

UNIVERSIDADE FEDERAL DO RIO GRANDE
PÓS-GRADUAÇÃO EM OCEANOGRAFIA BIOLÓGICA

**Efeitos de um evento de deposição de lama fluída
sobre a macrofauna vagante da zona de
arrebentação de uma praia arenosa no sul do Brasil.**

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RESUMO

Conforme exigências do Programa de Pós-Graduação em Oceanografia Biológica da FURG, esta dissertação é composta de uma parte em português, constituída de uma introdução geral, objetivos, materiais e métodos, resultados, considerações gerais e bibliografia; tendo como apêndice o trabalho escrito na língua inglesa intitulado “Effects of a fluid mud deposition event on vagile macrofauna inhabiting a subtropical sandy beach” a ser submetido ao periódico “Continental Shelf Research”. O conteúdo da dissertação pode ser assim resumido: Eventos de deposição de lama fluída ocorrem repetidamente na praia do Cassino, sul do Brasil. O objetivo deste estudo foi avaliar a influência de um destes eventos sobre a estrutura da ictiofauna da zona de arrebentação desta praia. As amostragens foram realizadas, com o auxílio de uma rede de arrasto de praia, em dois locais controle (A1 e A2) e três locais sob deposição de lama (B1, B2 e B3). A ação de ondas foi o parâmetro dominante na diferenciação entre os locais de coleta, com baixa hidrodinâmica nos setores sob influência de lama e alta hidrodinâmica nos locais controle. Durante o período de estudo (21/04 a 17/08/2009) 15471 peixes e crustáceos foram capturados e separados em 33 *taxa*. Indivíduos de comprimento total (CT) menores que 50 mm corresponderam a 65% das capturas, sendo aqueles de CT menores que 30 mm os mais numerosos e principais responsáveis pelo padrão espacial de abundância. O local mais hidrodinâmico (A2) apresentou a maior diversidade e menor abundância relativa; enquanto B2 e B3, locais sob influência de lama, e de menor hidrodinâmica, registraram os menores valores de diversidade e as maiores abundâncias. Três diferentes hipóteses foram propostas para explicar a maior captura de juvenis em locais de lama. A primeira evoca que correntes longitudinais junto à costa seriam as responsáveis pelo deslocamento e agregações de juvenis em direção a áreas de menor energia. A segunda sugere que indivíduos juvenis escolheriam habitats de águas mais turvas, as quais forneceriam maior proteção contra predadores e maior disponibilidade de alimento. A terceira pondera que as áreas sob a influência de lama fluída apresentam maiores valores de viscosidade, o que dificulta a natação e diminui a velocidade de escape dos peixes juvenis, resultando em maior captura de indivíduos quando comparadas a áreas sem lama.

1. INTRODUÇÃO GERAL

Depósitos de lama podem ser encontrados próximos a costas arenosas em diversas regiões do mundo, incluindo regiões árticas, como o Alasca (Powers et al. 2002); regiões temperadas, como o sudoeste europeu (Lesueur et al. 1996); e em ambientes tropicais e subtropicais, como a Indonésia e o Brasil (Wright 1989; Calliari et al. 2009). Normalmente, estes depósitos estão associados a significativas descargas de rios ou à ressuspensão de depósitos fora da área costeira (Anthony et al. 2010; Holland et al. 2009). De acordo com Able (2007), a extensão de condições estuarinas (e.g. baixa salinidade e depósitos de lama) para a plataforma continental interna é um processo comumente observado em áreas costeiras associadas a estuários durante os períodos de grande vazão. Contudo, são poucos os registros de lugares ao redor do globo onde praias de fundos arenosos são episodicamente recobertas por uma camada de lama (Pereira et al. 2011). Dos estudos que registram este tipo de deposição de lama, a maioria aborda aspectos físicos e geológicos do processo (e.g. Dias & Alves 2009; Vinzon et al. 2009), não avaliando os impactos destes depósitos sobre a biodiversidade.

Na praia do Cassino, sul do Brasil, a deposição de lama na praia é um fenômeno recorrente e frequentemente relacionado a eventos de alta energia de ondas. Por exemplo, eventos de tempestade são capazes de remobilizar depósitos formados pela alta quantidade de matéria em suspensão originária do estuário da Lagoa dos Patos (Calliari et al. 2001).

O registro mais antigo de deposição de lama na praia do Cassino foi feito no início do século 20 (1901) (Calliari & Griep 1999), mas estes fenômenos passaram a ser mais freqüentes, e ter destaque na mídia, a partir da década de 90, quando começaram a causar impactos negativos sobre atividades relacionadas ao turismo (Calliari et al.

2009). Nesta década destaca-se o episódio ocorrido em 1998, que durou 14 meses e esteve, provavelmente, associado a substanciais operações de dragagem (Calliari et al. 2001) e ao forte evento de El Niño ocorrido neste mesmo ano (Odebrecht et al. 2003). Durante os eventos de El Niño ocorre o aumento na precipitação em toda a bacia de drenagem do sistema Patos-Mirim (Grimm et al. 1998; Kane 1999), o que resulta no aumento da vazão do estuário da Lagoa dos Patos e maior aporte de sedimentos para a plataforma continental adjacente (Calliari et al. 2001; Marques et al. 2009).

Os eventos de lama na Praia do Cassino promovem alterações na hidrodinâmica da zona de arrebentação, com destaque para a atenuação das ondas (Calliari et al. 2007). Como resultados destas alterações decorrem a diminuição na concentração de nutrientes (silicato, amônia e fosfato) na região da praia (Odebrecht et al. 2010); o declínio na abundância da diatomácea *Asterionellopsis glacialis* (Odebrecht et al. 2010) e o bloqueio dos aparatos respiratórios da fauna bentônica, causando elevada mortalidade de moluscos, crustáceos e outros invertebrados (Calliari et al. 2001). Embora existam trabalhos acerca dos depósitos de lama presentes na praia do Cassino, os efeitos destes fenômenos sobre a ictiofauna ainda não foram estudados.

2. OBJETIVOS

2.1. Objetivo geral

O presente trabalho teve como objetivo geral avaliar a influência da formação de depósitos de lama sobre a estrutura da ictiofauna e carcinofauna acompanhante que ocorrem na zona de arrebentação interna na Praia do Cassino.

2.2. Objetivos específicos

- Determinar a composição da ictiofauna e carcinofauna, bem como a abundância dos indivíduos de cada espécie ou taxa;
- Analisar as variáveis físico-químicas da água do mar nos locais onde o material biológico foi amostrado;
- Realizar uma comparação dos dados biológicos e físico-químicas entre os locais com e sem presença de lama através de análises estatísticas e ecológicas.

3. MATERIAIS E MÉTODOS

As amostragens foram realizadas no período de 21 de abril a 17 de agosto de 2009, uma semana após um evento de deposição de lama na praia ocorrido em 13/04/2009. As coletas ocorreram em cinco pontos distribuídos ao longo de 21 km de praia, sendo três pontos fixos (A1, A2 e B2) e dois móveis (B1 e B3). Os locais A1 e A2 foram escolhidos como “áreas controle”, devido à manutenção das características típicas de zona de arrebentação durante o período de deposição de lama; enquanto B1, B2 e B3 eram pontos situados sobre o depósito de lama (Figura 1 – apêndice).

Em todos os locais amostrados foram mensuradas as variáveis abióticas temperatura da água, salinidade, oxigênio dissolvido, pH (sonda multiparâmetro modelo YSI 556) e transparência da água (disco de Secchi).

A variação espacial e temporal das variáveis ambientais foi avaliada mediante uma Análise de Variâncias (ANOVA) de duas vias, sendo os pontos de amostragem (espaço) e as campanhas (tempo) utilizadas como fatores. A variável transparência da água foi avaliada apenas através de uma análise exploratória, devido a valores não observados em algumas campanhas, o que dificultou a obtenção de uma matriz balanceada para esta variável.

Para quantificar os possíveis efeitos do vento sobre a fauna, principalmente através da ação de ondas, um “fator médio de vento” (W) foi calculado (Gibson et al. 1993) para os valores obtidos de hora em hora considerando as 6 h anteriores a cada coleta. Os valores de W foram obtidos utilizando-se dados de direção e intensidade do vento fornecidos pela Estação Meteorológica da Praticagem da Barra de Rio Grande.

As amostras biológicas foram coletadas com o auxílio de uma rede de arrasto de praia, sempre durante o período diurno e em profundidades máximas de 1,2 m. Os

peixes e crustáceos capturados foram fixados com formalina a 10%, identificados até o menor nível taxonômico possível, medidos (comprimento total – CT) com precisão de 0,01 mm.

Com base na captura numérica calculou-se a captura por unidade de esforço (CPUE), a qual foi utilizada como medida de abundância relativa; a contribuição numérica percentual (N%), e a frequência de ocorrência (FO%) de cada espécie no total das amostras. Os valores de N% e FO% foram comparados com suas respectivas médias (μ N% e μ FO%), sendo classificados como: Abundante e Frequente; Abundante e Não frequente; Frequente e Não abundante; Presente (Garcia et al. 2006; Artioli et al. 2009). A variação da abundância por classe de comprimento foi baseada no cálculo de CPUE-CC (captura por unidade de esforço por classe de comprimento) (Vieira 2006).

A variação espacial da CPUE e CPUE-CC foi testada através da ANOVA de medidas repetidas, devido à dependência temporal das amostras. Os dados foram transformados $\log_{10} (x+1)$ e quando os pressupostos de normalidade e homocedasticidade não foram alcançados utilizou-se uma análise de variância não paramétrica (teste de Kruskal-Wallis).

A estrutura da associação de organismos capturados foi interpretada a partir da avaliação gráfica conjunta da riqueza de espécies, calculada pelo método de rarefação (Krebs 1989), e da equitatividade das espécies, calculada a partir do método Evar (Smith & Wilson 1996), associadas aos valores de abundância da comunidade (Lima & Vieira 2009).

A similaridade entre os locais de coleta foi avaliada a partir de uma análise de agrupamento, sendo que o índice de Distância Euclidiana foi utilizado para gerar a matriz de similaridade e o método de variância mínima (Ward's) foi utilizado para gerar

o dendograma. Os dados de abundância (CPUE) utilizados foram previamente selecionados (espécies responsáveis por acumularem 99% da captura total) e transformados $\log_{10} (x+1)$. A consistência dos agrupamentos foi testada através do método de reamostragem Bootstrap ($n = 5000$). Os mesmos dados foram aplicados em uma análise de correspondência para avaliar as associações entre os locais de estudo e as principais espécies capturadas (Malmgren et al. 1978). Relações entre as variáveis abióticas e a abundância das espécies nos locais de coleta foram avaliadas a partir de uma análise de correspondência canônica (ACC).

4. RESULTADOS

Considerando as variáveis abióticas foi encontrada variação espacial apenas em relação ao parâmetro transparência da água. Os locais com depósito de lama (B1, B2 e B3) apresentaram valores médios de transparência da água mais baixos quando comparados aos locais controle, indicando assim maior turbidez. As variáveis temperatura da água, salinidade, pH e oxigênio dissolvido apresentaram variações temporais significativas, sendo que apenas a temperatura e a salinidade mostraram acentuada tendência de queda em seus valores ao longo do tempo. Durante o período de amostragem predominaram ventos de O-SO (valores negativos de *W*), gerando uma menor energia de ondas na zona de praia, sendo esta muito mais atenuada nos locais com a presença de lama do que nos controles.

Foram capturados 15471 indivíduos, identificados e separados em 33 agrupamentos taxonômicos: quatro a nível de famílias, duas a nível de gêneros e 27 a nível de espécies, sendo sete espécies pertencentes ao subfilo Crustacea. Treze *taxa* acumularam 95% da abundância total. Entre estes apenas *Mugil liza* foi abundante e frequente em todos os locais de amostragem, enquanto *M. curema* foi a única abundante e frequente somente nos pontos com presença de lama. A espécie *Genidens barbatus* foi capturada exclusivamente nos três locais de fundo lamoso, sendo frequente em dois (B1 e B2). Os indivíduos da espécie de siri *Arenaeus cribrarius* corresponderam a 2/3 da captura total do subfilo Crustacea e estiveram presentes em todos os locais de coleta, apenas sendo considerados abundantes e/ou frequentes nos pontos de coleta fora da lama. Uma outra espécie de siri (*Callinectes danae*) e três espécies de camarões (*Artemesia longinaris*, *Litopenaeus schmitti* e *Pleoticus muelleri*) estiveram presentes somente nos locais com existência de lama.

A análise de CPUE-CC da ictiofauna indicou que indivíduos menores que 50 mm CT corresponderam às maiores capturas (64,6% do total), com 80,8% destes pertencentes à Mugilidae. Os peixes entre 50 e 100 mm CT corresponderam a 34,3% do total capturado, sendo 94% destes indivíduos pertencentes à Mugilidae, *Trachinotus marginatus* e *Brevoortia pectinata*. Os peixes acima de 100 mm CT representaram apenas 1% do total capturado, com *T. marginatus* constituindo 39,3% do amostrado.

Foram observadas diferenças espaciais significativas para abundância geral, sendo que B2 e B3 apresentaram médias maiores quando comparados aos locais controle (A1 e A2) e B1. Não houve diferença significativa na abundância entre os pontos controle (A1 e A2) e B1, assim como não houve diferença significativa entre B2 e B3.

Os indivíduos juvenis, de comprimento total inferior a 30 mm CT (classe 10 e 20 mm CT), foram os principais responsáveis pelo padrão espacial de abundância descrito. Os padrões de diferenças de média apresentados foram quase iguais aos descritos para a abundância total. As exceções incluem o local controle A1, que neste caso foi significativamente semelhante a todos locais de coleta, e o local B2 que passou a diferir de B1.

Os valores do índice de equitatividade calculados para os cinco pontos foram baixos (0,11 a 0,21). Os intervalos obtidos para cada ponto estiveram sobrepostos quando calculados valores ao acaso através de 5000 reamostragens. Os valores do índice de riqueza esperada (método de rarefação) variaram de 14,5 a 16,0, não sendo também observadas diferenças entre os pontos de coleta. O local de menor abundância (A2) mostrou ser o local de maior diversidade (maior equitatividade e maior riqueza esperada); enquanto B2 e B3, locais com maiores abundâncias, foram os que apresentaram a menor diversidade.

A análise de agrupamento indicou a presença de três grupos, sendo um representado pelos locais controle (A1 e A2), outro pelos pontos B2 e B3, e outro apenas por B1. A consistência de todos os grupos evidenciados nesta análise exibiu um caráter moderado, sendo mais alta (45%) a do grupo B2 e B3.

Os eixos 1 e 2 da análise de correspondência concentraram 71% da variabilidade total dos dados e mantiveram a mesma organização dos pontos de coleta descritos pela análise de agrupamento. As categorias taxonômicas *Micropogonias furnieri*, *Odontesthes argentinensis*, Atherinidae, Clupeidae e Engraulidae estiveram mais associadas aos pontos B2 e B3; as espécies *Arenaeus cribrarius*, *Atherinella brasiliensis* e *Menticirrhus littoralis* às “áreas controle”, e *Brevoortia pectinata* ao ponto B1, extremo norte do bolsão de lama. A categoria Mugilidae, o grupo mais abundante da área de estudo, esteve posicionada no centro dos eixos, demonstrando que este grupo não está associado a nenhum dos locais de amostragem em particular.

Das variáveis ambientais testadas na ACC apenas três (pH, salinidade e temperatura da água) foram significativas, de acordo com o teste de permutação de Monte Carlo. Aproximadamente 17% da variabilidade total dos dados biológicos foi explicada por estas três variáveis, com o primeiro eixo concentrando a maior explicabilidade (66%). A variável temperatura esteve fortemente correlacionada com o primeiro eixo e a salinidade tanto com o primeiro eixo quanto com o segundo. A direção do vetor pH foi quase perpendicular em relação aos demais, indicando que o efeito deste fator em relação aos de temperatura e salinidade sobre a fauna era praticamente independente. Entretanto, a análise canônica não indicou uma separação entre os locais de amostragem em função das variáveis ambientais analisadas.

5. CONSIDERAÇÕES FINAIS

- A praia do Cassino, de modo geral, mostrou-se composta por poucas espécies numericamente dominantes, representadas principalmente por formas juvenis.
- As variáveis abióticas apresentaram diferenças temporais, com temperatura e salinidade apresentando forte queda do início (outono) ao final (inverno) das coletas.
- A principal diferença ambiental entre os pontos controle (fundo arenoso) e aqueles afetados pelos depósitos de lama foi percebida na hidrodinâmica destes locais, com locais com lama apresentando menor ou nenhuma ação de ondas.
- Os locais com presença de lama apresentaram as maiores abundâncias de indivíduos e as menores riquezas e equitatividades, quando comparados aos locais controle.
- Locais com presença de lama concentraram indivíduos juvenis de tamanho inferior a 30 mm e três hipóteses foram propostas para explicar este agrupamento.
- A primeira hipótese remete à existência de correntes longitudinais junto à costa, as quais seriam as responsáveis pelo deslocamento e agregações de juvenis em direções a áreas de menor energia.
- A segunda hipótese sugere uma seleção ativa da macrofauna por habitats de águas mais turvas, uma vez que este tipo de ambiente forneceria maior proteção contra predadores e maior disponibilidade de alimento.
- A terceira hipótese considera o aumento da viscosidade da água em áreas com presença de lama fluída como responsável por dificultar a natação e diminuir a velocidade de escape dos peixes juvenis, resultando em maior captura de indivíduos quando comparada a áreas sem presença de lama fluída na coluna d'água.

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7. APÊNDICE

MANUSCRITO: formatado para o periódico Continental Shelf Research

EFFECTS OF A FLUID MUD DEPOSITION EVENT ON VAGILE MACROFAUNA
INHABITING A SUBTROPICAL SANDY BEACH.

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Effects of a fluid mud deposition event on vagile macrofauna inhabiting a subtropical sandy beach.

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ABSTRACT

Fluid mud deposition events occur regularly at Cassino Beach in south Brazil.

The aim of this study was to evaluate the influence of such event on the structure of the ichthyofauna inhabiting its surf zone (<1.2 m). Samples were collected using a beach seine net at two control locations (A1 and A2), and at three locations influenced by mud deposition (B1, B2, and B3). Wave action

was the dominant factor in differentiating between sampling sites, promoting low wind generated wave action at the mud-influenced sectors and high wind generated wave action at sectors without mud. During the study period (21 April to 17 August 2009) 15471 fishes and crustaceans were captured and separated into 33 taxonomic groups. Individuals of a total length (TL) up to 50 mm accounted for 65% of the catch, while individuals of TL <30 mm were the most numerous and influential in the spatial abundance pattern. The most hydrodynamic area (A2) had the lowest relative species abundance and greatest diversity, whereas the areas with low wind generated wave action that were under the influence of mud deposition (B2 and B3) had the highest species abundance values and lowest diversities. Three different hypotheses were proposed to explain the higher concentration and capture of juvenile fishes at mud locations. First, longshore currents may be responsible for the displacement of juvenile aggregations toward areas of lower energy. Second, individuals may select habitats with turbid waters, which may provide greater protection from predators and increased food availability. Third, areas under the influence of fluid mud deposition show higher values of viscosity, which may reduce swimming activity and hinder the escape of juvenile fishes from nets, resulting in an increased capture of individuals compared to areas without mud.

KEY WORDS: fish; mud deposits; surf-zone

1. INTRODUCTION

Mud deposits are often found near sandy shores in various regions of the world, ranging from Arctic regions, such as Alaska (Powers et al., 2002), to

temperate regions, such as southwestern Europe (Lesueur et al., 1996), as well as in tropical and subtropical regions, such as Indonesia and Brazil (Wright, 1989; Calliari et al., 2009). Typically, these mud deposits are associated with significant river discharges or resuspension of deposits outside the coastal area (Holland et al., 2009; Anthony et al., 2010). According to Able (2007), during periods of high estuarine flow, certain conditions, such as low salinity and high mud deposition, are commonly observed in coastal areas of the inner continental shelf. However, few locations around the globe have been documented to have beaches with sandy bottoms that are occasionally covered by a layer of mud (Pereira et al., 2011). Some examples are the Kerala coast, India (Gopinathan and Qasim, 1974; Mathew et al., 1995); locations north to the Amazon river, such as Amapá state (Brazil), French Guiana and Surinam (Wells and Coleman, 1977; Dolique and Anthony, 2005; Anthony et al., 2010); a mesotidal beach on the Mekong River delta coast, China (Tamura et al., 2010) and the southern coast of Brazil, at Tijucas Bay, Santa Catarina (Buynevich et al., 2005) and Cassino beach, Rio Grande do sul (Calliari et al., 2001; 2009). Among the studies that report this type of mud deposition, most have focused on physical and geological aspects of the process (e.g., Dias and Alves, 2009; Vinzon et al., 2009), rather than assessing the impacts of these deposits on biodiversity.

The oldest recorded mud deposition at Cassino Beach in south Brazil was in 1901 (Calliari and Griep, 1999). However, over the last century, these phenomena have become more frequent and have featured in the media since the 1990s because of the negative impact on tourism-related activities (Calliari

et al., 2009). The mud deposition event that occurred in 1998 and lasted 14 months stands out, and was probably associated with substantial dredging operations in the inner Patos lagoon estuary (Calliari et al., 2001) and with the strong El Niño event that occurred in the same year (Odebrecht et al., 2003). Higher than average precipitation during El Niño events in the Patos-Mirim drainage basin (Grimm et al., 1998; Kane, 1999) results in greater freshwater discharge into the Patos lagoon estuary. During such events, occurs a major input of sediments to the adjacent continental shelf (Calliari et al., 2001; Marques et al., 2009).

The mud events at Cassino Beach promote changes in the surf zone hydrodynamics, especially in the attenuation of waves (Calliari et al., 2007). These changes cause a decline in nutrient concentrations (i.e., silicates, ammonia, and phosphates) in the region of the beach (Odebrecht et al., 2010), a reduction in the abundance of the diatom *Asterionellopsis glacialis* (Odebrecht et al., 2010), and the obstruction of benthic fauna respiratory apparatus, causing high mortality among mollusks, crustaceans, and other invertebrates (Calliari et al., 2001; Silva et al., 2008).

The Cassino beach surf zone, like others around the globe, is considered a nursery area for several species (Monteiro-Neto et al., 2003; Rodrigues and Vieira, 2010), being some of economical importance to the artisanal and recreational local fisheries, such as plata pompanos, gulf kingfishes, mullets and whitemouth croakers (Szpilman, 2000; Basaglia and Vieira, 2005; Klippel et al., 2005; Peres and Klippel, 2005). Although several studies have investigated the deposition of mud at Cassino Beach, the effects of these phenomena on the

ichthyofauna and carcinofauna have not been assessed. The aim of this study was to evaluate the influence of mud deposits on the structure of the ichthyofauna, crabs and shrimps occurring in the surf zone of Cassino Beach in south Brazil.

2. METHODOLOGY

Cassino Beach is located south of the Patos lagoon mouth, the largest choked lagoon in the world, connected to the Atlantic Ocean through a single inlet between two rock-jetties. It is an exposed sandy beach mainly dissipative, composed of fine quartz sand, presenting multiple shore parallel sand bars (Pereira et al., 2011). The beach exhibits waves with average energy levels, showing higher waves in winter, lower waves in summer and a transitional pattern in autumn and spring. The alternation between two anticyclonic systems favors the predominance of NE winds from September to March and of SW winds from April to August (Cavalcanti et al., 1986). Longshore currents have a direct correlation with wind intensity and frequency. In that way, weak and constant currents directed SW are often observed during spring/summer, while NE currents are associated to autumn/winter (Tozzi and Calliari, 2000). The wind effect also figures as the main mechanism controlling the behavior of the Patos Lagoon coastal plume over the inner Southern Brazilian Shelf (SBS) in synoptic time scales (Marques et al., 2009).

The Patos Lagoon discharge represents an important local contribution to the nutrient and suspended sediments budget of the inner SBS (Marques et al., 2009). The mud depocenter, i.e. the site of maximum mud deposition, is

situated 9 km to the south of the Patos Lagoon estuary mouth, which is 10 km from the shore and at a depth of 15 m (Calliari et al., 2009). Because of the proximity of the depocenter to Cassino Beach, mud deposition is most frequent in the central sector of Cassino village.

Sampling was carried out from 21 April to 17 August 2009, starting a week after the mud deposition event on the beach. Thirteen field trips to sampling were carried out; the first nine were weekly, whereas the last ones four were fortnightly. The difference in the sampling frequency was due to attenuation of the mud deposit. The sampling effort was interrupted when we could not identify mud locations along the beach anymore.

During this period, samples were collected from five sites distributed along the 21 km of the beach, which comprised three fixed points (A1, A2, and B2) and two mobile points (B1 and B3). Sites A1 and A2 were selected as control areas, because they were mud free during the sampling period. Sampling site A1 was located 500 m South of the West Jetty of Patos Lagoon estuary and approximately 6 km North of the beginning of the observed mud deposit accumulation. Site A2 was located approximately 6 km to the south of the end of the mud deposit, while sites B1, B2, and B3 were located on the mud deposit. The sample design was selected to describe and compare the structure of fauna at locations of higher (B2), lower (B1 and B3) and without mud (A1 and A2) deposition (Fig. 1).

At each sampling point, five beach seine hauls were made perpendicular to the beach, using a beach seine net (9.0 long $\times$ 1.5 m high, with 2 mesh sizes, 13 mm on the wings and 5 mm in the 3 m central area). Each haul represented

one sample. The hauls were always performed during the daytime at a depth below 1.2 m. The following abiotic variables were measured at all sampling sites: water temperature, salinity, dissolved oxygen, pH (Multiparameter Probe, Model YSI 556), and water transparency (Secchi Disk).

The collected specimens of fishes, crabs and shrimps were fixed with 10% formalin and identified to the lowest possible taxonomic level in the laboratory (Figueiredo and Menezes, 1978, 1980, 2000; Menezes and Figueiredo, 1980, 1985; ICZN, 1994; D'Incao, 1999; Melo, 1999; Fischer et al., 2004; Menezes et al., 2010). Juveniles that could not be identified to the species level were grouped into higher taxonomic levels (genus and/or family). Such groups were given the status of "species" and were analyzed together with specimens identified to the lowest possible taxonomic level. The total length (TL) of the animals was measured to an accuracy of 1 mm.

Catch-per-unit effort (CPUE), defined as the average number of individuals per haul, was calculated and used as a measure of relative abundance. In order to verify the relative importance of each species, as well as their dominance pattern at each one of the sampling sites, we combined numerical percentage values (N%) (CPUE based) and frequency of occurrence (FO%) values. The values of N% and FO% were compared against their respective means (μ N% and μ FO%) and, according to the results, the species were classified as Abundant and frequent, Abundant and not frequent, Frequent and not abundant, or Present (Garcia et al., 2006; Artioli et al., 2009).

CPUE by size class per sample 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 size class (Vieira, 2006).

Three size classes were established based on the size frequency distribution of caught fishes and identified as 'Size Ecological Taxa' (SET): individuals smaller than 50 mm TL, between 50 and 100 mm TL, and equal to or larger than 100 mm TL. The CPUE of a SET was computed by summing the mean CPUE of each size class (10 mm) within that SET (Vieira, 2006).

The spatial and temporal variation of environmental variables was assessed by two-way analysis of variance (ANOVA), in which the sampling points (space) and field trips (time) were used as factors.

The spatial variation of CPUE and SETs was tested using repeated measures ANOVA, where the sampling points were considered as a factor, and CPUE values of each sampling point per sampling event were used as replicates. Data were transformed by $\log_{10}(x+1)$ and, if assumptions of normality and homoscedasticity were not met, nonparametric analysis of variance (Kruskal-Wallis) was used. All statistical analyses were completed using the free software PAST (Hammer et al., 2001) and p values lower than 0.05 were considered significant. The presence of missing values for water transparency made it difficult to obtain a balanced matrix for this variable. Hence, water transparency was only assessed through explanatory analysis.

To quantify the possible effect of wind on the fauna, principally through wave action, an "average factor of wind" (W) was calculated (Gibson et al., 1993) that considered the six h period prior to each collection. For this analysis, we used only the wind component V_v of the decomposition of vectors (Miranda

et al., 2002). W is positive when wind direction is between 50° and 230° and negative when between 231° and 49° . When the values of W are high and positive, this indicates strong winds towards the coast, with wave action on the beach being maximal. When the values of W are negative (winds along the coast or toward the open sea), wave action is low or even negligible. The values of W were obtained using wind speed and direction data provided by meteorological forecasting Pilot Station at the Rio Grande harbor, located at a distance of about 10 km from the study area.

The macrofauna assemblage diversity study was based on a graphical evaluation of three combined parameters: species richness, which was calculated by rarefaction (Krebs, 1989); species evenness, based on the Evar method, with 0 representing the minimum evenness and 1 the maximum (Smith and Wilson, 1996) and total abundance values (Lima and Vieira, 2009).

The similarity among the sampling sites was assessed through cluster analysis, using the Euclidian distance to generate the similarity matrix, and the minimum-variance method (Ward's) as the clustering strategy. The abundance data (CPUE) was previously selected (species responsible for accumulating 99% of the total catch) and transformed by $\log_{10}(x+1)$. The consistency of the clusters was tested by Bootstrap resampling ($n = 5000$). Correspondence analysis was used to evaluate the associations between the study sites and the principal species of the same dataset (Malmgren et al., 1978). Both tests were also performed using the PAST free software (Hammer et al., 2001).

The relationship between abiotic variables and species abundance at the sites was evaluated based on canonical correspondence analysis (CCA) using

the CANOCO software (Leps and Smilauer, 2003). The biological matrix included CPUE data of the 11 most abundant species collected during the study period. The environmental matrix contained values of temperature, salinity, pH, dissolved oxygen, and Secchi disk. In both matrices, data were previously $\log_{10}(x+1)$ transformed.

In the multivariate statistical analysis only, data on the species *Mugil liza* (Menezes et al., 2010), *Mugil curema* and *Mugil* sp.1 (ICZN, 1994) were grouped into a single category called Mugilidae. This grouping was performed because those species are hard to identify when juveniles and because they play the same ecological function in the environment (Vieira, 1991).

3. RESULTS

Throughout the study period, the temperature ranged between 10.5 °C and 24.5 °C, the salinity ranged between 21.7 and 36.2, and pH ranged between 6.7 and 8.7. The dissolved oxygen ranged between 5.3 mg/l and 10.9 mg/L, with one extreme low value (0.62 mg/L) measured at B2 site on 21 May 2009. There were no spatial variations for the described abiotic variables (Fig. 2a, b, c, d) but all presented temporal variation, with the temperature and salinity values presenting a sharp decreasing trend over time (Fig. 2e, f, g, h). The average values of water transparency (Secchi disk) were lower in areas with mud deposition (B1, B2, and B3), indicating higher turbidity (Fig. 3a). During the sampling period, W-SW winds (negative values of *W*) predominated, generating lower wave energy in the beach area (Fig. 3b), which was much more attenuated in the locations with mud deposition than in the controls (Fig. 4).

A total of 15471 individuals were captured. After identification these individuals were separated into 33 taxonomic groups: four at the family level, two at the level of genera, and 27 at the species level, of which seven species belonged to the subphylum Crustacea (Table I).

Thirteen taxonomic groups accumulated 95% of the total catch. Only *Mugil liza* was abundant and frequent at all sampling sites, whereas *M. curema* was abundant and frequent only at the mud deposition sites. *Genidens barbatus* was captured exclusively at mud deposition sites and was frequent at two sampling sites (B1 and B2). The crab species *Arenaeus cribrarius* accounted for two-thirds of the total catch of the subphylum Crustacea and was present at all sampling sites, being abundant and/or frequent only at sampling sites without mud. Another species of crab (*Callinectes danae*) and three species of shrimp (*Artemesia longinaris*, *Litopenaeus schmitti*, and *Pleoticus muelleri*) were only present at sites with mud deposition.

The fish fauna SET analysis indicated that individuals smaller than 50 mm TL were more abundant (64.6% of the total), of which 80.8% were Mugilidae. Fishes between 50 and 100 mm TL accounted for 34.3% of the total catch, of which 94% of individuals belonged to Mugilidae, *Trachinotus marginatus* and *Brevoortia pectinata*. Fishes above 100 mm TL represented just 1% of the total catch, with *T. marginatus* constituting 39.3% of those samples (Fig. 5 and Table I).

CPUE values had significant spatial differences among sites ($p < 0.0001$), with B2 and B3 showing higher means compared with those of the control sites (A1 and A2) and B1 (Table II). There was no statistically significant difference in

CPUE between the control sites (A1 and A2) and B1, and there was also no significant difference between B2 and B3 (Table II). Juvenile individuals smaller than 30 mm TL (class 10 and 20 mm) were primarily responsible for the spatial pattern of abundance, showing the same pattern of CPUE as described above, except for site A1, equal to all sites; and B2, significantly different from B1 ($p = 0.001$).

The Mugilidae group was primarily responsible for the high abundance values associated with sites B2 (2937 *M. liza* individuals caught in just one sampling trip - 08 June 2009) and B3 (2816 *M. curema* and *Mugil* sp.1 individuals caught in just one sampling trip - 21 April 2009).

The evenness index values for all five points were low (0.11 to 0.21) (Fig. 6) and no significant difference was observed among sites ($n=5000$ Bootstrap samples). The richness index (rarefaction method) ranged from 14.5 to 16.0 (Fig. 6), but no statistically significant differences were found among sites. The lowest abundance value (A2) was observed at the site of greatest diversity (higher evenness and higher expected richness), whereas the sites with highest abundance (B2 and B3) had the lowest diversity (Fig. 6).

Cluster analysis indicated the presence of three groups in terms of sample similarity. The first group was represented by the two control sites (A1 and A2), the second group was represented by sites B2 and B3, whereas the third group was represented by B1 (Fig. 7). The consistency of the three observed groups in this analysis was moderate, with the higher value (45%) in the second group (B2 and B3) (Fig. 7).

Axes 1 and 2 from the correspondence analysis (Fig. 8) accounted for 71% of the total data variability, with the arrangement of the sampling sites being maintained as that described in the cluster analysis. The taxa *Micropogonias furnieri*, *Odontesthes argentinensis*, Atherinidae, Clupeidae, and Engraulidae had a greater association with sites B2 and B3. *Arenaeus cribrarius*, in addition to *Atherinella brasiliensis* and *Menticirrhus littoralis*, was primarily associated with the control sites. *Brevoortia pectinata* was primarily associated with the northernmost site of the mud deposit (B1) (Fig. 8). Mugilidae, the most abundant category in the study area, remained in the center of the axes, indicating no particular association with any of the sampling sites.

Of the five environmental variables tested using CCA, only pH, salinity, and water temperature were significant (Monte Carlo, 5000 permutations, $p < 0.05$). Approximately 17% of the total biological data variability was explained by these three variables, with the first axis accounting for the highest explicability (66%) (Table III). Temperature variability was strongly correlated with the first axis, whereas salinity was correlated with both the first and second axes. The direction of the pH vector was almost perpendicular to the other 2 parameters, indicating that the effect of pH on the fauna was virtually independent of temperature and salinity. Most sampling sites were inversely located to the temperature vector, because sampling began in mid-autumn and lasted until almost the end of winter. Based on the analyzed environmental variables, the canonical correspondence analysis did not indicate any separation between the sampling sites (Fig. 9).

4. DISCUSSION

Although the study comprehended a time period of mud deposition, the sampled fish community did not differ from previous works in the area (e.g. Monteiro-Neto et al., 2003; Lima and Vieira, 2009). The data showed few numerically important species, which were primarily represented by juveniles. These observations suggest that the fish community structure at Cassino Beach is likely to be stable in a long-term analysis (i.e., years to decades). Our results did not differ from others studies worldwide that characterize the surf zone of sandy beaches as low diversity areas (Lasiak, 1984; Layman, 2000; Monteiro-Neto et al., 2003), with a few numerically dominant species (Lasiak, 1984; Ross et al., 1987; Romer, 1990; Layman, 2000) of small size (Clark et al., 1996; Félix et al., 2007) represented mainly by juveniles (Gibson et al., 1993; Clark et al., 1994; Monteiro-Neto et al., 2003; Vasconcellos et al., 2007). Such features reveal the importance of surf zone as a nursery area for both fish and crustaceans (Lasiak, 1981).

The seasonal pattern of fish abundance and diversity at Cassino Beach is strongly influenced by variations in physical-chemical parameters (Lima and Vieira, 2009). Hence, localized short-term variations were expected in the structure of the fish assemblage in response to various environmental factors (Romer, 1990). During the study period, the fish assemblage structure followed the declining trend of temperature and salinity from autumn to winter. Among the studied taxa, only the abundance of the dominant Mugilidae remained virtually unchanged throughout the study period. This observation indicated the constancy and numerical abundance of juvenile mullets in the study area

(Vieira, 1991; Monteiro-Neto et al., 2003). According to Monteiro-Neto et al. (2003), the water temperature of Cassino Beach plays an important role in regulating the migration and spawning period of adult fish. Thus, juvenile recruitment determines the species associations and seasonal variations in abundance of the surf zone assemblage. As a result, an even greater abundance of individuals is observed during the spring and summer (Lima and Vieira, 2009).

Salinity plays a major role on fluid mud formation, even though its effect on the studied fish community structure was lower when compared to the temperature effect. The reduction in salinity at the inner shelf is one of the contributing factors in the generation of fluid mud (Udaya Varma and Kurup, 1969; Nair, 1976). At Cassino beach this salinity reduction process is promoted by Patos lagoon water flow. In southern Brazil, El Niño events are strongly associated with heavy rainfall, directly affecting the water flow and discharge of major rivers in the Patos lagoon watershed (Garcia and Vieira, 2001). Aside from the high discharge of fresh water reducing salinity (Odebrecht et al., 2010), the volume of sediments that are exported from the Patos Lagoon is increased, leading to a more significant contribution of fine sediments (clay minerals) to the area of mud deposition adjacent to the coast (Holland et al., 2009; Silva, 2010).

Because of the reduction in wave energy, a mud deposition event is visually characterized by a complete absence of surf zone (Calliari et al., 2001; Pereira et al., 2011). Wave action is one of the main factors that affects the fish and invertebrate community structure of sandy beaches (Romer, 1990; Clark, 1997), being the dominant environment factor detected in the present study.

The sampling sites located outside the influence of mud (A1 and A2) had greater wind generated wave action, and were subjected to higher waves when compared to the other sampling sites. Although influenced by mud, B1 had higher wind generated wave action compared to B2 and B3. In fact, B2 was in an area devoid of surface water oscillations. The highest total abundance values were observed at the sampling sites with lower hydrodynamics (B2 and B3). In contrast, low abundance values were associated with sampling sites that were more exposed to wave action (A1, A2, and B1), suggesting an inverse relationship between wave action and species abundance. Similar studies elsewhere had also observed this pattern (Romer, 1990; Clark, 1997; Watt-Pringle and Strydom, 2003; Vasconcellos et al., 2007).

The present study was carried out across a four month period during a single event of mud deposition at Cassino Beach. The study period covered both autumn and winter, when the abundance of fish species is naturally lower at the coast of Rio Grande do Sul state, especially because of low temperatures. It is also worth noting that our results are characterized by high spatial and temporal variability, which is typical of naturally stressful and dynamic habitats such as the surf zone (Lima and Vieira, 2009; Odebrecht et al., 2010). In particular, this condition complicated the identification of contrasts between control and mud deposition sites. Despite these limitations, it was possible to recognize spatial variations in the patterns of abundance, evenness, and composition of fish and crustaceans at Cassino Beach. These patterns may be related to changes in local wind generated wave action at areas which were under the influence of mud deposition.

Juvenile fishes are commonly found in shoals, and three hypotheses may explain the concentration of juveniles in mud dominated environments. The first one is related to the presence of longshore currents. An oblique wave's incidence and differences in the crests height are responsible for a water setup and, as a result, lateral pressure gradients arise from the accumulation of water on the coast. These gradients generate parallel flows along the shore line (Calliari et al., 2003) in sandy bottom areas located both to the north and south of muddy areas. Watt-Pringle and Strydom (2003) suggested that the aggregation behavior of shoals serves as a temporary shelter near the coast, aided by the littoral drift currents. Fishes could use these conditions to move without the swimming effort, thus saving energy. The SW-NE longshore currents direction, established by the predominance of W-SW winds, could therefore be responsible for driving juvenile fishes toward B3 and B2 locations. Layman (2000) also noted the preferential use of lower energy surf zone habitats by fishes and proposed that this phenomenon may be the end result of small-scale parallel movements along the coast. Therefore, lower wave energy found at mud deposition sites would favor fish aggregation, which in turn would lead to higher juvenile abundance.

The second theory is related to active habitat selection by fish for areas of higher turbidity. The presence of water with lower levels of transparency is generally considered advantageous for juvenile fishes, because this condition provides greater protection against predators. In addition, areas of lower visibility often exhibit higher densities of zooplanktons, which serve as food for these fishes (Blaber and Blaber, 1980; Lasiak, 1981; Clark et al., 1996; Garcia

and Vieira, 1997; Layman, 2000). These two advantageous characteristics of higher turbidity areas could, therefore, contribute to a greater fish abundance in muddy areas. The higher abundance values found to B2 and B3 locations could also be related to this hypotheses once areas of higher water turbidity would reduce the visual acuity of fish, reducing their ability to detect the sampling fish net (Warfel and Merriman, 1944 *apud* Lasiak, 1984), thus leading to higher capture rates than those in areas of lower turbidity.

The third hypotheses takes into account water viscosity and its influence on the swimming ability and vulnerability to the fish gear. Areas of the surf zone containing fluid mud are characterized by water with higher density and viscosity (Pereira, 2010). In particular, any change in viscosity is felt physically by juvenile fishes, which have low values of Reynolds number ($\sim 1 \times 10^3$) because of their small size and corresponding low speed, thus allowing the forces of viscosity to prevail over the forces of inertia (Fuiman and Batty, 1997; Massel, 1999). These forces negatively influence the ability of juvenile fishes to swim and, consequently, decrease their escape velocity. This would results in greater capture rates compared with those in areas devoid of mud.

These three hypotheses are not necessarily independent and could have concomitant effects on the studied fish assemblages. Thus observed results may be explained by the longshore currents generating high concentrations of juveniles that are associated with the high turbidity and viscosity of water, which in turn hinders escape and facilitates the capture of these species. Such mud-induced changes in the turbidity and viscosity of water are not permanent, and it is likely that these species as a whole are able to recover to pre-disturbance

conditions after the interruption of mud deposition events. Future experiments in laboratory and/or *in situ* should be carried out in order to evaluate these hypotheses and their influences on fish abundance.

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Figure Captions

Figure 1: Map showing the location of sampling sites at Cassino beach, southern Brazil. Sites A1 and A2 are the control areas and B1, B2 and B3 represent mud deposition areas.

Figure 2: Spatial (left column) and temporal (right column) environmental variables variation recorded at sampling sites in Cassino beach: Temperature (a, e); Salinity (b, f); Dissolved oxygen (c, g) and pH (d, h).

Figure 3: Mean values of (a) water transparency and (b) “wind factor” (W) recorded at sampling sites.

Figure 4: Site A2 exhibiting wave action (a) and site B3 showing wave damping effect caused by mud (b). Both pictures were captured at the same day (June 08, 2009).

Figure 5: Number of individuals $\log_{10}(x+1)$ by size classes (total length) of fishes captured between April and August 2009 at Cassino beach surf zone.

Figure 6: General diversity of sampled ichthyofauna. Species richness $[E(S)]$ at axis x and evenness (E_{var} index) at axis y. The circles size correspond to total abundance values.

Figure 7: Sampling stations dendrogram generated by Ward's minimum variance method. Support for branching pattern was determined using bootstrap (n = 5000).

Figure 8: Correspondence analysis map showing sampling sites (dark triangles) and the eleven species responsible for accumulate 99% of total capture (grey balls).

Figure 9: Canonical correlation analysis relating the abundance and species composition with environmental variables: a) Spatial samples, and b) CPUE values for each taxon codes*.

1 - *Arenaeus cribrarius*; **2** – *Atherinella brasiliensis*; **3** – *Atherinidae*; **4** – *Brevoortia pectinata*; **5** – *Clupeidae*; **6** – *Engraulidae*; **7** – *Menticirrhus littoralis*; **8** – *Micropogonias furnieri*; **9** – *Mugilidae*; **10** – *Odontesthes argentinensis*; **11** - *Trachinotus marginatus*.

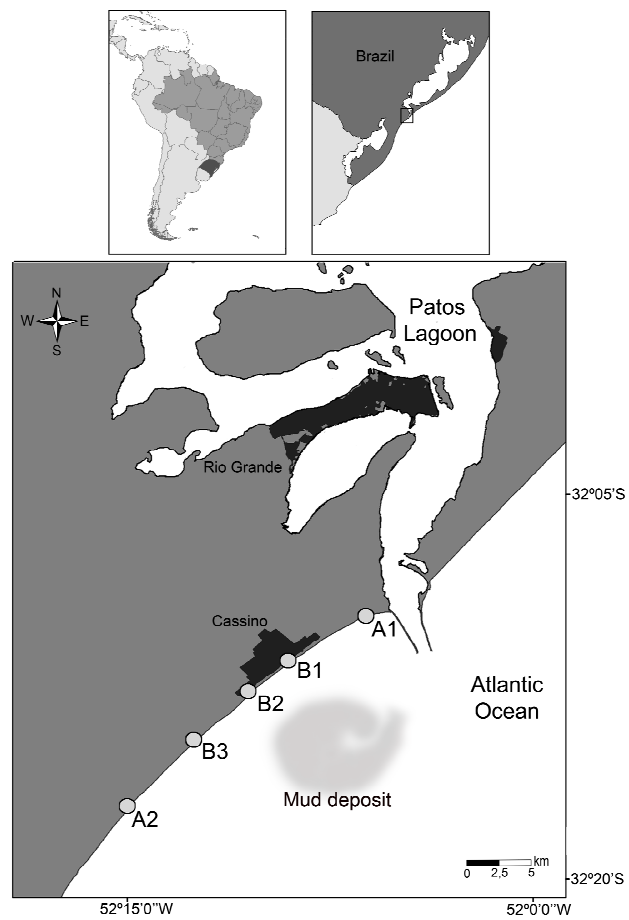


Figure 1.

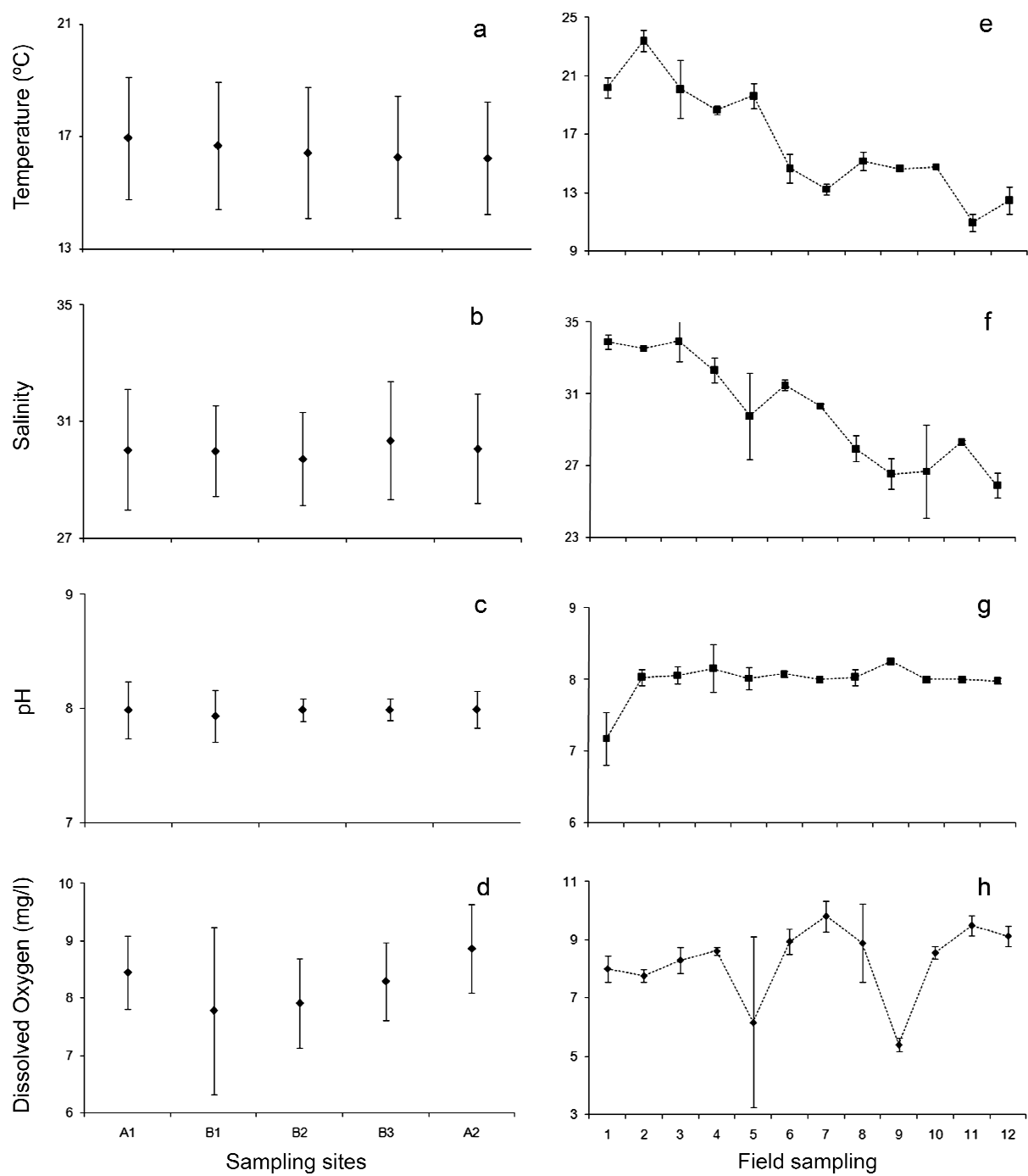


Figure 2.

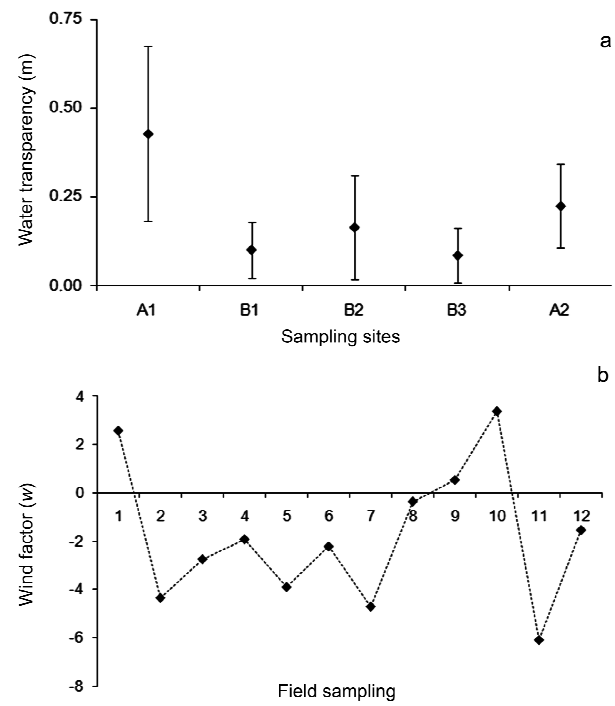


Figure 3.

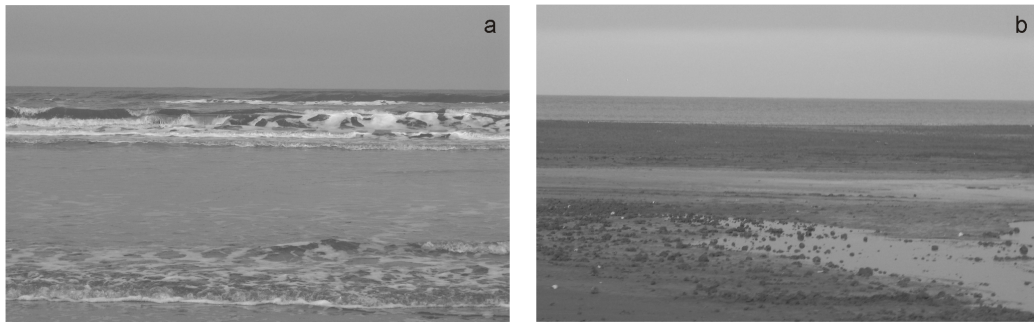


Figure 4.

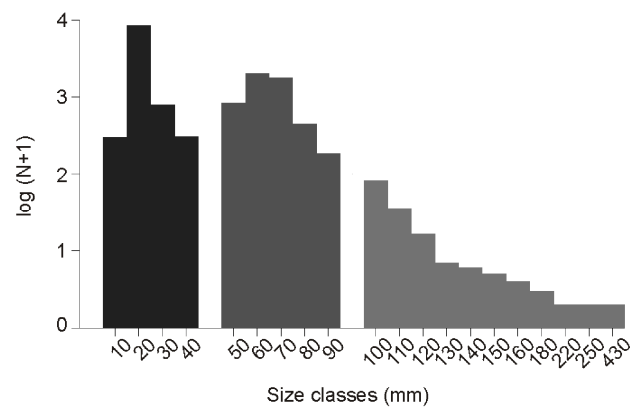


Figure 5.

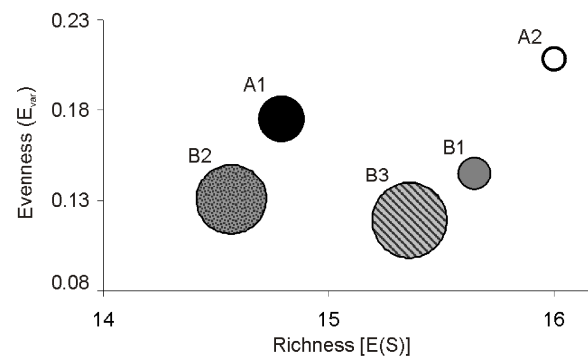


Figure 6.

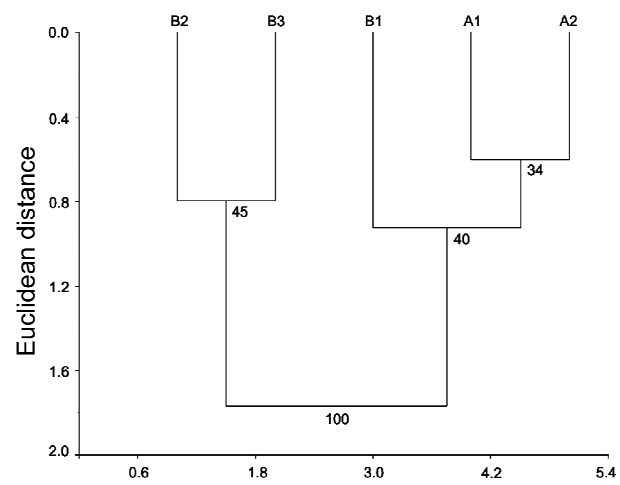


Figure 7.

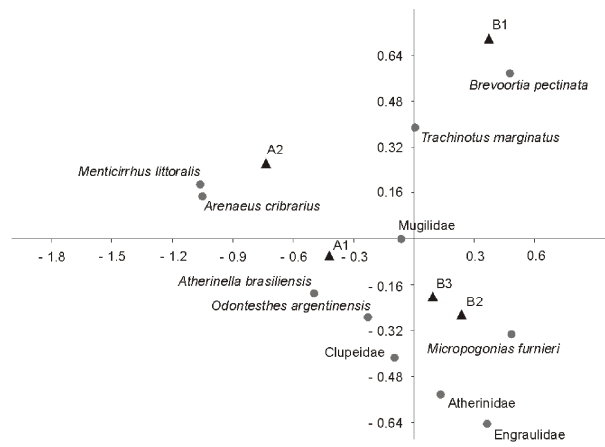


Figure 8.

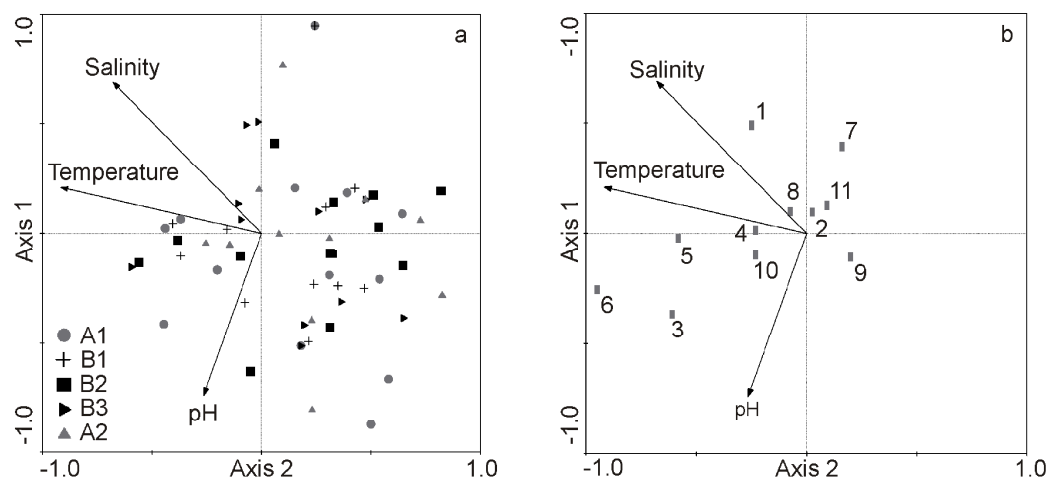


Figure 9.

Species are classified by relative importance decreasing order and sorted as ABUNDANT and FREQUENT (black)

ABUNDANT and NOT FREQUENT (dark grey), FREQUENT and NOT ABUNDANT (light grey), and PRESENT (white)

(*) Species responsible for accumulate 99% of total capture.

Species	A1				B1				B2				B3				A2			
	Number	Size (mm)			Number	Size (mm)			Number	Size (mm)			Number	Size (mm)			Number	Size (mm)		
		Mean	Min	Max		Mean	Min	Max		Mean	Min	Max		Mean	Min	Max		Mean	Min	Max
Mugil liza ^(*)	1849	27.56	22.0	44.0	350	27.75	22.0	131.0	4157	27.72	16.0	156.0	1225	27.89	20.0	93.0	310	27.44	22.0	75.0
Mugil curema ^(*)	96	77.09	54.0	133.0	190	68.55	41.0	106.0	325	76.00	20.0	135.0	1530	70.55	36.0	127.0	28	73.86	45.0	108.0
Trachinotus marginatus ^(*)	92	65.97	21.0	141.0	293	83.21	22.0	124.0	81	69.74	42.0	113.0	445	62.40	29.0	142.0	105	50.52	20.0	96.0
Clupeidae ^(*)	142	21.74	16.0	26.0	3	24.33	23.0	26.0	82	23.65	16.0	29.0	707	22.36	15.0	28.0	18	22.33	18.0	27.0
Brevoortia pectinata ^(*)	32	53.25	28.0	88.0	283	60.50	39.0	89.0	53	54.96	28.0	80.0	181	52.17	20.0	113.0	8	42.88	27.0	64.0
Arenaeus cribrarius ^(*)	27	45.00	13.0	82.0	2	56.50	41.0	72.0	9	24.33	10.0	72.0	20	41.45	10.0	70.0	52	58.12	38.0	105.0
Micropogonias furnieri^(*)	.....	.....	.....	.....	27	40.48	19.0	71.0	306	43.73	10.0	112.0	109	44.18	17.0	139.0	10	49.50	32.0	66.0
Menticirrhus littoralis ^(*)	12	48.42	34.0	60.0	1	137.00	137.0	137.0	1	93.00	93.0	93.0	21	50.14	22.0	115.0	35	49.31	25.0	90.0
Mugil sp. 1 ^(*)	1	45.00	45.0	45.0	3	78.00	74.0	84.0	4	72.75	55.0	82.0	1650	63.44	39.0	91.0	1	64.00	64.0	64.0
Atherinella brasiliensis ^(*)	37	81.05	48.0	125.0	2	62.50	61.0	64.0	15	60.60	24.0	86.0	10	68.10	40.0	86.0	5	81.40	64.0	97.0
Genidens barbus	.....	.....	.....	.....	18	90.56	81.0	105.0	26	85.88	71.0	93.0	10	88.10	79.0	96.0	.....	.....	.....	.....
Lycengraulis grossidens	6	102.50	90.0	119.0	2	165.00	141.0	189.0	3	119.67	60.0	157.0	3	99.33	64.0	165.0	1	147.00	147.0	147.0
Odontesthes argentinensis ^(*)	12	72.50	30.0	118.0	1	94.00	94.0	94.0	4	68.75	22.0	155.0	33	48.39	24.0	253.0	4	71.25	30.0	189.0
Atherinidae ^(*)	7	19.71	15.0	29.0	.....	.....	.....	.....	11	17.09	15.0	19.0	45	18.71	13.0	25.0	1	15.00	15.0	15.0
Menticirrhus sp.	4	34.25	32.0	36.0	.....	.....	.....	.....	7	29.86	12.0	43.0	6	25.00	18.0	31.0	5	24.00	17.0	29.0
Oncopterus darwinii	6	38.33	34.0	46.0	1	31.00	31.0	31.0	.....	.....	.....	.....	6	44.33	16.0	157.0	3	22.67	17.0	29.0
Pomatomus saltatrix	2	98.00	90.0	106.0	1	95.00	95.0	95.0	2	95.50	82.0	109.0	2	106.50	91.0	122.0	.....	.....	.....	.....
Artemesia longinaris	.....	.....	.....	.....	2	87.00	80.0	94.0	1	78.00	78.0	78.0	6	73.67	65.0	81.0	.....	.....	.....	.....
Callinectes danna	.....	.....	.....	.....	2	78.50	55.0	102.0	14	102.86	90.0	117.0	4	67.25	29.0	101.0	.....	.....	.....	.....
Callinectes sapidus	3	79.00	40.0	125.0	9	91.89	40.0	120.0	10	54.50	14.0	129.0	.....	.....	.....	.....	.....	.....	.....	.....
Engraulidae ^(*)	4	17.75	16.0	19.0	.....	.....	.....	.....	64	21.47	16.0	35.0	158	20.06	17.0	29.0	.....	.....	.....	.....
Farfantepenaeus paulensis	2	70.50	67.0	74.0	.....	.....	.....	.....	1	74.00	74.0	74.0	.....	.....	.....	.....	.....	.....	.....	.....
Scianidae	.....	.....	.....	.....	.....	.....	.....	.....	1	16.00	16.0	16.0	2	18.50	18.0	19.0	.....	.....	.....	.....
Caranx latus	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	45.00	45.0	45.0	.....	.....	.....	.....
Chloroscombrus crysurus	1	56.00	56.0	56.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Jenynsia multidentata	.....	.....	.....	.....	.....	.....	.....	.....	1	12.00	12.0	12.0	.....	.....	.....	.....	.....	.....	.....	.....
Litopenaeus schmitti	.....	.....	.....	.....	.....	.....	.....	.....	1	15.00	15.0	15.0	.....	.....	.....	.....	.....	.....	.....	.....
Paralichthys orbignyanus	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	167.00	167.0	167.0
Pleoticus muelleri	.....	.....	.....	.....	.....	.....	.....	.....	1	89.00	89.0	89.0	.....	.....	.....	.....	.....	.....	.....	.....
Prionotus punctatus	.....	.....	.....	.....	.....	.....	.....	.....	1	123.00	123.0	123.0	.....	.....	.....	.....	.....	.....	.....	.....
Syngnathus folletti	.....	.....	.....	.....	.....	.....	.....	.....	1	88.00	88.0	88.0	.....	.....	.....	.....	.....	.....	.....	.....
Trachinotus carolinus	.....	.....	.....	.....	2	116.50	69.0	164.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Trichiurus lepturus	.....	.....	.....	.....	1	430.0	430.0	430.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Table II: Repeated measures analysis of variance (ANOVA) results for relative abundance of sampled ichthyofauna at Cassino beach.

	Sum of sqrs	df	Mean square	F	p(same)
<i>Between groups</i>	4.6823	4	1.170570	7.751	0.000081
<i>Subjects</i>	8.1570	11	0.741543		
<i>Total</i>	19.4842	59			

Tukey's pairwise comparisons					
	A1	B1	B2	B3	A2
A1		n.s.	n.s.	0.02737	n.s.
B1			n.s.	0.01769	n.s.
B2				n.s.	0.002831
B3					0.000217
A2					

Table III: CCA results performed on the relative abundance (CPUE) of fish species.

Axes	1	2	3
<i>Biplot scores of environment variables</i>			
Temperature	-0.9197	0.2092	0.3323
Salinity	-0.6803	0.6883	-0.2519
pH	-0.2648	-0.7396	-0.6188
<i>Summary statistics for ordination axes</i>			
Eigenvalues	0.140	0.047	0.025
Species-environment correlations	0.700	0.542	0.457
Cumulative percentage variance			
of species data	11.3	15.1	17.1
of species-environment relation	66.0	88.3	100.0