertical slack of the inner net (Purbayanto et al., 2000) because more slacking causes more entangling (instead of gill-catching) of the fish (Moth-Poulsen, 2003). The capture efficiency of a trammel net depends on the fish size, morphology and the behavior of each species (Reis and Pawson, 1999), but it also varies according to the way that a fish is caught (Fabi et al. 2002). In our study, the TN-25 m caught mainly fishes with sizes above 150 mm TL, represented mostly by *T. carolinus*, *T. marginatus* and *S. hispidus*. Such species have a tall body and spines in the dorsal and anal fins, thus making them more susceptible to capture by trammeling/pocketing, even at smaller sizes. Conversely, the 340 mm TL peak was

represented mainly by adults of *M. liza*, and their swimming behavior increases the catch probability in such nets, despite their streamlined body shape.

The choice of a sampling method to assess fish assemblage is a critical point during the planning of field sampling. The limitations of a sampling method must be fully considered. Beach seines are active samplers and therefore, they are used to pursue the fish. Pierce et al. (1990) enumerated several other advantages of beach seines over other types of fishing gears (e.g., trammel nets): (i) the gear is simple and easy to deploy, (ii) sampling is rapid, and as a consequence, several replicates can be performed in less time, (iii) the beach seine enables an accurate assessment of the temporal distribution patterns and (iv) most species can be captured equally, but fish that live close to or in the sediment (e.g., flatfish) may not be susceptible to capture by a net. The major sources of limitations for the use of the beach seine, are: (i) physical obstructions (e.g., rocks, tree branches and macrophytes), which is not an issue in sandy beach surf zones, (ii) the high probability of escape for fishes smaller than the mesh of the net, which is reduced in the case of the BS-9 m due to the use of a 5-mm mesh in the center panel. However, as mentioned before, larger fish tend to swim faster and avoid the net (Allen et al., 1992), resulting in their capture by the longer beach seine.

Both beach seines used in this study were easy to use and caught nearly all fish species within the surf zone fish community. They can therefore serve as complementary samplers with respect to the size distribution. The catch efficiency may be influenced by fish behavior, physical conditions, or both at the time of collection (e.g., harsh sea conditions may roll the net up over itself; Allen et al., 1992). Due to operational difficulties (i.e., harsh conditions, strong winds and variations in the tide amplitude caused mainly by storms) and laborious handling, the TN-25 m was not

considered a good sampling net for use in the surf zone, but it may be used as a complementary net to catch larger fish.

Acknowledgements

We would like to thank the “Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)”, the colleagues of the “Laboratório de Ictiologia, Instituto de Oceanografia, Universidade Federal do Rio Grande (FURG)”, and the anonymous reviewers of this manuscript. We also thank to Marlucy Claudino and Mário V. Condini. The first author was funded with a PhD grant by CAPES.

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Table 1

Species caught using three different sampling gears in the shallow surf zones (≤ 1.5 m) of two sandy beaches adjacent to Patos Lagoon estuary (Brazil). The catches are expressed as the number of individuals (No.), and the size ranges are expressed as the total length (mm). The species were classified by relative importance: frequent and abundant (black), frequent and not abundant (light grey), not frequent and abundant (dark grey), present (without color) and absent (-).

| Species | Beach seine 1 (BS-9m) | | | Beach seine 2 (BS-30m) | | | Trammel net (TN-25m) | | |
|----------------------------------|-----------------------|-------|---------|------------------------|-------|---------|----------------------|------|---------|
| | No. | % | Min-Max | No. | % | Min-Max | No. | % | Min-Max |
| <i>Trachinotus marginatus</i> | 3098 | 28.1 | 15-145 | 3306 | 26.1 | 11-186 | 28 | 12.6 | 130-230 |
| <i>Mugil liza</i> | 2380 | 21.6 | 11-117 | 160 | 1.3 | 24-610 | 85 | 38.1 | 235-570 |
| <i>Odontesthes argentinensis</i> | 1980 | 18.0 | 16-236 | 4622 | 36.5 | 37-327 | 6 | 2.7 | 205-365 |
| <i>Brevoortia pectinata</i> | 1480 | 13.4 | 19-165 | 1001 | 7.9 | 23-211 | 6 | 2.7 | 139-260 |
| <i>Mugil curema</i> | 629 | 5.7 | 24-87 | 44 | 0.3 | 35-261 | - | - | - |
| <i>Lycengraulis grossidens</i> | 609 | 5.5 | 25-147 | 118 | 0.9 | 56-240 | - | - | - |
| <i>Menticirrhus littoralis</i> | 362 | 3.3 | 18-120 | 966 | 7.6 | 45-281 | 8 | 3.6 | 278-400 |
| <i>Menticirrhus americanus</i> | 84 | 0.8 | 15-119 | 558 | 4.4 | 80-280 | 3 | 1.3 | 295-308 |
| <i>Oncopterus darwinii</i> | 83 | 0.8 | 14-194 | 907 | 7.2 | 31-186 | - | - | - |
| <i>Atherinella brasiliensis</i> | 182 | 1.7 | 21-123 | 28 | 0.2 | 64-156 | - | - | - |
| <i>Micropogonias furnieri</i> | 23 | 0.2 | 15-230 | 105 | 0.8 | 89-660 | 10 | 4.5 | 250-645 |
| <i>Pomatomus saltatrix</i> | 18 | 0.2 | 42-120 | 52 | 0.4 | 88-165 | 4 | 1.8 | 242-315 |
| <i>Genidens barbatus</i> | 1 | < 0.1 | 86 | 98 | 0.8 | 77-148 | - | - | - |
| <i>Paralichthys orbignyanus</i> | - | - | - | 42 | 0.3 | 136-434 | 7 | 3.1 | 190-660 |
| <i>Trachinotus carolinus</i> | 7 | 0.1 | 62-151 | 52 | 0.4 | 68-195 | 25 | 11.2 | 150-213 |
| <i>Stephanolepis hispidus</i> | 4 | < 0.1 | 68-215 | 39 | 0.3 | 55-182 | 26 | 11.7 | 80-270 |
| <i>Polydactylus virginicus</i> | 13 | 0.1 | 32-96 | 3 | < 0.1 | 104-172 | - | - | - |
| <i>Mugil cf. hospes</i> | 24 | 0.2 | 33-109 | 223 | 1.8 | 51-160 | - | - | - |
| <i>Oligoplites saliens</i> | 10 | 0.1 | 33-113 | 204 | 1.6 | 62-110 | - | - | - |
| <i>Syngnathus folletti</i> | 5 | < 0.1 | 84-126 | 1 | < 0.1 | 101 | - | - | - |
| <i>Anchoa marinii</i> | 4 | < 0.1 | 24-90 | 4 | < 0.1 | 89-94 | - | - | - |
| <i>Harengula clupeola</i> | 3 | < 0.1 | 68-102 | 3 | < 0.1 | 72-98 | - | - | - |
| <i>Eucinostomus melanopterus</i> | 3 | < 0.1 | 15-18 | 3 | < 0.1 | 93-152 | - | - | - |
| <i>Genidens planifrons</i> | 1 | < 0.1 | 138 | 5 | < 0.1 | 102-148 | 4 | 1.8 | 292-465 |
| <i>Platanichthys platana</i> | 1 | < 0.1 | 87 | 38 | 0.3 | 71-105 | - | - | - |
| <i>Pogonias cromis</i> | 1 | < 0.1 | 64 | 1 | < 0.1 | 210 | - | - | - |
| <i>Hyporhamphus unifasciatus</i> | 1 | < 0.1 | 281 | 8 | 0.1 | 258-305 | - | - | - |
| <i>Gobisox strumosus</i> | 1 | < 0.1 | 20 | - | - | - | - | - | - |
| <i>Hyleurochilus fissicornis</i> | 1 | < 0.1 | 27 | - | - | - | - | - | - |
| <i>Astroscopus sexspinosus</i> | - | - | - | 2 | < 0.1 | 120-127 | 1 | 0.4 | 170 |
| <i>Trichiurus lepturus</i> | - | - | - | 14 | 0.1 | 88-917 | 1 | 0.4 | 745 |
| <i>Sardinella janeiro</i> | - | - | - | 36 | 0.3 | 164-220 | 1 | 0.4 | 172 |

| | | | | | | | | | |
|-------------------------------|-------|---|---|-------|-------|--------|-----|-----|---------|
| <i>Selene vomer</i> | - | - | - | 7 | 0.1 | 48-103 | 1 | 0.4 | 138 |
| <i>Caranx latus</i> | - | - | - | 5 | < 0.1 | 89-120 | - | - | - |
| <i>Eucinostomus argenteus</i> | - | - | - | 4 | < 0.1 | 90-158 | - | - | - |
| <i>Ramnogaster arcuata</i> | - | - | - | 1 | < 0.1 | 57 | - | - | - |
| <i>Trachinotus goodei</i> | - | - | - | 1 | < 0.1 | 159 | - | - | - |
| <i>Rhinobatos horkelli</i> | - | - | - | - | - | - | 1 | 0.4 | 440 |
| <i>Macrodon ancylodon</i> | - | - | - | - | - | - | 2 | 0.9 | 280-360 |
| <i>Umbrina canosai</i> | - | - | - | - | - | - | 3 | 1.3 | 300-570 |
| <i>Stellifer rastrifer</i> | - | - | - | - | - | - | 1 | 0.4 | 160 |
| Number of species | 28 | | | 35 | | | 20 | | |
| Total | 11008 | | | 12661 | | | 223 | | |

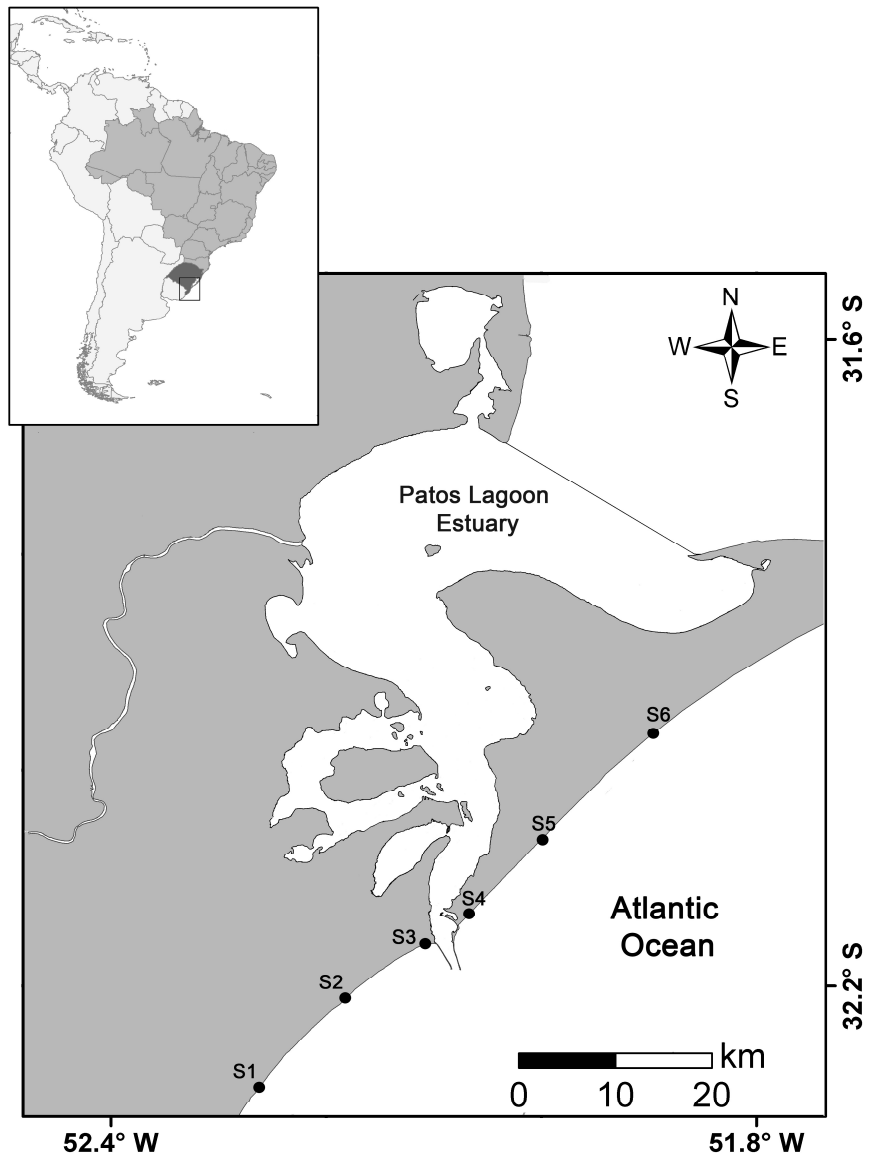


Fig. 1. Study area and location of sampling sites in Cassino (S1-S3) and Mar Grosso (S4-S6) beaches, southern Brazil.

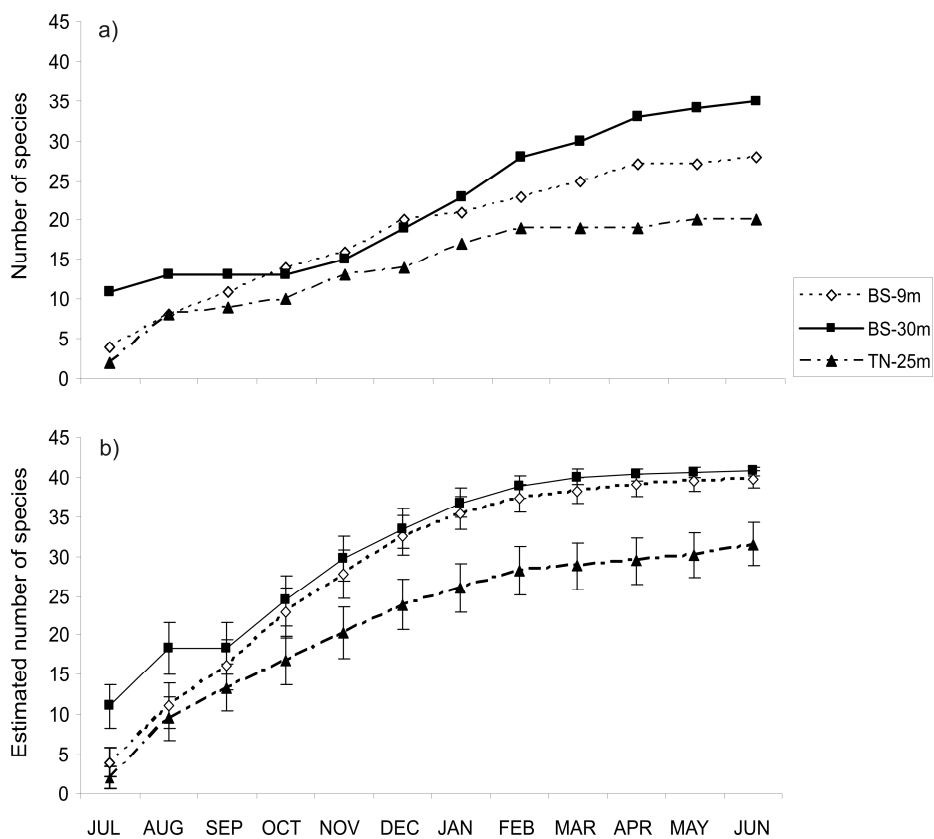


Fig. 2. Comparison of species-accumulation curves by sampling gear and by month. Curves of total species collected during the period (a) and estimated curves achieved with 9,999 resamplings, with (\pm) standard deviation bars (b).

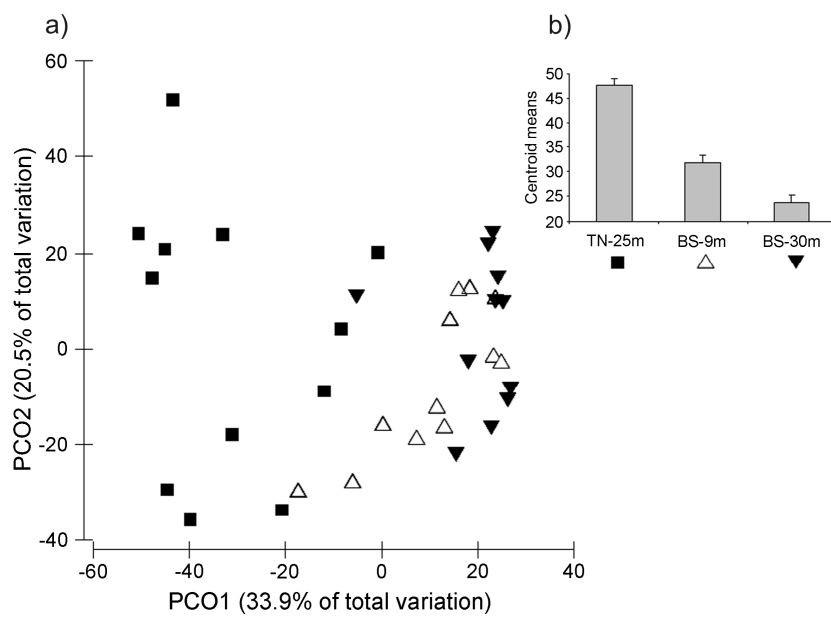


Fig. 3. PCO ordination showing multivariate dispersion of the data between the sampling gears (a) and a histogram showing the pair-wise comparison between the sampling gears based on PERMDISP (b).

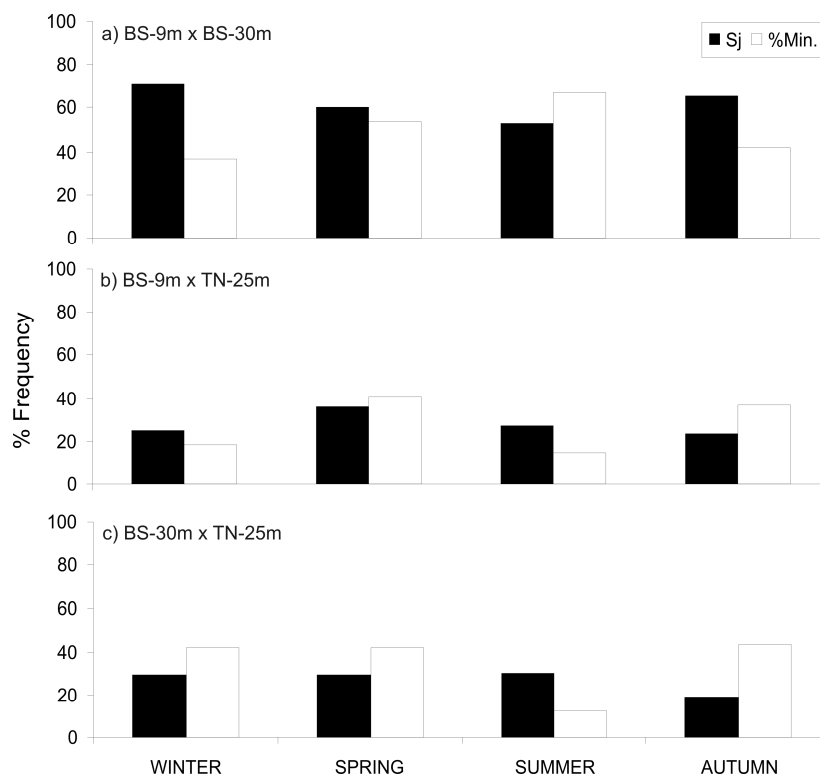


Fig. 4. Similarity indexes (S_j = Jaccard coefficient and %Min = Percent Similarity) by sampling gears by seasons BS = beach seine and TN = trammel net.

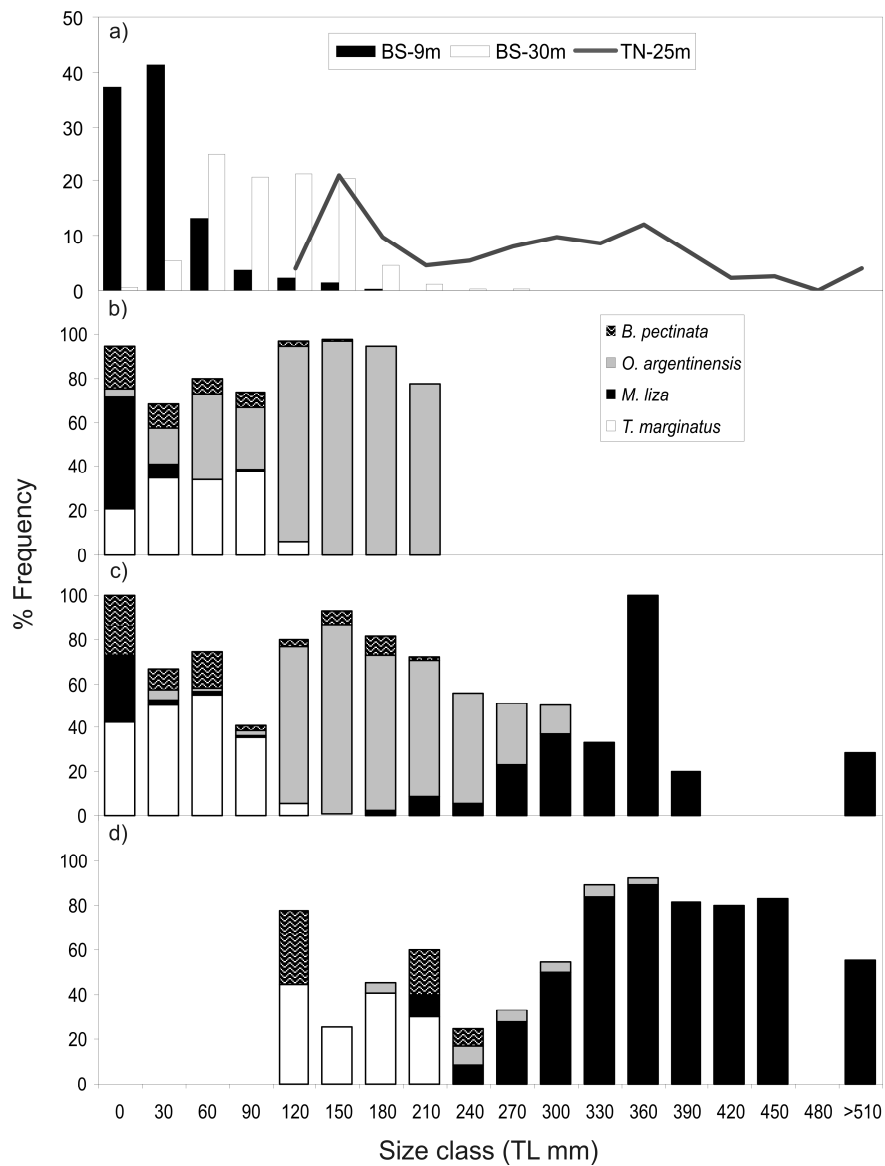


Fig. 5. Length-frequency distribution of all fish caught ($S = 41$) by sampling gear (a) and the proportion contributed by the four dominant species according to the sampling gear used BS-9m (b), BS-30m (c) and TN-25m (d).

ANEXO III

Assessing surf zone fish assemblage variability in southern Brazil.

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(A ser submetido no periódico *Estuarine, Coastal and Shelf Science*)

Assessing surf zone fish assemblage variability in southern Brazil.

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ABSTRACT

Surf zone fish assemblages were investigated in order to evaluate their patterns of variability at two sandy beaches (Cassino and Mar Grosso) in southern Brazil, using Generalized Linear Models (GLM). Fish were collected monthly from July 2009 to June 2011 and beach seine hauls were conducted with two beach seine nets: i) 9 x 1.5 m (multifilament 13 mm stretch mesh in the wings and a 5 mm stretch mesh in the centre 3 m section) and ii) 30 x 1.8 m (12 mm stretch monofilament nylon with a 30 cm inferior bar with a 12 mm multifilament stretch mesh). GLMs were used in two different approaches: to assess and compare fish species richness we used a Poisson model; and to explain the occurrence and variability in abundance of the two most abundant species (*Mugil liza* and *Trachinotus marginatus*) we used a Logistic and Gamma models, respectively. A set of nine explanatory variables (beach seine type, local of sampling, season, water salinity and transparency, wind direction and velocity, long-shore current direction and number of surf break lines) were used in order to explain the patterns of target variables. At large scale seven variables explained 24.8% of variance of species richness, but season (16.2%) and net type (3.0%) were the most important. The presence/absence of *M. liza* was associated with net type (20.4%), whereas the abundance was associated with net type (12.1%) and other five explanatory variables. The presence/absence and abundance of *T. marginatus* was associated mainly with season (18.6% and 22.3%, respectively). Species richness seemed to be strongly related with season, although the choice of sampling gear used could play an important role. Warmer months were richer in number of species and the larger beach seine net was able to catch more species than the smaller one.

Keywords: shallow water habitats, explanatory variables, *Mugil liza*,
Trachinotus marginatus, sandy beaches

1. Introduction

Sandy beaches and the adjacent surf zones represents the world's largest type of open shoreline ecosystem (Defeo et al., 2009), and are probably the most utilized of coastal environments for human activities; however, many aspects of surf zone ecology are poorly known. This environment is characterized as a semi-enclosed system that connects terrestrial environments with offshore waters (McLachlan and Brown, 2006). Although the surf zone area should be considered a physically dynamic environment (with little habitat complexity), it forms a productive ecosystem, serving important functions and playing multiple roles for juvenile fish as nursery area, feeding ground, and migratory pathway (Beyst et al. 1999; Beyst et al., 2002; Hibino et al., 2006; Inoue et al., 2008; Bergamino et al., 2011; Nakane et al. 2011).

A set of physical conditions may influence the species composition, distribution and abundance of the surf zone fish assemblage, and several studies have suggested that seasonality, wave exposure, turbidity and wind, are the main factors that may alter the structure of surf zone fish assemblages (Gibson et al., 1993; Clark, 1997; Vasconcellos et al., 2011). Besides, we know that the study of surf zone fish assemblages is based on extensive knowledge using several types of beach seine nets (e.g., Clark et al., 1996; Layman, 2000; Suda et al., 2002; Wilber et al., 2003; Vasconcellos et al., 2007; Inoue et al., 2008; Prestelo & Monteiro-Neto, *in press*) to obtain a description of the fish assemblage structure (and relations with environmental variables), but seldom using more than one sampling gear simultaneously. The use of different sampling gears to assess surf zone fish assemblage may produce different results, and to adequately sample surf zone fishes and obtain accurate conclusions, is essential to use different

types of sampling gears, or at least, seine nets with different mesh sizes (McLachlan and Brown, 2006).

All knowledge achieved studying the fish community of southern Brazilian surf zones (see Ramos and Vieira, 2001; Monteiro-Neto et al., 2003; Rodrigues and Vieira, 2012) used only one kind of sampling gear and few explanatory variables to explain the pattern of fish assemblage distribution. Therefore, to date we still do not know if the patterns reported are real or influenced by the sampler. In fact, some studies used a range of sampling gears to provide accurate measurements of fish assemblage structure (Queirolo et al., 2009; Scharf et al., 2009). Lima and Vieira (2009) using another kind of sampler (a large beach seine) on southern Brazilian surf zones. These studies caught fish at larger sizes than previously caught by the studies using the beach seine, bringing new information on the species composition and size distribution of fish.

Thus, the aims of this study were to evaluate the patterns of variability of fish assemblages in two sandy beaches sampled with two different gears simultaneously, using as proxies a set of explanatory variables. Furthermore, we compared the size structure and relative abundance of *Mugil liza* and *Trachinotus marginatus*, the most abundant species in this system.

2. Materials and methods

2.1. Study area

The surf zone fish assemblage of two sandy beaches along the Rio Grande do Sul coast, southern Brazil, were investigated: Cassino and Mar Grosso (Fig. 1). Three sampling sites at each beach were sampled monthly and constitute a spatial replicate for each beach (Rodrigues and Vieira 2012).

The coastline in the southernmost Brazil is characterised by extensive wave-dominated, straight sandy beaches, with sediments ranging from very fine to medium sand (Siegle and Calliari, 2008). The sandy beaches near the mouth of Patos Lagoon (PL) estuary are classified as dissipative (Pereira et al., 2010) and are associated with one or two longshore sandbars (Calliari and Klein, 1993). The pattern of coastal water circulation along this coastline undergoes strong seasonal changes. During the winter, south-westerly (SW) winds force the Rio de La Plata waters with low salinities and temperatures to lower latitudes ($\sim 28^\circ$ S); while in the summer, dominant north-easterly (NE) winds bring tropical waters with high salinities and temperatures to $\sim 32^\circ$ S (Möller et al., 2008). The predominant pattern in the NE winds directs the plume of the PL estuary in a southern direction. Fine sediments provided by this plume are transported to the south and deposited offshore as fluid mud. Stormy conditions, such as cold front passages, can rework and transport the fluid mud from the inshore to the surf zone and offshore of Cassino, attenuating the wave energy (Calliari et al. 2007). There are no records of fluid mud deposits at Mar Grosso, located northward of the jetties.

2.2. Sampling surveys and data acquisition

The fish assemblages at Cassino and Mar Grosso beaches were sampled monthly from July 2009 to June 2011. Fish were collected using two types of beach seine nets: *Beach Seine 9m* (BS-9 m), called locally “*Picarê*” (multifilament 9 m long x 1.5 m height; 13 mm stretch mesh in the wings and a 5 mm stretch mesh in the centre 3 m section), and *Beach Seine 30m* (BS-30 m), called locally “*Cerco*” (30 m long x 1.8 m height; 12 mm monofilament nylon stretch mesh with a 30 cm inferior bar with a 12 mm multifilament stretch mesh). Each beach seine haul was replicated five times per

gear at each sampling site (10 hauls per site), with a total of 60 hauls per month. This design resulted in a total of 1420 samples, because we did not sample in site S6, in January and November 2010 due adverse climatic conditions. All fish caught were transported in ice to the laboratory. Subsequently, individual fish were identified, counted and measured the total length (TL) with 1 mm precision.

Since the main goal was not to describe interannual variations in composition and abundance of fish species in the surf zone, we analyzed the data set as a whole, without distinguishing between sampling periods I (July 2009 to June 2010) and II (July 2010 to June 2011). However, we grouped the months into seasons to get a better view of the seasonal behavior of the fish assemblages throughout the period. To do so, the months were grouped in the austral seasons as follows: winter = July, August and September; spring = October, November and December; summer = January, February and March and autumn = May, April and June.

At each site, eight environmental variables were registered at the beginning of each haul: sea surface water temperature (°C); salinity at the surface; transparency (Secchi disc reading); wind velocity was taken with a handheld digital anemometer; wind direction was registered using a GPS Garmin *eTrex*; the number of break lines (from “0” - without waves and break lines to “6” - with waves and six break lines); wave height (H_s) and long shore current direction (without current, north to south and south to north). Wave height and number of bars were obtained by visual observations. These variables were used as candidate predictor variables in GLM. All wind directions were grouped in the four main directions (north, east, south and west) to reduce variables in the GLM. We also used the beach seine type (BS-9 m and BS-30 m), local

(Cassino and Mar Grosso beaches) and season of the year (winter, spring, summer and autumn) as predictor variables.

2.3. Data analyses

Before the analysis, the suite of candidate predictor variables described above was pair plotted in order to investigate collinearity between independent variables, as they may reduce the precision in estimating the variable coefficients and their significance (Beger and Possingham, 2008). If a collinearity was detected between variables, the variable known to have a more ecological importance was maintained, while the other variable (or variables) was eliminated from the analysis. With this approach, we eliminated two variables (temperature and significant wave height; H_s) and the models were fitted with nine uncorrelated predictor variables derived from a suite of 11 initial candidate variables. The seasonal pattern of environmental variables registered during the study period at both beaches, are given in Table 1.

To determine the relative importance of each species, and their dominance pattern at each beach, we used the approach described in Garcia and Vieira (2001) and adjusted by Artioli et al. (2009) and Mont'Alverne et al. (2012), based on the combination of numerical percentage (N%) and frequency of occurrence (FO%) values.

Generalized linear model (GLM) were used to analyze the data set since this method has a strong statistical foundation, allowing ecological relationships to be modeled realistically (Austin, 2002). The GLM's were conducted in R software (R Development Core Team, 2005), in three steps. Firstly, we investigated the variation of fish species richness between each beach in response to a set of predictor variables. For this, we used a Poisson distribution with a log link function (Hastie and Tibshirani,

1990). Secondly, we estimated the probability of presence of the two most important species at surf zone of both beaches, using a Logistic regression model with a logit link function (Hosmer and Lemeshow, 1989). Logistic regression represents the probability of occurrence, P , as a function of a linear combination of habitat predictors, which can include single variables as well as higher-order (quadratic and interaction) terms. Lastly, we estimated the abundance of the two most important species using a Gamma distribution model, only for positive catches (França et al., 2011). The Poisson model allows zero values to be included in the analyses, but the dependent variable in this case is the nearest integer to the encounter rate (Ye et al., 2005).

A stepwise selection procedure, with nominal cut-off at $p = 0.05$, was used to determine which variables should be retained in the final model. Additionally a *drop1* command in R software was used to compare the full model with a model in which the interaction is dropped, using a Chi-square test. This command drops each explanatory variable in turn, and each time it calculates the difference between deviances and compares the difference to a Chi-square distribution (Zuur et al., 2007). When several descriptors are used simultaneously, this method selects only the significant ones. All models were tested to overdispersion. The final model was fitted only with the significant variables and the percentage of total deviance explained and relative contribution of each factor were evaluated for each model independently.

For each net, the number of individuals by size class per sample (CPUE-SC) was obtained by multiplying the ratio of the total number of individuals caught to the total number of individuals measured by the number of individuals measured for each 10 mm TL size class (Garcia and Vieira, 2001; Vieira, 2006) and the size frequency distribution compared between nets.

The abundance data for Gamma model and CPUE-SC analysis was log-transformed [$\text{Log}(x+1)$] in order to meet the assumptions of normality and homogeneity of variances. In order to calculate the species richness for each seine independently of the total number sampled (N), the rarefaction technique (E[S]) was performed (Hurlbert, 1971; Krebs, 1999) using the Software PAST ver. 2.12 (Hammer et al., 2001).

3. Results

3.1. Species composition

The abundances of the dominant {abundant ($N\% \geq \bar{X}$ N%) and frequent ($FO\% \geq \bar{X}$ FO%)} species shifted between beaches and in relation with the sampling gear used, but the species composition did not vary spatially (Table 2). A total of 44,763 fishes from 45 species were caught in both beaches, and most fishes were mainly juveniles with $60.0\% \leq 60$ mm TL. Thirty four species were common at both beaches (75.6% of similarity) and nine species were caught only at Cassino (BS-9 m caught *Trachinotus falcatus* and *Chromis flavicauda*; and BS-30 m caught *Astroscopus sexspinosus*, *Gobiesox strumosus*, *Genidens genidens*, *Paralonchurus brasiliensis*, *Ramnogaster arcuata*, *Trichiurus lepturus* and *Umbrina canosai*), and two species were exclusive at Mar Grosso beach; *Hypleurochilus fissicornis* caught with BS-9m and *Trachinotus goodei* caught with BS-30m.

At Cassino, using BS-9 m five species were dominant (*Mugil liza*, *Trachinotus marginatus*, *M. curema*, *Brevoortia pectinata* and *Odontesthes argentinensis*) and represented 91.6% of total catch. Four species (Leptocephala larvae, *T. falcatus*, *C. flavicauda* and *Myctoperca marginata*) were caught only with BS-9 m. Using BS-30 m, seven species were dominant (*M. liza*, *T. marginatus*, *B. pectinata*, *O. argentinensis*,

Menticirrhus littoralis, *Oncopterus darwinii* and *Micropogonias furnieri*) and represented 88.6% of the total catch. Fourteen species were caught only with BS-30 m (Table 2).

At Mar Grosso, using BS-9 m the same five species caught at Cassino were dominant, and they represented 91.6% of the total catch. Six species (*Anchoa marinii*, *Syngnathus folletti*, *Leptocephalii* larvae, *M. marginata*, *G. strumosus* and *Pogonias cromis*) were caught only with BS-9 m. Using BS-30 m seven species were dominant (*T. marginatus*, *B. pectinata*, *O. argentinensis*, *M. littoralis*, *O. darwinii*, *M. furnieri* and *M. americanus*) and represented 94.2% of the total catch. Nine species were caught only with BS-30 m at Mar Grosso beach (Table 2).

3.2. Species richness variation

In general, the analysis of deviance showed that seven explanatory variables were significant predictors for the species richness variation in both beaches (Table 3). The model explained 24.9% of the deviance, with season accounting for most of it (16.2%), followed by beach seine type and current direction corresponding for 3.0% and 2.6%, respectively. Salinity, transparency, wind direction and number of break lines were also significant ($p < 0.05$) and together, they explained 3.1% of the deviance.

In general, species richness increased with temperature and the warmer seasons (spring and summer) registered the highest average number of species caught (12.2 ± 2.3 and 13.8 ± 3.5 , respectively) (Fig. 2a). Significant differences between gears were also registered, and BS-30 m caught more species than BS-9 m (Fig. 2b). Salinity and transparency had little explanatory power (0.5% and 0.2%, respectively; Table 3); however, the number of species was highest in salinities between 25-30 and water

transparency under 40 cm (Fig. 2c-d, respectively). In relation with surf zone conditions, species richness was high with low surf zone wave energy (0-3 break lines) (Fig. 2e), and more species were caught when surf zone conditions had two (19.3 ± 4.7) or none (18.3 ± 5.1) break lines. With regard to the current direction, species richness was higher in samples taken with northward current (25.8 ± 3.8) or without current (22.3 ± 5.0) (Fig. 2f). Although wind direction was a significant predictor, with 1.6% of deviance explained, the mean species richness was considered low (15.3 ± 5.0) only when wind blew from the west (Fig. 2g).

3.3 General abundance patterns

Spatial comparisons revealed that overall abundance was significantly higher ($F = 4.652$; $p = 0.0319$) in Cassino than Mar Grosso beaches, but no difference was found in overall abundance between sampling gears ($F = 1.337$; $p = 0.2478$). However, a significant interaction was found between beaches and sampling gears ($F = 12.342$; $p < 0.001$), with significant differences being found between BS-9 m and BS-30 m ($p = 0.0053$) in Mar Grosso beach, and between BS-9 m in both beaches ($p = 0.0004$). In general, the fish size composition changed in relation with the sampling gear used and beach sampled (Table 2 and Fig. 3). BS-9 m caught more fish with sizes ≤ 60 mm TL (92.0%), whereas BS-30 m caught more fish with sizes > 60 mm TL (81.3%) (Fig. 3).

3.4. Abundance patterns and size composition for the two most abundant species

The presence, abundance and size distribution of *Mugil liza* and *Trachinotus marginatus*, were analyzed individually because both species represented 51.6% of the catches at Cassino and 46.8% at Mar Grosso (Table 2).

Generalized linear models revealed that occurrence of both species was associated with a set of seven explanatory variables and four of them (beach seine type, season, current direction and number of surf break lines) were common to both species (Table 4). The model for *M. liza* explained 25.1% of the deviance, with beach seine type accounting for 20.4%. The model for *T. marginatus*, explained 22.7% of the deviance, with season accounting for 18.6%.

The abundance of *M. liza* was associated mainly with beach seine type, sampling local, and to a lesser degree with current direction, season, wind direction and number of surf break lines (Table 4). The model explained 32.8% of the deviance. High variability in the catches of *M. liza* were registered (Fig. 4). The highest mean number of individuals were taken with BS-9 m (1309.7 ± 1419.7) in comparison with BS-30 m (54.7 ± 38.5) (Fig. 4a). Significant differences in the mean number of individual were registered between local, and highest mean number of individuals were taken at Cassino (2289.7 ± 1630.5), than Mar Grosso (439.0 ± 101.4) (Fig. 4b). *Mugil liza* was captured along all seasons, but high catches were associated mainly with cold seasons (autumn = 186.1 ± 254.7 ; winter = 146.6 ± 429.3) rather than warmer seasons (spring = 81.4 ± 130.0 ; summer = 40.7 ± 63.7) (Fig. 4c). The mean number of individuals caught was highly associated with calm surf zone conditions, northerly winds (567.8 ± 790.6 ; Fig. 4d), no current (1057.3 ± 1336.2 ; Fig. 4e), and a single surf break line (549.8 ± 985.3 ; Fig. 4f).

The abundance of *T. marginatus* was associated only with season and the model explained 22.3% of the deviance (Table 4). The mean number of individuals caught increased from winter (45.4 ± 41.4) to summer (543.0 ± 490.4), with high variability in the catches registered in this season (Fig. 5).

Mugil liza were caught at sizes between 20 to 30 mm TL and during all seasons at both beaches (Fig. 6). At Cassino, high catches were registered in autumn and winter, using BS-9 m. The BS-30 m caught fewer individuals during autumn, spring and summer, with high catches at 20 mm TL during autumn. Mar Grosso showed smaller catches than Cassino, and they were made basically with BS-9 m during autumn and winter.

Trachinotus marginatus were caught during all seasons at both beaches, but peak catches occurred during summer, reinforcing the strong seasonal effect (Fig. 7). Although were caught more *T. marginatus* at Mar Grosso, no differences were found in abundance between both beaches ($F = 1.258$; $p = 0.262$). At Cassino, BS-9 m caught more individuals ≤ 60 mm TL (especially in summer), and BS-30 m caught individuals with sizes > 60 mm TL during all seasons, but especially in summer and autumn. The same pattern was observed at Mar Grosso.

4. Discussion

4.1. Species composition and sampling gears

The abundances of dominant species shifted between beaches (as well the total abundance) but sampling gear and the species composition did not vary spatially. Both beaches were very similar in terms of fish species composition, and showed low richness, being dominated by few abundant species, composed mainly by juveniles. The low number of species caught in this study are in consonance with other studies made in southern Brazilian surf zones (e.g., Barreiros et al., 2004 in Santa Catarina ($S = 67$); Godefroid et al., 2004 in Paraná ($S = 70$); Pessanha and Araújo, 2003 in Rio de Janeiro ($S = 55$)) and worldwide (e.g., Inoue et al., 2008 in Japan ($S = 32$); Wilber et al., 2003

in United States ($S = 57$); Valesini et al., 1997 in Austrália ($S = 26$)). Although McLachlan and Brown (2006) said that surf zone fish assemblage could support a wide diversity of fish species (up to 160), few are usually resident (or surf zone related) and many species can be considered rare, with few dominant species.

In our study, we caught nine dominant species in both beaches, from which four are estuarine related (*Mugil liza*, *Mugil curema*, *Brevoortia pectinata* and *Micropogonias furnieri*), three are surf zone related (*Trachinotus marginatus*, *Menticirrhus littoralis* and *Oncopterus darwini*) and two are estuarine resident (*Odontesthes argentinensis* and *Menticirrhus americanus*). Because of the proximity of the estuary, the most abundant species caught were directly related with the estuary. Several authors found that the presence of a river mouth or estuary reflects the species composition in the adjacent surf zone (McLachlan and Brown, 2006; Sato et al., 2008). For example, Mugilids (in our case, *M. liza* and *M. curema*) strongly aggregate in response to freshwater in the surf zone (Vieira, 1991; Strydom, 2003), what appears to be a trigger to juvenile aggregation (Sato et al., 2008). In comparison with other surf zone areas, the same pattern was observed (low diversity and few dominant species), but some changes in species composition occurred, probably because there is a clear latitudinal pattern in fish diversity (Vieira and Musick, 1993). In fact, Araújo and Azevedo (2001) studying the fish assemblage of similar environments (estuaries and beaches) from southeast-south Brazilian coast found a separation in species composition related to latitudinal differences. Nevertheless, the fish assemblages were dominated mainly by juveniles of Carangidae, Mugilidae and Sciaenidae (Araújo and Azevedo, 2001). This pattern of few families dominating surf zones are reported to other surf zones all over the world (e.g., Nash and Santos, 1998; Layman, 2000). Indeed, there

may be an equivalence in species composition (or families) between beaches all over the world (or between different latitudes), just as there are for other marine and coastal ecosystems (Sheaves, 2012). Furthermore, fluctuations in species composition is a feature that acts more in a specific level than structural (Pessanha and Araújo, 2003), and may occur in accordance with particularities of each beach as habitat (Modde and Ross, 1981) and in response to interactions with environmental changes (Ayvazian and Hyndes, 1995; Gibson et al., 1996; Potter et al., 2001).

4.2. GLM performance applied to species richness

The surf zone fish assemblage of southern Brazilian sandy beaches have been studied in relation to community structure and spatio-temporal variations (Ramos and Vieira, 2001; Monteiro-Neto et al., 2003; Lima and Vieira, 2009), as well as the effects of mud deposition events (Mont'Alverne et al., 2012), and the presence of rocky jetties (Rodrigues and Vieira, 2012). The present work is the first in analyzing sampling gear effects and environmental predictor variables in order to explain spatio-temporal fish assemblage structure variation.

The model used was successful in describing and predicting species richness, and the GLM results showed that both beaches presented no differences in relation to species composition, with season being the most important explanatory variable influencing the variation of species richness. In fact, the increase in temperature is the most important factor regulating species richness and abundance of fish in subtropical beaches and shallow areas (McFarland, 1963), with species peak abundance being registered during warm months (Gibson et al., 1993; Layman, 2000; Potter et al., 2001). The temperature is also an important factor that generates variability in sandy beach

macrobenthic invertebrates, since it contributes to the seasonal variation of recruits (Silva et al., 2008), ensuring prey availability to juvenile fishes (Monteiro-Neto and Cunha, 1990; Rodrigues and Vieira, 2010). Also, with the increase in abundance, more rare species were caught during summer, increasing the diversity in the area. A high richness specially related to rare species during summer in southeast Brazilian sandy beaches was also reported by Pessanha et al. (2003). In addition to the increase in temperature during warmer months, the surf zone environment became more stable with the Brazil Current reaching high latitudes, bringing waters with high salinities and temperatures (Möller et al., 2008). This complex situation seems to explain the presence of some occasional coastal marine warm waters species (e.g., *Trachinotus carolinus*, *T. falcatus* and *Caranx latus*). Hot summer months also reflect the recruitment patterns determined by the reproductive activity and coastal circulation (Ross et al., 1987; Gibson et al., 1993, Lamberth et al., 1995), and by the temporary use of adjacent high productivity areas.

As reported by Rodrigues and Vieira (manuscript submitted) the largest beach seine (BS-30 m) caught more species than the smaller one (BS-9 m), but there is a highest similarity between both sampling gears, since they catch the same dominant species. The GLM model showed significant differences in fish composition using different sampling gears. This difference probably was related to rare and some large species caught mainly with BS-30 m. According Říha et al. (2008) longer nets shows a more representative picture of a fish community than smaller nets, since they can catch more active and bigger fish, increasing the fish richness of the sampler.

The rare species were mostly vagrant from other habitats (e.g., estuary, deeper coastal waters) or are not common in the catches because they have low vulnerability to

the net. Thus, several authors (e.g., Francis et al., 2005; Francis et al., 2011) suggested that rare species have to be removed from the analysis. Since part of the objective of this study was comparing the performance of the two different beach seines, we choose to maintain these rare species in the analysis. The BS-30 m caught a lot of individuals with sizes ≥ 100 mm TL, a size that generally escape from the smaller beach seine (Rodrigues and Vieira, chapter 2), and for this reason, the larger beach seine is considered a complementary sampling gear to be used in surf zone environments.

Current direction was also a significant factor in explaining the variation in species richness, with more species being caught in samples taken in periods with calm waters or with northward current. In fact, when the surf zone did not have a longshore current, the hauling operation was easier to perform, increasing the probability to catch more fish and species. On the other hand, northward currents, associated with southeast-southwest winds, could aggregate fish shoals in the inner surf zone area, increasing the probability to catch more fish and more vagrant species. Busoli and Muelbert (2003) studying ichthyoplankton in Cassino beach surf zone reported an accumulation of fish eggs and larvae near the mouth of Patos Lagoon estuary, most related with southeast-southwest winds that generates a northward longshore current piling up coastal water along the shoreline. Although wind patterns are an important factor to transport plankton to the coast (Boehlert and Mundy, 1988) and influence directly in the distribution of fish larvae in the surf zone of Cassino beach (Busoli and Muelbert, 2003), it seems that for juvenile fish inhabiting sandy beaches near Patos Lagoon estuary, this factor is not that important as reported by Gibson et al. (1993) for fishes and macrocrustaceans in a Scottish sandy beach community. In this sense, wind is directly related with longshore current direction and number of surf break lines, a

measure of wave energy and another significant variable in the model, however with low explanatory power.

We found that species richness decreased with an increase in number of break lines (0 to 6), probably because fish would avoid the turbulence caused by wave action or because the difficulty of sampling during harsh conditions (e.g. net roll up). Contrary, high richness was reported when water transparency was low (< 50 cm), and the fact that high wave energy increase the water turbulence, reducing the visual field and the capability to find food resources, it seems not the case for the study area. For estuaries, the presence of turbid waters is generally considered to be advantageous for juvenile fish, as it provides cover from predators and higher densities of prey than clear waters (Johnston et al., 2007; Chiu and Abrahams, 2010; Yagi et al., 2011). Although this study and others made in the same area (Lima and Vieira, 2009; Mont'Alverne et al., 2012) found that an increase in wave energy, at least up to a certain level, increases the diversity, several authors reported the contrary for other surf zones (e.g., Romer, 1990; Clark, 1997; Gaelzer and Zalmon, 2003). This incongruence seems to be a problem of defining "high wave energy" in surf zones. However, Robertson and Lenanton (1984) believed that exposed beaches with high wave energy are structurally more homogeneous environments to nektonic organisms, improving the capability to retain more species.

Salinity was also a significant factor in explaining the variation in species richness, but with low explanatory power. Several studies reported its importance for some surf zones (Pessanha et al., 2003; Vasconcellos et al, 2007; Jarrin and Shanks, 2010), but always showing a low explanatory power. Salinity is an important factor to explain the fish structure in estuaries (e.g., Garcia et al., 2003; Harrison and Whitfield,

2006; Whitfield and Cowley, 2010; Vasconcelos et al., 2009), but it seems less important to explain the structure in surf zone fish assemblages (Nanami and Endo, 2007; Lima and Vieira, 2009; Rodrigues and Vieira, 2012).

In the present work, all environmental variables used in GLM analysis were measured during the field sampling (at on time measure) and this kind of measure represents only an instantaneous moment within a time series. Although our model had a good performance, future studies using environmental variables that describe the average conditions (i.e., monthly) experienced by fish should be done, since such variables can be more powerful than point measurements (Francis et al., 2005). For example, Attrill (2002) has shown that salinity variation, rather than salinity per se, is a better predictor of invertebrate species diversity in estuaries.

4.3. *The use of surf zone by juveniles of Mugil liza and Trachinotus marginatus*

Marine coastal shallow areas serve as nurseries for a variety of species widely distributed on the shallow continental shelf (Lenanton and Potter, 1987), and this study revealed the importance of surf zone environment for juveniles of striped mullet *M. liza*, an estuarine related species and the plata pompano *T. marginatus*, a marine specie. Those two species have importance in local fisheries and were dominant in both beaches studied, being strictly related with the surf zone environment during part of their life span. The models used to assess occurrence and abundance (Logistic and Gamma respectively) performed well for both species, since they identified the most important variables to explain the fish behavior in the surf zone environment.

For *M. liza* the beach seine used was the main factor explaining their occurrence and abundance in the surf zone, with a set of other less important significant

variables in the model. The small beach seine caught significantly more individuals with sizes below 30 mm TL than the larger one. Juveniles of *M. liza* with sizes below to 30 mm TL occur all year-round in estuarine and adjacent marine habitats of the PL estuary, being more abundant during cold months (Vieira, 1991; Vieira and Scalabrin, 1991), as observed in our study. It is believed that small size (20 to 30 mm TL) individuals enter in estuaries to grow. When reaching maturity, individuals migrate to northern offshore waters to spawn (for details; see Vieira, 1991). There were significant differences in abundance of striped mullet between both beaches, probably because the southward predominance in the displacement of the PL plume, favors large concentration of juveniles at Cassino than at Mar Grosso beach. Furthermore, the ingress of new recruits from spawning stocks located in more southern waters (Uruguay and Argentina) can not be discarded.

Calm sea conditions (i.e., surf zone without longshore current and with less than two break lines) were directly related with large catches of *M. liza*, probably because when sea conditions are harsh the ground line of the seine may roll up over head line (Allen et al., 1992), increasing the escape and, consequently reducing the number of individuals caught. Also, shoals may be more spread out and difficult to catch, due to the turbulent waters and breaking waves.

Juveniles of *T. marginatus* are surf zone resident and their occurrence and abundance was directly related with warmer months, with peak abundance in the summer. Adults are found in deeper coastal waters and juveniles stay part of their life span in the surf zone of sandy beaches (Lemos et al., 2011). In southern Brazilian coast, the spawning period occurs from late spring (November) through the end of summer (February) in coastal waters (~ 20-40 m), and eggs and larvae drift with the current to

the surf zone, arriving as juveniles with sizes above 10-20 mm TL (Lemos et al., 2011). The spawning period for *Trachinotus* in United States Atlantic coast waters occurs in late winter/early spring, when juveniles of the Florida pompano (*T. carolinus*) and the permit (*T. falcatus*) are relatively common during spring and summer in high energy surf zones of the Gulf (Ruple, 1984). However, Flores-Coto et al. (2000) found larvae of *T. falcatus* with 5.2 mm during August, suggesting a summer spawning in this species in the northern Hemisphere, similarly what has been observed for *T. marginatus* in the southern Hemisphere (Lemos et al., 2011). In this sense, our findings are in agreement with studies made all over the world, which reported high abundance of juveniles of *Trachinotus* in high energy surf zones during warmer months.

High abundances of *T. marginatus* during warmer months are probably associated with the high availability of prey items (i.e., benthic crustaceans) during this season (Neves et al., 2008). According with Monteiro-Neto and Cunha (1990) the species is highly opportunistic and feed primarily on the bottom or on organisms displaced from the sand by wave action. This behavior can explain the direct relation of *T. marginatus* with high energy surf zones, although differences in abundance in beaches with different degrees of wave exposure were not found (Rodrigues and Vieira, 2012). The continuous wave action on the sandy bottom, although stressful, provides large amounts of food, allowing the capture of prey for those species adapted to these conditions (Clark, 1997). This seems to be the case of juveniles of *T. marginatus* that use the surf zone environment for recruitment and feeding grounds. High abundances were registered in summer with the size class distribution ranging from 20 to < 120 mm TL, since sizes above 120 mm TL migrate to deeper coastal water to grow (Lemos et al., 2010). Similar behavior was proposed by Bellinger and Avault (1970) and Modde

(1980) for *T. carolinus* in Gulf of Mexico. The behavior of juveniles of *T. marginatus* indicates a nursery use of surf zone, as reported by other species of *Trachinotus* (Adams and Blewett, 2004).

5. Conclusion

In summary, there is a significant difference in abundance between beaches, but sampling gears and the species composition did not vary spatially, with both beaches showing similar fish faunal composition. The GLM model used was successful in describing and predicting species richness, and no differences in relation to species composition were found between both beaches, with season being the most important explanatory variable influencing the variation of species richness. However, the choice of sampling gear used played an important role, since the larger beach seine caught significantly more species than the smaller one, but in general, catching the same dominant species.

Two species (*M. liza* and *T. marginatus*) were dominant in both beaches. For *M. liza*, the type of beach seine used was the main factor explaining the occurrence and abundance, with high catches of small individuals (≤ 30 mm TL) directly associated with BS-9 m and higher abundances at Cassino beach. For *T. marginatus* the occurrence and abundance was directly related with warmer months (peak abundance during summer), and no significant differences were observed between the beach seines, with the size distribution ranging between 20 and 120 mm TL.

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Table 1. Mean and standard deviation for environmental variables registered at Cassino and Mar Grosso, southern Brazil, during the 2-years of sampling.

| Environmental variables | Cassino | | | | Mar Grosso | | | |
|-------------------------|------------|------------|------------|------------|------------|-------------|------------|------------|
| | Winter | Spring | Summer | Autunm | Winter | Spring | Summer | Autunm |
| Temperature (°C) | 13.1 ± 0.3 | 19.1 ± 0.2 | 24.1 ± 0.1 | 18.6 ± 0.0 | 13.3 ± 0.2 | 19.15 ± 0.2 | 24.5 ± 0.4 | 18.1 ± 0.5 |
| Salinity | 25.6 ± 1.7 | 28.7 ± 0.4 | 32.1 ± 0.1 | 30.9 ± 0.4 | 23.3 ± 0.8 | 24.2 ± 1.7 | 31.3 ± 0.0 | 31.0 ± 0.3 |
| Transparency (cm) | 29.6 ± 3.2 | 27.8 ± 1.8 | 41.8 ± 2.4 | 43.9 ± 1.5 | 36.6 ± 3.2 | 37.8 ± 5.0 | 33.2 ± 2.7 | 29.2 ± 3.5 |
| Wind (m/s) | 3.1 ± 0.1 | 6.7 ± 0.5 | 5.8 ± 0.1 | 4.7 ± 0.1 | 4.6 ± 0.4 | 4.8 ± 0.1 | 5.4 ± 0.0 | 6.7 ± 0.1 |
| Number of break lines | 1 ± 0.2 | 2 ± 0.1 | 1 ± 0.0 | 2 ± 0.1 | 3 ± 0.1 | 3 ± 0.1 | 2 ± 0.1 | 4 ± 0.0 |

Table 2

List of fish species caught by beach seine nets (BS-9 m; BS-30m) in shallow surf zone areas from Cassino and Mar Grosso beaches, southern Brazil. Size range (minimum-maximum, mean and \pm standard deviation) and total catch (number of individuals caught), are represented. Species are classified by relative importance: abundant and frequent (black box), abundant and not frequent (dark grey box), frequent and not abundant (light grey box), present (without color boxes) and absent (-).

| Species | Cassino | | | | Mar Grosso | | | |
|----------------------------------|----------------------------|-------------|----------------------------|-------------|---------------------------|-------------|-----------------------------|-------------|
| | BS-9m | | BS-30m | | BS-9m | | BS-30m | |
| | Total length (mm) | Total catch | Total length (mm) | Total catch | Total length (mm) | Total catch | Total length (mm) | Total catch |
| <i>Mugil liza</i> | 18-117 (26.7 \pm 4.3) | 6604 | 24-610 (98.0 \pm 104.4) | 265 | 11-83 (27.2 \pm 3.7) | 1254 | 24-510 (179.9 \pm 137.0) | 63 |
| <i>Trachinotus marginatus</i> | 14-143 (41.0 \pm 20.2) | 4027 | 11-186 (78.0 \pm 22.3) | 2492 | 12-145 (38.8 \pm 20.6) | 3537 | 19-170 (78.4 \pm 20.3) | 3952 |
| <i>Mugil curema</i> | 22-88 (35.8 \pm 6.4) | 1756 | 35-261 (105.5 \pm 28.3) | 91 | 23-87 (34.6 \pm 7.6) | 396 | 35-208 (82.8 \pm 37.2) | 59 |
| <i>Brevoortia pectinata</i> | 16-165 (37.7 \pm 20.1) | 1722 | 23-237 (81.5 \pm 26.2) | 946 | 19-154 (29.9 \pm 9.3) | 1336 | 34-211 (127.1 \pm 45.8) | 368 |
| <i>Odontesthes argentinensis</i> | 20-236 (86.4 \pm 48.5) | 775 | 39-327 (153.7 \pm 26.8) | 2855 | 16-233 (68.0 \pm 40.5) | 1645 | 37-310 (155.0 \pm 28.9) | 2356 |
| <i>Menticirrhus littoralis</i> | 25-176 (56.5 \pm 17.0) | 195 | 32-328 (117.8 \pm 35.0) | 471 | 18-120 (47.6 \pm 15.8) | 277 | 31-281 (112.0 \pm 29.9) | 1024 |
| <i>Oncopterus darwinii</i> | 20-194 (56.9 \pm 40.6) | 55 | 30-186 (79.4 \pm 25.9) | 728 | 14-109 (36.6 \pm 19.9) | 120 | 31-122 (67.9 \pm 18.3) | 780 |
| <i>Micropogonias furnieri</i> | 15-230 (121.0 \pm 105.5) | 8 | 80-660 (199.2 \pm 45.5) | 836 | 17-210 (39.3 \pm 26.1) | 57 | 58-254 (172.4 \pm 42.5) | 433 |
| <i>Menticirrhus americanus</i> | 16-48 (28.1 \pm 5.4) | 70 | 70-303 (128.0 \pm 38.6) | 191 | 12-119 (24.7 \pm 11.2) | 141 | 15-270 (121.6 \pm 25.2) | 417 |
| <i>Lycengraulis grossidens</i> | 22-115 (35.2 \pm 12.5) | 605 | 55-206 (127.6 \pm 24.0) | 113 | 27-147 (63.8 \pm 41.6) | 13 | 90-240 (133.3 \pm 22.1) | 74 |
| <i>Atherinella brasiliensis</i> | 21-147 (82.7 \pm 18.6) | 141 | 64-200 (101.5 \pm 27.9) | 38 | 60-102 (80.5 \pm 10.4) | 75 | 116-125 (121.3 \pm 3.9) | 4 |
| <i>Paralichthys orbignyanus</i> | - | - | 136-470 (237.1 \pm 67.4) | 65 | - | - | 149-434 (262.9 \pm 122.8) | 9 |
| <i>Anchoa marinii</i> | 24-60 (30.9 \pm 6.5) | 169 | 89-95 (91.6 \pm 2.8) | 5 | 21-90 (42.8 \pm 31.8) | 4 | - | - |
| <i>Eucinostomus melanopterus</i> | 15-26 (17.9 \pm 2.2) | 34 | 93-179 (148.8 \pm 38.2) | 4 | 15-18 (16.8 \pm 1.5) | 4 | 143-152 (147.5 \pm 6.4) | 2 |
| <i>Mugil cf. hospes</i> | 25-89 (55.6 \pm 15.0) | 22 | 28-129 (86.3 \pm 20.3) | 43 | 32-109 (52.6 \pm 24.1) | 20 | 60-160 (95.7 \pm 11.6) | 185 |
| <i>Pomatomus saltatrix</i> | 61-120 (100.9-13.3) | 17 | 88-253 (112.6 \pm 26.9) | 52 | 42-104 (79.7 \pm 33.1) | 3 | 88-153 (107.8 \pm 18.3) | 19 |
| <i>Oligoplites saliens</i> | 33-113 (71.0 \pm 24.1) | 10 | 62-110 (89.3 \pm 9.1) | 204 | 39-64 (49.7 \pm 8.2) | 7 | 55-89 (71.3 \pm 9.9) | 18 |
| <i>Polydactylus virginicus</i> | 70-96 (78.6 \pm 9.5) | 7 | 104-104 (104.0 \pm 0.0) | 1 | 32-64 (41.8 \pm 11.3) | 6 | 113-172 (142.5 \pm 41.7) | 2 |
| <i>Harengula clupeiola</i> | 46-102 (72.8 \pm 27.6) | 5 | 72-123 (98.8 \pm 19.7) | 8 | 71-78 (74.5 \pm 4.9) | 2 | 82-95 (88.3 \pm 5.9) | 4 |
| <i>Trachinotus carolinus</i> | 62-73 (70.0 \pm 4.6) | 5 | 67-164 (97.0 \pm 33.6) | 25 | 60-151 (108.7 \pm 45.8) | 3 | 72-195 (116.2 \pm 31.1) | 37 |
| <i>Syngnathus folletti</i> | 90-126 (101.8 \pm 16.4) | 4 | 101-101 (101.0 \pm 0.0) | 1 | 84-104 (94.0 \pm 14.1) | 2 | - | - |
| <i>Leptocephala larvae</i> | 35-36 (35.5 \pm 0.7) | 2 | - | - | 37-50 (43.5 \pm 9.2) | 2 | - | - |
| <i>Stephanolepis hispidus</i> | 68-215 (141.5 \pm 103.9) | 2 | 55-114 (75.0 \pm 15.9) | 34 | 82-101 (91.5 \pm 13.4) | 2 | 91-182 (121.6 \pm 37.8) | 5 |
| <i>Trachinotus falcatus</i> | 25-26 (25.5 \pm 0.7) | 2 | - | - | - | - | - | - |
| <i>Chloroscombrus chrysurus</i> | 50-50 (50.0 \pm 0.0) | 1 | 48-57 (52.8 \pm 2.7) | 15 | 40-48 (44.8 \pm 3.3) | 5 | 45-70 (55.8 \pm 6.0) | 21 |
| <i>Chromis flavicauda</i> | 22-22 (22.0 \pm 0.0) | 1 | - | - | - | - | - | - |
| <i>Genidens barbuis</i> | 86-86 (86.0 \pm 0.0) | 1 | 77-130 (92.4 \pm 6.8) | 108 | - | - | 134-148 (141.3 \pm 6.4) | 4 |
| <i>Hyporhamphus unifasciatus</i> | 281-281 (281.0 \pm 0.0) | 1 | 258-305 (280.0 \pm 24.5) | 4 | - | - | 280-300 (290.8 \pm 9.8) | 4 |

| | | | | | | | | |
|-----------------------------------|--------------------|-------|--------------------------|------|-----------------------|------|------------------------|------|
| <i>Myctoperca marginata</i> | 23-23 (23.0 ± 0.0) | 1 | - | - | 20-24 (22.2 ± 1.8) | 5 | - | - |
| <i>Platanichthys platana</i> | 87-87 (87.0 ± 0.0) | 1 | 71-105 (97.1 ± 5.5) | 58 | - | - | 89-101 (95.9 ± 3.8) | 14 |
| <i>Astroscoptes sexspinosus</i> | - | - | 120-400 (215.7 ± 159.7) | 3 | - | - | - | - |
| <i>Caranx latus</i> | - | - | 89-120 (109.3 ± 13.9) | 4 | - | - | 42-100 (71.0 ± 41.0) | 2 |
| <i>Eucinostomus argenteus</i> | - | - | 140-158 (149.0 ± 12.7) | 2 | - | - | 90-126 (108.0 ± 25.5) | 2 |
| <i>Genidens genidens</i> | - | - | 84-205 (116.4 ± 47.8) | 7 | - | - | - | - |
| <i>Genidens planifrons</i> | - | - | 102-168 (144.5 ± 31.3) | 4 | 138-130 (138.0 ± 0.0) | 1 | 133-148 (138.7 ± 8.1) | 3 |
| <i>Gobiesox strumosus</i> | - | - | 20-20 (20.0 ± 0.0) | 1 | - | - | - | - |
| <i>Hypleurochilus fissicornis</i> | - | - | - | - | 27-27 (27.0 ± 0.0) | 1 | - | - |
| <i>Paralonchurus brasiliensis</i> | - | - | 145-145 (145.0 ± 0.0) | 1 | - | - | - | - |
| <i>Pogonias cromis</i> | - | - | 210-210 (210.0 ± 0.0) | 1 | 64-64 (64.0 ± 0.0) | 1 | - | - |
| <i>Rammogaster arcuata</i> | - | - | 57-57 (57.0 ± 0.0) | 1 | - | - | - | - |
| <i>Sardinella janeiro</i> | - | - | 178-178 (178.0 ± 0.0) | 1 | - | - | 164-220 (185.3 ± 14.1) | 35 |
| <i>Selene vomer</i> | - | - | 48-48 (48.0 ± 0.0) | 1 | - | - | 57-103 (75.4 ± 15.0) | 9 |
| <i>Trachinotus goodei</i> | - | - | - | - | - | - | 159-159 (159.0 ± 0.0) | 1 |
| <i>Trichiurus lepturus</i> | - | - | 87.5-917 (274.4 ± 300.0) | 15 | - | - | - | - |
| <i>Umbrina canosai</i> | - | - | 161-161 (161.0 ± 0.0) | 1 | - | - | - | - |
| Total catch | | 16243 | | 9694 | | 8920 | | 9906 |
| Number of species | | 29 | | 38 | | 28 | | 30 |
| Hurlbert rarefaction E[S] | | 23 | | 34 | | 26 | | 28 |

Table 3

Analysis of deviance for the poisson-based GLM fitted to the species richness values for Cassino and Mar Grosso beaches, southern Brazil. Values for deviance for each factor, residual deviance (Res. Dev.), deviance, percentage of the total deviance explained by each factor (% Expl.) and *p*-values are presented.

| | Predictors | <i>p</i> -value | Res. Dev. | Deviance | % Expl. |
|----------|-------------------|-----------------|-----------|----------|---------|
| Species | Null | | 1866.5 | | |
| Richness | Main effects | | | | |
| | Beach seine type | 9.733 E-14 | 1811.1 | 55.4 | 3.0 |
| | Season | < 2.2 E-16 | 1508.5 | 302.6 | 16.2 |
| | Salinity | 0.0020 | 1498.9 | 9.5 | 0.5 |
| | Transparency | 0.0444 | 1494.9 | 4.0 | 0.2 |
| | Wind direction | 1.918 E-16 | 1465.6 | 29.3 | 1.6 |
| | Longshore | | | | |
| | Current direction | 3.430 E-11 | 1417.4 | 48.2 | 2.6 |
| | Break lines | 0.0001 | 1402.6 | 14.8 | 0.8 |
| | Total explained | | | | 24.9 |

Table 4

Goodness-of-fit for the Logistic and Gamma GLM fitted to *Mugil liza* and *Trachinotus marginatus* densities in both beaches. Values of deviance for each factor, residual deviance (Res. Dev.), deviance, percentage of the total deviance explained by each factor (% Expl.) and *p* values are presented.

| Predictor | <i>p</i> value | Res. Dev. | Deviance | % Expl. |
|-----------------------------|----------------|-----------|----------|---------|
| Logistic model | | | | |
| <i>M. liza</i> | | | | |
| Null | | 1902.3 | | |
| Main effects | | | | |
| Beach seine type | < 2.2 E-16 | 1513.9 | 388.5 | 20.4 |
| Season | 1.577 E-16 | 1484.1 | 29.8 | 1.6 |
| Wind direction | 0.0038 | 1470.7 | 13.4 | 0.7 |
| Longshore current direction | 3.166 E-08 | 1436.2 | 34.5 | 1.8 |
| Break lines | 0.0012 | 1425.7 | 10.5 | 0.6 |
| Total explained | | | | 25.1 |
| <i>T. marginatus</i> | | | | |
| Null | | 1931.1 | | |
| Main effects | | | | |
| Beach seine type | 6.706 E-07 | 1906.4 | 24.7 | 1.3 |
| Beach | 0.0057 | 1898.8 | 7.6 | 0.4 |
| Season | < 2.2 E-16 | 1539.5 | 359.3 | 18.6 |
| Wind velocity | 5.413 E-08 | 1509.9 | 29.6 | 1.5 |
| Longshore current direction | 0.0022 | 1497.7 | 12.2 | 0.6 |
| Break lines | 0.0333 | 1493.2 | 4.5 | 0.2 |
| Total explained | | | | 22.7 |
| Gamma model | | | | |
| <i>M. liza</i> | | | | |
| Null | | 213.6 | | |
| Main effects | | | | |
| Beach seine type | < 2.2 E-16 | 187.7 | 25.9 | 12.1 |
| Beach | < 2.2 E-16 | 168.3 | 19.5 | 9.1 |
| Season | 1.563 E-05 | 161.5 | 6.8 | 3.2 |
| Wind direction | 0.0002 | 156.2 | 5.3 | 2.5 |
| Longshore current direction | 1.304 E-07 | 147.6 | 8.6 | 4.0 |
| Break lines | 9.442 E-05 | 143.5 | 4.1 | 1.9 |
| Total explained | | | | 32.8 |
| <i>T. marginatus</i> | | | | |
| Null | | 296.6 | | |
| Main effects | | | | |
| Season | < 2.2E-16 | 230.5 | 66.1 | 22.3 |
| Total explained | | | | 22.3 |

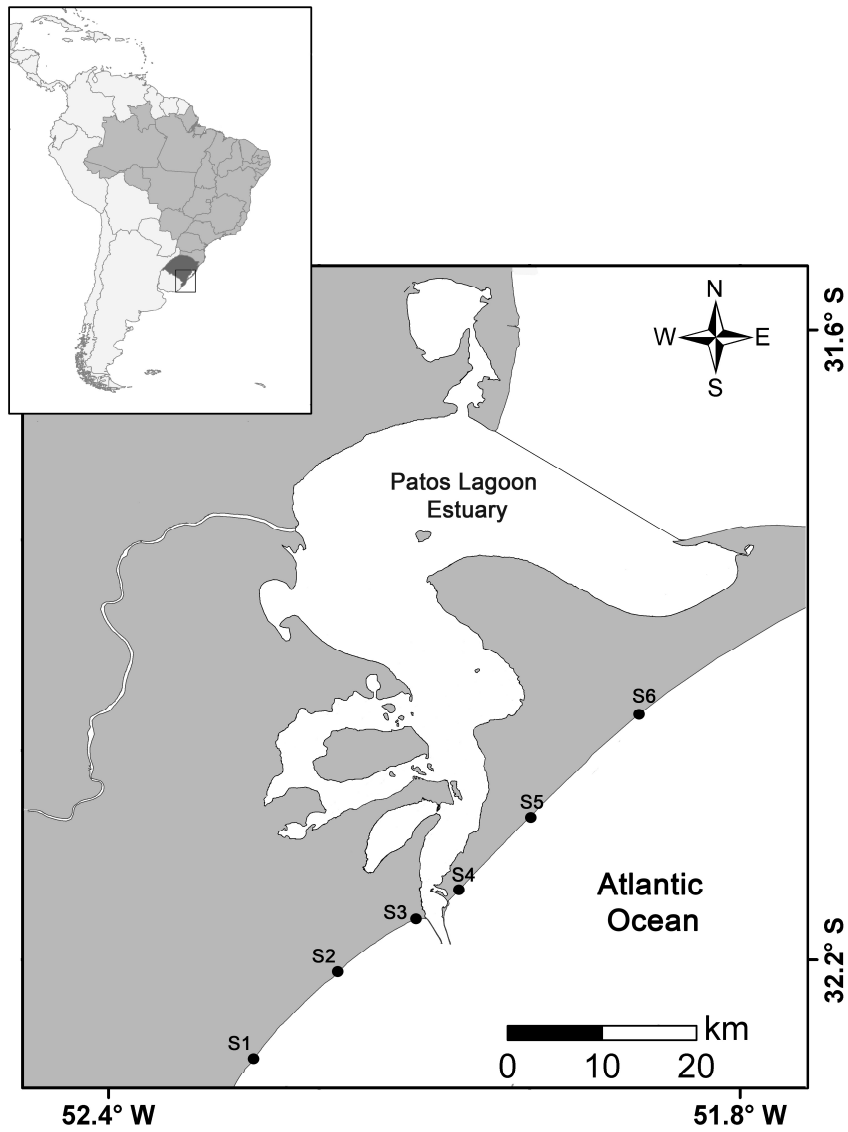


Fig. 1. Study area and location of sampling sites in Cassino (S1-S3) and Mar Grosso (S4-S6) beaches, southern Brazil.

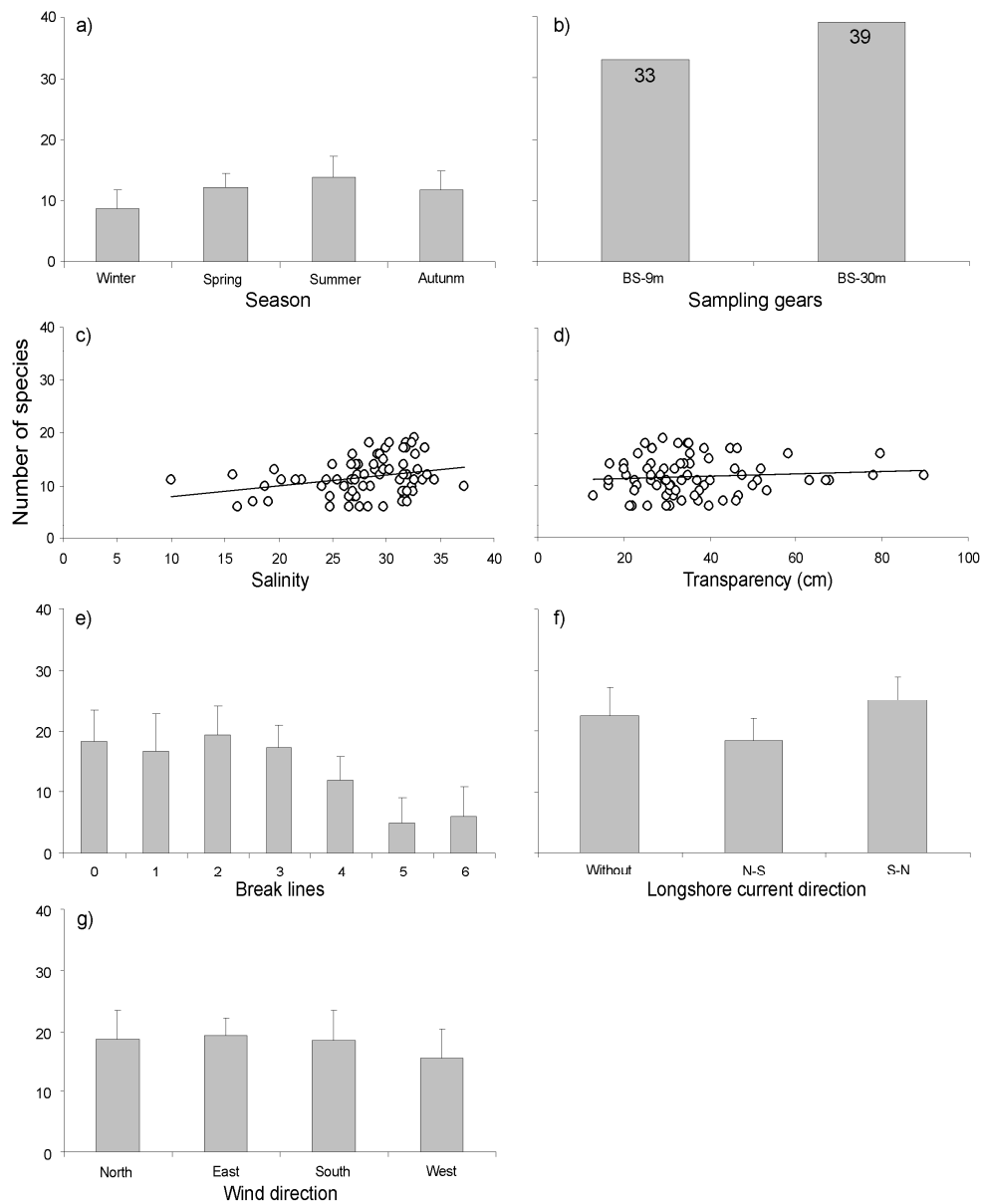


Fig. 2. Relations between significant variables in the model and species richness. a) season, b) sampling gears, c) salinity, d) transparency, e) break lines, f) longshore current direction and g) wind direction. Standard deviation above bars.

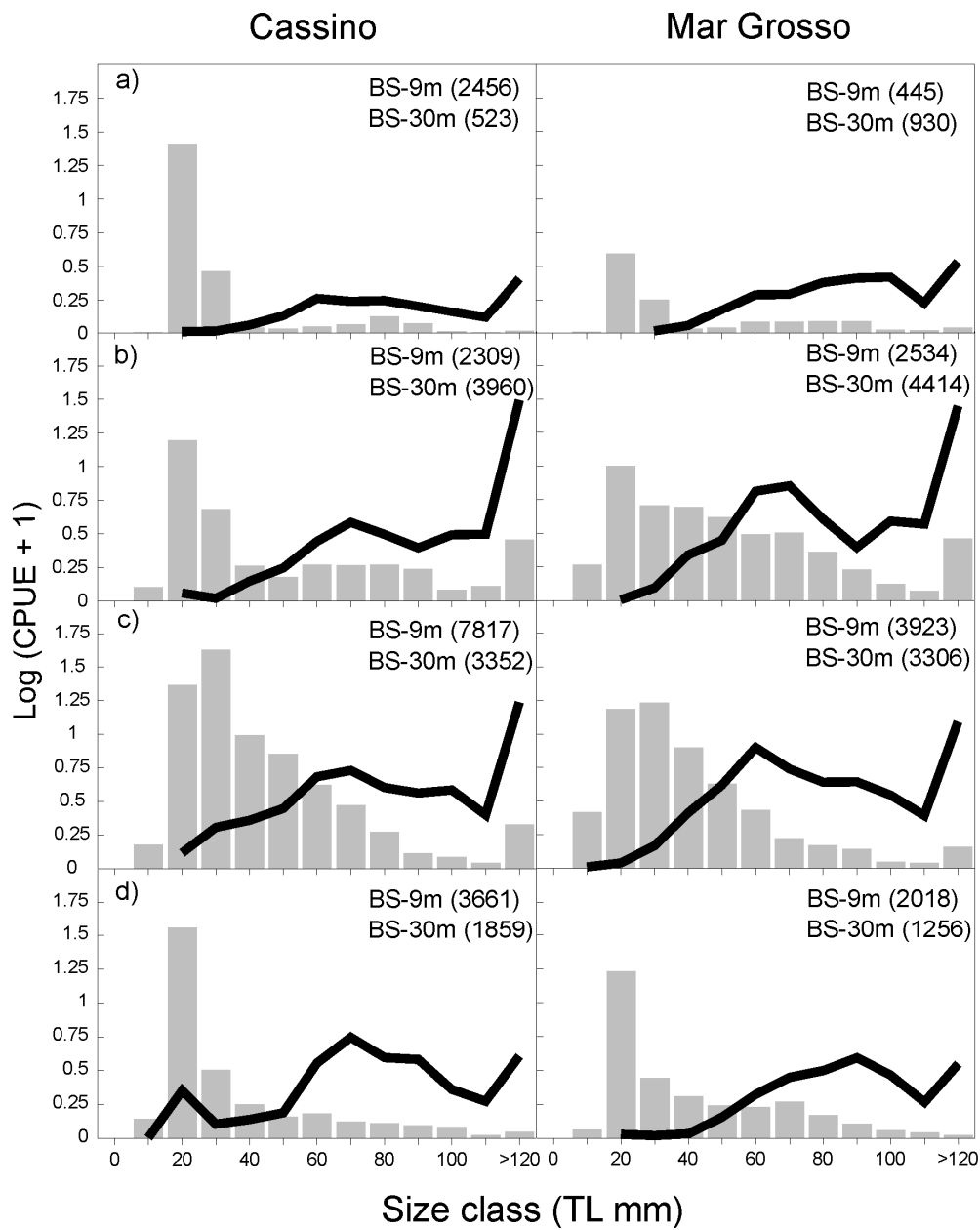


Fig.3. Distribution of CPUE per size class for all individuals caught during the 2-years sampling, for seasons of the year. a) winter, b) spring, c) summer and d) autumn. Beach seine 9m (BS-9m) and Beach seine 30m (BS-30m). Number of catches given in parentheses.

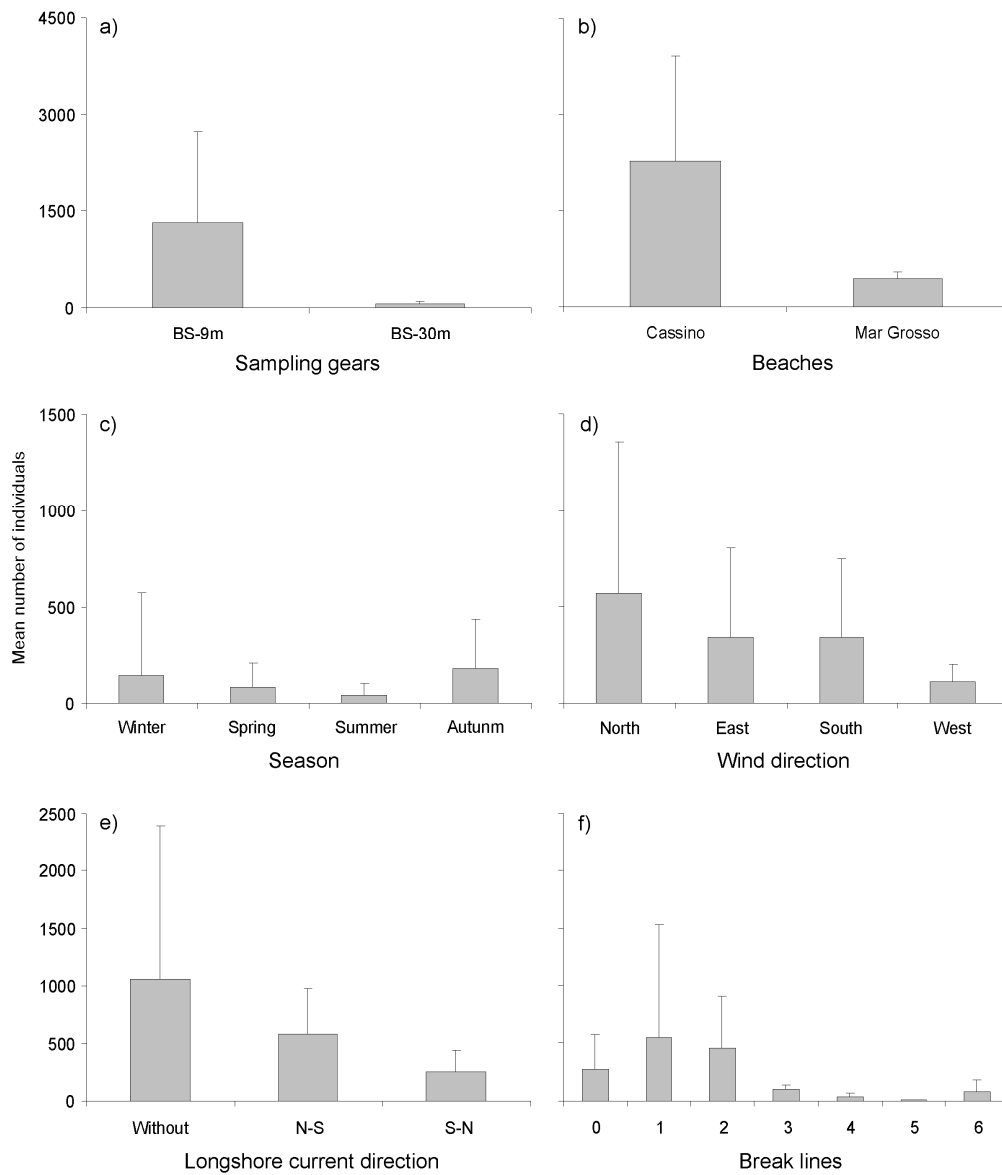


Fig. 4. Relations between significant variables in the model and abundance of *M. liza* (mean number of individuals). a) sampling gears, b) beaches, c) season, d) wind direction, e) longshore current direction and f) break lines. Standard deviation above bars.

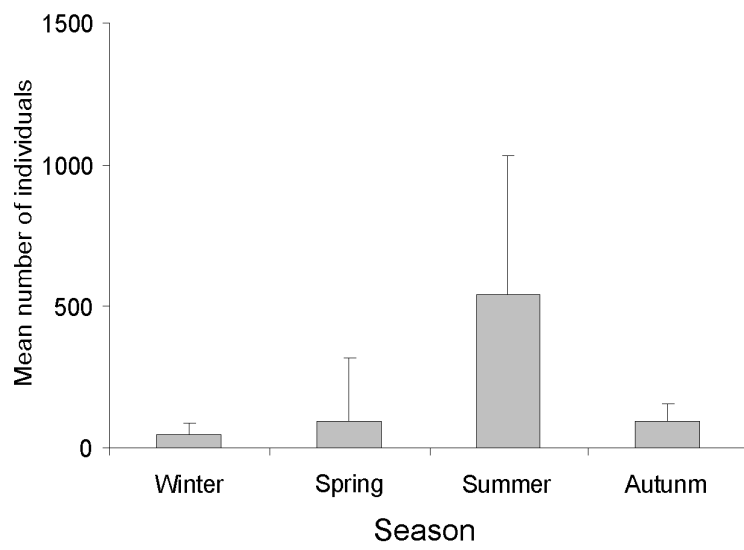


Fig. 5. Relation between season and abundance of *T. marginatus* (mean number of individuals). Standard deviation above bars.

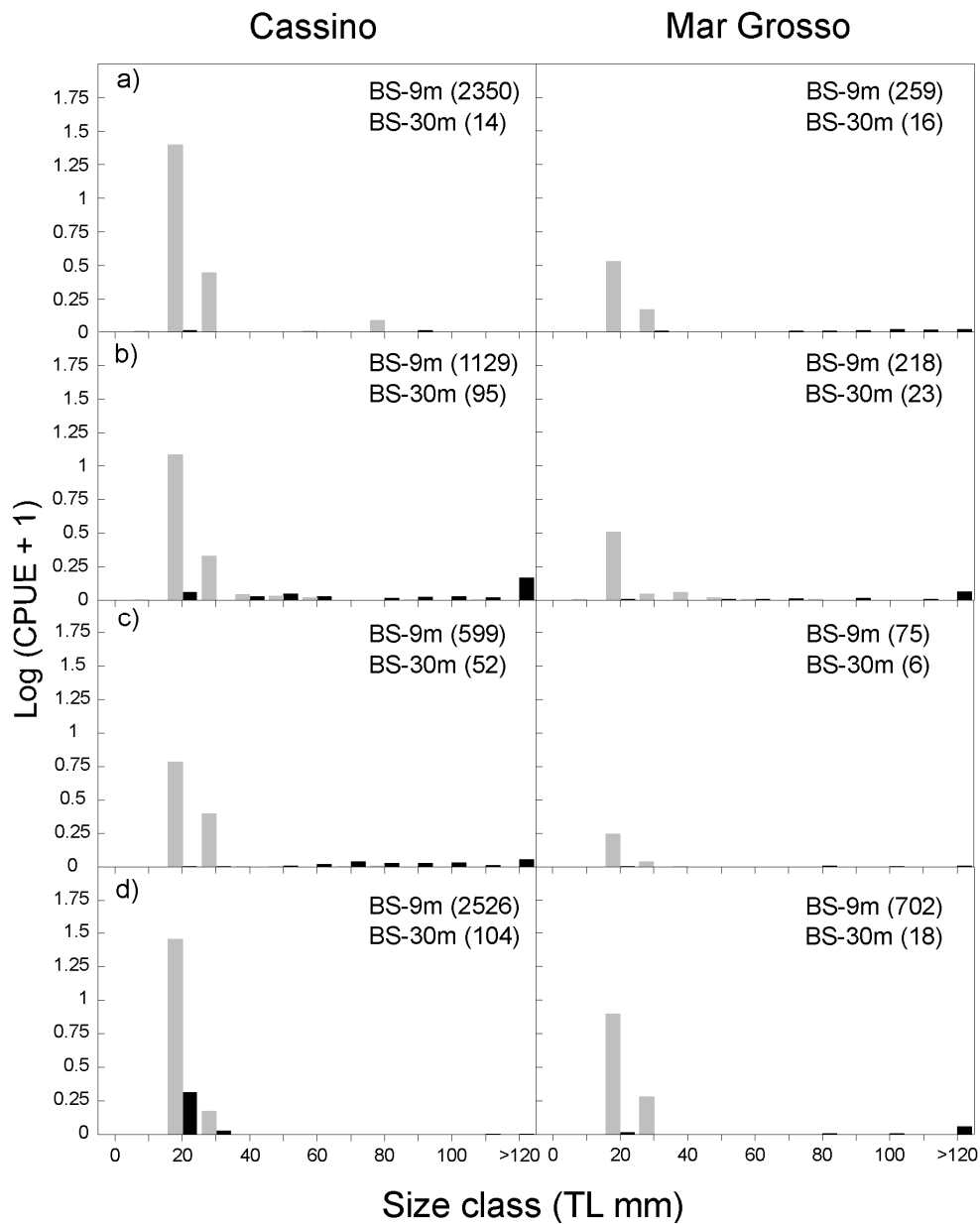


Fig. 6. Distribution of CPUE per size class for *Mugil liza* caught during the 2-years sampling, for seasons of the year. a) winter, b) spring, c) summer and d) autumn. Beach seine 9m (BS-9m) and Beach seine 30m (BS-30m). Number of catches given in parentheses.

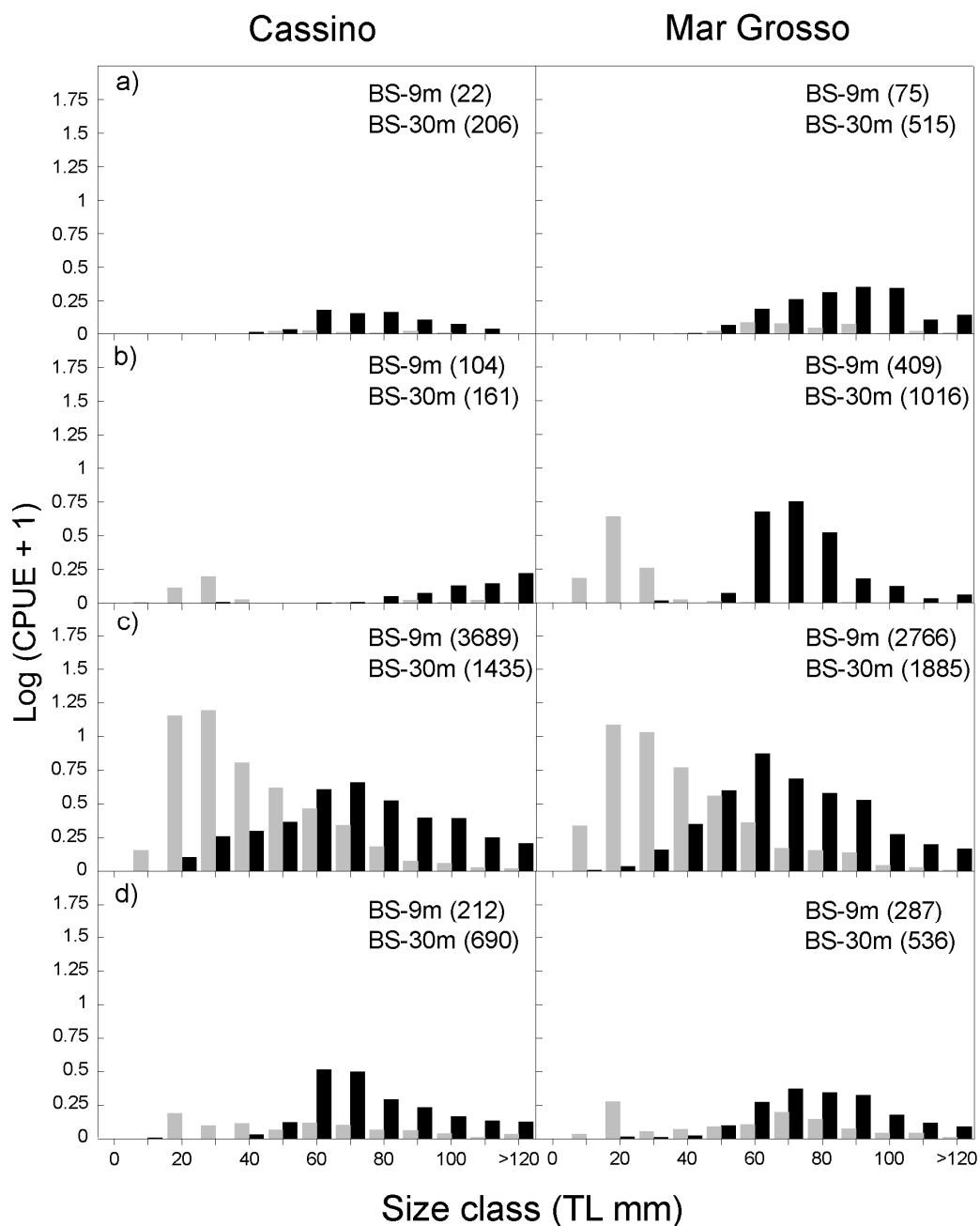


Fig. 7. Distribution of CPUE per size class for *Trachinotus marginatus* caught during the 2-years sampling, for seasons of the year. a) winter, b) spring, c) summer and d) autumn. ■ Beach seine 9m (BS-9m) and ■ Beach seine 30m (BS-30m). Number of catches given in parentheses.

ANEXO IV

Variação interanual na assembleia de peixes da zona de arrebentação de duas praias subtropicais adjacentes a um estuário.

Rodrigues, Fábio Lameiro; Moraes Leonardo Evangelista; Vieira, João Paes

(Periódico a ser definido)

Variação interanual na assembleia de peixes da zona de arrebentação de duas praias subtropicais sobre influência estuarina.

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RESUMO

O presente estudo objetiva avaliar variações interanuais na composição e abundância da assembleia de peixes da zona de arrebentação de duas praias arenosas separadas por um estuário, e identificar os fatores que influenciam estas variações. Para tanto, analisou-se um banco de dados de coletas mensais, para um período contínuo de 12 meses (Junho 2001 a Maio 2002) e um segundo período de 24 meses (Julho 2009 a Junho 2011), cujos dados foram gerados a partir de um protocolo de amostragens padronizadas. Variáveis ambientais (temperatura, salinidade, transparência, vazão e componentes do vento) foram adicionadas ao modelo para tentar identificar relações entre estas variáveis e os padrões encontrados. Duas características marcaram os períodos analisados: i) a presença de um evento *El Niño* de fraca intensidade no segundo período, e ii) o aumento na temperatura da água em superfície entre os verões. Não houve mudança na composição de espécies entre os períodos, porém foi registrada uma queda significativa na abundância total e na diversidade ao longo do tempo. Sete espécies foram dominantes em ambos os períodos, sendo três espécies diretamente relacionadas com a zona de arrebentação (*Trachinotus marginatus*, *Menticirrhus littoralis* e *M. americanus*). Juvenis de *Mugil liza*, *M. littoralis*, *M. americanus* e *T. marginatus* registraram uma queda significativa na abundância média entre o passado e o presente. Para as demais espécies não foram identificadas queda ou elevação, estatisticamente significativas na abundância entre os períodos analisados. Quando descartada a variabilidade natural, associada a variações nas condições climáticas, a hipótese mais parcimoniosa para explicar a queda na abundância média das espécies está relacionada ao aumento na pressão de pesca exercida sobre as espécies dominantes.

Palavras-chave: zonas costeiras rasas, séries temporais, variabilidade, esforço de pesca, mudanças climáticas, sul do Brasil.

ABSTRACT

The present study aims to evaluate interannual variations in the composition and abundance of the surf zone fish assemblage of two sandy beaches separated by an estuary, and to identify the factors influencing these variations. Hence, we analyzed a data set composed by two sampling periods: June 2001 to May 2002 and July 2009 to June 2011. Fish abundance data were collected monthly with a standardized sampling protocol. Environmental variables (temperature, salinity, transparency, estuary flow and wind components) were included in the model to try to explain variability patterns. Two features characterized the periods analyzed: i) the presence of a low intensity *El Niño* in the two-year period, and ii) an increasing tendency in surface water temperature during summers. In general, species composition remained unchanged between periods, but the total abundance decrease significantly over the time. Seven species were dominant in both periods, of which three species were directly related to the surf zone environment (*Trachinotus marginatus*, *Menticirrhus littoralis* and *M. americanus*) and one species is known for using the surf zone as a pathway while migrating into estuaries (*Mugil liza*). Juveniles of this species recorded a significant drop in average abundance between past and present data. Trends observed for other species (decrease or increase in abundance) were not statistically significant. Apart from the natural variability associated with changes in climatic conditions, the most parsimonious hypothesis to explain the drop in average abundance of fish species is related to the increase in the fishing pressure on the dominant species.

Keywords: shallow coastal areas, time series, variability, fishing effort, climate change, southern Brazil

1. INTRODUÇÃO

Mundialmente, a zona de arrebentação de praias arenosas é caracterizada por apresentar uma alta hidrodinâmica, com variações na abundância e composição de espécies de peixes, relacionadas principalmente a fatores ambientais (p. ex. temperatura, salinidade, grau de exposição às ondas) (Beyst et al. 2002, Lazzari et al. 2003, Inui et al. 2010). Este ambiente é conhecido por ser uma área de criação e alimentação (McLachlan & Brown 2006), assim como rota de passagem para muitas espécies de peixes marinhos costeiros em conexão com sistemas estuarinos, sendo conhecidas como importantes áreas de pré-recrutamento de espécies estuarino-relacionadas (p. ex. *Mugil* e *Brevoortia*) (Beck et al. 2003, Able et al. 2011). Consequentemente, poucas espécies (p. ex. *Trachinotus* spp. e *Menticirrhus* spp.) são realmente aptas para viverem neste ambiente em função da alta hidrodinâmica reinante (Clark 1997).

A ictiofauna que utiliza a zona de arrebentação das praias arenosas situadas no extremo sul do Brasil é relativamente bem conhecida (Ramos & Vieira 2001, Monteiro-Neto et al. 2003, Lima & Vieira 2009, Rodrigues & Vieira 2012), tendo sido apresentados os padrões de composição e dominância típicos deste tipo de habitat (i.e., baixa diversidade e dominância de poucas espécies). Além disso, este ambiente é uma importante área de recrutamento de espécies que estão diretamente relacionadas com o zona de arrebentação (p. ex. o pampo *Trachinotus marginatus* e o papa-terra *Menticirrhus littoralis*) e espécies estuarino relacionadas, tais como a tainha *Mugil liza*, a savelha *Brevoortia pectinata* e o papa-terra *Menticirrhus americanus* (Garcia et al. 2003, Lemos et al. 2011, Rodrigues & Vieira 2012). Fatores físicos são os grandes reguladores da dinâmica deste ambiente, que é fortemente influenciado pelo padrão de vento, ondas e ondulações, que determinam a variação do nível médio do mar e o

direcionamento da Pluma do Estuário da Lagoa dos Patos (PELP), influenciando diretamente a distribuição de sedimentos e a presença de água menos salina na região costeira adjacente. Por exemplo, os ventos de nordeste, predominantes na região, tendem a favorecer o espalhamento da PELP em direção sul, formando um bolsão de água menos salina e com alto teor de sedimentos finos, ao longo de grande extensão da orla da praia do Cassino (Möller et al. 2001, Marques et al. 2010). A intensificação deste evento (águas menos salinas + sedimentos finos) é causada principalmente pela vazão do ELP, a qual é regulada especialmente pela descarga continental da grande bacia de drenagem do sistema Patos-Mirim (~ 200.000 km²) (Möller et al. 2001). Esta descarga continental possui um forte componente interanual, controlado por variações no padrão de chuva na bacia de drenagem, que são dirigidas principalmente por fenômenos climáticos (p. ex. *El Niño* Oscilação Sul - ENSO) (Grimm et al. 1998, Garcia et al. 2003, Möller & Fernandes 2010). Anomalias positivas de chuva em toda a bacia de drenagem durante eventos ENSO promovem fortes descargas em todos os tributários da Lagoa dos Patos, resultando em uma forte vazão estuarina (de 2.400 para 12.000 m³/s) e, por conseguinte, um aumento na intensidade da influência da pluma estuarina na região costeira adjacente (Vaz et al. 2006). Este efeito cascata promovido pela alteração no regime de chuvas na região se inverte durante eventos *La Niña*, quando são observadas anomalias negativas de chuva na região.

As praias arenosas adjacentes ao ELP (praia do Cassino e Mar Grosso, Fig. 1), tendem a apresentar uma forte dinâmica temporal (assim como ocorre no ELP), sendo fortemente regida por ciclos sazonais regulados pela temperatura (Chao et al. 1985, Garcia et al. 2012, Moraes et al. 2012, Rodrigues & Vieira 2012). Adicionalmente, o efeito de fenômenos climáticos sobre o regime de chuvas da região, como mencionado

acima, impõe um importante componente interanual na dinâmica temporal da biota e dos fatores abióticos do ELP (Garcia et al. 2003, Odebrecht et al. 2010), o qual parece se refletir também, em áreas pouco profundas da região costeira adjacente (Odebrecht et al. 2010, Dumont & D’Incao 2011).

A maioria dos trabalhos que tem como foco o estudo da assembleia de peixes da zona de arrebentação de praias arenosas engloba análises utilizando uma curta série temporal (12-24 meses) (p. ex. Monteiro-Neto et al. 2003, 24 meses; Nanami & Endo 2007, 24 meses; Lima & Vieira 2009, 12 meses), e estudos relacionando informações obtidas em períodos distintos (i.e., passado e presente) e na mesma região, são praticamente inexistentes. Adicionalmente, diante do contexto mencionado acima e que vem sendo observado para o ELP, e também na região costeira adjacente, o presente estudo objetivou: i) avaliar possíveis variações de interanuais na composição e abundância da assembleia de peixes da zona de arrebentação, e ii) identificar os fatores que podem estar influenciando nestas variações.

2. MATERIAL E MÉTODOS

2.1. Área de estudo

A área de estudo compreendeu duas praias arenosas localizadas no extremo sul do Rio Grande do Sul (RS) e adjacentes ao Estuário da Lagoa dos Patos (Fig. 1). A costa do RS possui orientação nordeste-sudoeste e é caracterizada por uma extensa e retilínea planície costeira, com os grãos formadores das areias da praia variando de muito finos (próximo aos molhes) a médios (praias mais distantes aos molhes, ~ 20 km) (Siegle & Calliari 2008). A linha de praia é dominada por ondas (níveis médios de energia), sendo que as maiores ondas ocorrem durante o inverno e as menores, durante

o verão, com padrões intermediários sendo observados no outono e na primavera (Calliari & Klein 1993). A maré apresenta baixa amplitude (0,47 m) e o vento é o principal fator regulador do nível do mar na costa, ocorrendo um predomínio de ventos de nordeste ao longo de todo o ano (primavera e verão) ocorre o abaixamento do nível do mar, e ventos do quadrante sul durante o outono/inverno, que causam a elevação do nível do mar (Möller et al. 2001). O padrão de vento também é responsável pela intensificação ou redução da vazão do ELP, com o aumento dos fluxos de vazante e enchente durante os ventos de nordeste e sudoeste, respectivamente, o que influencia diretamente na intensidade da PELP.

2.2. Desenho amostral

As amostragens foram realizadas mensalmente, durante três períodos não consecutivos (I = Junho 2001 a Maio 2002; II = Julho 2009 a Junho 2010 e III = Julho 2010 a Junho 2011), em duas praias arenosas (Cassino e Mar Grosso) separadas pelos molhes da barra do estuário da Lagoa dos Patos (Fig. 1). Em cada praia foram escolhidos dois pontos para a coleta dos peixes e obtenção das variáveis ambientais. Durante os três períodos utilizou-se o mesmo amostrador, uma rede de arrasto de praia com 9 m de comprimento por 1,5 m de altura, com malha 13 mm (entre nós opostos) nas asas e 5 mm (entre nós opostos) nos 3 m centrais. Cada arrasto era feito de forma perpendicular a linha de praia, em profundidades inferiores a 1,5 m e sempre se evitando arrastar a rede na mesma área amostrada no arrasto anterior. O material coletado era acondicionado em sacos plásticos contendo formalina 10%, e transportado para o Laboratório de Ictiologia (IO/FURG). No laboratório, os peixes eram identificados com o auxílio de guias de identificação específicos, medidos o

comprimento total em milímetros e registrado o número total de indivíduos por espécie/por amostra.

As variáveis ambientais registradas e utilizadas na análise foram obtidas de duas maneiras. Registro *in situ* e simultâneos às amostragens biológicas, da temperatura da água em superfície (°C), salinidade e transparência (disco de Secchi, m). Com relação à variável salinidade, deve-se ressaltar que diferentes equipamentos de medição foram utilizados ao longo dos três períodos (refratômetro – período-I; termo-salinômetro e refratômetro – períodos-II e III), pode ter gerado uma discrepância nas leituras, como evidenciado pelas análises prévias desta variável (resultados não apresentados), e que sugerem diferenças significativas entre os três períodos. No entanto Rodrigues & Vieira (2012) demonstram que a salinidade não é um fator significativo para explicar a variabilidade da assembleia de peixes nas duas praias previamente estudadas. Sendo assim, optou-se por retirar a salinidade das análises, pois não foi possível identificar se as diferenças observadas entre os três períodos analisados eram reais ou estavam associadas às mudanças nos equipamentos.

As informações referentes à vazão do ELP foram obtidas a partir de dados de vazão dos três principais rios do sistema Patos-Mirim (Jacuí, Taquarí e Camaquã), adquiridos junto à web site da Agência Nacional das Águas (ANA - <http://hidroweb.ana.gov.br/>). A soma das descargas mensais destes três rios corresponde a 70% da vazão de toda bacia de drenagem e, portanto, foi utilizada como um indicador do aporte de água doce no ELP e da vazão deste estuário (Vaz et al. 2006). Dados de vento foram obtidos junto à “Divisão de Pesquisa Ambiental do Centro de Ciências da Pesca da NOAA - National Oceanic and Atmospheric Administration”, na web site: http://las.pfeg.noaa.gov/las6_5/servlets/dataset. Neste banco de dados se escolheu a

informação próxima a área de estudo (32° S; 52° W), obtendo-se os valores mensais dos componentes zonal (direção oeste-leste) e meridional (direção sul-norte) do vento acima da superfície do mar até 10 m.

2.3. *Análise de dados*

Para a análise proposta neste manuscrito, optou-se por analisar o banco de dados como um todo, considerando apenas três fatores: “Períodos” (três níveis: períodos I, II e III), “Estação do Ano” (quatro níveis: verão, outono, inverno e primavera) e “Local” (dois níveis: Cassino e Mar Grosso). Os pontos de coleta não foram considerados com um fator para as análises, pois trabalhos prévios (ver ANEXO I e III) concluem que não há diferenças espaciais significativas nas variáveis ambientais, abundância e composição das espécies entre os pontos de coleta, justificando a utilização dos mesmos, como réplicas espaciais.

Os dados de abundância total e por espécie foram calculados com base no número de indivíduos por arrasto (CPUE). A importância das espécies dominantes foi calculada com base na média da percentagem numérica (N%) e frequência de ocorrência (FO%), para cada ano. Desta forma, as espécies foram classificadas em: frequente e abundante (quando N% e FO% de cada espécie estiveram acima da média), não frequente e abundante (quando apenas N% de cada espécie esteve acima da média), frequente e pouco abundante (quando apenas FO% de cada espécie esteve acima da média), presente (quando N% e FO% estiveram abaixo da média) e ausente (quando a espécie não foi capturada) (Garcia & Vieira 2001). Foi calculado o índice de Margalef como um indicativo da diversidade de espécies. Com base nos valores mensais por ponto de coleta foi testado o efeito dos fatores “Período” e “Local” para as variáveis

CPUE total, CPUE por espécie e índice de Margalef. Para tanto, foi utilizada a Análise de Covariância (ANCOVA), sendo que as variáveis ambientais foram incluídas como co-variáveis. Devido ao forte efeito sazonal observado na região, o fator “Estação do ano” não foi incluído na análise, sendo que a co-variável temperatura foi incluída no modelo como indicador deste efeito sazonal. Deste modo, foi possível avaliar os efeitos dos dois fatores de interesse (“Período” e “Local”), após filtrar o efeito sazonal. A escolha desta análise foi feita seguindo dois critérios: 1º) ajuste dos dados aos pressupostos das análises paramétricas (normalidade e homocedasticidade) e, 2º) acomodação de dados discrepantes (outliers). Os dados de abundância foram transformados [$\text{Log}(\text{CPUE} + 1)$] e as variáveis ambientais foram transformadas em escore z . Uma possível interação entre “Período” e “Local” foi testada e não se identificando interação, as análises foram conduzidas de forma independente.

Análise de Correspondência Canônica (CCA) foi usada para identificar uma estruturação das espécies em relação aos três períodos avaliados, e avaliar a influência das variáveis ambientais nesta estrutura (*tripplot*). Com o objetivo de evitar o forte efeito sazonal, apenas os meses correspondentes ao verão de cada período (Janeiro, Fevereiro e Março) foram considerados nesta análise. A escolha de usar o verão foi fundamentada em dois requisitos: i) maior abundância dos indivíduos durante esta estação e ii) menor variabilidade dentro do conjunto de dados analisados. Para a análise foram incluídas apenas as espécies frequentes e abundantes durante o verão e somente as variáveis ambientais significativas (componentes do vento e temperatura), que foram avaliadas usando o teste de permutação de Monte Carlo ($n = 9.999$; $p < 0,05$) (Lepš & Šmilauer 2003).

3. RESULTADOS

A média por estações do ano das variáveis abióticas variou ao longo dos anos, sendo que as maiores variações observadas entre os períodos foram durante a primavera e o verão (Tabela 1). A transparência não mostrou um claro padrão de mudanças ao longo dos períodos, sendo que os valores médios estiveram sempre abaixo de 0,5 m. A temperatura média da água em superfície para cada estação do ano variou entre os períodos, principalmente durante o verão. Os períodos-II e III apresentaram maiores temperaturas médias (25,22 e 23,46 °C, respectivamente) em comparação com o período-I (21,75 °C). A componente zonal do vento em superfície também variou ao longo dos períodos, sugerindo em média a predominância de ventos do quadrante leste nos períodos-I e III e do quadrante norte no período-II (Tabela 1). Maiores valores de vazão foram registrados para o período-II, seguido pelo período-I, com a vazão durante o verão do período-II sendo três vezes maior do que a vazão dos demais períodos.

O modelo linear demonstra uma relação positiva e significativa da abundância total com a temperatura e a vazão do ELP. Não houve interação significativa entre os fatores “Período” e “Local” ($p = 0,46$) e o modelo demonstra diferenças significativas nas abundâncias médias (CPUE) entre os três períodos analisados, sendo que no períodos-II e III foram registradas médias significativamente menores do que no período-I ($p < 0,001$) (Tabela 2; Fig. 2a). Observa-se ainda, que de uma maneira geral, houve uma diminuição na riqueza de espécies (Fig. 2b) e na diversidade (Fig. 2c), nos períodos II e III em relação ao período-I.

Nove espécies foram frequentes e abundantes em pelo menos um período, sendo que apenas três espécies (*Mugil liza*, *Trachinotus marginatus* e *Brevoortia pectinata*) foram frequentes e abundantes ao longo dos três períodos analisados (Tabela 3). A abundância média de *M. Liza* e *T. marginatus* foi significativamente maior no

período-I ($p < 0,01$), se comparadas com os períodos-II e III (Fig. 3). Durante o período-II observa-se uma queda nas abundâncias médias de *M. liza* (CPUE méd. = 8,67) e *T. marginatus* (CPUE méd. = 8,67) com um progressivo aumento no período-III (CPUE méd. = 19,66 e 14,02 respectivamente), porém sem atingir os patamares do período-I (CPUE méd. = 24,65 e 27,28 respectivamente). Embora valores mais altos da CPUE de *M. liza* sejam observados durante o período-III, nota-se que estes valores não são consistentes ao longo de todo o ano, como acontece no período-I (Tabela 3). *Menticirrhus americanus* e *M. littoralis* foram frequentes e abundantes na primavera e verão do período-I, registrando também um abrupto e significativo ($p < 0,01$) declínio nas abundâncias médias nos demais períodos estudados (Tabela 3; Fig. 3).

Não foi observada diferença significativa entre as abundâncias médias, entre períodos, de *B. pectinata* ($p = 0,15$), *Mugil curema* ($p = 0,13$) e *Odontesthes argentinensis* ($p = 0,66$) (Fig. 3), sendo que a abundância de *B. pectinata* apresentou uma queda contínua entre os períodos (I CPUE méd. = 6,72; II CPUE méd. = 4,62 e III CPUE méd. = 2,27), ocorrendo o inverso com as capturas de *M. curema*, que foram aumentando gradativamente do período-I (CPUE méd. = 1,02) até o período-III (CPUE méd. = 7,78). *Odontesthes argentinensis* foi frequente e abundante apenas no período-II (CPUE méd. = 4,84) apresentando baixos valores de abundância média nos demais períodos.

Temperatura e componentes do vento explicaram 23,2% da variabilidade total dos verões, sendo que 64,6% da variabilidade foi explicada pelo eixo-1 (Tabela 4; Fig. 4), o qual parece sugerir um gradiente de temperatura (alta correlação), contrastando a temperatura da água em superfície no verão do período-I (menos quente) em relação ao verão dos demais períodos (mais quentes). De certa forma, a ordenação confirma os

resultados encontrados nas análises anteriores, demonstrando que a temperatura da água em superfície durante o verão do período-I foi menos quente, e caracterizado pela maior abundância de *M. liza*, *T. marginatus*, *B. pectinata*, *M. americanus* e *M. littoralis*, em relação aos demais períodos. As componentes do vento (zonal e meridional) estiveram fortemente correlacionadas com o eixo-2, indicando uma possível associação de *M. curema*, *Atherinella brasiliensis* e *T. marginatus*, com vento proveniente do quadrante sul. Já *O. argentinensis* parece estar mais associada a vento proveniente do quadrante oeste.

4. DISCUSSÃO

Variações interanuais na composição e abundância de peixes são registradas para estuários, as quais geralmente estão associadas às mudanças no regime de chuvas da bacia de drenagem, na hidrodinâmica costeira e circulação estuarina (Martinho et al. 2009, Jenkins et al. 2010, Martino & Houde 2010, França et al. 2011, Moraes 2011), sendo que informações a respeito de possíveis variações interanuais (e suas causas) na composição e abundância dos peixes que habitam a zona de arrebentação, ainda são escassas. Isto ocorre, principalmente devido à inexistência de séries temporais (mesmo que de curta duração), visto que a grande maioria dos trabalhos que são realizados neste ambiente abordam escalas temporais menores ou iguais a 24 meses contínuos (p. ex. Monteiro-Neto et al. 2003, Nanami & Endo 2007, Lima & Vieira 2009).

A não continuidade da série temporal analisada não nos permite inferir com maior precisão, sobre tendências de longo-prazo. No entanto, os resultados apresentados no presente trabalho são suficientes para indicar que mudanças interanuais estão ocorrendo na assembleia de peixes na zona de arrebentação de praias arenosas do sul do

Brasil, com destaque para espécies típicas deste habitat (p. ex. *M. littoralis* e *T. marginatus*). Estes resultados refletem os padrões que são observados em séries de longo prazo para a região. Por exemplo, uma série com cerca de 15 anos de amostragens mensais contínuas, obtidas para a praia do Cassino, demonstra uma forte redução na abundância de juvenis de *Menticirrhus* (dados não publicados; Fig. 5). Duas características marcaram o período de estudo em relação às condições ambientais: 1) a presença de um evento *El Niño* de fraca intensidade (período-II) e 2) tendência de aumento na temperatura da água em superfície. Esta tendência parece ser suportada por séries históricas da temperatura superficial do mar na região, obtidas a partir de modelos gerados pela NOAA (Fig. 6).

Ecossistemas subtropicais são caracterizados por marcada sazonalidade nos componentes biológicos em resposta à variação da temperatura (Day et al. 1989, Ciotti et al. 1995, Castillo-Rivera et al. 2010, Martino & Houde 2010, Kristiansen et al. 2011). A maioria dos trabalhos realizados na zona de arrebentação de praias arenosas subtropicais aponta a temperatura da água em superfície, como a principal variável ambiental que regula os padrões de sazonalidade da estrutura e abundância dos juvenis de peixes encontrados neste ambiente (Bell et al. 2001, Pessanha et al. 2003, Barreiros et al. 2004, Vasconcellos et al. 2011), sendo o mesmo encontrado para as praias do sul do Brasil (Monteiro-Neto et al. 2003, Lima & Vieira 2009, Rodrigues & Vieira 2012).

A zona de arrebentação de praias arenosas também é considerada por muitos autores como uma importante área de criação, alimentação, transição e de pré-recrutamento para inúmeras espécies de peixes de elevada importância comercial. Sabe-se que durante a primavera e início do verão, a região marinha costeira do RS é local de agregação reprodutiva para várias espécies de peixes de importância ecológica e

comercial (p. ex. a corvina *Micropogonias furnieri* Castello 1986, Haimovici & Umpierre 1996; o pampo *Trachinotus marginatus* Lemos et al. 2011). Neste período, os cardumes se agregam devido às condições favoráveis de temperatura da água e de aumento na abundância de alimento, o qual está associado ao efeito cascata promovido pela combinação entre elevação da temperatura e maior aporte de nutrientes na região costeira promovido pela grande vazão estuarina registrada durante a primavera (Chao et al. 1985, Abreu et al. 1995, Ciotti et al. 1995, Martins et al. 2007, Garcia et al. 2012). Além disso, é durante os meses quentes, que ocorre um considerável aumento na diversidade e na abundância dos juvenis de peixes que usam a zona de arrebentação estuarina e marinha em determinado período da sua vida, além de ser uma estação onde as variações nas condições ambientais são muito menores (Garcia et al. 2012). No entanto, a tendência de aumento da temperatura na região, não parece estar se convertendo em condições que favoreçam as espécies na zona de arrebentação.

Em comparação com as demais espécies, o parati *M. curema* foi a única espécie que apresentou um aumento na abundância média ao longo dos três períodos estudados, sendo que a maior abundância foi registrada durante o verão do período-III. Este considerável aumento na abundância desta espécie ao longo dos períodos pode estar relacionado a um aumento na temperatura média da superfície da água, como observado nos resultados deste trabalho e na série histórica gerada pela NOAA (ver Fig. 6), visto que juvenis de *M. curema* são mais abundantes em águas com temperatura acima de 20°C (Vieira 1991). O aumento da temperatura em regiões subtropicais e temperadas tem sido o argumento utilizado para explicar a ampliação e restrição na distribuição de espécies de clima quente e de clima frio, respectivamente (Nakano et al. 1996, Dulvy et al. 2008). No entanto, esta hipótese não parece explicar as reduções

observadas para as outras espécies (p. ex. *M. americanus*, *M. littoralis* e *T. marginatus*), pois elas distribuem-se em áreas de clima mais quentes ao longo da costa brasileira (Menezes & Figueiredo 1980).

Os períodos-I e III foram caracterizados pela neutralidade de eventos ENSO, enquanto que no período-II foi observado um *El Niño* de fraca intensidade. Para a região sul do Brasil, sabe-se que os eventos *El Niño* são caracterizados pelo aumento nas chuvas, predomínio de ventos NE e temperaturas mais elevadas (Grimm et al. 1998, Barros et al. 2002). Assim, a ocorrência do *El Niño* no período-II pode justificar a maior temperatura registrada neste período, mas também não parece elucidar os padrões observados para as espécies. Por exemplo, juvenis da tainha *M. liza* estão presentes na zona de arrebenção adjacente ao ELP ao longo de todo o ano, utilizando este habitat como local de pré-recrutamento e entrando no estuário quando as condições são favoráveis (Vieira 1991). Eventos *El Niño* parecem afetar a variabilidade interanual na abundância de juvenis no ELP, pois as anomalias positivas de vazão registradas neste estuário durante estes eventos, tendem a bloquear a entrada de ovos e larvas das espécies de origem marinha no ELP (Garcia et al. 2003, Martins et al. 2007, Vieira et al. 2008, Möller et al. 2009). Portanto, esperar-se-ia que a abundância de *M. liza*, bem como de outras espécies estuarino-relacionadas (p. ex. *B. pectinata* e *M. americanus*), se mantivesse ou até mesmo aumentasse na zona de arrebenção, devido ao efeito de aprisionamento dos juvenis, causado pelo padrão de circulação costeiro e influenciado pela forte vazão estuarina. No entanto, os resultados sugerem uma tendência de redução de juvenis de *M. liza* e de outras espécies estuarino-residentes. Moraes (2011), analisando uma longa série temporal para o ELP, identificou um declínio na abundância dos juvenis de *M. liza* ao longo dos últimos anos (mesmo que com condições favoráveis

para uma elevada abundância no estuário), inferindo que efeitos antrópicos, entre eles o aumento na pressão de pesca, poderiam estar afetando o recrutamento da espécie. No entanto, o autor enfatiza que a alta variabilidade temporal no recrutamento desta espécie dificulta a identificação de padrões claros. Tendo em vista que a espécie utiliza a zona de arrebentação somente como área de passagem e pré-recrutamento para o estuário, variações na abundância média desta espécie na zona de arrebentação podem também estar diretamente relacionadas aos fatores identificados por Moraes (2011) para o ELP.

A savelha *B. pectinata* apresentou uma tendência de queda na abundância ao longo dos períodos, resultado contrário ao obtido por Moraes (2011) que observou um aumento na abundância desta espécie no ELP. No entanto, deve-se ressaltar que o hábitat preferencial desta espécie quando juvenil é o estuário e não a zona de arrebentação de praias marinhas, que é utilizada somente como uma área de passagem. Sendo assim, a hipótese mais plausível é que os períodos de baixa abundância de *B. pectinata* na zona de arrebentação, coincidem com períodos de condições favoráveis para que os juvenis desta espécie penetrem no estuário, ocorrendo uma queda natural na sua abundância na zona de arrebentação, devido ao deslocamento dos juvenis para o interior do estuário.

Duas espécies típicas da zona de arrebentação das praias do sul do Brasil, o pampo *T. marginatus* e o papa-terra *M. littoralis*, apresentaram uma tendência de queda na abundância média ao longo dos períodos analisados. A hipótese mais provável para explicar esta tendência estaria relacionada a um aumento na pressão de pesca exercida sobre estas espécies, ao longo dos últimos anos. Informações referentes a desembarques/capturas de *T. marginatus* são praticamente inexistentes e quando existentes são confusas, mas parecem indicar que esta espécie é capturada

principalmente durante o inverno, por pescadores amadores do litoral norte do estado do Rio Grande do Sul (Peres & Klippel 2005) e por pescadores artesanais que utilizam redes de espera na zona de arrebenção da praia do Cassino. Em geral, as capturas são compostas, na sua maioria, por indivíduos abaixo do tamanho de primeira maturação (Lemos 2010). Já o papa-terra *M. littoralis* e a espécie estuarino-relacionada *M. americanus* são as principais espécies alvo da pesca amadora ao longo de todo o litoral do RS, sendo capturadas durante todo o ano no litoral norte do estado (Santos-Lewis et al. 1999, Braun & Fontoura 2004, Peres & Klippel 2005) e durante a primavera e o verão no litoral sul. A pressão de captura no litoral norte é maior sobre os indivíduos que já atingiram o tamanho de primeira maturação (Santos-Lewis et al. 1999), enquanto que cerca de 50% dos indivíduos capturados no litoral sul geralmente estão abaixo do tamanho de primeira maturação de 200 mm (Basaglia & Vieira 2005). Além da pesca amadora, há registro de uma pesca artesanal de beira de praia, voltada especificamente para a captura destas espécies, porém sem regulamentação e registro de capturas. Somando-se a isto, estas espécies são pescadas com redes de emalhe de fundo, pela frota industrial costeira da região sul do Brasil (Klippel et al. 2005).

Ainda que a temperatura da água em superfície registrada para os verões dos três períodos analisados tenha mostrado uma considerável elevação, o que poderia favorecer o aumento na abundância das espécies que frequentam a zona de arrebenção, o padrão encontrado foi o inverso. A hipótese mais plausível para explicar a diminuição na abundância de juvenis de certas espécies (*M. liza*, *T. marginatus*, *M. littoralis* e *M. americanus*) seria o aumento na pressão de pesca destas espécies dominantes na zona de arrebenção, o que pode ter causado uma considerável redução nos estoques, principalmente de *M. littoralis* e *M. americanus*, espécies que são

consideradas típicas deste ambiente e que sofrem com a pesca no litoral do estado, ao longo de todo o ano.

No entanto, embora a hipótese de um aumento na pressão de pesca sobre as espécies acima citadas possa explicar a queda na abundância das espécies dominantes na zona de arrebentação, ela por si só, não explicaria a queda na riqueza de espécies e diversidade observada ao longo dos períodos II e III em relação ao período I. De fato, outros fatores podem afetar o recrutamento em águas costeiras e conseqüentemente a abundância das espécies. Tais fatores podem ser abióticos (como os previamente discutidos) e/ou interações bióticas, tais como a presença/ausência de recursos alimentares em quantidades suficientes, predação e a presença de adultos desovando próximo a costa. Além disso, perturbações físicas no hábitat, podem ter efeito indireto sobre a abundância de determinadas espécies. Como exemplo, perturbações causadas por deposição de lama fluída na zona entremarés, e que tem ocorrido com certa frequência desde 1998 na praia do Cassino (Calliari et al. 2000, Mont'Alverne et al. 2012), podem causar efeito negativo e direto (mortalidade) sobre a associação macrobentônica da zona entremarés (Silva et al. 2008), que constitui um importante recurso alimentar para as espécies que estão diretamente relacionadas com a zona de arrebentação (i.e., *Menticirrhus* spp. e *T. marginatus*) (Monteiro-Neto & Cunha 1990, Rodrigues & Vieira 2010, Mont'Alverne et al. 2012). Além do mais, Mont'Alverne et al. (2012) demonstraram que durante um evento de deposição de lama na praia do Cassino, a abundância de *M. littoralis* foi maior nas áreas sem lama, do que nas áreas com lama, o que pode indicar que a espécie estaria evitando locais com reduzida disponibilidade alimentar e com ondas mais atenuadas. Portanto, mudanças no tipo de sedimento do ambiente e na qualidade da água (mais material fino em suspensão)

certamente diminuem a quantidade de alimento disponível para estas espécies, o que pode estar acontecendo a partir da recorrência destes eventos de deposição de lama fluída.

Embora a salinidade seja um fator importante em estruturar a assembleia de peixes que estão diretamente relacionados com o estuário (Able et al. 2006, Wasserman & Strydom 2011) ela não é significativamente importante para as espécies que usam o dinâmico ambiente da zona de arrebentação das praias arenosas adjacentes ao estuário da Lagoa dos Patos (Rodrigues & Vieira 2012). Além disso, a queda na riqueza de espécies e diversidade, observada ao longo dos períodos analisados, dificilmente poderia ser atribuída à elevação desta variável, visto que muitas das espécies que são responsáveis por um aumento na riqueza e diversidade (p. ex. *T. falcatius*, *Selene vomer*), principalmente durante a primavera e o verão, estão associadas com as águas mais quentes e salinas da corrente do Brasil, que durante esta época do ano atingem latitudes mais altas (Möller et al. 2008). No entanto, espécies estuarino-relacionadas e que toleram menos o aumento da salinidade (p. ex. *Atherinella brasiliensis*) poderiam ser inibidas, evitando a zona de arrebentação durante períodos de elevada salinidade.

Em síntese, a abundância média das espécies dominantes no sistema caiu sistematicamente ao longo dos períodos analisados, e fatores, como por exemplo, a variabilidade natural (em menor grau) imposta ao sistema e a própria pressão de pesca, podem estar levando a uma diminuição do estoque reprodutor e, conseqüentemente, a uma redução no recrutamento das espécies diretamente ligadas a zona de arrebentação.

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Tabela 1. Valores médios das variáveis ambientais usadas na análise entre os três períodos. Valores expressos em média (Méd.) e desvio padrão (DP).

| Período | Estação | Transparência (m) | | Temperatura da água em superfície (°C) | | Salinidade em superfície | | Vento em superfície zonal (m/s) | | Vento em superfície meridional (m/s) | | Vazão Estuário (m ³ /s ⁻¹) | |
|---------|-----------|-------------------|------|--|------|--------------------------|------|---------------------------------|------|--------------------------------------|------|---|---------|
| | | Méd. | DP | Méd. | DP | Méd. | DP | Méd. | DP | Méd. | DP | Méd. | DP |
| Ano I | Inverno | 0,19 | 0,12 | 14,42 | 1,73 | 15,59 | 5,58 | -0,98 | 1,80 | -1,06 | 1,20 | 2258,75 | 1094,01 |
| | Primavera | 0,29 | 0,25 | 19,25 | 1,22 | 21,07 | 4,90 | -2,57 | 0,43 | -0,65 | 1,00 | 1606,53 | 1014,19 |
| | Verão | 0,25 | 0,08 | 21,75 | 0,97 | 16,89 | 6,20 | -2,01 | 0,40 | -0,91 | 0,42 | 557,25 | 208,55 |
| | Outono | 0,48 | 0,35 | 17,88 | 1,55 | 21,35 | 6,91 | -0,52 | 0,58 | -0,39 | 0,02 | 1982,96 | 139,25 |
| Ano II | Inverno | 0,42 | 0,22 | 14,19 | 1,07 | 23,13 | 5,08 | -0,52 | 2,21 | 0,49 | 0,77 | 1860,15 | 1056,78 |
| | Primavera | 0,33 | 0,26 | 19,95 | 2,01 | 24,91 | 4,64 | -2,48 | 0,50 | -2,51 | 0,66 | 3545,40 | 1097,57 |
| | Verão | 0,40 | 0,16 | 25,22 | 1,97 | 27,25 | 2,86 | -0,66 | 0,20 | -2,20 | 0,83 | 1830,36 | 1350,31 |
| | Outono | 0,30 | 0,21 | 18,67 | 2,99 | 28,83 | 3,04 | -0,41 | 0,62 | -0,29 | 0,50 | 940,02 | 312,05 |
| Ano III | Inverno | 0,26 | 0,08 | 12,60 | 1,78 | 24,34 | 6,61 | -1,05 | 1,36 | -1,11 | 0,96 | 2411,77 | 867,55 |
| | Primavera | 0,37 | 0,24 | 19,00 | 2,01 | 27,33 | 6,09 | -2,15 | 0,74 | -0,22 | 1,63 | 475,85 | 189,53 |
| | Verão | 0,35 | 0,24 | 23,46 | 2,10 | 36,18 | 1,48 | -3,70 | 0,17 | -0,31 | 1,03 | 593,43 | 182,22 |
| | Outono | 0,38 | 0,19 | 18,58 | 2,39 | 33,13 | 1,44 | 0,34 | 0,54 | 0,25 | 0,66 | 928,44 | 187,49 |

Tabela 2. Análise de covariância (ANCOVA) da abundância, por períodos. gl = graus de liberdade, SQ = soma dos quadrados e QM = quadrado médio. Valores em negrito são significativos.

| Fontes de variação | gl | SQ | QM | Teste F | p-valor |
|-----------------------------------|-----|--------|--------|---------|-----------------|
| Intercepto | 1 | 266,50 | 266,50 | 1221,26 | 0,000000 |
| Temperatura da água em superfície | 1 | 14,02 | 14,02 | 64,26 | 0,000000 |
| Vazão | 1 | 1,01 | 1,01 | 4,61 | 0,033640 |
| Período | 2 | 4,50 | 2,25 | 10,32 | 0,000067 |
| Local | 1 | 2,39 | 2,39 | 10,97 | 0,001185 |
| Período*Local | 2 | 0,34 | 0,17 | 0,78 | 0,460325 |
| Erro | 136 | 29,68 | 0,22 | | |
| Total | 143 | 49,84 | | | |

Tabela 3. Importância das espécies dominantes na zona de arrebentação das praias arenosas adjacentes ao ELP, durante os três períodos analisados. Méd. = Média e DP = Desvio padrão.

| Espécies | Período I | | | | | | Período II | | | | | | Período III | | | | | |
|----------------------------------|-----------|-------|-------|-------|-------|-------|------------|-------|-------|-------|------|-------|-------------|------|-------|-------|-------|-------|
| | Inv | Pri | Ver | Out | Méd. | DP | Inv | Pri | Ver | Out | Méd. | DP | Inv | Pri | Ver | Out | Méd. | DP |
| <i>Mugil liza</i> | 16,33 | 26,63 | 28,92 | 26,72 | 24,65 | 5,64 | 5,35 | 13,95 | 4,15 | 11,23 | 8,67 | 4,69 | 36,30 | 5,30 | 6,15 | 30,90 | 19,66 | 16,25 |
| <i>Trachinotus marginatus</i> | 1,68 | 13,05 | 84,87 | 9,53 | 27,28 | 38,68 | 0,25 | 4,10 | 25,82 | 4,50 | 8,67 | 11,59 | 0,27 | 0,42 | 53,77 | 1,63 | 14,02 | 26,50 |
| <i>Odontesthes argentinensis</i> | 0,10 | 1,58 | 6,52 | 0,63 | 2,21 | 2,94 | 1,45 | 13,95 | 3,82 | 0,13 | 4,84 | 6,26 | 0,33 | 0,58 | 1,43 | 0,38 | 0,68 | 0,51 |
| <i>Menticirrhus americanus</i> | - | 9,85 | 9,75 | 0,53 | 6,71 | 5,35 | - | - | 0,18 | 0,28 | 0,23 | 0,07 | - | 0,52 | 0,42 | - | 0,47 | 0,07 |
| <i>Menticirrhus littoralis</i> | 0,18 | 7,30 | 17,12 | 0,72 | 6,33 | 7,89 | - | 0,03 | 2,07 | 1,63 | 1,24 | 1,07 | - | 0,13 | 0,90 | 0,15 | 0,39 | 0,44 |
| <i>Mugil curema</i> | 0,07 | 0,70 | 2,35 | 0,95 | 1,02 | 0,96 | 0,13 | 0,28 | 8,92 | 0,45 | 2,45 | 4,32 | 0,13 | - | 21,90 | 1,32 | 7,78 | 12,24 |
| <i>Oncopterus darwinii</i> | 2,27 | 12,52 | - | 0,18 | 4,99 | 6,60 | 0,05 | 0,35 | 0,13 | - | 0,18 | 0,15 | 0,03 | 1,35 | - | - | 0,69 | 0,93 |
| <i>Bervoortia pectinata</i> | 0,18 | 0,73 | 21,67 | 4,30 | 6,72 | 10,13 | 0,03 | 4,67 | 2,33 | 11,45 | 4,62 | 4,93 | - | 0,12 | 6,45 | 0,25 | 2,27 | 3,62 |
| <i>Atherinella brasiliensis</i> | 0,03 | 0,12 | 0,05 | 10,57 | 2,69 | 5,25 | - | 1,77 | 0,03 | 0,05 | 0,62 | 1,00 | - | 0,03 | 0,20 | 0,23 | 0,16 | 0,11 |
| <i>Mugil cf. hospes</i> | - | 0,02 | 1,20 | 3,93 | 1,72 | 2,01 | - | - | 0,22 | 0,15 | 0,18 | 0,05 | - | - | 0,03 | 0,10 | 0,07 | 0,05 |
| <i>Lycengraulis grossidens</i> | - | 0,05 | 0,07 | 0,03 | 0,05 | 0,02 | 0,02 | 0,13 | 9,73 | 0,03 | 2,48 | 4,84 | 0,03 | - | 0,07 | 0,03 | 0,04 | 0,02 |
| Outras espécies | 0,23 | 0,83 | 2,60 | 0,18 | 0,96 | 1,13 | 0,17 | 0,48 | 1,18 | 0,38 | 0,55 | 0,44 | 0,05 | 0,08 | 2,02 | 0,90 | 0,76 | 0,92 |
| CPUE total | 21,08 | 73,38 | 175,1 | 58,28 | | | 7,45 | 39,72 | 58,58 | 30,30 | | | 37,15 | 8,53 | 93,33 | 35,90 | | |
| Número de espécies | 13 | 16 | 23 | 18 | | | 11 | 16 | 19 | 15 | | | 7 | 11 | 19 | 16 | | |
| Margalef | 3,94 | 3,49 | 4,26 | 4,18 | | | 4,98 | 4,07 | 4,42 | 4,10 | | | 1,66 | 4,66 | 3,97 | 4,19 | | |

- Frequente e abundante.
- ▒ Frequente e não abundante.
- Abundante e não frequente.
- Presente.
- Ausente.

Tabela 4. Resultados da CCA com base na abundância relativa (CPUE) das espécies dominantes somente durante o verão de cada período.

| Eixos | 1 | 2 | 3 |
|------------------------------------|---------|---------|---------|
| Matriz de correlação | | | |
| Temperatura da água em superfície | 0,6674 | 0,3915 | -0,6335 |
| Vento em superfície - zonal | 0,1003 | -0,6291 | -0,7708 |
| Vento em superfície - meridional | -0,4043 | 0,9070 | 0,1178 |
| Resumo estatístico da ordenação | | | |
| Auto-valores | 0,150 | 0,074 | 0,008 |
| Correlação espécies-variáveis | 0,647 | 0,586 | 0,305 |
| Porcentagem da variância explicada | | | |
| Espécies | 15,0 | 22,3 | 23,2 |
| Relação espécies-variáveis | 64,6 | 96,4 | 100,0 |

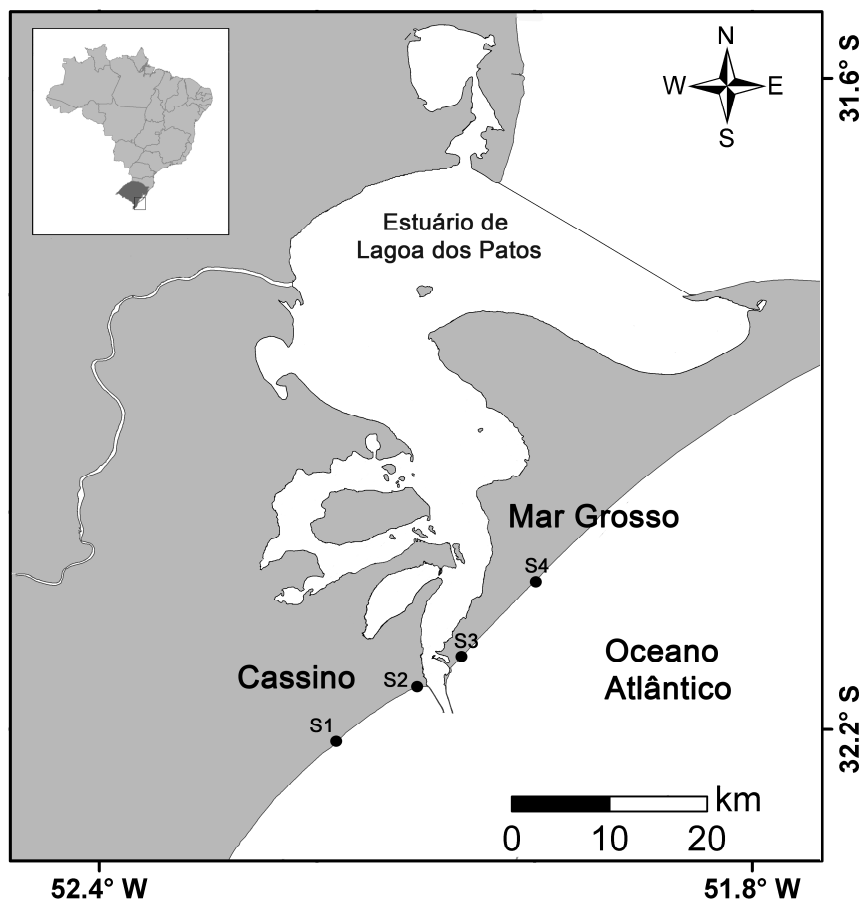


Figura 1. Área de estudo e localização dos pontos de coleta em cada uma das praias.

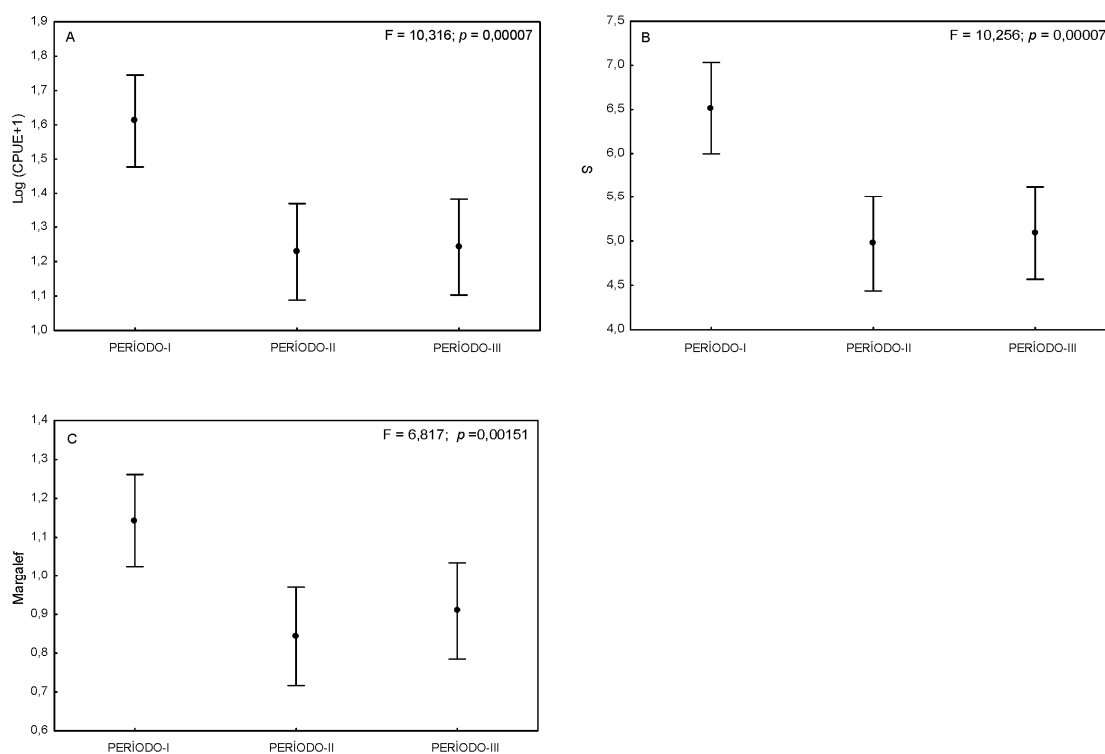


Figura 2. Média da captura por unidade de esforço (CPUE) (A), riqueza média de espécies (B) e diversidade de Margalef (C), ao longo dos três períodos analisados (Período-I = Junho 2001/Maio 2002; Período-II = Julho 2009/Junho 2010; Período-III = Julho 2010/Junho 2011). Barras verticais indicam intervalo de confiança a 95%.

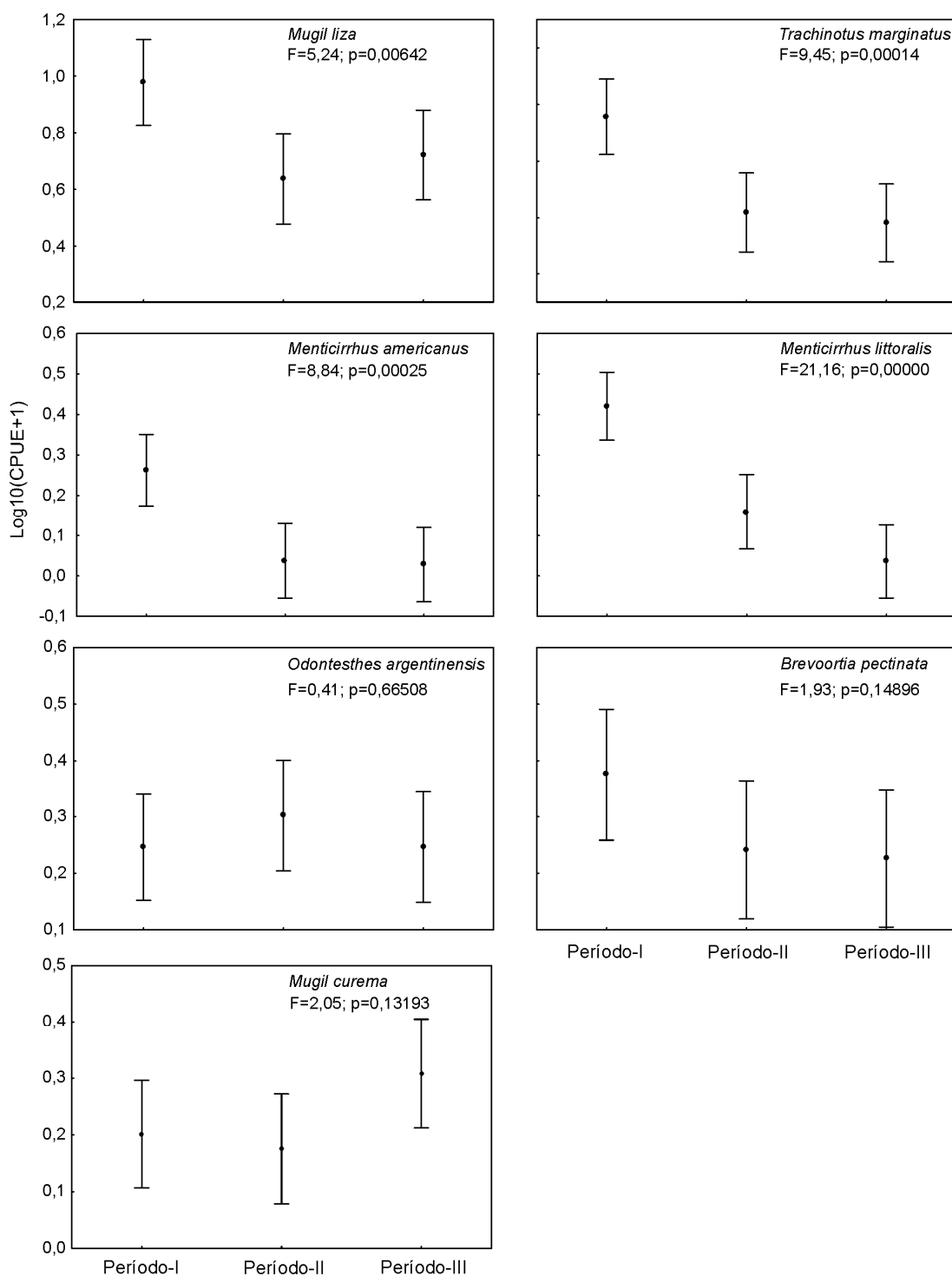


Figura 3. Variação na abundância média (CPUE) das espécies que apresentaram uma marcada variação na abundância ao longo dos três períodos analisados (Período-I = Junho 2001/Maio 2002; Período-II = Julho 2009/Junho 2010; Período-III = Julho 2010/Junho 2011). Barras verticais indicam intervalo de confiança a 95%.

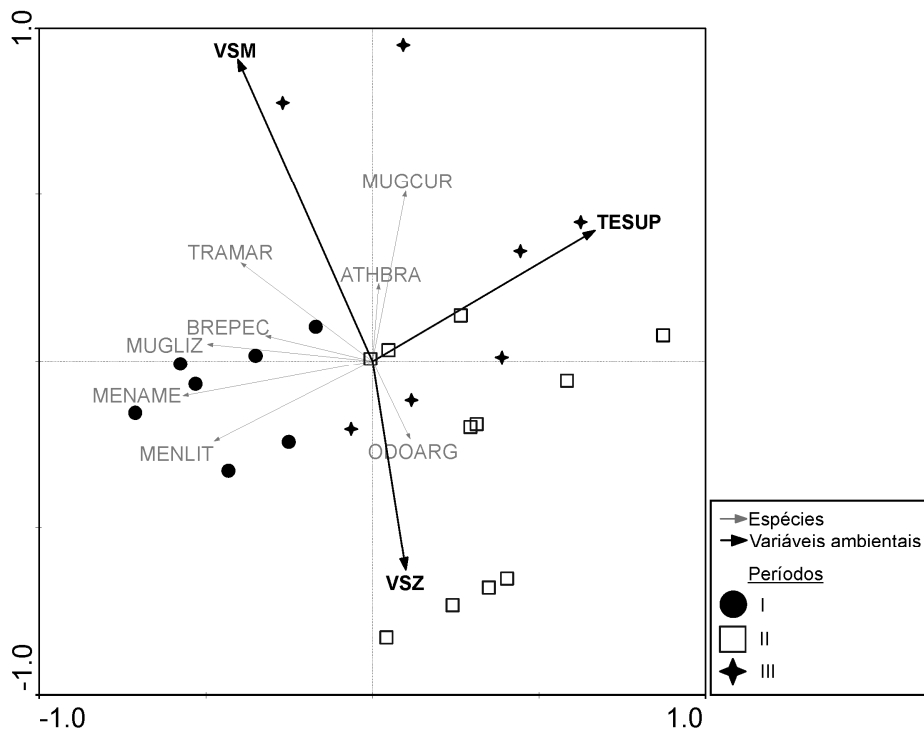


Figura 4. Análise de Correlação Canônica (CCA) com base na abundância relativa (CPUE) das espécies dominantes e distribuição das variáveis ambientais ao longo dos três períodos analisados. MUGCUR = *Mugil curema*, ATHBRA = *Atherinella brasiliensis*, TRAMAR = *Trachinotus marginatus*, BREPEC = *Brevoortia pectinata*, MUGLIZ = *Mugil liza*, MENAME = *Menticirrhus americanus*, MENLIT = *Menticirrhus littoralis* e ODOARG = *Odontesthes argentinensis*. TESUP = Temperatura da água em superfície (°C), VSM = Vento em superfície - meridional (m/s), VSZ = Vento em superfície - zonal (m/s).

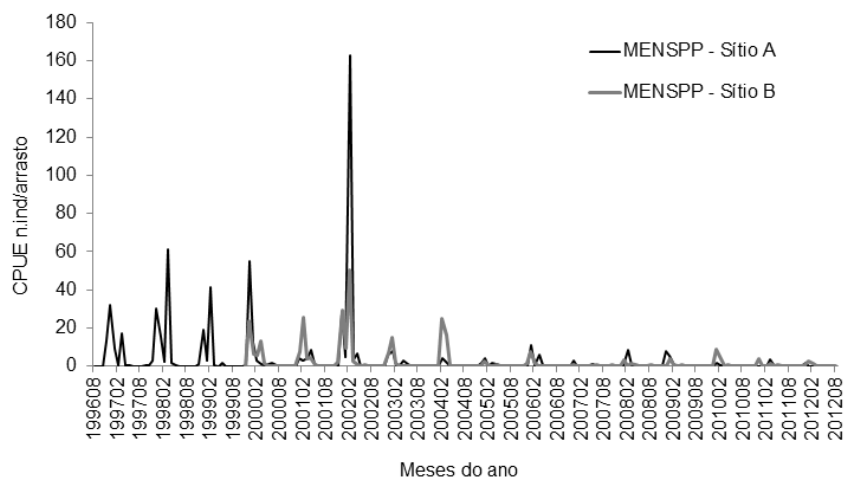


Figura 5. Evolução temporal da abundância (indivíduos por arrasto) de juvenis do gênero *Menticirrhus* (*M. americanus* e *M. littoralis*) em dois sítios (A = Estação Marinha de Aquacultura e B = molhe oeste da barra da Lagoa dos Patos) de amostragem na praia do Cassino (RS – Brasil) entre agosto de 1996 e agosto de 2012 (Dados fornecidos pelo projeto PELD site 8).

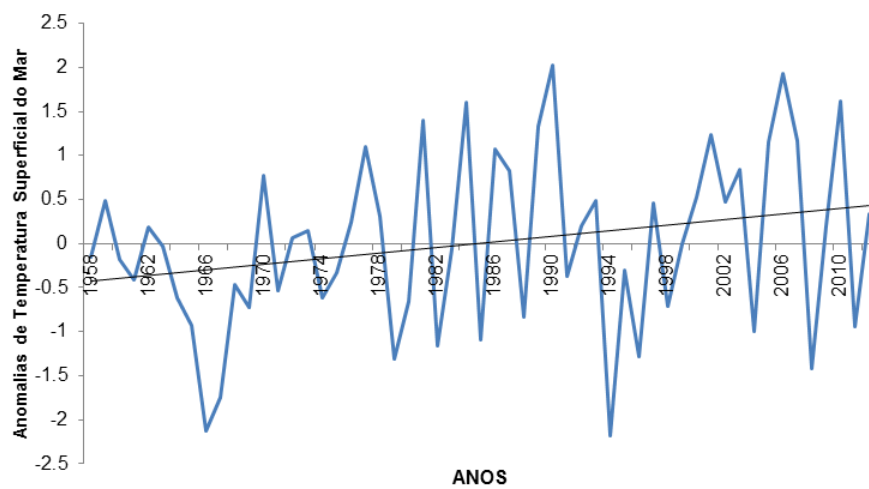


Figura 6. Tendência de aumento na temperatura da superfície do mar durante o verão, para o Atlântico Sul. Fonte: NOAA.