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Distribuição Espaço-Temporal de *Scolelepis* cf. *squamata* (Muller, 1808) (Polychaeta: Spionidae) como Ferramenta para Estudos da Dinâmica Sedimentar Costeira

Dissertação apresentada à Pós-Graduação em Zoologia da Universidade Federal do Rio de Janeiro como parte dos requisitos necessários para à obtenção do grau de Mestre em Ciências Biológicas – Zoologia.

PPGZOO
Rio de Janeiro
2003

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Rio de Janeiro, 05 de agosto de 2003.

Trabalho realizado de forma integrada entre os laboratórios:

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Ficha Catalográfica

Neves, Gabriela

Distribuição Espaço-Temporal de *Scolelepis* cf. *squamata* (Muller, 1808) (Polychaeta: Spionidae) como Ferramenta para Estudos da Dinâmica Sedimentar Costeira

Rio de Janeiro. UFRJ, Museu Nacional, 2003.

i-xi, 1-48

Tese: Mestrado em Ciências Biológicas (Zoologia)

1. *Scolelepis* cf. *squamata* 2. Spatial variation 3. Temporal variation 4. Density 5. Body size 6. Morphodynamics 7. Sediment 8. Sand Beach

I – Universidade Federal do Rio de Janeiro

II - Teses

Aos meus amados pais e irmão, por toda a confiança, força e amor incondicional todo o sempre.

"Corpo de Mandinga
iê, é mandingueiro camará!"

(Da Capoeira Baiana)

"...Aquele chororô me fez tão bem
Já não aguentava mais aquele nó
Que me prendia a voz
Agora veja você estou tão zen
Cantei namu myóho rengue kyó
Ohmnamashivaya..."

Tonho Gebara (Nó)

"Thank you, Lord, for what you've done for me.
Thank you, Lord, for what you're doing now.
Thank you, Lord, for ev'ry little thing.
Thank you, Lord, for you made me sing.
Say I'm in no competition,
But I made my decision.
You can keep your opinion.
I'm just calling on the wise man's communion.
Thank you, Lord, for what you've done for me.
Thank you, Lord, for what you're doing now.
Thank you, Lord, for ev'ry little thing.
Thank you, Lord, for you made me sing.
Sing along, sing along.
I don't fear their humiliation,
Just to prove my determination.
I don't yield to temptation,
I haven't learn't my lesson in Revelation".

Bob Marley (Thank you Lord)

"Positive Vibration!"

Bob Marley

"....Você é lua, você é terra
Uma filha de aquário com ascendente em escorpião
Tem sempre um sonho e uma dor sincera
E ainda acha que esse mundo tem solução."

Tonho Gebara (Filha de Aquarius)

"...Desconfio de qualquer autoridade
Política, religiosa, científica ou moral
Que elege os ignorantes e os detentores da verdade
Cria um muro que impede de ver o mundo se abrindo colossal
Se pra ser feliz devo manter algum padrão
Vou seguir na contra mão
Só quero dar uma volta do outro lado pra ver como é que está."

Tonho Gebara (Lado Oposto)

AGRADECIMENTOS ESPECIAIS

Ao meu orientador Paulo Cesar de Paiva pela acolhida e apoio nas fases mais difíceis, pelo carinho, confiança, ensinamentos e oportunidades. Não é à toa que você é o grande Paulinho Poliqueta, tão querido e amado por todos!

Ao meu co-orientador Marcelo Sperle Dias por ter me ensinado a amar a Oceanografia Geológica; pela grande e maravilhosa oportunidade de fazer parte do Grupo de Estudos em Dinâmica Sedimentar (GEDiS) e pela grande confiança, generosidade e amizade. Seriam necessárias muitas páginas de agradecimentos.... Muitíssimo Obrigada!

À Dr. Elianne Pessoa Omena por ter sido uma das idealizadoras do projeto "A Influência da Dinâmica Sedimentar sobre a Fauna de Anelídeos Poliquetas na Praia de Dois Rios, Ilha Grande, RJ." e pelo grande auxílio no trabalho de campo e laboratório e ainda nas fases iniciais do trabalho.

Aos meus oceanógrafos de plantão: Luciana Bispo Pereira e Gustavo Matsuda.

À Lu por toda amizade, generosidade, carinho, colo nos momentos difíceis e ensinamentos...ensinamentos estes que foram desde como organizar uma grande campanha oceanográfica em um curto espaço de tempo (sem enlouquecer!) a como se medir perfis de praia e até como usar a cromoterapia em planilhas do excell, dentre muitos outros... Amiga, você mora no meu coração!

Ao Bicho por todo o amor, amizade e companheirismo sempre.... por todos os ensinamentos, conselhos e tudo mais que uma pessoa possa merecer... por toda a ajuda na elaboração da tese que foi desde a triagem dos poliquetas até as fundamentais discussões sobre morfodinâmica de praias, culminando na criação do "Disque Morfodinâmica", muito utilizado na parte crucial da tese. Sem você, o resultado do trabalho não seria o mesmo... Sempre no meu coração!

Aos meus professores Renato Ventura, Andrea Junqueira, Débora Pires e Helena Passeri pelas valiosas contribuições ao trabalho, sempre bem vindas das participações como banca examinadora dos seminários de tese.

Aos estudantes de oceanografia que fazem e fizeram parte do Grupo de Estudos em Dinâmica Sedimentar, em especial: Cris, Diogo, Fábio e Daniel, além da Lu, minha oceanógrafa preferida, por compartilhar todo o trabalho de campo e laboratório.

À todos os alunos do curso de Oceanografia da Universidade do Estado do Rio de Janeiro que fizeram parte do trabalho de campo do Grupo de Estudos em Dinâmica Sedimentar e que sem pestanejar trabalharam durante madrugadas a fio coletando dados e triando poliquetas.... Sem o sacrifício de todos vocês, este trabalho não seria possível.... Imensos Agradecimentos!

À todos os funcionários do Centro de Estudos Ambientais e Desenvolvimento Sustentável (CEADS/UERJ) por todo o carinho e cuidados sempre.

Ao Seu Francisco pelo carinho e pelas divertidas horas na Toyota da UERJ durante o trajeto Abraão - Dois Rios –Abraão e à Dona Tereza pelos momentos de descontração na "night" de Dois Rios.

À Jacyra, oceanógrafa e técnica do Laboratório de Oceanografia Geológica pelos ensinamentos a respeito das técnicas de análise granulométrica do sedimento e pelo auxílio no trabalho de campo.

Aos meus companheiros do laboratório de Polychaeta: Alejandro, Bia, Christine, Edgard, Elisa, Gian, Gilvan, Joana, Letícia, Maria Claudia, Priscilla, Ricardo, Rômulo e Vinícius pelo companheirismo e carinho mesmo a grandes distâncias...

À minha grande amiga Maria Claudia Rayol Sola pela amizade, carinho e lealdade sempre! Pela presença, companheirismo e força em todos os momentos... pelas permanentes discussões sobre a tese e ainda por compartilhar os ensinamentos sobre morfodinâmica de praias.... em campo!

À minha grande amiga Noa Magalhães pela amizade e amor. Por compartilhar de grandes momentos da minha vida; pelo colo e pela bronca.... e ainda por ter me levado até a "Oficina da Mente"; responsável pelo meu bem estar mental e aprendizado fundamental na leitura de toda a bibliografia da tese.

Aos meus pais japoneses Mario e Luzia Matsuda por todo o amor, carinho e compreensão....pela enorme torcida, confiança e força. Amo e admiro muito vocês.

Ao mano pela torcida, confiança e amor.

Aos meus pais por tudo! Pelo amor incondicional, confiança, carinho, proteção, dedicação, generosidade e força...pela possibilidade de cursar o mestrado sem bolsa; sem vocês não seria possível a realização deste trabalho. Muito amor!

À Vida!

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INTRODUÇÃO GERAL

Em termos gerais, as praias são consideradas ambientes instáveis, onde o estresse físico, causado pela energia de ondas e pela variação das marés, representa um fator limitante para o estabelecimento de várias espécies bentônicas (Butman, 1987). O hidrodinamismo tem sido considerado um dos parâmetros mais importantes para a distribuição espacial de organismos bentônicos, pois atua diretamente sobre a dispersão de larvas e juvenis, controlando o recrutamento e estabelecimento das populações (Butman, *op cit.*). Além disso, o hidrodinamismo, traduzido pela ação de ondas e correntes é o principal responsável pela dinâmica sedimentar e consequentemente, pela morfologia das praias arenosas (Short, 1979).

Estudos têm revelado que a estrutura da comunidade é bastante afetada pelo estado morfodinâmico da praia. Em praias protegidas, a densidade e riqueza de espécies são bastante superiores às encontradas em praias expostas (McLachlan, 1983; Jaramillo & Gonzales, 1991). A distribuição e abundância das espécies da macrofauna em praias arenosas têm sido relacionadas a muitos fatores tais como: diâmetro do grão e/ou conteúdo de matéria orgânica, inclinação da praia, ação de ondas, teor de umidade do sedimento, temperatura e presença de alimento (Bally, 1983; McLachlan, *op cit.*; Donn Jr. *et al.*, 1986). Embora seja difícil analisar a influência destes fatores isoladamente, acredita-se que a estrutura da comunidade é frequentemente determinada pelo estado morfodinâmico, sendo os fatores físicos, na maioria das vezes, predominantes sobre os biológicos. Recentemente têm se considerado não apenas a importância da granulometria como também da dinâmica sedimentar e do regime hidrodinâmico (Snelgrove & Butman, 1994).

Baly (1983), em uma extensa revisão da literatura sobre a macrofauna de praias arenosas, constatou a existência de correlação negativa entre o número de espécies e o grau de exposição, mas por outro lado, o tamanho individual e a biomassa foram maiores em ambientes expostos. Jaramillo *et al.* (1993) analisaram 10 tipos de praias, do Centro-Sul do Chile, com diferentes graus de exposição, considerando desde praias refletivas até praias dissipativas. Os autores verificaram que o número de espécies, abundância e biomassa total aumentavam de acordo com o gradiente decrescente de exposição e diminuíam de acordo com o aumento da partícula sedimentar e da inclinação da praia. Embora alguns autores tenham sugerido o papel do hidrodinamismo sobre as comunidades bentônicas em praias arenosas (McLachlan, 1983; Jaramillo & Gonzales, 1991), poucos estudos são de caráter interdisciplinar, o que dificulta o estabelecimento de correlações mais precisas entre a fauna e os parâmetros físico-químicos e biológicos atuantes.

No entanto, os estudos que investigam a relação da morfodinâmica de praias com a estrutura da macrofauna bentônica falham por não darem importância as escalas espaciais e temporais adotadas. Frequentemente, o desenho amostral utilizado nestes estudos inclui poucas escalas espaciais, que muitas vezes estão associadas a uma baixa replicação (James & Fairweather, 1996). Ainda, os estudos que levam em consideração a variação longitudinal e transversal ao longo das praias arenosas, normalmente se utilizam de uma área muito restrita, de onde são traçados somente um ou dois transects, desconsiderando toda a variação hidrodinâmica existente ao longo da praia (e.g. McLachan, 1990; Defeo *et al.*, 1992; Jaramillo *et al.*, 1993). E além disso, desconsideram os fatores transientes, ou seja, as variações temporais e sazonais (e.g. Defeo *et al.*, 1992; Jaramillo *et al.* 1993; McLachlan, 1996).

No Brasil, a investigação do papel da morfodinâmica sobre as comunidades bentônicas está apenas se iniciando. Neste sentido destacam-se os trabalhos de Santos (1994); Souza & Gianuca (1995); Borzone & Souza (1997); Veloso *et al.* (1997); Omena & Amaral (1997); Souza & Borzone, (2000) e Veloso & Cardoso (2001). A influência da morfodinâmica na dinâmica populacional de espécies do gênero *Scolelepis* tem sido investigada em alguns trabalhos. Santos (1991) verificou a relação existente entre a estrutura da população de *Scolelepis gaucha* e o grau de energia incidente em uma praia do litoral do Rio Grande do Sul, enquanto que Shimizu (1997), avaliou o padrão de distribuição de *Scolelepis squamata* ao longo dos perfis da praia de Barequeçaba, litoral de São Paulo, utilizando como variáveis a densidade e as classes de tamanho da população.

A espécie *Scolelepis squamata* é característica da região entre marés de praias arenosas e apresenta ampla distribuição geográfica, sendo reportada em todos os oceanos (Souza & Borzone, 2000). Na costa brasileira, é conhecida principalmente em praias do litoral dos Estados de São Paulo (Amaral, 1979; Shimizu, 1997), onde registra uma grande frequência de ocorrência e abundância relativa, e do Paraná (Souza & Gianuca, 1995; Borzone & Souza, 1997; Souza & Borzone, 2000). No entanto, de acordo com

Radashevsky (com. pess.), o estado taxonômico desta espécie é controverso, de onde se fazem necessários maiores estudos.

Nos últimos quatro anos o Grupo de Estudos em Dinâmica Sedimentar (GEDiS / UERJ) vem desenvolvendo estudos integrados sobre processos de transporte de sedimentos litorâneos e da morfodinâmica das praias (Sperle *et al.*, 2000; 2001). Estes projetos têm permitido compreender importantes fenômenos de erosão e deposição que ocorrem na maioria dos ambientes costeiros, em especial em praias da Ilha Grande. Informações sobre a distribuição dos poliquetas ao longo da região entremarés de diversas praias já vêm sendo monitoradas, e vêm indicando uma forte relação com a dinâmica sedimentar destas praias (Omena *et al.*, 2001; Neves *et al.*, 2002).

O objetivo deste estudo é examinar a relação entre a distribuição espaço-temporal de *Scolelepis* cf. *squamata* e a morfodinâmica da praia de Dois Rios (Ilha Grande, litoral sul do Estado do Rio de Janeiro) em escalas longitudinal e transversal, utilizando como variáveis a densidade e o tamanho da espécie. Os resultados referentes a este trabalho serão apresentados e discutidos em formato de artigo científico. As referências bibliográficas pertinentes a esta seção serão apresentadas ao final das Conclusões Gerais, sendo assim o último item deste trabalho.

Artigo - *Scolelepis* cf. *squamata* (Muller, 1808) (Polychaeta: Spionidae) Spatial-Temporal Distribution as a Tool for Coastal Sedimentary Dynamics: Constraints from a Sand Beach, Brazil.

ABSTRACT

A population of the spionid polychaete *Scolelepis* cf. *squamata* was studied on Dois Rios beach, an embayed oceanic beach located at Ilha Grande (a coastal island), at the southeastern Brazilian coast. The relationship between beach morphodynamics and the spatial-temporal distribution of this species along and across the beach was evaluated in relation to density and body size variables. Sampling was carried out during spring low tides of May/2001, July/2001, November/2001 and January/2002. Eight transects with different hydrodynamical influences were chosen along the entire beach. The intertidal beach was divided into three across-shore zones, where three replicate samples were randomly collected from each zone at each transect. Differences in *S. squamata* long-shore distribution occurred mainly due to beach morphodynamics, where species densities increased from erosional (low tide terrace) to depositional (reflective) beach states and species body size increased from depositional to erosional ones. However, exceptions that could not be explained by the morphodynamic state per se, seems to be related to hydrodynamic patterns. The association between intermediate to large *S. squamata* body sizes and coarser skewed sands, shows the great importance of passive transport of individuals in determining species distribution. A correlation between sediment size and *S. squamata* distribution were not found, although a clear relationship between species distribution and marine sediment transport were found. *S. squamata* densities were lower during high hydrodynamic periods due to their weaker resistance to transport by wave action. In spite of the high hydrodynamics, smallest *S. squamata* body sizes were found in this period, that coincided with a species recruitment. The close association observed among *S. squamata* spatial-temporal distribution, morphodynamic beach state and sediment transport, supports the hypothesis that this species density and body size distribution might be used as a tool for correlating beach morphodynamics, hydrodynamics and sediment transport in oceanic sandy beaches.

Keywords: *Scolelepis* cf. *squamata*, Spatial variation, Temporal variation, Density, Body size, Morphodynamics, Sediment, Sand beach.

RESUMO

A população de *Scolelepis* cf. *squamata* da praia de Dois Rios, Ilha Grande, litoral sul do Estado do Rio de Janeiro, foi analisada durante as marés baixas de Maio/2001, Julho/01, Novembro/01 e Janeiro/02. A relação entre a distribuição espaço-temporal de *S.squamata* e a morfodinâmica da praia de Dois Rios foi examinada em escalas longitudinal e transversal, utilizando como variáveis a densidade e o tamanho da espécie. Foram traçados oito transectos que estiveram submetidos a diferentes influências hidrodinâmicas ao longo da praia. A face de praia foi dividida em três regiões transversais, de onde foram tomadas três réplicas aleatórias em cada um dos pontos ao longo da praia. As diferenças observadas na distribuição longitudinal foram explicadas pela morfodinâmica da praia, onde a densidade aumentou do estado de erosão (terraço de baixa mar) para o de deposição (refletivo) e o tamanho aumentou do estado de deposição para o de erosão. As exceções observadas neste padrão foram explicadas pelo regime hidrodinâmico local. A relação observada entre tamanhos intermediários para grandes de *S. squamata* e a assimetria negativa do sedimento, mostram a importância do transporte passivo na distribuição da espécie. Não foi encontrada uma correlação entre a distribuição de *S. squamata* e o tamanho do grão, porém, foi encontrada uma evidente relação entre a distribuição da espécie e o transporte de sedimento marinho. Baixas densidades de *S. squamata* foram observadas durante períodos de alta hidrodinâmica, devido a sua baixa resistência ao transporte pela ação de ondas. Mesmo sob influência de alta hidrodinâmica, pequenos tamanhos de *S. squamata* foram encontrados durante este período, que coincidiu com o período de recrutamento da espécie. A associação observada entre a distribuição espaço-temporal de *S. squamata,* o estado morfodinâmico da praia e o transporte de sedimento, sustenta a hipótese de que a densidade e o tamanho da espécie podem ser utilizados como ferramenta para correlacionar a morfodinâmica, hidrodinâmica e o transporte de sedimentos em praias arenosas oceânicas.

Palavras Chave: *Scolelepis cf. squamata*, Variação espacial, Variação temporal, Densidade, Tamanho, Morfodinâmica, Sedimento, Praia arenosa.

I. INTRODUCTION

The variation in distribution, composition and structure of sand beaches macrofauna had been largely related to changes in beach morphodynamics (McLachlan, 1983; 1990; 1996; Mc Ardle and McLachlan, 1991; 1992; Defeo *et al.*, 1992; Jaramillo and McLachlan, 1993; Veloso and Cardoso, 2001). However, disturbance by waves and currents could not be easily characterized in a way that is useful for benthic ecologists and the sediment transport literature is truly sparse. For this reason, the potential interaction between the biota and physical regime would be only properly understood if one appreciates the basics of physical processes (Hall, 1994).

The importance of spatial and temporal scales chosen for ecological investigations is not well known. Further, studies on across-shore variation of sandy beach macrofauna are usually done at only one site which covers only a small portion of the entire beach, thus along-shore variations were not considered (James and Fairweather, 1996). Indeed, most sandy beaches populations presents marked spatial distribution patterns in response to an environment that is spatially and temporally structured by sharp, small-scale gradients (Defeo and Rueda, 2002).

In Brazil, ecological studies on sandy beaches are just on the beginning (e.g. Santos, 1994; Souza and Gianuca, 1995; Borzone and Souza, 1997; Veloso *et al.*, 1997; Omena and Amaral, 1997; Veloso and Cardoso, 2001). The relationship between species of the genus *Scolelepis* (Polychatea: Spionidae) and beach morphodynamics have been investigated by some authors. Santos (1991), evaluated the morphodynamical influence of a temporary freshwater stream on the population dynamics of *Scolelepis gaucha* species, whereas Shimizu (1997) studied the zonation pattern of *Scolelepis squamata* densities and different size classes across a sand beach.

Species of the genus *Scolelepis* are among the most conspicuous components describing intertidal zonation on sandy beaches, where they are numerically dominant members of the macrofauna (McLachlan, 1993; Borzone and Souza, 1997). *Scolelepis squamata* have a large range of distribution in sand beaches, mainly located on the intertidal zone along the Brazilian Southwestern coast, where it can be found in different beach zones (Shimizu, 1997; Souza and Borzone, 2000).

The aims of this study are: i) to examine the relationship between beach morphodynamics and the spatial-temporal distribution of *Scolelepis* cf. *squamata* along and across the beach and ii) evaluate this relation according to species density and body size.

II. METHODS

II.1 *Study Site*

Sampling was done at Dois Rios beach, which is an embayed microtidal oceanic beach, located at the southeastern part of Ilha Grande (a coastal island; Ilha Grande means Big Island), between coordinates 23° 06' S, 23° 18' S and 44° 05' W, 44° 30' W at the southeastern coast of Rio de Janeiro State, Brazil. Facilities were supported by the center of environmental studies (CEADS) of Universidade do Estado do Rio de Janeiro, located at Dois Rios village. Dois Rios beach is NE - SW oriented (Figure 1). East to north-easterly swells and low waves predominate almost throughout September to March (spring and summer seasons). When episodic storm events happens; generally at winter and autumn seasons (April to August), south to south-westerly swells predominate, altering the wave climate. There is a gradient of hydrodynamical exposure increasing from the southwestern end of the beach to the northeastern. Wave height at Dois Rios are lower than 0.5 m, increasing in size slightly towards the northeast. Besides, the presence of two islands (Armação islands) protects the extreme northeastern part of the beach. Dois Rios also have two streams (Dois Rios means two streams), one located at the extreme southwestern part of the beach (Barra Grande stream) and the other on the extreme northeastern (Barra Pequena stream). These streams have different sediment composition and the mean grain size of Barra Pequena stream is coarser than Barra Grande (Bispo, 2002). Mean grain size of sand at Dois Rios is 0.11 mm, which means fine sand. The modal beach state is morphodynamicaly classified as intermediate. Within this intermediate stage, the southwestern parts and the extreme northeastern of the beach have a reflective configuration, whereas the northeastern parts of the beach have a low tide terrace configuration (Bispo, *op cit.*). During the time sampled, high spring tides ranged from 1.0 m to 1.3 m and low spring tides ranged from 0.1 m to 0.4 m. High neap tides ranged from 0.7 m. to 0.9 m and low neap tides ranged from 0.4 m to 0.5 m.

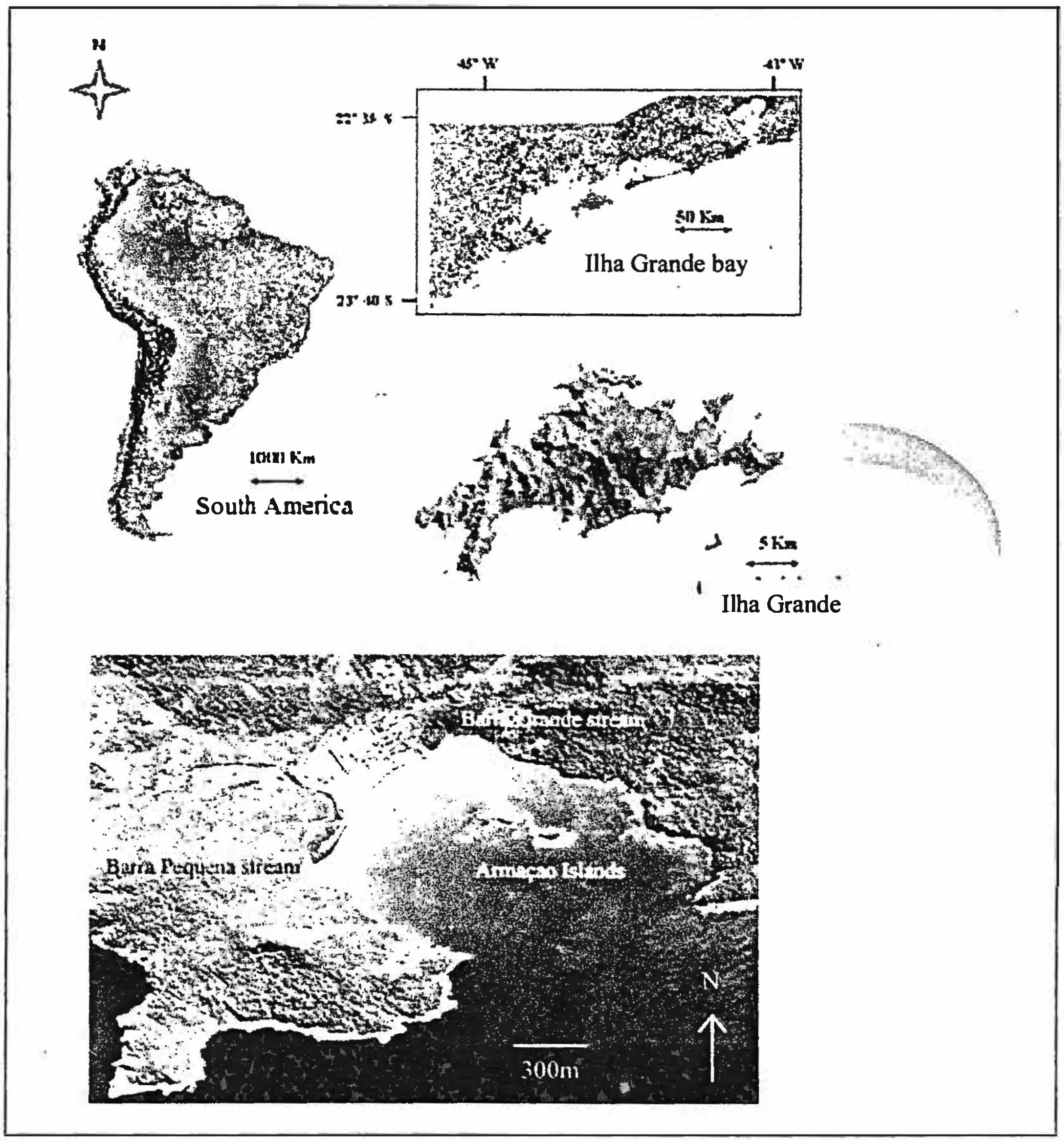

Figure 1 - Map of the coast of Brazil showing the location of the study site and regional location of Dois Rios bay, showing the position of Barra Grande and Barra Pequena streams and Armação islands (Modified from Bispo, 2002).

II.2 *Sampling and Sample Processing*

Sampling was carried out during spring low tides in May 2001, November 2001 and January 2002 and during neap low tides in July 2001. Eight sites were chosen at 200 m intervals along the entire beach. At each site a transect were laid from the highest drift line to the lowest surf zone, where transect profiles were surveyed using a topographical equipment.

On the basis of faunal studies, the intertidal beach exposed at low tide was divided into three cross-shore beach zones: high, medium and low intertidal. The high intertidal beach zone extended between the high water table mark (the high of the previous high tide) and the upper limit of swash zone. Medium intertidal beach zone extended from the lower part of the high intertidal beach zone down to the lower limit of the swash zone and it is central on the position of the mean sea level. Low intertidal beach zone extended between the lower part of the medium intertidal beach zone to at about 15 m down-shore the surf zone (the most seaward point) (Figure 2). Overall, the sampling design had two spatial scales: an across-shore (zones) and a long-shore (transects). Three replicate samples were randomly collected from each zone at each transect using a 100 mm diameter corer to 25 cm depth. All samples were sieved through a 0.5 mm mesh and *S. squamata* individuals were sorted and preserved with 4% formalin in seawater. After counting *S. squamata* individuals, the width of the 3th setiger (Shimizu, 1997) of 1420 individuals randomly chosen (in respect to transects and zones) was measured to determine the population structure size.

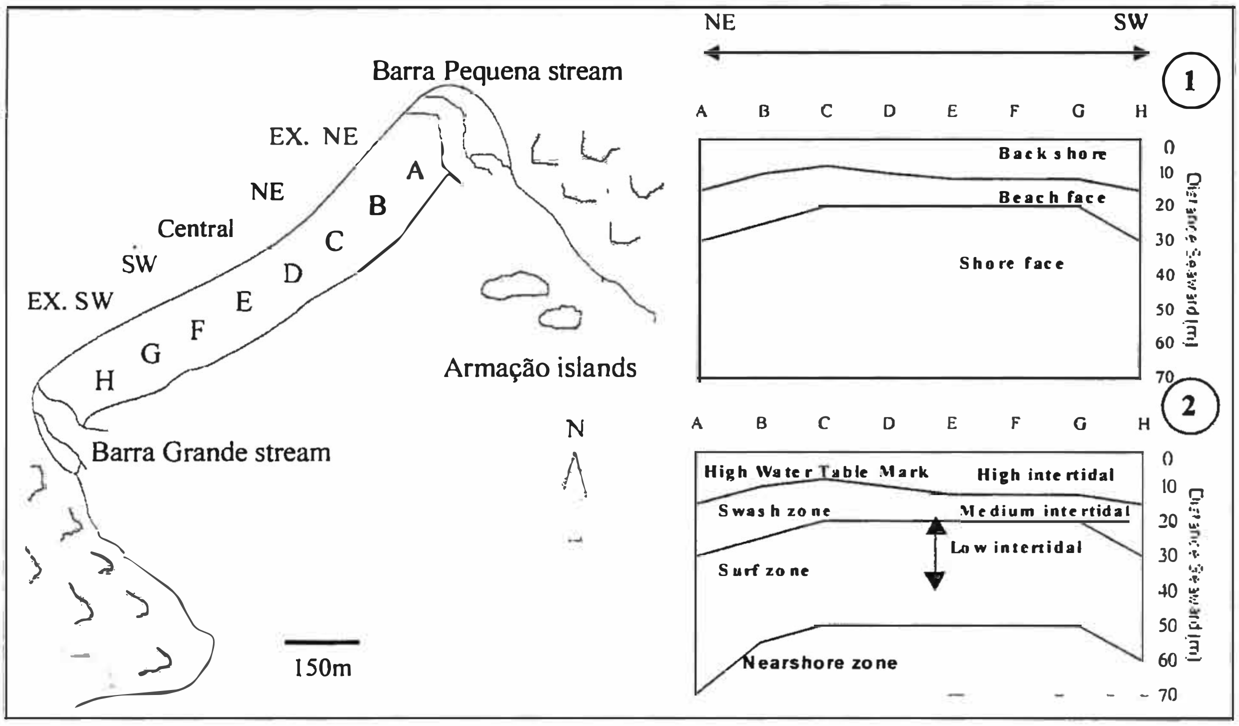

Figure 2 - Dois Rios beach, showing the position of the sampling sites [Extreme NE (EX. NE), NE, Central, SW and Extreme SW (EX. SW)], transects (A – H) and examples of the cross-shore sampling design. Beach morphology nomenclature according to (1) Muehe (1995) and (2) Short (2000) together with the sampling design of this study. Modified from Bispo, 2002.

Sediment samples for grain-size analysis were taken using the same corer. Procedures suggested by Suguio (1973) were applied using the statistical parameters of Folk and Ward (1957).

Long-shore transects were also grouped at five sites regarding wave exposure. Transect A, located at the extreme northerly end of the beach were at extreme NE site; transects B and C, located at the northern part of the beach were at NE site; transects D and E, located at central beach were at central site; transects F and G, located at the southern part of the beach were at the SW site and transect H, located at the extreme southerly end of the beach were at extreme SW site. At each site, wave height (H_b) and wave period (T) were recorded using the horizon and a stopwatch at the time of sampling.

The morphodynamic state of each transect was recorded after Dean's dimensionless parameter ($\Omega = H_b/TW_s$, where H_b is wave heigth , W_s is grain size as defined by sediment fall velocity and T is wave period) (Wright and Short, 1984) and Surf scaling index [$\varepsilon = a_b \omega_i^2/(g \tan^2\beta)$], where a_b is wave breaker amplitude, ω_i is wave radian frequency, g is acceleration of gravity and β is beach bed gradient (Guza and Inman, 1975). A sensitivity plot of the contribution of wave height, sediment size and wave period to Ω and beach type was used in terms of conversion from sand size (ϕ) to sediment fall velocity (cm/sec) (Short, 2000). Morphodynamical classifications of each transect were recorded according to the six major beach states proposed by Short (1979) and Wright and Short (1984).

II.3 *Statistical Analysis*

The sampling design was orthogonal with respect to transects, zones and time, so interactions between long-shore (transects) and across-shore (zones) variation was assessed using a two-way ANOVA. A three-way ANOVA was applied to assess the interactions among long-shore, across-shore and time (months) variation. Before analysis, density of *S. squamata* were log transformed ($\log_e x+1$) and a regression analysis was used to transform the width of the 3th setiger (w_d) to total body size length ($y = a + b\, w_d$), where a = intercept and b = slope.

A Principal Component Analysis (PCA) (Ludwig and Reynolds, 1988) was used to detect patterns in the distribution of *S. squamata*. A matrix composed by biotic variables such as density; mean body size; percentage of larger and smaller body sizes (percentile

66% and 33%, respectively); body size skewness, and abiotic variables such as sediment particle parameters [mean particle size (ϕ), percentage of coarse and fine sands, skewness and standard deviation]; slope and morphodynamic parameters [Dean's dimensionless parameter (Ω) and Surf scaling index (ε)] was applied.

III. RESULTS

III.1 *The Beach*

III.1.1 *Waves and Slope*

Along all four months sampled, the most exposed sites at Dois Rios beach (NE and Central), exhibited steeper profiles (Figure 3), higher slopes (Table 1) and higher wave height than sheltered ones (NE extreme, SW, SW extreme) (Table 2). During all period studied, transect C showed the steeper profiles and higher slopes, whereas transect H showed gentle profiles and lower slopes (Figure 3). Transect A tended to have longer wave period while transect H tended to have shorter one, showing an increasing gradient from SW to NE site. South-west swells and high waves occurred in May/01 while south swells and high waves also predominate in July/01. Low waves and north-east swells occurred in Nov/01 while east swells and low waves also predominate in Jan/02 (Table 2).

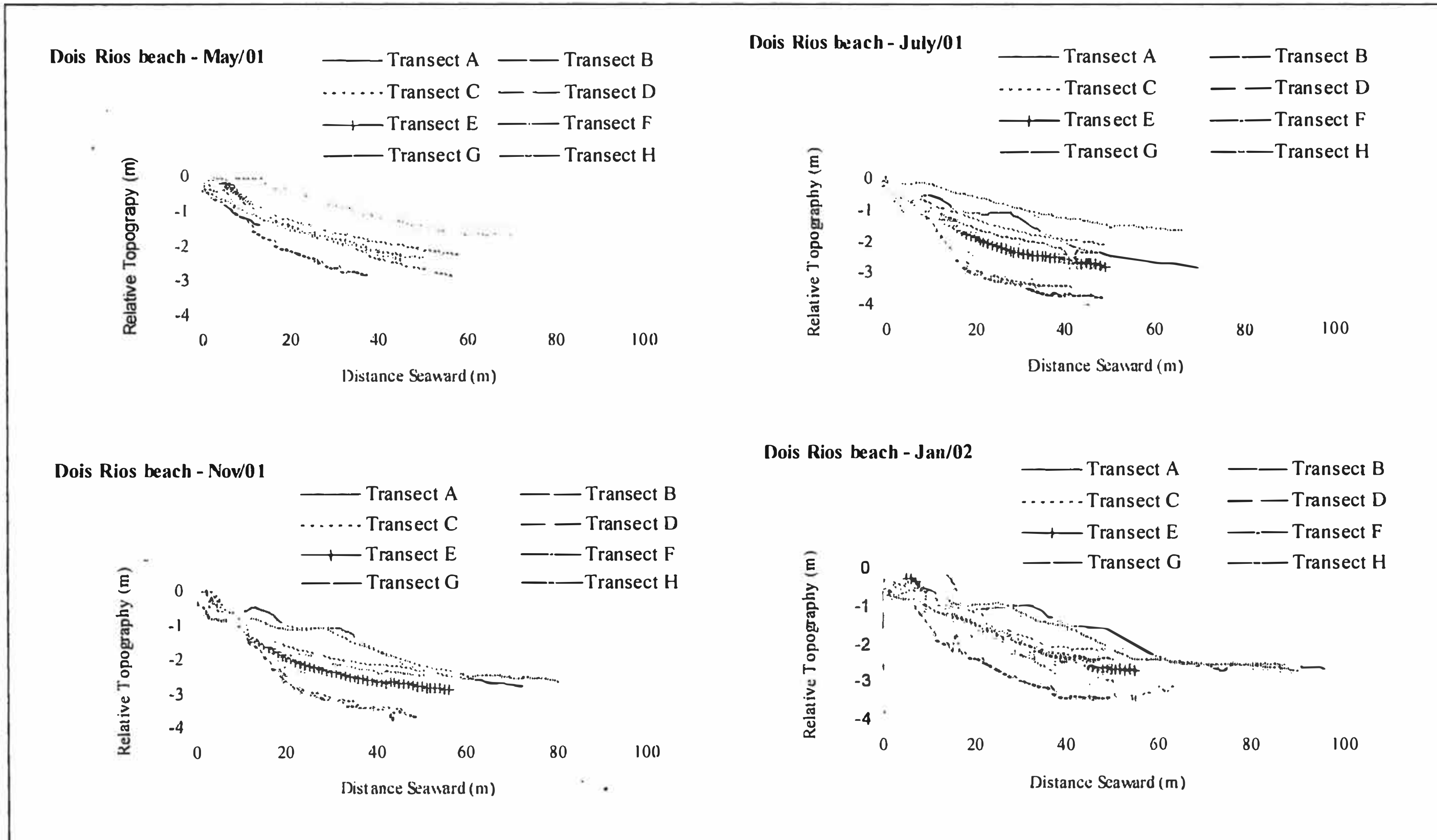

Figure 3 – Beach profile of Dois Rios along the four months studied (Data from GEDiS data bank).

Table 1 - Beach slope (^{0}) at high, medium, low intertidal zone along the four months studied indicating the sampling site and transect surveyed. (* absent data).

		May-01			Jul-01			Nov-01			Jan-02		
Site	Transect	Zone			Zone			Zone			Zone		
		High	Medium	Low	High	Medium	Low	High	Medium	Low	High	Medium	Low
Extreme NE	A	*	*	*	1.49	0.03	0.69	3.75	1.42	1.10	1.85	3.18	0.08
NE	B	4.05	2.40	1.65	5.96	2.09	0.60	5.00	1.56	1.31	1.88	3.59	1.23
NE	C	4.21	2.63	2.02	8.97	2.54	1.24	5.29	1.91	1.00	3.27	2.87	1.07
Central	D	3.85	2.26	1.60	5.33	1.80	1.73	5.10	2.06	0.96	2.36	2.40	1.72
Central	E	3.21	1.88	1.94	4.63	2.06	1.18	4.02	2.19	1.31	3.10	2.80	1.93
SW	F	3.28	2.10	1.65	3.04	1.97	1.48	3.69	2.03	1.01	2.51	2.87	1.14
SW	G	3.38	2.27	1.69	2.97	2.26	1.25	3.10	1.12	0.98	2.29	3.30	1.07
Extreme SW	H	2.14	1.78	1.39	2.06	1.33	1.07	1.74	2.14	0.25	2.67	3.12	0.50

Table 2 - Wave height (cm) and period (s) along the four months studied indicating the sampling site and swell of each period surveyed.

	May-01		Jul-01		Nov-01		Jan-02	
	SW swell		S swell		NE swell		E swell	
Site	Height	Period	Height	Period	Height	Period	Height	Period
Extreme NE	85.7	9.6	35.0	10.7	38.6	10.5	38.7	12.3
NE	85.5	9.7	100.0	10.5	50.0	7.2	45.6	9.9
Central	82.7	9.1	60.0	10.3	60.8	7.2	43.6	8.8
SW	69.7	9.7	54.4	10.1	38.3	8.0	41.3	9.6
Extreme SW	24.7	4.5	50.0	11.5	35.2	7.1	37.7	8.6

III.1.2 *Sediment Parameters*

Mean particle size ranged from fine to very fine sand along the beach. However, there were a longshore gradient in which transects A, B and C (NE extreme and NE sites) have a higher coarse sand contribution than those from Central, SW and SW extreme sites. (Figure 4). Sediment samples from May/01 were most symmetrical in Central and SW sites and coarse skewed in NE extreme and NE sites. They were also well to very well sorted for the most part of the beach, except for transects A and B which show moderately sorted particles. In July/01, sediment particles were most coarse skewed. However, they were strongly coarse skewed in NE extreme, NE and Central sites. In respect to degree of scatter, particles from transect E and SW site were most well sorted than the other ones. In Nov/01 and Jan/02 sediment samples were also most coarse skewed, although in Nov/01 sediment particles were most moderately well sorted, with exception of transects A and E, which had poor sorted and well sorted particles, respectively. In Jan/02 sediment particles were well sorted for the entire beach (Table 3).

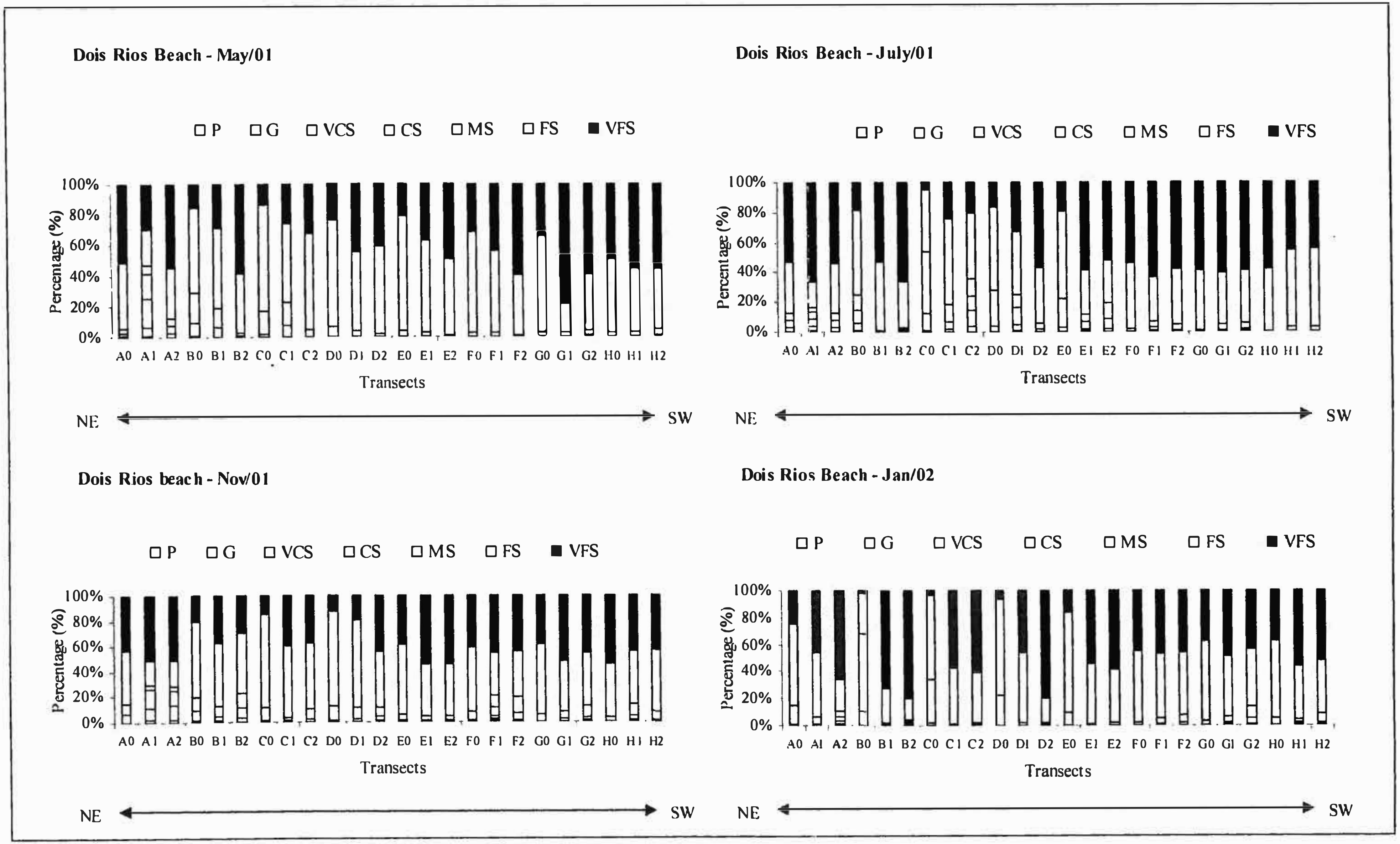

Figure 4 - Percentage of sediment sizes and textural group classification along-shore (transects A; B; C; D; E; F; G; H) and across-shore (zones 0 High; 1 Medium; 2 Low) along the four months studied (Data from GEDiS data bank).

P Pebble; G granule; VCS Very coarse sand; CS Coarse sand; MS Medium sand; FS Fine Sand; VFS very Fine Sand

Table 3 - Statistical sediment parameters along-shore (transects A; B; C; D; E; F; G; H) and across-shore (zones H High; M Medium; L Low) along the four months studied.
TG textural Group (MD Medium sand; FS Fine sand; VFS Very fine sand); M Mean particle size (ϕ); SK Skewness (S Symmetrical; CS Coarse skewed; SCS Strongly coarse skewed); SD Standard deviation (WS Well sorted; MWS Moderately well sorted; MS Moderately sorted; PS Poorly sorted)

		May-01						Jul-01						Nov-01						Jan-02					
Transect	Zone	TG	M	SK		SD		TG	M	SK		SD		TG	M	SK		SD		TG	M	SK		SD	
A	H	FS	2.97	CS	-0.16	MWS	0.55	FS	2.93	SCS	-0.36	MS	0.84	FS	2.77	SCS	-0.38	MS	0.75	FS	2.61	S	-0.1	MWS	0.59
A	M	MS	1.7	SCS	-0.45	PS	1.65	FS	2.97	SCS	-0.52	PS	1.14	FS	2.23	SCS	-0.68	PS	1.46	FS	2.87	CS	-0.27	MWS	0.51
A	L	FS	2.92	SCS	-0.42	MS	0.8	VFS	3.07	CS	-0.29	MS	0.86	FS	2.21	SCS	-0.7	PS	1.49	VFS	3.02	SCS	-0.47	MS	0.74
B	H	FS	2.27	CS	-0.23	MS	0.84	FS	2.29	SCS	-0.4	PS	1.07	FS	2.48	CS	-0.28	MS	0.77	MS	1.72	S	-0.06	MWS	0.59
B	M	FS	2.58	SCS	-0.32	MS	0.78	VFS	3.02	S	-0.04	MWS	0.51	FS	2.75	CS	-0.22	MWS	0.69	VFS	3.12	CS	-0.22	WS	0.41
B	L	VFS	3.04	CS	-0.12	WS	0.49	VFS	3.14	S	-0.06	MWS	0.55	FS	2.47	SCS	-0.39	MS	0.9	VFS	3.23	CS	-0.17	WS	0.44
C	H	FS	2.48	S	-0.04	MWS	0.57	MS	1.85	CS	-0.11	MS	0.74	FS	2.51	S	0.03	MWS	0.5	FS	2.11	S	-0.14	MWS	0.5
C	M	FS	2.49	CS	-0.29	MS	0.85	FS	2.57	CS	-0.17	MS	0.76	FS	2.86	S	-0.02	MWS	0.5	VFS	3.02	CS	-0.3	WS	0.4
C	L	FS	2.83	FS	0.11	MWS	0.57	MS	1.93	SCS	-0.43	PS	1.43	FS	2.78	CS	-0.12	MWS	0.68	VFS	3.04	CS	-0.23	WS	0.43
D	H	FS	2.71	S	-0.01	MWS	0.53	FS	2.35	CS	-0.15	MS	0.72	FS	2.5	S	-0.01	MWS	0.5	FS	2.3	S	0.4	WS	0.48
D	M	FS	2.93	S	-0.05	WS	0.49	FS	2.35	SCS	-0.51	PS	1.11	FS	2.59	S	-0.03	MWS	0.54	FS	2.94	CS	-0.11	WS	0.41
D	L	FS	2.93	S	0.08	WS	0.48	VFS	3.02	CS	-0.22	MWS	0.55	FS	2.84	SCS	-0.31	MWS	0.69	VFS	3.07	CS	-0.25	WS	0.44
E	H	FS	2.7	S	0.02	WS	0.46	FS	2.48	CS	-0.16	MWS	0.71	FS	2.85	CS	-0.13	WS	0.47	FS	2.55	S	-0.02	WS	0.48
E	M	FS	2.86	S	-0.03	WS	0.46	VFS	3	SCS	-0.34	MWS	0.79	FS	2.99	CS	-0.24	WS	0.46	VFS	3	CS	-0.22	WS	0.39
E	L	FS	3	S	0.01	WS	0.45	FS	2.75	SCS	-0.48	MWS	0.93	FS	2.99	CS	-0.22	WS	0.47	VFS	3.02	CS	-0.27	WS	0.41
F	H	FS	2.81	S	0.01	WS	0.47	VFS	3.01	CS	-0.12	WS	0.45	FS	2.85	CS	-0.24	MWS	0.52	FS	2.92	CS	-0.11	WS	0.41
F	M	FS	2.94	S	0.02	WS	0.49	VFS	3.14	S	-0.1	WS	0.7	FS	2.6	SCS	-0.55	MWS	0.99	FS	2.9	CS	-0.23	WS	0.46
F	L	VFS	3.07	S	-0.07	WS	0.46	VFS	3.01	CS	-0.2	MWS	0.52	FS	2.66	SCS	-0.47	MWS	0.82	FS	2.86	CS	-0.28	MS	0.53
G	H	FS	2.82	S	-0.04	WS	0.46	VFS	3.04	CS	-0.14	WS	0.42	FS	2.83	CS	-0.14	WS	0.48	FS	2.82	S	-0.09	WS	0.46
G	M	FS	2.92	S	-0.04	MWS	0.5	VFS	3.05	CS	-0.19	MWS	0.53	FS	2.92	SCS	-0.35	MWS	0.57	FS	2.9	CS	-0.3	MWS	0.5
G	L	VFS	3.07	S	-0.07	MWS	0.54	VFS	3.02	CS	-0.23	MWS	0.54	FS	2.82	SCS	-0.32	MWS	0.7	FS	2.76	SCS	-0.4	MS	0.7
H	H	FS	2.99	S	-0.04	MWS	0.51	VFS	3.04	CS	-0.11	WS	0.42	FS	2.99	CS	-0.2	WS	0.46	FS	2.79	C	-0.13	WS	0.49
H	M	VFS	3.02	CS	-0.12	MWS	0.5	FS	2.92	S	-0.07	MWS	0.5	FS	2.79	CS	-0.3	MS	0.72	FS	2.99	CS	-0.26	WS	0.47
H	L	VFS	3.03	S	-0.08	MWS	0.56	FS	2.91	S	-0.05	MWS	0.51	FS	2.84	CS	-0.22	MWS	0.56	FS	2.91	SCS	-0.38	MWS	0.57

III.1.3 *Beach Morphodynamics*

According to Dean's dimensionless parameter (Ω), Surf scaling index (ε) and beach profiles also, the morphodynamic state of Dois Rios beach ranged from intermediate low tide terrace to reflective (Table 4; Figure 3). Although both parameters showed slight differences in each transect classification, we decided to adopt the Dean's dimensionless; which were the most precise for Dois Rios beach for classification matters and both of the parameters for terms of multivariate analysis. As a consequence of storm events, the beach was in a low tide terrace stage in May/01 (except transect H). Two months latter (July/01), a high hydrodynamics still prevails, although we could note a recovering stage as wave height was lower. At this time, the most exposed transects for that wave climate on the NE site (B and C) remained in a low tide terrace stage whereas the other ones turned to a reflective stage. A lower hydrodynamic condition occurred in Nov/01 (spring season). At this period, the Central transects (D and E) were in a low tide terrace stage as they were at the most exposed site for NE swells, as well as the remaining beach was in a reflective stage. As a reflection of the lower hydrodynamism, the whole beach was in a reflective stage in Jan/02. We could observe the occurrence of an accretionary sequence in Dois Rios beach from low tide terrace to a reflective stage, as wave height was in a decrease from May/01 to Jan/02 (Table 2). Regarding morphodynamics, some considerations must be done: In general, Dois Rios beach have two types of reflective transects (i) low profile with fine to very fine sands (F, G and H); (ii) steep profile with fine sands with a relative greater coarser content (A, B, C, D) and (iii) steep profile with fine to very fine sands (E). Besides, assessing the temporal variation of the transects, we could observe that transect A could shift to lower profile with coarse sands and transect E shift to steeper profile with fine sands with a greater coarser content. According to Short (2000), headlands, rocks, reef and structures will all impact the beach and surf zone through their influence on wave refraction and attenuation, and by limiting the development of longshore currents, rips and rip feeder currents. Considering this statement, we believe that Dois Rios beach also have some characteristics that might be influencing it morphodynamics: (i) the boundary headlands and beach curvature that produce a long-shore gradient in wave height, where NE and Central sites are always more exposed than NE extreme, SW and SW extreme sites (Figure 1); (ii) the presence of Barra Pequena and Barra Grande streams (Figures 1 and 2); the first acting as constant supply of coarse sands to transect A (NE extreme site) and the latter a constant supply of fine sands to transect H (SW extreme site); (iii) the presence of the Armação islands in front of transect A, acting as a natural obstacle to onshore/offshore transport and (Figure 2); (iv) the formation of a rip channel in front of transect E, which could give place to a rip current action, and might also act as a lowering wave action by its higher local depth (Figure 5).

Table 4 - Morphodynamic parameters of each transect along the four months studied.
D Dean's dimensionless parameter; S Surf scaling parameter; D state Morphodynamic state after Dean's dimensionless parameter (LTT Low Tide Terrace; R Reflective) (Wright *et al* 1985).
(* absent data)

	May-01			Jul-01			Nov-01			Jan-02		
Transect	D	S	D state	D	S	D state	D	S	D state	D	S	D state
A	1.69	*	LTT	0.73	0.72	R	0.66	1.30	R	0.67	0.08	R
B	1.73	4.63	LTT	2.02	1.82	LTT	1.33	2.89	R	0.93	1.82	R
C	1.71	5.67	LTT	1.52	3.78	LTT	1.41	2.20	R	0.94	1.58	R
D	1.95	4.69	LTT	1.12	3.23	R	1.68	2.60	LTT	1.03	2.74	R
E	1.95	5.66	LTT	1.20	2.20	R	1.87	3.56	LTT	1.07	3.08	R
F	1.58	3.79	LTT	1.23	2.55	R	0.98	1.56	R	0.93	1.56	R
G	1.58	3.88	LTT	1.22	2.15	R	1.03	1.51	R	0.91	1.47	R
H	1.23	0.89	R	0.96	0.69	R	1.06	0.16	R	0.95	0.32	R

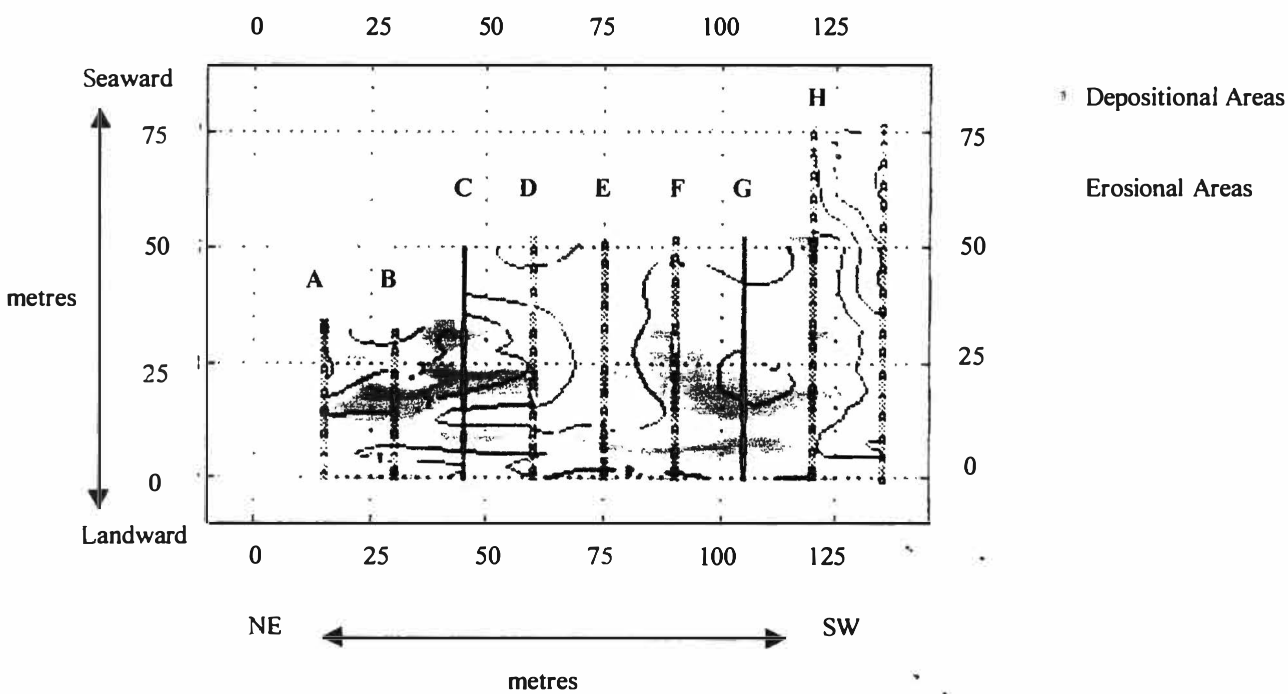

Figure 5 – Map of Dois Rios beach, showing topographical differences between two following summer periods (february/1999 to december/2000). The arrow and circle shows a great erosional area at transect E, which might be a rip channel formation. (Modified from GEDis data bank).

II.2 *S. squamata Distribution*

III.2.1 *Species Density – Spatial-Temporal Distribution*

Two-way ANOVA revealed significant differences in *S. squamata* long-shore distribution (along transects; F= 18.09; P<0.05) (Figure 6). A general trend was observed when samples from all months were analyzed together. Two major groups were formed: Group 1 was composed by A, B, C and D transects and was characterized by coarser sediments content, high waves height (except for the protected transect A) and low *S. squamata* densities. Group 2 were composed by transects E, F, G and H and was characterized by finer sediments content, low waves height (except for the exposed transect E) and high densities of *S. squamata* species (Figure 6).

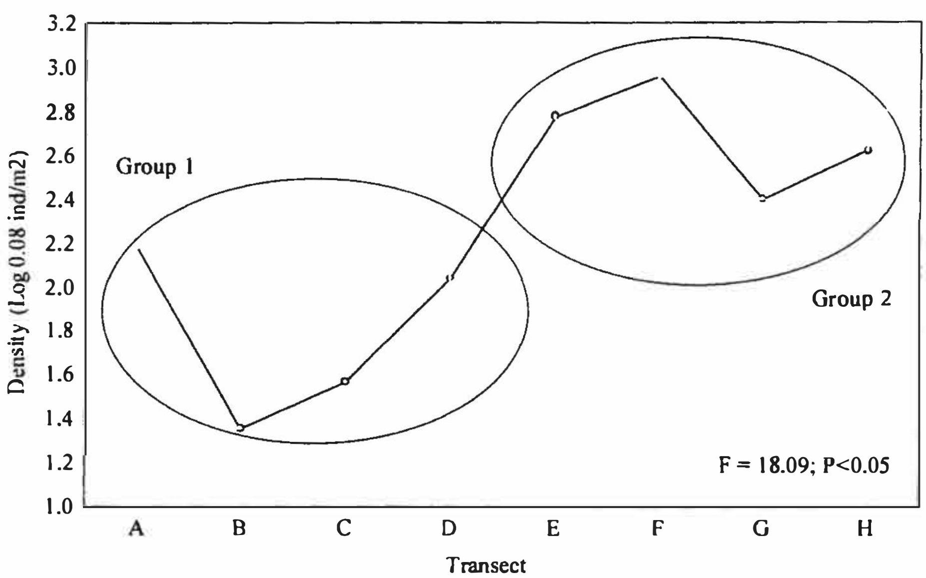

Figure 6 - *S. squamata* density variation along-shore over the four months studied.

Here, we could observe that the central exposed site of Dois Rios supported transects with a different behavior, as transect D seems to be more influenced by high wave processes and thus have a similar behavior as NE exposed site than transect E, which behaves like transects located at the more sheltered SW site. In general, at a small scale analysis (i.e each transect), we observed that inside Group 1, transect A recorded highest *S. squamata* densities followed by transects D, C, B, respectively. In Group 2, transect F recorded the highest values followed by transects E, H, G, respectively (Figure 6).

However, this trend was not a rule for each month analyzed, as we could observe a slight variability inside each group at each month. (Figure 7).

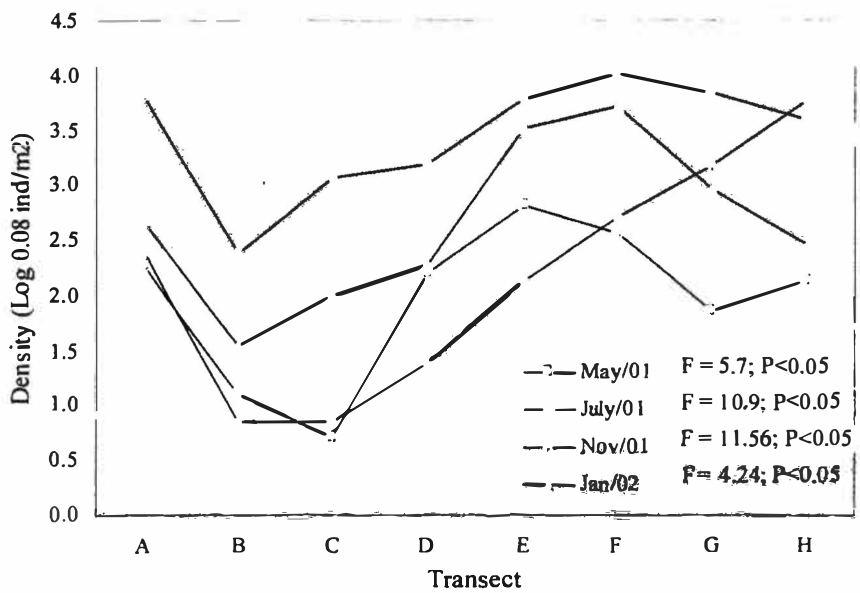

Figure 7 - *S. squamata* density variation along-shore over each month surveyed.

Medium intertidal zone have higher densities than low and high intertidal, respectively, as significant differences on across-shore distribution were detected (F=22.31; P<0.05) (Figure 8). During the storm event (May/01) the lowest and even null density values of *S. squamata* were recorded on the high intertidal zone. However, during low hydrodynamics (Nov/01 and Jan/02) high densities of this species were recorded within this zone. (Figure 9). *S. squamata* population tended to behave as the same way both along and across-shore at Dois Rios beach, except during high hydrodynamics (May/01 and July/01), where differences in high intertidal zone occurred. No significant differences between long-shore and across-shore interactions were recorded (F= 1.29; P>0.05).

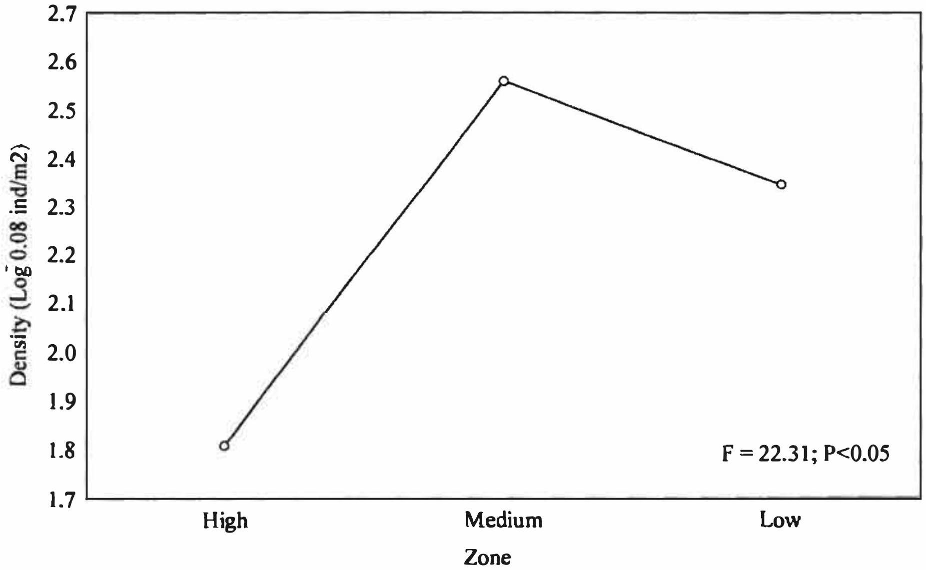

Figure 8 - *S. squamata* density variation across-shore over the four months studied.

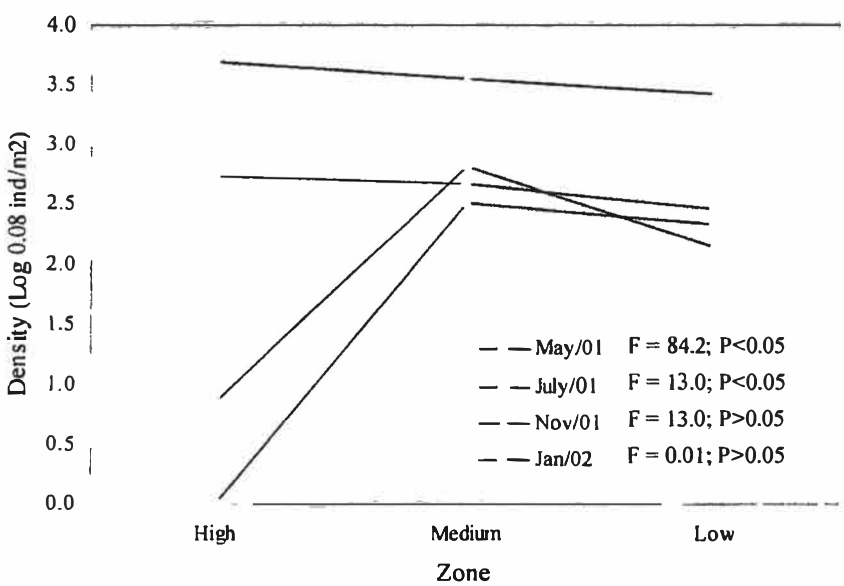

Figure 9 - *S. squamata* density variation across-shore over each month surveyed.

S. squamata temporal distribution showed significant differences. Time variation recorded high F-ratio values ($F=82.17$; $P<0.05$) (Figure 10), showing its great influence on spatial trends both along- and across-shore ($F= 5.03$; $P<0.05$; $F= 12.49$; $P<0.05$). Highest density values were recorded in low hydrodynamic conditions of Nov/01 and Jan/02 whereas the lowest were accounted in highest hydrodynamics which occurred in May/01 and July/01. Three-way ANOVA revealed no significant differences among interactions along-shore, across-shore and time (F=1.05; P>0.05).

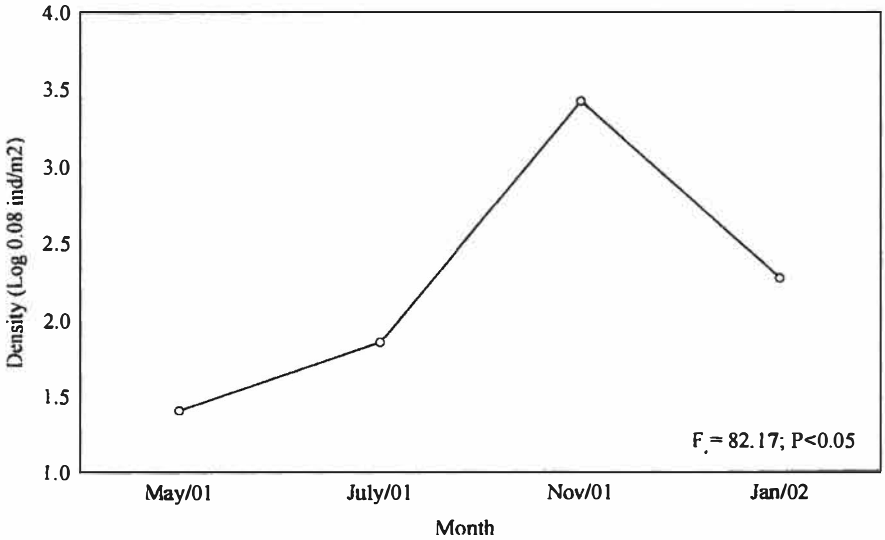

Figure 10 - *S. squamata* temporal density variation.

III.2.2 *Species Body Size – Spatial-Temporal Distribution*

S. squamata population structure was unimodal in all samples, in which the overall body size ranged from 3 to 32 mm (Figure 11).

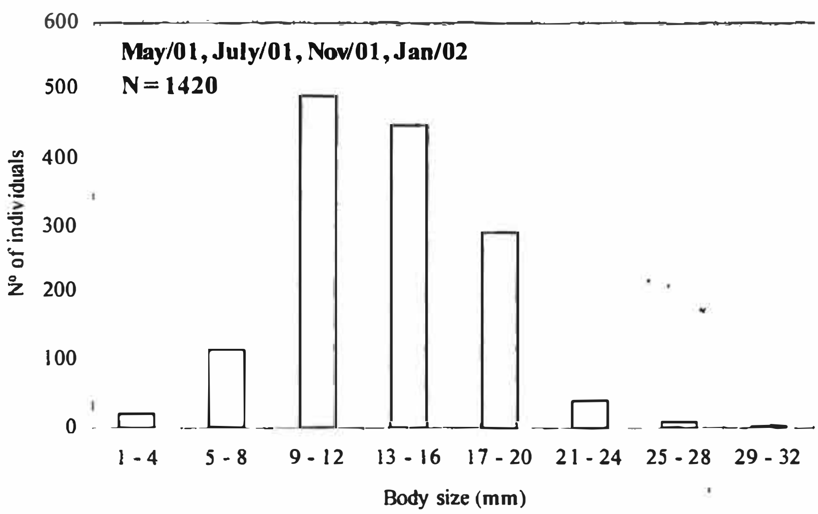

Figure 11 - Size-frequency distributions of *S. squamata* species at Dois Rios beach along the 4 months surveyed.

Two-way ANOVA also revealed significant differences in along-shore distribution of *S. squamata* body sizes (F= 52.16; P<0.05). In the same way as we observed for species density, a general trend was observed when samples from all months were analyzed together. In this case, three major groups were formed: Group 1 were composed by B, C and D transects and was characterized by coarser sediments content, high waves height and large *S. squamata* body sizes. Group 2 were composed by transects F, G and H and was characterized by finer sediments content, low waves height and small *S. squamata* body sizes. Group 3 were composed by transects A and E which did not form a cohesive group in respect to abiotic factors (Figure 12). Transect A were characterized by coarser sediments and low waves height whereas transect E were characterized by finer sediments and high wave height. At these transects, intermediate values of *S. squamata* body sizes were recorded. (Figure 12).

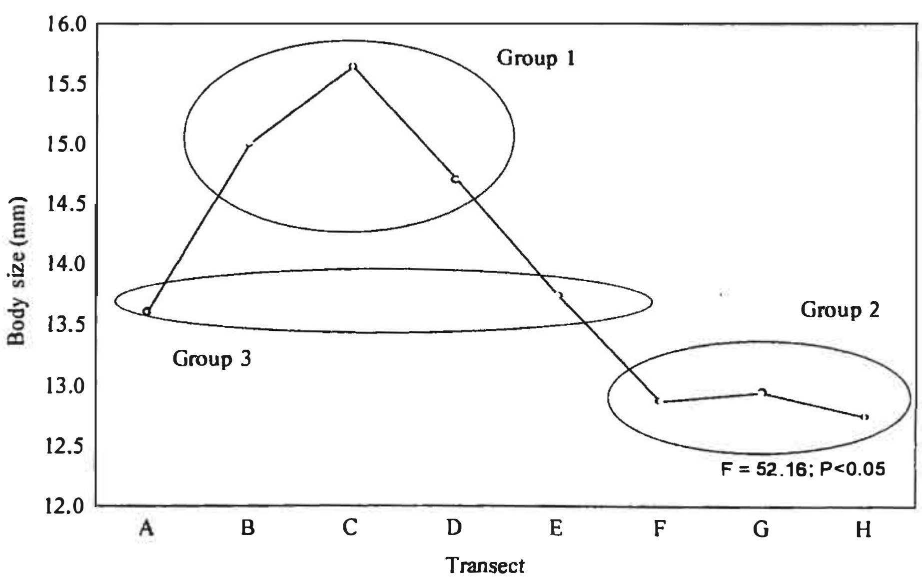

Figura 12 – S. squamata body size variation along-shore over the four months studied.

At a small scale analysis we observed that inside Group 1, transect C recorded highest *S. squamata* body sizes followed by transects B, D respectively. Inside Groups 2 and 3, *S. squamata* body sizes did not show a great variation and tended to be similar (Figure 12). However, as we could observe for density parameter, this trend was not a rule for each month analyzed, as we could observe a slight variability within and among groups at each month (Figure 13).

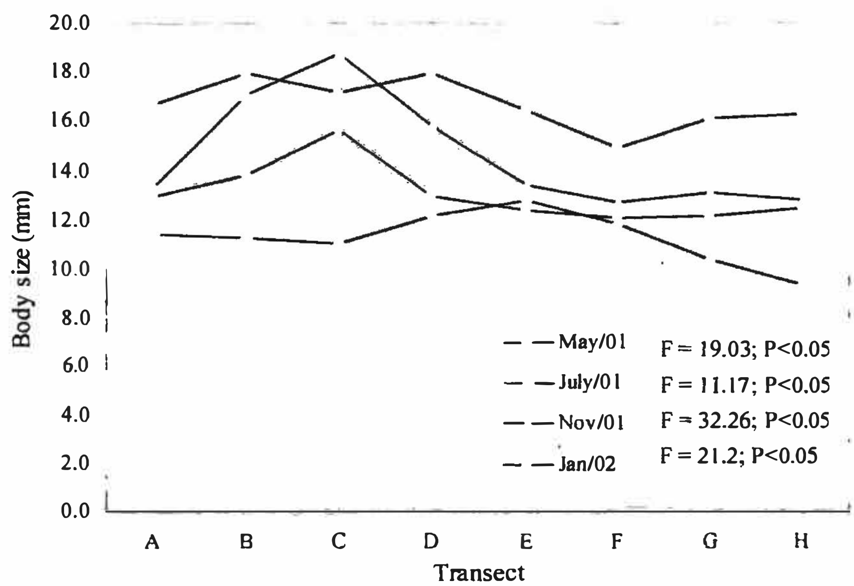

Figure 13 - *S. squamata* body size variation along-shore over each month surveyed.

Significant differences were also observed on across-shore distribution (F=100.48; P<0.05). High intertidal zone recorded largest body sizes while medium intertidal, the intermediate, and low intertidal the lowest (Figure 14). As a consequence of the lowest and even null densities of *S. squamata* recorded in May/01, medium intertidal zone accounted for the largest body sizes in that period (Figure 15). Interactions between along-shore and across-shore were also significant (F= 8.04; P<0.05).

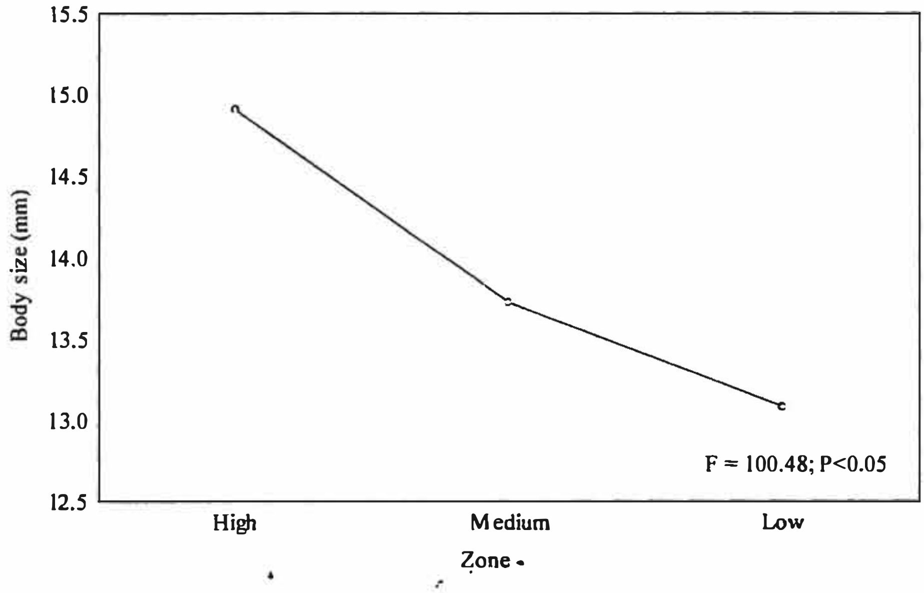

Figure 14 – *S. squamata* body size variation across-shore over the four months studied.

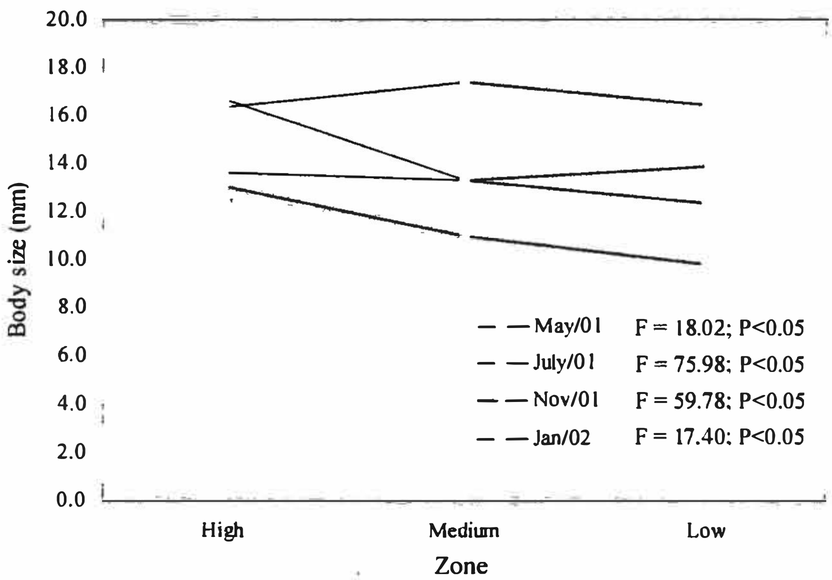

Figure 15 - *S. squamata* body size variation across-shore over each month surveyed.

S. squamata body size temporal distribution showed significant differences. Time variation recorded high F-ratio values (F= 467.99; P<0.05) (Figure 16), showing its greater influence on spatial trends both along- and across-shore (F= 14.50; P<0.05; F= 33.55; P<0.05). The Largest (32 mm) and the smallest (3 mm) body sizes were recorded during high hydrodynamic periods of May/01 and July/01, respectively (Figure 17). Size-frequency distribution of the population indicated a main recruitment period in July/01, although such recruitment was not reflected in a density increment in this period (Figures 16 and 17). Intermediate body sizes (9 to 16 mm) were most observed during low hydrodynamic periods (Nov/01 and Jan/02) (Figure 17). Three-way ANOVA revealed significant differences among interactions long-shore, across-shore and time (F=9.54; P<0.05).

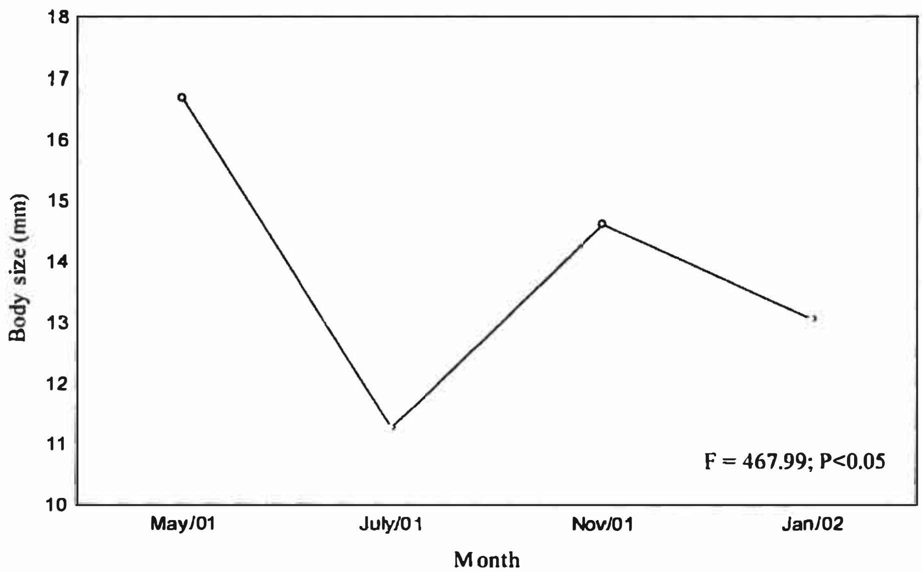

Figure 16 - *S. squamata* temporal body size variation

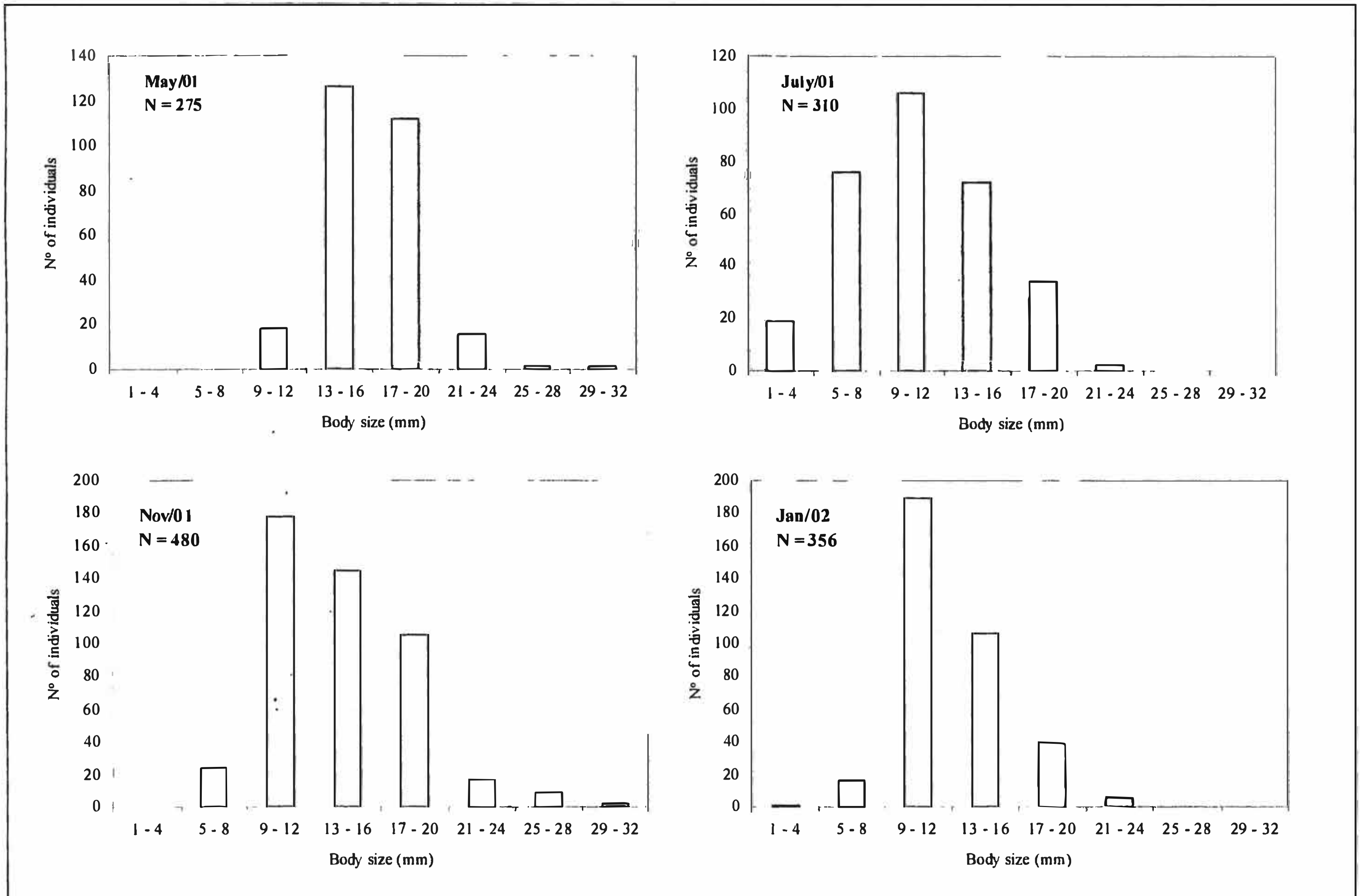

Figure 17 - Size-frequency distributions of *S. squamata* species at Dois Rios beach along each months surveyed.

III.2.4 *Multivariate Analysis*

The first two components obtained from PCA accounted for 58.56% of total variation in *S. squamata* distribution (Figure 18). The first component explained 31.07% of the variation and was related mainly to hydrodynamical factors. This component showed a negative relation with density, small body sizes and in a lower extent to positive degree of body size assimetry (left to the main axis). A positive relation was observed with large and mean body sizes, steep slopes, fine skewed sands and low tide terrace to reflective coarse sand morphodynamic stages (right to the main axis). Largest *S. squamata* body sizes were observed at the more exposed sites, where could be noticed the relationship between this species and slope and morphodynamic beach state also. *S. squamata* largest body sizes with negative degree of assimetry were associated to medium intertidal zones of the NE extreme and central sites (transect E). Thus, intermediate to large *S. squamata* body sizes were mainly deposited in the swash zone of these areas, in agreement with the sediment statistics (coarse skewed). Smaller densities of *S. squamata* were also associated to the more exposed sites at Dois Rios.

The second component explained 27.49% of the variation and was related mainly to sediment granulometry factor. This component showed a relation with well sorted and coarse sands (positive to the main axis) to mean particle size and fine sands (negative to the main axis). Here, the biotic variables were plotted near the central position of this axis, showing that particle size parameters did not explain the spatial-temporal variation of *S. squamata* population along Dois Rios beach.

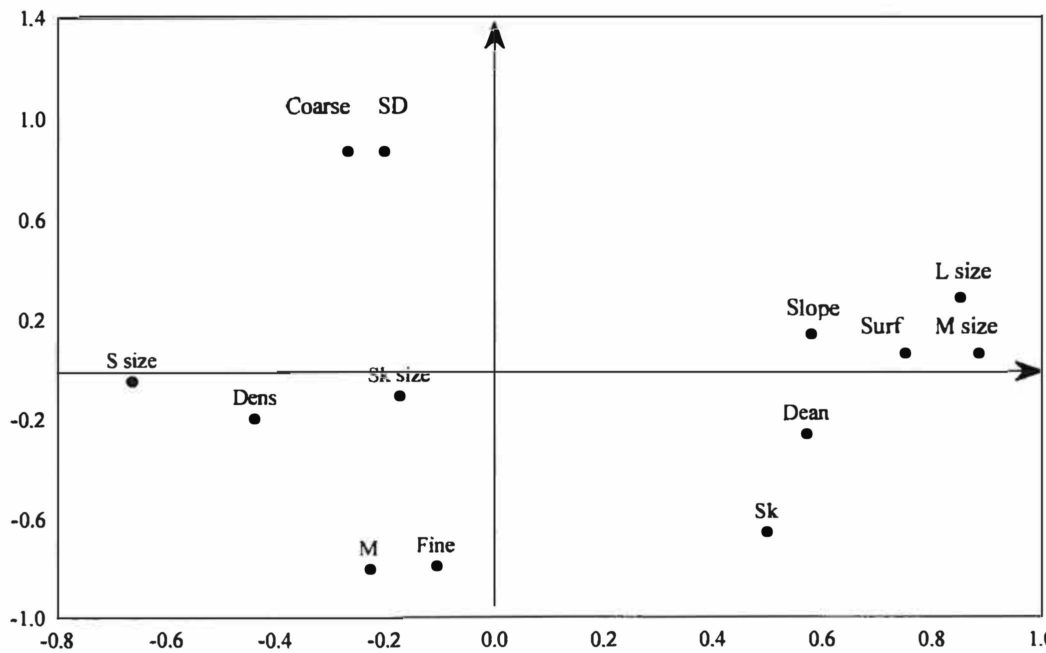

Figure 18 - Plot of two factorial plan of the Principal Component Analysis (PCA). *Dens S. squamata* density; *S size S. squamata* small body sizes; *L size S. squamata* large body sizes; *M size S. squamata* mean body size; *Sk size S. squamata* lenght skewness; *M* Mean particle size; *Coarse* Percentage of coarse sands (pebble + very coarse sand + coarse sand); *Fine* Percentage of fine sands (fine sand + very fine sand); *SK* Sediment skewness; *SD* Sediment standard deviation; *Slope*; *Dean* Ω morphodynamic state; *Surf* ε morphodynamic state.

IV. DISCUSSION

IV.1 *The Beach*

IV.1.1 *Waves, Slope and Sediment size*

Sand beaches are a product of waves interacting with a sandy bed at the shoreline (Short and Wright, 1983). The zone of interaction begins at wave base and extends shoreward across the nearshore and surfzone to the upper limit of swash action. The extent and nature of this zone is dependent on two parameters; the level of wave energy which controls the depth of wave base and limit of swash action; and sediment size which influences sediment transport and beach gradients (Short and Wright, *op cit.*). Along the four months sampled, Dois Rios beach morphology revealed a close interaction between wave action, sediment size and slope parameters, showing an increasing gradient of exposure from the SW sites towards to the NE. In general, the most exposed sites (high waves) exhibited longer wave period, steeper profiles and higher coarse sediment content than sheltered ones. However, regarding mean particle size parameter, transect A have high coarse sediments content although is placed at a sheltered site. This exception occurs due to the constant supply of coarse sediments from Barra Pequena stream (Bispo, 2002).

IV.1.2 *Sediment Transport*

Sediment analysis parameters are one of the ways to understand sedimentary dynamics, as we could determine where sediments have been deposited and what processes have been occurring at a given place (Suguio, 1973; Buchanan, 1984). Sediment particles could have a higher degree of assimmetry and scatter when it is going to be deposited on its own transport direction (Suguio, *op cit.*). Skewness and standard deviation sediment statistical parameters also reported us the dynamics occurring at Dois Rios beach, which frequently recorded coarse skewed sediments, showing that the selective transport is predominant in its embayed beach. However, under the storm event of May/01 sediments were symmetrical almost all along the beach, suggesting that an one-directional seaward transport were occurring, probably as a consequence of the great waves energy condition. Besides, the coarse skewed sediments recorded in transects A and B (NE extreme and NE site) under this event could be a consequence of a great coarse sands drainage from Barra Pequena stream, probably as a consequence of the storm event in that occasion.

Well sorted sediments were common in Dois Rios beach. The one-directional seaward transport that occurred in May/01, led to a great transport of sediments for most of the beach. However, differences observed in NE sites (discussed above) were also stated by standard deviation parameter, as sediment particles from transects A and B were moderately sorted in that event. In the same way, the one-directional landward transport that occurred in Jan/02, as a consequence of the depositional condition (low waves; reflective beach state) also led to a great transport of sediments for the entire beach The selective transport pattern were evident in July/01, as we could observe an increasing gradient of standard deviation parameter to SW direction (more sheltered site), showing a transport of particles towards SW sites. In Nov/01, differences in standard deviation parameter stated for transects A and E, could also point to the influence of Barra Pequena stream to the NE extreme site and also to a probable local circulation that occurs nearby the central transect E, might a consequence of a rip current action, associated to the rip channel, observed in front of transect E and thus led to a transport of sediment particles. Short (2000), mentioned that the rip currents velocity vary tremendously according to waves climate and tides, as it may even double their speeds under high waves and falling tides also.

IV.1.3 *Beach Morphodynamics*

Sequential changes (erosion-accretion) that occurs on the beaches are all dependent on the changes in wave height, period and grain size (Short, 1979). In nature, most beaches never, and none regularly, go through the entire dissipative-reflective sequence, rather most oscillate between two or three beach states (Short, *op cit.*). According to Dean's dimensionless parameter, Dois Rios beach state oscillates between low tide terrace to a reflective state in respect to waves climate and grain size. Wright *et al.* (1985) discussed the applicability of Dean's values to predict the long-term variation of the beach state. These authors found that this parameter provides a successful means of prediction due to its precision. All transects along Dois Rios beach showed a morphodynamic state in agreement with wave exposure in a spatial-temporal scale. Along the four months sampled we could observe that the more exposed sites for the respective wave climate were in a more erosional state. In this same way, we could also observe the accretionary sequence which was occurring all along the beach that reached the fully reflective state in Jan/02. Although Dois Rios acts like a wave dominated beach, it is not a rule, nor a true statement. The rocky headlands present on embayed beaches can have a major influence on beach planform, sediment transport and morphodynamics (Short, 2000). Wright *et al* (1979) stated that reflective beaches are favoured by a combination of deeply embayed or semi-protected environments, linear, slowly shoaling nearshore (seaward of break) profiles and relatively coarse beach material. These authors also argued that in these sheltered environments, low morphodynamic state parameters can occur besides the presence of fine to medium sand. Considering these statements, the reflective state of Dois Rios is characteristic of an embayed beach, with fine sediment particles and low waves. Barra Pequena stream and Armação islands seems to be responsible for the maintenance of the steep beach face and low morphodynamic parameter state in the NE extreme site, due to the constant supply of coarse sands necessary to form the sub-aerial beach and to the islands protection, thus lowering wave conditions (Bispo, 2002). Wright *et al* (*op cit.*) observed that the maintenance of the reflective state is also set by sediment supply alongshore from estuaries and rivers, in which the grain size of a river-supplied sediment affects the potential reflectiveness and the modal character of the inshore. In contrast, highly reflective beaches rely for their existence on their ability to reduce net offshore sediment flux by reflecting incident waves. The Armação islands and the rip channel seems to have a strong influence in transects A and E behavior; being responsible for a characteristic hydrodynamic in these areas. Muehe (1995) recorded that the direction, velocity and volume of sediments transported alongshore are dependent on the angle formed between the breaker waves and the shore line. In this way, dependent on the predominant swell, waves diffraction caused by Armação islands, could make a stronger longshore current and therefore an increase in hydrodynamics nearby the transect A. The rip channel located in front of transect E might be responsible for lessen the high wave action at this site, making it comparable to transects located at the SW sheltered sites. According to Short (2000), rips are distinguished by the presence of a deep rip channel, with less or no wave breaking compared to adjacent bars and to a disturbed water surface owing to current and converging currents. In fact, the possible presence of a rip current nearby transect E might be responsible for a transport of sediment particles as a consequent characteristic circulation pattern in this site.

IV.2 *S. squamata Distribution*

IV.2.1 *Spatial Distribution*

S. squamata densities and body sizes varied at spatial and temporal scales both along- and across-shore in the present study. Differences in *S. squamata* long-shore distribution occurred mainly due to beach morphodynamics, where species density variable increased from erosional (low tide terrace) to depositional (reflective) beach states and species body size increased from depositional to erosional ones. Several works also pointed to the variation in macrofaunal distribution along different beach states (McLachlan, 1983; 1990; Mc Ardle and McLachlan, 1991; 1992; Jaramillo and McLachlan, 1993), in which dissipative towards reflective conditions results in a decrease in macrofaunal assemblages abundance, in contrast with body size variable, which increases towards the reflective beach state. Mc Ardle and McLachlan (1991) classified reflective and dissipative beaches by various aspects of swash climate and physical parameters, such as slope and Dean's values. For these authors, reflective beaches have short frequent swashes, a narrow intertidal zone, a high frequency of swashes crossing the effluent line (line which separates saturated and unsaturated sand) and a high percentage of upwash above the effluent line. On the other hand, dissipative beaches have reverse conditions, i.e. long, infrequent swashes and few effluent line crossings. However, this classification scheme is on the classical basis that reflective beaches have high coarser sand content and steeper profiles, whereas dissipative beaches have high finer sand content and gentler profiles (i.g. McLachlan, 1983), which is not the case of Dois Rios beach. In this study, we have a reflective condition with fine sands and gentler profile that is much closer to the dissipative state cited above. As the same way, the low tide terrace condition that occurs in Dois Rios beach (i.e. coarser sands and steeper profiles) is much closer to the reflective state mentioned. For this reason, the results found in this study seems to be in some way reversed, in which high densities and small *S. squamata* body sizes are found in reflective states. A recent study about surf zone faunal assemblages (Barros et al, 2002) also reported a more abundant macrofauna in reflective than in intermediate (transverse bar and rip) beach states. In this study, the authors suggested that macrofaunal assemblages at reflective beaches are more stable than at intermediate, due to the lowest wave-action and more stable profile found in the reflective state.

Exceptions occurred in *S. squamata* long-shore distribution which could not be explained by the morphodynamic state per se, seems to be related to the influence of the Armação islands and to the rip channel, both responsible for changes in hydrodynamic patterns. The higher hydrodynamics nearby the transect A, seemed to be caused by an increase in the wave energy due to the diffraction in the islands at this site. Besides, lower hydrodynamics nearby the transect E, seemed to be caused by the presence of the rip channel, thus attenuating the high wave action at this site. For these reasons, low *S. squamata* densities are found at the sheltered, reflective transect A whereas high densities are found at the exposed, intermediate transect E. Mc Lachlan and Hesp (1984) investigating faunal responses to beach morphology and water circulation dynamics, have shown that bivalves species (*Donax faba*; *Donacilla augusta*) are primarily located in cusp bays of a reflective beach in Australia. These authors show that this pattern of distribution is associated to the net movement of swash and passive drift that occur in those areas of flatter slopes and slower swash speeds.

In relation to body size variable, *S. squamata* intermediate lengths were found within the influence of Armação islands and the rip channel. Multivariate analysis also pointed to the association between intermediate body sizes (positive degree of body size assimetry) and coarser skewed sands. These results shows the great importance of passive transport of individuals, by waves and currents, in determining *S. squamata* distribution, which accounts for larger body sizes at exposed sites; smaller body sizes at sheltered; and intermediate to large body sizes at characteristic hydrodynamical places where the increase in hydrodynamic forces (e.g. waves energy and rip currents) probably led to a selective transport of sediments and thus in *S. squamata* body sizes. In fact, as were described before, *S. squamata* distribution is related to skewness sediment statistical parameter, which is reflected in sediment transport characteristics. Giménez and Yannicelli (1997) discussed that the passive transport by swash could be a more important factor in determining the small sized organisms distribution. Brazeiro and Defeo (1996) postulated two types of species size related processes that could be explaining the organisms distribution: an active movement that may be exhibited by large species and a passive transport in which small species may be subjected. McLachlan (1983) related the species intraspecific zonation of size classes to two possible factors: (i) the differential sorting of the sizes in the swash or (ii) the active migration to areas differentially suitable to the organism at different life stages. *S. squamata* body size across-shore distribution showed this differential sorting of sizes, in which larger body sizes were found at the top of the swash zone, intermediates at the middle, where a constant swash activity was taking place, and the smaller body sizes at the lower swash zone. Many authors point out to a probable active migration of the organisms across- and along-shore beaches, suggesting that species responds to changes in physical conditions, most notably the degree of saturation of the sand (Cubit, 1968; Bally, 1983; McLachlan, 1983; Donn, Jr. et al, 1986; Jaramillo *et al*, 1993; Dugan and McLachlan, 1999). Although we could observe that *S. squamata* higher densities were found at the place where a constant swash activity were occurring (middle intertidal), we prefer not to relate this distribution to an active preference for suitable habitats (e.g. food resources; fluidity of the sand; tidal migrations) than to passive hydrodynamic sorting of these small sized organisms. Shimizu (1997), in a dissertation about population dynamics of *S. squamata* species on a sand beach, observed this same differential sorting of species size across-shore beach, where largest body sizes were located at a higher zone than the smallest. This author also evaluates the swash activity for being one of the factors responsible for *S. squamata* intraspecific zonation.

Although a correlation between sediment size and *S. squamata* distribution were not found, here we must consider the influence of Barra Pequena and Barra Grande streams, which largely contributes to differences in sediment size distribution along Dois Rios beach. The organism – sediment relationship has been largely studied by many authors. In a review, Snelgrove and Butman (1994) concluded that organism distribution might be evaluated in relation to the hydrodynamic and sediment transport processes that are in fact responsible for sediment distributions. Hall (1994) also supported this statement, pointing that correlations between sediment type and faunal communities are usually restricted to analysis of the static pattern of sediment granulometry, largely ignoring the hydrodynamic environment in which the organisms live. In the present work, we have been largely shown the relationship between *S. squamata* distribution and marine sediment transport, which is not necessarily related to the sediment size distribution along Dois Rios beach. The amount of stream drained sediment particles that comes from Barra Grande and Barra Pequena streams to Dois Rios beach, does not affect *S. squamata* distribution because it is intrinsically related to the hydrodynamic regime instead of the static pattern of sediment granulometry.

Differences between long-term (morphodynamic state) and short-term (sediment transport) changes in Dois Rios hydrodynamics could be observed by interactions between along- and across-shore *S. squamata* distribution. In relation to density variable, the morphodynamic state per se could satisfactory explain the distribution of the organisms, which exhibited the same distribution pattern all along the beach, respecting the influence of waves climate and slope over transects and zones. In contrast, *S. squamata* body sizes distribution along and across the beach were better explained by sediment transport, which shows a faster response to changes in hydrodynamics, as it was reflected in different patterns of distribution along transects and zones.

IV.2.2 Temporal Distribution

Many authors had been largely discussed the effects of seasonal changes of waves and swash climate in distribution and zonation pattern of sand beaches macrofauna (Dexter, 1979; 1984; McLachlan, 1983; Hall, 1994; Levinton, 1995; Giménez and Yannicelli, 1997). These authors attempted for the harsh physical climate caused by seasonal changes in the wind direction, responsible for drops in species density and also for a great variability in assemblages. In the present study, we could also observe lower *S. squamata* densities during the high hydrodynamic periods of May/01 and July/01. Hall (1994) mentioned that the shoal zone (seaward boundary by the limit of breaking waves) can be very wide during periods of storms, and sand (and also its associated macrofauna), can be held in suspension and be efficiently dispersed out to the seaward limit of the breaker waves and be moved alongshore. In a reverse condition, during low swells and calmer weather, this will tend to reward the movement and carry material back to the shore. In fact, during low period hydrodynamics, higher densities of *S. squamata* species were found at Dois Rios beach.

Tamaki (1987) compared the resistance to transport by wave action of several polychaete species on an intertidal sand flat, including three spionid species (*Spio filicornis*, *Rhynchospio glutaea*, *Prionospio Krusadensis*) and recorded that the distribution pattern of the adults along the tidal axis in the summer basically reflected the common distribution pattern of passive settling larvae. However, on winter and spring stormy days a difference occurred, especially in respect to juveniles (small sized) that inhabit the top 1.4 cm of the sediment layer and hence may be more susceptible to resuspension by waves. Once again, the discussion about the strategies that these organisms develop to avoid the washout by waves is attended. Santos (1991) compared the survival rate of two cohorts (group of individuals from the same species born in the same period) of *Scolelepis gaucha* species at a Brazilian sand beach under an erosional state, and observed that when organisms were large-sized, their tubes are able to dig deeper into the substrate and thus avoid being removed by physical forces. Levinton (1995) mentioned that in the winter, when much of the beach is eroded, intertidal invertebrates often migrate to subtidal parts of the beach, because the erosional forces are too great to allow them to maintain position. Evaluating *S. squamata* across-shore distribution, this species were not found at high intertidal zone during the storm period (May/01), being only at the middle and lower intertidal. However, here we do not related this behavior to a migratory cause, since we are dealing with a small sized and almost non-motile species which probably exhibits a distribution intrinsically related to the hydrodynamical forces. Short (2000) highlighted that the net result of erosion of the reflective beach state is the failure of the subaerial beach and its deposition usually at an attached bar or low tide terrace at the base of the beach, thus forming an erosive low tide terrace beach state. In this work, we have also stated the erosive low tide terrace state at Dois Rios beach during the storm condition, that were probably an erosion result of the previous reflective beach state which occurs during summer low-waves period. For this reason, as argued by Hall (1994), *S. squamata* individuals were probably washed up from the high intertidal beach, being dispersed out to the seaward limit of the breaker waves to an attached bar. Despite of the high hydrodynamics that still prevails in July/01, the lowering hydrodynamic condition allowed a reestablishment of *S. squamata* population at the high intertidal zone, by the landward movement of the sand onto the beach face.

Interactions between along- and across-shore distribution of *S. squamata* species, also point to the differences in waves climate, in which during high hydrodynamics, the population tended not to behave in the same way along transects and zones, just because of the low and also null densities recorded at the high intertidal. In respect to body size variable, although during the storm event we did not observe *S. squamata* individuals at the higher beach zone, the organisms inhabiting the middle and lower intertidal maintained the distribution size pattern, being larger at middle and smaller at lower intertidal.

Regarding the spatial *S. squamata* body size distribution, which increases from depositional (reflective) to erosional (low tide terrace) beach states, it would be expected, at a greater scale analysis, to found larger *S. squamata* individuals at the high hydrodynamic conditions of May/01 and July/01. Instead, larger body sizes were only found in May/01, whereas in July/01 we accounted for the smallest lengths registered in the study period. Analysis of the size-frequency data highlighted a recruitment period in July/01, thus the smallest body sizes. However, this recruitment was not related to any density increment, due to the high hydrodynamic condition, as discussed before. *S. squamata* population dynamics at Brazilian sand beaches have been evaluated by a few authors (Shimizu, 1997; Souza and Borzone, 2000). Since we did not surveyed monthly samples in this study, we could not identify more than one *S. squamata* recruitment (as were found for these authors), though we could also observe an inter-annual variations of abundance, a fact that could be related to a successful species recruitment. Santos (1991), mentioned that wind is the main factor driving *Scolelepis gaucha* larvae, which acts as passive particles along beaches of Southern Brazil. During planktonic development period, a sustained wind from one direction would tend to displace a population from its area of origin and probably cause a competition with their ecological equivalents. These results show that the hydrodynamical regime acts as main forces in structuring species distribution at a determinate area, neither as active selectors of length-frequency populations.

In this study, we could also estimate the importance of temporal variation in influencing the spatial patterns as could be stated by higher temporal F-ratio values. Seasonal shifts in waves climate give rise to a change in morphodynamic state and hydrodynamic patterns (as discussed in above topics), thus largely affecting the distributional spatial patterns of *S. squamata* in the beach. Differences between the long-term (morphodynamic state) and short-term (sediment transport) changes in Dois Rios hydrodynamics also influenced *S. squamata* density and body size spatial distribution when time variable were incorporated. This results show that physical factors, such as winds and waves, dictated by climate changes, controls the organisms distribution, which might be used as predictors of the morphodynamic state and sediment transport regime.

IV.2.3 Taxonomic Remark

S. squamata is a common sandy beach species with a large geographical distribution (Bolívar and Lana, 1987). It has been recorded for all seas, largely distributed along the North and Southwestern Atlantic coasts. However, it is possible that this large distribution may be a series of morphologically similar species (Souza and Borzone, 2000). Radashevsky (per. comm.) mentioned the long-lasting taxonomic controversy of this species and supported the existence of a sibling or pseudo-sibling species complex being hidden under the name of *S. squamata* along Brazilian Southwestern coast. Radashevsky also argued the existence of more than one species of the genus *Scolelepis* distributed along the same beach area. Considering this statement, we analyzed the size-frequency data of 1420 specimens measured, which were distributed all along Dois Rios beach. Since unimodal population structure size was found in this study along the four months surveyed, and no taxonomic differences were observed, it is unlikely that we are dealing with more than one *Scolelepis* species. However, in relation to the taxonomic controversy of *S. squamata*, further studies are necessary.

V. CONCLUSION

The close association observed among *Scolelepis* cf. *squamata* spatial-temporal distribution, morphodynamic beach state and sediment transport, supports the hypothesis that this species density and body size distribution might be used as a tool for correlating beach morphodynamics, sediment transport and hydrodynamics in oceanic sandy beaches.

VI. ACKNOWLEDGEMENTS

We would like to thank Dr. Elianne P. Omena, Oc. Luciana Bispo and Oc. Gustavo Matsuda for the great help in all stages of this work. We are also grateful to students from GEDiS/UERJ (Grupo de Estudos em Dinâmica Sedimentar/Universidade do Estado do Rio de Janeiro) for helping in field and laboratory work. This paper is a compilation of Gabriela Neves Msc. thesis which was both developed at MN/UFRJ (Museu Nacional/Universidade Federal do Rio de Janeiro) and at Geological Oceanography Laboratory/UERJ (Universidade do Estado do Rio de Janeiro), Brazil. Technical and logistical support was provided by CEADS/UERJ (Centro de Estudos Ambientais e Desenvolvimento Sustentável/ Universidade do Estado do Rio de Janeiro) and IB/UFRJ (Instituto de Biologia/ Universidade Federal do Rio de Janeiro). Financial support was provided by FAPERJ (Fundação de Amparo a Pesquisa do Estado do Rio de Janeiro) – Process: E-26/172269-2000 (FAP – APQ1).

VII. REFERENCES

Baly, R.1983. Factors affecting the distrubution of organisms in the intertidal zones of sandy beaches. In: Sandy beaches as Ecosystems. eds. McLachlan,A. & Erasmus, T., W.Junk Publishers, The Hague. pp. 391-380.

Barros, F., Underwood, A.J. and Lindegarth, M. 2002. A preliminary analysis of the structure of benthic assemblages of surf zones on two morphodynamic types of beach. Journal Marine Biology Associated United Kingdom 82: 353-357.

Bispo, L. 2002. Avaliação da Morfodinâmica da Praia de Dois Rios – Ilha Grande, RJ, em condições de Alta, Moderada e Baixa Hidrodinâmica. Monografia de Bacharelado. Universidade do Estado do Rio de Janeiro. Instituto de Geociências. 106p.

Bolívar G.A. and Lana, P.C. 1987. Spionidae (Annelida: Polychaeta) do litoral do Estado do Paraná. Nerítica 2: 107-148.

Borzone, C.A. and Souza, J.R.B.1997. Estrutura da macrofauna bentônica no supra, meso e infralitoral de uma praia arenosa do Sul do Brasil. In: Ecologia de Praias Arenosas do Litoral Brasileiro, Oecologia Brasiliensis, III. eds. Absalão, R.S. and Esteves, A.M., Rio de Janeiro, UFRJ, pp. 197-212.

Brazeiro, A and Defeo, O. 1996. Macrofauna zonation in microtidal sandy beaches: is it possible to identify patterns in such variable environments? Estuarine and Coastal Shelf Science 42: 523-536.

Buchanan, J.B. 1984. Sediment analysis. In Methods for the study of marine benthos. eds. Holme, N.A and McIntyre, A.D., Oxford, Blackwell Scientific Publications, pp. 41-65 pp.

Cubit, J. 1969. Behaviour and physical factors causing migration and aggregation of the sand crab Emerita analoga (Stimpson). Ecology 50: 118-123.

Defeo, O., Jaramillo, E., and Lyonnet, A. 1992. Community Structure and Zonation of the macroinfauna on the atlantic coast of Uruguai. Journal of Coastal Research 8: 830-839.

Defeo, O and Rueda, M. 2002. Spatial Strucutre, Sampling Design and Abundance Estimates in Sandy Beach Macroinfauna: Some Warnings and New Perspectives. Marine Biology 140: 1215-1225.

Dexter, D.M. 1979. Community structure and seasonal variation in intertidal Panamanian sandy beaches. Estuarine and Coastal Shelf Science 9: 543-558.

Dexter, D.M. 1984. Temporal and Spatial Variability in the Community Structure of the fauna for four sandy beaches in southeastern New South Wales. Australian Journal of Marine and Freshwater Research 35: 663-672.

Donn, T.E., Clarke, Jr. D.J., McLachlan, A., and Du Toit, P. 1986. Distribution and abundance of *Donax serra* Roding (Bivalvia: Donacidae) as related to beach morphology. I. Semilunar migrations. Journal of Experimental Marine Biology and Ecology 102: 121-131.

Dugan, J.E. and McLachlan, A. 1999. An Assesment of Longshore Movement in *Donax serra* Roding (Bivalvia: Donacidae) on an Exposed Sandy Beach. Journal of Experimental Marine Biology and Ecology 234: 111-124.

Folk, R.L. and Ward, W.C. 1957. Brazos river bay: a study in the significance of grain size parameters. Journal of Sedimentary Petrology 4: 101-121.

Giménez, L. and Yannicelli, B. 1997. Variability of Zonation Patterns in Temperate Microtidal Uruguaian Beaches with Different Morphodynamic Types. Marine Ecology progress Series 160:197-207.

Guza, R.T. and Inman, D.I. 1975. Edge waves and Beach cusps. Journal of Geophysical Research 87(21): 2997-3012.

Hall, S.H. 1994. Physical disturbance and marine benthic communities: Life in unconsolidated sediments. Oceanography Marine Biology Annual Review 32: 179-239.

James, R.J. and Fairweather, P.G. 1996. Spatial variation of intertidal macrofauna on a sandy ocean beach in Australia. Estuarine and Coastal Shelf Science 43: 81-107.

Jaramillo, E. and McLachlan, A. 1993. Community and Population Responses of the Macroinfauna to physical factors over a range of exposed beaches in south-central, Chile. Estuarine and Coastal Shelf Science 37:615-624.

Jaramillo, E.; McLachlan, A. and Coetzee, P. 1993. Intertidal zonation patterns of macroinfauna over a range of exposed sandy beaches in South Central Chile. Marine Ecology Progress Series 101: 105-118.

Levinton, J.S 1995. Tidelands and Estuaries. In Marine Biology: Function, Biodiversity, Ecology. ed. Levinton, J.S, Oxford, pp. 271-288.

Ludwig J.A. and Reynolds, J.F. 1988. Statistical ecology: a primer on methods and computing. Wiley, New York.

Masselink, D and Short, A.D. 1993. The effect of tidal range on beach morphodynamics: a conceptual model. Journal of Coastal Research 9: 785-800.

McArdle, S. B. and McLachlan, A., 1991. Sand Beach Ecology: Swash Factors Relevant to the Macrofauna. Journal of Coastal Research 8: 398-407.

McArdle, S. B. and McLachlan, A., 1992. Dynamics of the swash zone and effluent line on sand beaches. Marine Ecology Progress Series 76: 91-99.

McLachlan, A. 1983. Sandy Beach Ecology: a review. In: Sandy beaches as Ecosystems eds. McLachlan, A. and Erasmus, T., W.Junk Publishers, The Hague. pp: 321-380.

McLachlan, A. 1990. Dissipative beaches and macrofauna communities on exposed intertidal sands. Journal of Coastal Research 6: 57-71.

McLachlan, A. 1996. Physical factors in benthic ecology: effects of changing sand particle size on beach fauna. Marine Ecology Progress Series 131: 205-211.

McLachlan, A. and Hesp, P. 1984. Faunal Response to Morphology and Water circulation of a Sandy Beach with cusps. Marine Ecology Progress Series 19: 133-144.

Muehe, D. 1995. Geomorfologia Costeira. In: Geomorfologia: uma atualização de bases e conceitos. eds. Guerra, A.J.T and Cunha, da S.B., Rio de Janeiro, Editora Bertrand Brasil.pp. 253-308.

Omena, E.P. and Amaral, C.Z. 1997. Distribuição espacial de Polychaeta (Annelida) em diferentes ambientes entremarés de praias de São Sebastião (SP). In: Ecologia de Praias Arenosas do Litoral Brasileiro, Oecologia Brasiliensis, III. eds. Absalão, R.S. and Esteves, A.M., Rio de Janeiro, UFRJ, pp. 183-196.

Santos, P.J.P. 1991. Morphodynamical Influence of a Temporary Freshwater Stream on the Population Dynamics of *Scolelepis gaucha* (Polychaeta: Spionidae) on a Sandy Beach in Southeast Brazil. Bulletin of Marine Science, 48(3): 657-664.

Santos, P.J.P.1994. Population dynamics and production of *Scolelepis gaucha* (Polychaeta: Spionidae) on the sandy beaches of Southern Brazil. Marine Ecology Progress Series 110: 159-165.

Shimizu, R.M. 1997. Ecologia Populacional de *Scolelelpis squamata* (Muller, 1806) (Polychaeta: Spionidae) e *Callichirus major* (Say, 1818) (Crustacea: Decapoda: Thalassinidea) da Praia de Barequeçaba (São Sebastião, SP). Dissertação de Mestrado. Universidade de São Paulo. Instituto de Biociências. 49p.

Short, A.D. 1979. Three Dimensional Beach-Stage Model. Journal of Geology 87: 553-571.

Short, A.D. 2000. Beach Morphodynamics. Universidade do Vale do Itajaí, Santa Catarina, Brasil. 175p.

Short A.D. and Wright, L.D. 1983. Phisical variability of sandy Beaches. In: Sandy beaches as Ecosystems. eds. McLachlan, A. and Erasmus, T., W.Junk Publishers, The Hague. pp. 133-144.

Snelgrove, P.V.C. and Buttman, C.A. 1994. Animal-sediment relationships revisited: cause versus effect. Oceanography Marine Biology Annual Review 32: 111-177.

Souza, J.R.B. and Gianuca, N.M. 1995. Zonation and seazonal variation of the intertidal macrofauna on a sandy beach of Paraná State, Brazil. Scientia Marina, 59(2): 103-111.

Souza, J.R.B and Borzone, C.A. 2000. Population Dynamics and Secondary production of *Scolelepis squamata* (Polychaeta: Spionidae) in an Exposed Sandy beach of Southern Brazil. Bulletin of Marine Science 67(1): 221-233.

Suguio, K. 1973. Introdução a Sedimentologia. São Paulo, Editora Edgard Blucher. Editora da Universidade de São Paulo, 317p.

Tamaki, A. 1987. Comparision of resistivity to transport by wave action in several polychaete species on an intertidal sand flat. Marine Ecology 37: 181-189.

Veloso, V., Cardoso. R. and Fonseca, D.B.1997. Spatio-temporal characterization of intertidal macrofauna at Prainha Beach (Rio de Janeiro State) In: Ecologia de Praias Arenosas do Litoral Brasileiro, Oecologia Brasiliensis, III. eds. Absalão, R.S. and Esteves, A.M., Rio de Janeiro, UFRJ. pp. 213-225.

Veloso, V.G and Cardoso, R.S. 2001. Effect of Morphodynamics on The Spatial and temporal Variation on Three Sandy Beaches, Rio de janeiro State, Brazil. Journal Marine Biology Associated United Kingdom 81: 369-375.

Wright, L.D and Short, A.D. 1984. Morphodynamic Variability of Surf Zones and Beaches: A Syntesis. Marine Geology 56: 93-118.

Wright, L.D.; Chappell, J.; Thom, B.G.; Bradshaw, M.P. and Cowell, P. 1979. Morphodynamics of Reflective and Dissipative Beach and Inshore Systems: Southeastern Australia. Marine Geology 32: 105-140.

Wright, L.D., Short A.D. and Green, M.O. 1985. Short-term Changes in Morphodynamic states of beaches and surf zones: an empirical predictive model. Marine Geology 62: 339-364.

CONCLUSÃO GERAL

A variação espaço-temporal da densidade e do tamanho da espécie *Scolelepis* cf. *squamata* foi verificada tanto na escala longitudinal quanto na transversal ao longo da praia de Dois Rios. A morfodinâmica da praia de Dois Rios assim como o regime hidrodinâmico, mostraram ser fatores determinantes na distribuição da população ao longo da praia. No entanto, a variação da densidade esteve mais relacionada com a morfodinâmica em si, enquanto que a distribuição do tamanho mostrou uma maior relação com a hidrodinâmica e dinâmica de sedimentos. A resposta da variável densidade ao ambiente, ocorreu em macroescala, ou seja, quando foi observada a sua relação com a morfodinâmica, que se traduz pelas diferenças na morfologia da praia ao longo do tempo. Por outro lado, as diferenças com relação a variável tamanho puderam ser observadas em microescala, já que esta respondeu com maior rapidez à dinâmica sedimentar, sem que houvesse a necessidade de um acúmulo de modificações ao longo do tempo. No entanto, as variações na distribuição de *S. squamata* tanto na micro como na macroescala, foram explicadas pela sua relação com o transporte de sedimentos e a hidrodinâmica. Ou seja, a espécie em questão apresenta uma mobilidade intrinsecamente relacionada ao movimento do sedimento marinho, sendo desta forma, ditada pelo transporte passivo, que tem como forçante a hidrodinâmica do meio. Não foi observada a relação entre o tamanho médio do sedimento da praia de Dois Rios e a distribuição de *S. squamata*, já que o tamanho do grão somente não reflete a dinâmica do transporte de sedimentos, que é responsável pelas diferenças na distribuição da espécie. A composição diferenciada de sedimentos na praia de Dois Rios, esteve associada não somente ao transporte de sedimentos marinhos, como também ao aporte sedimentar dos rios Barra Pequena e Barra Grande. Devido a estas diferenças, foi possível avaliar separadamente a influência das forçantes sedimentares e hidrodinâmicas, onde o hidrodinamismo revelou ser a forçante determinante na distribuição da espécie ao longo da praia. A relação observada entre as componentes temporal e espacial ocorreu devido a associação destas com a hidrodinâmica, que varia sazonalmente. Desta forma, as alterações sazonais na morfodinâmica da praia, refletiram em mudanças na distribuição longitudinal e transversal da espécie.

A relação observada entre a distribuição espaço-temporal de *Scolelepis* cf. *squamata*, o estado morfodinâmico e o transporte de sedimentos na praia de Dois Rios, sustenta a hipótese de que a distribuição da densidade e do tamanho da espécie podem ser utilizadas como ferramenta para correlacionar a morfodinâmica, o transporte de sedimentos e a hidrodinâmica de praias arenosas oceânicas.

REFERÊNCIAS BIBLIOGRÁFICAS

Amaral, A.C.Z.1979. Ecologia e contribuição dos anelídeos poliquetos para a biomassa bêntica da zona das marés, no litoral norte do Estado de São Paulo. Boletim. do Instituto Oceanográfico de São Paulo 28: 1-52.

Baly, R.1983. Factors affecting the distrubution of organisms in the intertidal zones of sandy beaches. In: Sandy beaches as Ecosystems. eds. McLachlan,A. and Erasmus, T., W.Junk Publishers, The Hague. pp. 391-380.

Borzone, C.A. & Souza, J.R.B.1997. Estrutura da macrofauna bentônica no supra, meso e infralitoral de uma praia arenosa do Sul do Brasil. In: Ecologia de Praias Arenosas do Litoral Brasileiro, Oecologia Brasiliensis, III. eds. Absalão, R.S. & Esteves, A.M., Rio de Janeiro, UFRJ, pp. 197-212.

Buttman, C.A.1987. Larval settlement of soft sediment invertebrates: the spatial scales of patterns explained by active habitat selection and the emerging hole of hydrodynamical processes. Oceanography Marine Biology Annual Review 25: 113-165.

Defeo, O., Jaramillo, E., Lyonnet, A. 1992. Community Structure and Zonation of the macroinfauna on the atlantic coast of Uruguai. Journal of Coastal Research 8: 830-839.

Donn, T.E., Clarke, Jr. D.J., McLachlan, A., and Du Toit, P. 1986. Distribution and abundance of *Donax serra* Roding (Bivalvia: Donacidae) as related to beach morphology. I. Semilunar migrations. Journal of Experimental Marine Biology and Ecology 102: 121-131.

James, R.J. & Fairweather, P.G. 1996. Spatial variation of intertidal macrofauna on a sandy ocean beach in Australia. Estuarine and Coastal Shelf Science 43: 81-107.

Jaramillo, E.; McLachlan, A. & Coetzee, P. 1993. Intertidal zonation patterns of macroinfauna over a range of exposed sandy beaches in South Central Chile. Marine Ecology Progress Series 101: 105-118.

Jaramillo, E & Gonzalez, M. 1991. Community structure and zonation of the macroinfauna along a dissipative-reflective range of beach category in southern Chile. Studies on Neotropical Fauna and Environment, 26: 193-212.

McLachlan, A. 1983. Sandy Beach Ecology: a review. In: Sandy beaches as Ecosystems. eds. McLachlan, A. & Erasmus, T., W.Junk Publishers, The Hague. pp. 321-380.

McLachlan, A. 1990. Dissipative beaches and macrofauna communities on exposed intertidal sands. Journal of Coastal Research 6: 57-71.

McLachlan, A. 1996. Physical factors in benthic ecology: effects of changing sand particle size on beach fauna. Marine Ecology Progress Series 131: 205-211.

Neves, G.; Sperle, M.; Omena, E., Paiva, P.C. & Bispo, L. 2002. Utilização de Indicadores Biológicos como Ferramenta para Estudos da Dinâmica Sedimentar Costeira: Distribuição Espaço-Temporal de *Scolelepis squamata* Muller, (1808) (Polychaeta: Spionidae). I Simpósio Brasileiro de Oceanografia. Resumo, São Paulo, SP.

Omena, E.P. & Amaral, C.Z. 1997. Distribuição espacial de Polychaeta (Annelida) em diferentes ambientes entremarés de praias de São Sebastião (SP). In: Ecologia de Praias Arenosas do Litoral Brasileiro, Oecologia Brasiliensis, III. eds. Absalão. R.S. & Esteves, A.M., Rio de Janeiro, UFRJ. pp. 183-196.

Omena, E.P., Sperle, M., Bispo, L. Motta, M. 2001. Polychaete Spatial Distribution as a Tool for Sedimentary Dynamics: Evaluation at Sandy Beaches. An Ocean Odyssey - IAPSO / IABO. Resumo, Mar del Plata, v. 1, n. 1.

Santos, P.J.P. 1991. Morphodynamical Influence of a Temporary Freshwater Stream on the Population Dynamics of *Scolelepis gaucha* (Polychaeta: Spionidae) on a Sandy Beach in Southeast Brazil. Bulletin of Marine Science, 48(3): 657-664.

Santos, P.J.P.1994. Population dynamics and production of *Scolelepis gaucha* (Polychaeta: Spionidae) on the sandy beaches of Southern Brazil. Marine Ecology Progress Series 110: 159-165.

Shimizu, R.M. 1997. Ecologia Populacional de *Scolelelpis squamata* (Muller, 1806) (Polychaeta: Spionidae) e *Callichirus major* (Say, 1818) (Crustacea: Decapoda:

Thalassinidea) da Praia de Barequeçaba (São Sebastião, SP). Dissertação de Mestrado. Universidade de São Paulo. Instituto de Biociências. 49p.

Short, A.D. 1979. Three Dimensional Beach-Stage Model. Journal of Geology 87: 553-571.

Snelgrove, P.V.C. & Buttman, C.A. 1994. Animal-sediment relationships revisited: cause versus effect. Oceanography Marine Biology Annual Review 32: 111-177.

Souza, J.R.B. &.Gianuca, N.M. 1995. Zonation and seazonal variation of the intertidal macrofauna on a sandy beach of Paraná State, Brazil. Scientia Marina, 59(2): 103-111.

Souza, J.R.B, Borzone, C.A. 2000. Population Dynamics and Secondary production of Scolelepis squamata (Polychaeta: Spionidae) in an Exposed Sandy beach of Southern Brazil. Bulletin of Marine Science 67(1): 221-233.

Sperle, M.; Pereira, L. B.; Martins, C., 2001. Tidal effects at short time beach morphodynamics: implications from monitoring odd beaches at Ilha Grande bay, southeast Brazil. An Ocean Odyssey - IAPSO / IABO. Resumo, Mar del Plata, v. 1, n. 1.

Sperle, M.; Pereira, L. B.; Motta, M. 2000. High Frequency Beach Morphodynamics: Results from Monitoring Odd Beaches at Ilha Grande, Southeast Brazil. 5th International Congress on Marine Sciences, Resumo Expandido. Havana. v. 1.

Veloso, V., Cardoso. R. & Fonseca, D.B.1997. Spatio-temporal characterization of intertidal macrofauna at Prainha Beach (Rio de Janeiro State) pp: 213-225. In: Ecologia de Praias Arenosas do Litoral Brasileiro, Oecologia Brasiliensis, III. Eds. Absalão, R.S. & Esteves, A.M., UFRJ.

Veloso, V.G & Cardoso, R.S. 2001. Effect of Morphodynamics on The Spatial and temporal Variation on Three Sandy Beaches, Rio de janeiro State, Brazil. Journal Marine Biology Associated United Kingdom 81: 369-375.