

UNIVERSIDADE ESTADUAL DE CAMPINAS INSTITUTO DE BIOLOGIA

JOSÉ WEVERTON SANTOS DE SOUZA

METACOMUNIDADE: DINÂMICA ESPACIAL E TEMPORAL DE ANELÍDEOS CAPITELLIDAE EM CÂNIONS SUBMARINOS

METACOMMUNITY: SPATIAL AND TEMPORAL DYNAMICS OF CAPITELLIDAE ANNELIDS IN SUBMARINE CANYONS

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Educação não transforma o mundo. Educação muda as pessoas. Pessoas transformam o mundo - Paulo Freire

Resumo

Cânions submarinos são formações geomorfológicas complexas e sua presença promove um aumento na heterogeneidade da margem continental. Essa complexidade tem um impacto direto na distribuição faunística espaço-temporal, variando de acordo com a escala espacial analisada. Nesse contexto, investigamos a montagem de metacomunidade de Capitellidae (Annelida) em cânions submarinos durante dois períodos sazonais. A tese se encontra dividida em três capítulos. Capítulo 1: discutimos os efeitos da intrusão de quatro massas de água sobre a heterogeneidade ambiental e métricas de diversidade. Evidenciamos a ocorrência das massas de Água Tropical, Água Central do Atlântico Sul, Água Intermediária Antártica e Água Profunda do Atlântico Norte. A ocorrência dessas massas de água promoveu uma estratificação ambiental vertical e aumento da heterogeneidade ambiental. Registramos altas taxas de βdiversidade promovidas por turnover e species sorting. As maiores taxas de βdiversidade ocorreram águas profundas. A intrusão de massas de água ricas em O₂ agiu negativamente na riqueza, abundância e diversidade. Esses resultados sugerem que as massas de água geram um forte gradiente ambiental capaz de selecionar conjuntos de espécies locais e que O₂ é um fator secundário e não limitante para essas comunidades, uma vez que incremento de abundância, riqueza e diversidade estiveram fortemente relacionadas com temperatura e salinidade. Capítulo 2: abordamos a influência de escalas espaciais na percepção dos padrões ambientais e biológicos em diferentes períodos sazonais. Constatamos um aumento da heterogeneidade ambiental associada ao aumento da escala espacial. Além disso, nossos resultados indicaram a influência de processos neutros e de nicho na β-diversidade de anelídeos Capitellidae e que a escala espacial analisada influencia diretamente os padrões observados e são dependentes das características de cada sistema, no qual, o componente ambiental quase sempre foi mais importante para montagem dessas comunidades, principalmente em maior escala espacial. Capítulo 3: investigamos a sobreposição de nicho espacial batimétrico e dentro das camadas de sedimento como estratégia para a coexistência das espécies sob diferentes condições ambientais. Constatamos que as espécies apresentam restrições ao longo dos gradientes ambientais, e isso refletiu em baixa amplitude de nicho ambos os cânions e períodos sazonais. Além disso, verificamos que grandes conjuntos de espécies se sobrepõem no uso do espaço batimétrico e segregam sua distribuição verticalmente nas camadas de sedimento como estratégia de coexistência e redução de possíveis interações competitivas. A redução de nutrientes orgânicos ao longo do gradiente batimétrico, promoveu a redução no uso das camadas de sedimento e declínio de riqueza e densidade. Esses padrões evidenciam a existência de processos de compartilhamento e diferenciação de nicho nos gradientes batimétrico e camadas de sedimento e influência da disponibilidade de nutrientes mediando a montagem dessas comunidades. Acreditamos que esses resultados contribuam significativamente para o conhecimento ambiental e biológico em mar profundo, especialmente em cânions submarinos, devido sua alta complexidade e por serem pouco explorados. Além disso, esses ambientes podem ser considerados potenciais hotspots de diversidade, portanto, esses dados podem ser fundamentais para orientar o estabelecimento adequado de Áreas Marinhas Protegidas visando à conservação desses ambientes tão singulares.

Palavras-chave: beta diversidade, mar profundo, montagem de comunidades, poliqueta

Abstract

Submarine canyons are complex geomorphological formations, and their presence promotes an increase in the heterogeneity of the continental margin. This complexity has a direct impact on the spatio-temporal faunal distribution, varying according to the spatial scale analyzed. In this context, we investigated the assembly of the Capitellidae (Annelida) metacommunity in submarine canyons during two seasonal periods. The thesis is divided into three chapters. Chapter 1: We discuss the effects of the intrusion of four water masses on environmental heterogeneity and diversity metrics. We evidenced the occurrence of masses of Tropical Water, Central Water of the South Atlantic, Intermediate Antarctic Water and Deep Water of the North Atlantic. The occurrence of these water masses promoted vertical environmental stratification and increased environmental heterogeneity. We recorded high rates of β-diversity promoted by turnover and species sorting. The highest rates of β -diversity occurred in deep waters. The intrusion of water masses rich in O₂ had a negative effect on richness, abundance and diversity. These results suggest that water masses generate a strong environmental gradient capable of selecting sets of local species and that O₂ is a secondary and nonlimiting factor for these communities, since increases in abundance, richness and diversity were strongly related to temperature and salinity. Chapter 2: we address the influence of spatial scales on the perception of environmental and biological patterns in different seasonal periods. We found an increase in environmental heterogeneity associated with increasing spatial scale. Furthermore, our results indicated the influence of neutral and niche processes on the β -diversity of Capitellidae annelids and that the spatial scale analyzed directly influences the observed patterns and is dependent on the characteristics of each system, in which the environmental component was almost always most important for assembling these communities, especially on a larger spatial scale. Chapter 3: we investigated the bathymetric spatial niche overlap and within sediment layers as a strategy for species coexistence under different environmental conditions. We found that species present restrictions along environmental gradients, and this reflected low niche amplitude in both canyons and seasonal periods. Furthermore, we found that large sets of species overlap in the use of bathymetric space and segregate their distribution vertically in the sediment layers as a strategy for coexistence and reducing possible competitive interactions. The reduction of organic nutrients along the bathymetric gradient promoted a reduction in the use of sediment layers and a decline in richness and density. These patterns highlight the existence of niche sharing and differentiation processes in bathymetric gradients and sediment layers and the influence of nutrient availability mediating the assembly of these communities. We believe that these results contribute significantly to environmental and biological knowledge in the deep sea, especially in submarine canyons, due to their high complexity and because they are little explored. Furthermore, these environments can be considered potential hotspots of diversity, therefore, these data can be fundamental to guide the adequate establishment of Marine Protected Areas aiming at the conservation of these unique environments.

Keywords: beta diversity, deep sea, community assembly, polychaete

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INTRODUÇÃO GERAL

Cânions submarinos são feições geomorfológicas que recortam o talude e em alguns casos, a plataforma continental (Mulder et al., 2004), constituindo uma zona de transferência de matéria e energia entre a plataforma e o sopé continental (Gardner, 1989). Essas feições geológicas são bastante complexas e podem estar confinadas ao talude continental ou incisos na plataforma (De Leo et al. 2020) e em ambos, podem apresentar recortes em seu interior (canais tributários, ravinas). Somada à essa variabilidade morfológica, os padrões de hidrografia dinâmicos (decorrente da movimentação de massas de água e correntes marinhas), podem aumentar o fluxo, transporte e acúmulo de sedimento (Company et al., 2008) e, consequentemente, promover o aumento da produtividade, tornando esses ambientes hotspots de biodiversidade em mar profundo (De Leo et al., 2010; Bernardino et al. 2019). Além disso, os processos que ocorrem dentro de cânions podem ser influenciados pelo perfil morfodinâmico do talvegue (leito do cânion), os quais podem apresentar baixa declividade (perfil convexo) ou maior declividade (extremamente côncavos) (De Leo, 2012). Essa conjunção de características geomorfológicas (maturidade, perfil morfodinâmico) e oceanográficas (correntes, massas de água) individuais dos cânions, tornam os processos ambientais e biológicos no interior de cada um deles, peculiares e dinâmicos.

Embora exista uma grande quantidade de cânions submarinos em todo o mundo (mais de 660; De Leo et al., 2010), a estrutura das comunidades bentônicas, biomassa, riqueza e diversidade foram investigadas em menos de 0,5% em nível mundial (Curdia et al., 2004; McClain; Barry, 2010; Cunha et al., 2011; De Leo, 2012). Contudo, embora os padrões da margem continental ainda sejam mal descritos, alguns estudos demonstram que os padrões faunísticos estão intimamente correlacionados com fortes gradientes ambientais (Danovaro et al., 2008; Levin; Sibuet, 2012). Portanto, devido à alta complexidade física dos habitats encontrados em cânions submarinos, as previsões dos padrões ocasionados por cânions sobre a diversidade biológica e em diferentes escalas espaciais não são simples (Vetter; Dayton, 1998; De Leo, 2012). Dentre os organismos que habitam esses sistemas, a macrofauna bentônica (ou seja, organismos com tamanho superior a 0.5 mm e que vivem associados ao leito oceânico) é um componente predominante da biodiversidade, porém seus aspectos ecológicos ainda são poucos explorados (Xavier et al. 2013). Nesse sentido, uma abordagem bastante utilizada em estudos com diferentes escalas espaciais, é a de metacomunidade. Embora essa abordagem tenha sido proposta na década de 1990 (Gilpin; Hanski, 1991), tem obtido crescente destaque em estudos de ecologia (Leibold et al., 2004; Leibold; Norberg, 2004; Bandelj et al., 2012; Hubert et al., 2015), e pode ser definida como o conjunto de comunidades locais conectadas por dispersão de espécies (Leibold et al., 2002; Leibold et al., 2004; Leibold; Norberg, 2004). Estas comunidades podem apresentar padrões de abundância, riqueza, diversidade e composição, promovidos por processos análogos da teoria de comunidades, como dispersão e seleção de espécies (Vellend, 2010) envolvendo a teoria de nicho (Leibold et al., 2002; Leibold; Norberg, 2004; Leibold et al., 2004) e neutra (Leibold; Norberg, 2004; Leibold et al., 2004). A partir destas abordagens, é possível analisar os padrões e os processos que determinam a organização de metacomunidade em diferentes escalas (Gilpin; Hanski, 1991; Lansac-Tôha et al., 2021), e se esta organização responde ao gradiente ambiental (Leibold et al., 2002).

Para a avaliação dos padrões de dinâmica das metacomunidades, quatro modelos teóricos foram desenvolvidos: dinâmica de manchas (Patch-dynamic) - onde as manchas de habitat são similares e a colonização desses habitats por diferentes espécies, são dependentes dos processos de dispersão; seleção de espécies (Species-sorting) nessa perspectiva ocorre heterogeneidade ambiental entre os habitats, e as interações locais são dependentes da variabilidade ambiental, que age como filtro seletor; efeito de massa (Mass effect) - ocorre elevada dispersão, capaz de vencer os fatores ambientais, possibilitando que as espécies colonizem manchas de habitats locais; e paradigma neutro (Neutral paradigm) - ocorre distribuição aleatória de espécies, decorrente de eventos estocásticos, onde as perdas e ganhos de espécies orientam as dinâmicas e estrutura dessas metacomunidades (Leibold et al., 2004). Essas variações na organização das comunidades são determinadas pela substituição de espécies e aninhamento entre comunidades vizinhas (Baselga, 2010), determinando as taxas de βdiversidade para comunidades regionais (Leibold; Noberg, 2004; Anderson et al., 2011; Lansac-Tôha et al., 2021). A intensidade das substituições de espécies e aninhamento entre comunidades, além de sofrerem influência dos filtros ambientais, podem ser influenciadas por processos espaciais, uma vez que o grau de proximidade entre manchas de habitats pode favorecer ou dificultar o deslocamento de espécies (Checon et al., 2018; Corte et al., 2018). Essas dinâmicas em metacomunidades são complexas,

uma vez que esses processos agem simultaneamente na determinação da organização de metacomunidades (Cottenie, 2005).

A organização das comunidades bentônicas pode ser determinada por um conjunto de filtros ambientais, no qual, em um contexto geral, pode-se destacar a profundidade, concentração de oxigênio, níveis de salinidade, o sedimento, a textura do grão e a heterogeneidade do ambiente de fundo (Heino, 2000; Teske; Wooldridge, 2003; Netto, 2006; Pech et al., 2007; Fonseca; Pech et al., 2007; Magalhães; Barros, 2011; Teive, 2013; Valanko et al., 2015). Além dessas características do habitat, a distribuição da fauna pode ser facilitada pelo hidrodinamismo, o qual exerce forte influência na dispersão das larvas de muitas espécies de poliquetas, ampliando o alcance dessa dispersão espacial, principalmente por meio das correntes marinhas e energia de ondas (Valanko et al., 2010a,b; Corte et al., 2018). Eventos sazonais também podem promover variações na estrutura de comunidades bentônicas, principalmente em espécies que apresentem larvas planctônicas e adultos móveis (Corte et al., 2018). O estudo das dinâmicas de metacomunidades macrobentônicas em ambientes marinhos é incipiente, sendo desenvolvida em poucos estudos (De Leo, 2012). Em cânions submarinos, esses estudos são inexistentes, o que compromete o entendimento dos padrões de metacomunidade que organizam a biodiversidade em diferentes escalas, informação de importância para a conservação da biodiversidade e previsão de impactos antrópicos nos ecossistemas naturais (Record et al., 2021).

Os poliquetas são um dos principais grupos biológicos bentônicos e que habitam cânions submarinos. Estes organismos são representados por mais de 17.000 espécies e 86 famílias, no Brasil tem-se registro de 1.149 espécies e 68 famílias (Amaral et al., 2013). A família Capitellidae é uma das dominantes na costa brasileira (ver Lana et al., 2017; Silva et al., 2016; 2017), sendo comumente abundantes em fundos lamosos ricos em matéria orgânica (Dean, 2001). Devido a elevada abundância e ao hábito alimentar detritívoro (Fauchald; Jumars, 1979; Jumars et al., 2015), os capitelídeos são importantes para o funcionamento dos ecossistemas marinhos por contribuir no fluxo energético destes ambientes (García-Garza, 2009), uma vez que facilitam a recuperação de detritos orgânicos depositados no fundo do mar. Após incorporarem a matéria orgânica, esta é transformada em biomassa animal, tornando-se disponível para os níveis tróficos superiores (Amaral; Migotto, 1980; Paiva, 2006; Lana et al., 2009) ao serem consumidos por algumas espécies de peixes (Amaral; Migotto, 1980) e além

disso, são comumente utilizados como bioindicadores de impactos ambientais (Dean, 2001; Dean, 2008; Omena et al., 2012; Dafforn et al., 2013; Checon et al., 2018).

Alguns estudos realizados em cânions sugerem que a maior heterogeneidade do habitat e a deposição de matéria orgânica são responsáveis pelo aumento da biodiversidade bentônica e promovem pontos críticos de biomassa (Vetter, 1994; Vetter; Dayton, 1998; Schlacher et al., 2007, 2010; McClain; Barry, 2010). Alguns estudos reportam uma maior diversidade e biomassa da fauna bentônica dentro de cânions, quando comparados ao talude adjacente (Rowe et al., 1982; Sardá et al., 2009; Gage et al., 1995; Vetter; Dayton, 1998; Mamouridis et al., 2011; Cunha et al., 2011; Bernardino et al., 2019), enquanto outros não mencionaram diferenças significativas entre essas duas feições (Houston; Haedrich, 1984; Maurer et al., 1994). Contudo, a composição de espécies das comunidades que habitam cânions, pode ser bem distinta daquelas encontradas no talude adjacente (Company et al., 2012). Alguns autores apontam que o distanciamento da costa causa impactos no aporte de material orgânico particulado derivado do continente, onde seus efeitos em geral, são negativos sobre a diversidade (ver Vetter; Dayton, 1998; De Leo et al., 2010).

Embora esses sistemas apesentem essa grande diversidade biológica, estes ambientes sofrem crescentes ameaças decorrentes de atividades humanas (ex.: pesca de fundo, extração de petróleo e gás, despejo de esgoto e lançamento de gases) as quais podem ocasionar perda da biodiversidade (Ramirez-Llodra et al., 2010; Levin; Sibuet, 2012). Os organismos de mar profundo exercem ainda grande importância para as comunidades humanas, pois desempenham inúmeros serviços ambientais, atuando diretamente na redução do gás carbônico e metano lançados na atmosfera por ação antrópica, uma vez que a bomba biológica (processo pelo qual o CO₂ atmosférico é incorporado ao oceano profundo por meio de atividades biológicas) transporta carbono da atmosfera para massas de água oceânicas profundas, retendo carbono em carbonatos, além da ação de oxidação do metano por bactérias (Thurber et al., 2014). Além disso, a macrofauna atua na ciclagem de nutrientes, especialmente pela ação de bioturbação gerada por organismos detritívoros, como é o caso dos capitelídeos, fornecendo energia para suprir a produtividade superficial e a pesca, e consequentemente beneficiam a sociedade (Thurber et al., 2014). Logo, descrever e quantificar os padrões de biodiversidade em cânions submarinos são cruciais para identificar hotspots de biodiversidade e para o desenvolvimento de estratégias de conservação, que podem incluir a designação de áreas para proteção permanente de regiões marinhas protegidas (Ramirez-Llodra et al., 2010; Levin; Sibuet, 2012; Ismail et al., 2018).

Diante dessas informações, nessa tese realizamos uma investigação sobre os fatores que afetam a organização da metacomunidade de Capitellidae em cânions submarinos na margem continental de Sergipe, NE, Brasil, proporcionando um maior conhecimento deste táxon e dos mecanismos ecológicos que promovem o pool regional de espécies em cânions submarinos. Essas informações serão úteis em futuros plano de manejo e gerenciamento da margem continental, na delimitação de possíveis áreas prioritárias para conservação por meio dos padrões de β-diversidade (Baselga, 2010). Sendo assim, com o levantamento biológico e conjunto de variáveis ambientais, a tese foi dividida em três capítulos, os quais abordaram diferentes aspectos das comunidades de Capitellidae e sua organização, especificamente investigamos: 1) quais massas de água e correntes marinhas ocorrem nos cânions submarinos e como a presença dessas massas de água influenciam na heterogeneidade ambiental e na organização da metacomunidade; 2) os efeitos de diferentes escalas espaciais, em dois períodos sazonais, sobre a heterogeneidade ambiental e na percepção dos padrões de βdiversidade, coocorrência de espécies e influência dos componentes ambientais e espaciais; e por último 3) investigamos a sobreposição de nicho espacial em dois gradientes de profundidade e as estratégias para coexistência das espécies de mar profundo em dois períodos sazonais e gradientes de enriquecimento e qualidade de nutrientes orgânicos.

Capítulo 1

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Influence of water masses on environmental heterogeneity and organization of Capitellidae annelids in submarine canyons

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ABSTRACT

The circulation system induced by currents and water masses can promote an increase in environmental heterogeneity in marine systems due to their wide variation in physical and chemical characteristics. However, this influence on heterogeneity and diversity in submarine canyons is little known. In this study, were documented how water masses with different physicochemical characteristics can promote an increase in the heterogeneity and organization of Capitellidae annelids in two large canyons (10°30' 11°27S, 36°20' 37°16W) during 2013 in Brazil. The Tropical (TW), Central South Atlantic (SACW), Intermediate Antarctic (AAIW) and Deep North Atlantic (NADW) water masses were recorded in the São Francisco and Japaratuba canyons. The TW and SACW masses showed the highest temperature and salinity, while NADW showed the highest availability of nutrients and oxygen. The area of TW, AAIW and NADW showed the greatest environmental heterogeneity in São Francisco canyon - SFC, while in the Japaratuba canyon - JPC, the greatest heterogeneity occurred in AAIW and NADW. The β -diversity was proportional to the increase in habitat heterogeneity, as the AAIW and NADW, the areas with the greatest heterogeneity had the high β -diversity. The β -diversity patterns were promoted by turnover, species sorting and mass effect. The intrusion of O₂-rich water masses (NADW and AAIW) promoted a decline in the abundance and richness of Capitellidae. These results suggest that the intrusion of water masses inside the canyons promotes an increase in heterogeneity, generating a diversified gradient that selects locally varied sets of species, promoting high levels of β -diversity, and that the low availability of O₂ is not a limiting factor for Capitellidae communities.

Keywords community assembly, nestedness, polychaetes, species sorting

Introduction

The ocean floor is formed by two major provinces, the continental margin and the ocean basin, the first being formed by the shelf, slope, and continental rise (Sumida et al. 2020; De Leo et al. 2020). Submarine canyons, when present, cut the continental margin and can be characterized as sinuous valleys in the seabed (Shepard 1972, 1981; Mulder et al. 2004) constituting very complex geological features due to their topography, presenting a mosaic of habitat types (Gardner et al. 2003; Schlacher et al. 2010; De Leo et al. 2010). Within these large systems it is possible to find dynamic hydrographic patterns due to water masses and marine currents, which can increase the flow, transport, and accumulation of sediment within the canyons (Company et al. 2008).

Submarine canyons can be classified as blind, when they are confined to the continental slope, or shelf-incising, when they enter the continental shelf (Shepard 1981). These valley-shaped depressions usually change the environmental dynamics of the continental slope, as they promote a greater connection between the continental margin and the deep ocean zone, facilitating the increase in the inflow of particulate matter in deep waters (Spurgin and Allen 2014). In addition, canyons contribute to the channeling of water masses (Weaver et al. 2004) carried by complex current systems (Silveira et al. 2015, 2020) and can promote an increase in environmental heterogeneity (here considered as the variation in abiotic conditions between the set of samples/sites within a region (water mass)), because these water masses have distinct physicochemical characteristics and hydrodynamics can affect the sediment-water interface (Solé et al. 2016; Du et al. 2022). Thus, each habitat within the canyon present a specific set of characteristics determined by the type of water mass and currents action at each depth, which promote an environmental/vertical stratification throughout the canyon (Rudels et al. 1991; Silveira et al. 2015, 2020). Such processes make these systems heterogeneous and dynamic, challenging the past view that the deep sea was formed by stable and homogeneous habitats (McClain and Hardy 2010; Puerta et al. 2020).

Due to the hight heterogeneity within canyons, a diverse set of species may occur in distinct habitat patches (Ziv 1998), promoting an increase in β -diversity. In canyons, one of the main sources of variability are the water masses, intensity of vertical flow driven by currents (Solé et al. 2016) and their associated variables, such as oxygen levels (Woulds and Cowie 2007), amount of nutrients (Cathalot et al. 2015), temperature (Yasuhara and Danovaro 2014), and circulation patterns (Henry et al. 2014; Somoza et al.

2014) that cause changes and directly influence the distribution and connectivity of communities through the dispersal of deep-sea benthic species (Puerta et al. 2020).

Among the organisms that make up the benthic fauna, polychaete annelids are abundant and diverse (Fauchald 1977; Capa and Hutchings 2021), and Capitellidae are one of the most frequently encountered families in the different types of habitats, being abundant in sandy-mud substrates rich in organic matter (Dean 2001; García-Garza 2009; Lana et al. 2017). As a result of this high abundance and their detritivore feeding habit (Fauchald and Jumars 1979; Jumars et al. 2015), capitellids are important for the functioning of marine ecosystems by contributing to the nutrient cycling and energy flow of these environments (García-Garza 2009), as they facilitate the recovery of organic debris deposited in the sediment. After incorporating this organic matter, and transforming it into animal biomass, it is made available for higher trophic levels when they are consumed by for example certain fish species (Amaral and Migotto 1980; Paiva 2006; Lana et al. 2009). In addition, as Capitellidae is indicator of polluted environments (Dean 2001; Dean 2008; Omena et al. 2012; Dafforn et al. 2013; Checon et al. 2018), the studies of the dynamics involving species from this family can provide support for their use in monitoring different marine areas.

The effects of water mass characteristics (temperature, salinity, oxygen) within submarine canyons, acting on the structure and organization of metacommunities of macrobenthic assemblages are little known. As water masses occur all over the world, seven of them being recognized in the Southwest Atlantic Ocean (Silveira et al. 2015; Silveira et al. 2020), it is crucial to understand how this important source of change in environmental characteristics can promote the spatial heterogeneity of deep-sea habitats (Santos et al. 2020). Information regarding patterns in macrobenthic communities, especially β -diversity, can be important in delimiting priority areas for conservation (Baselga 2010) as well as in the recognition of the influence of environmental filters and spatial conditions limiting or expanding the occurrence of species, which are still poorly known.

In this context, the general objective of this work was to investigate how the occurrence of water masses inside submarine canyons can increase environmental heterogeneity and influence the organization of annelids of the Capitellidae family.

Therefore, a set of environmental and biological data was used, which served as a basis to test three hypotheses (Fig. 1): (1) areas influenced by different water masses present distinct physicochemical characteristics (Solé et al. 2016). Thus, the intrusion of water masses in the São Francisco (SFC) e Japaratuba (JPC) canyons would promote increase vertical heterogeneity and consequently, an environmental stratification (that is, a strong environmental gradient promoted by the stacking of water masses with distinct physicochemical characteristics); (2) As spatial heterogeneity of the habitat contributes to high values of β -diversity (Checon et al. 2018; Corte et al. 2018; Santos et al. 2020), we expect to record high rates of β -diversity can be found in more heterogeneous areas in SFC and JPC canyons. and between areas under the influence of different water masses can increase the carrying capacity in these environments (McClain and Rex 2015); thus, we infer that greater richness, abundance, and diversity will be evidenced in areas with influence of oxygen-rich water masses in SFC and JPC canyons.



Fig. 1 Illustrative scheme of the main hypotheses in this study. Colored boxes represent areas under the influence of different water masses and different degrees of environmental heterogeneity, and dissolved oxygen (O₂), that promote vertical stratification of the environment. Thick arrows represent higher species sharing, thin arrows represent intermediate sharing, dashed arrows represent low sharing, and dotted arrows represent very low species sharing between areas. TW = Tropical Water, SACW = South Atlantic Central Water, AAIW = Antarctic Intermediate Water, NADW = North Atlantic Deep Water, β_{JAC} = Jaccard β -diversity, N = Abundance, S = Richness, H' = Diversity.

Material and Methods

Study area

This study was carried out in the Southwest Atlantic Ocean, in submarine canyons on the continental margin of the State of Sergipe, NE, Brazil, within the scope of the Project "Environmental Characterization of the Sergipe-Alagoas Basin – MARSEAL" (Federal University of Sergipe and Petrobras). The studied canyons are shelf-incising and consequently cut across the continental shelf and slope area, causing narrowing in these systems (Fontes et al. 2017). The São Francisco (SFC) and Japaratuba (JPC) canyons (Fig. 2) are the largest in the study area. The SFC has a width of 10 km and a slope from the edge to the bottom of 850 m, while the JPC is 21 km wide at the edge of the platform and the gap between the edge and the bottom of the canyon is more than 1,400 m (Fontes et al. 2017). At the head of the canyons, the seabed is muddy, with no occurrence of carbonate, with a predominance of siliciclastic sediments due to the strong fluvial influence, especially in SFC (França et al. 1976).



Fig. 2 Location of collection stations in the São Francisco and Japaratuba canyons on the continental margin of Sergipe, NE, Brazil. Source: MARSEAL Project – PETROBRAS. N3 = 50 m; N4 = 400 m; N5 = 700 m; N6 = 1,000 m; N7 = 1,300 m; N8 = 1,900; N9 = 3,000 m.

Sampling Design and Sample Treatment

Between March 12nd and April 5th, 2013, an oceanographic campaign was carried out in the São Francisco and Japaratuba canyons (Fig. S1; Table 1). Sample collections always took place using a standardized sampling design, carried out in the same isobaths (50, 400, 700, 1,000, 1,300, 1,900 and 3,000) in the two submarine canyons. A collection station with a radius of 150 m was established in each isobath and, within this area, a box

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corer (dimensions = $50 \times 50 \times 50 \text{ cm}$) was launched in triplicate and CTD sounder SBE 911 plus (Fig. S2), totaling 42 samples for sediment and water variables.

From each box corer, nine sediment templates of 10x10x10 cm were removed, a total volume of 0.09 m³, destined for faunal analysis, the sum of these nine templates constituting one sample. These samples were placed in plastic jars with 10% formalin buffered with borax and dyed rose bengal. Afterwards, a 10th template for sediment collection was taken for the analysis of substrate variablesrelated to the classification of particle size (mean grain diameter (Φ), skewness, kurtosis, and degree of selection) and determination of total carbonate contents (%), total organic carbon (%), total nitrogen (%), and total organic phosphorus (µg.g-¹). Also, at the time of collection of biological samples and sediment, the water masses properties (salinity (psu), temperature (°C) and oxygen – O₂ (mg/L)) were measured using a CTD.

The biological samples were washed through sieves with meshes of 0.5 and 0.3 mm, using a compression hose with low flow. The sediment retained in the sieves was placed in jars with 70% alcohol and subsequently sorted under a stereoscopic microscope and the organisms were separated into higher taxonomic levels and placed in glass flasks with 70% alcohol. The capitelids were separated and identified in morphospecies using a stereoscopic (Zeiss Stemi SV11) and optical (Zeiss Scope.A1) microscope, using specialized bibliography (Ewing 1984; Dean 2001; Green 2002; García-Garza 2009; Silva et al., 2017; Silva and Amaral 2019; 2020; 2022).

To determine the mean grain size (Phi (Φ)) of the sediment, particle size was measured by laser diffraction using the Malvern Mastersizer 3000. The textural classification of the grains was determined according to Wentworth (1922). Subsequently, statistical parameters related to the degree of selection (measured by the standard deviation of the sample), skewness (degree of displacement of the grains to one side of the normal curve) and kurtosis (shape measure, characterizing the flattening of the normal curve) were determined according to Folk and Ward (1957).

The total carbonate content (%) was obtained by the gravimetric method of carbonate elimination by hydrochloric acid. For the determination of total organic carbon and nitrogen, first the inorganic carbon fraction had to be removed from the sediments by adding hydrochloric acid (10% HCl), in a controlled pH environment (± 2). The acid (10% HCl) was added in successive steps, until the end of the sediment decarbonation reaction, marked by pH stabilization. Then, about 5 to 10 mg of dry and decarbonated

sediment were weighed directly into tin capsules and inserted into the elemental analyzer (Thermo Finningan EA1112) for the determination of organic carbon (C_{org}) and total nitrogen (N_{total}) by the method of dry combustion (Hedges and Stern, 1984). The concentration calculation was done by the equipment, considering the peak area generated for both elements (C_{org} and N_{total}).

To determine the organic phosphorus content (P_{org}), the sediment was dried at 60°C and then homogenized and sieved on a 2.0 mm mesh. Afterward, the sediment was dried again in an oven for 2 hours at a temperature of 105°C for subsequent weighing of 0.2 to 0.5 g of sediment. This material was calcined at a temperature of 550°C for 2 hours to oxidize the organic matter and release all phosphorus compounds in the form of orthophosphates. Then, the calcination residue was transferred to a centrifuge tube and 20 mL of 1.0 mol.L⁻¹ HCl was added, after which it was stirred for 16 hours, followed by centrifugation at 4,000 rpm for 15 minutes. Subsequently, an aliquot of this extract was transferred to a 100 mL volumetric flask and neutralized by the addition of 1.0 mol.L⁻¹ HCl using phenolphthalein.

For the determination of inorganic phosphorus, the same procedure as for total phosphorus was adopted without calcining the sediment sample (Aspila et al. 1976). The total phosphorus and inorganic phosphorus content in the final extract was quantified by the molybdenum blue spectrophotometric method (Grasshoff et al. 1983), which consists of transferring a known volume of extract (between 5 and 20 mL) to a graduated measuring cylinder 20 mL (the transferred volume should be noted, and the final 20 mL volume should be topped up with distilled water when necessary). In each sample, the fractions of total phosphorus and inorganic phosphorus were determined using the method proposed by Aspila et al. (1976). Organic phosphorus was calculated by the difference between total phosphorus and inorganic phosphorus.

The granulometric analyses (grain size) and statistical parameters of the sediment were performed at Universidade Estadual Paulista (UNESP). The determination of total carbonate contents (%) was developed by the team from the GeoRioeMar laboratory at the Universidade Federal de Sergipe (UFS). The processing and determination of chemical variables (organic carbon, nitrogen and organic phosphorus) were carried out by the team from the Laboratório de Química Ambiental at UFS.

Water masses

To classify and verify which water masses occurred within the canyons during the samplings on the continental margin of the state of Sergipe, the obtained data with CTD sounder SBE 911 plus was interpoled generating a T-S diagram. For interpretation of this diagram, we used the classification proposed by Silveira et al. (2015), Santos et al. (2020) and Sumida et al. (2020) for other regions of Brazil. For this analysis we only used data referring to the water/sediment interface.

Data analysis

Spatial-vertical heterogeneity in areas affected by different water masses

Initially, the environmental data was checked for multicollinearity using the car package (Fox and Weisberg, 2019). Variables with Variance Inflation Factor - VIF values > 3 were removed from the analysis (degree of selection, total nitrogen, and total organic carbon) (Table S1). Thus, of the 11 variables measured, only eight were considered for environmental characterization (grain mean, skewness, kurtosis, total carbonates, total phosphorus, salinity, temperature, and oxygen). Afterward, to investigate the environmental heterogeneity between the water masses areas, a Permutational Multivariate Dispersion - PERMDISP analysis was performed using the betadisper function (Anderson 2006). The variability of environmental filters between water masses and canyons was investigated through the Multivariate Permutation Analysis – PERMANOVA using adonis2 function (Anderson 2006; Oksanen et al. 2018). For these analyses, collection stations were used as fixed factors nested in the water mass scale. Additionally, an ordination was performed using Principal Component Analysis -PCA to illustrate the differences in heterogeneity and diversity of habitats within the canyons. These analyzes were processed based on Euclidean distances for sediment and water data.

For these analyses, the substrate variables carbonate, and skewness was transformed into arcsine and by $log_{10}(x+2)$, respectively. The packages vegan (Oksanen et al. 2018), FactoMineR (Le et al. 2008) and factoextra (Kassambara and Mundt 2020) were used for analysis and *ggplot2* (Wickham 2016) for plotting the graphics, both in the R software (R Core Team 2020).

Initially, samples without occurrence of Capitellidae fauna were removed from the models. After, to verify differences in the composition of Capitellidae species between areas affected by different water masses, a PERMANOVA analysis was applied, from which the level of significance of variation ($\alpha = 0.95$) between the water masses was obtained. The β -diversity of the Capitellidae fauna in areas under the influence of water masses was investigated using PERMDISP (Anderson et al. 2006), from which the dispersion and average distance to the centroid of each water mass were calculated, where greater dispersions indicate greater diversity. The differences in the means of the centroids of each group (i.e., water masses) were calculated using the TukeyHSD function. This function uses the set of confidence intervals in the differences between the mean levels of a factor based on the student range statistic. To visualize these results, a Principal Coordinates Analysis – PCoA was performed. These analyzes were processed in the vegan package (Oksanen et al. 2018) and the graphs in ggplot2 in the R software, using a species abundance matrix preceded by the Hellinger transformation (Legendre and Cáceres 2013) and the Bray-Curtis dissimilarity metric.

Furthermore, the rates of variation in species composition that determine the β diversity between different water masses were investigated. For this, the general β diversity between all areas within the SFC and JPC canyons was initially calculated and then a paired comparison (i.e., within the same isobath) was performed between all water masses to obtain the variation rates and mechanisms that determine the β -diversity. This calculation was performed using the Jaccard index, based on a matrix of presence and absence of species, expressed using the following formula: $\beta jac = \beta tur + \beta nes \equiv \frac{b+c}{a+b+c} = \frac{2b}{2b+a} + (\frac{c-b}{a+b+c})(\frac{a}{2b+a})$, where *a* is the number of species shared between two cells (communities); *b* is the number of unique species for the poorest location and c is the number of unique species for the richest location (Baselga 2010). With this, it was possible to calculate the rates of variation in species composition between areas affected by water masses. We then calculated the β -diversity partitioning to identify the contribution of the ecological mechanisms of nesting (β_{NES}) and turnover (β_{TUR}) that structure the metacommunity and determine the regional β -diversity (Baselga 2010). This analysis was made using the betapart package (Baselga and Orme 2012) in the R software.

Variation in richness, abundance, and diversity in areas under the influence of O₂ - rich water masses

Initially, abundance (N; number of individuals for each sample), richness (S; number of species for each sample) and Shannon-Wiener diversity (H') were calculated. Subsequently, a PERMANOVA was applied to verify the variation of S, N and H' between water masses. Afterward, Generalized Linear Models - GLM were developed using the set of environmental variables (water mass properties and substrate variables) to investigate which of them promote an increase or decline in these indices (S, N and H'). Some data underwent a previous transformation: the total carbonate (Carb) was transformed by arcsine because it is a percentage data; Skewness was logarithmized by $log_{10}(x+2)$ in order to correct asymmetry in data distribution and for presenting negative values. Models were adjusted using the quasipoisson distributions and log canonical link for abundance in order to solve the overdispersion of the data (residual deviance >> degree of freedom); and poisson distributions and log canonical link for richness; and gaussian and identity canonical link for diversity due to underdispersion of data (residual deviance << degree of freedom). For this, all the environmental variables were used to compose the GLM's (complete model), followed by the simplification of these models. According to James et al. (2013). This simplification consisted of the gradual removal (one variable at a time) of the environmental variables. In this sense, simplification occurred always starting with the variable with the lowest deviance. This process was carried out until obtaining the significant variables that explain the increase or decrease of S, N, H' (simplified model). The simplified model was tested by ANOVA followed by the "F" test for models with a quasipoisson distribution and the "Chisq" test for models with a poisson distribution. Relationships between ecological indices and environmental variables were analysed through the graphical output smooth curves of glm method. These analyses were performed in the R software using car packages (Fox and Weisberg 2019) and graphs plotted with ggplot2 (Wickham 2016) in the R software.

Results

Water Masses

The occurrence of four water masses and two marine currents were recorded (Table 1). These water masses were classified according to their salinity levels, temperature, and depth, and from the interpolation of these data, the Tropical Water (TW), South Atlantic Central Water (SACW), Antarctic Intermediate Water (AAIW) and North Atlantic Deep Water (NADW) were registered (Fig. 3). The Northern Brazil Undercurrent and Deep Contour Current were registered according to Santos et al. (2020) (Table 1).

Table 1 Geographical coordinates (SIRGAS 2000), water mass (WM), current and depth of the collecting stations (ST) for biological samples and environmental filters in the São Francisco (SFC) and Japaratuba (JPC) canyons on the margin Sergipe, NE, Brazil. NBUC = Northern Brazil Undercurrent; DCC = Deep Contour Current; TW = Tropical Water; SACW = South Atlantic Central Water; AAIW = Antarctic Intermediate Water; NADW = North Atlantic Deep Water.

	SFC		JPC				
ST	Latitude	Longitude	Latitude	Longitude	WM	Current*	Depth
N3	-10,597	-36,3487	-10,874	-36,8233	TW	NBUC	50 m
N4	-10,619	-36,3406	-10,906	-36,817	SACW	NBUC	400 m
N5	-10,672	-36,3028	-10,960	-36,7995	AAIW	NBUC	700 m
N6	-10,715	-36,2481	-11,011	-36,7622	AAIW	NBUC	1000 m
N7	-10,728	-36,1959	-11,039	-36,7367	NADW	DCC	1300 m
N8	-10,773	-36,1174	-11,172	-36,7255	NADW	DCC	1900 m
N9	-11,087	-35,8977	-11,513	-36,5908	NADW	DCC	3000 m
			/				

*Santos et al. (2020)



Fig. 3 Temperature – Salinity diagram (T-S) for the São Francisco - SFC and Japaratuba - JPC submarine canyons on the continental margin of Sergipe, NE, Brazil, based on temperature and salinity values. Water masses: TW = Tropical Water; SACW = South Atlantic Central Water; AAIW = Antarctic Intermediate Water; NADW = North Atlantic Deep Water. N3 to N9 = sampling stations in SFC (light blue) and JPC (light pink).

The temperature of the bottom water and the organic phosphorus were the variables with the greatest range of variation, where the temperature ranged between 2.5 to 26 °C and the organic phosphorus between 98.7 and 325.9 μ g.g⁻¹. The total carbonate contents also showed broad variation, with minimum and maximum values of 6.3 and 30.9%. The other parameters showed a low range of variation (Table 2).

Table 2 Environmental variables (water mass properties and substrate variables) recorded during oceanographic campaigns carried out in the São Francisco (SFC) and Japaratuba (JPC) canyons. Values represent mean \pm standard deviation. WM = Water masses, TW = Tropical Water, SACW = South Atlantic Central Water, AAIW = Antarctic Intermediate Water, NADW = North Atlantic Deep Water, Temp = Temperature (°C), Sal = Salinity (psu), P_{org} = Organic Phosphorus (µg.g⁻¹), Carb = Total carbonates (%), Phi = Grain Average (Φ), Sk = Skewness, Kur = Kurtosis, O₂ = Dissolved Oxygen (mg/L).

	São Francisco canyon				Japaratuba canyon			
	TW	SACW	AAIW	NADW	TW	SACW	AAIW	NADW
Temp (°C)	23.7±0.0	$9.4{\pm}0.0$	4.6±0.7	$3.4{\pm}0.5$	26.0 ± 0.0	13.0 ± 0.0	4.7 ± 0.7	3.4±0.6
Sal (psu)	37.1 ± 0.0	34.8 ± 0.0	34.4 ± 0.0	34.8 ± 0.1	37.2 ± 0.0	35.2 ± 0.0	34.4 ± 0.0	34.9 ± 0.0
O ₂ (mg/L)	$5.9{\pm}0.0$	$6.0{\pm}0.0$	6.2 ± 0.1	7.2 ± 1.0	$6.0{\pm}0.0$	$6.0{\pm}0.0$	$6.0{\pm}0.0$	$7.4{\pm}0.9$
$P_{org}(\mu g.g^{-1})$	$313.8{\pm}0.0$	207.7 ± 0.0	182.3 ± 18.0	119.8 ± 12.7	127.7±0.0	$325.9{\pm}0.0$	206.8 ± 24.4	285.0±12.2
Carb (%)	11.7 ± 0.4	12.1 ± 0.1	12.3 ± 1.1	8.9 ± 1.0	12.96 ± 0.7	14.93 ± 0.6	19.11 ± 2.3	25.61±2.3
Phi (Φ)	6.1 ± 0.0	$6.4{\pm}0.0$	$6.4{\pm}0.0$	6.1±0.5	6.3±0.1	$6.4{\pm}0.0$	6.0 ± 0.3	5.5 ± 0.9
Sk	$0.3{\pm}0.0$	$0.3{\pm}0.0$	$0.3{\pm}0.0$	0.1 ± 0.1	$0.3{\pm}0.0$	$0.2{\pm}0.0$	$0.1{\pm}0.0$	$0.2{\pm}0.0$
Kur	1.3 ± 0.5	$1.0{\pm}0.0$	$0.9{\pm}0.0$	1.0 ± 0.0	$0.9{\pm}0.0$	$0.9{\pm}0.0$	2.3±3.3	1.0 ± 0.0

Spatial-vertical heterogeneity in areas affected by different water masses

Within the canyons, along the areas under the influence of different water masses, dissimilar characteristics were evidenced, promoting a stratification within these systems regarding their physicochemical properties. In SFC and JPC, O_2 showed increasing values, being higher in the area under the influence of NADW (PERMANOVA P = 0.01; pseudo-F = 19.2; Fig. 4A; Table S3). The contents of P_{org} and total carbonate varied differently inside both canyons. Within the SFC, the highest P_{org} concentration was associated with TW and lower in NADW, while in JPC this distribution pattern was increasing, with lower values being recorded in TW and higher in the areas of influence of SACW and NADW (Fig. 4C). Total carbonate, on the other hand, had the highest concentration in shallow waters (TW and SACW) and was lowest in NADW in SFC, while in JPC the lowest carbonate contents were registered in TW and SACW and higher in AAIW and NADW (Fig. 4B) (PERMANOVA P = 0.01; pseudo-F = 19.2).



Fig. 4 Boxplots showing the variation of environmental variables (water mass properties and substrate variables) between water masses Tropical Water (TW), South Atlantic Central Water (SACW), Intermediate Antarctic Water (AAIW) and North Atlantic Deep Water (NADW) inside the São Francisco (SFC) and Japaratuba (JPC) canyons on the continental margin of Sergipe, NE, Brazil. The dashed line represents the overall mean. The Carb was transformed into arcsine and the Sk was logarithmized by $log_{10}(x+2)$. Letters of different colors should not be compared. Different letters over the boxplots indicate significant differences (p < 0.05) between the water masses within each canyon.

Asterisk (*) indicate significant differences in water masses between canyons. Ns = not significant ($p \ge 0.05$).

From the first two axes of the PCA it was possible that PC1 explains 36.6% of the variation in the data, while PC2 explains 23%. This ordination revealed that PC1 is associated with water masses and depth, while PC2 is associated with canyons (Fig. 5). There was a greater influence of temperature, fine grains, and grain skewness in the areas under the influence of TW and SACW, while the area under the influence of NADW was formed by a higher concentration of P_{org} , total carbonate and higher levels of O₂. The AAIW presented intermediate levels of these parameters and lower salinity (Fig. 5).

Investigations into the effects of dispersion, which reflects the spatial heterogeneity within the areas of influence of water masses within the canyons, revealed that the area under the influence of NADW and AAIW had the highest multivariate dispersion in JPC (PERMDISP, p < 0.001), reflecting greater spatial heterogeneity in the deeper areas of the JPC canyon and less heterogeneity recorded for TW and SACW (Fig. 8A; Table S4). In the SFC, an increase in environmental heterogeneity was recorded in deep (AAIW and NADW) and shallow (TW) waters, and low heterogeneity for SACW (Fig. 8A; Table S4).



Fig. 5 Principal Component Analysis (PCA) based on environmental variables (water mass properties and substrate variables) in the area under the influence of Water Masses (WM) Tropical (TW), South Atlantic Central (SACW), Antarctic Intermediate (AAIW) and North Atlantic Deep (NADW) in São Francisco (SFC) and Japaratuba (JPC) submarine canyons on the Sergipe continental margin. O₂ = Dissolved Oxygen, Temp = Temperature, Sal = Salinity, Kur = Kurtosis, Sk = Skewness, P_{org} = Organic Phosphorus, Carb = Total Carbonate, Phi = Grain Average (Φ). The Carb was transformed into arcsine and the Sk was logarithmized by $log_{10}(x+2)$. N3 to N9 = sampling stations in SFC (light blue) and JPC (light pink).

β-diversity rates related to species substitution and selection between areas under the influence of different water masses

A total of 821 individuals were registered, belonging to 11 genera and 34 morphospecies of Capitellidae annelids (Fig. 6). The most abundant species were *Mediomastus* sp.2 (259 ind.) and *Parheteromastus* sp.1 (176 ind.), which represented 31.5 and 21.4% of the total abundance, respectively.

Species composition varied significantly among almost all water masses in both canyons (PERMANOVA, p = 0.001; Pseudo-F = 5.18; Table S2). In the SFC, dissimilarity in composition between TW and NADW was recorded (Fig.7; Table S2). In the JPC, the TW mass showed faunistic dissimilarity from the AAIW and NADW masses (Fig. 7; Table S2). No variation in composition was recorded between the SFC and JPC canyons (Table S2). Capitellidae communities showed significantly lower β -diversity in the TW area of influence, contrasting with the higher β -diversity recorded for SACW, AAIW and NADW in JPC and AAIW and NADW in SFC (PERMDISP p = 0.04; Fig. 8B). We also highlight that the SACW areas in the SFC did not show any occurrence of Capitellidae; as well as some areas within the NADW referring to the 3,000 m isobath in the JPC.



Fig. 6 Abundance of Capitellidae taxa captured in the São Francisco (A - B) and Japaratuba (C - D) canyons and their proportions according to the masses of Tropical Water (TW), Central South Atlantic Water (SACW), Intermediate Antarctic Water (AAIW) and North Atlantic Deep Water (NADW) on the continental margin of Sergipe, NE, Brazil. Ni = Not identified. Others = taxa with abundance of less than 3 individuals.



Fig. 7 Principal Coordinates Analysis – PCoA for Capitellidae species recorded in areas under the influence of Tropical Water (TW), South Atlantic Central Water (SACW), Intermediate Antarctic Water (AAIW) and North Atlantic Deep Water (NADW) in São Francisco – SFC and Japaratuba – JPC submarine canyons, on the continental margin of Sergipe, NE, Brazil. The community matrix was transformed by Hellinger and distances were calculated using Bray-Curtis. N3 to N9 = sampling stations in SFC (light blue) and JPC (light pink).



Fig. 8 Environmental heterogeneity (A) and β -diversity (B) for the four areas under the influence of the Tropical Water Masses (TW), South Atlantic Central Water (SACW), Intermediate Antarctic Water (AAIW) and North Atlantic Deep Water (NADW) in the São Francisco and Japaratuba canyons on the Sergipe continental margin, NE, Brazil. The β -diversity measure is the distance from the centroids for each area. Different letters indicate significant differences (p < 0.05) in the Multivariate Dispersion Permutation Analysis (PERMDISP).

Species restrictions along the environmental gradient provided by the water masses reflected in the overall β -diversity for the study area, which was quite high ($\beta_{JAC} = 0.93$) mainly due to species turnover ($\beta_{TUR} = 0.88$) (Table 3), showing that habitat patches restrict most species, corroborating in a combined way with the species selection and mass effect paradigms. In both canyons, the lowest β -diversity rates were registered between waters masses with more similar characteristics, as between the AAIW and NADW ($\beta_{JAC} = 0.80$ in SFC and $\beta_{JAC} = 0.66$ in JPC) (Table 3; Fig. S3). In the SFC, the area under the influence of SACW did not show any occurrence of Capitellidae (Fig. 6).

Table 3 β -diversity (β_{JAC}) and ecological mechanisms of nestedness (β_{NES}) and turnover (β_{TUR}) for the São Francisco (SFC) and Japaratuba (JPC) canyons on the continental margin of Sergipe, NE, Brazil. TW = Tropical Water; SACW = South Atlantic Central Water; AAIW = Antarctic Intermediate Water; NADW = North Atlantic Deep Water.

		water, INAD W	I WI III Alla	nic Deep wate
Canyo	n Category	βјас	βtur	βnes
SFC+JI	PC General	0.93	0.88	0.05
	TW vs AAIW	0.90	0.80	0.10
SFC	TW vs NADW	0.90	0.80	0.10
	AAIW vs NADW	0.80	0.80	0.00
	TW vs SACW	0.80	0.77	0.03
	TW vs AAIW	0.93	0.90	0.03
JPC	TW vs NADW	0.88	0.80	0.08
	SACW vs AAIW	0.92	0.90	0.02
	SACW vs NADW	0.86	0.80	0.06
	AAIW vs NADW	0.66	0.66	0.00

Effect of water masses properties and substrate variables on richness, abundance and diversity

The distribution patterns of abundance, richness, and diversity as a function of dissolved oxygen (O₂) levels revealed a decreasing relationship. The highest values of abundance, richness and diversity were registered in areas of low oxygenation, under the influence of TW in the SFC and the areas of TW and SACW in the JPC (Fig. 9; Table 4). Abundance, on the other hand, was influenced by a set of factors and in different ways, depending on the analyzed system. In both canyons, the increase in temperature (Fig. 10B and F) and salnity (Fig. 10A and E) promoted an increase in abundance. On the other hand, the influence of the levels of total carbonates, organic phosphorous and skewness was different in both canyons, while in the SFC the increase in abundance (Figs. 10C, I and K) in the JPC this relationship was inverse, where the increase in these variables
promoted abundance decline (Figs. 10G, J and D). Diversity and richness were associated with increased temperature and salinity 10M-T). Kurtosis showed low influence in the ecological indices (Fig. 10H and L). The other variables did not significantly influence (complete GLM's in Table S5).



Fig. 9 Variation of ecological indices of abundance (A), richness (B) and diversity (C) among Water Masses: Tropical Water (TW), South Atlantic Central Water (SACW), Intermediate Antarctic Water (AAIW) and North Atlantic Deep Water (NADW) in the São Francisco (SFC) and Japaratuba (JPC) canyons on the continental margin of Sergipe, NE, Brazil. Letters of different colors should not be compared. Different letters over the boxplots indicate significant differences (p < 0.05) between the water masses within each canyon.



Fig. 10 Smooth curves showing the relationship between the environmental variables (water mass properties and substrate variables) and ecological index of abundance (A – L), richness (M – P) and diversity (Q – T) of Capitellidae in the São Francisco (SFC) and

Japaratuba (JPC) canyons on the continental margin of Sergipe, NE, Brazil. Shaded areas indicate standard errors of smooth curve.

Table 4 Results of univariate PERMANOVA results showing the variations in ecological indices of abundance, diversity, and richness between the: Tropical Water (TW), South Atlantic Central Water (SACW), Intermediate Antarctic Water (AAIW) and North Atlantic Deep Water (NADW) in the submarine canyons São Francisco (SFC) and Japaratuba (JPC) on the continental margin of Sergipe, NE, Brazil. Values in bold indicate significant differences between water masses (WM).

Canyon	WM	WM Abundance Diversity		Richness	
		p-value	p-value	p-value	
Canyon SFC JPC	NADW vs AAIW	1	1	1	
SFC	TW vs AAIW	0.03	0.002	0.005	
	TW vs NADW	0.001	0.001	0.009	
	AAIW vs SACW	0.08	0.92	0.27	
	NADW vs SACW	0.14	0.94	0.09	
JPC	TW vs SACW	0.001	0.33	0.17	
	NADW vs AAIW	1	0.75	0.90	
	TW vs AAIW	<0.001	0.02	0.001	
	TW vs NADW	<0.001	0.001	<0.001	

Discussion

The presence of four water masses was evidenced in the submarine canyons, which promoted an increase in environmental heterogeneity and habitat diversification through vertical stratification. In addition, we found significant changes in the abundance, richness, and composition of Capitellidae annelids assemblages between areas affected by different masses in the submarine canyons. Due to the environmental variability, the species between the masses were distinct, resulting in high β -diversity mainly due to turnover processes, strongly associated with vertical environmental stratification and related to increased environmental heterogeneity in water masses. Contrary to what was predicted, abundance and richness did not increase with the presence of oxygen-rich water masses.

The four water masses are carried by two complex systems of currents in both canyons driven by the Northern Brazil Undercurrent (NBUC) and the Deep Contour Current Anticyclones (DCCA) (Santos et al. 2020). The NBUC is formed from the bifurcation of the South Equatorial Current and transports the water masses TW, SACW and AAIW. This WM around the Sergipe continental margin in a north/northeast direction following in towards the equator (Silveira et al. 2015; Santos et al. 2020). On the other hand, the NADW is transported by anticyclones formed by the instability of the

Deep Contour Current that disintegrates when trying to circumvent an area with complex physiography in the continental rise entering the SFC initially and later the JPC, in a south/southeast direction (Calixto 2016; Santos et al. 2020).

These masses are characteristic of the Southwest Atlantic Ocean and occupy the first three kilometers of the water column in a stratified way (Silveira et al. 2000; Santos et al. 2020; Sumida et al. 2020). However, this is the first study that has documented and identified water masses in the SFC and JPC canyons in Sergipe continental margin. The high temperatures (upper 20°C) and salinities (upper 36 psu) recorded in TW are related to the strong radiation and high evaporation, common in tropical oceans; on the other hand, the upper limit of the SACW can be tracked by the 20°C isotherm and salinity of 34.5 to 36 psu (Miranda 1985) and is formed by the sinking of water in the Subtropical Convergence area, followed by surface spreading (Silveira et al. 2000). The AAIW is a cold-water mass with the lowest salinity (34.2 psu) among the masses found in the South Atlantic Ocean and the NADW is the deepest mass (1,500 to 3,000 m), with the lowest temperature (2°C to 6°C) (Santos et al. 2020; Silveira et al. 2020). Thus, the presence of these water masses influences the environmental stratification in both canyons, corroborating findings that the vast availability of habitats at the bottom, due to the high spatial heterogeneity at various scales, promote environmental and structural changes in benthic communities (Gaever et al. 2009; Vanreusel et al. 2010; Guilini et al. 2012; Danovaro et al. 2013).

The effect of masses on the spatial heterogeneity of the deep-sea has been investigated in terms of physio-chemical variations (e.g.: temperature, salinity, organic matter flux, the concentration of oxygen, current velocity, and stability, sediment type, and bathymetric gradients; Levin et al. 2001). The effects of these masses on diversity are commonly reported for bacterial communities, due to the great sensitivity of these organisms to variations in the unique characteristics of each mass, and it is common to use these organisms (bacteria) as indicators of water masses due to high environmental filtration and degree of correlation (Fu et al. 2013; Cao et al. 2020). Most research carried out on the continental margin of Brazil has focused on the influence of SACW and its seasonal upwelling/uplifting processes, and its effects on increasing abundance and richness, generally significant due to the increase in the availability of resources, in

addition to increasing phytoplankton productivity (Saldanha-Corrêa and Gianesella 2004; Shimabukuro et al. 2016).

The magnitude of the effects of water masses on the benthic assemblages may be scale-dependent. On a large spatial scale (continental margin S and SE of Brazil), water masses and their associated parameters may have a low influence on community structure, due to horizontal homogenization due to the displacement of SACW (De Leo et al. 2020) along the continental margin towards southern Brazil (Silveira et al. 2015). This horizontal homogenization is often related to current systems, which can shift sets of species to other areas, generating nesting patterns, since on a long-time scale, such species can have their distributions expanded (Hebbeln et al. 2019). The areas closest to the surface, where TW and SACW are present in the canyon axes, present the highest vertical flows (uplift and down lift of SACW and TW), depending on the most important current regime at each moment. It is possible that, in this area, the currents generated in the continental shelf, dominated by the wind most of the time, are the main mechanism associated with vertical movements in the canyons, which can generate vertical transport of SACW in both directions (Del-Giovannino et al. 2019), and consequently the influence of SACW at the surface (Parente et al. 2021). On the other hand, in deeper areas, where mainly AAIW and NADW dominate, vertical movements are much reduced (Del-Giovannino et al. 2019). The results obtained showed that deep water masses with similar environmental characteristics and low vertical flux (AAIW and NADW) hosted different sets of species due to faunal turnover, while areas dominated by TW and SACW were also structured by turnover, but small contributions were recorded from species nesting to β-diversity patterns. This indicates the occurrence of movement of species between these areas. These movements may have been facilitated due to vertical flow movements in the water masses located closer to the head of the canyons.

In previous studies, the spatial heterogeneity of the habitat represented one of the main factors for the organization and structure of deep-sea benthos (Etter and Grassle 1992; Gaever et al. 2009; Vanreusel et al. 2010). However, for the large canyons (SFC and JPC) on the Sergipe continental margin, the increase in β -diversity was not directly associated with the availability of microhabitats (environmental heterogeneity). The role of environmental heterogeneity acting on faunal turnover, according to Zeppilli et al. (2016) is still largely unknown, as most studies involving the deep sea have focused their investigations on variations in benthic biodiversity between deep sea systems (eg,

canyons vs. continental slope) (Danovaro et al. 2009). In the present study, although NADW was characterized as a very heterogeneous area, it supported low diversity indices (β-diversity, N and S) because of other factors. It was notable that areas with high temperatures (mainly in tropical waters) and low heterogeneity (such as in TW) supported rich, abundant, and diverse communities, as faunal communities from tropical regions (such as the northeast of the Brazil), are adapted to higher temperatures, which contributed to the higher rates of β -diversity recorded for the study area, evidencing the synergistic effect between one or more environmental factors. This evidence may suggest that the wide temperature range recorded inside the canyons (from the headwaters to the bottom [TW to NADW]) promotes a relationship temperature/diversity 'right-skewed' unimodal (i.e., with greater species diversity in environments with greater temperature) (Yasuhara and Danovaro 2016). This is due to the fact that temperature effects only become evident when they represent environmental extremes, characterizing a strong gradient, where sets of specific species inhabit tolerable ranges, corroborating the metabolic hypothesis and island biogeography theory as the main mechanisms identified for explain this relationship (Yasuhara and Danovaro 2016). Thus, it is known that not only the effect of deep-sea environmental heterogeneity, but the set of environmental filters acting together with heterogeneity, such as the quantity and quality of food available to be used as a resource and energy source by the deep-sea fauna (Gaever et al. 2009; Vanreusel et al. 2010) and temperature changes have great influence on patterns of faunal organization (Yasuhara and Danovaro 2016).

The high turnover rates for Capitellidae communities among the deep-sea water masses can be explained by the large vertical stratification and specific characteristics of the bottom, such as grain size, suggesting that the areas with different oceanographic characteristics and their associated physiochemical properties (water masses properties) are colonized by different sets of species of Capitellidae due to environmental variations. This pattern of faunal turnover due to strong environmental gradients has been observed in other studies (see Gaever et al. 2009; Vanreusel et al. 2010; Guilini et al. 2012; Danovaro et al. 2013). Associated with this, the highest β -diversity rates between TW vs AAIW and TW vs NADW (in SFC), TW vs AAIW and TW vs SACW (in JPC) are related to the background characteristics as to the degree of selection (DS) and grain size (Phi) in the areas of influence of the water masses. Studies show that particulate mattereating organisms (such as Capitellidae) tend to ingest sediments in specific size classes

(see Wheatcroft and Jumars 1987; Self and Jumars 1988; Wheatcroft et al. 1990; Wheatcroft 1992), so habitats with higher grain selectivity and fine grains (such as the areas in TW) allowed a greater diversity of species for warmer waters and with well-selected grains and positive symmetry.

One of the main markers for classifying water masses are the oxygen levels (De Leo et al. 2020; Silveira et al. 2020). We found a negative relationship between the diversity of Capitellidae (N and S) and the increase in O₂. Conversely, other variables, such as salinity and temperature, had a positive influence, as higher N and S were found in areas with TW intrusion (hot and saline waters). Previous studies have investigated the influence of hypoxia in marine environments and observed that the low concentrations of O2, common in shallower waters (TW and SACW), are related to high temperatures, which diffuse the O₂ into the atmosphere, reducing its concentration in the marine environment (Graham 1983; Kramer 1987). However, in the present study, the TW and SACW water masses, although presenting lower O₂ values, do not represent true hypoxic conditions and do not due to the low variability of this property between the water masses. Deep-sea studies have reported similar patterns of increased diversity associated with rising temperatures, especially for tropical environments with a wide range of variation (Hunt et al. 2005; Yasuhara et al. 2014). Under lower O₂ conditions, the benthic fauna requires adaptations for optimization and better uptake of O₂ (Rantin et al. 1993; Fraser et al. 2006). For many groups of oxi-regulator annelids, the maintenance of metabolism is kept stable even when the environmental O₂ is reduced (Prosser 1973). Such is the case of many capitellid species, as the group is known for being tolerant to hypoxic conditions, with different taxa of the family presenting an opportunistic behavior in organically enriched areas, being one of the most common indicator taxa of pollution in the benthic environment (Pearson and Rosenberg 1978; Giangrande and Gravina, 2015; Silva et al. 2017; Checon et al. 2021; Gravina et al. 2020). The metabolism pathways and behavioral adaptations that allow these patterns to have been described for multiple species (Méndez et al. 2000; Horng et al. 2009; Rakocinski and Gillam 2017). For instance, it was evidenced that for the capitelid Capitella teleta Blake, Grassle, Eckelbarger 2009, when inhabiting areas under hypoxic conditions, it develops several adaptations, mainly concerning the reduced body size, increased production of respiratory pigments, ventilatory behavior and anaerobic breathing capacity (Rakocinski and Gillam 2017).

These low O₂ areas support benthic ecosystems that fundamentally differ from well-oxygenated environments in terms of abundance, species composition, and diversity (Sanders 1969). These patterns were evidenced for the SFC and JPC canyons between water masses with different levels of O₂. Thus, species that inhabit oxygen-poor waters, may present strategies related to the spatial sharing of the niche within the sediment layers, since species that live in very low oxygen concentrations are generally vertical migratory (Sameoto et al. 1987; Kinzer et al. 1993; Saltzman and Wishner 1997). In shallower water environments (50 m in this study) under the influence of water masses with low oxygenation (eg, TW and SACW area of influence in the present study), most organisms show behavioral adaptations, where they generally tend to move out of the low O₂ area or to the surface of the sediment, causing a dense grouping of animals in oxygenated water or on the surface of the sediments (Saltzman and Wishner 1997; Levin 2003) or use compacted mud to obtain greater stability in the oxygen flow inside galleries (Smith 1986; Levin and Edesa 1997; Levin et al. 2000). In this study, the higher abundance of Capitellidae species in areas with poorer O₂ concentrations may suggest that this group adopts strategies related to migrations in the sediment layers in search of O₂. Due to the scarcity of ecological studies involving Capitellidae in the deep sea, we recommend that future studies focus their investigations on the vertical displacement patterns and body size of capitellids within the sediment layers in areas under the influence of low oxygenation, for a better understanding of the mechanisms that allow the coexistence of this large number of species in oligotrophic waters and with low O2 concentration (eg, TW and SACW in this study), since the patterns and drivers for Capitellidae species recorded here do not correspond to patterns identified for coastal ecosystems (eg, increase in abundance and richness related to nutrient availability (Tsutsumi et al. 1990)).

Finally, our results, for the first time, showed that the intrusion of water masses into the interior of submarine canyons can promote an increase in environmental heterogeneity and vertical environmental stratification between water masses, corroborating our first hypothesis. This gradient promoted high rates of β -diversity mainly between areas under the influence of spatially distant water masses and dissimilar in environmental characteristics (water masses properties and substrate variables). The increase in β -diversity was not directly related to the increase in environmental heterogeneity, corroborating partially with our second hypothesis. N and S declined with the intrusion of oxygen-rich masses into canyons, evidencing that O₂ is a secondary factor for capitelid annelid communities, with temperature and salinity being the main driver of N, H' and S, which did not corroborate with our third hypothesis. Furthermore, we conclude that the soft sediments of both canyons, which are heterogeneous and vertically stratified throughout the studied system, must be protected to preserve their biological resources and maintain their developed ecological functions (nutrient cycling by detritivorous capitelid species) (see Thurber at al. 2014 for more information), since turnover rates were high and no assemblage was characterized as a subset of larger ones, even those with reduced species number, as observed for NADW and AAIW. These high turnover rates that make up the β -diversity can help in the delimitation of priority areas for conservation (Magurran 2005; Baselga 2010; Checon et al. 2018), since our results showed low species redundancy, showing that environmental impacts, even on a local scale, generate a loss of diversity at the continental margin scale (γ -diversity), therefore, future management and conservation plans must consider a greater number of priority areas and that contemplate the vast diversity of habitats formed by the performance of the water masses recorded in this study.

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Author contribution J. Weverton S. Souza performed the analyzed the data, wrote the paper, prepared figures and tables, reviewed drafts of the paper and identified the

capitelids. Hélio H. Checon analyzed the data, wrote the paper, reviewed drafts of the paper. Camila F. da Silva reviewed drafts of the paper and identified of capitelids. Carmen R. Parisotto Guimarães conceived and designed the sampling collections, contributed reagents/materials, reviewed drafts of the paper. Marcelo Dottori contributed analysis tools, reviewed drafts of the paper, and A. Cecília Z. Amaral contributed reagents/materials/analysis tools, reviewed drafts of the paper.

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Availability of data and material All data supporting the findings of this study are available within the manuscript and its Supplementary Information and appendices.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Capítulo 2

Effect of different spatial scales on environmental and β-diversity patterns of Capitellidae in submarine canyons of NE Brazil

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Abstract

The effect of the spatial scale has great influence on the patterns observed in environmental heterogeneity – EH and β -diversity. In larger scales, there is an increase in EH, since a greater range of micro-habitats is contemplated in broader scales and, consequently, greater β -diversity is generally associated with environmental filtering effects, due to increased heterogeneity as a reflection of environmental variability as presupposed by the hypothesis of habitat heterogeneity. In this study, we evaluated the influence of spatial scale in EH and the β -diversity, rates of co-occurrence in patterns of Capitellidae annelids and effects of spatial and environmental components in two large submarine canyons, a little-studied ecosystem. The increase in the spatial scale promoted an increase in environmental heterogeneity, being higher in continental margin scale than in the small scale. Despite being smaller, heterogeneity at a small scale presents significant oscillations due to local environmental characteristics. The βdiversity patterns showed a significant increase as a function of the increase in the spatial scale, revealing greater changes in species exchange rates at the largest analyzed scales. The co-occurrence patterns revealed that on small scale, communities were structured randomly, while on an intermediate scale, random and positive patterns were registered. On the other hand, on a large scale, the communities showed positive distribution patterns in response to the environmental gradient. Spatial factors were more important at small scale (only SFC dry period) and at large scale. In the other small-scale and medium-scale categories, environmental factors prevailed. Thus, we conclude that the results obtained indicate the influence of neutral and niche processes on the β-diversity of Capitellidae annelids in submarine canyons and that the spatial scale analyzed directly influences the observed patterns and are dependent on characteristics of each system.

Keywords: Co-occurrence, deep-sea, mass effect, metacommunity, species sorting

Introduction

Understanding distribution biodiversity patterns and the processes that give rise to them has fundamental theoretical and applied importance (Levin, 1992). Every biological pattern depends on ecological processes acting on different spatial scales, and their correct understanding requires the analysis of phenomena occurring on different dimensions (Levin, 1992; Heino et al. 2015c; Lansac-Tôha et al. 2021). The spatial variation of biological communities (β -diversity), for example, sustains conservation theory and practice (Barton et al. 2013), and a growing body of research has indicated that spatial scale has important influences on the measurement and interpretation of β diversity patterns (e.g., Sreekar et al. 2018).

β-diversity is expected to increase with the spatial scale as larger distances among sites are likely to increase the range of microhabitats, leading to higher environmental heterogeneity (i.e., variation in environmental conditions, EH) and environmental filtering (i.e., strong effect of environmental variables on community assembly) (Nekola; Branco, 1999; Tews et al. 2004; Heino et al. 2015a,b). Increasing geographical distances is also expected to enhance dispersal limitation, resulting in spatially structured assemblages and consequently higher β-diversity over large spatial scales (Nekola and White, 1999, Shurin et al. 2009). On the other hand, biological interactions such as trophic interactions and competition are expected to affect βdiversity on smaller scales (Kissling; Schleunig, 2015). While the influence of spatial scale on biodiversity and environmental patterns is widely recognized in terrestrial and aquatic systems (e.g., De Leo et al. 2014; Alves-Martins et al. 2019; Gallucci et al. 2020; Lansac-Tôha et al. 2021), community ecology has historically focused on a single spatial scale. Consequently, the patterns and processes shaping the spatial scaling of βdiversity remain to be better explored (Barton et al. 2013, Sreekar et al. 2018).

An effective way to understand how ecological processes determine biodiversity patterns at different scales is the metacommunity approach (Gilpin; Hanski, 1991; Leibold et al. 2004; Leibold; Norberg, 2004; Heino et al. 2015c). A metacommunity is a set of local assemblages regulated by environmental (niche differentiation), spatial variables (associates to dispersal) and random process (Leibold et al. 2004). In theory, neighboring assemblages would be more similar when dispersal rates are high, reflecting in a small-scale spatially structured metacommunity with lower β -diversity. Conversely, species may reach optimal patches and enhance the importance of environmental filtering with lower dispersal rates (Leibold et al. 2004; Cottenie, 2005),

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leading to higher beta diversity at larger scales. With excessively high dispersal, the importance of spatial processes increases again due to a mass-effect wich allows species to colonize suboptimal patches, thereby reducing the environmental control and potentially reducing β -diversity at larger scales (Heino and Grönroos, 2013; Corte et al. 2018).

An advantage of the metacommunity approach relies on its applicability in different scales, allowing us to better understand how biodiversity patterns are shaped by environmental and spatial processes according to the scale investigated. Furthermore, metacommunity ecology can be especially useful in aquatic habitats (Heino et al. 2015c, Corte et al. 2018), since they are characterized as open systems, and thus linked to each other via dispersal (Gray; Elliott, 2009). Also, dispersal rates in marine environments are dependent on environmental features operating at different scales, such as the seafloor slope and action of currents (Norkko et al. 2001a,b; Valanko et al. 2010a,b). Nevertheless, most investigations around metacommunity organization in aquatic ecosystems were done in freshwater habitats (Heino et al. 2015c), with very few investigations in marine environments (e.g., Checon et al. 2018; Corte et al. 2018).

In deep marine habitats, submarine canyons constitute a geomorphological feature that connects the continental shelf and the continental rise, being essential to the transfer of matter and energy between these environments (Gardner, 1989; Griggs et al. 1969). Although there are almost 700 submarine canyons worldwide (De Leo et al. 2010), the structure, biomass, richness, and diversity of benthic assemblages have been investigated in less than 0.5% of them (Curdia et al. 2004; De Leo et al. 2010; Cunha et al. 2011). Within these large systems, it is possible to find tributary channels and ravines, as well as dynamic hydrographic patterns due to water masses and marine currents, which can increase the flow, transport and accumulation of sediment within the canyons (Company et al. 2008). These environments can increase marine regional diversity and provide vary habitats for diverse and abundant local communities (Ismail et al. 2018). Environmental heterogeneity, along with organic matter input, are considered main drivers of deep benthic biodiversity (Etter; Grassle, 1992; Escobar-Briones et al. 2008). Nevertheless the high physical complexity of habitats found in submarine canyons and the scarcity of studies, precludes the understanding of their biodiversity patterns at different spatial scales (Vetter; Dayton, 1998).

In this study, we performed the first investigation on the β -diversity patterns and metacommunity organization of macrobenthics assemblages in submarine canyons at

different scales. We focused our analyses on Capitellidae polychaetes, one the marine benthic taxa with higher number of individuals and species. Capitellidae are commonly found from the intertidal zone to deep-water ecosystems regions (Silva et al. 2017; De Leo et al. 2014; Robertson et al. 2020; Rodríguez et al. 2021), present a deposit-feeding habit, and many species exhibit opportunistic behavior, inhabiting organic-rich muddy environments where they reach high densities (Dean, 2001). We used a hierarchical sampling design with two spatial scales, to test the hypotheses that: (a) increasing spatial scale will promote an increase in EH, since as the spatial extent increases a greater variety of habitat types is contemplated (Cavender-Bares et al. 2009; De Leo et al. 2014); (b) increase in heterogeneity will lead to higher rates of β -diversity, since greater environmental variability at larger scales will promote changes in species composition as a result of species sorting (Chase; Leibold 2003); (c) in the smaller scale, we expected to find negative species co-occurrence due to the lower availability of microhabitats (low heterogeneity) (Cavender-Bares et al. 2009; Thorpe et al. 2011; Sutton et al. 2021); (d) we infer that the influence of spatial processes will be greater on a smaller scale, since the reduction in spatial distance between locations facilitates the dispersal of species as a result of the mass effect process. On the other hand, environmental variables will prevail on larger scales due higher environmental variable and lower dispersion (Heino et al. 2015c). In this case, although low dispersion occurs, there will be no limitation of dispersion, since marine environments are highly connected, therefore, there is a predominance of environmental filters (see Figure 1).



Figure 1. Illustrative scheme of the main hypotheses in this study, showing the effects of spatial scale on environmental heterogeneity (EH) and β -diversity for metacommunity organization in two submarine canyons (C1 and C2) in two seasonal periods. In this scheme, the spatial component can be understood as species dispersion, thus, dispersion is high on a small scale (C1 and C2) due to the proximity of sites and low when sites are distant (i.e., large scale – C1+C2). On a small scale, high dispersion rates lead to a strong spatial signal, as nearby locations are homogeneous, generating mass effects. As the scale increases, from smaller to large scales, dispersion rates are reduced and, as a result, few species can break through the environmental filters,

promoting species sorting – at large scale, or very low dispersion rates show that the species are restricted locally (dispersion limitation). Also, on a small scale, due to reduced space, pairs of different species may never be recorded together in patches of local habitats, generating negative co-occurrence patterns (checkboard structure).

Material and Methods

Study area

The continental margin of the state of Sergipe, in Northeast Brazil, is subdivided into continental shelf, continental slope and continental rise (França et al. 1976; Guimarães, 2010). The study area comprised two large mature canyons (incised on the continental shelf and slope), São Francisco (SFC) (11 km wide) and Japaratuba (JPC) (21 km wide) (França et al. 1976) (Figure 2). The SFC has its formation directly associated with the São Francisco River, due to its large flow and distance of only 8 km from the coast, appearing on the isobaths of 15 to 20 m (Fontes et al. 2017). The JPC is larger and deeper, but unlike the SFC, it has no connection with the Japaratuba River and is located 10 km away (30 m isobath) (Fontes et al. 2017). Sedimentation rates in the SFC are fast (37 – 39 cm/1000 years), while in the JPC these rates are much lower (7 cm/1000 years) (Fontes et al. 2017). Both canyons have scars on their margins, due to recent mass movements in the SFC and old ones in the JPC (Borges et al. 2017; Oliveira-Junior et al. 2017), and "V" cross-section shape (França et al. 1976; Fontes, 2015).

Sampling design

We defined two spatial scales that contemplate a vast environmental gradient in the levels of small scale – SS [individuals canyons – SFC and JPC ($v = 1.89 \text{ m}^3$ in each canyon)] in two seasonal period, and large scale – LS [SFC+JPC ($v = 3.78 \text{ m}^3$ each seasonal period)].

Sampling was performed between March and April 2013 (dry period) and October and November 2013 (rainy period) as part the project "Environmental characterization of the sedimentary basin of Sergipe-Alagoas – MARSEAL" in partnership with PETROBRAS and the Federal University of Sergipe - UFS. The same sampling design was used in both periods. In each canyon, sediment samples were collected in triplicate, at seven stations located in the isobaths of 50 m, 400 m, 700 m, 1000 m, 1300 m, 1900 m and 3000 m (**Figure 2; Table S3**).

Sediment samples were obtained using a Box Corer bottom grab with dimensions of 50 x 50 x 50 cm, equipped with nine templates measuring 10 x 10 x 10 cm, sampling a total volume of 0.09 m³ per sample, intended for faunal analysis (**Figure 2; Figure S1**). All samples were packed in plastic pots with 10% formaldehyde buffered with borax and Bengal rose dye. In addition to the biological data, from each sample, sediment samples were obtained by an additional 10 x 10 x 10 cm template (**Figure 2**) to evaluate the granulometry (mean grain size (Phi [ϕ]), sediment fractions (%) of sand (very coarse; coarse, medium, fine, very fine and total); silt (coarse, medium, fine, very fine and total); clay (very coarse, coarse, medium, fine, very fine and total) and total mud (silt + clay)) and determination of total organic carbon (%), total nitrogen (%), organic phosphorus (µg.g⁻¹) and quality of organic matter (carbon/nitrogen ratio – C/N).



under a stereoscopic microscope. The organisms found were separated at higher taxonomic levels and placed in glass vials with 70% alcohol. The capitelids were

selected and identified in morphospecies with the aid of stereoscopic (Zeiss Stemi SV11) and optical (Zeiss Scope.A1) microscopes, using specialized bibliography (Ewing, 1984; Dean, 2001; Green, 2002; García-Garza, 2009; Silva et al. 2016; Silva et al. 2017).

Procedures for environmental data

Sediment granulometry was evaluated by the laser diffraction method using the Marvern Mastersizer 3000 equipment, at Universidade Estadual Paulista – UNESP. The sediment fractions were divided using the classification scale of Wentworth, 1922. Afterward, the statistical parameters of the sediment (mean, sorting coefficient, skewness and kurtosis) was calculed. For the determination of the total carbonate (Carb_T) content, the gravimetric method of carbonate elimination with hydrochloric acid treatment was applied, carried out by the GeoRioeMar laboratory at Federal University of Sergipe – UFS.

For geochemical analyses, organic carbon (C_{org}) and total nitrogen (N_T) were initially determined, it was necessary to eliminate inorganic carbon by adding an acidic solution (HCl 10%), in successive steps until pH stabilization. About 5 to 10 mg of dry and decarbonated sediment were weighed in tin capsules and inserted into the elemental analyzer Thermo Finningan, model EA1112, for the determination of Corg and NT by the dry combustion method (Hedges; Stern, 1984). To determine the total phosphorus (P_T) 0.5 g of the sediment was weighed, which was previously dried in an oven for 2 hours at a temperature of 105 °C. Then the sample was calcined at a temperature of 550 °C for 2 hours, for oxidation of organic matter and release of all phosphorus compounds in the form of orthophosphates, and subsequent extraction step in acid medium. For the determination of inorganic phosphorus (Pinorg), the same procedure as the PT was used without the step of calcination of the sediment sample (Aspila et al. 1976). The P_T and Pinorg content in the final extract was quantified by the molybdenum blue spectrophotometric method (APHA, 2005; Grasshoff et al. 1983). Organic phosphorus (P_{org}) was calculated by the difference between P_T and P_{inorg} . These methods were carried out by the Environmental Chemistry Laboratory at UFS.

Data analysis

Initially, the multicollinearity between the 30 environmental variables used in the complete model was investigated (**Appendix 1**). The multicollinearity models were performed sequentially, and from each model, the variable with the highest inflation value was removed through the analysis of the Variance Inflation Factor – VIF. For these models, VIF > 10 was considered as a cut-off value for multicollinearity, and with that, 16 environmental variables were used in the subsequent analyzes to characterize the habitat and relationship with the fauna (see model M15 **Appendix 1**). This analysis was developed in the R software (R Core Team, 2021) using the car package (Fox; Weisberg, 2019).

a) increasing the spatial scale will promote an increase in EH

An environmental characterization was carried out to show the variability the two spatial scales considered SS [canyons – SFC and JPC ($v = 1.89 \text{ m}^3$) in each seasonal period] and LS [SFC+JPC each seasonal period ($v = 3.78 \text{ m}^3$)] through a Principal Component Analysis (PCA). To verify whether the increase in spatial scale (SS and LS) promotes an increase in EH, the multivariate dispersion effect was investigated, using a Multivariate Dispersion Permutation Analysis – PERMDISP (Anderson, 2006), based on Euclidean distances, for each special scale (SS and LS). From this analysis, it is possible to measure the average distance of the samples of each scale to the centroid of each group (SS and LS) in a multivariate space based on an analysis order of principal coordinates (Anderson et al. 2006). Thus, the greater the average distance of sampling sites from their centroid at each spatial scale, the greater the environmental heterogeneity. To measure the significance (p < 0.05) of the centroids of each scale, 999 permutations were performed. Subsequently, Tukey's test was applied for paired comparisons between the two spatial scales (SS and LS) during the two seasonal periods (dry and rainy).

b) On larger scales, the largest β -diversity will be recorded

To verify whether the increase in spatial scales promotes an increase in the β diversity of the metacommunity capitellids in the continental margin in NE, Brazil, a PERMDISP analysis (Anderson, 2006) was carried out using the biological data to obtain the values of multivariate dispersion and average distance to the centroid for each scale. The matrix of metacommunities containing the abundance of species in each locality was transformed using the Hellinger transformation (Legendre; Gallagher, 2001). In the PERMDISP, greater dispersions in the assemblage indicate greater β -diversity. For this analysis, species composition matrices were considered individually for all spatial scales (SS [v = 1.89 m³] and LS [v = 3.78 m³]) and the distances for centroid were calculated based on Bray-Curtis dissimilarity metric. The Tukey's test was applied for paired comparisons between the two spatial scales during the two seasonal periods.

c) in the smallest scale, it is expected to find negative species co-occurrence

To investigate species distribution patterns at different spatial scales (SS and LS) probabilistic species co-occurrence models (prob_{cooccur}: Probability that both species occur at a site) were applied (see Veech, 2013), which calculates the observed (obs_{cooccur}: Observed number of sites having both species) and expected (exp_{cooccur}: Expected number of sites having both species) frequencies of co-occurrence between each pair of species with base in sp1_inc (number of sites [or samples] that have species 1) and sp^2 inc (number of sites that have species 2). For this, binary matrices (presence and absence) of species were used containing the sampling sites ordered by levels of pre-established scales. In this test, columns p^{tt} and p^{gt} give us our p-values. If $p^{tt} < 0.05$, then the species pair co-occur at a frequency lower than we would expect to find by chance. If $p^{gt} < 0.05$, the pair co-occurs at a rate higher than we would expect to find by chance. As a result, species may exhibit positive (species co-occur more than expected by chance), negative (species co-occur less than expected by chance), or random patterns (co-occurrence patterns do not differ from those expected by chance) (for more information see Veech, 2013; Griffth et al. 2016). Thus, the study of associations can provide supporting evidence for ecological processes or factors that lead to a particular pattern of co-occurrence (Rahman et al. 2021).

d) Effects of spatial processes will be greater on continental margin

To evaluate the relative contributions of environmental and spatial processes on the organization of Capitellidae metacommunities, the partition of variance was performed using Redundancy Analysis (RDA) (Borcard et al. 1992). The matrix of metacommunities was transformed by Hellinger (Legendre; Gallagher, 2001), while the environmental matrix was standardized. Afterward, separate analyzes were performed for the set of spatial and environmental variables. The set of environmental variables

used refers to water and sediment variables, while the spatial filters are constituted by a distance matrix based on Moran Eigenvector Maps (dbMEM), which transforms pairs of geographic coordinates into a truncated Euclidean distance matrix. The eigenvectors generated are the dbMEM used as spatial variables in the analyzes (Borcard; Legendre, 2002; Griffith et al. 2006). A redundancy analysis (RDA) was carried out using the environmental and spatial datasets. To evaluate the individual and shared contributions of these datasets to the explained variance, a variation partition approach was performed, decomposing the variance in [E] purely environmental, [E \cap S] shared between spatial and environmental, [S] purely spatial, and [Residual] unexplained variation (Borcard et al. 1992; Legendre et al. 2005; Griffith et al. 2006). The final environmental and spatial variables were selected separately for the RDA models using a forward selection procedure with a significance level of p < 0.05 and 999 permutations (Blanchet et al. 2008).

All analyzes were carried in the R software (R Core Team, 2021), out using the *Vegan* (Oksanen et al. 2019), *FactoMineR* (Le et al. 2008) and *factoextra* (Kassambara; Mundt, 2020), *FD* (Laliberté; Legendre, 2010; Laliberté et al. 2014) packages for PERMDISP, PCA and RDA; and *cooccur* package (Griffith et al. 2016) for co-occurrence models. Graphical presentations of the results were prepared using the *ggplot2* (Wickham, 2016).

Results

Environmental characterization

The grain size in the São Francisco (SFC) and Japaratuba (JPC) submarine canyons ranged from very fine silt to very coarse sand, with a predominance of grains in the fine fraction (silt and clay), and among the fine grains, the highest proportion was of silt, corresponding to 85% of the sediments that make up the seabed inside the canyons **(Table S1)**. The bathymetric distribution of grain size in the interior of SFC in both seasonal periods (SP), revealed that 50 m and 400 m isobath were influenced by the greatest influence of salinity, organic phosphorus (P_{org}), C:N_{ratio}, silt (medium and coarse), total carbonate (Carb_T), and grains with positive skewness. Already at 3000 m, the deepest area it is formed by the highest levels of C_{org}, medium (MS) and very fine (VFS) sand, and poorly selected grains, evidenced by the highest sorting coefficient (SC) **(Table S1)**.

In the JPC the spatial patterns in the bathymetric oscillated in different ways during the two SP. When analyzing these patterns during the dry period we evidenced a low influence of P_{org} on the 50 m isobath, high salinity and higher mean silt content (MSi). In 1900 and 3000 m receive the greatest contributions of organic nutrients (P_{org} and C_{org}) and $Carb_T$ (for more details see **Table S1**). In the rainy season, the 3000 m isobath receives greater contributions from MS, CS and SC. Already at 50 and 400 m a greater influence of salinity and C:N_{ratio} (**Table S1**).

The comparison between the canyons reveals that the environmental characteristics are different (p = 0.001; Pseudo-F = 10.28; **Table 2**). The SFC receives greater contributions from VFC, VCS, MSi, C:N_{ratio} (Figure 3). JPC on the other hand, presents a more complex environmental structure, retaining a greater contribution of C_{org}, Carb_T and grains with MS, VFS texture, Kur and poorly sorted grains (SC) (Figure 3).



Figure 3. Principal Component Analysis (PCA) based on environmental variables in the submarine canyons São Francisco (A - C) and Japaratuba (B - D) in São Francisco and Japaratuba during the seasonal periods dry and rainy in Sergipe continental margin. Carb_T = Total carbonates (%); VFC = Very fine clay; CSi = Coarse silt; MSi = Medium silt; VFSi = Very fine silt; VCS = Very coarse sand; CS = Coarse sand; MS = Medium sand; VFS = Very fine sand; SC = Sorting coefficient; Kur = Kurtosis; Sal = Salinity (psu), C:N_{ratio} = Carbon/Nitrogen ratio; P_{org} = Organic Phosphorus (μ g.g⁻¹), C_{org} = Organic Carbon.

Table 2. Multivariate PERMANOVA based on the matrix environmental variables in São Francisco – SFC and Japaratuba – JPC submarine canyons during dry and rainy seasonal periods – SP in Sergipe continental margin, NE, Brazil. d.f. = degrees of freedom, SS = sum of squares, n° perm = number of permutations.

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	Fator	d.f	SS	R ²	Pseudo-F	P (perm)
	SP	1	0.023	0.03	3.29	0.0408

Canyon	2	0.144	0.19	10.28	0.0001
Residual	80	0.561	0.77		
Total	83	0.728	1.00		

a) the increase in the spatial scale will promote an increase in EH

We evidenced an increase in EH with the increase of the spatial scale, with the heterogeneity being higher in LS (SFC+JPC in rainy). The lowest EH small scale (in SFC) (PERMDISP, p = 0.001) (Figure 4A). Thus, we found that on a smaller scale, EH generally is low, but presents significant oscillations due to local environmental characteristics (Figure 4A).



Figure 4. Environmental heterogeneity (A) and β -diversity (B) for two spatial scales (small scale – individual canyons [V = 1.89 m³] and large scale – SFC+JPC each period [V = 3.78 m³] in São Francisco (SFC) and Japaratuba (JPC) submarine canyons during dry and rainy seasonal periods in the continental margin of Sergipe, NE, Brazil.

b) the increase in the spatial scale will promote an increase in β -diversity

An abundance of 1,306 individuals was registered, belonging to 12 genera and 41 morphospecies of Capitellidae annelids. The most abundant species were *Mediomastus* sp. 2 (representing 34% of total abundance) and *Parheteromastus* sp. 1 (18% of total abundance) and *Leiochrides* sp. 2 (14.2%). The β -diversity patterns showed a considerable and significant increase (PERMDISP, p = 0.001; **Table 3**) as a function of the increase in the spatial scale, revealing greater changes in species composition rates at the largest analyzed scales (LS) (**Figure 4B and Table 3**).

Table 3. Permutation test for multivariate dispersion homogeneity (PERMDISP) based on the matrix environmental (Env) and species composition (β -diversity) for three spatial scales – SS (small scale [V = 1.89 m³], large scale – LS [V = 3.78 m³] in São

			Dry			Rainy		
Environmental	Scale	Unit	SFC	JPC	SFC+JPC	SFC	JPC	SFC+JPC
	SS	SFC	-	0.18	0.12	0.23	0.31	0.04
	SS	JPC	0.19	-	0.89	0.97	0.68	0.70
	LS	SFC+JPC	0.13	0.88	-	0.92	0.69	0.50
	SS	SFC	0.22	0.97	0.92	-	0.70	0.68
	SS	JPC	0.32	0.66	0.69	0.72	-	0.34
	LS	SFC+JPC	0.04	0.70	0.49	0.68	0.34	-
Species	Scale	SS	SFC	JPC	SFC+JPC	SFC	JPC	SFC+JPC
	SS	SFC	-	0.06	0.11	0.26	0.02	0.001
	SS	JPC	0.05	-	0.05	0.71	0.29	0.06
	LS	SFC+JPC	0.11	0.10	-	0.88	0.11	0.01
	SS	SFC	0.26	0.71	0.88	-	0.43	0.17
	SS	JPC	0.02	0.29	0.11	0.43	-	0.52
	LS	SFC+JPC	0.001	0.06	0.01	0.16	0.52	-

Francisco (SFC) and Japaratuba (JPC) submarine canyons during dry and rainy seasonal periods in the continental margin of Sergipe, NE, Brazil. P-values in bold represent significant differences (p < 0.05).

c) in the smaller scale, it is expected to find negative species co-occurrence

From the probabilistic models, it was possible to identify evidence of positive, negative and random patterns of co-occurrence between pairs of species. On a small scale (SS; $v = 1.89 \text{ m}^3$) the species showed patterns of co-occurrence with a predominance of random distribution in both canyons (SFC and JPC) in dry and rainy periods. In the SFC, during the rainy period, 25% of the co-occurrence patterns were non-random (ie guided by some deterministic process) and positive (**Table 4**). These positive co-occurrence profiles occurred among juvenile individuals, *Mediomastus* sp. 1 and *Mediomastus* sp. 2 (Figure 5A). In the SFC, during the dry period, 100% of co-occurrence patterns were random (**Table 4**). In the JPC canyon, 20.9% (dry period) and 45.5% (rainy period) of non-random associations were evidenced. In the dry period, these patterns were predominantly positive, with some negative species associations, while in the rainy season, the non-random patterns were all negative (**Table 4**). These negative associations were related to eight (dry period) and 10 (rainy period) pairs of species (**Figure 5B – C**).

At a large scale (LS; $v = 3.78 \text{ m}^3$), the metacommunity was mostly randomly structured; however positive co-occurrence patterns were recorded between canyons (SFC+JPC) in dry and rainy periods in response to the environmental gradient (**Table 4**). In the dry period, 12 associations between five species were responsible for the positive co-occurrence pattern (*Mediomastus* sp. 1, *Mediomastus* sp. 2, *Parheteromastus* sp. 1, *Mediomastus* sp. 3 and *Notomastus* sp. 9; **Figure 5D**). During the rainy season, only six pairs of species presented a positive pattern of co-occurrence (Mediomastus sp. 2, Notomastus sp. 2, Mediomastus sp. 1 and Parheteromastus sp. 1; Figure 5E).

Table 4. Results of probabilistic co-occurrence models for the small scale -SS (V = 1.89 m³) and large scale -LS (V = 3.78 m³) in São Francisco -SFC and Japaratuba - JPC submarine canyons during dry and rainy seasonal periods in Sergipe continental margin, NE, Brazil. U = Unclassifiable.

U	Scale	Category	Species	Sites	Positive	Negative	Random	% non-	U
								random	
Dry	SS	SFC ^a	14	21	0.0	0.0	6	0.0	0.0
Dry	SS	JPC ^b	32	21	8.0	1.0	31.0	20.9	3.0
Rainy	SS	SFC ^c	15	21	2	0.0	6	25.0	25.0
Rainy	SS	JPC^{d}	23	21	0	10.0	11.0	45.5	1.0
Dry	LS	SFC+JPC ^e	36	42	12.0	0.0	30.0	28.6	0.0
Rainy	LS	$SFC+JPC^{f}$	28	42	6.0	0.0	17.0	26.0	0.0

^a Of 91 species pair combinations, 85 pairs (93.41 %); ^b Of 496 species pair combinations, 453 pairs (91.33 %); ^c Of 105 species pair combinations, 97 pairs (92.38 %); ^d Of 253 species pair combinations, 231 pairs (91.3 %); ^e Of 630 species pair combinations, 588 pairs (93.33 %); ^f Of 378 species pair combinations, 355 pairs (93.92 %) – were removed from the analysis because expected co-occurrence was < 1.



Figure 5. Heat map showing the negative, random, and positive species associations determined by the probabilistic co-occurrence model for metacommunities of

Capitellidae in the smaller scale $[V = 1.89 \text{ m}^3 (A - C)]$ and large scale $[V = 3.78 \text{ m}^3 (D - E)]$ in São Francisco (A) and Japaratuba (B - C) submarine canyons during dry (B and D) and rainy (A, C and E) seasonal periods in Sergipe continental margin, NE, Brazil. Species names are positioned to indicate the columns and rows that represent their pairwise relationships with other species.

d) Effects of spatial and environmental processes will be greater smaller scale for structure on metacommunity

Spatial and environmental processes significantly influenced the organization of the Capitellidae metacommunity. The environmental variables used were very fine silt, salinity, carbon/nitrogen ratio, P_{org}, C_{org}, very coarse sand, total phosphorus, coarse sand, medium sand, coarse silt, very fine sand, total carbonates, kurtosis and medium silt (**Table 6**). The number of environmental variables retained for the partial RDA model ranged from 4 (in SS) to 11 (in LS) (**Table 6**).

The perception of spatial and environmental patterns and effects demonstrated dependence on the spatial scale. On a small scale, the pure environmental component [E] was shown to control metacommunity variation in the SFC during the rainy season $(R_{adj}^2 = 0.17, p = 0.001; Figure 6B; Table 5)$, JPC in both seasonal periods (Dry: $R_{adj}^2 = 0.15, p = 0.01; Rainy: R_{adj}^2 = 0.21, p = 0.01; Figure 6C - D, Table 5)$ and also on LS in both seasonal periods ($R_{adj}^2 = 0.20, p = 0.01; Figure 6E - F, Table 5$). On the large scale, there was an increase in the importance of the spatial component [S], becoming the main driver of the Capitellidae metacommunity ($R_{adj}^2 = 0.11, p = 0.01; Figure 6G, Table 5$). The shared variation [E \cap S] was 0.15 and the unexplained variance [Residual] was 0.66 (Table 5).



margin, NE, Brazil. [E] = pure environmental variations; [S] = pure spatial variation; [E \cap S] = variation shared by [E] and [S]; R = Residual.

Scale	Dry					Rainy			
Small	SFC	[E]	[S]	$[E \cap S]$	R	[E]	[S]	$[E \cap S]$	R
	R_{adj}^2	0.10	0.18	0.68	0.029	0.17	0.008	0.69	0.11
	p-value	0.001	0.001			0.001	0.35		
	d.f	4	9			6	5		
	F	11.59	12.59			4.84	1.21		
	JPC	[E]	[S]	$[E \cap S]$	R	[E]	[S]	$[E \cap S]$	R
	R_{adj}^2	0.15	0.11	0.27	0.46	0.21	0.09	0.40	0.28
	p-value	0.01	0.03			0.01	0.02		
	d.f	4	4			4	5		
	F	2.05	1.7			2.05	2.03		
Large	SFC+JPC	[E]	[S]	$[E \cap S]$	R	[E]	[S]	$[E \cap S]$	R
	R_{adj}^2	0.20	0.004	0.78	0.002	0.20	0.004	0.78	0.002
	p-value	0.001	0.001			0.001	0.003		
	d.f	11	8			11	8		
	F	130.3	4.49			130.3	4.49		

Table 6. Variables selected by forward procedure for the environmental and spatial process in the small scale – SS $[V = 1.89 \text{ m}^3]$ and large scale – LS $[V = 3.78 \text{ m}^3]$ in São Francisco – SFC and Japaratuba – JPC submarine canyons during dry and rainy seasonal periods in Sergipe continental margin, NE, Brazil. Spatial eigenvectors (dbMEMs) with low numbers represent large-scale, whereas high numbers represent
small-scale patterns. Env var = Environmental variables; S eigenvectors = Spatial eigenvectors; VFSi = very fine silt; Sal = salinity (psu); C:N = Carbon/Nitrogen ratio; P_{org} = Organic Phosphorus (µg.g⁻¹), C_{org} = Organic Carbon (%); VCS = Very coarse sand; P_T = Total Phosphorus; CS = Coarse sand; MS = Medium sand; CSi = Coarse silt; VFS = Very fine sand; Carb_T = Total carbonates (%); Kur = Kurtosis; MSi = Medium silt.

Scale	SFC	Dry			SFC	Rainy		
SS	Env var	F	Р	R_{adj}^2	Env var	F	Р	R_{adj}^2
	VFSi	10.72	0.002	0.31	VFSi	7.07	0.002	0.23
	Sal	15.79	0.002	0.86	VCS	9.25	0.002	0.46
	Porg	9.79	0.002	0.91	Sal	6.83	0.004	0.59
	Corg	9.05	0.002	0.94	P _T	10.61	0.002	0.74
	-				CS	7.11	0.012	0.81
					MS	8.45	0.008	0.87
	S eigenvectors				S eigenvectors			
	dbMEM1	214.6	0.001	0.17	dbMEM2	41.88	0.001	0.17
	dbMEM6	151.0	0.001	0.12	dbMEM1	32.48	0.001	0.13
	dbMEM3	69.2	0.001	0.05	dbMEM4	22.26	0.001	0.09
	dbMEM10	49.7	0.001	0.03	dbMEM6	21.01	0.001	0.08
	JPC				JPC			
	Env var	F	Р	R_{adj}^2	Env var	F	Р	R_{adj}^2
	Sal	5.3	0.002	0.20	Sal	4.23	0.002	0.13
	CS	4.8	0.002	0.35	C_{org}	5.8	0.002	0.31
	CSi	3.7	0.002	0.45	PT	4.6	0.004	0.42
	Corg	2.6	0.006	0.51	MS	5.2	0.004	0.54
	-				VFS	4.0	0.008	0.61
	S eigenvectors				S eigenvectors			
	dbMEM2	7.0	0.001	0.13	dbMEM6	16.66	0.001	0.18
	dbMEM5	4.3	0.001	0.07	dbMEM1	7.6	0.001	0.08
	dbMEM4	0.07	0.001	0.07	dbMEM4	7.3	0.001	0.08
	dbMEM3	0.06	0.003	0.07	dbMEM5	6.4	0.001	0.07
LS	SFC+JPC				SFC+JPC			
	Env var	F	Р	R _{adj} ²	Env var	F	Р	R_{adj}^2
	Porg	42.7	0.002	0.62	Porg	42.7	0.002	0.62
	P _T	18.0	0.002	0.78	P _T	18.0	0.002	0.78
	VFS	21.2	0.002	0.88	VFS	21.2	0.002	0.88
	Carb _T	12.8	0.002	0.92	Carb _T	12.8	0.002	0.92
	Kur	8.6	0.002	0.94	Kur	8.6	0.008	0.94
	CSi	10.0	0.002	0.96	CSi	10.0	0.002	0.96
	MS	17.6	0.002	0.97	MS	17.6	0.004	0.97
	MSi	6.9	0.002	0.98	MSi	6.9	0.002	0.98
	Corg	4.4	0.006	0.98	C_{org}	4.4	0.002	0.98
	Sal	5.14	0.004	0.98	Sal	5.1	0.006	0.98
	C:N _{ratio}	6.22	0.002	0.99	C:N _{ratio}	6.2	0.006	0.99
	S eigenvectors				S eigenvectors			
	dbMEM4	3541.5	0.001	0.002	dbMEM4	3541.5	0.001	0.002
	dbMEM5	1427.0	0.001	0.001	dbMEM5	1427.0	0.001	0.001
	dbMEM1	1251.3	0.001	0.000	dbMEM1	1251.3	0.001	0.009
	dbMEM3	722.1	0.001	0.000	dbMEM3	722.1	0.001	0.005

Discussion

Our results showed that the patterns and processes observed in submarine canyons vary according to the spatial scale analyzed and the individual characteristics of each canyon and seasonal period analyzed. In general, we were able to verify that the increase in spatial scale promoted an increase in environmental heterogeneity and β diversity of Capitellidae annelids in submarine canyons. We found that on a smaller scale (SS) co-occurring pairs of species showed random patterns of co-occurrence, reaching 100% of random associations in the SFC during the dry period. Pure spatial filtering prevailed in only one case in the SS. Spatial filtering may indicate dispersion limitation regarding mass effects. In this specific case, the spatially structured metacommunity in the SFC indicates small-scale mass effects. In other cases, environmental filtering plays a crucial role in metacommunity organization, which was driven by species selection and mass effect. This set of factors contributed to positive co-occurrence patterns, with pairs of species with similar ecological requirements occurring together along the environmental gradient, and randomly, overcoming barriers through species dispersal. Contrary to what we expected, there was no predominance of the checkboard structure (negative co-occurrence patterns) at the local scale. Our findings help understand the effects of scale on environmental and ecological patterns observed in metacommunities of Capitellidae in submarine canyons and allow inferring that stochastic processes prevail at small scales while the importance of deterministic factors increases with spatial scale.

The structuring mechanisms of benthic communities have been investigated in different parts of the world, mainly in marine ecosystems. In this context, several studies revealed that the organization of benthic communities is determined mainly due to environmental filtering related to sediment characteristics and granulometry at local scales (Fonseca; Netto, 2006; Pech et al. 2007; Sutton et al. 2021). However, the few studies that investigated the effect of spatial scale on benthic communities have found a significant contribution of dispersal-related processes on the observed patterns (De Leo et al. 2014; Sutton et al. 2021).

The high dispersion of individuals from the source (habitats under optimal environmental conditions) to the sink area (habitats with suboptimal environmental conditions), in heterogeneous environments, are characteristics of metacommunities with a predominance of mass effect and consequently forming local communities in suboptimal conditions maintained by the constant arrival of new individuals (Mouquet; Loreau, 2003; Leibold et al. 2004). In habitats of low heterogeneity (homogeneous), dynamics related to trade-offs between colonization-dispersal, predict that better colonizers exclude better dispersers, characterizing a patch-dynamic (Mattheus, 1966; Leibold et al. 2004). In habitats with similar characteristics and species with similar

abilities, the metacommunity would be guided by random processes (neutral model) (Leibold et al. 2004). These processes can act simultaneously to structure metacommunities, which makes them dynamic in space and time (Cottenie, 2005). Thus, the diversity patterns that we evidenced in the SFC and JPC associated with the increase in spatial scale may be related to different processes. In the first moment, this stems from the fact that at smaller spatial scales even, spatial factors can exert stronger pressure, promoting greater variation in the composition of species that form local communities due to limitations in dispersal rates between habitat patches (Shurin et al. al. 2009), as observed for SFC in dry period. In addition, on LS, environmental filters, associated with the biology of the species and their respective adaptations to each type of habitat, can limit the distribution of species to tolerable environmental zones, thus, changes in EH start to exert strong selective pressure and explain the differences in β -diversity patterns (Chase; Leibold 2003; Anderson et al. 2006; Bandelj et al. 2012).

In the present study, the increase in β -diversity was directly associated with the increase in EH, showing that the diversification and availability of microhabitats promote changes in the composition of species on a large scale. However, high βdiversity rates were also observed at JPC (SS scale), evidencing that local environmental characteristic and other deterministic (e.g., species interactions, environmental and spatial filters) or stochastic processes (random dispersion) may be playing important roles in composition changes at small scales (Chase; Leibold 2003). Furthermore, on a SS, biological interactions based on density are stronger (Wiens; Donoghue 2004); however, contrary to what we expected (checkboard structure mediated by competition, due to negative patterns of co-occurrence between species), in SS and LS, species co-occurrence patterns were predominantly randomly and positive patterns structure. These random factors are also commonly indicated as drivers for the formation of communities, acting directly in the assembly and evolution of communities (Hubbell, 2001; Kelly et al. 2008; Chave, 2009). The absent patterns negative cooccurrence in this study, may be associated with the fact that the competition in benthic organisms in the deep sea can occur in situations where the resource is limited, and better competitors can efficiently colonize local habitats and in some cases, modify the environment biologically, preventing or hindering colonization by other species (Voight et al. 2023). However, these processes (random and deterministic) can operate overlapping in the assembly of communities, alternating in the degree of importance

throughout geographic space (Cavender-Bares et al. 2009). In our study, stochastic processes predominated in structuring local communities (SS), while the deterministic ones (environmental filtering, environmental heterogeneity, interactions) operated more strongly on the LS scale.

Capitellidae taxa are consumers of subsurface deposits (Fauchald; Jumars, 1979; Jumars et al. 2015) and consequently belong to the same trophic guild, which could suggest an increase in competitive interactions between species and the expected pattern would be of competitive exclusion since they would present niche conservatism, and consequently, the same environmental requirements (Webb et al. 2002), competing directly for the resource in smaller scale, due to high ecological similarity (that is, high convergence of functional characteristics) (Sutton et al. 2021). The absence of negative patterns of co-occurrence may be related to the availability of resources (Corg and PT, for example). In analyzes involving trophic guilds in benthic macrofauna, it was found that observed that the co-occurrence patterns differ in each group, thus, it was found that polychaetes consumers of deposits (including Capitellidae) showed random distribution patterns. Evidence of negative interactions were only observed in groups of carnivorous, herbivorous and burrowing polychaetes (Pagliosa, 2005). In our study the spatial scale expansion (SS to LS) significantly increased positive co-occurrence patterns (ie, aggregate distribution of species). The increase in environmental heterogeneity associated with the increase in spatial scale may have effects on species aggregation since environmental filtering will select species with similar ecological requirements (species sorting). The co-occurrence patterns that were observed at local scales (SS scale) may be associated with some stabilizer or equalizer processes acting on a SS scale (see Chesson, 2000).

In our study, the stabilizing mechanisms may be acting in the maintenance of these local communities, as it acts in the niche differentiation of the species, preventing dominant and higher aptitude species from excluding less competitive species (Chesson, 2000). This approach supports our results, since the SS scale showed no negative co-occurrence patterns. According to HilleRisLambers et al. (2012), niche stabilizing ecological divergences make species coexist by partitioning resources, promoting species diversity during the assembly of local communities, avoiding competitive exclusion. Linked to this fact, we emphasize that this niche differentiation in Capitellidae may be occurring in the use of space. Although we have recorded several sets of species coexisting in the same local habitats, they may be segregating vertically

within the sediment column as a resource partitioning strategy and habitat use. Infauna investigations in sediments from deep water systems (2,000 to 8,000 m) are still scarce, however, recent data have indicated that benthic invertebrates present intense vertical migratory flow distribution within the sediment column with peaks of density in the superficial portion impoulsed due to the availability of food resources (Shimabukuro et al. 2022). However, although Capitellidae is a monophyletic group, monophyly is not supported in several genera of the family (eg Barantolla, Heteromastus and Notomastus) (see Tomioka et al. 2018). This may indicate that species of certain genera may have different ecological requirements due to evolutionary differences related to distinct ancestors, such as in paraphyletic groups. However, we emphasize the importance of further investigations about these aspects, since very little is known about the phylogeny and functional traits of this group, mainly on species in deep oceans, which are largely unknown. Still in this context, positive co-occurrence patterns may be associated with positive interactions, predation and environmental filtering on convergent traits (Peters, 2003; Valiente-Banuet; Verdú, 2007; Cavender-Bares et al. 2009), because in a context of conservatism of functional characters, environmental filtering selects sets of species that are ecologically similar and adapted to these filters, implying the structuring of a community with more related species (Webb et al. 2002) and similar than expected by chance (Blomberg et al. 2003), as observed on a LS in this study.

Our results, for the first time, showed that the increasing of spatial scale in submarine canyons can promote an increase in EH, corroborating with our first hypothesis. This heterogeneity promoted high β -diversity, spatial patters distributions species formed by species co-occurrence random and positive, supporting our second hypothesis and refuting our third hypothesis. The species co-occurrence models indicate the pair species local communities were distributed randomly and the effect large spatial scale and environment extent generate metacommunity in high scale with positive patterns. In addition, greater influence of spatial filters on a small scale (only in the SFC) and on a larger scale were evidenced, partially corroborating our fourth hypothesis. There was a predominance of environmental filtering in the intermediate scale (between canyons). Thus, we conclude that, similar to studies carried out in other marine and terrestrial systems, the results obtained indicate the influence of random and niche processes on the β -diversity of Capitellidae annelids in submarine canyons and that the spatial scale analyzed directly influences the observed patterns. We emphasize

the importance of new studies that investigate vertical migration patterns of Capitellidae within sediment layers as a strategy for coexistence on a local scale and under which conditions these migrations are intensified. Finally, we believe that investigations revealing and quantifying EH in the deep sea can guide the proper establishment of Marine Protected Areas (Ismail et al. 2018), mainly in submarine canyons, due to their high structural complexity, still little explored (compared to other marine systems), with the occurrence of specific oceanographic patterns and with strong currents affecting habitat heterogeneity (Ismail et al. 2018), which makes canyons potential biodiversity hotspots (De Leo et al. 2010; Ismail et al. 2018; Bernardino et al. 2019).

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Capítulo 3

Niche spatial overlap: strategies for Capitellidae (Annelida) species coexistence in environmental gradient in submarine canyons (NE, Brazil)

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Abstract

The use of space can be associated with different factors, among which environmental variables are mentioned as those that exert the greatest influence on the biota and determine the distribution gradient of benthic communities. Among the benthic macrofauna, the polychaetes of the family Capitellidae are marine annelids that have different life strategies, associated with functional traits, their species being infauna diggers, build galleries inside the sediment. In this way, species can use more than one vertical sediment layers, and present changes in the use of space as a strategy for coexistence to reduce the selective pressure of competition. Therefore, the general objective of this study was to investigate the bathymetric distribution patterns and within the sediment layers - SL in different environmental conditions, as strategies for species coexistence. The continental margin of Sergipe is composed of a narrow continental shelf, an extensive continental slope, submarine canyons and an extensive continental rise. Sampling was carried out in two seasonal periods - SP in São Francisco - SFC and Japaratuba - JPC canyons. Environmental characteristics varied along the canyon bed. In the SFC during both SP shallow depth isobaths are enriched with Porg and C:Nratio and great depths are rich in Corg. In the JPC during the dry period, isobaths near the head of the canyon, have large concentrations of Porg, and at great depths (from 1900 m) are found sediments rich in nutrients (Porg and Corg) and Carb_T. In the rainy season, the highest concentrations of Corg, Porg and Carb_T were recorded in the intermediate portion (700 to 1900m). An abundance of 1,306 individuals was registered and 41 species of Capitellidae annelids. Species distribution showed restrictions along environmental gradients, reflecting the low niche width observed for species both canyons and SP. The niche overlap showed that large groups of species overlap in the use of bathymetric space and segregate their distribution vertically in SL as a strategy for coexistence and to reduce competition for the resource. The availability of organic detritus influenced the richness – S and density – D. The reduction of organic nutrients promoted the reduction in the use of SL and S and D. Thus, we conclude that the results obtained indicate the niche sharing and differentiation processes on the bathymetric and SL of Capitellidae annelids in submarine canyons and with pairs of species that did not show any kind of spatial overlap in SL, which may indicate potential competitive interactions.

Keywords: continental margin, environmental drivers, niche width, spatial distribution

Introduction

The structure and organization of biological communities are strictly related to local conditions and resources (Holt, 2009), mainly for sympatric species (i.e., populations that occur in the same geographic area and thus regularly encounter one another) (Falcón-Brindis et al. 2019). Thus, environments with greater availability of resources can influence the composition of species and how they use space (Downes et al. 1998; McClain et al. 2020). In the benthic macrofauna, organisms can use the resource in different ways, since the species can be epibenthic or infauna. The infauna organisms (those that burrow into the substrate) can develop important roles for sediments by increasing connections at sediment/water interfaces and altering geochemical gradients and promoting influence in the sediments structure (Meysman et al. 2006; Barsanti et al. 2011; Lalonde et al. 2010; Velde et al. 2016). Among the benthic macrofauna, the polychaetes of the family Capitellidae are marine annelids (Amaral et al. 2013) that have different life strategies, associated with functional traits, their species being infaunal diggers, build galleries inside the sediment (Levin et al. 1997; Levin et al. 2000).

The use of space can be associated with different factors, among which environmental variables are mentioned as those that exert the greatest influence on the biota and determine the distribution gradient of benthic communities (Bandelj et al. 2012; Gaurisas; Bernardino, 2023). These factors are the main parameters that would limit the distribution of organisms within tolerable environmental zones, causing temporal and spatial variations in species composition (De Leo et al. 2012; Gaurisas; Bernardino, 2023). Thus, species that live in very low oxygen concentrations are vertical migrants (Sameoto et al. 1987; Kinzer et al. 1993; Saltzman; Wishner, 1997), with a tendency to move to the surface of the sediment, where the higher proportions of oxygen, causing a dense grouping of animals in oxygenated waters (Saltzman; Wishner, 1997; Levin, 2003), or build tubes or migrate from galleries (Kristensen, 1985; Murphy, Reidenbach, 2016). Furthermore, sedentary species (such as Capitellidae species) generally use compacted mud to obtain greater stability in the flow of oxygen within the gallery (Smith, 1986; Levin et al. 1997; Levin et al. 2000).

Due to this wide range of lifestyle habits, these organisms are distributed across different ecosystems, with a strong relationship between lifestyle habits and diet being recognized (Paiva, 2006). Among these environments are the submarine canyons. These environments are deep and narrow valleys with high and steep slopes and are

characterized by complicated patterns of hydrography, flow, transport, and sediment accumulation (Shepard, 1972) and are considered biodiversity hotspots, as they harbor faunal communities distinct from the adjacent slope (De Leo, 2012; De Leo et al. 2010; Vetter et al. 2010). These deep-sea systems are characterized by low availability of chemical energy (nutrients) and vulnerable to changes in carbon flux from surface waters, particularly below 200 m (McClain et al. 2020). Therefore, materials of terrestrial origin (allochthonous) can enter the marine ecosystem through interactions between rivers and the ocean, and consequently promoting organic enrichment in these areas (Boyer et al. 2006), and which can be consumed by animals and returned as energy to the food chain (Porter et al. 2014; Whitney et al. 2018). This allochthonous organic matter can be a driver for ecosystem structure and function (Pardo et al. 2023; Ciraolo; Snelgrove, 2023). Therefore, changes in the availability of organic carbon can affect community properties, such as biomass, abundance, and richness (Brown et al. 2004; McClain et al. 2012). These presence of submarine canyons on the continental margin affect the distribution of benthic communities by increasing habitat heterogeneity (Vetter, 1994; Vetter; Dayton, 1998; Rowe et al. 2008), promoting channeling of currents by promoting upwellings (Hickey, 1997) and by transporting sediments from the platform to the slope through turbidity currents or mass dispersion events (Arzola et al. 2008; Stigter et al. 2011), high concentration rates of suspended particulate matter, and the transport of organic matter from shore to deep waters (Bosley et al. 2004; Company et al. 2008; Genin, 2004), such characteristics directly interfere in the composition and organization of benthic communities inside submarine canyons.

Therefore, the ability of polychaetes to survive in a wide variety of habitats, from optimal conditions to extreme environmental gradients, is associated with a great capacity to tolerate environmental changes due to adaptive strategies, due to environmental changes related to temperature, salinity (Díaz-Castañeda; Reish, 2009), low oxygen rates (Levin, 2003). As a result, polychaetes generally adopt different strategies, such as morphological and behavioral changes (Childress; Siebel, 1998). Therefore, the general objective of this study was to investigate the origin of organic matter input and bathymetric and sediment layers distribution patterns and within the sediment in different environmental conditions, as strategies for species coexistence. Thus, we used a set of biotic and environmental data to test the hypotheses that i) the contribution of terrestrial organic material will be recorded in the isobaths closest to the continent; ii) the overlap rates of spatial niches between isobaths will be high and lower

between sediment layers; iii) we will record high richness and density in isobaths with greater nutrient availability (Corg) and better quality (C:N ratio); Since the energetic needs of organisms affect almost all ecological aspects, species are adapted to specific levels of organic carbon availability and occupy a specific metabolic niche (McClain et al. 2020) (see Fig. 1).



Figure 1. Hypothetical scheme illustrating the hypotheses used in this study, showing the entry of organic content into the interior of the canyons, the overlapping of the spatial niche in the bathymetric gradient (depth in meters) and the sharing of the spatial niche within the sediment layers (depth in centimeters), and increase in richness (S) and density (D) towards the head of the canyons. $O_{jk} = Niche spatial overlap.$

Study area

The continental margin of Sergipe (SCM) is composed of a narrow continental shelf, an extensive continental slope, submarine canyons and an extensive continental rise (Oliveira et al. 2017). Sergipe continental shelf has a width varying between 12 and 35 km and a slope of 1:1000 (Suguio, 2003). The continental slope, on the other hand, presents a high degree of inclination, with bathymetry ranging from 50 to 3,000 m, where the continental rise begins (Oliveira et al. 2017). The SCM has six canyons (São Francisco, Sapucaia, Piranhas, Japaratuba, Vaza-Barris and Piauí-Real) (Fontes et al. 2017; Oliveira-Jr et al. 2017), of which the largest and of greater expressiveness, are the

canyons São Francisco – SFC (to the north), and Japaratuba – JPC (to the center-north), which comprise the places where this study was carried out. Both canyons cut the shelf and the continental slope, and therefore are the regions where the slope is closest to the coast (~12 km away) (Fontes et al. 2017). The JPC, has larger dimensions compared to the SFC, however it is not linked to the current fluvial system of the Japaratuba river. This canyon is incised in the platform 10 km from the coastline, at the 30 m isobath, reaching a width of 21 km at the limit with the continental slope. The gap between the edge of the continental shelf and the bottom of the canyon reaches more than 1,400 m (**Figure 1**) (Fontes et al. 2017).



Figure 2. Location of collection stations and sample design applied in the São Francisco – SFC and Japaratuba – JPC canyons on the continental margin of Sergipe – SE, NE, Brazil.

Sampling design

The collections were carried out during the execution of the project "Environmental characterization of the sedimentary basin of Sergipe-Alagoas - MARSEAL" in partnership with PETROBRAS and the Federal University of Sergipe - UFS. Sampling

was carried out in two periods in 2013, between March and April (dry period) and October and November (rainy period). The same sampling design was used in both periods. In each canyon, sediment samples were collected in triplicate, at seven stations located in the isobaths of 50 m, 400 m, 700 m, 1000 m, 1300 m, 1900 m and 3000 m (Table S1). Sediment samples were obtained using a Box Corer bottom grab with dimensions of 50 x 50 x 50 cm, equipped with nine templates measuring 10 x 10 x 10 cm, sampling a total volume of 0.09 m³ per sample, intended for faunal analysis. Each sample was stratified into fractions of 0 - 2, 2 - 5 and 5 - 10 cm and subsequently washed in a 0.3 mm sieve. All samples were packed in plastic pots with 10% formaldehyde buffered with borax and Bengal rose dye. In addition to the biological data, from each sample, sediment samples were obtained by an additional 10 x 10 x 10 cm template to evaluate the granulometry (mean grain size (Phi $[\phi]$), sediment fractions (%) of sand (very coarse; coarse, medium, fine, very fine and total); silt (coarse, medium, fine, very fine and total); clay (very coarse, coarse, medium, fine, very fine and total) and total mud (silt + clay)) and determination of total organic carbon (%), total carbonate (%), total nitrogen (%), organic phosphorus (µg.g-1) and quality of organic matter (carbon/nitrogen ratio – C:N_{ratio}) (see Figure 1).

Procedures for biological data

The biological samples already fixed, were washed over sieves with 0.3 mm mesh, using a compression hose with low flow. In addition, a 63 µm screen was placed at the end of the hose to avoid contamination of the samples. The sediment retained on the sieves was placed in pots with 70% alcohol to preserve the organisms. Subsequently, the material was screened under a stereoscopic microscope by the team from the Coastal Ecosystems laboratory at the Federal University of Sergipe and placed in glass vials with 70% alcohol.

The capitelids were separated and will be identified at a specific level with the aid of a stereoscopic and optical microscope, using specialized bibliography (Dean, 2001; Green, 2002; García-Garza, 2009; Silva et al. 2016; Silva et al. al. 2017). Identification at the generic level will be based on the number of thoracic setigers, position of the notopodium and/or neuropodium and location of the thorax and abdomen and the presence of simple bristles and/or hooks. The identification in morphospecies will be based on the observation of morphological characteristics of the head (prostomium), such as the shape (rounded, acuminate, pointed), the presence or absence of palpodium and eyes, papillae at the anterior end of the pharynx, the presence of gills and presence, quantity and disposition of bordered setigers. Color patterns will also be observed after individuals are exposed to methyl green dye, which allows a better visualization of bordered setigers, and color patterns presented by each species.

Procedures for environmental

Sediment granulometry was evaluated by the laser diffraction method using the Marvern Mastersizer 3000 equipment, at Universidade Estadual Paulista – UNESP. The sediment fractions were divided using the classification scale of Wentworth, 1922. For the determination of the total carbonate (Carb_T) content, the gravimetric method of carbonate elimination with hydrochloric acid treatment was applied, carried out by the GeoRioeMar laboratory at Federal University of Sergipe - UFS. For geochemical analyses, organic carbon (C_{org}) and total nitrogen (N_T) were initially determined, it was necessary to eliminate inorganic carbon by adding acidic solution (HCl 10%), in successive steps until pH stabilization. About 5 to 10 mg of dry and decarbonated sediment were weighed in tin capsules and inserted into the elemental analyzer Thermo Finningan, model EA1112, for the determination of Corg and N_T by the dry combustion method (Hedges; Stern, 1984). To determine the total phosphorus (P_T) 0.5 g of the sediment was weighed, which was previously dried in an oven for 2 hours at a temperature of 105 °C. Then the sample was calcined at a temperature of 550 °C for 2 hours, for oxidation of organic matter and release of all phosphorus compounds in the form of orthophosphates, and subsequent extraction step in acid medium. For the determination of inorganic phosphorus (Pinorg), the same procedure as the PT was used without the step of calcination of the sediment sample (Aspila et al. 1976). The P_T and Pinorg content in the final extract was quantified by the molybdenum blue spectrophotometric method (APHA, 2005; Grasshoff et al. 1983). Organic phosphorus (P_{org}) was calculated by the difference between P_T and P_{inorg} . These methods were carried out by the Environmental Chemistry Laboratory at UFS.

Data analysis

Environmental characterization

We tested multicollinearity between variables by Variance Inflation Factor (VIF) (O'Brien, 2007). Variables that had a VIF value above 10 were excluded from the

model. After removing each variable with high inflation, 15 of them were used for environmental characterization: $Carb_T = Total carbonates$ (%); VFC = Very fine clay; CSi = Coarse silt; MSi = Medium silt; VFSi = Very fine silt; VCS = Very coarse sand; CS = Coarse sand; MS = Medium sand; VFS = Very fine sand; SD = Sorting coefficient; Kur = Kurtosis; Sal = Salinity (psu), C:N_{ratio} = Carbon/Nitrogen ratio; P_{org} = Organic Phosphorus ($\mu g.g^{-1}$), C_{org} = Organic Carbon (**Table S2**).

For these analyses, the substrate variables carbonate, and skewness was transformed into arcsine and by $log_{10}(x+2)$, respectively. The variability of environmental variables between water masses and canyons was investigated through the Multivariate Permutation Analysis – PERMANOVA (Anderson 2006; Oksanen et al. 2018). Additionally, an ordination was performed using Principal Component Analysis – PCA to viewer the differences of habitats in the interior both canyons and seasonal periods.

i) contribution of terrestrial organic material for marine sediments

Initially the Carbon-Nitrogen – C:N_{ratio} of particulate matter is used to explain the origin of land and sea particles. The C:N_{ratio} values of organic matter reflect the amount of carbon in relation to the amount of nitrogen that constitute the particulate organic material (Flavel; Murphy, 2006). Data from C:N_{ratio} 15, for example, indicate that there are 15 g of carbon for every 1 g of nitrogen in organic matter. When an organic substrate has a C:N_{ratio} between 1 and 15, there is rapid mineralization and release of N that will be available to primary producers (Brust, 2019). C:N_{ratio} \geq 8 indicates organic material of terrigenous (allochthonous) origin, while lower values reveal material of marine (autochthonous) origin (Nasir et al. 2016).

ii) The rates of spatial niche overlap between bathymetric gradient will be high and lower between sediment layers

Initially were investigated of differences in species composition between bathymetric gradients and sediment layers – SL in two seasonal periods using PERMANOVA analysis. Afterwards, a non-Metric Multidimensional Scaling (nMDS) will be made to visualize these patterns. For these analyses, a matrix with species abundance data transformed by Hellinger (Legendre; Gallagher, 2001) was used with Bray-Curtis dissimilarity metric was used.

Subsequently, the spatial niche width (N_w) and niche overlap (O_{jk}) were calculated for bathymetric and sediment layers. Initially, were investigated N_w using the Levin index (Hurlbert, 1978). Through this index it is possible to ascertain the degree of spatial width of the species, which is estimated through the distribution of each species among the different spatial resources (see Hurlbert 1978; Fugi et al. 2008). These values can range from 1 (when the species uses a single spatial resource) to 10 (when the species uses all resources in similar proportions). Afterwards, generalized linear models – GLM were used to investigate N_w differences between bathymetric gradient and sediment layers between seasonal periods and in each canyon. For this, Gaussian distribution and F test were used.

To assess the rates of O_{jk} in space use (bathymetric and vertical stratification within sediment layers) for each species pairs, we used the Pianka index for pairwise species. The values of this index range from 0 to 1, with values close to 1 revealing a high niche overlap, may indicate competition or sharing of resources. For interpretation of the results, we considered the spatial overlap of the interspecific niche high: when species pairs truly overlap their special niche, ie $O_{jk} > 0.6$ in bathymetric gradient and sediment layers; moderate: when the niche overlap in the bathymetric gradient $O_{jk} > 0.6$ and $O_{jk} >$ 0.40 < 0.60 in the sediment layers, revealing differences in habitat use; and low: when the niche spatial overlap is $O_{jk} < 0.4$ in both environmental gradients. These results were visualized through an interpolation between the spatial overlap of bathymetric niche and sediment layers. To verify the strength of correlation between these metrics, a Spearman correlation analysis was performed.

iii) high richness and density in isobaths with greater nutrient availability (C_{org}) and better quality (C:N_{ratio})

GLM's were applied to investigate the influence of the amount of organic nutrients and quality of these nutrients on the richness - S (number of species) and density - D (number of individuals per m²). For this, the variables were used to compose the GLM models, followed by the mechanical simplification of these models according to James et al. (2013). This simplification consisted of the gradual removal (one variable at a time) of the environmental variables. In this sense, simplification occurred always starting with the variable with the highest p-value. This process was carried out until obtaining the significant variables that explain the increase or decrease of S and D. For the analysis, S was transformed by square root and D by log_{10} . The GLM's were adjusted with quasi-poisson family and Chisq test.

All analyzes were carried in the R software (R Core Team, 2021) out using the *Vegan* (Oksanen et al. 2019), *FactoMineR* (Le et al. 2008) and *factoextra* (Kassambara; Mundt, 2020) for PCA, nMDS and PERMANOVA; *spaa* package (Zhang, 2016) for niche overlap and niche width models and *car* packages (Fox; Weisberg, 2019) for GLM models. Graphical presentations of the results were prepared using the *ggplot2* (Wickham, 2016) and GraphPad Prism 8.0 software.

Results

Environmental characterization

The grain size in the São Francisco (SFC) and Japaratuba (JPC) submarine canyons ranged from very fine silt to very coarse sand, with a predominance of grains in the fine fraction (silt and clay), and among the fine grains, the highest proportion was of silt, corresponding to 85% of the sediments that make up the seabed inside the canyons **(Table S3)**. From the environmental characteristics, which showed significant variations along the bathymetric environmental gradient.

In the SFC it is possible to evidence the formation of three environments with similar characteristics in both seasonal periods. The 50 m and 400 m isobath were influenced by the greatest influence of salinity, organic phosphorus (P_{org}), C:N ratio, silt (medium and coarse), total carbonate (Carb_T), and grains with positive skewness. The isobaths of 700, 1000, 1300 and 1900 m form a large region, since they receive a greater contribution of grains in the texture very coarse sand (VCS), very fine clay (VFC), very fine silt (VFSi) and total phosphorus (P_{T}) (Figure 3A – B). Already at 3000 m, the deepest area sampled in this study, it is formed by the highest levels of C_{org}, medium (MS) and very fine (VFS) sand, and poorly selected grains, evidenced by the highest sorting coefficient (SD) (Figure 3A – B). In the JPC the spatial patterns in the bathymetric gradient oscillated in different ways during the dry and rainy seasons. When analyzing these patterns during the dry period we evidenced a low influence of P_{org} on the 50 m isobath, high salinity and higher mean silt content (MSi) (Figure 3C).

The other isobaths do not present a well-defined separation, however, it can be seen that 400 and 1000 m receive the greatest influence of VFSi, VFC and C:N_{ratio}, while 1900 and 3000 m receive the greatest contributions of organic nutrients (P_{org} and

 C_{org}) and Carb_T. The 700 m isobath is a region with higher concentrations of sand (MS, CS and VFS), while 1300 m is more neutral, showing intermediate rates of these variables (Figure 3C). In the rainy season, the influence of environmental variables on the bathymetry gradient shows some changes in relation to the dry season. In this sense, the 3000 m isobath receives greater contributions from MS, CS and SD (Figure 3D). Already at 50 and 400 m it is possible to notice greater influence of salinity and C:N ratio (Figure 3D). At 700 to 1900 m are isobaths under the influence of particulate organic material (C_{org} , P_{org} and P_{T}), sand (VFS), silt (CSi, MSi, VFSi) and Carb_T (Figure 3D).



Figure 3. Principal Component Analysis (PCA) based on environmental variables in the submarine canyons São Francisco (A - B) and Japaratuba (C - D) during dry (A - C) and rainy (B - D) seasonal period in Sergipe continental margin. Carb_T = Total

carbonates (%); VFC = Very fine clay; CSi = Coarse silt; MSi = Medium silt; VFSi = Very fine silt; VCS = Very coarse sand; CS = Coarse sand; MS = Medium sand; VFS = Very fine sand; SD = Sorting coefficient; Kur = Kurtosis; Sal = Salinity (psu), C:N_{ratio} = Carbon/Nitrogen ratio; P_{org} = Organic Phosphorus (µg.g⁻¹), C_{org} = Organic Carbon.

i) Contribution of terrestrial organic material for marine sediments

The C:N_{ratio} in the SFC canyon ranged from 5.3 to 13.0 during the dry period and 4.1 to 11 during the rainy period. The highest C:N_{ratio} in the SFC were recorded at the 50 m isobath, while the lowest ratios were measured at the 3000 m isobath, during both seasonal periods. In the JPC canyon, the C:N_{ratio} was between 5.6 to 9.2 during the dry season and between 3.7 to 9.2 in the rainy season. The highest C:N_{ratio} ratios were recorded at the 400 m isobath in both seasonal periods, and the lowest C:N_{ratio} ratios were associated with the 1000 m isobaths in the dry period and 3000 m during the rainy season. (Figure 4 and Table S2).



Figure 4. Carbon/Nitrogen ratio (C: N_{ratio}) along the bathymetric gradient in the São Francisco and Japaratuba submarine canyons during dry and rainy periods on the continental margin of Sergipe, Northeastern Brazil.

An abundance of 1,306 individuals was registered, belonging to 12 genera and 41 species of Capitellidae annelids. The most abundant species were Mediomastus sp. 2 (representing 34% of total abundance), Parheteromastus sp. 1 (18% of total abundance) and Leiochrides sp. 2 (14.2%). Of these species, 29 of them showed low abundance (N < 5) (Figure S1). In the SFC canyon, the most abundant species were *Mediomastus* sp. 2, Parheteromastus sp. 1, Mediomastus sp. 1 and Notomastus sp. 2 (Figure S4A and C). The distribution of these species oscillated in the sediment layers. In the dry and rainy seasonal periods, Mediomastus sp. 2, Parheteromastus sp. 1 inhabited deeper SL (5-10 cm) in greater proportion (Figure S4A and C). In the dry and rainy season, only two taxa were distributed in the three sediment layers - Notomastus sp. 2 and juveniles in the dry SP (Figure 4A) and Notomastus sp. 2 and Mediomastus sp. 1 in the rainy SP (Figure S4C). In the JPC canyon, the most abundant species were Mediomastus sp. 2, Parheteromastus sp. 1, Mediomastus sp. 3 and Notomastus sp. 1 in dry SP (Figure S5A) and Mediomastus sp. 2, Leiochrides sp. 1, Parheteromastus sp. 1 and Notomastus sp. 9 in rainy period (Figure S5C). In both SP, Mediomastus sp. 2, Mediomastus sp. 3 inhabited deeper extracts (5 - 10 cm) in greater proportion (Figure S5A – D). Few groups predominated on the surface of the sediment (0 - 2 cm), among which juvenile individuals stand out and Notomastus sp. 2 (Figure S5A). In the dry SP, seven taxa were distributed in the three sediment layers (Figure S5A - B). In rainy period only one species (Parheteromastus sp. 1) were distributed in the three sediment layers (Figure S5C).

ii) the rates of spatial niche overlap between bathymetric gradient will be high and lower between sediment layers

The composition of the metacommunity showed significant fluctuations. During the dry period, both canyons presented distinct faunal composition for the bathymetric gradient and sediment layers, while in the rainy period, there were some context-dependent relationships, thus, in SFC only SL presented differences, while in JPC differences in composition occur in bathymetric gradient (Table 1).

 Table 1. Multivariate PERMANOVA based on the matrix communities Capitellidae in

 São Francisco – SFC and Japaratuba – JPC submarine canyons during dry and rainy

Canyon	SP	Fator	d.f	SS	R ²	Pseudo-F	P (perm)
SFC	Dry	Bathymetry	5	2.94	0.45	3.75	0.0003
	-	SL	2	0.86	0.13	2.75	0.0106
		Residual	15	1.72	0.26		
		Total	22	6.50	1.00		
JPC	Dry	Bathymetry	5	5.66	0.25	3.33	<0.0001
	·	SL	2	1.58	0.07	2.33	<0.0001
		Residual	45	15.27	0.67		
		Total	52	22.52	1.00		
SFC	Rainy	Bathymetry	6	2.17	0.21	0.99	0.4842
	-	SL	2	1.29	0.12	1.77	0.0354
		Residual	18	6.58	0.65		
		Total	26	10.05	1.00		
JPC	Rainy	Bathymetry	6	4968.2	0.95	129.5	0.0333
	-	SL	2	3717.1	0.71	47.03	0.2663
		Residual	37	14.62.0	0.28		
		Total	45	5179.1	1.00		

seasonal periods – SP in Sergipe continental margin, NE, Brazil. d.f. = degrees of freedom, SS = sum of squares, n° perm = number of permutations, SL = sediment layers

In the SFC during the dry period we evidenced a cluster of species associated with the 50 m isobath, while another set of species was associated with the 1000 and 1300 m isobaths and few species associated with deeper environments (1900 to 3000 m) (Figure 5A). These species showed segregation within the sediment layers, predominating in deeper sediment layers (2 - 5 and 5 - 10 cm; Figure 5B and Table 1) and few species inhabiting the superficial layer (Figures S4A and 4B). In the rainy season, the composition showed faunistic dissimilarity only between the SL (Table 1). We found that specific faunal groups occurred in each SL, with juveniles, *Notomastus* sp. 2 and *Mediomastus* sp. 1 occurring with low abundance in this SL (Figure 5D). In the layers of 2 - 5 and 5 - 10 cm, in addition to the species shared with the other SL, four species have restricted occurrence in each of these SL (Figures S4D and 4D).



Figure 5. nMDS plots showing the compositional fauna of Capitellidae species in São Francisco submarine canyon during the dry (A-B) and rainy (C-D) seasonal periods in bathymetric (50 to 3000m) and sediment layers (0 to 10 cm) gradients on the Sergipe continental margin, NE, Brazil. Data were transformed by Hellinger. Bar sp. 1 = *Barantolla* sp. 1; Bar sp. 2 = *Barantolla* sp. 2; Capi sp. 1 = *Capitella* sp. 1; Cap sp. 5 = Capitellidae sp. 5; Cap sp. 6 = Capitellidae sp. 6; Leioc sp. 3 = *Leiochrides* sp. 3; Med sp. 1 = *Mediomastus* sp. 1; Med sp. 3 = *Mediomastus* sp. 3; Noto sp. 1 = *Notomastus* sp. 1; Not sp. 2 = Notomastus sp. 2; Med sp. 2 = *Mediomastus* sp. 2; Not sp. 9 = *Notomastus* sp. 9; Par sp. 1 = *Parheteromastus* sp. 1; Per sp. 1 = *Peresiella* sp. 1.

In the JPC during both SP many species have high abundance on the 50 m isobath (Figure 6A - C). We found two smaller groups in the dry period, which are formed by two sets of association of species, one referring to isobaths located in the middle portion of the canyon (400, 700 m) and the third referring to species of deep waters (1000, 1300, 1900 and 3000 m) (Figure 6A). While in the rainy season the faunistic separation between the other isobaths is not well established (Figure 6C). The distribution of the

fauna among the sediment layers in the dry period reveals that a large group of species occurs in the three strata (mainly in deep waters [400 to 3000 m]; see Figures 6A-B), homogenizing the regions. On the other hand, the shallow water species (they are more restricted to the 2-5 and 5 10 cm SL) (Figure 6A - B). During the rainy season, however, the composition did not show significant variation (Figure 6D; Table 1).



Figure 6. nMDS plots showing the compositional fauna of Capitellidae species in Japaratuba submarine canyon during the dry (A - B) and rainy (C - D) seasonal periods in bathymetric (50 to 3000m) and sediment layers (0 to 10cm) gradients on the Sergipe continental margin, NE, Brazil. Data were transformed by Hellinger. Bar sp. 1 = *Barantolla* sp. 1; Bar sp. 2 = *Barantolla* sp. 2; Capi sp. 1 = *Capitella* sp. 1; Capi sp. 2 = *Capitella* sp. 2; Cap sp. 1 = Capitellidae sp. 3; Cap sp. 4 = Capitellidae sp. 4; Das sp. 1 = *Dasybranchus* sp. 1; Dec sp. 1 = *Decamastus* sp. 1; Het sp. 3 = *Heteromastus* sp. 1; Het sp. 3 = *Heteromastus* sp. 1; Het sp. 3 = *Leiocapitella* sp. 2; Leioc sp. 1 = *Leiocapitella* sp. 1; Leio sp. 2 = *Leiocapitella* sp. 2; Leioc sp. 3 = *Leiochrides* sp. 3; Mas sp. 1 = *Mastobranchus* sp. 1; Mas sp. 2 = *Mastobranchus* sp. 2; Med sp. 1 = *Mediomastus* sp. 3; Med sp. 4 = *Mediomastus* sp. 4; Med sp. 5 = *Mediomastus* sp. 5; Neo sp. 1 =

Neoheteromastus sp. 1; Not sp. 1 = Notomastus sp. 1; Not sp. 2 = Notomastus sp. 2; Not sp. 3 = Notomastus sp. 3; Not sp. 5 = Notomastus sp. 5; Not sp. 6 = Notomastus sp. 6; Not sp. 7 = Notomastus sp. 7; Not sp. 8 = Notomastus sp. 8; Not sp. 9 = Notomastus sp. 9; Not sp. 10 = Notomastus sp. 10; Not sp. 11 = Notomastus sp. 11; Not sp. 12 = Notomastus sp. 12; Par sp. 1 = Parheteromastus sp. 1; Per sp. 2 = Peresiella sp. 2; Scy sp. 1 = Scyphoproctus sp. 1.

The distribution of species along the depth gradient (bathymetric and sediment layers) revealed that most species present some type of restriction in habitat use. During the dry period, the use of space in the bathymetric gradient was restricted for most species, only six (in SFC) and five (in JPC) species showed above-average niche width (N_w mean = 2.2 ± 1.93 in SFC and 3.88 ± 3.86 in JPC). As for the use of vertical space inside the sediment layers, only six (SFC) and 13 (JPC) species showed greater niche amplitude (N_w mean = 1.49 ± 0.49 in SFC and 1.43 ± 0.56 in JPC) (Figure S2). In the rainy SP the mean niche width of the species in the bathymetric gradient were smaller in relation to the dry SP (N_w mean = 2.19 ± 2.01 in SFC and 2.80 ± 2.24 in JPC). The vertical spatial resource sharing revealed that the use of space in the sediment layers was higher for four (SFC) and ten (JPC) species, which presented niche width above the average for each canyon (N_w mean = 1.39 ± 0.62 in SFC and 1.42 ± 0.55 in JPC) (Figure S3). In general, all species showed low Nw indices and most restricted to one type of habitat, either in the bathymetric gradient or sediment layers ($N_w = 1$) (see Figures S2 and S3). The patterns of bathymetric niche amplitude and SL showed significant oscillations only in the JPC (Figure 7B). The N_w was greater in the bathymetric gradient during the dry period. In addition, species from the dry period showed greater Nw in relation to the bathymetric gradient, when compared to the rainy period (Figure 7B).



Figure 7. Niche width (N_w) for the Capitellidae metacommunity as a function of the bathymetric (Bath) and sediment layers (SL) gradient in the São Francisco (A) and Japaratuba (B) canyons during dry and rainy periods on the continental margin of Sergipe. The bold number represents significant variations.

The degree of niche overlap (O_{jk}) of the metacommunity showed varied ranges of oscillations, with groups of species with high niche overlap $(O_{jk} > 0.60)$ and pairs of species that did not show spatial niche overlap $(O_{jk} = 0)$ (see Table S4 to S11). We infer that the niche overlap for metacommunity is greater in the bathymetric gradient and smaller between sediment layers for both canyons and seasonal periods (Table 2). The correlation of niche overlap between species pairs for the two depth gradients (bathymetric and sediment layers) in both canyons revealed that there is a strong positive correlation (r > 60, p < 0.001) between the bathymetric niche overlap and in sediment layers (Table 3). Large assemblages of species show high niche overlap in the bathymetric gradient; however, they inhabit different layers of the sediment (Figure 8). It is still possible to infer that some pairs of species show high rates of niche overlap both in the gradient and in the sediment layers (Figure 8).

Table 2. Spatial niche overlap in the bathymetric gradient and sediment layers in the São Francisco canyon during the dry and rainy season on the continental margin of Sergipe, NE, Brazil.

Canyon	Dry period		Rainy period		
	Bathymetric	Sediment layers	Bathymetric	Sediment layers	
SFC	0.50	0.35	0.42	0.17	
JPC	0.33	0.17	0.49	0.29	


Figure 8. Smooth curves showing the co-relationship between bathymetric spatial niche overlap and niche overlaps in sediments layers in the São Francisco – SFC (A – B) and Japaratuba – JPC (C – D) canyons during the dry (A – C) and rainy (B – D) seasonal periods on the continental margin of Sergipe, NE, Brazil. Each dot represents a pair of species. O_{jk} = Pianka index overlap niche.

Table 3. Spearman correlation for niche overlap rates in bathymetric gradient and sediment layers in São Francisco and Japaratuba canyons during dry and rainy periods on the continental margin of Sergipe, NE, Brazil.

Canyon	SP	S	r	p-valor
SFC	Dry	711	0.62	< 0.001
	Rainy	711	0.62	< 0.001
JPC	Dry	711	0.62	< 0.001
	Rainy	711	0.62	< 0.001

iii) high richness and density in isobaths with greater nutrient availability (Corg) and better quality (C:Nratio)

In SFC during both seasonal periods high richness and density were registered in 50 m and decline in increasing bathymetric gradient. In general, the superficial sediment layer (0 - 2 cm) presented low richness and density; the highest richness and density

were associated with the 5 – 10 cm sediment layer. The distribution of these metrics (richness and density) revealed that there is a prevalence of richness and density in the 5 – 10 cm SL between the 50 to 1300 m isobaths (Figure 9). In both periods, high richness and density were associated with isobaths with high concentration of P_{org} and C:N_{ratio} which presented species using the three layers of sediment (Figure 9; Table 4). The decline of P_{org} and C:N_{ratio} towards deeper bathymetric regions influenced negativity to S and D (Figura 9A – B; Table 4). Furthermore, it is possible to observe a reduction in the use of sediment layers in bathymetric ranges with low nutrient contents (C_{org}, C:N_{ratio} and P_{org}) (Figure 9; Table 4). During the rainy season, in addition to P_{org} and C:N_{ratio} contents, C_{org} levels also influenced S and D (Figure 9C – D; Table 4). The levels of C_{org} provided an increase in S and D in the isobaths of 50, 1000 and 1300 m, with the species being distributed among the three SL (Figure 9C – D; Table 4).



Figure 9. Distribution of richness (A and C) and density (B and D) along the bathymetric, sediment layers – SL and organic matter gradients in São Francisco canyon

during the dry (A – B) and rainy (C – D) seasonal periods in Sergipe Continental margin, NE, Brazil. C:N_{ratio} = Carbon/Nitrogen ratio; P_{org} = Organic Phosphorus (µg.g⁻¹), C_{org} = Organic Carbon.

In JPC in both seasonal periods, richness and density showed a decreasing pattern in the bathymetric gradient (Figure 10). The lowest richness and density were recorded at 0-2 cm. Greater richness and density were associated with the 5-10 cm sediment layer, except for the 700 m isobath in the dry season (Figure 10A – B) and 1300 to 3000 m in the rainy season (Figure 10C – D). During the dry period, the distribution of S and D between the sediment layers occurred along the entire canyon (Figure 10A – B). During the rainy season, spatial patterns oscillated between sediment layers. From the 400 m isobath, the species showed a preference for habitat use by only one or two SL (except at 1900 m) (Figure 10C – D). During the dry period, high richness and density were negatively associated with isobaths with low Porg and Carb_T concentration and positively with C:N_{ratio} (Figure 10; Table 4). During the rainy season, higher S and D was associated with higher availability of Porg nutrients and higher quality – C:Nratio (Figure 10C - D). The decline of these variables towards deep waters promoted a decline in S and D along the bathymetric gradient and a reduction in vertical habitat use (SL) (Figure 10C – D). For density, there was a strong negative relationship with C_{org} rich organic debris, as Corg availability showed an increasing pattern in the bathymetric gradient and density declined proportionately and reduced vertical habitat use (Figure 10D).



Figure 10. Distribution of richness (A and C) and density (B and D) along the bathymetric, sediment layers (SL) and organic matter gradients in Japaratuba canyon during the dry (A – B) and rainy (C – D) seasonal periods in Sergipe Continental margin, NE, Brazil. Carb_T = Total carbonates (%); C:N_{ratio} = Carbon/Nitrogen ratio; P_{org} = Organic Phosphorus (μ g.g⁻¹), C_{org} = Organic Carbon.

Table 4. Generalized linear models – GLM showing influence the environmental variables in richness (S) and density on the São Francisco (SFC) and Japaratuba (JPC) canyons during the dry and rainy seasonal periods in Sergipe continental margin, NE, Brazil. Density were transformed by log_{10} and richness by square root. Carb_T = Total carbonates (%); C:N_{ratio} = Carbon/Nitrogen ratio; P_{org} = Organic Phosphorus (µg.g⁻¹), C_{org} = Organic Carbon.

Canyon	SP	Ecological	Environmental	Residual	Residual	р
		metric	variable	d.f.	deviance	
SFC	Dry	Richness	Porg	10	41.38	0.006
	-	Density	Porg	10	912455	0.012
	Rainy	Richness	Porg	19	49.44	0.003
			C:N _{ratio}	18	29.89	< 0.001
			C_{org}	17	13.92	< 0.001
		Density	Porg	19	2690	< 0.001
			C:Nratio	18	1555	< 0.001
			C_{org}	17	8768	< 0.001
JPC	Dry	Richness	Porg	16	46.43	0.026
			Carb _T	15	16.60	< 0.001
			C:N _{ratio}	14	11.84	0.029
		Density	Porg	16	8942.2	< 0.001
			Carb _T	15	3817.3	< 0.001
			C:Nratio	14	3770.1	< 0.001
	Rainy	Richness	Porg	12	38.26	0.010
	-		Carb _T	11	22.09	< 0.001
			C:Nratio	10	12.99	0.002
		Density	Porg	12	6195.8	< 0.001
		-	CarbT	11	2636.5	< 0.001
			C:N _{ratio}	10	1349.4	< 0.001
			Corg	9	1337.9	< 0.001

Discussion

Our results showed that the canyons present a wide range of environmental characteristics along the bathymetric gradient. In this gradient, organic nutrients accumulate in specific and distinct portions depending on the canyon and seasonal period analyzed, evidencing the spatial-temporal dynamics and particularities of each analyzed system. Furthermore, we found that the environmental gradients provided by bathymetry and sediment layers promoted variation in the faunal composition. Associated with this, we found that few species had a large niche breadth, and most of them, being recorded in a few sets of habitats. We also showed that the niche overlap rates are higher in the bathymetric gradient, and large groups of species migrate vertically in the sediment layers, reducing the spatial overlap of the niche, promoting sharing and use of the resource, allowing the coexistence of species. Finally, we found

that the orientation of richness and density were driven by the availability of organic detritus, and mainly by the nutritional quality of the organic matter. In organically enriched regions, the richness and density were distributed inside the sediment layers, while the reduction of organic nutrients promoted the reduction of richness, density and in the use of vertical space. These results helped to understand the coexistence patterns and strategies used by Capitellidae species, and how they respond to the availability of organic nutrients and how the reduction of these nutrients impacts richness, density, and habitat use.

Production of autochthonous and allochthonous organic matter

The measurement of the magnitude C:N_{ratio} particulate matter is used to explain the origin of terrestrial and marine particles (Nasir et al. 2016). From that, our patterns showed that both canyons and seasonal periods present organic matter predominantly of autochthonous origin (marine) (C:N_{ratio} < 8.0). However, the SFC canyon showed influence of allochthonous (terrigenous) organic matter in its head (50 m). This may be associated with the fact that the SFC is directly linked to the São Francisco river, due to the high historical flow of this river and the proximity of its mouth (~8 km) (Fontes et al. 2017). The incision of the SFC in the continental shelf can be seen from the 15 m isobath and reduces to almost a third of its original width, extending 19 km inland (Fontes et al. 2017). Thus, due to this great proximity to the coast and the intense river discharge, the channeling of terrigenous organic debris to the sea-bottom is facilitated.

In the JPC canyon, allochthonous organic matter inputs were recorded in the 400 m isobath. The JPC it is not linked to the current fluvial system of the Japaratuba river. This canyon is incised in the platform 10 km from the coastline, at the 30 m isobath, reaching a width of 21 km at the limit with the continental slope (Fontes et al. 2017). Thus, the supply of terrigenous nutrients in 400 m in the JPC may come from the sediment plume formed by the São Francisco River, since the particulate material produced by the continental drainage of this river is displaced in the north-south direction of the platform (Guimarães, 2010) due to wind action (Parente et al. 2021). Because of this, organic debris can be deposited in regions farther from the head of the canyon. This shows that even at a greater spatial distance, nutrient discharges originating on the continent still have an impact on the marine environment. This displacement to distant regions occurs because the allochthonous particulate organic

matter that persists during transport is pre-oxidized, becoming more resistant to microbial degradation (Holtvoeth, 2004; Nasir et al. 2016).

Mechanisms for coexistence for habitat use and our relationship with ecosystem function

Mechanisms for species coexistence have been investigated in several parts of the world (Pickett et al. 2018; McClain et al. 2020). Spatial niche segregation stands out as one of the main mechanisms for species coexistence (Rochette; Grand, 2004). In our study, the segregation of the spatial resource was clearly evidenced, since we found many sets of species that showed differentiation in the use of strata within the sediment layers (lower O_{jk}) and coexisting in the same bathymetric ranges (higher O_{jk}). These patterns may reflect interspecific competition that acted on community assemblies (ghost of competition past) (Steiner et al. 2007; Ferguson et al. 2014) and allowed the coexistence of species at the bathymetric scale and consequently promoted an increase in richness on a local scale.

The observed coexistence patterns may indicate the occurrence of important roles for the functioning of the benthic compartment in the deep sea, since, in situations where there is greater use of spatial resources by several species (as observed mainly in the JPC during the dry period and in some cases in SFC) these environments can be more resilient. This occurs for several reasons, as the colonization of the vertical niche by several local species (differentiation in habitat use), causes reworking and in situ transport of sediments upward and downward on the ocean floor, which can be intensified by density and the identity of species (Gilbert et al. 2007; Volkenborn et al. 2007), directly affecting the texture, composition and reorganization of sedimentary particles through bioturbation processes (Volkenborn et al. 2007). This may suggest from our results that bathymetric bands with greater densities, richness and use of wider bathymetric space (see **Fig. 9 and 10**) are areas of great importance, since species from these regions may be playing crucial roles for the functioning of these systems and increasing the resilience of these environments due to trophic redundancy.

Furthermore, sedentary polychaetes (such as Capitellidae) can build tubes or migrate galleries within the sediment, raise respiratory structures higher above the sediment/water interface to access water with more oxygen and allow greater oxygenation within the layered tube. of deeper sediment (Kristensen, 1985; Murphy; Reidenbach, 2016). As a result, the observed patterns, with greater agglomeration of

density and richness in the deeper extracts of the sediment, may favor oxygenation in reducing sediment layers. These species generally use compacted mud to obtain greater stability in the oxygen flow within the gallery (Levin et al. 1997; Levin et al. 2000), this may explain the fact that in our results, Capitellidae were recorded in isobaths with predominantly muddy bottoms (medium silt) and inhabiting deeper sediment layer (5 -10 cm). The greater occupation of species in the strata at greater depth in the sediment column in both canyons may also contribute to the cycling of organic material that is inaccessible to most faunal groups. This is because, according to Pardo et al. (2023) macrofauna plays a fundamental role in the processing, biological absorption, and fate of organic matter, with implications for ecosystem functioning, benthic-pelagic coupling, carbon burial and biogeochemical cycles, since the benthic compartment is an important link between the large Corg reservoirs stored on land and the sea. capitellids are important for the functioning of marine ecosystems as they contribute to the energy flow of these environments (García-Garza, 2009), as they facilitate the recovery of organic debris deposited on the seabed. This occurs after incorporating the available organic matter, and when transformed into animal biomass, it returns available to the higher trophic levels (Amaral; Migotto, 1980; Paiva, 2006; Lana et al. 2009) when consumed by some species of fish (Amaral; Migotto, 1980).

Access to the deeper layers of the sediment can be driven by several factors that direct the vertical distribution of benthic macrofauna and limit the occurrence of most species to the most superficial strata (Bessa et al. 2007; Touhami et al. 2018). However, among benthic organisms, polychaetes tend to have high density and biomass in deeper strata, among which the Capitellidae Heteromastus filiformis (Claparède, 1864), Capitella capitata (Fabricius, 1780) and Mediomastus fragilis Rasmussen, 1973 were the most abundant in deeper strata (Touhami et al. 2018). This information corroborates our results since the highest density and species richness was recorded in the 5-10 cm sediment layer. In the deep sea, the density of organisms can be driven by benthic O₂ consumption rates and amount of total organic carbon available (Shimabuko et al. 2022). In our results, spatial resource sharing was greater in situations where nutrient availability was limited in terms of quality (C:Nratio) and quantity of organic debris (Porg and Corg), boosting the richness and density of Capitellidae, thus as, the orientation of the distribution in the sediment layers, since, in bathymetric ranges with high availability of Porg and with greater C:Nratio, spatial segregation within the sediment layers occurred in all extracts (0 to 10 cm) and as resource availability declined, the use

of vertical space was limited to the upper strata. This may reveal that in situations of reduced availability of organic resources, detritivores benthic species can adopt strategies of agglomeration on the surface of the sediment in search of particulate organic material, which tend to be deposited in greater concentration on the surface portion of the ocean floor. These patterns can also be intensified in situations where the benthic macrofauna presents greater energy expenditure and with high energy demand, causing these organisms to seek places with greater availability of chemical energy (Brown et al. 2004; Pardo et al. 2023).

Furthermore, the movement of benthic organisms within the sediment may be associated with body size, which directly implies their burrowing capacity. Linked to this fact, Shimabukuro et al. (2022) recorded an agglomeration of benthic meiofauna in the fauna on the sediment surface in the deep sea. This information may support our results, since there was a greater concentration of juvenile capitellids in the upper strata of both canyons in our study, which may reflect the reduced size associated with the shorter colonization time.

Our results showed that there is connectivity between continental and marine systems, with discharges of organic nutrients enriching both submarine canyons, corroborating our first hypothesis, however, in the specific case of the JPC the inputs of organic material do not seem to be associated with the river Japaratuba. We also showed that species tend to present greater vertical spatial segregation in situations where bathymetric overlap increases, corroborating our second hypothesis. Furthermore, a greater influence of Porg and C:Nratio was evident, partially corroborating our third hypothesis. Thus, it's possible conclude that the results obtained indicate that the input and autochthonous production of organic material have a great influence on the increase in the density and richness of Capitellidae annelids, as well as being important drivers for the direction of the species in the deep sea. We emphasize the importance of new studies that investigate the relationship between the size of organisms and the vertical displacement patterns of Capitellidae within sedimentary layers. Ultimately, we believe that our findings may indicate that Capitellidae species respond to specific organic enrichment gradients and their trophic and spatial niche responses can potentially link community to ecosystem scales in future studies.

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CONSIDERAÇÕES FINAIS

Os resultados apresentados nesse estudo, mostraram que os cânions submarinos São Francisco e Japaratuba apresentam características oceanográficas (biológica, geológica, química e física) diversas. Assim, registramos uma grande diversidade de espécies de anelídeos Capitellidae, e estas estiveram distribuídas por uma grande variedade de habitats em resposta a processos de nicho (filtragem ambiental, interações) e neutros (estocásticos). Essas evidências ressaltam a necessidade de um olhar atento à conservação desses ambientes, na margem continental Sergipe-Alagoas no Nordeste do Brasil, uma vez que estas espécies atuam diretamente na ciclagem de nutrientes e funcionamento do ecossistema.

No capítulo 1 evidenciamos as massas de água e correntes marinhas que ocorrem na área estudada, além disso, revelamos como a canalização dessas massas e correntes, por essas feições geomorfológicas, contribuem para o aumento da heterogeneidade ambiental e influência na organização da metacomunidade de Capitellidae. Nossos registros evidenciaram a ocorrência das massas de Água: Tropical (AT), Central do Atlântico Sul (ACAS), Intermediaria Antártica (AIA) e Profunda do Atlântico Norte (APAN) promoveram aumento na heterogeneidade ambiental e na estratificação ambiental vertical. Além disso, encontramos mudanças significativas na abundância, riqueza e composição das assembleias de anelídeos Capitellidae entre áreas afetadas por diferentes massas nos cânions submarinos. Devido à variabilidade ambiental, as espécies entre as massas eram distintas, resultando em alta diversidade principalmente devido a processos de substituição de espécies (turnover), fortemente associados à estratificação ambiental vertical e pouco relacionados ao aumento da heterogeneidade ambiental nas massas de água. Ao contrário do que se previa, a abundância e a riqueza não aumentaram com a presença de massas de água ricas em O₂, evidenciando que o O₂ é um fator secundário não limitante para as comunidades de anelídeos capitelídeos, sendo a temperatura e a salinidade os principais impulsionadores de abundância, diversidade e riqueza. Além disso, inferimos que os sedimentos moles de ambos os cânions, que são heterogêneos e estratificados verticalmente ao longo do sistema estudado, devem ser protegidos para preservar seus recursos biológicos e manter suas funções ecológicas (ciclagem de nutrientes por espécies de capitelídeos detritívoros), uma vez que as taxas de turnover foram altas e nenhuma assembleia foi estruturada espacialmente aninhada (*nesting*), mesmo aquelas com número reduzido de espécies, ressaltando a baixa redundância de espécies, fazendo com que possíveis impactos ambientais, mesmo em escala local, podem gerar uma perda de diversidade na escala da margem continental (β -diversidade), portanto, futuros planos de gestão e conservação devem considerar um maior número de áreas prioritárias e que contemplem a vasta diversidade de habitats formados pela atuação da água massas e envolver diferentes escalas para percepção desses padrões espaciais.

Em nosso Capítulo 2 evidenciamos que os padrões e processos observados nos cânions submarinos variam de acordo com a escala espacial e com as características individuais de cada sistema e período sazonal analisado. De modo geral, pudemos concluir que o aumento das escalas espaciais promove incremento na heterogeneidade ambiental e na β-diversidade dos anelídeos Capitellidae em cânions submarinos. Descobrimos que em menor escala pares de espécies apresentaram padrões aleatórios de coocorrência. Filtros espaciais também exerceram influência, revelando comunidades espacialmente estruturadas, indicando limitação de dispersão em relação aos efeitos de massa no SFC cânion. Para os demais casos, a filtragem ambiental foi a principal responsável pela estrutura da metacomunidade, que foi impulsionada pela seleção de espécies (species sorting) e pelo efeito de massa (mass effect). Este conjunto de fatores contribuiu para padrões de coocorrência positivos, com pares de espécies com exigências ecológicas semelhantes ocorrendo juntos ao longo do gradiente ambiental, e de forma aleatória, superando barreiras através da dispersão de espécies. Outro fato importante, é que ao contrário do que esperávamos, não houve predominância da estrutura checkboard (padrões negativos de coocorrência) na escala local. Estes resultados nos permitem compreender os efeitos da escala nos padrões ambientais e ecológicos observados em metacomunidades de Capitellidae em cânions submarinos e permitem inferir que os processos estocásticos prevalecem em pequenas escalas enquanto a importância dos fatores determinísticos aumenta com a escala espacial. No entendo, enfatizamos a importância de que estudos futuros investiguem padrões de migração vertical de Capitellidae dentro de camadas sedimentares como estratégia de coexistência em escala local e em quais condições essas migrações são intensificadas, uma vez que, a ausência de padrões com estrutura checkboard, podem ser reflexo de estratégias de compartilhamento de nicho como forma de coexistência e mitigar interações negativas.

No capítulo 3 mostraram que os cânions apresentam uma ampla gama de características ambientais ao longo do gradiente batimétrico. Neste gradiente, os nutrientes orgânicos se acumulam em porções específicas e distintas dependendo do cânion e do período sazonal analisado, evidenciando a dinâmica espaço-temporal e as particularidades de cada sistema analisado. Além disso, evidenciamos a existência de conectividade entre os sistemas continental e marinho, com descargas de nutrientes orgânicos de origem terrígena, incrementando nos teores de nutrientes em ambos os cânions submarinos. Mostramos também que as espécies tendem a apresentar maior segregação espacial vertical em situações em que a sobreposição batimétrica aumenta. Além disso, ficou evidente uma maior influência de Porg e relação carbono/nitrogênio (C:N_{ratio}). Assim, concluímos a partir dos resultados, que a entrada e a produção autóctone de material orgânico têm grande influência no aumento da densidade e riqueza de anelídeos Capitellidae, além de serem importantes direcionadores para o direcionamento das espécies no mar profundo. Ressaltamos a importância de novos estudos que investiguem a relação entre o tamanho dos organismos e os padrões de deslocamento vertical dos Capitellidae dentro das camadas sedimentares.

Em síntese, após todas as descobertas apresentadas nessa tese, acreditamos que investigações que revelem e quantifiquem a heterogeneidade ambiental em mar profundo podem orientar o estabelecimento adequado de áreas prioritárias para conservação, principalmente em cânions submarinos, devido à sua alta complexidade estrutural, ainda pouco explorada, com a ocorrência de padrões oceanográficos específicos e com fortes correntes que afetam a heterogeneidade dos habitats (Ismail et al. 2018), o que torna os cânions potenciais *hotspots* de biodiversidade (De Leo et al. 2010; Ismail et al. 2018; Bernardino et al. 2018; Bernardino et al. 2019). Portanto, futuros planos de gestão e conservação devem considerar um maior número de áreas prioritárias e que contemplem a vasta diversidade de habitats formados pela atuação das massas de água e envolver diferentes escalas para percepção desses padrões espaciais. Em última análise, acreditamos que as nossas descobertas podem indicar que as espécies de Capitellidae respondem a gradientes específicos de enriquecimento orgânico e que as suas respostas ao nicho trófico e espacial podem potencialmente ligar escalas de comunidade à ecossistemas.

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Figure S1 – Collection of samples with the box corer in the submarine canyons São Francisco and Japaratuba: a) time when the Box Corer climbs, after obtaining the sample; b) Box Corer in the vessel and opening of the top cover to remove the samples; c) layout of templates to remove the sediment for biological analysis – yellow dashed line (i) and substrate variables – red dashed line (ii).



Figure S2 – Sample design applied in the submarine canyons São Francisco (SFC) and Japaratuba (JPC) on the continental margin of Sergipe, NE, Brazil. TW = Tropical Water, SACW = South Atlantic Central Water, AAIW = Antarctic Intermediate Water, NADW = North Atlantic Deep Water, N3 = 50 m, N4 = 400 m, N5 = 700, N6 = 1.000, N7 = 1300, N8 = 1900 and N9 = 3000.



Figure S3 – Venn diagram showing the number of restricted and shared species among the water masses: Tropical Water (TW), South Atlantic Central Water (SACW), Antarctic Intermediate Water (AAIW) and North Atlantic Deep Water (NADW), for annelids species from Capitellidae in the São Francisco (A) and Japaratuba (B) canyons on the continental margin of Sergipe, NE, Brazil.



Table S1 Multicollinearity analysis between water masses properties and substrate variables used for environmental characterization in the São Francisco and Japaratuba canyons. M = Model; $C_{org} = total$ organic carbon; N = total nitrogen; $P_{org} = organic$ phosphorus; Carb = Total carbonate; Sal = Salinity; Temp = Temperature; Phi = Mean of the grain; DS = Degree of selection; Sk = Skewness; Kur = Kurtosis; O₂ = oxygen. Variables in bold indicate multicollinearity through Variance Inflation Factor - VIF.

М	Ν	Porg	Corg	Carb	Sal	Temp	Phi	DS	Sk	Kur	O2
1	11.6	4.8	6.5	6.3	1.9	2.92	4.0	23.1	16.4	1.3	3.6
2	11.5	4.7	6.4	4.7	1.7	2.8	2.6	-	4.1	1.2	3.5
3	-	2.7	5.8	2.7	1.6	2.5	2.3	-	2.4	1.1	3.5
4	-	2.3	-	2.4	1.3	1.9	2.5	-	2.4	1.0	2.2

Table S2 Multivariate PERMANOVA based on the matrix composition of species recorded in regions under the influence of water masses (WM): Tropical (TW), South Atlantic Central (SACW), Intermediate Antarctic (AAIW) and North Atlantic Deep (NADW) in the São Francisco (SFC) and Japaratuba (JPC) canyons on the continental margin of Sergipe, NE, Brazil. d.f. = degrees of freedom, SS = sum of squares, n^o perm = number of permutations.

General test	d.f.	SS	\mathbf{R}^2	F	n° perm	Р
Water Masses (WM)	3	3.170	0.34	3.92	9999	<0.001***
Canyon (C)	1	0.429	0.04	1.59	9999	0.009
WM x C	2	0.812	0.08	1.51	9999	0.083
Residual	18	4.840	0.52			
Total	24	9.252	1.00			
Paired test SFC	TW	SACW	AAIW	NADW		
TW	-	-	0.098	0.014		
SACW	-	-	-	-		
AAIW	0.098	-	-	0.426		
NADW	0.014	-	0.426	-		
Paired test JPC	TW	SACW	AAIW	NADW		
TW	-	0.102	0.028	0.028		
SACW	0.102	-	0.083	0.055		
AAIW	0.028	0.083	-	0.583		
NADW	0.028	0.055	0.583	-		

Table S3 Univariate PERMANOVA model showing variations in water masses properties and substrate variables in the São Francisco and Japaratuba canyons, on the continental margin of Sergipe, NE, Brazil. C = Canyon, WM = Water masses, P_{org} = Organic phosphorus (µg.g⁻¹), Carb = Total carbonates (%), Phi = Grain Average (Φ), O₂ = Dissolved Oxygen (mg/L), Sk = Skewness, Kur = Kurtosis, d.f = degrees of freedom, SS = sum of squares. The Carb was transformed into arcsine and the Sk was logarithmized by log₁₀(x+2).

Variable	Fator	d.f	SS	R ²	Pseudo-F	P (perm)
Porg	WM	3	0.005	0.09	27.06	< 0.0001***
	С	1	0.011	0.21	181.19	< 0.0001***
	WM x C	3	0.033	0.64	180.32	<0.0001***
	Resíduo	34	0.002	0.04		
	Total	41	0.051	1.00		
Carb	WM	3	0.007	0.04	7.56	<0.0001***
	С	1	0.115	0.64	355.84	<0.0001***
	WM x C	3	0.045	0.25	46.61	<0.0001***
	Resíduo	34	0.011	0.06		
	Total	41	0.179	1.00		
Phi	WM	3	0.005	0.12	2.09	0.1050
	С	1	0.003	0.09	4.81	0.0175*
	WM x C	3	0.002	0.07	1.22	0.3323
	Resíduo	34	0.027	0.69		
	Total	41	0.038	1.00		
Sk	WM	3	-7227.7	-1.33	-7366.1	0.9405
	С	1	5421.9	0.99	16577.2	0.1508
	WM x C	3	7226.9	1.33	7365.2	0.1203
	Resíduo	34	11.1	0.00		
	Total	41	5432.2	1.00		
Kur	WM	3	0.021	0.06	0.83	0.4395
	С	1	0.00	0.00	0.28	0.8973
	WM x C	3	0.04	0.12	1.68	0.2313
	Resíduo	34	0.29	0.81		
	Total	41	0.35	1.00		
O_2	WM	3	0.01	0.47	10.51	0.0006***
	С	1	0.00	0.00	0.08	0.7415
	WM x C	3	0.00	0.00	0.03	0.98
	Residual	34	0.01	0.51		
	Total	41	0.02	1.00		

Table S4 Permutation Test for multivariate dispersion homogeneity (PERMDISP) based on water masses properties and substrate variables measured in regions under the influence of water masses (WM): Tropical (TW), South Atlantic Central (SACW), Intermediate Antarctic (AAIW) and North Atlantic Deep (NADW) in the São Francisco and Japaratuba canyons on the continental margin of Sergipe, NE, Brazil. d.f. = degrees of freedom, ss = sum of squares, n^o perm = number of permutations.

General test SFC	d.f.	SS	Mean	F	n° perm	Р
WM	2	0.001	0.000	0.192	9999	0.90
Residual	8	0.034	0.004			
General test JPC	d.f.	SS	Mean	F	n° perm	Р
WM	3	0.121	0.040	1.273	9999	0.003
Residual	10	0.317	0.031			
Paired test SFC	TW	SACW	AAIW	NADW		
TW	-	-	0.865	0.588		
SACW	-	-	-	-		
AAIW	0.865	-	-	0.775		
NADW	0.588	-	0.775	-		
Paired test JPC	TW	SACW	AAIW	NADW	_	
TW	-	0.733	0.303	0.003		
SACW	0.878	-	0.293	0.001		
AAIW	0.286	0.256	-	0.435		
NADW	0.001	0.001	0.359	-		

Table S5 Generalized linear models – GLM for ecological index of abundance (N), richness (S) and diversity (H') and environmental variables (water masses properties and substrate variables) in the São Francisco – SFC and Japaratuba – JPC canyons, NE, Brazil. Sal = Salinity; P_{org} = organic phosphorus; Temp = Temperature; Phi = mean of the grain; Sk = Skewness; Kur = kurtosis; O₂ = Oxygen; Carb = total carbonate. The Carb was transformed into arcsine and the Sk was logarithmized by $log_{10}(x+2)$. Values in bold represent significant influence (p < 0.05).

Canyon	Ecological	Environmental	Deviance	Residual	Residual	F	р
•	index	variable		d.f.	Deviance		•
SFC	Ν	Null		18	1052.32		
		Porg	30.23	17	456.65	20.3252	0.0025
		Carb	66.10	16	1012.56	19.1054	1.32110 ⁻⁵
		Sal	131.39	15	237.32	543.110	1.59010 ⁻¹⁴
		Temp	123.25	14	54.21	43.3454	5.7210 ⁻⁷
		Sk	15.31	13	45.67	6.6567	0.0125
		Kur	30.71	12	34.65	10.5656	0.0157
	S	Null		18	67.554		
		Sal	49.76	17	43.560		0.0040
		Temp	22.56	16	11.657		0.0001
	Η'	Null		24	31.435		
		Sal	7.943	23	14.658	123.323	0.004
		Temp	4.554	22	10.614	34.9875	0.021
JPC	Ν	Null		24	1732.85		
		Porg	41.98	23	1690.86	15.2037	0.0010
		Carb	70.12	22	1620.74	25.3945	8.52810 ⁻⁵
		Sal	1378.71	21	242.03	499.289	1.40910 ⁻¹⁴
		Temp	153.21	20	88.81	55.4852	6.67010 ⁻⁷
		Sk	14.23	19	74.59	5.1530	0.0357
		Kur	26.74	18	47.85	9.6839	0.0060
	S	Null		24	81.107		
		Sal	50.425	23	30.682		1.23810 ⁻¹²
		Temp	19.795	22	10.888		8.62310 ⁻⁰⁶
	H'	Null		24	24.271		
		Sal	7.943	23	16.328	32.1290	0.003
		Temp	4.554	22	11.774	52.4102	0.004

Appendix A. Multicollinearity analysis between particle size, chemical and physical environmental variables used for environmental characterization in the São Francisco and Japaratuba canyons in the continental margin of Sergipe, NE, Brazil. M = Model; Carb_T = Total Carbonate; CC = Coarse clay; MC = Medium clay; FC = Fine clay; VFC = Very fine clay; TC = Total clay; CSi = Coarse silte; MSi = Medium silte; FSi = Fine silte; VFSi = Very fine silte; TSi = Total silte; VCS = Very coarse sand; CS = Coarse sand; MS = Medium sand; FS = Fine sand; VFS = Very fine sand; TS = Total sand; SC = Sorting coefficient; Sk = Skewness; Kur = Kurtosis; Sal = Salinity; Temp = Temperature; C:N = Carbon/Nitrogen ratio; P_{org} = Organic phosphorous; N_T = Total nitrogen; C_{org} = Organic carbon; P_{inorg} = inorganic Phosphorous; PT = Total phosphorous. Variables in bold indicate multicollinearity through Variance Inflation Factor - VIF.

	Models														
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15
Carb _T	9.0	9.0	9.0	8.9	7.4	7.2	7.2	7.0	7.0	6.8	6.4	6.3	6.3	6.1	4.4
CC	9690.0	1338.6	1080.8	-	-	-	-	-	-	-	-	-	-	-	-
MC	643.9	593.6	582.9	271.3	249.8	197.2	-	-	-	-	-	-	-	-	-
FC	936.4	269.6	251.2	222.2	207.9	192.4	70.3	64.2	49.0	38.3	38.0	-	-	-	-
VFC	57.1	56.5	56.4	56.4	55.8	53.6	39.8	33.5	31.9	25.6	25.2	2.9	2.9	2.9	2.6
TC	10594.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CSi	67.9	57.8	49.8	48.7	47.9	36.2	32.1	32.1	29.6	10.5	10.5	10.2	8.0	8.0	7.1
MSi	552.2	390.1	376.1	248.9	246.3	106.6	106.6	94.0	61.0	10.0	9.5	9.52	9.1	9.0	7.7
FSi	520.7	309.9	309.5	130.7	130.6	130.4	100.7	98.6	98.0	-	-	-	-	-	-
VFSi	1420.3	1005.2	963.8	179.1	161.5	107.8	92.6	67.7	16.9	14.6	13.6	7.8	6.1	6.1	5.9
TSi	3359.6	3193.9	412.9	361.6	358.5	-	-	-	-	-	-	-	-	-	-
MUD	3618.6	3578.8	-	-	-	-	-	-	-	-	-	-	-	-	-
VCS	53.8	47.3	46.5	45.5	10.7	10.7	10.5	8.1	8.1	7.5	7.3	6.4	5.9	5.9	3.8
CS	20.4	16.7	16.1	15.7	14.9	14.9	14.6	12.1	11.0	10.3	10.3	7.4	4.9	4.9	4.9
MS	38.0	35.4	34.8	34.7	12.0	11.3	11.3	10.5	10.3	9.4	9.4	8.4	7.4	7.3	5.0
FS	73.5	73.5	65.5	63.3	40.8	38.9	38.7	33.9	32.7	30.6	30.3	30.3	-	-	-
VFS	487.4	482.3	474.5	473.2	22.4	21.2	20.9	19.5	19.0	18.8	18.7	18.5	6.1	6.0	6.0
TS	841.2	829.5	800.6	797.4	-	-	-	-	-	-	-	-	-	-	-
Median	203.5	192.1	189.7	185.8	185.4	161.3	136.5	133.1	-	-	-	-	-	-	-
SC	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.5
Sk	29.1	28.6	28.1	27.4	26.9	25.2	24.1	21.3	13.1	12.9	12.2	12.1	10.8	10.7	-
Kur	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0
Sal	12.0	11.9	11.9	11.8	11.6	9.2	8.5	7.1	7.1	7.12	6.1	6.0	5.8	1.9	1.9
Temp	27.3	27.1	27.0	25.7	25.6	22.4	20.6	13.8	13.8	13.7	13.6	13.6	12.3	-	-
C:N	114.6	112.9	109.3	105.2	98.0	97.9	97.7	5.7	5.7	5.7	5.5	5.4	5.0	4.6	3.9
Porg	55.4	55.3	53.3	51.3	51.2	51.1	51.1	43.1	42.6	42.3	3.5	3.4	3.2	3.1	2.8
NT	215.7	215.0	206.2	201.5	187.9	187.8	187.8	-	-	-	-	-	-	-	-
Corg	53.1	53.0	52.6	51.7	44.8	44.6	44.5	6.8	6.8	6.8	6.0	5.9	5.9	3.3	3.2
Pinorg	120.7	119.7	114.0	109.1	108.6	108.5	108.4	94.3	93.5	93.4	-	-	-	-	-
PT	122.9	122.4	116.9	111.3	110.4	110.4	110.1	89.6	88.7	88.6	3.6	3.6	2.9	2.8	2.8
Table S1. Environmental variables used for environmental characterization in the São Francisco (SFC) and Japaratuba (JPC) canyons in the continental margin of Sergipe, NE, Brazil. Values represent mean \pm standard deviation. Carb_T = Total carbonates (%); VFC = Very fine clay; CSi = Coarse silt; MSi = Medium silt; VFSi = Very fine silt; VCS = Very coarse sand; CS = Coarse sand; MS = Medium sand; VFS = Very fine sand; SC = Sorting coefficient; Kur = Kurtosis; Sal = Salinity (psu), C:N_{ratio} = Carbon/Nitrogen ratio; P_{org} = Organic Phosphorus (µg.g⁻¹), C_{org} = Organic Carbon.

_		Dry			Rainy	
-	SFC	JPC	SFC+JPC	SFC	JPC	SFC+JPC
Carb _T	10.7(1.8)	20.4(5.4)	15.6(6.3)	11.1(1.3)	22.4(6.2)	16.7(7.2)
VFC	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)
CSi	15.1(2.1)	18.1(1.4)	16.6(2.3)	14.0(3.3)	16.9(2.5)	15.4(3.2)
MSi	27.0(3.1)	24.7(2.4)	25.9(3.0)	26.2(3.3)	23.9(3.5)	25.1(3.6)
VFSi	14.4(2.4)	13.8(1.3)	14.1(1.9)	15.2(2.5)	14.1(1.8)	14.7(2.2)
VCS	0(0)	0(0)	0(0)	0.2(1.0)	0(0)	0.1(0.7)
CS	0.0(0.1)	0.0(0.1)	0.0(0.1)	0.3(1.1)	0.0(0.0)	0.1(0.8)
MS	0.8(2.3)	0.5(0.7)	0.6(1.7)	0.2(0.7)	1.0(1.6)	0.6(1.3)
VFS	2.1(2.3)	4.8(3.7)	3.5(3.3)	2.5(3.9)	5.5(4.7)	4.0(4.5)
SC	1.6(0.2)	1.7(0.1)	1.6(0.2)	1.6(0.2)	1.6(0.4)	1.6(0.3)
Kur	1.0(0.2)	1.3(1.8)	1.1(1.2)	0.9(0.1)	0.9(0.0)	0.9(0.1)
Sal	35.0(0.8)	35.1(0.9)	35.0(0.8)	35.1(0.9)	35.1(0.9)	35.1(0.9)
C:N _{ratio}	8.0(2.4)	6.9(1.2)	7.4(1.9)	7.1(2.0)	5.8(1.8)	6.4(2.0)
Porg	177.9(67.6)	246.0(66.4)	212.0(74.6)	155.7(38.5)	197.4(67.6)	176.6(58.3)
Corg	1.1(0.0)	1.2(0.2)	1.1(0.1)	1.1(0.1)	1.2(0.2)	1.1(0.1)
PT	596.8(44.3)	665.3(103.6)	631.1(86.0)	563.8(116.9)	676.6(71.7)	620.2(111.5)

Table S2. Results of the co-occurrence analysis for Capitellidae (Annelida) species in the São Francisco (SFC) and Japaratuba (JPC) canyons during dry and rainy seasons on the continental margin of Sergipe, NE, Brazil. Scy sp. 1 = Scyphoproctus sp. 1; Cap sp. 1 = Capitellidae sp. 1; Cap sp. 4 = Capitellidae sp. 4; Par sp. 1 = Parheteromastus sp. 1; Not sp. 1 = Notomastus sp. 1; Not sp. 2 = Notomastus sp. 2; Not sp. 3 = Notomastus sp. 3; Not sp. 9 = Notomastus sp. 9; Not sp. 11 = Notomastus sp. 1; Leioc sp. 1 = Leiochrides sp. 1; Leioc sp. 3 = Leiochrides sp. 3; Bar sp. 1 = Barantolla sp. 1; Med sp. 1 = Mediomastus sp. 1; Med sp. 2 = Mediomastus sp. 2; Med sp. 3 = Mediomastus sp. 3; Leio sp. 1 = Leiocapitella sp. 1; Leio sp. 2 = Leiocapitella sp. 2.

SFC Rainy	sp ₁	sp ₂	sp^1_{inc}	sp ² _inc	obscooccur	prob _{cooccur}	exp _{cooccur}	p ^{lt}	p ^{gt}
	Juvenile	Med sp. $\overline{2}$	5	3	3	0.077	1.1	1.00	0.027
	Juvenile	Med sp. 1	5	3	3	0.077	1.1	1.00	0.027
JPC Dry	Scy sp. 1	Med sp. 2	3	5	3	0.067	1.0	1.00	0.021
	Par sp. 1	Med sp. 2	3	5	3	0.067	1.0	1.00	0.021
	Not sp. 3	Med sp. 1	4	4	3	0.071	1.1	0.99	0.032
	Not sp. 3	Med sp. 3	4	4	3	0.071	1.1	0.99	0.032
	Not sp. 2	Not sp. 11	9	3	0	0.120	1.8	0.04	1.000
	Not sp. 9	Med sp. 2	3	5	3	0.067	1.0	1.00	0.021
	Med sp. 2	Med sp. 1	5	4	4	0.089	1.3	1.00	0.003
	Med sp. 2	Med sp.3	5	4	4	0.089	1.3	1.00	0.003
	Med sp. 1	Med sp. 3	4	4	3	0.071	1.1	0.99	0.032
JPC Rainy	Juvenile	Leio sp. 2	7	12	1	0.429	6.0	0.00	1.000
	Par sp. 1	Leio sp. 2	3	12	0	0.184	2.6	0.00	1.000
	Not sp. 2	Leio sp. 2	3	12	0	0.184	2.6	0.00	1.000
	Leioc sp. 1	Leio sp. 2	3	12	1	0.184	2.6	0.03	1.000
	Bar sp. 1	Leio sp. 2	4	12	1	0.245	3.4	0.00	1.000
	Not sp. 9	Leio sp. 2	4	12	0	0.245	3.4	0.00	1.000
	Med sp. 2	Leio sp. 2	3	12	0	0.184	2.6	0.00	1.000
	Med sp. 1	Leio sp. 2	2	12	0	0.122	1.7	0.01	1.000
	Cap sp. 4	Leio sp. 2	2	12	0	0.122	1.7	0.01	1.000
	Leio sp. 1	Leio sp. 2	2	12	0	0.122	1.7	0.01	1.000
SFC+JPC dry	Juvenile	Med sp. 1	12	7	6	0.124	3.2	0.99	0.020
	Par sp. 1	Not sp. 9	6	5	5	0.044	1.2	1.00	0.000
	Par sp. 1	Med sp. 2	6	8	6	0.071	1.8	1.00	0.000
	Par sp. 1	Med sp. 1	6	7	6	0.062	1.6	1.00	0.000
	Par sp. 1	Med sp. 3	6	5	4	0.044	1.2	0.99	0.004
	Not sp. 3	Med sp. 1	4	7	3	0.041	1.1	0.99	0.046
	Not sp. 1	Med sp. 1	4	7	3	0.041	1.1	0.99	0.046
	Not sp. 9	Med sp. 2	5	8	5	0.059	1.5	1.00	0.000
	Not sp. 9	Med sp. 1	5	7	5	0.052	1.3	1.00	0.000
	Med sp. 2	Med sp. 1	8	7	7	0.083	2.2	1.00	0.000
	Med sp. 2	Med sp. 3	8	5	5	0.059	1.5	1.00	0.000
	Med sp. 1	Med sp. 3	7	5	4	0.052	1.3	0.99	0.010
SFC+JPC rainy	Par sp. 1	Not sp. 2	5	12	5	0.077	2.1	1.00	0.008
	Par sp. 1	Med sp. 2	5	6	5	0.038	1.1	1.00	0.000
	Not sp. 2	Med sp. 2	12	6	6	0.092	2.6	1.00	0.002
	Not sp. 2	Med sp. 1	12	5	5	0.077	2.1	1.00	0.008
	Not sp. 9	Med sp. 2	5	6	4	0.038	1.1	0.99	0.003
	Med sp. 2	Med sp. 1	6	5	5	0.038	1.1	1.00	0.000

Table S3. Geographical coordinates (SIRGAS 2000) for the biological and environmental variables sampling stations (SS) in the São Francisco (SFC) and Japaratuba (JPC) canyons during the dry and rainy periods on the continental margin of Sergipe, NE, Brazil.

		Dry	period		Rain	y period	
SS	Canyon	Latitude	Longitude		Latitude	Longitude	Depth (m)
N3	SFC	-10.5973	-36.3487	-	-10.59718	-36.348375	50
N4	SFC	-10.6192	-36.3406		-10.618888	-36.34089	400
N5	SFC	-10.6725	-36.3028		-10.672518	-36.302493	700
N6	SFC	-10.7152	-36.2481		-10.716394	-36.248076	1000
N7	SFC	-10.7284	-36.1959		-10.728655	-36.196482	1300
N8	SFC	-10.773	-36.1174		-10.773976	-36.118225	1900
N9	SFC	-11.0873	-35.8977		-11.08713	-35.898231	3000
N3	JPC	-10.8741	-36.8233		-10.874151	-36.823316	50
N4	JPC	-10.9069	-36.817		-10.906724	-36.816336	400
N5	JPC	-10.9608	-36.7995		-10.960641	-36.799692	700
N6	JPC	-11.0112	-36.7622		-11.01162	-36.762093	1000
N7	JPC	-11.0398	-36.7367		-11.039963	-36.736575	1300
N8	JPC	-11.1727	-36.7255		-11.172669	-36.72492	1900
N9	JPC	-11.513	-36.5908		-11.513103	-36.591181	3000

Table S1. Geographical coordinates (SIRGAS 2000) for the biological and environmental variables sampling stations (SS) in the São Francisco (SFC) and Japaratuba (JPC) canyons during the dry and rainy periods on the continental margin of Sergipe, NE, Brazil.

		Dr	y period	Rai	ny period	
SS	Canyon	Latitude	Longitude	Latitude	Longitude	Bathymetry (m)
N3	SFC	-10.5973	-36.3487	-10.59718	-36.348375	50
N4	SFC	-10.6192	-36.3406	-10.618888	-36.34089	400
N5	SFC	-10.6725	-36.3028	-10.672518	-36.302493	700
N6	SFC	-10.7152	-36.2481	-10.716394	-36.248076	1000
N7	SFC	-10.7284	-36.1959	-10.728655	-36.196482	1300
N8	SFC	-10.773	-36.1174	-10.773976	-36.118225	1900
N9	SFC	-11.0873	-35.8977	-11.08713	-35.898231	3000
N3	JPC	-10.8741	-36.8233	-10.874151	-36.823316	50
N4	JPC	-10.9069	-36.817	-10.906724	-36.816336	400
N5	JPC	-10.9608	-36.7995	-10.960641	-36.799692	700
N6	JPC	-11.0112	-36.7622	-11.01162	-36.762093	1000
N7	JPC	-11.0398	-36.7367	-11.039963	-36.736575	1300
N8	JPC	-11.1727	-36.7255	-11.172669	-36.72492	1900
N9	JPC	-11.513	-36.5908	-11.513103	-36.591181	3000

Table S2. Multicollinearity analysis between particle size, chemical and physical environmental variables used for environmental characterization in the São Francisco and Japaratuba canyons in the continental margin of Sergipe, NE, Brazil. M = Model; Carb_T = Total Carbonate; CC = Coarse clay; MC = Medium clay; FC = Fine clay; VFC = Very fine clay; TC = Total clay; CSi = Coarse silte; MSi = Medium silte; FSi = Fine silte; VFSi = Very fine silte; TSi = Total silte; VCS = Very coarse sand; CS = Coarse sand; MS = Medium sand; FS = Fine sand; VFS = Very fine sand; TS = Total sand; SD = Sorting coefficient; Sk = Skewness; Kur = Kurtosis; Sal = Salinity; Temp = Temperature; C:N_{ratio} = Carbon/Nitrogen ratio; P_{org} = Organic phosphorous; N_T = Total nitrogen; C_{org} = Organic carbon; P_{inorg} = inorganic Phosphorous; PT = Total phosphorous. Variables in bold indicate multicollinearity through Variance Inflation Factor - VIF.

							Moc	lels							
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15
Carb _T	9.0	9.0	9.0	8.9	7.4	7.2	7.2	7.0	7.0	6.8	6.4	6.3	6.3	6.1	4.4
CC	9690.0	1338.6	1080.8	-	-	-	-	-	-	-	-	-	-	-	-
MC	643.9	593.6	582.9	271.3	249.8	197.2	-	-	-	-	-	-	-	-	-
FC	936.4	269.6	251.2	222.2	207.9	192.4	70.3	64.2	49.0	38.3	38.0	-	-	-	-
VFC	57.1	56.5	56.4	56.4	55.8	53.6	39.8	33.5	31.9	25.6	25.2	2.9	2.9	2.9	2.6
TC	10594.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CSi	67.9	57.8	49.8	48.7	47.9	36.2	32.1	32.1	29.6	10.5	10.5	10.2	8.0	8.0	7.1
MSi	552.2	390.1	376.1	248.9	246.3	106.6	106.6	94.0	61.0	10.0	9.5	9.52	9.1	9.0	7.7
FSi	520.7	309.9	309.5	130.7	130.6	130.4	100.7	98.6	98.0	-	-	-	-	-	-
VFSi	1420.3	1005.2	963.8	179.1	161.5	107.8	92.6	67.7	16.9	14.6	13.6	7.8	6.1	6.1	5.9
TSi	3359.6	3193.9	412.9	361.6	358.5	-	-	-	-	-	-	-	-	-	-
MUD	3618.6	3578.8	-	-	-	-	-	-	-	-	-	-	-	-	-
VCS	53.8	47.3	46.5	45.5	10.7	10.7	10.5	8.1	8.1	7.5	7.3	6.4	5.9	5.9	3.8
CS	20.4	16.7	16.1	15.7	14.9	14.9	14.6	12.1	11.0	10.3	10.3	7.4	4.9	4.9	4.9
MS	38.0	35.4	34.8	34.7	12.0	11.3	11.3	10.5	10.3	9.4	9.4	8.4	7.4	7.3	5.0
FS	73.5	73.5	65.5	63.3	40.8	38.9	38.7	33.9	32.7	30.6	30.3	30.3	-	-	-
VFS	487.4	482.3	474.5	473.2	22.4	21.2	20.9	19.5	19.0	18.8	18.7	18.5	6.1	6.0	6.0
TS	841.2	829.5	800.6	797.4	-	-	-	-	-	-	-	-	-	-	-
Median	203.5	192.1	189.7	185.8	185.4	161.3	136.5	133.1	-	-	-	-	-	-	-
SD	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.5
Sk	29.1	28.6	28.1	27.4	26.9	25.2	24.1	21.3	13.1	12.9	12.2	12.1	10.8	10.7	-
Kur	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0
Sal	12.0	11.9	11.9	11.8	11.6	9.2	8.5	7.1	7.1	7.12	6.1	6.0	5.8	1.9	1.9
Temp	27.3	27.1	27.0	25.7	25.6	22.4	20.6	13.8	13.8	13.7	13.6	13.6	12.3	-	-
C:N _{ratio}	114.6	112.9	109.3	105.2	98.0	97.9	97.7	5.7	5.7	5.7	5.5	5.4	5.0	4.6	3.9
Porg	55.4	55.3	53.3	51.3	51.2	51.1	51.1	43.1	42.6	42.3	3.5	3.4	3.2	3.1	2.8
NT	215.7	215.0	206.2	201.5	187.9	187.8	187.8	-	-	-	-	-	-	-	-
Corg	53.1	53.0	52.6	51.7	44.8	44.6	44.5	6.8	6.8	6.8	6.0	5.9	5.9	3.3	3.2
Pinorg	120.7	119.7	114.0	109.1	108.6	108.5	108.4	94.3	93.5	93.4	-	-	-	-	-
PT	122.9	122.4	116.9	111.3	110.4	110.4	110.1	89.6	88.7	88.6	3.6	3.6	2.9	2.8	2.8

Apêndices Capítulo 3

Table S3. Particle size, chemical and physical environmental variables used for environmental characterization in the São Francisco and Japaratuba canyons during dry and rainy seasons in the continental margin of Sergipe, NE, Brazil. Values represent mean \pm sorting coefficient. IC = Individual canyon; Carb_T = Total carbonates (%); VFC = Very fine clay; CSi = Coarse silt; MSi = Medium silt; VFSi = Very fine silt; VCS = Very coarse sand; CS = Coarse sand; MS = Medium sand; VFS = Very fine sand; SD = Sorting coefficient; Kur = Kurtosis; Sal = Salinity (psu), C:N_{ratio} = Carbon/Nitrogen

. j 0 11.							
Dry			São Fi	rancisco canyo	n		
	50	400	700	1000	1300	1900	3000
Carb _T	11.6(0.4)	12.1(0.1)	12.2(0.6)	12.5(1.6)	9.5(0.6)	9.0(0.2)	8.1(1.6)
VFC	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)
CSi	18.2(0.6)	15.7(1.2)	15.7(1.6)	14.7(1.3)	12.5(2.0)	12.8(0.5)	16.2(0.3)
MSi	32.3(0.8)	29.3(1.1)	27.6(1.3)	27.4(1.2)	25.9(1.1)	24.2(0.4)	22.7(1.2)
VFSi	11.9(0.6)	14.3(0.9)	15.0(1.0)	15.4(0.9)	17.0(1.3)	16.7(0.1)	10.8(2.2)
VCS	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
CS	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0.4(0.2)
MS	0(0)	0(0)	0(0)	0(0)	0(0)	0.1(0.0)	5.8(3.2)
VFS	1.1(0.1)	1.0(0.3)	1.3(0.1)	0.7(0.1)	0.8(0.2)	2.0(0.5)	7.4(1.9)
SD	1.4(0.0)	1.5(0.0)	1.5(0.0)	1.5(0.0)	1.5(0.0)	1.6(0.0)	2.1(0.1)
Kur	1 3(0 5)	0.9(0.0)	0.9(0.0)	0.9(0.0)	0.9(0.0)	0.9(0.0)	10(0.0)
Sal	37.0(0)	34.7(0)	34 3(0)	344(0.0)	34 6(0)	34 9(0 0)	34 9(0)
C·N	13.0(2.1)	7 5(0)	7.8(0.0)	72(1.0)	8 2(0)	63(0)	5 3(0)
D.1 Vratio	313.7(0)	207.7(0.0)	198.7(0.0)	165.8(0)	115.5(0)	107.6(0)	1361(0)
C org	12(0)	1.0(0)	103(0)	105.0(0)	113.3(0)	1 1(0)	1 2(0)
	1.2(0)	(10, 0)	1.05(0)	550 6(0)	1.0(0)	502.0(0)	(1.2(0))
PT Drv	447.1(0)	010.8(0)	003.0(0) Iana		367.9(0)	393.0(0)	015.2(0)
DIY	50	400	700	1000	1300	1900	3000
Carbr	12 9(0 7)	14 9(0 6)	17 2(1 3)	21.0(0.7)	23 3(1 1)	27 2(1 5)	267(17)
VFC	0.1(0.0)	0.1(0.0)	0.0(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)
CSi	18 7(1 0)	17 1(1 4)	16 4(1 0)	19.2(1.0)	18 9(1 7)	18 2(1 1)	18 4(1 1)
MSi	27 0(1 1)	26 3(1 2)	237(2.1)	250(1.7)	252(1.7)	24 7(0 4)	20 4(0.9)
VES	$\frac{2}{14} \frac{1}{10} \frac{1}{10} \frac{1}{10} \frac{1}{10}$	20.3(1.2) 15 $4(0.9)$	$\frac{23.7(2.1)}{12.8(1.8)}$	25.0(1.0) 15.0(0.8)	$\frac{23.2(1.1)}{14.0(0.6)}$	27.7(0.4) 13 2(0.6)	12 4(1.0)
VCS	14.1(0.8)	0(0)	12.0(1.0)	0(0)	1 = .0(0.0)	13.2(0.0)	12.4(1.1)
rus CS	0(0)	0(0)	0(0)	0(0)		0(0)	0(0) 0.1(0.1)
MS	0(0)	0(0)	1.2(0.7)		0.0(0.1)	0(0)	0.1(0.1) 0.7(1.1)
MS VEC	0(0)	0(0)	1.3(0.7)	0(0)	0.8(0.6)	0.7(0.2)	0.7(1.1)
VFS	1.7(0.2)	1./(0.4)	9.1(4.1)	3.5(0.3)	4.6(0.7)	5.7(0.3)	7.8(6.8)
SD	1.5(0.0)	1.6(0.0)	1.8(0.1)	1.6(0.0)	1.7(0.0)	1.7(0.0)	2.0(0.1)
Kur	0.9(0.0)	0.9(0.0)	1.0(0.0)	3.6(4.7)	0.9(0.0)	0.9(0.0)	0.9(0.0)
Sal	37.2(0.0)	35.2(0)	34.4(0)	34.4(0)	34.7(0)	34.9(0)	34.9(0.0)
C:N _{ratio}	6.9(0)	9.2(0)	5.9(0)	5.6(0.0)	7.2(0)	7.7(0)	5.7(0)
Porg	127.6(0.0)	325.9(0)	229.1(0.0)	184.5(0)	279.6(0)	274.3(0)	301.0(0)
Corg	0.8(0.0)	0.9(0)	1.1(0)	1.2(0)	1.2(0)	1.5(0.0)	1.5(0)
P _T	481.6(0.0)	803.1(0.0)	613.7(0)	761.7(0)	625.2(0)	733.0(0)	639.2(0)
Rainy		100	São Fi	rancisco canyo	n 1200	1000	2000
G 1	50	400	/00	1000	1300	1900	3000
Carb _T	11.0(0.0)	11.5(0.1)	12.5(0.2)	11.5(0.2)	10(0.7)	10.1(0.7)	11.4(3.1)
VFC	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.0(0.0)
CS1	16.3(2.8)	15.9(1.7)	13.3(1.9)	12.6(3.9)	13.4(0.6)	9.0(2.2)	17.6(1.0)
MS1	31.5(1.5)	28.9(0.9)	26.1(1.7)	26.3(2.3)	25.9(0.4)	23.5(0.6)	21.5(1.9)
VFSi	12.8(1.4)	14.6(1.1)	15.4(0.9)	16.4(2.3)	16.3(0.3)	19.0(1.8)	11.8(0.4)
VCS	0(0)	0(0)	1.5(2.6)	0(0)	0(0)	0(0)	0(0)
CS	0(0)	0(0)	1.4(2.4)	0(0)	0(0)	0(0)	1.1(1.9)
MS	0(0)	0(0)	0.0(0.0)	0(0)	0(0)	0.1(0.1)	1.3(1.5)
VFS	1.1(0.2)	0.8(0.7)	1.1(0.0)	1.0(0.4)	0.9(0.1)	1.2(1.3)	11.8(2.0)
SD	1.4(0.0)	1.5(0.0)	1.7(0.4)	1.5(0.0)	1.5(0)	1.4(0.1)	1.9(0.1)
Kur	1.0(0.0)	0.9(0.0)	1.1(0.4)	0.9(0.0)	0.9(0)	0.9(0.0)	0.9(0.1)
Sal	37.2(0)	35.2(0)	34.4(0)	34.5(0.0)	34.8(0.0)	35.0(0.0)	34.9(0)
C:N _{ratio}	11.0(0)	7.1(0.0)	7.5(0)	7.0(0)	7.6(0)	5.3(0.0)	4.1(0)
Porg	107 1(0 0)	102 2(0.0)	168 7(0)	211.3(0)	150.1(0)	149.4(0)	111.0(0)
0	197.1(0.0)	102.2(0.0)	100.7(0)	=(-)	10011(0)	· /	· /
Corg	197.1(0.0) 1.1(0)	1.0(0)	1.0(0)	0.9(0.0)	1.1(0)	1.1(0)	1.3(0)
C _{org} P _T	197.1(0.0) 1.1(0) 418.9(0.0)	1.0(0) 354.5(0)	1.0(0) 639.9(0)	0.9(0.0) 631.4(0)	1.1(0) 615.0(0)	1.1(0) 623.9(0)	1.3(0) 662.9(0)
C _{org} P _T Rainy	197.1(0.0) 1.1(0) 418.9(0.0)	102.2(0.0) 1.0(0) 354.5(0)	1.0(0) 639.9(0) Japa	0.9(0.0) 631.4(0) ratuba canyon	1.1(0) 615.0(0)	1.1(0) 623.9(0)	1.3(0) 662.9(0)
C _{org} P _T Rainy	197.1(0.0) 1.1(0) 418.9(0.0) 50	102.2(0.0) 1.0(0) 354.5(0) 400	1.0(0) <u>1.0(0)</u> <u>639.9(0)</u> <u>Japa</u> <u>700</u>	0.9(0.0) 631.4(0) ratuba canyon 1000	1.1(0) 615.0(0) 1300	1.1(0) 623.9(0) 1900	1.3(0) 662.9(0) 3000
C _{org} P _T Rainy Carb _T		102.2(0.0) 1.0(0) 354.5(0) 400 11.7(7.3)	1.0(0) 639.9(0) Japa 700 19.8(1.2)	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2)	1.1(0) 615.0(0) 1300 26.0(1.5)	1.1(0) 623.9(0) 1900 29.6(1.1)	1.3(0) 662.9(0) 3000 26.6(0.6)
C _{org} P _T Rainy Carb _T VFC	$ \begin{array}{r} 197.1(0.0) \\ 1.1(0) \\ 418.9(0.0) \\ \hline 50 \\ 18.8(1.9) \\ 0.1(0.0) \\ \end{array} $	102.2(0.0) 1.0(0) 354.5(0) 400 11.7(7.3) 0.1(0.0)	1.0(0) 639.9(0) Japa 700 19.8(1.2) 0.1(0.0)	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0)	1.1(0) 615.0(0) 1300 26.0(1.5) 0.1(0)	1.1(0) 623.9(0) 1900 29.6(1.1) 0.1(0.0)	1.3(0) 662.9(0) 3000 26.6(0.6) 0.0(0.0)
Corg PT Rainy CarbT VFC CSi	$ \begin{array}{r} 197.1(0.0) \\ 1.1(0) \\ 418.9(0.0) \\ \hline 50 \\ 18.8(1.9) \\ 0.1(0.0) \\ 17.1(2.8) \\ \end{array} $	102.2(0.0) 1.0(0) 354.5(0) 400 11.7(7.3) 0.1(0.0) 15.3(3.5)	1.0(0) 639.9(0) Japa 700 19.8(1.2) 0.1(0.0) 17.8(2.0)	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0)	1.1(0) 615.0(0) 1300 26.0(1.5) 0.1(0) 17.3(0.9)	1.1(0) 623.9(0) 1900 29.6(1.1) 0.1(0.0) 17.3(0.7)	1.3(0) 662.9(0) 3000 26.6(0.6) 0.0(0.0) 15.0(4.5)
Corg PT Rainy CarbT VFC CSi MSi	$ \begin{array}{r} 197.1(0.0) \\ 1.1(0) \\ 418.9(0.0) \\ \hline 50 \\ 18.8(1.9) \\ 0.1(0.0) \\ 17.1(2.8) \\ 27.3(0.4) \\ \end{array} $	102.2(0.0) 1.0(0) 354.5(0) 400 11.7(7.3) 0.1(0.0) 15.3(3.5) 25.4(1.1)	1.0(0) 639.9(0) Japa 700 19.8(1.2) 0.1(0.0) 17.8(2.0) 24.7(1.1)	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0) 25.5(0.0)	1.1(0) 615.0(0) 1 1300 26.0(1.5) 0.1(0) 17.3(0.9) 24.5(0.3)	1.1(0) 623.9(0) 1900 29.6(1.1) 0.1(0.0) 17.3(0.7) 23.6(0.5)	1.3(0) 662.9(0) 3000 26.6(0.6) 0.0(0.0) 15.0(4.5) 16.3(3.3)
Corg PT Rainy CarbT VFC CSi MSi VFSi	$ \begin{array}{r} 197.1(0.0) \\ 1.1(0) \\ 418.9(0.0) \\ \end{array} $ $ \begin{array}{r} 50 \\ 18.8(1.9) \\ 0.1(0.0) \\ 17.1(2.8) \\ 27.3(0.4) \\ 14.8(0.9) \\ \end{array} $	$\begin{array}{r} 102.2(0.0)\\ 1.0(0)\\ 354.5(0)\\ \hline \\ 400\\ 11.7(7.3)\\ 0.1(0.0)\\ 15.3(3.5)\\ 25.4(1.1)\\ 15.4(1.4)\\ \end{array}$	1.0(0) 639.9(0) Japa 700 19.8(1.2) 0.1(0.0) 17.8(2.0) 24.7(1.1) 14.6(0.1)	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0) 25.5(0.0) 15(0.4)	1.1(0) 615.0(0) 1300 26.0(1.5) 0.1(0) 17.3(0.9) 24.5(0.3) 14.9(0.5)	1.1(0) 623.9(0) 1900 29.6(1.1) 0.1(0.0) 17.3(0.7) 23.6(0.5) 14.1(1.0)	$\begin{array}{r} 1.3(0) \\ 662.9(0) \\ \hline \\ 3000 \\ 26.6(0.6) \\ 0.0(0.0) \\ 15.0(4.5) \\ 16.3(3.3) \\ 10.2(0.9) \end{array}$
Corg PT Rainy CarbT VFC CSi MSi VFSi VCS	$\begin{array}{r} 197.1(0.0)\\ 1.1(0)\\ 418.9(0.0)\\ \hline \\ 50\\ 18.8(1.9)\\ 0.1(0.0)\\ 17.1(2.8)\\ 27.3(0.4)\\ 14.8(0.9)\\ 0(0)\\ \end{array}$	$\begin{array}{r} 102.2(0.0)\\ 1.0(0)\\ 354.5(0)\\ \hline \\ \hline \\ 400\\ 11.7(7.3)\\ 0.1(0.0)\\ 15.3(3.5)\\ 25.4(1.1)\\ 15.4(1.4)\\ 0(0)\\ \end{array}$	1.0(0) 1.0(0) 639.9(0) Japa 700 19.8(1.2) 0.1(0.0) 17.8(2.0) 24.7(1.1) 14.6(0.1) 0(0)	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0) 25.5(0.0) 15(0.4) 0(0)	$\begin{array}{c} 1.1(0) \\ 615.0(0) \\ \hline \\ 1300 \\ 26.0(1.5) \\ 0.1(0) \\ 17.3(0.9) \\ 24.5(0.3) \\ 14.9(0.5) \\ 0(0) \end{array}$	$\begin{array}{c} 1.1(0) \\ 623.9(0) \\ \hline \\ \hline \\ 1900 \\ 29.6(1.1) \\ 0.1(0.0) \\ 17.3(0.7) \\ 23.6(0.5) \\ 14.1(1.0) \\ 0(0) \\ \end{array}$	$\begin{array}{c} 1.3(0) \\ 662.9(0) \\ \hline \\ 3000 \\ 26.6(0.6) \\ 0.0(0.0) \\ 15.0(4.5) \\ 16.3(3.3) \\ 10.2(0.9) \\ 0(0) \end{array}$
Corg PT Rainy CarbT VFC CSi MSi VFSi VCS CS	$ \begin{array}{r} 197.1(0.0) \\ 1.1(0) \\ 418.9(0.0) \\ \hline 50 \\ 18.8(1.9) \\ 0.1(0.0) \\ 17.1(2.8) \\ 27.3(0.4) \\ 14.8(0.9) \\ 0(0) \\ 0(0) \\ \end{array} $	$\begin{array}{r} 102.2(0.0)\\ 1.0(0)\\ 354.5(0)\\ \hline \\ \hline \\ 400\\ 11.7(7.3)\\ 0.1(0.0)\\ 15.3(3.5)\\ 25.4(1.1)\\ 15.4(1.4)\\ 0(0)\\ 0.0(0.0)\\ \end{array}$	Jobar (0) 1.0(0) 639.9(0) Japa 700 19.8(1.2) 0.1(0.0) 17.8(2.0) 24.7(1.1) 14.6(0.1) 0(0) 0(0)	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0) 25.5(0.0) 15(0.4) 0(0) 0(0)	$\begin{array}{c} 1.1(0) \\ 615.0(0) \\ \hline \\ 1300 \\ \hline \\ 26.0(1.5) \\ 0.1(0) \\ 17.3(0.9) \\ 24.5(0.3) \\ 14.9(0.5) \\ 0(0) \\ 0.0(0.0) \\ \end{array}$	$\begin{array}{c} 1.1(0) \\ 623.9(0) \\ \hline \\ 1900 \\ 29.6(1.1) \\ 0.1(0.0) \\ 17.3(0.7) \\ 23.6(0.5) \\ 14.1(1.0) \\ 0(0) \\ 0.0(0) \end{array}$	$\begin{array}{c} 1.3(0) \\ 662.9(0) \\ \hline \\ 3000 \\ 26.6(0.6) \\ 0.0(0.0) \\ 15.0(4.5) \\ 16.3(3.3) \\ 10.2(0.9) \\ 0(0) \\ 0.1(0.1) \end{array}$
Corg PT Rainy CarbT VFC CSi WSi VFSi VCS CS MS	$ \begin{array}{r} 197.1(0.0) \\ 1.1(0) \\ 418.9(0.0) \\ \hline 50 \\ 18.8(1.9) \\ 0.1(0.0) \\ 17.1(2.8) \\ 27.3(0.4) \\ 14.8(0.9) \\ 0(0) \\ 0(0) \\ 0(0) \\ 0(0) \\ \end{array} $	$\begin{array}{r} 102.2(0.0)\\ 1.0(0)\\ 354.5(0)\\ \hline \\ \hline \\ 400\\ \hline \\ 11.7(7.3)\\ 0.1(0.0)\\ 15.3(3.5)\\ 25.4(1.1)\\ 15.4(1.4)\\ 0(0)\\ 0.0(0.0)\\ 0.5(0.2)\\ \hline \end{array}$	1.0(0) 1.0(0) 639.9(0) Japa 700 19.8(1.2) 0.1(0.0) 17.8(2.0) 24.7(1.1) 14.6(0.1) 0(0) 0(0) 0(0) 0,4(0.4)	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0) 25.5(0.0) 15(0.4) 0(0) 0(0) 0(0)	$\begin{array}{c} 1.1(0) \\ 615.0(0) \\ \hline \\ 1300 \\ \hline \\ 26.0(1.5) \\ 0.1(0) \\ 17.3(0.9) \\ 24.5(0.3) \\ 14.9(0.5) \\ 0(0) \\ 0.0(0.0) \\ 0.6(0.5) \\ \hline \end{array}$	$\begin{array}{c} 1.1(0) \\ \underline{623.9(0)} \\ \hline \\ 1900 \\ 29.6(1.1) \\ 0.1(0.0) \\ 17.3(0.7) \\ 23.6(0.5) \\ 14.1(1.0) \\ 0(0) \\ 0.0(0) \\ 1.3(1.0) \end{array}$	$\begin{array}{c} 1.3(0) \\ 662.9(0) \\ \hline \\ 3000 \\ 26.6(0.6) \\ 0.0(0.0) \\ 15.0(4.5) \\ 16.3(3.3) \\ 10.2(0.9) \\ 0(0) \\ 0.1(0.1) \\ 4.0(2.7) \\ \end{array}$
Corg PT Rainy CarbT VFC CSi MSi VFSi VCS CS MS VFS	$ \begin{array}{r} 197.1(0.0) \\ 1.1(0) \\ 418.9(0.0) \\ \hline 50 \\ 50 \\ 18.8(1.9) \\ 0.1(0.0) \\ 17.1(2.8) \\ 27.3(0.4) \\ 14.8(0.9) \\ 0(0) \\ 0(0) \\ 0(0) \\ 0(0) \\ 1.4(0.5) \\ \end{array} $	$\begin{array}{r} 102.2(0.0)\\ 1.0(0)\\ 354.5(0)\\ \hline \\ 400\\ \hline \\ 11.7(7.3)\\ 0.1(0.0)\\ 15.3(3.5)\\ 25.4(1.1)\\ 15.4(1.4)\\ 0(0)\\ 0.0(0.0)\\ 0.5(0.2)\\ 2.9(0.5)\\ \hline \end{array}$	1.0(0) 1.0(0) 639.9(0) Japa 700 19.8(1.2) 0.1(0.0) 17.8(2.0) 24.7(1.1) 14.6(0.1) 0(0) 0.0(0) 0.4(0.4) 4.4(1.0)	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0) 25.5(0.0) 15(0.4) 0(0) 0(0) 0(0) 3.4(0.6)	$\begin{array}{c} 1.1(0) \\ 615.0(0) \\ \hline \\ 1300 \\ \hline \\ 26.0(1.5) \\ 0.1(0) \\ 17.3(0.9) \\ 24.5(0.3) \\ 14.9(0.5) \\ 0(0) \\ 0.0(0.0) \\ 0.6(0.5) \\ 3.9(0.6) \\ \hline \end{array}$	$\begin{array}{c} 1.1(0) \\ \underline{623.9(0)} \\ \hline \\ 1900 \\ \underline{29.6(1.1)} \\ 0.1(0.0) \\ 17.3(0.7) \\ \underline{23.6(0.5)} \\ 14.1(1.0) \\ 0(0) \\ 0.0(0) \\ 1.3(1.0) \\ \underline{6.0(0.5)} \end{array}$	$\begin{array}{c} 1.3(0) \\ 662.9(0) \\ \hline \\ 3000 \\ 26.6(0.6) \\ 0.0(0.0) \\ 15.0(4.5) \\ 16.3(3.3) \\ 10.2(0.9) \\ 0(0) \\ 0.1(0.1) \\ 4.0(2.7) \\ 16.3(0.3) \\ \end{array}$
Corg PT Rainy CarbT VFC CSi MSi VFSi VSS CS MS VFS SD	$\begin{array}{r} 197.1(0.0)\\ 1.1(0)\\ 418.9(0.0)\\ \hline \\ 50\\ 18.8(1.9)\\ 0.1(0.0)\\ 17.1(2.8)\\ 27.3(0.4)\\ 14.8(0.9)\\ 0(0)\\ 0(0)\\ 0(0)\\ 1.4(0.5)\\ 1.5(0.0)\\ \end{array}$	$\begin{array}{r} 102.2(0.0)\\ 1.0(0)\\ 354.5(0)\\ \hline \\ \hline \\ 400\\ 11.7(7.3)\\ 0.1(0.0)\\ 15.3(3.5)\\ 25.4(1.1)\\ 15.4(1.4)\\ 0(0)\\ 0.0(0.0)\\ 0.5(0.2)\\ 2.9(0.5)\\ 1.6(0.0)\\ \hline \end{array}$	1.000 1.0(0) 639.9(0) Japa 700 19.8(1.2) 0.1(0.0) 17.8(2.0) 24.7(1.1) 14.6(0.1) 0(0) 0(0) 0.4(0.4) 4.4(1.0) 1.7(0.0)	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0) 25.5(0.0) 15(0.4) 0(0) 0(0) 0(0) 3.4(0.6) 1.6(0.0)	$\begin{array}{c} 1.1(0) \\ 615.0(0) \\ \hline \\ 1300 \\ 26.0(1.5) \\ 0.1(0) \\ 17.3(0.9) \\ 24.5(0.3) \\ 14.9(0.5) \\ 0(0) \\ 0.0(0.0) \\ 0.6(0.5) \\ 3.9(0.6) \\ 1.7(0.0) \\ \end{array}$	$\begin{array}{c} 1.1(0) \\ \underline{623.9(0)} \\ \hline \\ 1900 \\ \underline{29.6(1.1)} \\ 0.1(0.0) \\ 17.3(0.7) \\ \underline{23.6(0.5)} \\ 14.1(1.0) \\ 0.0(0) \\ 1.3(1.0) \\ 6.0(0.5) \\ 1.1(1.0) \end{array}$	$\begin{array}{c} 1.3(0) \\ 662.9(0) \\ \hline \\ 3000 \\ \hline \\ 26.6(0.6) \\ 0.0(0.0) \\ 15.0(4.5) \\ 16.3(3.3) \\ 10.2(0.9) \\ 0(0) \\ 0.1(0.1) \\ 4.0(2.7) \\ 16.3(0.3) \\ 2.1(0.1) \\ \hline \end{array}$
Corg PT Rainy CarbT VFC CSi MSi VFSi VCS CS MS VFS SD Kur	$ \begin{array}{r} 197.1(0.0) \\ 1.1(0) \\ 418.9(0.0) \\ \hline 50 \\ 18.8(1.9) \\ 0.1(0.0) \\ 17.1(2.8) \\ 27.3(0.4) \\ 14.8(0.9) \\ 0(0) \\ 0(0) \\ 0(0) \\ 1.4(0.5) \\ 1.5(0.0) \\ 0.9(0.0) \\ \end{array} $	$\begin{array}{r} 102.2(0.0)\\ 1.0(0)\\ 354.5(0)\\ \hline \\ \hline \\ 400\\ 11.7(7.3)\\ 0.1(0.0)\\ 15.3(3.5)\\ 25.4(1.1)\\ 15.4(1.4)\\ 0(0)\\ 0.0(0.0)\\ 0.5(0.2)\\ 2.9(0.5)\\ 1.6(0.0)\\ 0.9(0.0)\\ 0.9(0.0)\\ \hline \end{array}$	$\begin{array}{r} 1.0(0) \\ 1.0(0) \\ 639.9(0) \\ \hline \\ \hline \\ 700 \\ \hline \\ 19.8(1.2) \\ 0.1(0.0) \\ 17.8(2.0) \\ 24.7(1.1) \\ 14.6(0.1) \\ 0(0) \\ 0(0) \\ 0.4(0.4) \\ 4.4(1.0) \\ 1.7(0.0) \\ 0.9(0.0) \\ \hline \\ \end{array}$	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0) 25.5(0.0) 15(0.4) 0(0) 0(0) 0(0) 3.4(0.6) 1.6(0.0) 0.9(0)	$\begin{array}{c} 1.1(0) \\ 615.0(0) \\ \hline \\ 1300 \\ \hline \\ 26.0(1.5) \\ 0.1(0) \\ 17.3(0.9) \\ 24.5(0.3) \\ 14.9(0.5) \\ 0(0) \\ 0.0(0.0) \\ 0.6(0.5) \\ 3.9(0.6) \\ 1.7(0.0) \\ 0.9(0.0) \\ \hline \end{array}$	$\begin{array}{c} 1.1(0) \\ 623.9(0) \\ \hline \\ \hline \\ 1900 \\ 29.6(1.1) \\ 0.1(0.0) \\ 17.3(0.7) \\ 23.6(0.5) \\ 14.1(1.0) \\ 0(0) \\ 0.0(0) \\ 1.3(1.0) \\ 6.0(0.5) \\ 1.1(1.0) \\ 0.9(0.0) \\ \end{array}$	$\begin{array}{c} 1.3(0) \\ 662.9(0) \\ \hline \\ 3000 \\ \hline \\ 26.6(0.6) \\ 0.0(0.0) \\ 15.0(4.5) \\ 16.3(3.3) \\ 10.2(0.9) \\ 0(0) \\ 0.1(0.1) \\ 4.0(2.7) \\ 16.3(0.3) \\ 2.1(0.1) \\ 2.1(0.1) \\ 0.8(0) \\ \hline \\ \end{array}$
Corg PT Rainy CarbT VFC CSi MSi VCS CS MS VFS SD Kur S2al	$\begin{array}{r} 197.1(0.0)\\ 1.1(0)\\ 418.9(0.0)\\ \hline \\ \hline \\ 50\\ \hline \\ 18.8(1.9)\\ 0.1(0.0)\\ 17.1(2.8)\\ 27.3(0.4)\\ 14.8(0.9)\\ 0(0)\\ 0(0)\\ 0(0)\\ 0(0)\\ 1.4(0.5)\\ 1.5(0.0)\\ 0.9(0.0)\\ 37.3(0)\\ \hline \end{array}$	$\begin{array}{r} 102.2(0.0)\\ 1.0(0)\\ 354.5(0)\\ \hline \\ \hline \\ 400\\ 11.7(7.3)\\ 0.1(0.0)\\ 15.3(3.5)\\ 25.4(1.1)\\ 15.4(1.4)\\ 0(0)\\ 0.0(0.0)\\ 0.5(0.2)\\ 2.9(0.5)\\ 1.6(0.0)\\ 0.9(0.0)\\ 35.0(0.0)\\ \hline \\ \end{array}$	$\begin{array}{r} 1.0(0) \\ 1.0(0) \\ 639.9(0) \\ \hline \\ \hline \\ 700 \\ \hline \\ 19.8(1.2) \\ 0.1(0.0) \\ 17.8(2.0) \\ 24.7(1.1) \\ 14.6(0.1) \\ 0(0) \\ 0(0) \\ 0(0) \\ 0.4(0.4) \\ 4.4(1.0) \\ 1.7(0.0) \\ 0.9(0.0) \\ 34.5(0) \\ \hline \end{array}$	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0) 25.5(0.0) 15(0.4) 0(0) 0(0) 0(0) 3.4(0.6) 1.6(0.0) 0.9(0) 34.5(0)	$\begin{array}{c} 1.1(0) \\ 615.0(0) \\ \hline \\ 1300 \\ \hline \\ 26.0(1.5) \\ 0.1(0) \\ 17.3(0.9) \\ 24.5(0.3) \\ 14.9(0.5) \\ 0(0) \\ 0.0(0.0) \\ 0.6(0.5) \\ 3.9(0.6) \\ 1.7(0.0) \\ 0.9(0.0) \\ 34.7(0.0) \\ \hline \end{array}$	$\begin{array}{c} 1.1(0) \\ 623.9(0) \\ \hline \\ \hline \\ 1900 \\ 29.6(1.1) \\ 0.1(0.0) \\ 17.3(0.7) \\ 23.6(0.5) \\ 14.1(1.0) \\ 0.0(0) \\ 1.3(1.0) \\ 6.0(0.5) \\ 1.1(1.0) \\ 0.9(0.0) \\ 34.9(0.1) \\ \end{array}$	$\begin{array}{c} 1.3(0) \\ 662.9(0) \\ \hline \\ 3000 \\ 26.6(0.6) \\ 0.0(0.0) \\ 15.0(4.5) \\ 16.3(3.3) \\ 10.2(0.9) \\ 0(0) \\ 0.1(0.1) \\ 4.0(2.7) \\ 16.3(0.3) \\ 2.1(0.1) \\ 0.8(0.0) \\ 34.9(0.0) \\ 34.9(0.0) \\ \end{array}$
Corg PT Rainy Carbt VFC CSi MSi VFSi VCS CS MS VFS SD Kur Sal C:N	$\begin{array}{r} 197.1(0.0)\\ 1.1(0)\\ 418.9(0.0)\\ \hline \\ 50\\ \hline \\ 18.8(1.9)\\ 0.1(0.0)\\ 17.1(2.8)\\ 27.3(0.4)\\ 14.8(0.9)\\ 0(0)\\ 0(0)\\ 0(0)\\ 0(0)\\ 1.4(0.5)\\ 1.5(0.0)\\ 0.9(0.0)\\ 37.3(0)\\ 7.7(0)\\ \hline \end{array}$	$\begin{array}{r} 102.2(0.0)\\ 1.0(0)\\ 354.5(0)\\ \hline \\ \hline \\ 400\\ 11.7(7.3)\\ 0.1(0.0)\\ 15.3(3.5)\\ 25.4(1.1)\\ 15.4(1.4)\\ 0(0)\\ 0.0(0.0)\\ 0.5(0.2)\\ 2.9(0.5)\\ 1.6(0.0)\\ 0.9(0.0)\\ 35.0(0.0)\\ 9.2(0)\\ \end{array}$	$\begin{array}{r} 1.0(0) \\ 1.0(0) \\ 639.9(0) \\ \hline \\ \hline \\ 39.8(1.2) \\ 0.1(0.0) \\ 17.8(2.0) \\ 24.7(1.1) \\ 14.6(0.1) \\ 0(0) \\ 0(0) \\ 0.4(0.4) \\ 4.4(1.0) \\ 1.7(0.0) \\ 0.9(0.0) \\ 34.5(0) \\ 5.0(0) \\ \end{array}$	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0) 25.5(0.0) 15(0.4) 0(0) 0(0) 0(0) 0(0) 0.4(0.6) 1.6(0.0) 0.9(0) 34.5(0) 4.3(0)	$\begin{array}{c} 1.1(0) \\ 615.0(0) \\ \hline \\ 1300 \\ \hline \\ 26.0(1.5) \\ 0.1(0) \\ 17.3(0.9) \\ 24.5(0.3) \\ 14.9(0.5) \\ 0(0) \\ 0.0(0.0) \\ 0.6(0.5) \\ 3.9(0.6) \\ 1.7(0.0) \\ 0.9(0.0) \\ 34.7(0.0) \\ 5.6(0.0) \\ \hline \end{array}$	$\begin{array}{c} 1.1(0) \\ 623.9(0) \\ \hline \\ \hline \\ 1900 \\ 29.6(1.1) \\ 0.1(0.0) \\ 17.3(0.7) \\ 23.6(0.5) \\ 14.1(1.0) \\ 0.0(0) \\ 1.3(1.0) \\ 6.0(0.5) \\ 1.1(1.0) \\ 0.9(0.0) \\ 34.9(0.1) \\ 5.1(0) \end{array}$	$\begin{array}{c} 1.3(0) \\ 662.9(0) \\ \hline \\ 3000 \\ 26.6(0.6) \\ 0.0(0.0) \\ 15.0(4.5) \\ 16.3(3.3) \\ 10.2(0.9) \\ 0(0) \\ 0.1(0.1) \\ 4.0(2.7) \\ 16.3(0.3) \\ 2.1(0.1) \\ 0.8(0.0) \\ 34.9(0.0) \\ 37(0) \end{array}$
Corg PT Rainy CarbT VFC CSi MSi VFSi VCS CS MS VCS CS MS VFS SD Kur Sal C:Nratio P	$\begin{array}{r} 197.1(0.0)\\ 1.1(0)\\ 418.9(0.0)\\ \hline \\ 50\\ \hline \\ 18.8(1.9)\\ 0.1(0.0)\\ 17.1(2.8)\\ 27.3(0.4)\\ 14.8(0.9)\\ 0(0)\\ 0(0)\\ 0(0)\\ 0(0)\\ 1.4(0.5)\\ 1.5(0.0)\\ 0.9(0.0)\\ 37.3(0)\\ 7.7(0)\\ 271.0(0)\\ \end{array}$	$\begin{array}{r} 102.2(0.0)\\ 1.0(0)\\ 354.5(0)\\ \hline \\ \hline \\ 400\\ 11.7(7.3)\\ 0.1(0.0)\\ 15.3(3.5)\\ 25.4(1.1)\\ 15.4(1.4)\\ 0(0)\\ 0.0(0.0)\\ 0.5(0.2)\\ 2.9(0.5)\\ 1.6(0.0)\\ 0.9(0.0)\\ 35.0(0.0)\\ 9.2(0)\\ 153.9(0)\\ \hline \end{array}$	$\begin{array}{r} 1.0(0) \\ 1.0(0) \\ 639.9(0) \\ \hline \\ Japa \\ \hline 700 \\ \hline 19.8(1.2) \\ 0.1(0.0) \\ 17.8(2.0) \\ 24.7(1.1) \\ 14.6(0.1) \\ 0(0) \\ 0(0) \\ 0(0) \\ 0(0) \\ 0.4(0.4) \\ 4.4(1.0) \\ 1.7(0.0) \\ 0.9(0.0) \\ 34.5(0) \\ 5.0(0) \\ 5.0(0) \\ 3024(0) \\ \hline \end{array}$	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0) 25.5(0.0) 15(0.4) 0(0) 0(0) 0(0) 0(0) 3.4(0.6) 1.6(0.0) 0.9(0) 34.5(0) 4.3(0) 205.1(0)	$\begin{array}{c} 1.1(0) \\ 615.0(0) \\ \hline \\ 1300 \\ \hline \\ 26.0(1.5) \\ 0.1(0) \\ 17.3(0.9) \\ 24.5(0.3) \\ 14.9(0.5) \\ 0.0(0) \\ 0.0(0.0) \\ 0.6(0.5) \\ 3.9(0.6) \\ 1.7(0.0) \\ 0.9(0.0) \\ 34.7(0.0) \\ 5.6(0.0) \\ 148.7(0) \\ \hline \end{array}$	$\begin{array}{c} 1.1(0) \\ 623.9(0) \\ \hline \\ \hline \\ 1900 \\ 29.6(1.1) \\ 0.1(0.0) \\ 17.3(0.7) \\ 23.6(0.5) \\ 14.1(1.0) \\ 0.0(0) \\ 1.3(1.0) \\ 6.0(0.5) \\ 1.1(1.0) \\ 0.9(0.0) \\ 34.9(0.1) \\ 5.1(0) \\ 202.1(0) \end{array}$	$\begin{array}{c} 1.3(0) \\ 662.9(0) \\ \hline \\ \hline \\ 3000 \\ 26.6(0.6) \\ 0.0(0.0) \\ 15.0(4.5) \\ 16.3(3.3) \\ 10.2(0.9) \\ 0(0) \\ 0.1(0.1) \\ 4.0(2.7) \\ 16.3(0.3) \\ 2.1(0.1) \\ 0.8(0.0) \\ 34.9(0.0) \\ 34.9(0.0) \\ 37.7(0) \\ 98.7(0) \\ \end{array}$
Corg PT Rainy CarbT VFC CSi MSi VFSi VCS CS MS VFS SD Kur Sal C:Nratio Porg C	$\begin{array}{r} 197.1(0.0)\\ 1.1(0)\\ 418.9(0.0)\\ \hline \\ 50\\ \hline \\ 50\\ 18.8(1.9)\\ 0.1(0.0)\\ 17.1(2.8)\\ 27.3(0.4)\\ 14.8(0.9)\\ 0(0)\\ 0(0)\\ 0(0)\\ 0(0)\\ 0(0)\\ 1.4(0.5)\\ 1.5(0.0)\\ 0.9(0.0)\\ 37.3(0)\\ 7.7(0)\\ 271.0(0)\\ 0.9(0)\\ \end{array}$	$\begin{array}{c} 102.2(0.0)\\ 1.0(0)\\ 354.5(0)\\ \hline \\ \hline \\ 400\\ \hline \\ 11.7(7.3)\\ 0.1(0.0)\\ 15.3(3.5)\\ 25.4(1.1)\\ 15.4(1.4)\\ 0(0)\\ 0.5(0.2)\\ 2.9(0.5)\\ 1.6(0.0)\\ 0.9(0.0)\\ 35.0(0.0)\\ 9.2(0)\\ 153.9(0)\\ 1.6(0)\\ \hline \\ \end{array}$	$\begin{array}{r} 1.0(0) \\ 1.0(0) \\ 639.9(0) \\ \hline \\ \hline \\ 39.9(0) \\ \hline \\ 19.8(1.2) \\ 0.1(0.0) \\ 17.8(2.0) \\ 24.7(1.1) \\ 14.6(0.1) \\ 0(0) \\ 0.4(0.4) \\ 4.4(1.0) \\ 1.7(0.0) \\ 0.9(0.0) \\ 34.5(0) \\ 5.0(0) \\ 302.4(0) \\ 1.1(0) \\ \hline \end{array}$	0.9(0.0) 631.4(0) ratuba canyon 1000 24.0(0.2) 0.1(0.0) 18.4(1.0) 25.5(0.0) 15(0.4) 0(0) 0(0) 0(0) 3.4(0.6) 1.6(0.0) 0.9(0) 34.5(0) 4.3(0) 205.1(0) 1.3(0)	$\begin{array}{c} 1.1(0) \\ 615.0(0) \\ \hline \\ 1300 \\ \hline \\ 26.0(1.5) \\ 0.1(0) \\ 17.3(0.9) \\ 24.5(0.3) \\ 14.9(0.5) \\ 0(0) \\ 0.0(0.0) \\ 0.6(0.5) \\ 3.9(0.6) \\ 1.7(0.0) \\ 0.9(0.0) \\ 34.7(0.0) \\ 5.6(0.0) \\ 148.7(0) \\ 12.(0) \\ \end{array}$	$\begin{array}{c} 1.1(0) \\ 623.9(0) \\ \hline \\ \hline \\ 1900 \\ 29.6(1.1) \\ 0.1(0.0) \\ 17.3(0.7) \\ 23.6(0.5) \\ 14.1(1.0) \\ 0.0(0) \\ 1.3(1.0) \\ 6.0(0.5) \\ 1.1(1.0) \\ 0.9(0.0) \\ 34.9(0.1) \\ 5.1(0) \\ 202.1(0) \\ 14(0) \end{array}$	$\begin{array}{c} 1.3(0) \\ 662.9(0) \\ \hline \\ 3000 \\ 26.6(0.6) \\ 0.0(0.0) \\ 15.0(4.5) \\ 16.3(3.3) \\ 10.2(0.9) \\ 0(0) \\ 0.1(0.1) \\ 4.0(2.7) \\ 16.3(0.3) \\ 2.1(0.1) \\ 0.8(0.0) \\ 34.9(0.0) \\ 3.7(0) \\ 98.7(0) \\ 98.7(0) \\ 1.6(0) \end{array}$

ratio; $P_{org} = Organic Phosphorus (\mu g.g^{-1}), C_{org} = Organic Carbon. IC = Individual canyon.$

Table S4. Spatial niche overlap in the bathymetric gradient in the São Francisco canyon during the dry seasonal period on the continental margin of Sergipe, NE, Brazil. Bar sp. 1 = Barantolla sp. 1; Bar sp. 2 = Barantolla sp. 2; Capi sp. 1 = Capitella sp. 1; Cap sp. 5 = Capitellidae sp. 5; Cap sp. 6 = Capitellidae sp. 6; Leioc sp. 3 = Leiochrides sp. 3; Med sp. 1 = Mediomastus sp. 1; Med sp. 3 = Mediomastus sp. 3; Noto sp. 1 = Notomastus sp. 1; Not sp. 2 = Notomastus sp. 2; Med sp. 2 = Mediomastus sp. 2; Not sp. 9 = Notomastus sp. 9; Par sp. 1 = Parheteromastus sp. 1; Per sp. 1 = Peresiella sp. 1.

	Cap sp. 5	Juvenile	Cap sp. 6	Par sp. 1	Not sp. 1	Not sp. 2	Leioc sp. 3	Bar sp. 1	Not sp. 9	Per sp. 1	Bar sp. 2	Med sp. 2	Med sp. 1
Juvenile	0.99												
Cap sp. 6	0	0											
Par sp. 1	0	0.99	0										
Not sp. 1	0	0.99	0	100									
Not sp.2	0.08	0.94	0	0.90	0.90								
Leioc sp. 3	0	0.09	0	0	0	0.38							
Bar sp. 1	0	0.99	0	1	1	0.9	0						
Not sp. 9	0	0.99	0	1	1	0.9	0	1					
Per sp. 1	0	0.99	0	1	1	0.9	0	1	1				
Bar sp. 2	0	0	0	0	0	0	0	0	0	0			
Med sp. 2	0	0.99	0	1	1	0.9	0	1	1	1	0		
Med sp. 1	0	0.99	0	1	1	0.9	0	1	1	1	0	1	
Med sp. 3	0	0.99	0	1	1	0.9	0	1	1	1	0	1	1

Table S5. Spatial niche overlap in the sediment layers in the São Francisco canyon during the dry seasonal period on the continental margin of Sergipe, NE, Brazil. Bar sp. 1 = Barantolla sp. 1; Bar sp. 2 = Barantolla sp. 2; Cap sp. 5 = Capitellidae sp. 5; Cap sp. 6 = Capitellidae sp. 6; Leioc sp. 3 = Leiochrides sp. 3; Med sp. 1 = Mediomastus sp. 1; Med sp. 3 = Mediomastus sp. 3; Noto sp. 1 = Notomastus sp. 1; Not sp. 2 = Notomastus sp. 2; Med sp. 2 = Mediomastus sp. 2; Not sp. 9 = Notomastus sp. 1; Per sp. 1 = Peresiella sp. 1.

	Cap sp. 5	Juvenile	Cap sp. 6	Par sp. 1	Not sp. 1	Not sp. 2	Leioc sp. 3	Bar sp. 1	Not sp. 9	Per sp. 1	Bar sp. 2	Med sp. 2	Med sp. 1
Juvenile	0.15			•	•	•	•	•	•	•		·	
Cap sp. 6	0	0											
Par sp. 1	0	0.65	0										
Not sp. 1	0	0.84	0	0.81									
Not sp.2	0	0.74	0	0.49	0.43								
Leioc sp. 3	0	0	0	0	0	0.20							
Bar sp. 1	0	0.31	0	0.88	0.44	0.41	0						
Not sp. 9	0	0.63	0	0.99	0.80	0.49	0	0.89					
Per sp. 1	0	0.31	0	0.88	0.44	0.41	0	1	0.89				
Bar sp. 2	0	0	0	0	0	0	0	0	0	0			
Med sp. 2	0	0.41	0	0.93	0.55	0.44	0	0.99	0.94	0.99	0		
Med sp. 1	0	0.53	0	0.98	0.68	0.47	0	0.95	0.98	0.95	0	0.98	
Med sp. 3	0	0.31	0	0.88	0.44	0.41	0	1	0.89	1	0	0.99	0.95

Table S6. Spatial niche overlap in the bathymetric gradient in the São Francisco canyon during the rainy seasonal period on the continental margin of Sergipe, NE, Brazil. Bar sp. 1 = Barantolla sp. 1; Bar sp. 2 = Barantolla sp. 2; Cap sp. 5 = Capitellidae sp. 5; Cap sp. 6 = Capitellidae sp. 6; Leioc sp. 3 = Leiochrides sp. 3; Med sp. 1 = Mediomastus sp. 1; Med sp. 3 = Mediomastus sp. 3; Noto sp. 1 = Notomastus sp. 1; Not sp. 2 = Notomastus sp. 2; Med sp. 2 = Mediomastus sp. 2; Not sp. 9 = Notomastus sp. 9; Par sp. 1 = Parheteromastus sp. 1; Per sp. 1 = Peresiella sp. 1.

	Juvenile	Cap sp. 1	Par sp. 1	Not sp. 2	Leioc sp. 2	Leioc sp. 3	Bar sp. 1	Not sp. 10	Not sp. 9	Med sp. 2	Med sp. 1	Med sp. 3	Bar sp. 3	Capi sp. 1
Cap sp. 1	0.85													
Par sp. 1	0.90	0.70												
Not sp. 2	0.70	0.54	0.77											
Leioc sp. 2	0.90	0.70	1	0.77										
Leioc sp. 3	0	0	0	0.31	0									
Bar sp. 1	0	0	0	0	0	0								
Not sp. 10	0	0	0	0.31	0	1	0							
Not sp. 9	0.90	0.70	1	0.77	1	0	0	0						
Med sp. 2	0.90	0.70	1	0.77	1	0	0	0	1					
Med sp. 1	0.90	0.70	1	0.77	1	0	0	0	1	1				
Med sp. 3	0.90	0.70	1	0.77	1	0	0	0	1	1	1			
Bar sp. 3	0.30	0.70	0	0	0	0	0	0	0	0	0	0		
Capi sp. 1	0.30	0.70	0	0	0	0	0	0	0	0	0	0	1	
Leio sp. 1	0.90	0.70	1	0.77	1	0	0	0	1	1	1	1	0	0

Table S7. Spatial niche overlap in the sediment layers in the São Francisco canyon during the rainy seasonal period on the continental margin of Sergipe, NE, Brazil. Bar sp. 1 = Barantolla sp. 1; Bar sp. 2 = Barantolla sp. 2; Cap sp. 5 = Capitellidae sp. 5; Cap sp. 6 = Capitellidae sp. 6; Leioc sp. 3 = Leiochrides sp. 3; Med sp. 1 = Mediomastus sp. 1; Med sp. 3 = Mediomastus sp. 3; Noto sp. 1 = Notomastus sp. 1; Not sp. 2 = Notomastus sp. 2; Med sp. 2 = Mediomastus sp. 2; Not sp. 9 = Notomastus sp. 9; Par sp. 1 = Parheteromastus sp. 1; Per sp. 1 = Peresiella sp. 1.

	Juvenile	Cap sp. 1	Par sp. 1	Not sp. 2	Leioc sp. 2	Leioc sp. 3	Bar sp. 1	Not sp. 10	Not sp. 9	Med sp. 2	Med sp. 1	Med sp. 3	Bar sp. 3	Capi sp. 1	
Cap sp. 1	0														
Par sp. 1	0	0.70													
Not sp. 2	0.59	0	0.04												
Leioc sp. 2	0.90	0	0	0.65											
Leioc sp. 3	0	0	0	0.10	0										
Bar sp. 1	0	0	0	0	0	0									
Not sp. 10	0	0	0	0.30	0	0.70	0								
Not sp. 9	0	0	0.11	0.43	0	0	0	0							
Med sp. 2	0	0.42	0.67	0.35	0	0	0	0	0.80						
Med sp. 1	0.24	0.63	0.92	0.33	0.27	0	0	0	0.34	0.81					
Med sp. 3	0	0.70	0.99	0	0	0	0	0	0	0.59	0.89				
Bar sp. 3	0	0.70	0	0	0	0	0	0	0	0	0	0			
Capi sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0		
Leio sp. 1	0	0.70	0.99	0	0	0	0	0	0	0.59	0.89	1	0	0	

Table S8. Spatial niche overlap in the bathymetric gradient in the Japaratuba canyon during the dry seasonal period on the continental margin of Sergipe, NE, Brazil. Bar sp. 1 = Barantolla sp. 1; Capi sp. 2 = Capitella sp. 2; Cap sp. 1 = Capitellidae sp. 1; Cap sp. 3 = Capitellidae sp. 3; Cap sp. 4 = Capitellidae sp. 4; Das sp. 1 = Dasybranchus sp. 1; Het sp. 1 = Heteromastus sp. 1; Leioc sp. 1 = Leiochrides sp. 1; Leioc sp. 2 = Leiochrides sp. 2; Leioc sp. 3 = Leiochrides sp. 3; Mas sp. 1 = Mastobranchus sp. 1; Mas sp. 2 = Mastobranchus sp. 2; Med sp. 1 = Mediomastus sp. 1; Med sp. 2 = Mediomastus sp. 2; Med sp. 3 = Mediomastus sp. 3; Med sp. 4 = Mediomastus sp. 4; Med sp. 5 = Mediomastus sp. 5; Not sp. 1 = Notomastus sp. 1; Not sp. 2 = Notomastus sp. 2; Not sp. 3 = Notomastus sp. 3; Not sp. 6 = Notomastus sp. 6; Not sp. 7 = Notomastus sp. 7; Not sp. 8 = Notomastus sp. 9; Not sp. 9; Not sp. 10 = Notomastus sp. 10; Not sp. 11 = Notomastus sp. 11; Not sp. 12 = Notomastus sp. 12; Par sp. 1 = Parheteromastus sp. 1; Per sp. 2 = Peresiella sp. 2; Scy sp. 1 = Scyphoproctus sp. 1; Juy = Juvenile.

	1101011	iasia	s sp.	12,1	ar sp	• 1	I um	cicro	masin	is sp. i	, 101	sp. 2	10	resie	iiu sp	<i></i> , .	J C y S	p. 1	JU	pnopi	ocin	, sp. 1	i, suv	30						
	Capi	Juv	Scy	Cap	Par	Not	Not	Not	Leioc	Leioc	Leioc	Bar	Not	Not	Cap	Not	Not	Mas	Mas	Het	Das	Not	Not	Not	Med	Per	Med	Med	Med	Med
	sp. 2		sp.	sp.	sp.	sp.	sp.	sp.	sp. 1	sp. 2	sp. 3	sp.	sp.	sp.	sp.	sp.	sp.	sp.	sp.	sp.	sp. 1	sp.	sp.	sp.	sp.	sp.	sp.	sp.	sp.	sp.
			1	1	1	3	1	2				1	10	9	3	12	11	2	1	1		6	8	7	2	2	1	3	4	5
Juv	0.76																													
Scy sp.1	0	0.56																												
Cap sp.1	0	0.01	0																											
Par sp.1	0	0.56	1	0																										
Not sp.3	0	0.56	0.98	0	0.98																									
Not sp.1	0	0.30	0	0	0	0																								
Not sp.2	0.33	0.76	0.79	0.42	0.79	0.80	0.11																							
Leioc sp.1	1	0.76	0	0	0	0	0	0.33																						
Leioc sp.2	0	0.56	1	0	1	0.98	0	0.79	0																					
Leioc sp.3	0	0.05	0	0	0	0.16	0	0.11	0	0																				
Bar sp.1	1	0.76	0	0	0	0	0	0.33	1	0	0																			
Not sp.10	0	0.29	0	0	0	0	0.94	0.21	0	0	0	0																		
Not sp.9	0	0.56	1	0	1	0.98	0	0.79	0	1	0	0	0																	
Cap sp.3	0	0.56	1	0	1	0.98	0	0.79	0	1	0	0	0	1																
Not sp.12	1	0.76	0	0	0	0	0	0.33	1	0	0	1	0	0	0															
Not sp.11	0.70	0.93	0.70	0	0.70	0.69	0	0.80	0.70	0.7	0	0.70	0	0.70	0.7	0.7														
Mas sp. 2	0	0.56	1	0	1	0.98	0	0.79	0	1	0	0	0	1	1	0	0.70													
Mas sp.1	0	0.30	0	0	0	0	1	0.11	0	0	0	0	0.94	0	0	0	0	0												
Het sp.1	1	0.76	0	0	0	0	0	0.33	1	0	0	1	0	0	0	1	0.70	0	0											
Das sp.1	1	0.76	0	0	0	0	0	0.33	1	0	0	1	0	0	0	1	0.70	0	0	1										
Not sp.6	1	0.76	0	0	0	0	0	0.33	1	0	0	1	0	0	0	1	0.70	0	0	1	1									
Not sp.8	0.70	0.57	0	0	0	0.11	0	0.32	0.70	0	0.70	0.70	0	0	0	0.7	0.50	0	0	0.70	0.70	0.7								
Not sp.7	0	0.56	1	0	1	0.98	0	0.79	0	1	0	0	0	1	1	0	0.70	1	0	0	0	0	0							
Med sp.2	0.01	0.57	0.99	0	0.99	0.98	0	0.79	0.01	0.99	0	0.01	0	0.99	0.99	0.01	0.70	0.99	0	0.01	0.01	0.01	0.01	0.99						
Per sp.2	0	0.56	1	0	1	0.98	0	0.79	0	1	0	0	0	1	1	0	0.70	1	0	0	0	0	0	1	0.99					
Med sp.1	0.01	0.61	0.99	0	0.99	0.98	0	0.81	0.07	0.99	0	0.07	0	0.99	0.99	0.07	0.70	0.99	0	0.07	0.07	0.07	0.05	0.99	0.99	0.99				
Med sp.3	0.06	0.60	0.99	0	0.99	0.98	0	0.81	0.06	0.99	0	0.06	0	0.99	0.99	0.06	0.70	0.99	0	0.06	0.06	0.06	0.04	0.99	0.99	0.99	0.99			
Med sp.4	0	0.56	1	0	1	0.98	0	0.79	0	1	0	0	0	1	1	0	0.70	1	0	0	0	0	0	1	0.99	1	0.99	0.99		
Med sp.5	0	0	0	0.94	0	0	0	0.33	0	0	0	0	0.31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Cap sp.4	0	0.05	0	0	0	0.16	0	0.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.70	0	0	0	0	0	0	0

Table S9. Spatial niche overlap in the sediment layers in the Japaratuba canyon during the dry seasonal period on the continental margin of
Sergipe, NE, Brazil. Bar sp. 1 = Barantolla sp. 1; Capi sp. 2 = Capitella sp. 2; Cap sp. 1 = Capitellidae sp. 1; Cap sp. 3 = Capitellidae sp. 3; Cap
sp. 4 = Capitellidae sp. 4; Das sp. 1 = Dasybranchus sp. 1; Het sp. 1 = Heteromastus sp. 1; Leioc sp. 1 = Leiochrides sp. 1; Leioc sp. 2 =
Leiochrides sp. 2; Leioc sp. 3 = Leiochrides sp. 3; Mas sp. 1 = Mastobranchus sp. 1; Mas sp. 2 = Mastobranchus sp. 2; Med sp. 1 = Mediomastus
sp. 1; Med sp. 2 = Mediomastus sp. 2; Med sp. 3 = Mediomastus sp. 3; Med sp. 4 = Mediomastus sp. 4; Med sp. 5 = Mediomastus sp. 5; Not sp. 1
= Notomastus sp. 1; Not sp. 2 = Notomastus sp. 2; Not sp. 3 = Notomastus sp. 3 Not sp. 6 = Notomastus sp. 6; Not sp. 7 = Notomastus sp. 7; Not
sp. 8 = Notomastus sp. 8; Not sp. 9 = Notomastus sp. 9; Not sp. 10 = Notomastus sp. 10; Not sp. 11 = Notomastus sp. 11; Not sp. 12 =
Notomastus sp. 12; Par sp. 1 = Parheteromastus sp. 1; Per sp. 2 = Peresiella sp. 2; Scv sp. 1 = Scvphoproctus sp. 1; Juv = Juvenile.

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	Capi	Juv	Scy	Cap	Par	Not	Not	Not	Leioc	Leioc	Leioc	Bar	Not	Not	Cap	Not	Not	Mas	Mas	Het	Das	Not	Not	Not	Med	Per	Med	Med	Med	Med
	sp. 2		sp.	sp.	sp.	sp.	sp.	sp. 2	sp. 1	sp. 2	sp. 3	sp.	sp.	sp.	sp.	sp.	sp.	sp.	sp.	sp.	sp. 1	sp.	sp.	sp.	sp.	sp.	sp.	sp.	sp.	sp.
			1	1	1	3	1					1	10	9	3	12	11	2	1	1		6	8	7	2	2	1	3	4	5
Juv	0.23																													
Scy sp.1	0	0.14																												
Cap sp.1	0	0	0																											
Par sp.1	0	0.24	0.94	0																										
Not sp.3	0	0.25	0.43	0	0.68																									
Not sp.1	0	0	0	0	0	0																								
Not sp.2	0.11	0.62	0	0.1	0.06	0	0																							
Leioc sp.1	0.79	0.63	0	0	0	0	0	0.23																						
Leioc sp.2	0	0.33	0.90	0	0.97	0.65	0	0.25	0																					
Leioc sp.3	0	0	0	0	0	0.21	0	0	0	0																				
Bar sp.1	0.89	0.14	0	0	0	0	0	0.12	0.72	0	0																			
Not sp.10	0	0.27	0	0.33	0	0	0	0.05	0	0	0	0																		
Not sp.9	0	0.22	0.92	0	0.99	0.72	0	0	0	0.95	0	0	0																	
Cap sp.3	0	0.22	0	0	0.30	0.87	0	0	0	0.30	0	0	0	0.37																
Not sp.12	0.44	0.22	0	0	0	0	0	0	0.33	0	0	0	0	0	0															
Not sp.11	0.31	0.26	0.70	0	0.67	0.30	0	0	0.23	0.63	0	0	0	0.65	0	0.70														
Mas sp. 2	0	0.22	0	0	0.30	0.87	0	0	0	0.30	0	0	0	0.37	1	0	0													
Mas sp.1	0	0.22	0	0	0	0	0	0	0	0	0	0	0.81	0	0	0	0	0												
Het sp.1	0.89	0.14	0	0	0	0	0	0.12	0.72	0	0	1	0	0	0	0	0	0	0											
Das sp.1	0.89	0.14	0	0	0	0	0	0.12	0.72	0	0	1	0	0	0	0	0	0	0	1										
Not sp.6	0.89	0.14	0	0	0	0	0	0.12	0.72	0	0	1	0	0	0	0	0	0	0	1	1									
Not sp.8	0.31	0.15	0	0	0	0	0	0	0.23	0	0	0	0	0	0	0.70	0.50	0	0	0	0	0								
Not sp.7	0	0.14	1	0	0.94	0.43	0	0	0	0.90	0	0	0	0.92	0	0	0.70	0	0	0	0	0	0							
Med sp.2	0.01	0.25	0.23	0	0.52	0.95	0	0.002	0.01	0.50	0	0.01	0	0.57	0.97	0	0.16	0.97	0	0.01	0.01	0.01	0.03	0.23						
Per sp.2	0	0.14	1	0	0.94	0.43	0	0	0	0.90	0	0	0	0.92	0	0	0.70	0	0	0	0	0	0	1	0.23					
Med sp.1	0.08	0.27	0.89	0	0.98	0.76	0	0.06	0.07	0.95	0	0.09	0	0.99	0.43	0	0.63	0.43	0	0.09	0.09	0.09	0	0.89	0.63	0.89				
Med sp.3	0.05	0.23	0.03	0	0.33	0.88	0	0.008	0.04	0.33	0	0.06	0	0.4	0.99	0	0.02	0.99	0	0.06	0.06	0.06	0	0.03	0.97	0.03	0.46			
Med sp.4	0	0.26	0.44	0	0.69	0.97	0	0	0	0.67	0	0	0	0.74	0.89	0	0.31	0.89	0	0	0	0	0	0.44	0.97	0.44	0.78	0.90		
Med sp.5	0	0	0	0	0	0	0	0.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Cap sp.4	0	0	0	0	0	0.21	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table S10. Spatial niche overlap in the bathymetric gradient in the Japaratuba canyon during the rainy seasonal period on the continental margin of Sergipe, NE, Brazil. Bar sp. 1 = Barantolla sp. 1; Bar sp. 2 = Barantolla sp. 2; Capi sp. 1 = Capitella sp. 1; Cap sp. 4 = Capitellidae sp. 4; Dec sp. 1 = Decamastus sp. 1; Het sp. 2 = Heteromastus sp. 2; Het sp. 3 = Heteromastus sp. 3; Leio sp. 1 = Leiocapitella sp. 1; Leio sp. 2 = Leiocapitella sp. 2; Leio c sp. 1 = Leiochrides sp. 1; Leio c sp. 2 = Leiochrides sp. 2; Mas sp. 2 = Mastobranchus sp. 2; Med sp. 1 = Mediomastus sp. 1; Med sp. 2 = Mediomastus sp. 2; Med sp. 3 = Mediomastus sp. 3; Neo sp. 1 = Neoheteromastus sp. 1; Not sp. 2 = Notomastus sp. 2; Not sp. 3 = Notomastus sp. 3; Not sp. 5 = Notomastus sp. 5; Not sp. 8 = Notomastus sp. 8; Not sp. 9 = Notomastus sp. 9; Not sp. 12 = Notomastus sp. 1; Juv = Juvenile.

	Juv	Par	Not	Not	Leioc	Bar	Not	Not	Mas	Not	Bar	Med	Med	Med	Cap	Capi	Leio	Dec	Het	Het	Neo	Leio
		sp.1	sp.3	sp.2	sp.1	sp.1	sp.9	sp.12	sp.2	sp.8	sp.2	sp.2	sp.1	sp.3	sp.4	sp.1	sp.1	sp.1	sp.2	sp.3	sp.1	sp.2
Par sp.1	0.37																					
Not sp.3	0.37	1																				
Not sp.2	0.37	1	1																			
Leioc sp.1	0.74	0	0	0																		
Bar sp.1	0.87	0.23	0.23	0.23	0.94																	
Not sp.9	0.40	0.99	0.99	0.99	0.04	0.27																
Not sp.12	0.37	0	0	0	0	0	0															
Mas sp.2	0.78	0.70	0.70	0.70	0.70	0.83	0.73	0														
Not sp.8	0.37	1	1	1	0	0.23	0.99	0	0.70													
Bar sp.2	0.37	1	1	1	0	0.23	0.99	0	0.70	1												
Med sp.2	0.37	1	1	1	0	0.23	0.99	0	0.70	1	1											
Med sp.1	0.37	1	1	1	0	0.23	0.99	0	0.70	1	1	1										
Med sp.3	0.37	1	1	1	0	0.23	0.99	0	0.70	1	1	1	1									
Cap sp.4	0.39	0	0	0	0	0	0	0.70	0	0	0	0	0	0								
Capi sp.1	0.74	0	0	0	1	0.94	0.04	0	0.70	0	0	0	0	0	0							
Leio sp.1	0.37	1	1	1	0	0.23	0.99	0	0.70	1	1	1	1	1	0	0						
Dec sp.1	0.37	1	1	1	0	0.23	0.99	0	0.70	1	1	1	1	1	0	0	1					
Het sp.2	0.37	1	1	1	0	0.23	0.99	0	0.70	1	1	1	1	1	0	0	1	1				
Het sp.3	0.37	1	1	1	0	0.23	0.99	0	0.70	1	1	1	1	1	0	0	1	1	1			
Neo sp.1	0.37	0	0	0	0	0	0	1	0	0	0	0	0	0	0.7	0	0	0	0	0		
Leioc sp.2	0.73	0	0	0	0	0.93	0.04	0	0.70	0	0	0	0	0	0	0.99	0	0	0	0	0	
Not sp.5	0.37	1	1	1	0	0.23	0.99	0	0.70	1	1	1	1	1	0	0	1	1	1	1	0	0

Table S11. Spatial niche overlap in the sediment layers in the Japaratuba canyon during the rainy seasonal period on the continental margin of Sergipe, NE, Brazil. Bar sp. 1 = *Barantolla* sp. 1; Bar sp. 2 = *Barantolla* sp. 2; Capi sp. 1 = *Capitella* sp. 1; Cap sp. 4 = Capitellidae sp. 4; Dec sp. 1 = Decamastus sp. 1; Het sp. 2 = *Heteromastus* sp. 2; Het sp. 3 = *Heteromastus* sp. 3; Leio sp. 1 = *Leiocapitella* sp. 1; Leio sp. 2 = *Leiocapitella* sp. 2; Leio c sp. 1 = *Leiochrides* sp. 1; Leio c sp. 2 = *Leiochrides* sp. 2; Med sp. 2 = *Mediomastus* sp. 2; Med sp. 2 = *Mediomastus* sp. 2; Med sp. 2 = *Mediomastus* sp. 2; Med sp. 2 = *Notomastus* sp. 2; Not sp. 2 = *Notomastus* sp. 2; Not sp. 3 = *Notomastus* sp. 3; Not sp. 5 = *Notomastus* sp. 5; Not sp. 8 = *Notomastus* sp. 8; Not sp. 9 = *Notomastus* sp. 9; Not sp. 12 = *Notomastus* sp. 1; Juv = Juvenile.

	Juv	Par	Not	Not	Leioc	Bar	Not	Not	Mas	Not	Bar	Med	Med	Med	Cap	Capi	Leio	Dec	Het	Het	Neo	Leio
		sp.1	sp.3	sp.2	sp.1	sp.1	sp.9	sp.12	sp.2	sp.8	sp.2	sp.2	sp.1	sp.3	sp.4	sp.1	sp.1	sp.1	sp.2	sp.3	sp.1	sp.2
Par sp.1	0.28																					
Not sp.3	0	0.65																				
Not sp.2	0.41	0.85	0.31																			
Leioc sp.1	0.68	0	0	0																		
Bar sp.1	0.55	0.20	0.31	0.1	0.83																	
Not sp.9	0.34	0.91	0.70	0.89	0.05	0.26																
Not sp.12	0	0	0	0	0	0	0															
Mas sp.2	0.65	0.65	0.50	0.63	0.65	0.79	0.73	0														
Not sp.8	0.43	0.65	0	0.94	0	0	0.70	0	0.50													
Bar sp.2	0	0.65	1	0.31	0	0.31	0.70	0	0.50	0												
Med sp.2	0.19	0.87	0.89	0.69	0	0.28	0.94	0	0.66	0.43	0.89											
Med sp.1	0.30	0.92	0.70	0.89	0	0.22	0.99	0	0.70	0.70	0.70	0.94										
Med sp.3	0	0.65	1	0.31	0	0.31	0.70	0	0.50	0	1	0.89	0.70									
Cap sp.4	0.15	0	0	0	0.39	0	0	0	0	0	0	0	0	0								
Capi sp.1	0.21	0	0	0	0	0.63	0	0	0.50	0	0	0	0	0	0							
Leio sp.1	0	0.65	1	0.31	0	0.31	0.70	0	0.50	0	1	0.89	0.70	1	0	0						
Dec sp.1	0	0.39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
Het sp.2	0.43	0.65	0	0.94	0	0	0.70	0	0.50	1	0	0.43	0.70	0	0	0	0	0				
Het sp.3	0	0.65	1	0.31	0	0.31	0.70	0	0.50	0	1	0.89	0.70	1	0	0	1	0	0			
Neo sp.1	0.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0.70	0	0	0	0	0		
Leioc sp.2	0.48	0	0	0	0.75	0.83	0.02	0	0.66	0	0	0	0	0	0	0.88	0	0	0	0	0	
Not sp.5	0	0.65	1	0.31	0	0.31	0.70	0	0.50	0	1	0.89	0.70	1	0	0	1	0	0	1	0	0



Figure S4. General abundance of Capitellidae species in São Francisco and Japaratuba submarine canyons in Sergipe Continental margin, NE, Brazil. (A) abundance > 5; (B) Abundance < 5.



Capitellidae species

Figure S2. Niche width for the Capitellidae metacommunity as a function of the bathymetric gradient and sediment layers in the São Francisco (A) and Japaratuba (B) canyons during dry seasonal period on the continental margin of Sergipe.



Figure S3. Niche width for the Capitellidae metacommunity as a function of the bathymetric gradient and sediment layers in the São Francisco (A) and Japaratuba (B) canyons during rainy seasonal period on the continental margin of Sergipe.





Figure S5. Total abundance of Capitellidae species and as a function of sediment layers in the Japaratuba submarine canyon during dry (A - B) and rainy (C - D) periods on the continental margin of Sergipe, NE, Brazil. B and D represent species with abundance < 10.



Table S4. Generalized linear models – GLM showing variability of richness (S) and density in bathymetric and sediment layers (SL) gradients in São Francisco (SFC) and Japaratuba (JPC) canyons during the dry and rainy seasonal periods in Sergipe continental margin, NE, Brazil. d.f. = degrees of freedom, SS = sum of squares. Bold numbers represent significant variations (p < 0.05).

Canyon	SP	Category	Ecological	d.f.	SS	F	р
			metric				
SFC	Dry	Bathymetric	Richness	5	4.91	2.96	0.109
			Density	5	23.6	10.6	0.006
		SL	Richness	2	0.84	0.62	0.552
			Density	2	0.51	0.09	0.911
	Rainy	Bathymetric	Richness	5	5.09	8.03	0.005
			Density	5	19.9	9.08	0.003
		SL	Richness	2	0.43	0.42	0.661
			Density	2	3.60	1.01	0.392
JPC	Dry	Bathymetric	Richness	5	8.96	6.86	0.003
			Density	5	43.6	14.36	< 0.001
		SL	Richness	2	0.36	0.23	0.795
			Density	2	0.55	0.08	0.921
	Rainy	Bathymetric	Richness	6	9.40	3.95	0.047
	-	-	Density	6	42.42	11.02	0.002
		SL	Richness	2	1.75	0.92	0.425
			Density	2	3.23	0.40	0.675

Anexos

1. Declaração de Bioética e Biossegurança



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DECLARAÇÃO

Em observância ao §5º do Artigo 1º da Informação CCPG-UNICAMP/001/15, referente a Bioética e Biossegurança, declaro que o conteúdo de minha Tese de Doutorado, intitulada "*Metacomunidade: dinâmica espacial e temporal de anelídeos Capitellidae em cânions submarinos*", desenvolvida no Programa de Pós-Graduação em Ecologia do Instituto de Biologia da Unicamp, não versa sobre pesquisa envolvendo seres humanos, animais ou temas afetos a Biossegurança.

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Nome do(a) orientador(a): Antonia Cecilia Zacagnini Amaral

Data: 30/10/2023

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