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A IMPORTÂNCIA DAS PRAIAS PARA O DESENVOLVIMENTO INICIAL DE ASSEMBLEIAS DE PEIXES E MACROCRUSTÁCEOS: VARIAÇÃO ESPAÇO-TEMPORAL DA ICTIOFAUNA EM PRAIAS ADJACENTES A UM ESTUÁRIO TROPICAL (RESEX ACAÚ-GOIANA PE/PB, BRASIL)

Carlos Henrique Figueiredo Lacerda

RECIFE – PE

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Tese apresentada ao Programa de Pós-Graduação em Oceanografia como requisito parcial à obtenção do título de Doutor em Oceanografia. Área de concentração em Oceanografia Biológica.

Orientador: Dr. Mário Barletta

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A função das praias como berçário para as assembleias de peixes: variação espaço-temporal da ictiofauna em praias adjacentes a um estuário tropical (reserva Extrativista Acaú-goina PE/PB, Brasil)

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LISTA DE FIGURAS

Apresentação

Capítulo 1: Caracterização e variação espaço-temporal da morfodinâmica e sedimentologia das praias adjacentes ao estuário do Rio Goiana

Capítulo 2: Temporal patterns in the intertidal faunal community at the mouth of a tropical Estuary

LISTA DE TABELAS

LISTA DE APÊNDICES

SUMÁRIO

CAPÍTULO 2: Temporal patterns in the intertidal faunal community at the mouth of a tropical Estuary

CAPÍTULO 3: Spatial and seasonal variations of intertidal community in estuarine sandy/mud beaches

RESUMO

As zonas costeiras são consideradas áreas de transição entre os domínios continental e marinho, apresentando alta complexidade e dinamismo. Representando aproximadamente 10% das áreas emersas habitáveis, abrigam atualmente cerca de dois terços da população mundial proporcionando inúmeros serviços econômico-sociais a sociedade humana, que em constante expansão sobrecarrega cada vez mais esses ambientes que exercem papéis ecológicos fundamentais na manutenção da biodiversidade (e produtividade) local e de ecossistemas adjacentes (terrestre e marinho). Dentre os diferentes ecossistemas costeiros, os sistemas estuarinos são bastante conhecidos por estarem presentes em praticamente toda a costa brasileira, assim como por apresentarem grande importância ecológica, econômica e social. Na costa nordeste do Brasil muitos ecossistemas estuarinos ainda encontram-se pouco ou até mesmo não estudados, deixando uma lacuna nos estudos ecológicos referentes a esses ecossistemas que além de grande dinamismo também apresentam muitas particularidades, principalmente ao longo dessa região (NE) onde a plataforma continental é mais estreita. Dessa forma, durante o período de doze meses o habitat praia estabelecido na porção externa do estuário do Rio Goiana foi amplamente estudado, tendo como objetivo principal, avaliar o potencial desse ambiente como berçário para as assembleias de peixes. Um total de três desenhos amostrais foram elaborados e executados nas praias adjacentes a foz do Rio Goiana. A partir do esforço amostral, aspectos relacionados à composição e dinâmica da comunidade de fauna, assim como, características morfodinâmicas e ambientais, foram descritos pela primeira vez nesse habitat, que atualmente encontra-se sob a condição de Reserva Extrativista (RESEX Acaú-Goiana). Foi identificado que as praias adjacentes ao estuário ocorrem junto a um extenso terraço de baixa-mar, cortado pelo canal principal do rio ao longo da margem sul do estuário. Por se tratar de um ambiente dominado pela maré, diferentes ciclos ambientais como o ciclo lunar e circadiano, apresentaram grande influencia nos padrões das variáveis ambientais (salinidade, temperatura da agua, oxigênio dissolvido e profundidade), assim como, no uso do habitat pelas diferentes espécies da fauna. A diferença no regime de chuvas ao longo do ciclo sazonal mostrou-se determinante na composição da comunidade biótica das praias, dominadas por espécies estuarinas durante a estação chuvosa, e abrigando um maior número de espécies costeiras durante a estação seca. Esse ciclo sazonal do habitat, estimulado pelas oscilações de variáveis ambientais como salinidade e temperatura, permite que o habitat contemple um maior número de espécies, e aumenta a eficiência do fluxo de energia entre a porção interna do estuário e habitats costeiros adjacentes. A porção externa do estuário do Rio Goiana proporciona um extenso habitat de aguas rasas, ideal para o desenvolvimento inicial de varias espécies de peixes e crustáceos. É nesse habitat, que o berçário de espécies chave para a subsistência de famílias tradicionais como, *Mugil* spp. e *Callinectes danae* ocorre. O grande acúmulo de matéria orgânica, típico de terraços de maré, associado às baixas profundidades e transparência, promovem proteção e recursos alimentares para inúmeras espécies em desenvolvimento inicial, se apresentando assim, como uma importante alternativa de berçário para as assembleias de peixes e crustáceos. As praias estudadas podem exercer um importante papel na manutenção da biodiversidade do ecossistema estuarino e adjacente. As informações levantadas no presente estudo são inéditas, podendo servir de auxilio aos órgãos competentes, em seus planos de manejo de ecossistemas costeiros em unidades de conservação.

Palavras-chave: ciclo lunar, conectividade, ritmo circadiano, sazonalidade, Terraço de baixa-mar, variação espaço-temporal.

ABSTRACT

Coastal areas are considered transition zones between continental and marine environments, with high complexity and dynamism. Representing approximately 10% of the habitable emerged areas, currently home to about two-thirds of the world population providing numerous services (economic and social) to human society, which in constantly expanding, overwhelms these environments which performing key ecological roles in the maintenance of local biodiversity (and productivity) and in the adjacent ecosystems (terrestrial and marine). Among the different coastal ecosystems, estuarine systems are well known to be present in practically the entire Brazilian coast, as well as presenting ecological, economic and social services. On the northeast coast of Brazil many estuarine ecosystems are still little or even not studied, leaving a gap in ecological estuarine studies, especially over this region (NE), where the continental shelf is narrower providing many particularities to this ecosystems. So, during the twelve-month period, the beach habitat established in the outer portion of the estuary Goiana was widely studied, with the main purpose of evaluating the potential of this environment as a nursery for fish assemblages. A total of three sampling designs were developed and implemented in the sandy beaches adjacent to Goiana River's mouth. Aspects related to the composition and dynamics of the faunal community, as well as, morphodynamic and environmental features, were described for the first time in this area, a Marine Conservation Unit, of type Extractive Reserve (RESEX Acaú-Goiás). It was identified that the adjacent estuarine beaches occur along an extensive low tide terrace, crossed by the Goiana main channel along the southern shore. As a tide dominated environment, different environmental cycles, such as circadian and lunar cycle, had great influence on the patterns of environmental variables (salinity, water temperature, dissolved oxygen and depth), as well as in habitat use by different fauna species. The differences in rainfall regime along the seasonal cycle, proved decisive in the composition of the biotic community, dominated by estuarine species during the rainy season, and harboring a greater number of coastal species during the dry season. This seasonal cycle of the habitat, allows the sandy beaches to contemplate a larger number of species, and increases the efficiency of energy flow between the inner portion of the estuary and adjacent coastal habitats. The outer portion of Goiana River estuary provides an extensive shallow water habitat, ideal for the initial development of various species of fish and crustaceans. In this habitat, the nursery of key species for the livelihoods of traditional families as *Mugil* spp. and *Callinectes danae* occurs. The large accumulation of organic matter (wrack), typical of tidal terraces, associated to lowest depths and water transparency, promote protection and food resources for many species in early development, presenting as an important alternative nursery and feeding site for fish and crustaceans species. Thus, the sandy beach habitat plays an important role in the livelihood of the local community, as well as in maintaining the biodiversity of estuarine-coastal continuum. The information gathered in this study, should be taken into account by environmental agencies in their planning of coastal ecosystems.

Keywords: circadian rhythm, connectivity, Low Tide Terrace, lunar cycle, seasonality, spatial-temporal variation.

Apresentação

Introdução

Zona de transição entre os domínios continental e marinho, as regiões costeiras se caracterizam como um ambiente complexo e dinâmico, sujeito a vários processos geológicos (Thurman, 1989). São nesses ambientes, que representam cerca de 10% das áreas emersas habitáveis, onde a grande maioria da população mundial se concentra (Hinrichsen, 1998). Em meio a esse cenário, as áreas de costa passaram a proporcionar inúmeros serviços econômico-sociais (transporte, turismo, fonte de proteína de alta qualidade, área para implementação de atividades industriais e portuárias, etc) a sociedade humana, ao mesmo tempo em que são reconhecidas como importantes zonas de transição, com alta produtividade biológica (proteica), e uma grande diversidade de habitats (Blaber *et al*., 1995; Constanza *et al*., 1997; Barletta & Blaber, 2007; Barletta *et al*., 2010). Esses diferentes habitats suportam uma grande diversidade de espécies, e são necessários para a manutenção da biodiversidade local e de ecossistemas adjacentes (terrestre e marinho).

A região costeira do nordeste brasileiro, em função de razões históricas e geográficas, como o início da colonização europeia e a implementação do cultivo da cana-de-açúcar, vem sendo até os dias atuais, um dos principais alvos do desenvolvimento urbano e econômico do país (Firjan, 2014). Na ultima década, um crescente aumento na renda per capita da população nordestina, seguida de um grande interesse do capital privado na região, vem trazendo cada vez mais investimentos, principalmente de infraestrutura, para a costa nordeste do país. Em meio a essa expansão, grande parte dos habitats costeiros (praias, florestas de mangue, estuários, recifes costeiros e bancos de fanerógamas) veem sofrendo constantes mudanças, antes de serem compreendidos seus papéis ecológicos para as diferentes espécies, e consequentemente, as possíveis consequências para a manutenção da biodiversidade, produtividade proteica e aporte de nutrientes e biomassa as aguas abertas.

Dentre os diferentes ecossistemas costeiros, os sistemas estuarinos são bastante conhecidos por estarem presentes em praticamente toda a costa brasileira, assim como por apresentarem grande importância ecológica, econômica e social (Coelho Jr., 2000; Barletta & Costa, 2009; Barletta *et al*., 2010). Inúmeros estudos (Blaber *et al*., 1995; Beck *et al*., 2001; Nagelkerken *et al*., 2001;Barletta *&* Blaber, 2007; Barletta *et al*., 2010) destacam os ecossistemas estuarinos como ambientes de alta produtividade, com a presença de diferentes habitats (canal principal, canais de maré, floresta de mangue, praias) que servem como ambiente de criação, crescimento e reprodução para várias espécies da fauna (aves, moluscos, peixes e crustáceos), algumas com importância comercial, e muitas fundamentais para subsistência de famílias que comumente habitam áreas adjacentes. Entre os diferentes habitats estuarinos, as praias arenosas e lodosas são ambientes bastante dinâmicos, sob constante influencia de variáveis bióticas e abióticas (regime de marés, aporte fluvial, acúmulo de matéria orgânica e resíduos). São nesses habitats de aguas rasas, sob condições favoráveis de alimentação, crescimento, refugio e conexão com diferentes habitats adjacentes, que inúmeras espécies de peixes e crustáceos passam sua fase inicial de vida, aumentando o seu *fitness* antes de fazerem parte das respectivas populações adultas (Blaber *et al*., 1995; Nagelkerken *et al*., 2000).

Estudos realizados em habitats de praia localizados em regiões tropicais (Blaber & Blaber, 1980; Pessanha & Araújo, 2003; Gaelzer & Zalmon, 2008; Barletta & Barletta-Bergan, 2009; Inui *et al*., 2010; Ramos *et al*., 2011), subtropicais (Lima & Vieira, 2009; Lercari *et al*., 2010; Mont´Alverne *et al*., 2012) e temperadas (Lastra *et al*., 2006; Dolbeth *et al*., 2008; Franco *et al*., 2008), demostram como a interação de diversas variáveis temporais (sazonalidade, ciclo lunar e ritmo circadiano), espaciais (distancia em relação à desembocadura do estuário, grau de exposição da praia) e ambientais (salinidade, temperatura da água, turbidez, profundidade), atuam nos padrões de comunidade (densidade, biomassa e numero de espécies) desses habitats. Na costa brasileira, a proximidade entre diferentes habitats de grande produtividade como recifes de corais, capim-marinho, manguezais, canal principal e canais de maré em estuários, pode levar as praias estuarinas a exercerem um papel chave na manutenção da biodiversidade e conexão biológica do ecossistema costeiro.

Na costa nordestina, estudos ecológicos nos habitats praia ainda são escassos, e informações sob o uso desses habitats pelas assembleias de peixes e crustáceos é raro. O presente estudo teve como objetivo identificar os fatores espaciais (distancia da desembocadura do estuário), temporais (sazonalidade, ciclo lunar e circadiano) e ambientais como salinidade, temperatura da agua, oxigênio dissolvido, profundidade, característica do sedimento e RTR (Relative Tidal Range), que afetam o uso desse habitat pela comunidade de peixes e macrocrustáceos, nas praias adjacentes ao Estuário do Rio Goiana. Da mesma forma, objetivou-se avaliar o papel de berçário desse ambiente para as diferentes espécies de peixes e macrocrustáceos.

A região estudada esta inserida na Reserva Extrativista Acaú-Goiana, localizada no extremo norte do estado de Pernambuco. As informações do uso desse habitat pela fauna, assim como os papéis ecológicos desse habitat para a manutenção da biodiversidade e proteína para as populações tradicionais locais, são de suma importância aos órgãos ambientais e gestores, responsáveis pela preservação e uso das áreas de costa e seus ecossistemas.

Objetivos

Objetivo Geral

Caracterizar e estudar as praias da porção externa do estuário do Rio Goiana, avaliando o papel desse habitat como uma alternativa de berçário e área de alimentação e crescimento para as assembleias de peixes e macrocrustáceos.

Objetivos específicos

- Caracterizar o perfil morfológico e sedimentológico das praias ás margens do estuário do Rio Goiana, assim como, correlacionar as variações temporais de tais perfis com as assembleias de peixes e macrocrustáceos.
- Caracterizar as assembleias de peixes e macrocrustáceos (número de espécies, densidade, biomassa e guildas ecológicas), nas diferentes praias adjacentes a desembocadura do Rio Goiana, ao longo de um ciclo sazonal.
- Identificar o papel de outras variáveis temporais como o ciclo lunar e circadiano no uso do habitat pelas assembleias de peixes e macrocrustáceos.

Metodologia

Área de estudo

O sistema estuarino do Rio Goiana localiza-se no extremo norte do estado de Pernambuco, delimitando a fronteira com o estado da Paraíba (Figura 1). Em uma área aproximada de 4700 ha, encontra-se habitats de grande importância ecológica como o canal principal do Rio Goiana, canais de maré, florestas de mangue e bancos de capim marinho. Plantações de cana de açúcar e atividades econômica-industriais como aquicultura e fabricas de cimento também fazem parte do complexo estuarino. Os municípios de Goiana (PE), Caaporã e Pitimbu (PB), são os principais centros urbanos que margeiam o estuário e exploram diretamente seus recursos. No ano de 2007, devido a sua importância para a subsistência de centenas de famílias, esse complexo estuarino foi responsável pela criação da Reserva Extrativista Acaú-Goiana (RESEX Acaú-Goiana; ICMBio, 2007) (Figura 1).

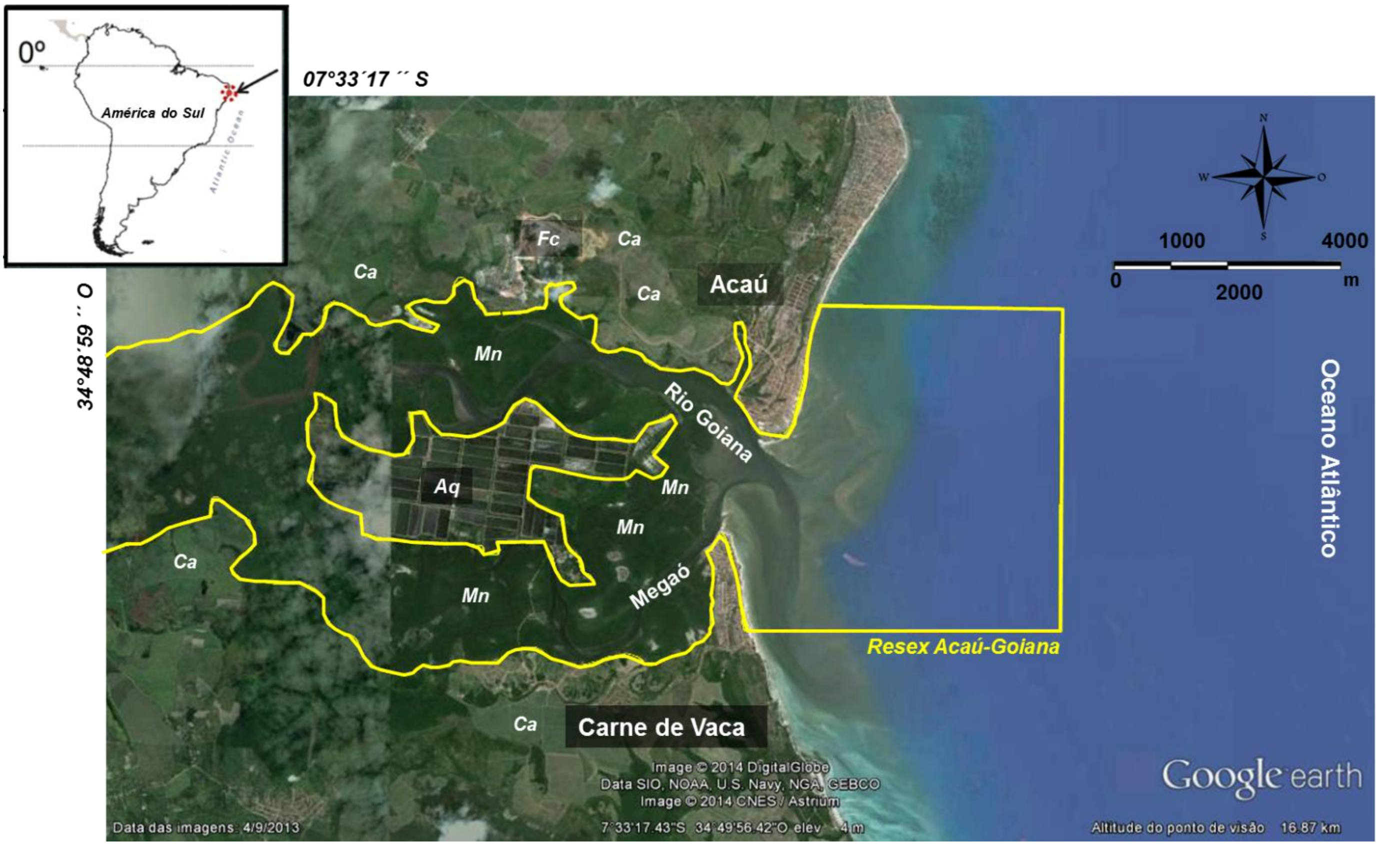

Figura 1. Estuário do Rio Goiana. Reserva Extrativista Acaú-Goiana demarcada pela linha amarela. ***Aq***, fazenda de aquicultura; ***Fc***, fabrica de cimento; ***Mn***, floresta de mangue; ***Ca***, cultivo de cana-de-açúcar.

A área de estudo concentra-se na porção externa do estuário, junto à foz do rio, onde são encontrados praias arenosos dispostas nas duas margens. As margens sul (Pernambuco) e norte (Paraíba) foram estudadas, assim como o efeito da distancia em relação a desembocadura do rio. Em Pernambuco, o balneário de Carne de Vaca é formado principalmente por vilas de pescadores e casas de veraneio. A região sofre influencia não só do Rio Goiana mais também do Megaó, um braço de mar que contorna a porção interna do balneário. Na margem norte encontra-se o município de Acaú, que abriga um maior número de habitantes e pescadores.

Seguindo o padrão climático regional, a diferença no regime das chuvas define as estações do ano na região. Barletta & Costa (2009) caracterizaram o local com temperaturas constantes (27±2°C) e quatro estações: inicio das chuvas (Março a Maio), final das chuvas (Junho a Agosto), inicio da seca (Setembro a Novembro) e final da seca

(Dezembro a Fevereiro). O regime de ventos da região consiste em ventos de menor intensidade e provenientes principalmente de nordeste e leste durante os meses de verão, seguido de ventos com intensidades um pouco maiores durante o inverno, provenientes principalmente de sul e sudeste (Apêndice 1).

Visando alcançar os objetivos propostos, entre os meses de outubro de 2010 e setembro de 2011, diferentes metodologias e desenhos amostrais foram realizados nas praias adjacentes ao Estuário do Rio Goiana.

Morfodinâmica e Sedimentologia

As seis áreas de amostragem foram caracterizadas quanto ao tipo de sedimento, energia das ondas (altura e período) e perfil topográfico. Para tal, sete pontos amostrais, sendo três pontos (pontos 1 a 3) na praia de Acaú (margem norte) e quatro pontos (4 a 7) na praia de Carne de Vaca (sul), foram selecionados. Em cada um dos pontos, mensalmente, foi realizado uma transversal levantando um perfil topográfico com teodolito e régua metrada, sempre na maré de sizígia durante a secante. A amostragem do sedimento foi realizada mensalmente na ocasião e local dos perfis topográficos. Em cada área de amostragem, três amostras superficiais do sedimento foram coletadas e homogeneizadas, dando origem a uma única amostra na quantidade média de 200g.

As amostras de sedimento foram analisadas no Laboratório de Oceanografia Geológica da UFPE (LABOGEO). Para análise granulométrica, foram lavadas com água destilada cerca de 40g de sedimento de cada uma das amostras, sendo estas pesadas novamente para obtenção do peso inicial e colocadas em estufa (60°C) por 24 horas para secagem. Por meio de um agitador de peneiras, foi realizado o método de peneiramento mecânico durante 12 minutos. Peneiras com intervalos de um phi (Φ) entre as frações (escala de *Wentworth*) foram utilizadas. Após a realização do peneiramento, foram pesados os sedimentos que ficaram retidos em cada peneira e somados o peso de cada fração para a obtenção do peso final. Os pesos de cada classe (peneira) foram utilizados para calcular os parâmetros estatísticos através do programa *Sysgran* (Camargo, 2006), que veio a fornecer valores de diâmetro médio, seleção, assimetria e curtose.

Para eliminação do carbonato de cálcio foi retirado cerca de 20g de cada amostra, sendo estas pesadas para obtenção do peso 1 ($\mathbf{P_1}$). Posteriormente, foi realizada a secagem de cada amostra em estufa (60°C por 24 horas) e adicionado 70% de ácido clorídrico (HCl) para liberação do $CaCO_3$. As amostras foram colocadas em uma capela por aproximadamente 24 horas antes de serem lavadas com água destilada e filtradas em papel filtro. Novamente as amostras foram colocadas em estufa com temperatura de 60°C, permanecendo 24 horas. Após essa etapa, os sedimentos já secos, foram novamente pesados para obtenção do peso 2 ($\mathbf{P_2}$). Para obtenção do percentil de $CaCO_3$ das amostras ($\mathbf{P}_{CaCO3}$) foi utilizada a seguinte equação:

$$\mathbf{P}_{CaCO3} = (\mathbf{P_1}\text{-}\mathbf{P_2})*100 / \mathbf{P_1} \qquad \text{(eq. 1)}$$

Outras variáveis como a altura das ondas (**Hb**) foi estimada visualmente no momento imediatamente anterior à sua quebra, enquanto o período (**T**), estimado com auxílio de um cronômetro, correspondendo à quantidade de cristas consecutivas passando em um ponto fixo na zona de surf em um período de trinta segundos. Os valores de velocidade média de decantação da partícula de sedimento, foram obtidos levando em conta o tamanho médio dos grãos, através das tabelas de Gibbs *et al*. (1971). Também foi calculado o RTR (Relative Tidal Range, Masselink & Short, 1993), um índice referente à amplitu de relativa da maré, calculado a partir da equação:

$$\mathbf{RTR} = \mathbf{TR}\ \text{(amplitude da maré)} / \mathbf{Hb} \qquad \text{(eq. 2)}$$

Para relacionarmos a amplitude da maré com a altura das ondas, uma régua metrada foi fixada em um ponto da área 1S (A1S) durante a maré de quadratura. Em um período de 24 horas, a cada hora a profundidade, altura das ondas e período foram aferidos.

Amostragem da comunidade de fauna e variáveis ambientais

Foram realizados dois delineamentos amostrais elaborados após amostragens piloto realizadas durante o segundo semestre de 2009. O primeiro foi realizado durante a maré de quadratura da lua crescente. Durante todo o período de estudo (12 meses) foram realizados três arrastos de praia mensais em cada área amostral, totalizando 216 arrastos (Apêndice 2).

O segundo delineamento foi realizado apenas na margem sul do estuário, na área amostral mais próxima da foz do rio (A1S), nos meses referentes ao final das estações seca (fevereiro e março) e chuvosa (agosto e setembro). Semanalmente, no dia exato de cada fase lunar, foram realizados três arrastos durante o crepúsculo matinal (aproximadamente as 04h50min nos meses de verão e as 05h20min nos meses de inverno), ao meio-dia (12:00h), no crepúsculo vespertino (aproximadamente as 17:30h) e a meia-noite (00:00h), totalizando 12 arrastos para cada fase lunar por mês, em um total de 192 arrastos (Apêndice 3).

Dessa forma, um total de 408 arrastos de praia foram realizados, com uma rede de arrasto com abertura de 7,0 metros (tralha superior: 10m; tralha inferior: 10m; altura: 1,8m; comprimento: 8,5m) e malhagem de 10mm na asa e 5mm no saco (entre-nós) (Apêndice 4). Cada arrasto teve a duração de cinco minutos, com as posições iniciais e finais registradas com GPS (Global Positioning System) para posterior calculo do volume arrastado. Os indivíduos das espécies de peixes e macrocrustáceos foram identificados (Figueiredo & Menezes, 1978, 1980; Fischer, 1978; Menezes & Figueiredo, 1980, 1985; Cervigón, 1985, 1991, 1993, 1994, 1996) contados, medidos (CP e CT) e pesados. As macroalgas marinhas e a vegetação proveniente do mangue capturada nos arrastos também foram quantificadas.

No momento anterior a cada arrasto, dados referentes às variáveis ambientais como temperatura da água (°C), oxigênio dissolvido ($mg.L^{-1}$) (Wissenschaftlich

Technische Werkstätten, WTW OXI 325), salinidade (WTW FL 197) e profundidade, foram aferidos. Os dados sobre os padrões de vento na região durante o período de estudo foram disponibilizados gratuitamente pelo Instituto Nacional de Pesquisas Espaciais / Centro de Previsão de Tempo e Estudos Climáticos (INPE / CPTEC, em www.cptec.inpe.br).

Estrutura da Tese

A tese encontra-se dividida em três capítulos, abordando os objetivos propostos. Os capítulos que se encontram aceitos para publicação ou em fase de submissão, estão sendo apresentados em forma de artigo científico, formatados de acordo com as normas do periódico escolhido para publicação.

Capítulo 1: **Caracterização e variação espaço-temporal da morfodinâmica e sedimentologia das praias adjacentes ao estuário do Rio Goiana**

Esse capítulo inicial apresenta os resultados provenientes dos levantamentos topográficos e sedimentológicos das praias estudadas. De forma detalhada, as variações espaço-temporais das características morfodinâmicas e sedimentológicas da área de estudo são descritas, assim como as interações entre fatores.

Capítulo 2: **Temporal patterns in the intertidal faunal community at the mouth of a tropical Estuary**

O segundo capítulo mostra como o uso do habitat pelas assembleias de peixes e macrocrustáceos, é diretamente influenciado por ciclos ambientais (sazonal, lunar e circadiano). O mesmo encontra-se aceito para publicação no periódico internacional *Journal of Fish Biology* (ISSN: 1095-8649).

Capítulo 3: **Spatial and seasonal variations of intertidal community in estuarine sandy/mud beaches**

O ultimo capítulo aborda de forma mais detalhada a comunidade de fauna da região adjacente à desembocadura do estuário. Destaca-se o modo em que as características da comunidade (número de espécies, densidade, biomassa e guildas ecológicas) respondem a fatores espaciais e temporais, assim como, o papel da dinâmica do Rio Goiana nos padrões de uso do habitat. Em formato de artigo científico, o presente capítulo encontra-se em fase de submissão para o mesmo periódico destacado anteriormente (*Journal of Fish Biology*; ISSN: 1095-8649).

Conclusões

Apresenta as principais conclusões obtidas no presente estudo.

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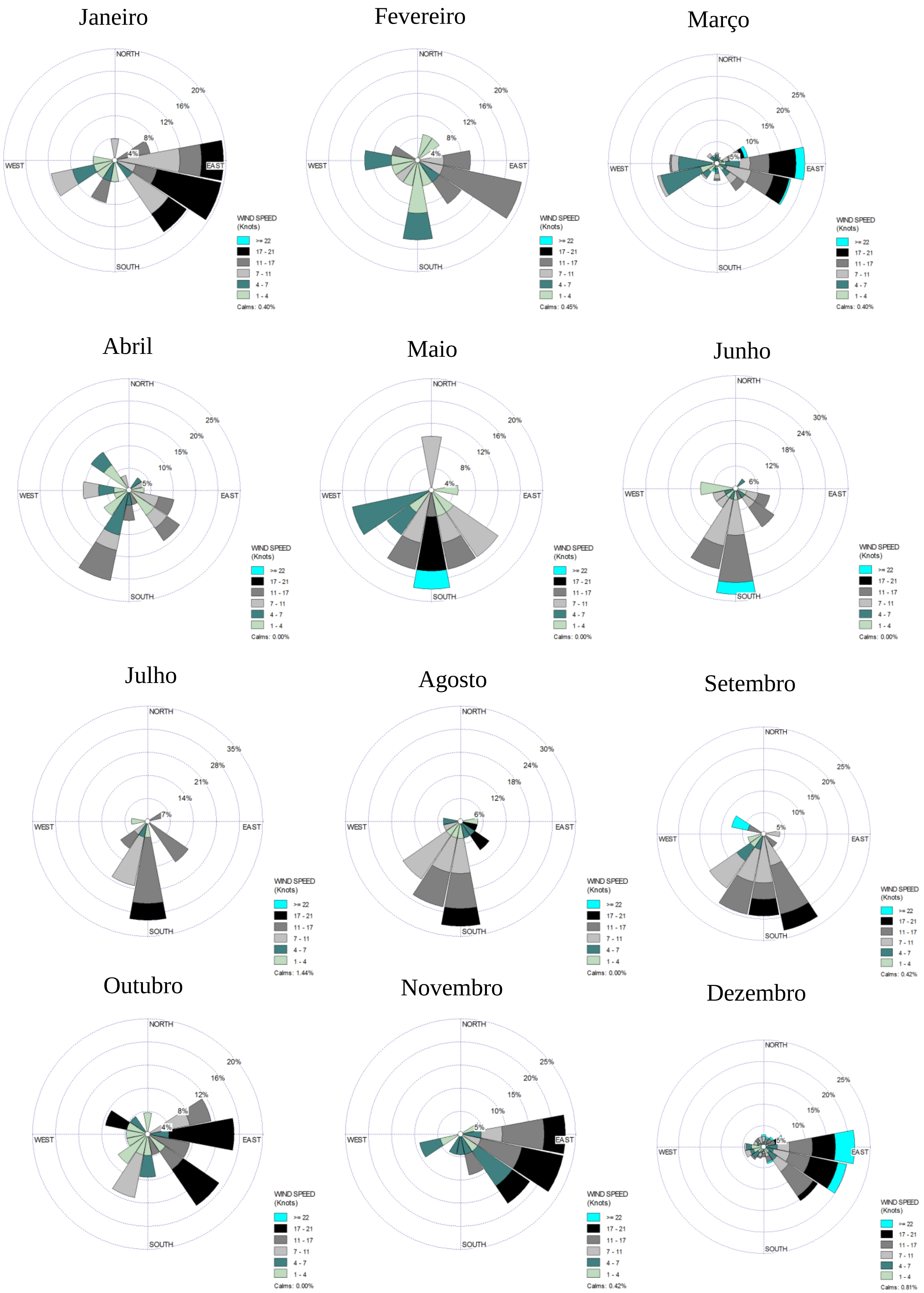
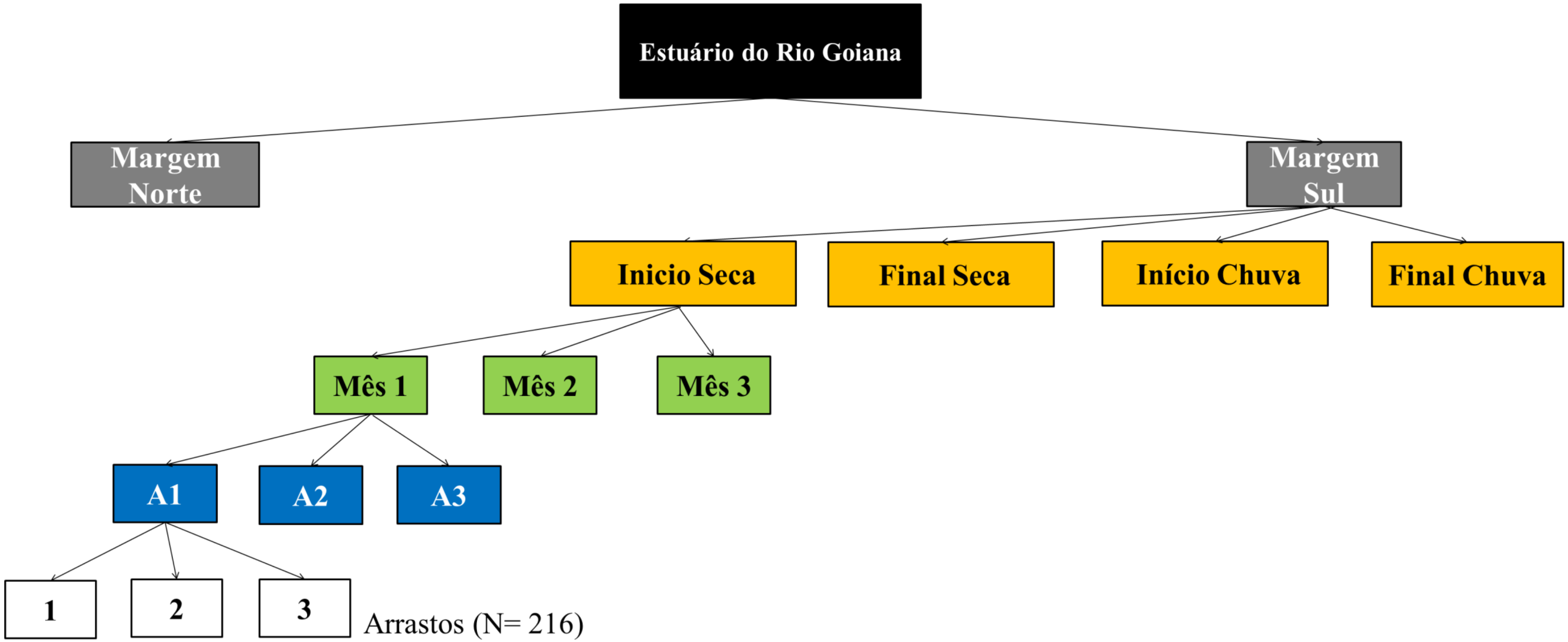
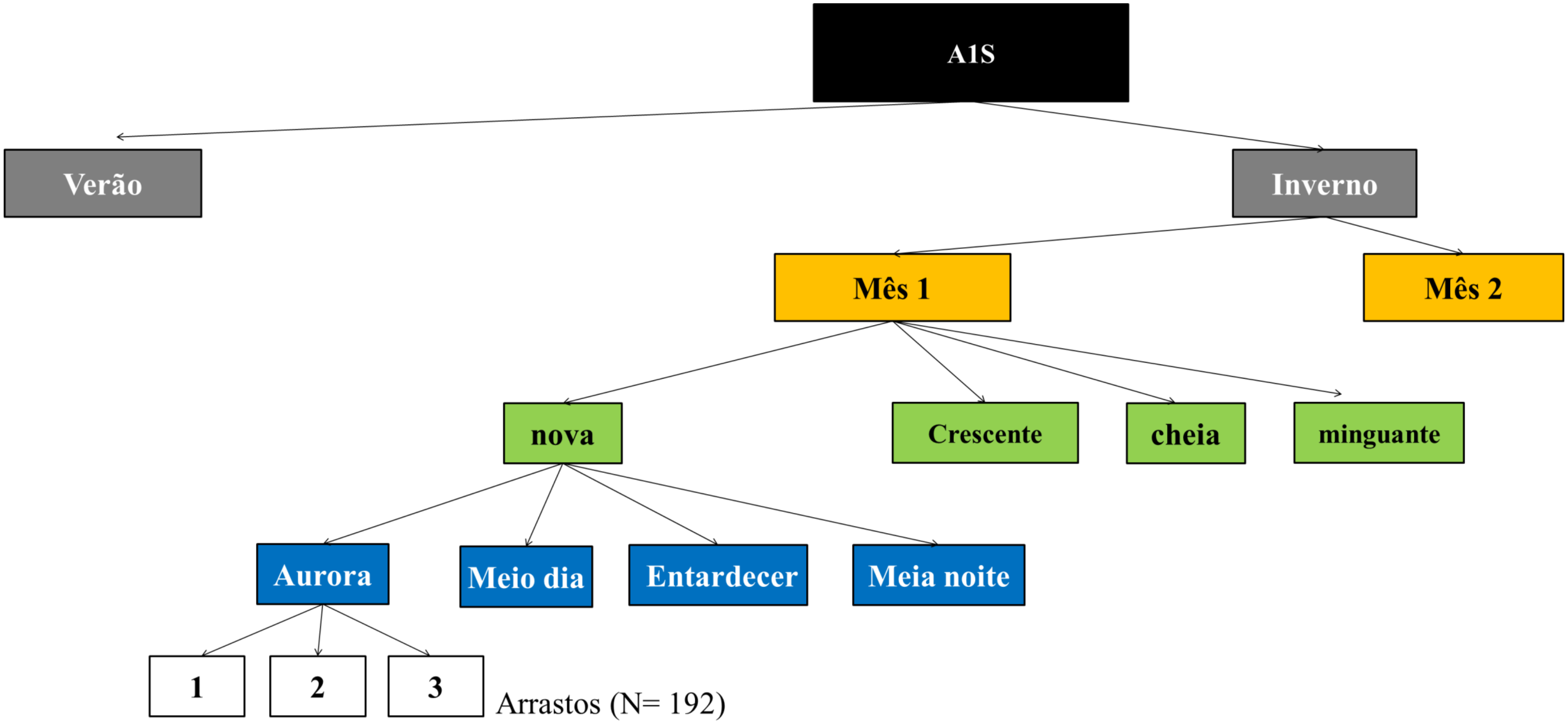
Apêndice 1. Direção e intensidade do vento durante o período de estudo (dados disponíveis em www.cptec.inpe.br, DCP-Goiana). Gráfico projetado pelo software gratuito WRPLOT View (versão 7.0).



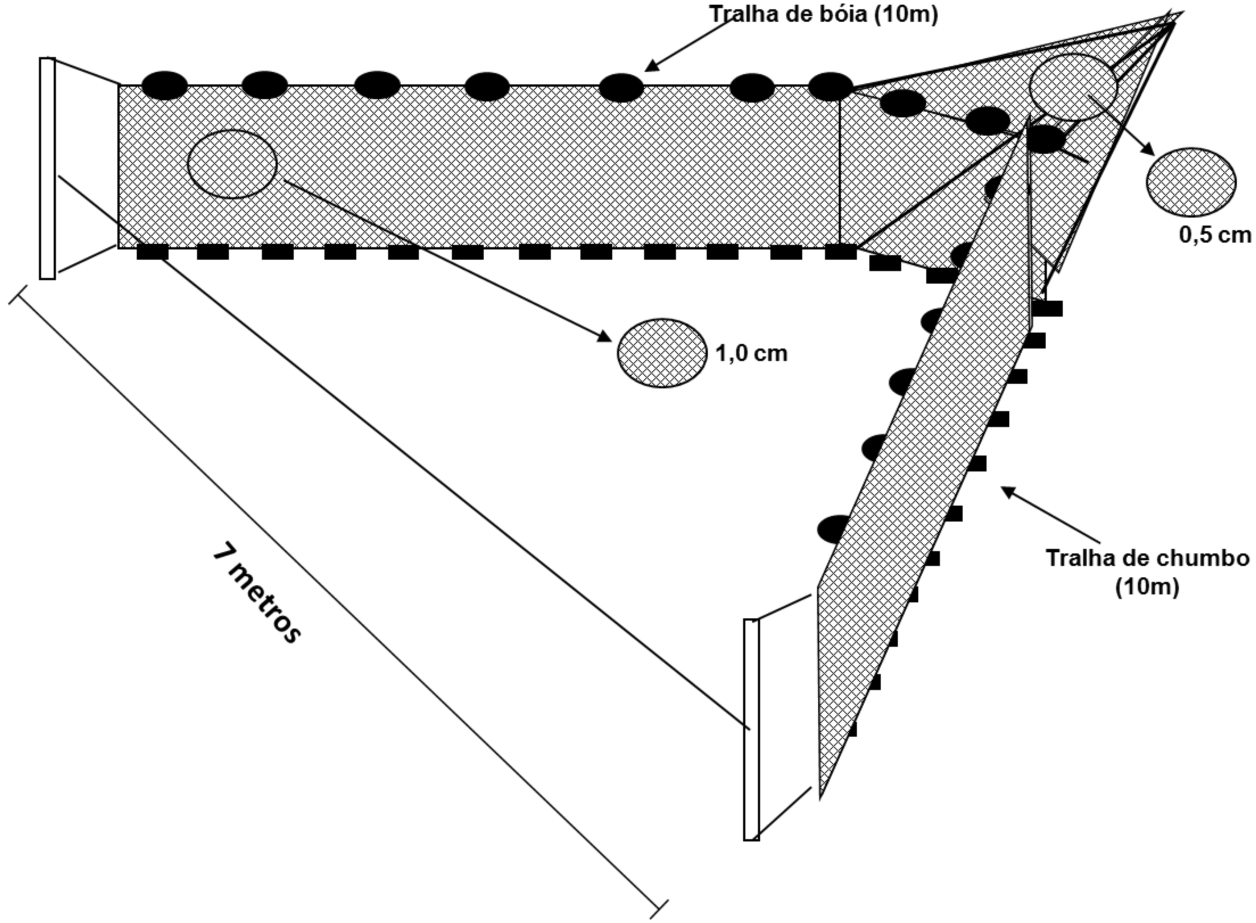
Apêndice 2. Desenho amostral, referente ao estudo espaço-temporal das praias adjacentes a desembocadura do Rio Goiana. A1, *área 1*; A2, *área 2*; A3, *área 3*.



Apêndice 3. Desenho amostral, referente ao estudo temporal do uso do habitat, na região de desembocadura do Rio Goiana. A1S, *área 1 sul*.



Apêndice 4. Modelo das dimensões da rede-de-arrasto utilizada na amostragem da comunidade das praias.



Capítulo 1

Caracterização e variação espaço-temporal da morfodinâmica e sedimentologia das praias adjacentes ao estuário do Rio Goiana

Introdução

Abrigando aproximadamente dois terços da população mundial, e consequentemente uma maior pressão antrópica, as regiões costeiras estão entre os ambientes mais dinâmicos do planeta (Hinrichsen, 1998; McLachlan & Brown, 2006). Marcadas pela interface entre continente, oceano e atmosfera, são formadas pela interação de diferentes processos naturais como ondas, ventos, marés e descargas fluviais, geralmente resultando em um equilíbrio dinâmico ao longo de diferentes ciclos (Birkemeier, 1984; Short, 1999; Pereira *et al*., 2010, 2012; Masselink *et al*., 2011).

A maior parte da costa marinha é formada por praias, depósitos de areia e cascalho gerado pela ação das ondas (Davis Jr. & FitzGerald, 2004; Bird, 2008). Esses ambientes são estabelecidos pela disponibilidade de espaço e sedimentos (arenosos ou não), não havendo assim, limites geográficos para a formação praial (Hoefel, 1998). Durante o processo de espraiamento, o papel das marés no estabelecimento de diferentes feições morfodinâmicas e sedimentológicas vem sendo cada vez mais estudado, tendo como base modelos desenvolvidos no final do século passado (Davis & Hayes, 1984; Wright & Short, 1984; Masselink & Short, 1993). Segundo tais modelos, a partir dos valores dos parâmetros Ômega de Dean (Ω) (Dean, 1973) e o Parâmetro Relativo de Maré (RTR) (Masselink & Short, 1993), é possível a classificação de praias quanto ao nível de energia (reflectiva, dissipativa, mista), quantificando o equilíbrio entre as forças das ondas e da maré em um determinado ambiente, assim como a relação dessas forças com as características morfo-sedimentares estabelecidas, entre os extremos refletivo e dissipativo.

No nordeste do Brasil a plataforma continental é estreita, rasa e quase totalmente recoberta por sedimentos carbonáticos (areias e cascalhos, consistindo principalmente de algas calcárias). Em sua porção semiárida, é marcada pela presença de pequenos rios onde se desenvolvem planícies alagáveis com lagunas, estuários, manguezais e piscinas naturais

(Amaral *et al*., 2003). Outras feições como dunas, falésias e franjas de recifes de arenito (incrustados por algas calcárias, briozoários e corais) são feições comuns nas praias da costa nordeste brasileira (Villwock, 1994).

Em meio a essas diferentes feições, regiões de desembocadura fluvial são constituídas principalmente por sedimentos inconsolidados e com teores variáveis de biodetritos (Corrêa 1980; Suguio, 2003), sendo importantes nos estudos sobre sedimentologia atual (Figueiredo & Calliari, 2006). Nesses ambientes de alto dinamismo, o ajuste morfodinâmico e sedimentar, é modelado quase que instantaneamente por agentes hidrodinâmicos (ondas, marés e correntes), geológicos (fonte de sedimento, declividade da plataforma interna), eólicos e biológicos (biodetritos) (Komar, 1998; Falcão-Quintela *et al.*, 2007). O conhecimento das propriedades morfodinâmicas e sedimentológicas das áreas de costa é essencial para estudos geológicos e ecológicos, visto que os diferentes tipos de depósitos sedimentares, assim como, mecanismos de atuação na deposição e transporte do sedimento, podem atuar diretamente nos padrões das comunidades de fauna adaptadas ao dinamismo praial (Lercari *et al*., 2010; Mont´Alverne *et al*., 2012; Oliveira & Pessanha, 2014). Em meio a diferentes perfis, praias de perfil refletivo tendem a ser ambientes agressivos e hostis para a macrofauna, com interações biológicas limitadas por fatores físicos. Por outro lado, em praias dissipativas essas interações tendem a contribuir como agentes estruturantes da comunidade, que normalmente apresenta maior diversidade e abundância (Defeo & McLachlan, 2005; McLachlan & Dorvlo, 2005; Lercari *et al*., 2010).

Grande parte dos estudos referentes à costa nordeste brasileira concentra-se na plataforma continental, sendo que pesquisas sobre morfodinâmica, sedimentologia, composição e comportamento da fauna presente nesses habitats, ainda é escassa, se reunindo principalmente em relatórios técnicos, monografias e resumos acadêmicos (Amaral *et al.*, 2003). Dessa forma, o presente estudo teve como objetivo analisar as características morfodinâmicas (perfil topográfico) e sedimentológicas (diâmetro médio, assimetria, grau de seleção e percentil de carbonato de cálcio) das praias adjacentes à desembocadura do estuário do Rio Goiana, assim como sua variabilidade espacial e temporal. As praias estudadas estão inseridas na Reserva Extrativista Acaú-Goiana, e os resultados podem auxiliar os órgãos competentes em seus deveres relacionados à integridade ambiental e preservação da biodiversidade.

Metodologia

Área de estudo

Foram estudadas as praias arenosas presentes na região de desembocadura do estuário do Rio Goiana, extremo norte do Estado (Figura 1). Desde 2007, a região do estuário e áreas adjacentes passaram a fazer parte de uma Reserva Extrativista, a Resex Acaú-Goiana (ICMBio, 2007). Em uma área aproximada de 4700 ha, encontram-se o canal principal do Rio Goiana, planícies alagadas, florestas de mangue, plantações de cana-de-açucar, viveiros de aquicultura e atividades industriais (Barletta & Coasta, 2009). Em sua porção externa, junto à desembocadura, são encontradas praias e bancos arenosos dispostos nas duas margens do estuário. O local encontra-se sob mesomarés semidiurnas, com altura máxima de 2,8 metros durante a sizígia. Formações rochosas em frente à margem norte do estuário contribuem para o estabelecimento de um extenso terraço de maré, cortado pelo canal principal do rio em sua margem sul.

Barletta & Costa (2009) caracterizam a região com temperaturas constantes (27±2°C) e definem as estações do ano pelas diferenças no regime das chuvas [IS, *inicio da seca* (Setembro a Novembro); FS, *final da seca* (Dezembro a Fevereiro); IC, *inicio da chuva* (Março a Maio); FC, *final da chuva* (Junho a Agosto)]. Na margem sul, em Pernambuco, o Balneário de Carne de Vaca é formado por pescadores e casas de veranistas. As praias apresentam dezenas de espigões, indicando problemas erosionais (Apêndice 1). Essa região sofre influência não só do

Rio Goiana mais também do Megaó, um braço de mar que margeia o balneário. Na margem norte encontra-se o município de Acaú, as praias no local sofrem influencia do Rio Goiana, assim como, da maior ocupação humana (Apêndice 2).

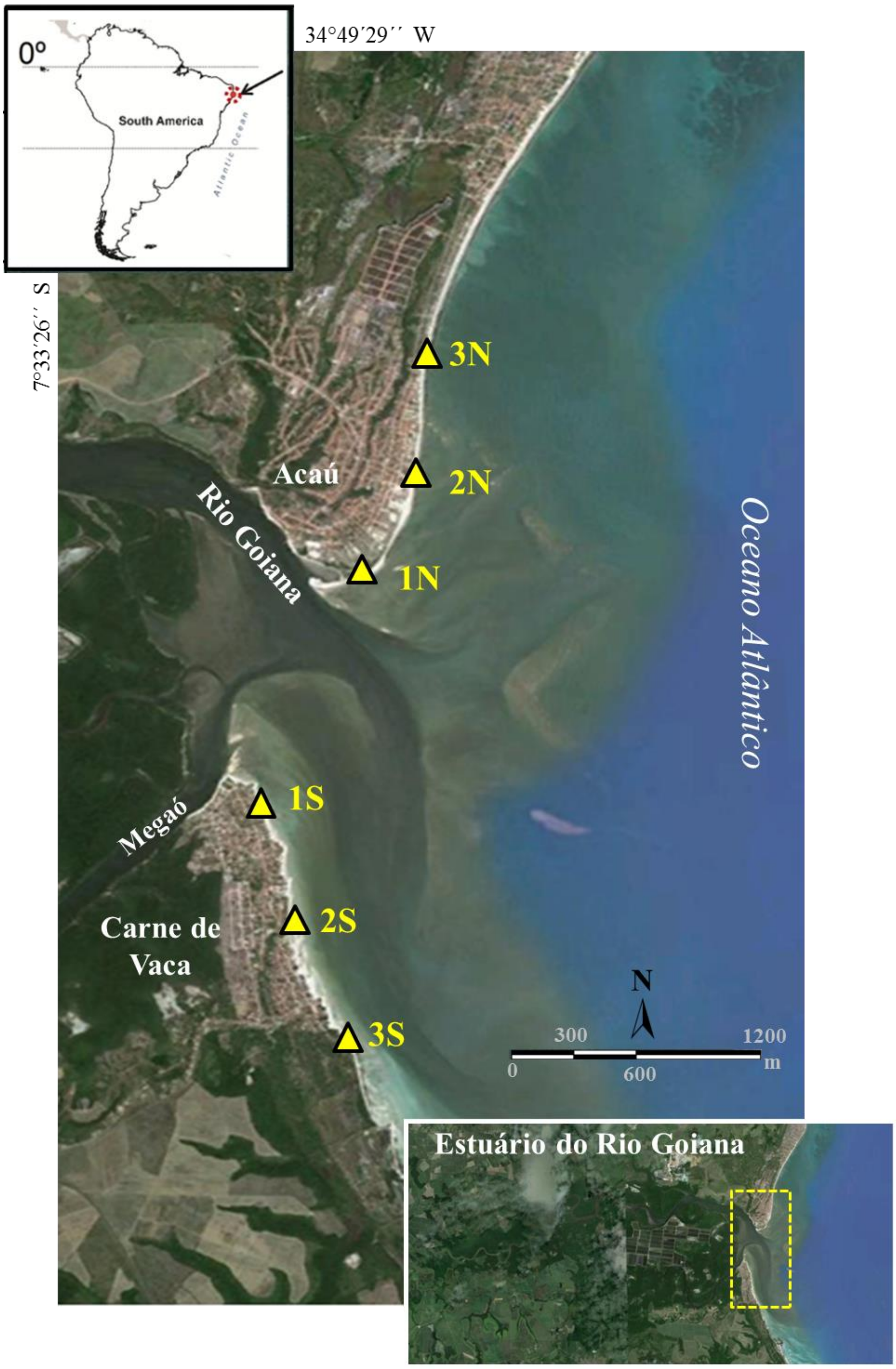


Figura 1. *Área de estudo, destacando os pontos amostrais (1, 2 e 3) na margem norte (N) e sul (S) do estuário. (fonte: Google Earth).*

Método amostral

Entre os meses de Outubro de 2010 e Setembro de 2011, três pontos amostrais na praia de Acaú, e outros três pontos na praia de Carne de Vaca (Figura 1) foram amostrados mensalmente. Os seis pontos amostrais, definidos a partir de referências fixas nas praias (marcos de referência), foram utilizados mensalmente para o levantamento de perfis topográficos, realizados com régua, tripé, nível e mira graduada. Também foram mensuradas medidas de energia como altura relativa das ondas (**Hs**), estimada visualmente no momento anterior à sua quebra, e período médio (**Tm**), correspondendo à quantidade de cristas consecutivas passando em um ponto fixo no intervalo de trinta segundos. Para a caracterização da área de estudo utilizou-se como base os modelos de morfodinâmica praial mais aceitos atualmente, propostos por Masselink & Short (1993), após a adequação de modelos preliminares (Davis & Hayes, 1984; Wright & Short, 1984; Short, 1991) onde a influencia da maré passou a ser considerada como força atuante no estabelecimento praial. Dessa forma, foram calculados os parâmetros Ômega de Dean (1973), adaptado por Wright e Short (1984) (eq. 1) e o parâmetro relativo de maré RTR (Relative Tidal Range; Masselink & Short, 1993) (eq. 2).

$$\mathbf{\Omega = Hb / \hat{w}_s T} \qquad \text{(eq. 1)}$$

$$\mathbf{RTR = T_R / Hb} \qquad \text{(eq. 2)}$$

Onde:
$\hat{w}_s$: *velocidade de sedimentação da partícula*
T_R: *amplitude da maré*

Para observar a relação da maré na altura relativa das ondas, um experimento de 24 horas foi realizado, onde uma régua graduada foi instalada verticalmente no terraço de maré (~30m da praia) durante a maré seca de uma lua crescente, a partir dai, em intervalos de 1 hora foi registrado o nível da maré, período e a altura das ondas.

Para o estudo sedimentológico, amostras de sedimento foram coletadas na ocasião da realização dos perfis topográficos, sendo retiradas em cada ponto três amostras superficiais (< 5cm, nas faces superior, média e inferior da praia), posteriormente agrupadas e homogeneizadas, dando origem a uma amostra composta (~200g).

Análise dos dados

As amostras foram analisadas no Laboratório de Oceanografia Geológica da UFPE (LABOGEO). Os dados levantados pelo perfil topográfico foram organizados em planilhas eletrônicas, processados e expressos graficamente por visualizadores de dados. Para análise granulométrica foram utilizadas aproximadamente 40g de sedimento de cada amostra, sendo estas lavadas com água destilada e pesadas para obtenção do *peso inicial*, antes de serem colocadas em estufa para secagem (60°C por 24 horas). Foi utilizado o método padrão de peneiramento mecânico (Suguio, 1973) por meio de um agitador de peneiras (12 minutos) com intervalos de um *phi* (Φ) entre as frações (escala de *Wentworth*). Após a realização do peneiramento, foram pesados os sedimentos que ficaram retidos em cada peneira e somados o peso de cada fração para a obtenção do *peso final*. Os pesos de cada classe foram utilizados para calcular os parâmetros estatísticos. Para isso, foi utilizado o programa *Sysgran* (Camargo, 2006) que nos forneceu os valores das variáveis: média (diâmetro), seleção e assimetria.

Para eliminação de carbonato de cálcio foi utilizado cerca de 20g de sedimento por amostra, sendo estas pesadas (*peso 1*) e secadas em estufa (60°C por 24 horas) para posterior adição de HCl (70%). Após esse processo, as amostras foram colocadas em uma capela por aproximadamente 24 horas antes de serem lavadas com água destilada e filtradas em papel filtro. Posteriormente, as amostras foram novamente colocadas a uma estufa com temperatura de 60° C, permanecendo 24 horas. Passada essa etapa os sedimentos secos foram novamente pesados (*peso 2*). Para obtenção do percentil de carbonato ($\mathbf{P_{Ca}}$) de cada amostra, o *peso 1* ($\mathbf{P_1}$) foi subtraído pelo *peso 2* ($\mathbf{P_2}$), multiplicado por 100 e dividido pelo *peso 1* (eq. 3).

$$\mathbf{P_{Ca}} = (\mathbf{P_1}\text{-}\mathbf{P_2})*100 / \mathbf{P_1} \qquad \text{(eq. 3)}$$

Após o processamento das amostras, uma análise de variância com três fatores (Three-Way ANOVA) foi realizada para identificar diferenças nas variáveis sedimentológicas (média, assimetria, seleção e percentil de $CaCO_3$) em relação aos fatores espaciais (margem e área) e temporais (sazonalidade). No caso de diferenças significativas identificadas pela ANOVA, um teste de médias (Bonferroni) a 5% de probabilidade foi realizado para identificar diferenças entre as médias.

Resultados

Os perfis topográficos de cada ponto amostral estão representados na Figura 2. Analisando o perfil dos diferentes pontos, é observado um terraço bem marcado com a ausência de bancos e conectado a face praial por uma pendente relativamente íngreme (Figura 2). Na avaliação temporal dos perfis, foi possível observar padrões de acreção e erosão nas margens norte e sul do estuário, respectivamente (Apêndice 3; Tabela I).

Os dados referentes às variáveis de energia (Hs, Tm, Ws, Ω e RTR) encontram-se na Tabela I. De acordo com os resultados obtidos ($\Omega>2$; $3<RTR<7$), a área de estudo é classificada como um terraço de baixa-mar (Masselink & Short, 1993), com atividade de ondas restrita e baixos valores de altura (Hs) registrados, estando estes positivamente correlacionados com o nível da maré (Figura 3).

Os dados sedimentológicos mostram que as praias adjacentes ao estuário do Rio Goiana são compostas principalmente por areia média ($1.0 < \Phi < 2.0$; Tabela I), apresentando assimetria negativa, principalmente nas áreas próximas a desembocadura do rio e na margem sul do Estuário (Apêndice 4, Figura 4a, Tabela I).

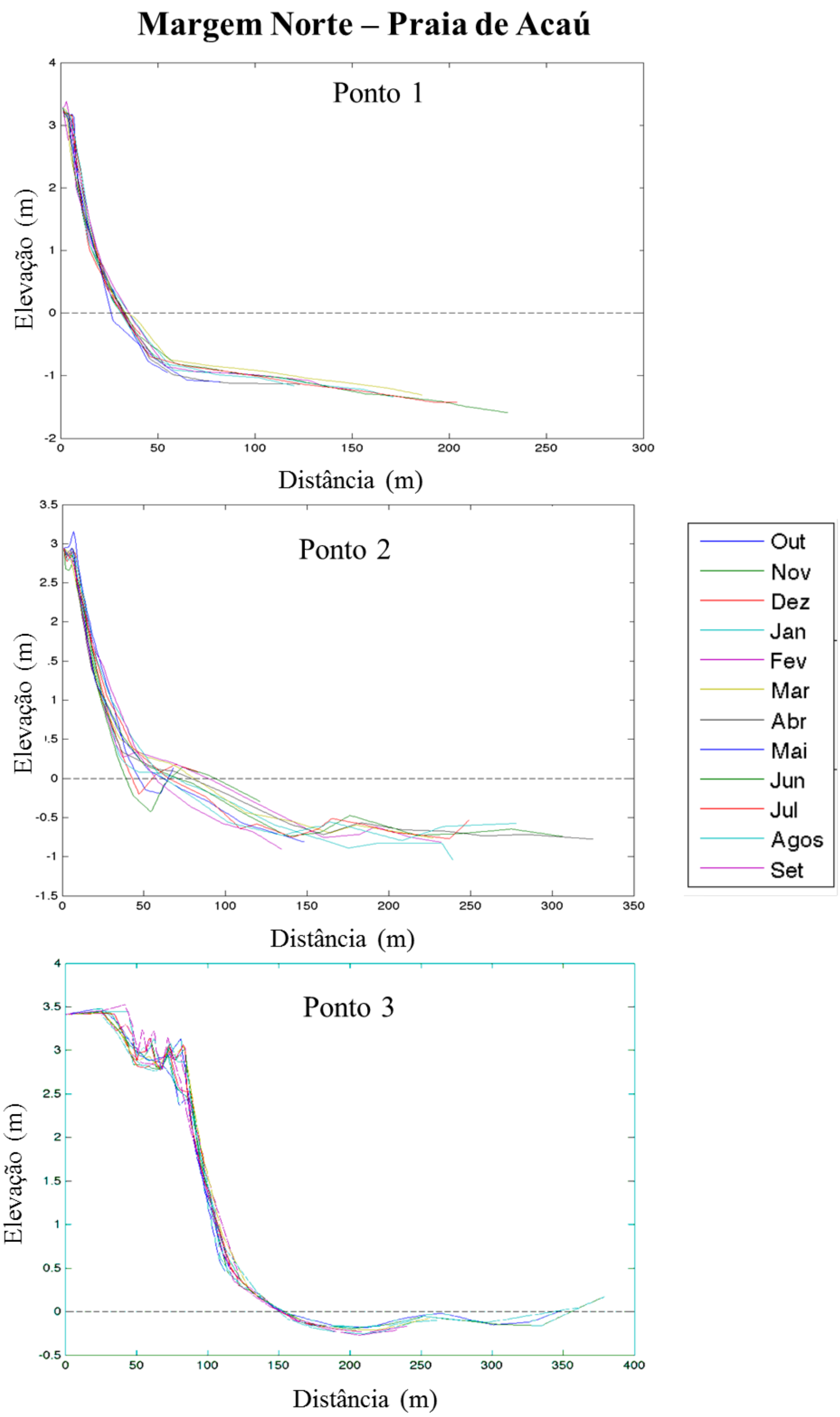


Figura 2a. *Perfis topográficos dos pontos amostrais distribuídos na margem norte (a – Praia de Acaú) do estuário do Rio Goiana.*

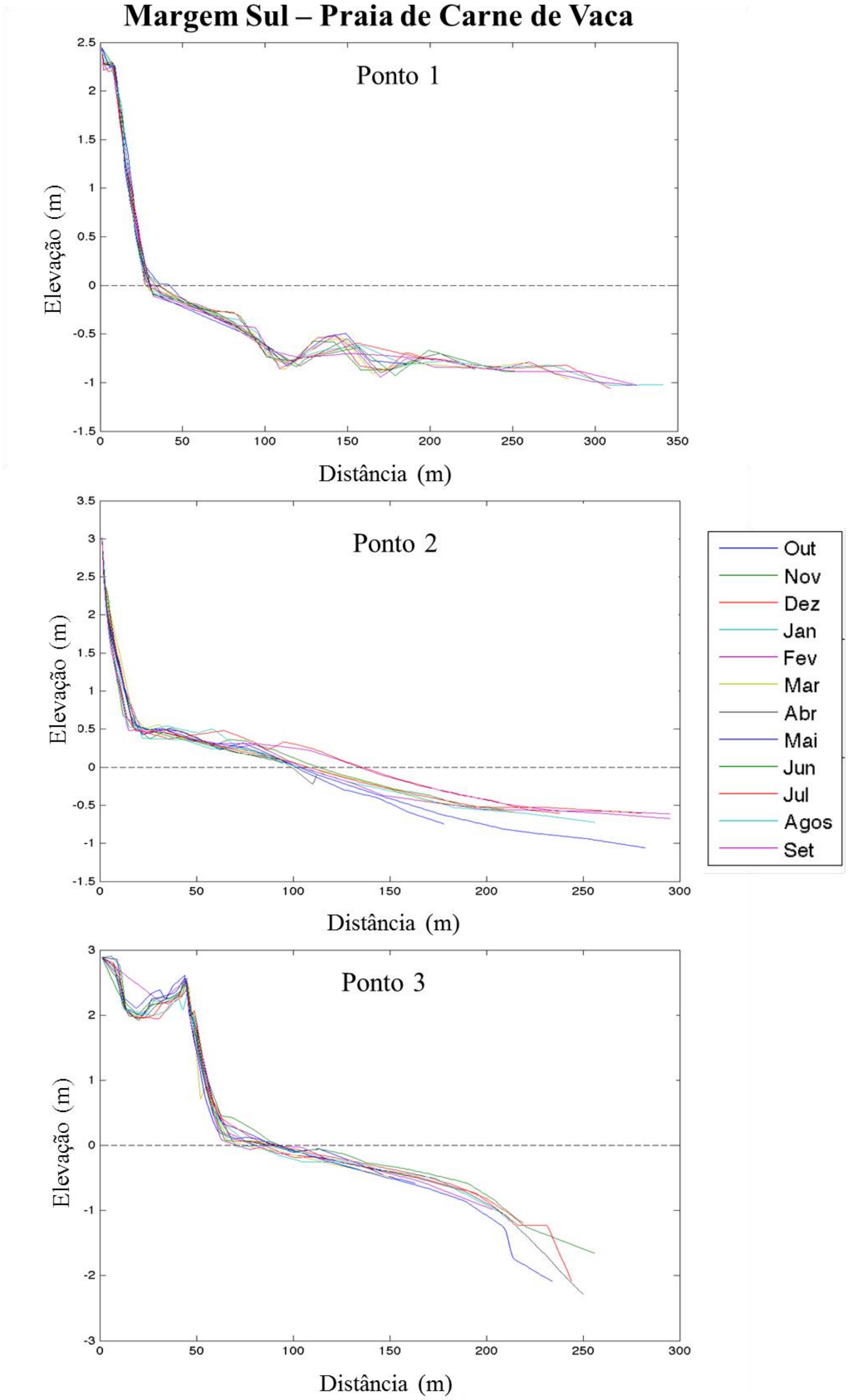


Figura 2b. *Perfis topográficos dos pontos amostrais distribuídos na margem sul (b – Praia de Carne de Vaca) do estuário do Rio Goiana.*

Tabela I: Valores médios das características do sedimento, assim como *período médio de onda* (**Tm**), *Ômega de Dean* (**Ω**) e **RTR**, nos diferentes pontos amostrais. **Mz**, *diâmetro do grão*; **Ws**, *velocidade de decantação da partícula*; **Hs**, *altura media de onda*.

		Margem					
		Norte			**Sul**		
		1	**2**	**3**	**1**	**2**	**3**
Média	**Φ**	2.00	1.90	2.04	1.58	1.17	1.58
	Class.	Areia média	Areia média	Areia fina	Areia média	Areia média	Areia média
Seleção	**Φ**	0.77	0.74	0.65	0.83	0.72	0.65
	Class.	Moderada	Moderada	Moderada	Moderada	Moderada	Moderada
Assimetria	**Φ**	-0.11	-0.12	-0.02	-0.21	-0.06	-0.12
	Class.	Negativa	Negativa	Negativa	Negativa	Negativa	Negativa
Percentil	**Cascalho**	0.18	0.11	0.10	1.39	3.23	1.32
	Areia	99.82	99.88	99.88	98.59	96.76	98.66
	Silte	0.00	0.00	0.02	0.02	0.00	0.03
	Argila	0	0	0	0	0	0
	$CaCO_3$	23.70	25.67	17.02	37.77	34.38	24.21
Deposição	**Líquido**	1.66	4.48	5.32	-6.20	-3.64	-8.08
(m^3/m)	**Tendência**	Acreção	Acreção	Acreção	Erosão	Erosão	Erosão
Mz (mm)		0.25	0.27	0.24	0.39	0.40	0.33
Ws (cm/s)		3.15	3.59	3.07	5.57	5.76	4.66
Hb (cm)		32.00	30.00	32.00	14.00	19.00	17.00
Hb Max		50.00	45.00	63.00	37.00	52.00	43.00
Ts		2.10	2.26	2.28	1.73	1.76	1.60
Ω		7.55	5.54	9.03	3.83	5.13	5.75
RTR		5.00	5.56	3.95	6.82	4.84	5.77

A análise de variância detectou variações espaciais nos padrões sedimentológicos, com material mais grosseiro na margem sul (Figura 4b; Tabela II), e interações significativas entre os fatores margem e estação ($P<0.05$). Da mesma forma, os sedimentos mais pobremente selecionados (maior grau de seleção) foram encontrados nos pontos mais próximos a desembocadura do rio (*P*<0,05) (Figura 4c; Tabela II).

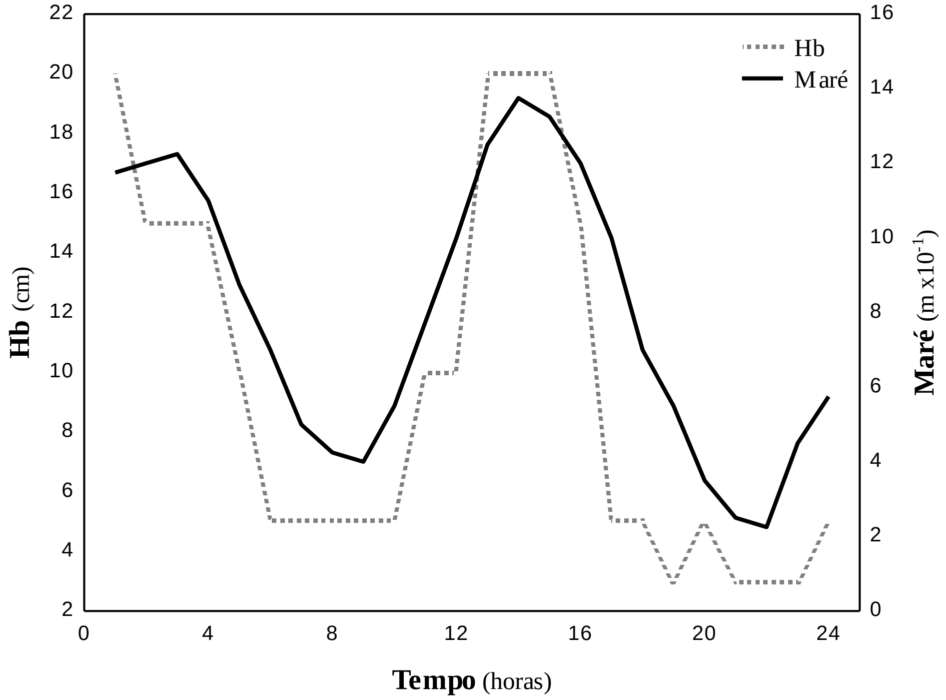


Figura 3: *Valores das variáveis, altura média de onda (Hs) e nível da maré (profundidade), ao longo de 24 horas.*

Em relação ao percentil de $CaCO_3$ no sedimento das praias, todas as amostras apresentaram concentrações desse composto, com diferenças espaciais e temporais identificadas pela análise de variância, além de interações significativas (*P*<0,01) entre os três fatores analisados (margem, estação e área). Os maiores teores médios (*P*<0,05) foram encontrados nos sedimentos da margem sul do estuário, com menores concentrações durante o final da estação chuvosa (FC) (Figura 4c; Tabela II). Com o objetivo de identificar a origem dos sedimentos bioclásticos, fotografias capturadas com o auxilio de uma lupa identificaram fragmentos de conchas de bivalves, foraminíferos, gastrópodes e partículas de algas calcárias do gênero *Halimeda* Lamouroux (Figura 5).

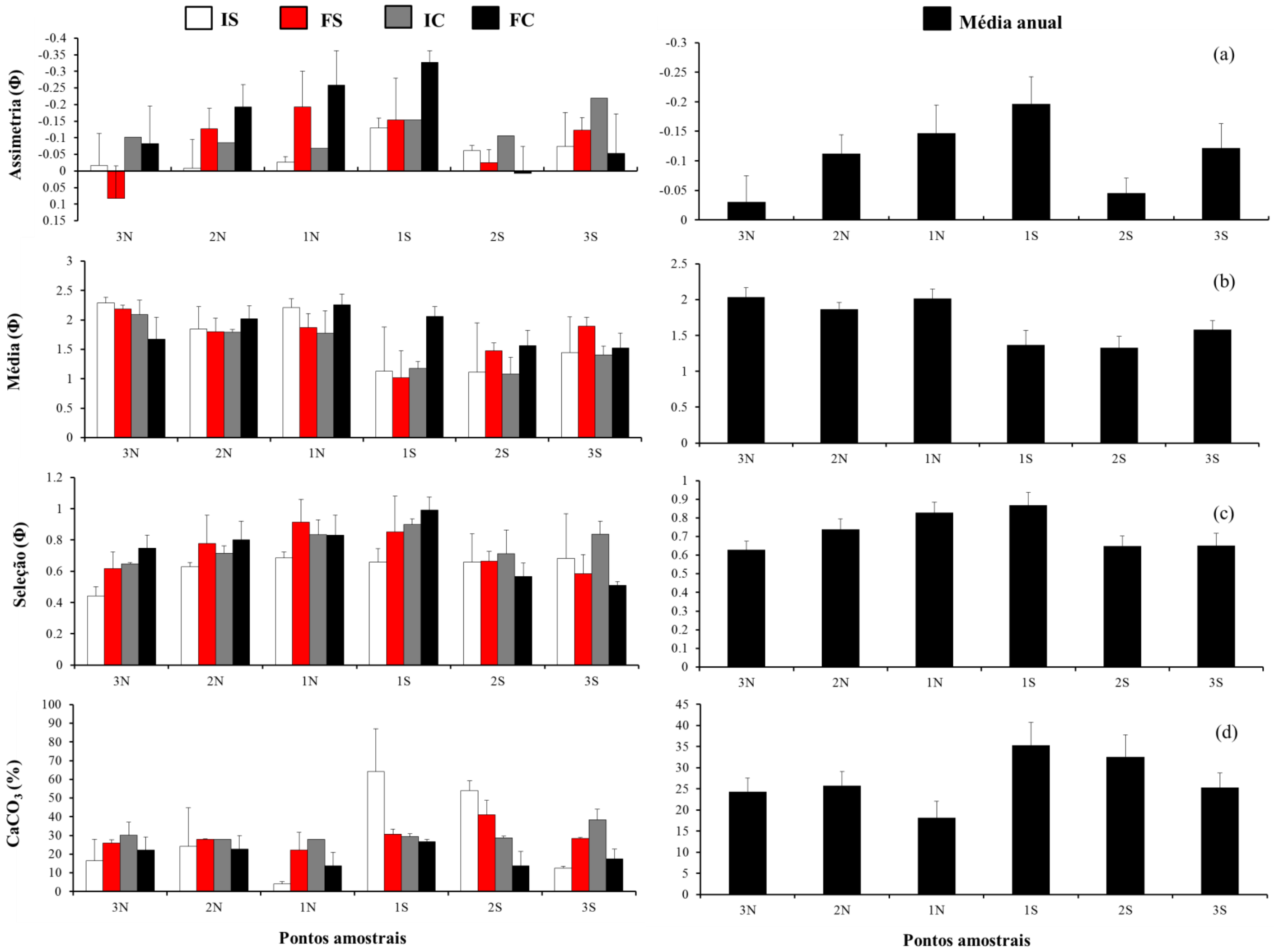


Figura 4. Valores médios (±erro padrão) das principais características do sedimento [assimetria (a), média (b), grau de seleção (c) e percentil de $CaCO_3$ (d)] nos diferentes pontos amostrais ao longo do período de estudo.

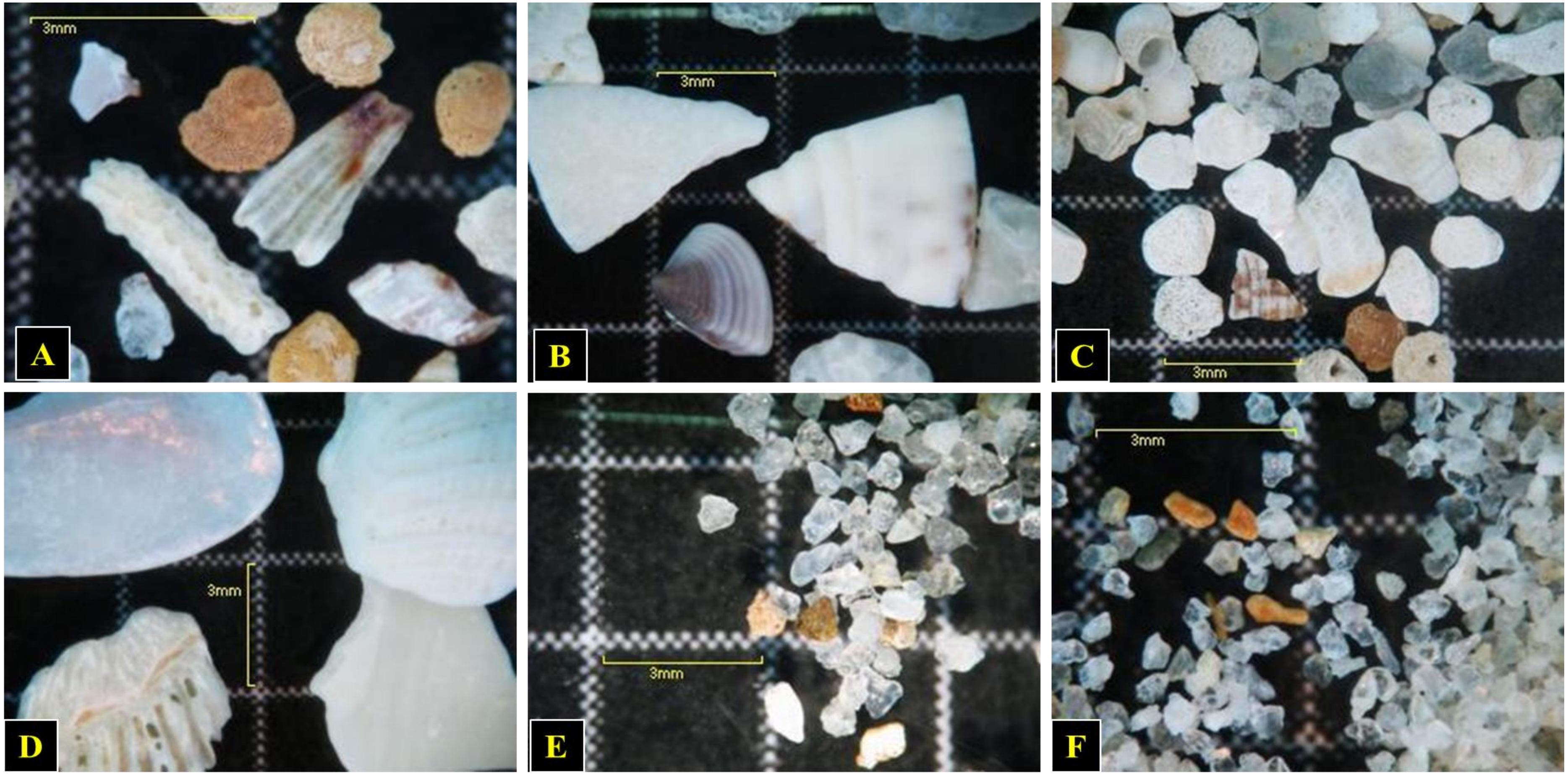


Figura 5: A) ponto 3S: Presença de partículas de algas calcária (*Halimeda* spp.) e fragmentos de organismos bivalves. B) ponto 2S: Presença de *Corbula* sp., partículas de bivalves e grãos de quartzo. C) ponto 1S: Presença de *Divaricella quadrisulcata*, *Natica* sp., fragmentos de alga calcária (*Halimeda* spp.), grãos de quartzo. D) ponto 1N: Presença de fragmentos do bivalve *Chione cancellatae* e alga calcária (*Halimeda* spp). E) ponto 2N: Presença de fragmentos de alga calcária (*Halimeda* spp.), grãos de quartzo e partículas de organismo calcário. F) ponto 3N: Presença de grãos de quartzo e partículas de algas calcária (*Halimeda* spp.).Todos os grãos presentes nas amostras da figura possuem *phi* 1,5 na escala de *Wentworth*

Tabela II: Resultados da análise de variância e teste de Bonferroni (5%) para os dados sedimentológicos. Diferenças entre os pontos amostrais estão identificados por (__). S, *margem sul*; N, *margem norte*; A1, A2 e A3, *pontos amostrais*. *$P<0.05$; **$P<0.01$.

	Margem (1)	Estação (2)	Área (3)	Interação
Média	N **	*ns*	*ns*	1 x 2 *
Seleção	*ns*	*ns*	A3 A2 A1 **	*ns*
Assimetria	*ns*	*ns*	*ns*	*ns*
$CaCO_3$	S **	FC IS FS IC *	*ns*	1 x 2 x 3 *

Discussão

Morfodinâmica

As diferenças observadas nos padrões de acreção e erosão entre as margens do estuário podem ocorrer sob influência de características locais, como o sentido (sul) do canal principal do Rio Goiana e a presença de recifes costeiros em frente à margem norte do estuário. De acordo com o modelo proposto por Masselink & Short (1993), o terraço de baixa-mar estabelecido na porção externa do estuário é um ambiente modificado pela maré, típico de praias de energia mista. Isso significa que o ambiente praial estudado encontra-se em um estágio intermediário, entre os extremos refletivo ($\Omega<1$) e dissipativo ($\Omega>6$). Dessa forma, foram observadas características de ambientes dissipativos, como a ausência de correntes de retorno e bancos arenosos (características provenientes da ação de ondas), assim como, características refletivas durante a maré alta, onde a energia incidente por meio de ondas (máx. 0.5m) ultrapassa a região do terraço refletindo diretamente na face praial. Dessa forma, embora a presença de uma zona de surfe extensa seja normalmente associada a praias de perfil dissipativo, o mesmo não ocorre nas praias estudadas em função da baixa energia incidente por meio de ondas, que não chegam a quebrar (dissipar) sobre a plataforma do terraço.

A presença de ondas de areia (*sand waves*) perpendiculares a costa (Apêndice 5) também foram marcantes nas duas margens do estuário. Da mesma forma, observa-se uma extensa plataforma de *swash* onde se estabelece o terraço, com a presença de barras de *swash* em sua área periférica, com uma em particular mais expressiva em forma de arco posicionada em frente à desembocadura do rio (Apêndice 5). Todas essas características, em conjunto com outras já descritas (direção predominante da deposição sedimentar, padrão misto de energia e transporte por ondas de forma secundaria) corroboram com a ideia de que a porção externa do estuário pode se tratar de um delta de maré vazante (Davis Jr. & Fitzgerald, 2004), necessitando estudos mais precisos relacionados à hidrodinâmica e transporte sedimentar para uma conclusão mais precisa.

Segundo Short (2006), o estabelecimento de praias de perfil íngreme e estreito durante a preamar, associado a um terraço extenso e plano na baixa-mar (50 a 2000m), é comum em praias localizadas próximas a estuários, onde a energia da maré é superior á das ondas. Segundo o autor, a partir de um RTR>3, torna-se mais visível o efeito da maré, com um terraço de baixa-mar proeminente, na maioria dos casos. Para ambientes semelhantes às praias estudadas ($\Omega > 2$, $7 > RTR > 3$), Short (2006) associa a bancos tridimensionais, formando circulações em célula e mantendo uma zona intermareal, onde podem ocorrer bancos formados pelo espraiamento das ondas (*swash bars*), assim como a alternância entre bancos e correntes de retorno. Como já mencionado, correntes de retorno e bancos arenosos não foram identificados na área de estudo, ao contrário das barras de *swash*, identificadas no entorno da plataforma de *swash*, onde se estabelece o terraço (Apêndice 5).

Sedimentologia

A formação de praias com predominância de areia média são encontradas em outras regiões de desembocadura na costa brasileira, como no caso das praias associadas ao delta do São Francisco (Santos *et al*., 2013), Laguna dos Patos (Figueiredo, 2005) e Barra do Chuí

(Calliari & Klein, 1993). Segundo Komar (1998), a fonte do sedimento, nível energético das ondas e declividade geral da plataforma interna são fatores determinantes do tamanho médio dos grãos. Segundo Davis Jr. & Fitzgerald (2004), a predominância de areia nos padrões sedimentares é comum em estuários dominados pela maré (caracterizados pela desembocadura mais aberta que a porção interna, em forma de funil), uma vez que o sedimento lamoso é em grade parte carregado pelas correntes locais.

O padrão de assimetria negativa também é comum no ambiente praial (Friedman, 1961,1967; Duane, 1964; Martins, 1965; Suguio, 1973), nesse caso, a cauda da curva de distribuição é mais acentuada para a esquerda, em direção aos grãos mais grossos (Φ negativo), como representado no Apêndice 4. O aumento do grau de seleção nas áreas mais próximas a desembocadura é esperado, pelo fluxo de água mais intenso e dinâmico nessa região. Sedimentos com maior grau de seleção geralmente indicam diferentes fontes e agentes atuando no processo de deposição, sendo características comuns em praias com sedimentos de origem fluvial (Folk, 1974; Martins, 2003), geralmente pobremente a moderadamente selecionados.

Os padrões sedimentares observados, como os menores valores de assimetria nas áreas próximas a desembocadura (principalmente na margem sul) e grãos de maior diâmetro na margem sul do estuário, são afetados diretamente pela maior presença de biodetritos nessa região, identificados pelo padrão do percentil de $CaCO_3$. Analisando as espécies identificadas nas amostras de sedimento, foi possível detectar que, com exceção do gênero *Halimeda*, as demais espécies (*Corbula* sp., *Chione cancellata*, *Divaricella quadrisulcata* e *Natica* sp.) são comuns de ambientes de praia, com substratos inconsolidados arenosos, típicos de regiões estuarinas, sendo estes prováveis componentes da mesofauna local. Por outro lado, *Halimeda* é um gênero de algas verdes de talo cenocítico e calcificado, comumente associadas a formações recifais, com grande importância ecológica em regiões tropicais (ciclo do carbono, manutenção de recifes de corais) (Dias, 2000; Bandeira-Pedrosa *et al*., 2004). Na costa nordeste do Brasil, segmentos calcificados e branqueados de *Halimeda* acumulam-se em grandes depósitos sob a plataforma, apresentando inclusive potencial econômico (Bandeira-Pedrosa *et al*., 2004). Desse modo, podemos supor que diferentes agentes estejam atuando na configuração sedimentar das praias estudadas. Fragmentos de *Halimeda* podem chegar às praias por interações de diferentes fatores como correntes costeiras (deriva litorânea), maré e atividade eólica. Por outro lado, biodetritos podem ser gerados localmente a partir da predação dos indivíduos da mesofauna do terraço.

Seguindo esse raciocínio, os padrões espaciais encontrados, onde a maior concentração de $CaCO_3$ predominou na margem sul do estuário, principalmente na área mais próxima a desembocadura, pode ser explicado pela maior produtividade bentônica que provavelmente ocorre nesse local, estimulada pelo maior aporte de nutrientes provenientes do rio. Outro indicador desse padrão de produtividade é a tradicional atividade de mariscagem, que se concentra na margem sul do estuário, próximo à desembocadura. Os maiores valores do percentil de $CaCO_3$ durante a estação seca, pode estar relacionado a maior produção primária que ocorre nesse período, em função do aumento da transparência e temperatura da água.

As características morfodinâmicas e sedimentológicas da área de estudo, diante das variáveis estudadas, são informações de suma importância para o manejo desses ambientes, frente a quesitos como ocupação urbana, preservação, turismo e uso das praias pela população local.

Conclusão

As praias localizadas na porção externa do estuário do Rio Goiana são associadas a um extenso terraço de baixa-mar. As margens norte e sul do estuário apresentam diferentes padrões de deposição sedimentar, com acreção na margem norte e erosão na margem sul. Os sedimentos apresentam variabilidade nos tamanhos dos grãos, com a predominância de areia média, distribuída em assimetria negativa. Em ambas as margens, o grau de seleção aumenta no sentido da desembocadura. Também foi possível concluir a ocorrência de sedimentos mais grosseiros na margem sul do estuário, decorrente do maior aporte de biodetritos.

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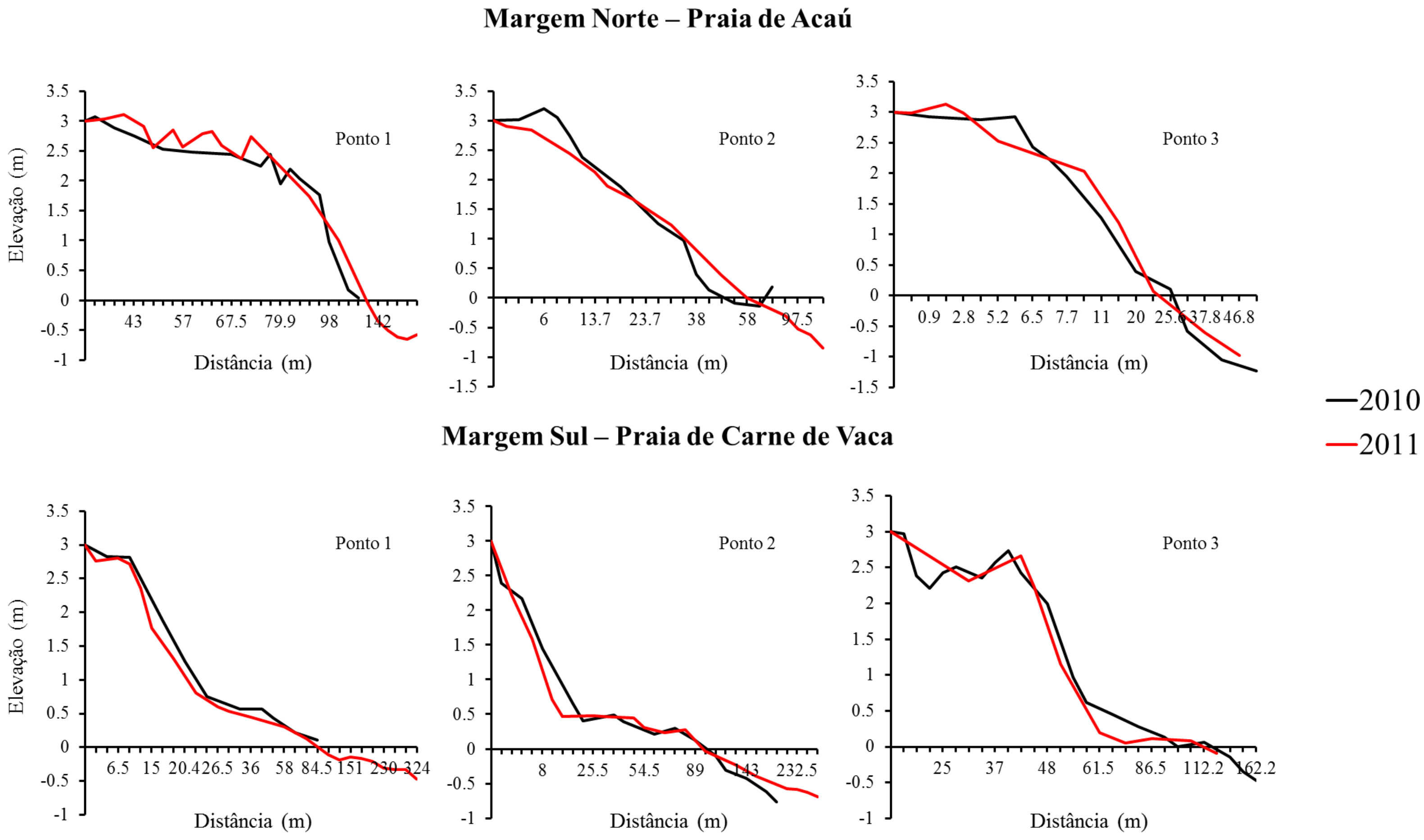
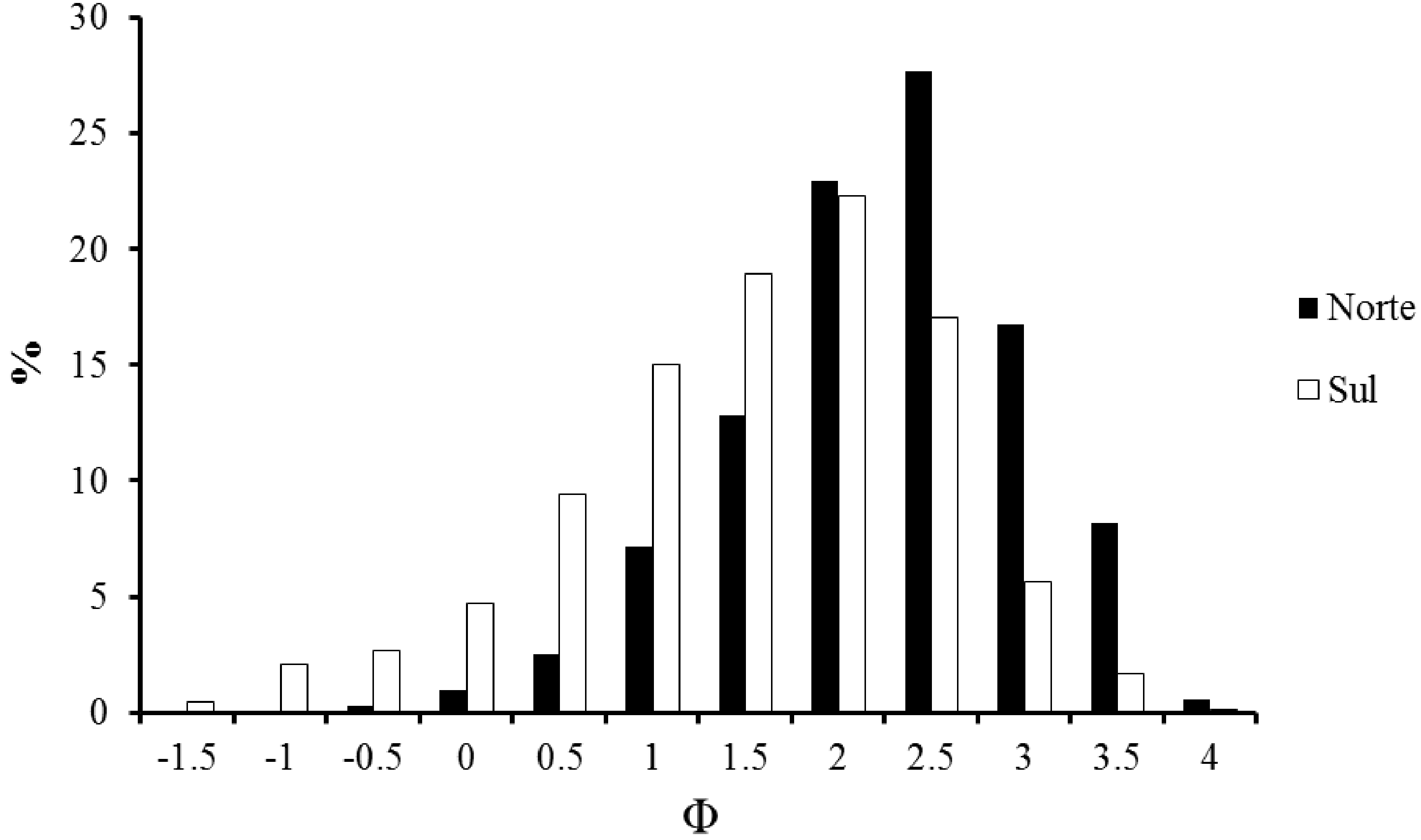
Apêndice 1. Praia de Carne de Vaca, margem sul do estuário.

Apêndice 2. Praia de Acaú, margem norte do estuário

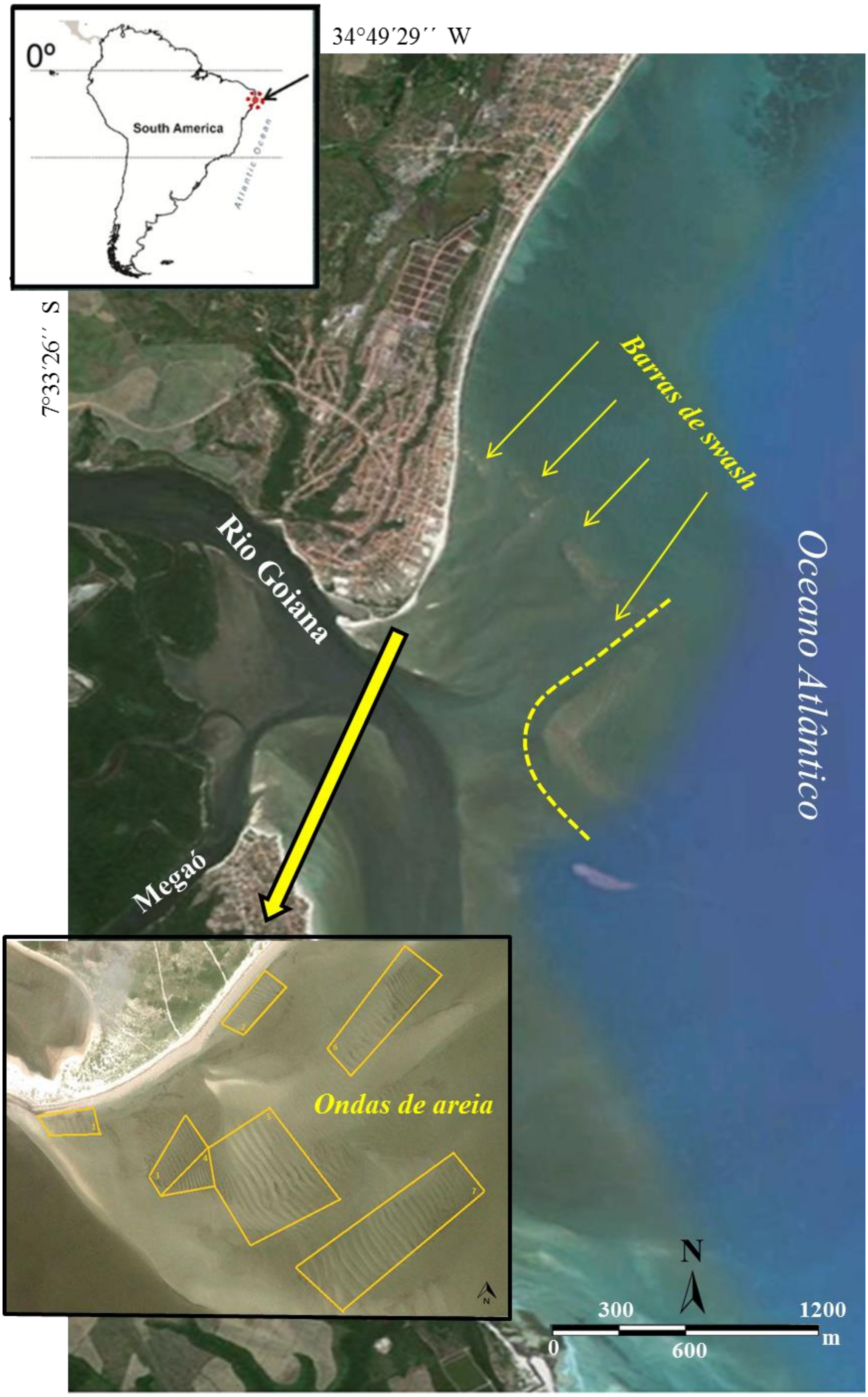
Apêndice 3. Variação temporal dos perfis topográficos de cada ponto amostral. Destaque para os padrões de acreção e erosão, nas margens norte e sul do estuário, respectivamente.



Apêndice 4. Histograma com a distribuição da granulometria sedimentar (diâmetro médio) nas margens norte e sul do estuário.



Apêndice 5. Porção externa do estuário do Rio Goiana. Destaque para as barras de *swash* e ondas de areia.



Capítulo 2

Temporal patterns in the intertidal faunal community at the mouth of a tropical Estuary

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Temporal patterns in the intertidal faunal community at the mouth of a tropical estuary

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Running title: Multi-temporal patterns on sandy beach community

Abstract The use of intertidal sandy beaches by fish and macrocrustaceans was studied in different temporal scales. Samples were taken along the lunar and diel cycles in the late of dry and rainy seasons. Fish assemblage (number of species, density and biomass), crustaceans and wrack biomass, showed significant interactions among all studied factors, and the combination moon phase and diel cycle, led to different patterns on environmental variables (depth, water temperature, dissolved oxygen) which affect the habitat use by the different species. Variances in faunal community were detected between seasons, stimulated by salinity fluctuations from freshwater input during the rainy season. These differences suggest an important cycling of habitats, increasing the connectivity among the adjacent habitats (estuary and coastal waters). Moreover, the results showed that, this intertidal sandy beach also provides an alternative nursery and protected shallow water for the initial development phase of many marine and estuarine species, supporting the highest number of species among similar habitats in others continents. In addition, this intertidal habitat showed an important role in the

maintenance of the ecological functions in the estuarine-coastal continuum ecosystem.

Keywords: Diel cycle, Environmental patterns, Ecological connectivity, Moon phase, Nursery, Young-of-the-year.

INTRODUCTION

The vast majority of humanity is concentrated along or near coasts, on just 10% of the Earth's land surface (Hinrichsen, 1998). The coastal zone provides many ecological and economic services to society (e.g. protein source, transport, tourism, space for industries and port activities). Within this scenario, inshore ecosystems undergo constant anthropogenic impacts and habitat loss, decreasing living resources availability (Barletta *et al*., 2010; Newton *et al*., 2012), a serious ecological issue for estuarine and coastal ecosystems.

Many species of fish and invertebrates use of a range of estuarine habitats, e.g. main channel (Barletta-Bergan *et al*. 2002a; Barletta *et al*., 2008; Araújo *et al*., 2012; Dantas *et al*., 2012), tidal creeks (Barletta-Bergan *et al*. 2002b; Koch *et al*., 2005; Barletta & Blaber, 2007; Ramos *et al*., 2011), sandy/mud beaches (Santos & Nash, 1995; Pessanha & Araújo, 2003) and sea grass beds (Nagelkerken *et al*., 2000; Unsworth *et al*., 2007) through their life cycles for different ecological functions. For instance, fishes and crustaceans species, use the estuarine system in the early development of their offspring, which means they also use the shallow waters, with its structural complexity and build-up of nutrients, as refuge and feeding grounds (Beck *et al*., 2001; Krumme *et al*., 2005; Dantas *et al*., 2013, Ramos *et al*. *in press*).

Several studies demonstrate temporal scales as time of day (Pessanha *et al*., 2003; Barletta & Barletta-Bergan 2009), moon phase (Blaber & Blaber, 1980; Barletta & Barletta-Bergan, 2009; Ramos *et al*., 2011) and seasons (Young & Potter, 2003;

Barletta *et al*., 2003, 2005, 2008) as controlling the use of estuarine habitats by aquatic communities.

The sandy beaches adjacent to estuarine areas are dynamic environments, which provide habitat for benthic macro fauna, fishes and birds (Defeo & McLachlan, 2005; McLachlan & Brown, 2006), and establish an important transition zone between continental and marine environments. Moreover, the proximity among different productive habitats (e.g. mangrove, main channel of estuaries, coral reefs, seas grass meadows and coastal waters) can assign essential key functions for such environments, which can represent productive ecotones of importance in the seaward exportation of energy and matter (Walker *et al*., 2003). In addition, in extensive intertidal sandy/muddy beaches, ecological niches are available in different temporal scales, and the aquatic community must rely on adaptations and strategies that promote the best use of these dynamic habitats (Naylor, 2001; Vinagre *et al*., 2006). In such environments, fish assemblages consist mostly in juveniles' schools, improving their fitness until recruitment to sub-adult populations under favorable conditions as feeding researches, optimal growth, refuge opportunities and connectivity with adjacent habitats (Blaber *et al*., 1989; Miller *et al*., 2001; Elliot & Dewailly, 1995; Vasconcelos *et al*., 2010).

In the Northeast Brazilian coast, ecological studies are scarce and information about intertidal environments used by fish assemblages are rare. Moreover, detecting the ecological functions of sandy beach habitats can assist fisheries and nature conservation managers in their planning of coastal habitats uses. The present study aims at identifying the seasonal, lunar and diel uses of these habitats by fauna. The hypothesis tested in this study is that the fluctuation of environmental factors (e.g. salinity, water temperature, dissolved oxygen and depth), affect the intertidal habitat use by beach faunal community (fish and macrocrustaceans) in different temporal scales (seasonal, lunar and diel).

MATERIALS AND METHODS

STUDY AREA

The sandy beaches studied here are located in the southern shores of the Goiana River Estuary, Northeast Brazil (Fig.1). The high sediment supply from the river and the presence of beachrocks near the river mouth makes it a low energy beach with a dissipative low tide terrace (Masselink & Short, 1993), which extends for hundreds of meters seawards. The tide is semi-diurnal, with a range of up to 2.5 meters during the new and full moon (spring tides), when flood tide occurs during the crepuscular period (dawn and dusk). The winds patterns in the region consist of lesser intensity winds from the north and northeast during the dry season, and higher intensity winds from de southeast and east during the rainy season (Medeiros & Kjerfve, 1993).

According to Barletta & Costa (2009), the region presents constant air temperature (27±2 °C) and a marked rainfall pattern, comprising four seasons: early rainy season (March to May), late rainy season (June to August), early dry season (September to November) and late dry season (December to February) (Fig. 2). The river flow and its influence on estuarine and coastal environments follow this seasonal pattern, and so do the fishing activities.

In 2007, the area became part of a Marine Conservation Unity (MCU) of the type Extractive Reserve (RESEX-Acaú/Goiana). This MCU covers an area of 4700 ha, including the river’s main channel and adjacent areas such as flooded mangrove forests, coastal habitats and even fishers settlements.

SAMPLING

Water temperature (°C), dissolved oxygen ($mg.L^{-1}$) (oximeter Cell Ox 340 WTW, Germany) and salinity (hand refractometer Atago S/Mill-E, Japan) were taken before each sampling. During the end of dry (February and April) and rainy (August and September) seasons of 2011 three replicate samples were taken at dawn, mid-day, dusk and midnight on the first day of each lunar phase (N = 192 samples). The beach community was sampled following the same planning with a beach seine net 10 m long, which had 7 meters of opening and consisted of 10 mm mesh-size (between knots) in the body and 5 mm in the cod-end. All samples lasted five minutes and the start and end positions were recorded by GPS (Garmin GPS 12 Navigation, Olathe, KS, U.S.A.) for subsequent calculation of the swept volume (V), which was defined as:

$$V = DLm \quad (1)$$

where, D is the average depth, L is the swept distance (m) and m is the length of net opening, which is equal to the width of the path swept by the beach seine net. The capture per unit of effort (CPUE) was used for estimation of density (eq. 2) and biomass (eq. 3) (Sparre & Venema, 1997):

$$\text{Density} = individuals * V^{-1} \ (\text{ind.m}^{-3}) \quad (2)$$

$$\text{Biomass} = grams * V^{-1} \ (\text{g.m}^{-3}) \quad (3)$$

Fish and crustaceans were identified (Figueiredo & Menezes, 1978, 1980; Fischer, 1978; Menezes & Figueiredo, 1980, 1985; Cervigón 1985, 1991, 1993, 1994, 1996; FAO, 2002; Humann & Deloach, 2002) counted, weighed and the total length (Lt) was measured.

STATISTICAL ANALYSIS

A factorial analysis of variance (Three-Way ANOVA), was used to identify differences in the number of fish species, density and biomass of fish and crustaceans, and wrack biomass among the factors lunar phase and diel cycle and its seasonal variations. When necessary, the data were standardized (Box & Cox, 1964) to increase normality. The Cochran's test was used to check the homogeneity of variances. In the case of significant differences identified by ANOVA, the Bonferroni test ($\alpha = 0.05$) to determine the difference between means was applied (Quinn & Keough, 2003).

A similarity matrix using the Bray–Curtis index (*Q*-mode) was computed using PRIMER (Clarke & Warwick, 1994). Preceding the analysis, the original data matrix (total density) was reduced (maintained species with more than 15% of frequency of occurrence) to remove any undue effects of rare species on the analysis (Gauch, 1982). The cluster was determined using ranked similarities.

Canonical correspondence analysis (CCA) was used to measure ecological interactions among the total density of faunal community (dependent variable) and environmental conditions (independent variables) for each season (dry and rainy) (ter Braak & Smilauer, 2002). CCA is a direct gradient analysis where the species composition, or distribution, is directly related to environmental variables (Palmer, 1993). To perform a CCA, a multiple least-squares regression was computed with the site scores (derived from weighted averages of species) as the dependent variables and the environmental variables as the independent variables (ter Braak, 1986; Palmer, 1993). The density data of faunal community were analyzed to extract patterns of variation in relation to the environmental data (direct gradient analysis). These analyses focused on symmetric and biplot scaling, and a Monte-Carlo permutation test was used to determine which environmental variables were significant to the variability of the dependent variables. With this procedure, statistical associations among fish assemblage patterns and environmental variables in each season were quantified. This method constrains the ordination of the species matrix by linear multiple regression on the environmental variables matrix, so that each successive canonical axis accounts for a smaller proportion of the total variance. The CCA was run with 100 iterations with randomized site locations to facilitate Monte-Carlo tests (between the eigenvalues and species–environment correlations). The CCA produces a biplot where environmental variables are represented as arrows (eigenvectors) radiating from the origin of the ordination. The length of an environmental vector is related to the strength of the relationship between the environmental variable that the vector represents and the species assemblages analyzed for each season (ter Braak, 1986).

RESULTS

ENVIRONMENTAL VARIABLES

The three-way ANOVA showed significant interactions among seasons *vs.* moon phase *vs.* diel cycle for salinity, temperature, dissolved oxygen and depth values (Table I; Fig. 3). Highest salinity values were observed during the new and full moon (spring tides), mainly at the crepuscular period, when the highest mean depths were recorded independent from season (Fig. 3). Moreover, under these moon phases' conditions, a great oscillation along the diel cycle was observed in salinity values during the rainy season (Fig. 3). On the other hand, temperature and dissolved oxygen showed the highest values during the dry season on the spring tides at mid-day, when the lowest mean water depths were recorded (Table I; Fig. 3).

THE SANDY BEACH COMMUNITY

Sixty-eight fish species and two species of crustaceans were captured, totalizing a mean density of 0.23 (ind.m^{-3}) and 0.64 (g.m^{-3}) biomass (Appendix 1). The intertidal fish assemblages were mainly composed by transient species and contributed for 78.6 % and 58.9 % of the total density and biomass of fauna respectively. The species *Lycengraulis grossidens* (Spix & Agassiz, 1829), *Anchovia clupeoides* (Swainson, 1839) and *Mugil* sp. were the most important species in number, representing 81.6 % of total fish density. Together with the species *Cathorops spixii* (Spix & Agassiz, 1829), *Sphoeroides testudineus* (L. 1758), *Stellifer rastrifer* (Jordan, 1889), *Menticirrhus americanus* (L. 1758), *Atherinella brasiliensis* (Quoy & Gaimard, 1825), *Achirus lineatus* (L. 1758) and *Polydactylus virginicus* (L. 1758), they accounted for 67.8 % of total fishes biomass (Appendix 1).

Crustacean species, represented principally by *Callinectes danae* (Smith, 1869) and *Litopenaeus schmitti* (Burkenroad, 1936), contributed 17.9 % and 41.4 % of total density and biomass of fauna, respectively. *Callinectes danae* were responsible for 46.3% of total crustaceans' density and 84.6 % of biomass (Appendix 1). The wrack accumulation on the intertidal foreshore is a remarkable feature of this habitat, representing 85.7 % of the mean absolute biomass of this intertidal habitat (Appendix 1).

VARIATIONS ON THE SANDY BEACH COMMUNITY ALONG THE SEASONS, LUNAR AND DIEL CYCLES

The three-way ANOVA showed significant interactions among seasons *vs.* moon phase *vs.* diel cycle for fish assemblage (total mean density, total mean biomass and number of species), crustaceans and wrack biomass (Tables II, III; Figs. 4, 5). The total mean fishes density and biomass showed the highest values on the rainy season during the first quarter moon (Tables II, III; Fig. 4). These values suffered strong influence of the abundance values of *Mugil* sp., which showed high occurrence on the rainy season during the first quarter moon at midnight and crepuscular period, with significant interactions among seasons *vs.* moon phase *vs.* diel cycle (Tables II, III; Appendices 2, 3).

Significant interactions among seasons *vs.* moon phase *vs.* diel cycle were also detected for abundance (density and biomass) of *L. grossidens* and *A. clupeoides* (Tables II, III; Appendices 2, 3). Highest abundance of *L. grossidens* occurred on the rainy season on the last quarter moon with high values at mid-day (except on full moon) (Tables II, III; Appendices 2, 3). *Anchovia clupeoides* showed highest abundance during the dry season at dusk, mainly on new and first quarter moon, and on rainy season during full moon at dusk and dawn (Tables II, III; Appendices 2, 3). The density values of *A. brasiliensis* showed significant differences for season and diel cycle (Table II; Appendix 2). The highest densities values for this species were observed during the rainy season, at mid-day and midnight (Table II). The *C. spixii* showed significant interactions among seasons *vs.* diel cycles for density, and among season *vs*. lunar phase *vs.* diel cycles for biomass (Tables II, III; Appendices 2, 3). During the rainy season highest abundance of this species occurred on new moon at mid-day, and during dry season on new and full moon at midnight (Tables II, III; Appendices 2, 3). Significant interactions among seasons *vs*. moon phase *vs*. diel cycle were detected for predator species, such as, *P. virginicus* (density) and *S. rastrifer* (biomass) (Tables II, III; Appendices 2, 3). These species showed highest values during the rainy season at the crepuscular periods and at midnight.

The crustaceans species (total mean) showed significant interactions between moon phase *vs.* diel cycle for density values and among seasons *vs*. moon phase *vs.* diel cycle for biomass (Tables II, III; Fig. 5). The highest abundance (density and biomass) of crustaceans' species occurred during the last and first quarter moon at midnight (Tables II, III; Fig. 5). *Callinectes danae* showed high abundance during the dry season at mid-day and midnight, with significant interactions among seasons *vs*. diel cycle (for density and biomass values), and between moon phase *vs.* diel cycle for biomass values (Tables II, III; Appendix 4). On the other hand, *L. schimitti* showed the highest abundance on the rainy season during the neap tides at midnight. Moreover, this species showed significant interactions between moon phases *vs.* diel cycle for density and among seasons *vs.* moon phases *vs*. diel cycle for biomass (Tables II, III; Appendix 4). Significant interactions were also detected among seasons *vs*. moon phase *vs*. diel cycle for wrack biomass, with high values during the dry season at mid-day and midnight (Table III; Appendix 5).

PATTERNS OF BEACH COMMUNITY AND ITS RELATION WITH ENVIRONMENTAL FACTORS

The *Q*-mode cluster analysis was conducted for each season. Both season showed fish and crustaceans community influenced by moon (tidal) and dial patterns. During the dry season, the cluster analysis showed three main groups [Fig. 6(a)]. The first group was subdivided into 2 sub-groups: Sub-group I.A, mostly represented by fish (*C. spixii*, *L. grossidens*, *A. clupeoides*, *M. americanus*) and crustaceans species (*L. schmitti* and *C. danae*) with highest densities principally during the neap tides at crepuscular period. Sub group I.B, was represented fish species, which showed highest densities principally during the last quarter moon at midnight. The second group was represented by *P. virginicus,* which was more abundant during the spring tides at midnight. Group III were characterized by the fish species, which were more common during the neap tides at mid-day and midnight (during the lowest tidal range).

During the rainy season, the cluster analysis also showed three main groups [Fig. 6(b)]. Group I could be subdivided into 2 sub-groups: Sub-group I.A, was formed by fish (*P. virginicus*, *S. brasiliensis*, *C. arenaceus*, *A. brasiliensis*, *M. americanus*, *B. rhonchus*, *S. herzbergii*, *A. lineatus*) and crustaceans (*L. schimitti*, *C. danae*) species, which were more common principally during the neap tides at midnight. The second sub-group (I.B) were characterized by the fish species (*C. spixii*, *S. rastrifer*, *H. unifasciatus*, *S. testudineus*) which were more abundant during the spring tides at crepuscular period. Group II was formed by fish species (*R. bahiensis*, *A. clupeoides*, except *L. grossidens*), which were more abundant principally at the crepuscular period during all phases of the moon cycle. Young-of-year of *Mugil* sp., which showed peaks of highest densities during the first quarter moon at midnight and dusk, formed the third group.

The CCA ordination (biplot diagrams) of species scores (Fig. 7), and regression analysis (Table IV) permitted to analyze the distribution of community groups per season (dry and rainy season), in relation to fluctuations of the environmental variables. The CCA output for dry season detected axis I being represented by depth (P=0.009) and water temperature (P= 0.049), which explained 62% of the community variance [Table IV; Fig. 7(a)]. *Achirus lineatus*, *C. danae*, *A. brasiliensis* and *S. testudineus* showed a positive correlation with water temperature and dissolved oxygen, occurring mainly at mid-day during ebb tides. On the other hand, *S. herzbergii*, *L. schimitti*, *P. virginicus*, *C. arenaceus*, *C. spixii*, *M. americanus* and *H. unifasciatus* showed height densities during ebb tides at midnight, with positive correlation with salinity [Fig. 7(a)].

Lycengraulis grossidens and *A. clupeoides* were correlated positively with the variables depth and salinity, occurring during flood tides at crepuscular period.

During the rainy season the CCA output indicated that axis I being represented by dissolved oxygen (*P*= 0.009) and depth (*P*= 0.029), explaining 68% of the community variance [Table IV; Fig 7(b)] YOY of *Mugil* spp. correlated negatively with these two environmental variables. This species showed peak of occurrence on ebb tides during the first quarter moon at dusk and midnight. Moreover, *C. spixii*, *L. grossidens*, *S. testudineus* and *M. americanus* showed highest densities at mid-day during ebb tides which resulting in a positive correlations of these species with the variables dissolved oxygen and water temperature [Table IV; Fig. 7(b)]. Moreover, spring tides at crepuscular period showed positive correlation with the fish species (*S. rastrifer*, *S. stellifer*, *A. clupeoides*, *H. unifasciatus* and *R. bahiensis*), and the environmental variables depth and salinity.

DISCUSSION

ENVIRONMENTAL VARIABLES

Fish assemblages' composition in the sandy beach habitat was influenced principally by the seasonal fluctuation of salinity. In addition, the interaction of the factors moon phase and diel period, defined different depth conditions, which controlled variables as water temperature and dissolved oxygen, and determined habitat occupation by the different species.

During the new and full moon, fast variations in the environmental variables occurred along the diel cycle. During rainy season, salinity is the variable most affected by the freshwater input. In the Goiana Estuary, other studies (Barletta & Costa, 2009; Dantas *et al*., 2010; Dantas *et al*., 2012; Lima *et al*., 2014) highlight salinity as the main characteristic of the estuarine ecocline, and appointed the salinity gradient as the determinant of the distribution and movements of the estuarine species in the internal portion of the estuary. In the present study, decrease of salinity values during the rainy season was the most important factor in the variance of the faunal community. On the other hand, during the dry season, temperature and dissolved oxygen were the most affected variables. During the new and full moon, lower depths (ebb tide) coincide with the period of highest solar radiation (mid-day), and the high values of temperature and dissolved oxygen during this period, suggest a high primary production rate. In this way, the patterns observed during the new and full moon (spring tides) did not occur during the first and last quarter moon (neap tides). The influence of the lunar cycle on the physico-chemical variables is expected in a low tide terrace, a tide-dominated environment (Masselink & Short, 1993). Here, the combination of environmental and biotic factors (e.g. favorable hydrologic regime, buildup of nutrients and organic matter, high productive) determine the conditions of use by the fauna (Inui *et al*., 2010; Lercari *et al*., 2010; Bergamino *et al*., 2011).

THE TEMPORAL CYCLES AND THE PATTERNS OF HABITAT USE BY THE INTERTIDAL COMMUNITY

In marine ecosystems, the intertidal zones are the habitats most affected by tidal cycles, which reflected on the intertidal communities, along the different spatial and temporal scales (Horn *et al*., 1999; Naylor, 2001; Burnaford, 2004). Many studies (e.g. Palmer, 1995; Horn *et al*., 1999; Naylor, 2001) considered that the combination of environmental cues (e.g. tidal variance, hydrostatic pressure, wave action, temperature and salinity) and endogenous rhythms are the mechanisms different species utilize to regulate each behavioral pattern and consequently intertidal habitat occupation. Added to these factors, mostly on the transient intertidal species, community conditions (e.g. high competition, predation risk, food availability) are determinant to the establishment of habitat use patterns by the different species.

Therefore, the influence of seasons, moon phase and diel cycle on fishes and invertebrates communities is well established in many coastal habitats, as tidal creeks (Barletta *et al*., 2003; Barletta & Barletta-Bergan, 2009; Ramos *et al*., 2011), main channel (Jaureguizar *et al*., 2004; Barletta *et al*., 2005, 2008), sandy beaches (Santos & Nash, 1995; Selleslagh & Amara, 2008), seagrass meadows (Guest *et al*., 2003), marsh creeks (Hampel *et al*., 2003), mudflats (Morrison *et al*., 2002), coral reefs (Takemura *et al*., 2004), and coastal platform waters (Primo *et al*., 2012).

In intertidal sandy beaches habitats showed strong interactions of these multi-temporal cycles (diel, lunar and seasonal), affecting the patterns of environmental variables, as well as space and resources availability. In sandy beaches habitats around the world, seasonal changes on fish community have already been reported (e.g. Santos & Nash, 1995; Suda *et al*., 2002 and Lima & Vieira, 2009). In the same way, during the night period, highest fish abundance was observed in many coastal habitats (e.g. Miller & Skilleter, 2006; Kopp *et al*., 2007; Unsworth *et al*., 2007). In most cases, the high availability of food due to movements of the zooplankton, e.g. migration and nocturnal activity of epibenthic fauna (Kibirige & Perissinotto, 2003; Cohen & Forward, 2005), and safety from visual predators (Kneib & Wagner, 1994; De Robertis, 2002; Primo *et al*., 2012), are the main reasons reported for this pattern. In the present study, these patterns were also observed, as well as the high abundance of fishes and crustaceans during the first and last quarter moon, which can be related to major comfortable conditions in the occupation of the habitat, with a minor tide dominance and major stability of the environmental variables (salinity, temperature, dissolved oxygen and tidal range).

Interaction between community (density) and environmental factors (season, lunar, diel) appears in the highest densities of young-of-the-year (YOY) of *Mugil* sp. during the rainy season, suggesting that the sandy beach habitat as an alternative nursery for this species (Beck *et al.,* 2001), which use the habitat mainly at midnight and in the crepuscular period, probably to reduce predation risk. Then, this species were accompanied by some predatory fish as *Strongylura marina* (Walbaum, 1792), *Cynoscion acoupa* (Lacepède, 1801), *Cynoscion leiarchus* (Cuvier, 1830) and *P. virginicus* which also occurred mainly at midnight and crepuscular period during the rainy season, which can suggest that the sandy beach habitat also provides alternative feeding grounds for some fish species. This fact also shows that the community factors (e.g. predation risk and prey availability) interact with the environmental factors, and is determinant in the occupation of this intertidal environment by fish assemblage.

Nonetheless, independent of the temporal and environmental factors, the main similarity found in fishes communities on beach habitats is the prevalence of zooplanktivorous and invertebrate feeders (Miller & Skilleter, 2006; Unsworth *et al*., 2007; Green *et al*., 2009), mostly represented by YOY and juveniles (Pessanha & Araujo, 2003; Selleslagh & Amara, 2008). This pattern also observed in the present study. Several species, including the two most frequent, *L. grossidens* and *A. clupeoides* were best represented by juveniles (Froese & Pauly, 2012). The highest density values of these species occurred under completely different conditions (season, lunar phase and diel cycle), which may indicate a strategy to mitigate some competition, and also suggest, the use of the environmental factors (season, lunar, diel) by these species in the process of habitat occupation. The high number of interactions among all studied factors (diel, lunar and season), detected on the analyses for environmental and community variables, shows the strong relation between environmental cues and community patterns.

COMPARISON OF INTERTIDAL FAUNA WITH OTHER SANDY BEACH HABITATS OF THE WORLD

Due to variations in sampling methods, sampling effort, sandy beach types (tidal *vs.* wave dominance) and the differences in duration of each study, care is needed when comparing density, biomass and number of species of these habitats.

Studies using beach seine nets in sandy beaches along the Brazilian coast (Pessanha & Araújo, 2003; Gaelzer & Zalmon, 2008; Lima & Vieira, 2009; Souza-Conceição *et al*., 2013; Oliveira & Pessanha, 2014), Europe (Santos & Nash, 1995; Beyst *et al*., 2001; Selleslagh & Amara, 2008), Southern Japan (Suda *et al*., 2002; Inui *et al*., 2010), Northern Australia (Blaber *et al*., 1995) and New Zealand (Morrison *et al*., 2002) recorded varying numbers of fish species, density and biomass (Table V).

The present study showed similar values of density (0.10 ind.m^{-2}) than sand beaches in Azores Islands (0.22 ind.m^{-2}; Portugal) and Albatross Bay (0.21 ind.m^{-2}; Northern Australia) (Table V). Moreover, the highest density was found in sandy beaches on La Canche estuary (1.79 ind.m^{-2} of fish and 6.2 ind.m^{-2} of crustaceans) in the French coast. In this nursery habitat, catches were dominated by high numbers of the brown shrimp *Crangon crangon* L. 1758, flatfish *Pleuronectes platessa* (L. 1758) and the European sprat *Sprattus sprattus* (Svetovidov, 1952).

The highest biomass was caught in Albatross Bay (5.05 g.m^{-2}) (Northern Australia), influenced by the presence of some brown stingrays (*Himantura* sp.). In the Azores Island, similar biomass was caught (4.5 g.m^{-2}), with samples dominated by the mullet *Chelon lobrosus* (Risso, 1827). Among Brazilian surveys, the present study showed biomass values (0.10 $g.m^{-2}$), lower than in the Cassino Beach (1.19 $g.m^{-2}$) in the Southern Brazilian coast (Table V).

The highest biodiversity (101 sp.) was found in Japanese surveys, in a low tide terrace on Doigahama beach (western Honshu), and in the Northern coast of Kyushu Island (83 sp.) (Table V). Moreover, high values of diversity were also found in sandy beaches in the Northeast Brazilian coast (~70 sp.) and in Southern Brazil (~76 sp.) (Table V).

Corroborating to the patterns of this study, Blaber *et al*. (1995), Morrison *et al*. (2002) and Pessanha & Araújo (2003), also detect interactions between fish species and diel rhythm, with some species with major abundance during the night period. On the other hand, Gaelzer & Zalmon (2008) and Morrison *et al*. (2002) found more species during the low tide. Similar assemblages of fishes (at species level) were detected among the present study, Pessanha & Araújo (2003), Souza-Conceição *et al*. (2013) and Oliveira & Pessanha (2014).

Interactions between temporal (season) and environmental (salinity and water temperature) factors, and the composition of fish assemblages, were detected in most studies. In the higher latitudes sandy beaches (Santos & Nash, 1995; Beyst *et al.*, 2001; Selleslagh & Amara, 2008; Lima & Vieira, 2009), the water temperature was the most important variable in the fishes assemblages' variance. At lower latitudes (this study; Pessanha & Araújo, 2003; Oliveira & Pessanha, 2014), salinity seems more significant in the species arrangement.

THE CONNECTIVE ROLE OF SANDY BEACHES AND THEIR RELATION WITH ENVIRONMENTAL VARIABLES

During the rainy season, the freshwater input changes the habitat conditions (salinity, temperature, dissolved oxygen and water turbidity), and lead estuarine species as *C. acoupa*, *Cynoscion microlepidotus* (Cuvier 1830), *Sciades couma* (Valenciennes 1840), *S. rastrifer*, *Stellifer stellifer* (Bloch 1790), *Stellifer brasiliensis* (Schultz 1945) to make part of the beach community. During this season, many fish species may have been attracted to the beach habitat by the high densities of prey (*Mugil* sp. and *Litopenaeus schimitti*). On the other hand, during the dry season, the beach habitat showed conditions (high temperature, salinity, dissolved oxygen, water transparency and wrack abundance) most similar to the coastal environments, and although a lower fish abundance have occurred, a great number of fishes species were detected. During this season, species commonly associated to reef and coastal environments as *Trachinotus falcatus* (L. 1758), *Oligoplites saurus* (Bloch and Schneider, 1801), *Chaetodipterus faber* (Broussonet, 1782) and *Caranx latus* (Agassiz, 1831), showed a low density, but common occurrence during all moon cycle in this habitat. Some of these species use the mangrove flood forest (tidal creeks) in their early stages of life (Barletta *et al*., 2003; Krumme *et al*., 2004; Ramos *et al*., 2011). In this case, sandy beach intertidal habitats could also promote for these species a safe path to the mangrove creeks during the dry season, promoting protection (shallow waters and spatial heterogeneity by the wrack abundance) and availability of resources (high primary production, invertebrates and wrack abundance) stimulated by the low tide terrace (Masselink & Short, 1993; Lercari *et al*., 2010).

These differences on faunal composition along the seasonal cycle suggest that sandy beaches have an important role in the connection between the internal portion of the estuary and the coastal environment. These adjacent habitats tend to dominate (environmental variables, nutrients and fauna community) the intertidal sandy beaches at different moments, promoting a habitat cycle, which contemplates these different assemblages, increasing the efficiency of the energy flow among adjacent habitats. This process appears to be quite vulnerable to changes on environmental patterns, e.g. climate changes and anthropic interventions.

According to Blaber *et al*. (1995), inshore shallow waters located between estuarine habitats and offshore environments, can have their own group of dependent juveniles, as well as an opportunistic group that can live in all three zones (estuary, inshore and offshore waters). These authors described the nursery function of these inshore waters for different fish categories. First, for some species whose adults live mainly offshore (e.g., Carangidae and Sciaenidae). Second for larger juveniles of many species, whose fry live in the estuary (e.g. Hemiramphidae and Mugilidae). Finally, for juveniles also common in the estuary and offshore waters (Clupeidae and Leiognathidae). The present study showed that this intertidal habitat also provided and alternative nursery and important shallow waters habitat for the initial development of fishes and crustaceans species, although complementary studies would be necessary to understand the temporal and spatial factors that drive this relationship.

CURRENT THREATS TO HABITAT INTEGRITY

In the Goiana River estuary, the surrounding sugarcane plantations and industrial activities are not included in the MCU area, and river basin land use sustainability is highly questionable (Barletta & Costa, 2009). Today, the main threats to the estuarine habitats integrity came from municipal sewage, sugarcane crop and milling, aquaculture and cement plants, which use the river flow in many ways including water supply and for effluents discharge. These practices can cause strong influence on the dynamic of chemical components of the water, cycle of nutrients and concentration of dissolved oxygen along the water column, as well as the establishment of chemical barriers along the river course, affecting the faunal community, which use the different zones of the estuary. A study with the top predator *Trichiurus lepturus* L. 1758, captured by the artisanal fishery fleet in the lower portion of the Goiana Estuary showed that the mercury concentration in the muscle of this fish is related negatively with rainfall and positively fish weight (Barletta *et al*., 2012). In studies realized with the demersal fish assemblage, plastics debris were detected in the stomach contents of Ariidae, Gerreidae and Sciaenidae (Possatto *et al*., 2010; Ramos *et al*. 2012, Dantas *et al*., 2013). In addition, Lima *et al*. (2014) proposed a conceptual model to explain the dynamics of microplastic debris in the column water of the main channel of Goiana Estuary. All these evidences suggest that this estuary is under anthropogenic pressure.

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FIGURES AND APPENDICES CAPTIONS

Figure 1. Study area. The sand beaches in the southern shore of the Goiana River Estuary, Northwest Brazil.

Figure 2. Rainfall data between October 2010 and September 2011. Historical rainfall pattern (red line). ⬚, *study period*.

Figure 3. Variations in salinity, temperature (°C), dissolved oxygen (mg.L^{-3}) and depth (m) for season (rainy and dry), moon phase (new, first quarter, full and last quarter) and diel rhythm (dawn, mid-day, dusk and midnight).

Figure 4. Variations in fish community (number of species, density and biomass), for season (rainy and dry), moon phase (new, first quarter, full and last quarter) and diel rhythm (dawn, mid-day, dusk and midnight).

Figure 5. Variations in the total crustaceans density and biomass, between the dry and rainy season, during the moon cycle and diel rhythm.

Figure 6. Cluster dendogram of the most frequent species on beach samples in the adjacent area of Goiana River Estuary during for dry (a) and rainy (b) season. Samples clustered by group average of ranked Bray-Curtis similarity index based on density values. Species: Polvi, *Polydactylus virginicus*; Stebr, *Stellifer brasiliensis*; Citar, *Citharichthys arenaceus*; Cdanae, *Callinectes danae*; Athbr, *Atherinella brasiliensis*; Menam, *Menticirrhus americanus*; Lschimitti, *Litopenaeus schimitti*; Bairo, *Bairdiella ronchus*; Scihe, *Sciades herzbergii*; Achli, *Achirus lineatus*; Catsp, *Cathorops spixii*; Stera, *Stellifer rastrifer*; Hypun, *Hyporhamphus unifasciatus*; Stest, *Sphoeroides testudineus*; Rhiba, *Rhinosardinia bahiensis*; Anccl, *Anchovia cluppeoides*; Lycgr, *Lycengraulis grossidens*; Mugsp, *Mugil* sp.

Figure 7. Canonical correspondent analysis ordination biplot showing species centroids in relation to environmental variables (T°C, water temperature; $O_{2,}$ dissolved oxygen; salinity; depth) for dry (a) and rainy (b) season. Δ, species: Mug, *Mugil* sp.; Citar, *C. arenaceus*; Lycgr, *L. grossidens*; Anccl, *A. clupeoides*; Sphte, *S. testudineus*; Achli, *A. lineatus*; Bairo, *B. ronchus*; Stest, *S. stellifer*; Rhiba, *R. bahiensis*; Stera, *S. rastrifer*; Hypun, *H. unifasciatus*; Stebr, *S. brasiliensis*; Catsp, *C. spixii*; Scihe, *S. herzberguii*; Athbr, *A. brasiliensis*; Menam, *M. americanus*; Polvi, *P. virginicus*; Calin, *Callinectes danae*; Litop, *Litopenaeus schimitti*. ○ moon phase (N, new moon; F, full moon; FS, first quarter moon; L, last quarter moon) and diel (DW, dawn; MD, mid-day; DS, dusk; MN, midnight).

Appendix 1. Total mean of density (ind.m^{-3} and %), biomass (g.m^{-3}), frequency of occurrence (%) and total length (*L*t ± SD) of fish and main crustaceans species, during the study period and along the moon cycle per seasons.

Appendix 2. Variations on density values of the main fish species along the study period during the moon and diel cycles.

Appendix 3. Variations on biomass of the main fish species along the study period during the moon and diel cycles.

Appendix 4. Variations in *Callinectes danae* and *Litopenaeus schimitti* densities and biomass, between the dry and rainy season, during the moon cycle and diel rhythm.

Appendix 5**.** Variations in biomass of wrack between the dry and rainy season, during the moon cycle and diel rhythm.

TABLE I. Summary of the three-way ANOVA and Bonferroni test results for the environmental variables (salinity, temperature, dissolved oxygen and depth). Differences among seasons, moon phases and diel variation were indicated by underlined (__). D, dry season; R, rainy season; NM, new moon; FM, full moon; LQ, last quarter moon; FQ, first quarter moon. CM, dawn; MD, midday; CV, dusk; MN, midnight.* P<0.05; **P<0.01

	Sourse of Variance			
Variables	**Season (1)**	**Moon phase (2)**	**Diel (3)**	**Interactions**
Environmental variables				
	**	**	**	**
Salinity	R D	FQ LQ NM FM	MD CM MN CV	1 x 2 x 3
	**	**	**	**
Temperature (°C)	R D	FQ LQ FM NM	MN CM CV MD	1 x 2 x 3
	**	**	**	**
Dissolved oxigen (mg.L^{-1})	R D	FQ LQ NM FM	MN CM CV MD	1 x 2 x 3
	**	**	**	**
Depth (m)	R D	FQ LQ NM FM	MN MD CM CV	1 x 2 x 3

TABLE II. Summary of the three-way ANOVA and Bonferroni test results for number of fish species and total density (fish and crustaceans). Differences among seasons, moon phases and diel variation were indicated by underlined (__). D, dry season; R, rainy season; NM, new moon; FM, full moon; LQ, last quarter moon; FQ, first quarter moon. CM, dawn; MD, midday; CV, dusk; MN, midnight; *ns*, non-significant (*P*>0.05). * <0.05;***P*<0.01.

	Sourse of Variance			
Variables	**Season (1)**	**Moon phase (2)**	**Diel (3)**	**Interactions**
Number of fish species	** D R	** FM NM LQ FQ	** MD CM CV MN	** 1 x 2 x 3
Fish (individuals.m^{-3})				
Total	** D R	** NM FM LQ FQ	*ns*	** 1 x 2 x 3
L. grossidens	** D R	** FM NM FQ LQ	** MN CV CM MD	** 1 x 2 x 3
A. clupeoides	*ns*	*ns*	** MN MD CM CV	** 1 x 2 x 3
Mugil sp.	** D R	** LQ FM NM FQ	** MD CV CM MN	** 1 x 2 x 3
C. spixii	*ns*	*ns*	** *ns*	* 1 x 3
S. testudineus	*ns*	*ns*	*ns*	*ns*
S. rastrifer	** D R	*ns*	*ns*	*ns*
M. americanus	*ns*	*ns*	*ns*	*ns*
A. brasiliensis	** D R	*ns*	* CV CM MN MD	*ns*
A. lineatus	* D R	*ns*	*ns*	*ns*
P. virginicus	* D R	*ns*	* CM CV MD MN	* 1 x 2 x 3
Crustaceans (individuals.m^{-3})				
Total	*ns*	** FM NM FQ LQ	** CV CM MD MN	** 2 x 3
C. danae	** R D	** FM FQ NM LQ	** CV CM MN MD	** 1 x 3
L. schimitti	** D R	* FM NM FQ LQ	** MD CV CM MN	** 2 x 3
Total density of fauna (fish + crutaceans)	** D R	FM NM FQ LQ	CM CV MD MN	** 1 x 2 x 3

TABLE III. Summary of the three-way ANOVA and Bonferroni test results biomass (Fish, crustaceans and wrack). Differences among seasons, moon phases and diel variation were indicated by underlined (__). D, dry season; R, rainy season; NM, new moon; FM, full moon; LQ, last quarter moon; FQ, first quarter moon. CM, dawn; MD, midday; CV, dusk; MN, midnight; *ns*, non-significant ($P>0.05$). * $P<0.05$; ** $P<0.01$

	Sourse of Variance			
Variables	**Season (1)**	**Moon phase (2)**	**Diel (3)**	**Interactions**
Fish ($g.m^{-3}$)				
Total	** D R	** NM FM LQ FQ	*ns*	** 1 x 2 x 3
L. grossidens	*ns*	** FM NM FQ LQ	*ns*	** 1 x 2 x 3
A. clupeoides	*ns*	*ns*	** MN MD CM CV	* 1 x 2 x 3
Mugil sp.	** D R	** LQ FM NM FQ	** MD CM CV MN	* 1 x 2 x 3
C. spixii	*ns*	** FQ LQ FM NM	* MD CM CV MN	** 1 x 2 x 3
S. testudineus	** D R	*ns*	* MN CM CV MD	* 1 x 2 x 3
S. rastrifer	** D R	*ns*	** MD CM CV MN	** 1 x 2 x 3
M. americanus	*ns*	*ns*	*ns*	*ns*
A. brasiliensis	*ns*	*ns*	*ns*	*ns*
A. lineatus	** D R	* FM LQ NM FQ	*ns*	*ns*
P. virginicus	*ns*	*ns*	*ns*	*ns*
Crustaceans ($g.m^{-3}$)				
Total	** R D	** NM FM FQ LQ	** CV CM MD MN	** 1 x 2 x 3
C. danae	** R D	*ns*	** CV CM MD MN	** 1 x 3 ** 2 x 3
L. schimitti	** D R	** FM NM LQ FQ	** MD CV CM MN	* 1 x 2 x 3
Wrack ($g.m^{-3}$)	** R D	*ns*	* CV CM MN MD	** 1 x 2 x 3
Total biomass of fauna (fish + crustacenas)	*ns*	** NM FM FQ LQ	** CM CV MD MN	** 1 x 2 x 3
Total Biomass (fish + crustaceans + wrack)	*ns*	*ns*	** CV CM MD MN	** 1 x 2 x 3

TABLE IV. Results of canonical correspondence analysis. * $P<0.05$; ** $P<0.01$

a. Dry season	Axis 1	Axis 2	
Eigenvalue	0.395	0.357	
Species-environmental correlation	0.832	0.803	
Cumulative % variance			
of species data	21.0	40.0	
of species environmetal relation	40.7	77.5	
Correlation with environmental variables			*p*-value
Salinity	0.4507	0.3158	0.4554
Water temperature (ºC)	0.4880*	-0.2823	0.0495
Dissolved oxygen (mg l^{-1})	0.1749	0.3953	0.0693
Depth (cm)	0.6606**	0.1629	0.0099
b. Rainy season	**Axis 1**	**Axis 2**	
Eigenvalue	0.145	0.077	
Species-environmental correlation	0.708	0.476	
Cumulative % variance			
of species data	18.6	28.4	
of species environmental relation	55.8	85.4	
Correlation with environmental variables			*p*-value
Salinity	0.2161	-0.4328	0.9307
Water temperature (ºC)	0.3920	0.0428	0.0990
Dissolved oxygen (mg l^{-1})	-0.1849**	-0.2634	0.0099
Depth (cm)	0.3596*	-0.3406	0.0297

TABLE V. Abundance (number of species, density and biomass) of fauna community in different sandy beaches and shallow water habitats along the Brazilian coast, European coast, Japan, New Zealand and Australia. Crust., crustaceans; —, no data.

Location	Latitude	Zone	Habitat	Study period	N	N° spp.		Density				Biomass				Source
								Fish		Crust.		Fish		Crust.		
				(months)	(samples)	Fish	Crust.	N	Mean (ind.m^{-2})	N	Mean (ind.m^{-2})	N	Mean (ind.m^{-2})	N	Mean (ind.m^{-2})	
Europe																
Belgian coast	51°15´N	Temperate	Sandy beach	15	60	24	8	—	—	—	—	—	—	—	—	Beyst et al. (2001)
English channel	50°33´N	Temperate	Sandy beach	33	156	19	8	121,72	1.79	421,600	6.20	—	—	—	—	Selleslagh & Amara (2008)
Azores	38°30´N	Temperate	Sandy beach	12	176	24	—	39,35	0.22	—	—	619.9	4.5	—	—	Santos & Nash (1995)
Japan																
Doigahama	34°17´N	Sub-Tropical	Sandy beach	60	1007	101		17,608	0.04	—	—	25.8	0.005	—	—	Suda *et al*. (2000)
Kyushu Island	33°70´N	Sub-Tropical	Sandy beach	12	504	83	—	6,597	—	—	—					Inui *et al*. (2010)
Brazil																
Northeast																
Mamanguape Estuary	06°47´S	Tropical, Semi-Arid	Sandy/Muddy beach	12	174	71	—	3,732	—	—	—	15.82	—	—	—	Oliveira & Pessanha (2014)
Goiana Estuary	07°32´S	Tropical, Semi-Arid	Sandy beach	4	192	68	4	11,478	0.1	3,653	0.02	29.35	0.34	24.84	0.16	This study
Southeast																
Arraial do Cabo	22°58´S	Tropical, Sub-Tropical	Sandy beach	12	432	44	—	26,357	—	—	—	229.03	—	—	—	Gaelzer & Zalmon (2008)
Sepetiba Bay	22°54´S	Tropical, Sub-Tropical	Sandy beach	4	192	55	—	48,768	—	—	—	21.5	—	—	—	Pessanha & Araujo (2003)
South																
Babitonga Bay	26°10´S	Sub-Tropical	Sandy beach	13	273	76	—	45,874	—	—	—	—	—	—	—	Souza-Conceição *et al.* (2013)
Cassino beach	32°15´S	Sub-Tropical	Sandy beach	12	180	37	—	10,066	0.09	—	—	128.5	1.19	—	—	Lima & Vieira (2009)
Australia (Northern)																
Albatross Bay	12°40´S	Tropical	Inshore shallow waters	6	18	45	—	2,193	0.21	—	—	52.04	5.05	—	—	Blaber *et al*. (1995)
New Zealand																
Manukau Harbor	37°10´S	Temperate	Tidal mudflat	1	64	13	—	7,089	—	—	—	—	—	—	—	Morrison *et al*. (2002)

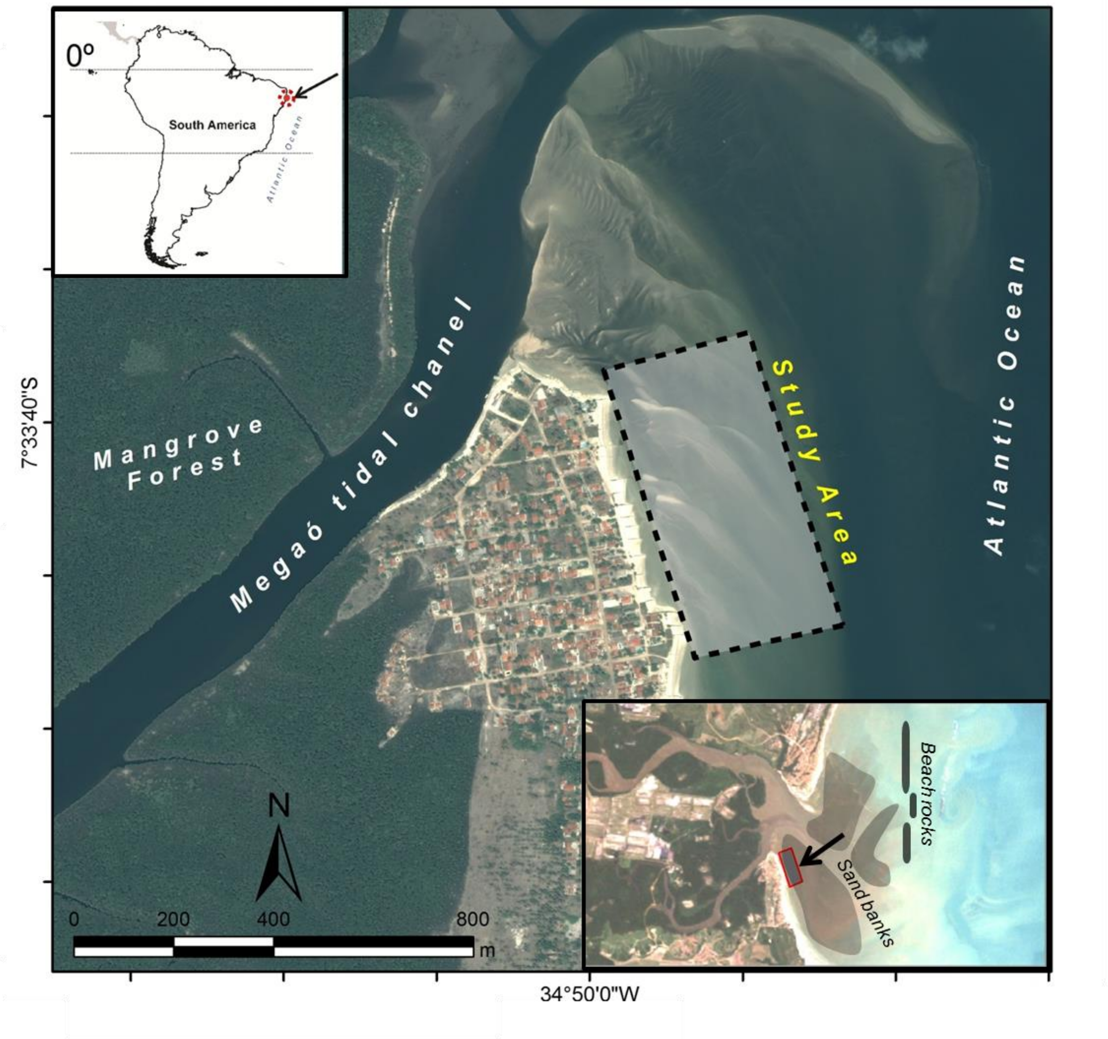

0º
South America
Atlantic Ocean
Mangrove
Forest
Megaó tidal chanel
Study Area
Atlantic Ocean
Beach rocks
Sand banks
N
0
200
400
800
m
7°33'40"S
34°50'0"W

Fig 1

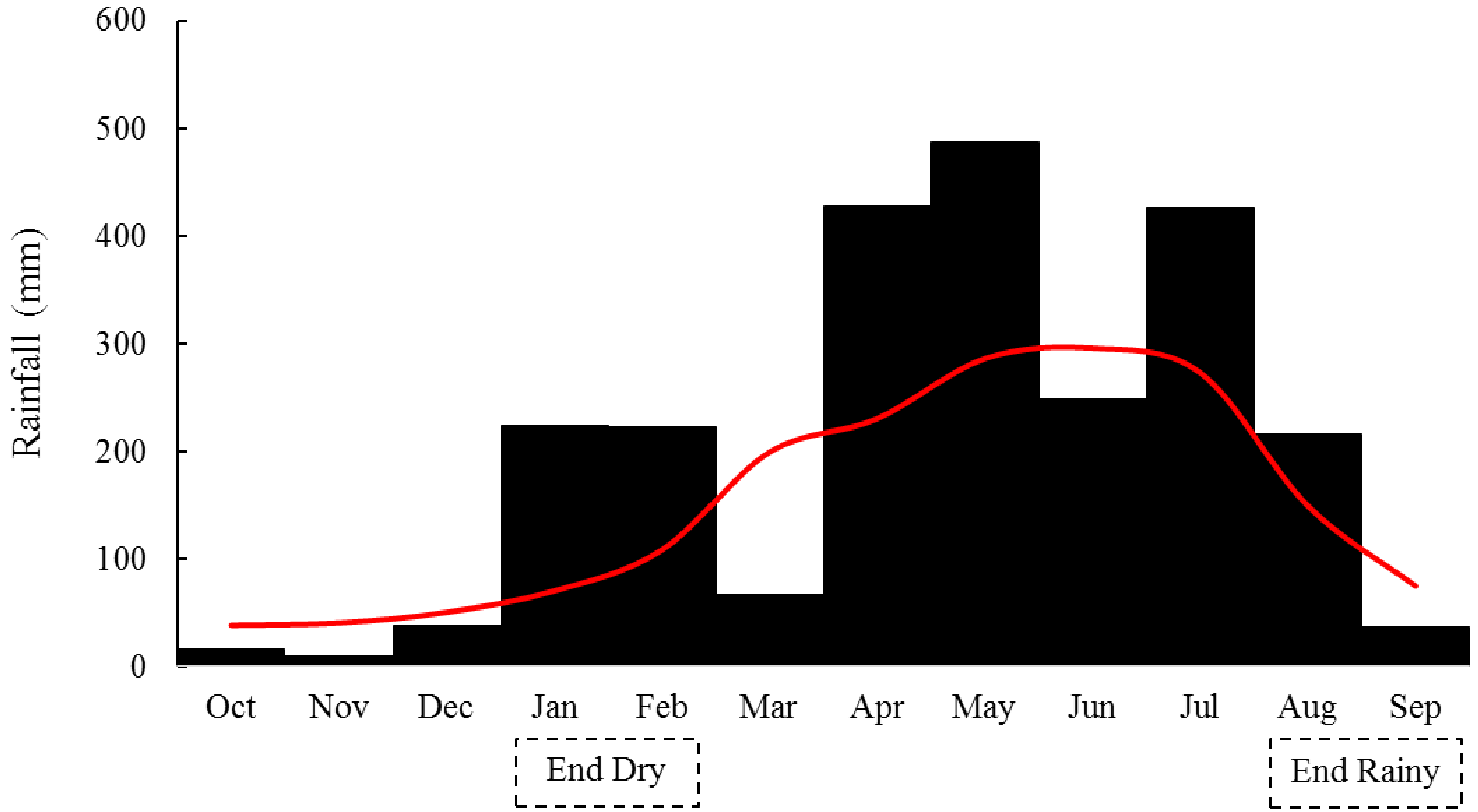
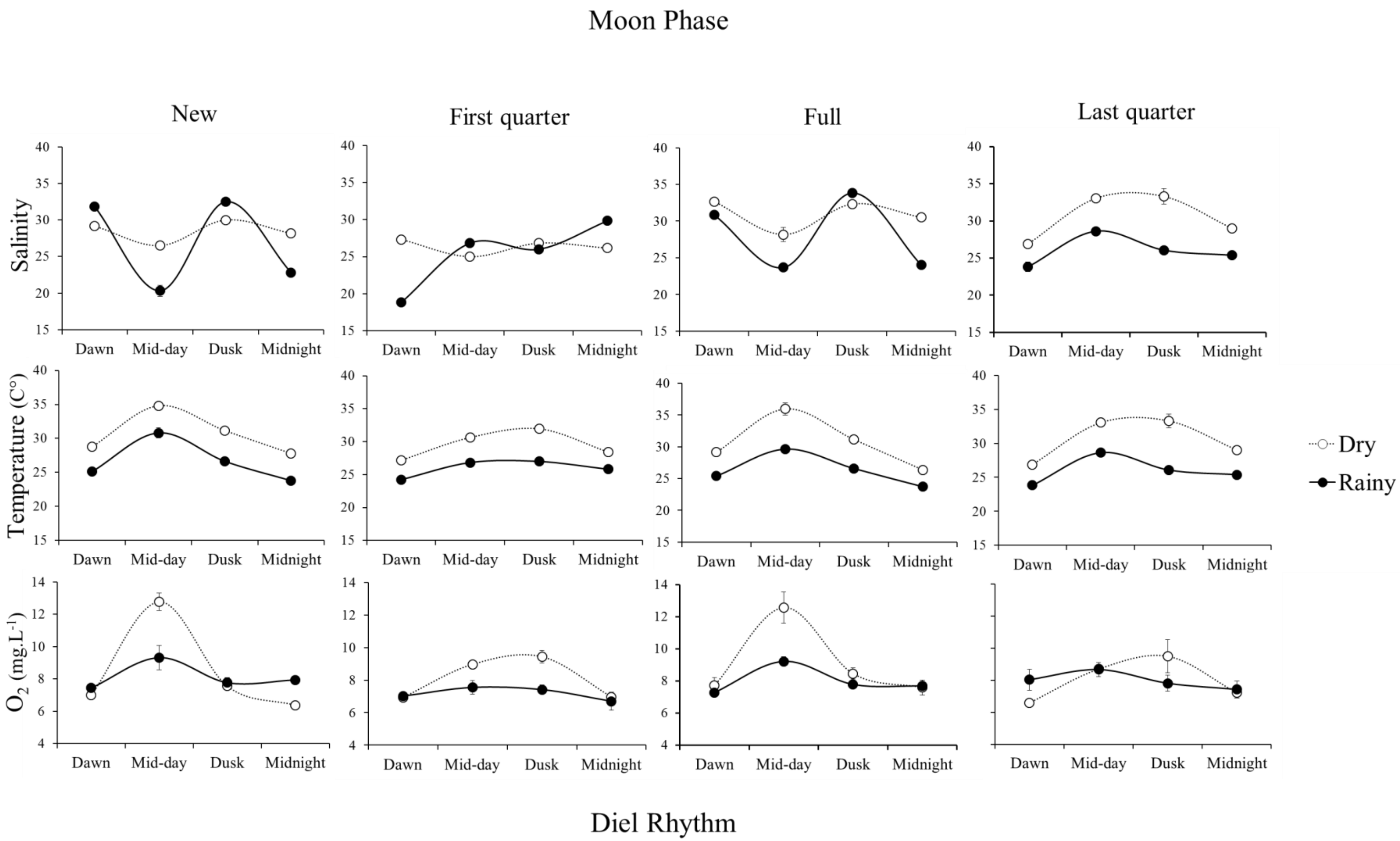

600
500
400
300
200
100
0
Rainfall (mm)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
End Dry
End Rainy

Fig 2



Moon Phase
New
First quarter
Full
Last quarter
Salinity
Temperature (C°)
O_2 (mg.L^{-1})
Dawn
Mid-day
Dusk
Midnight
Dry
Rainy
Diel Rhythm

Fig 3

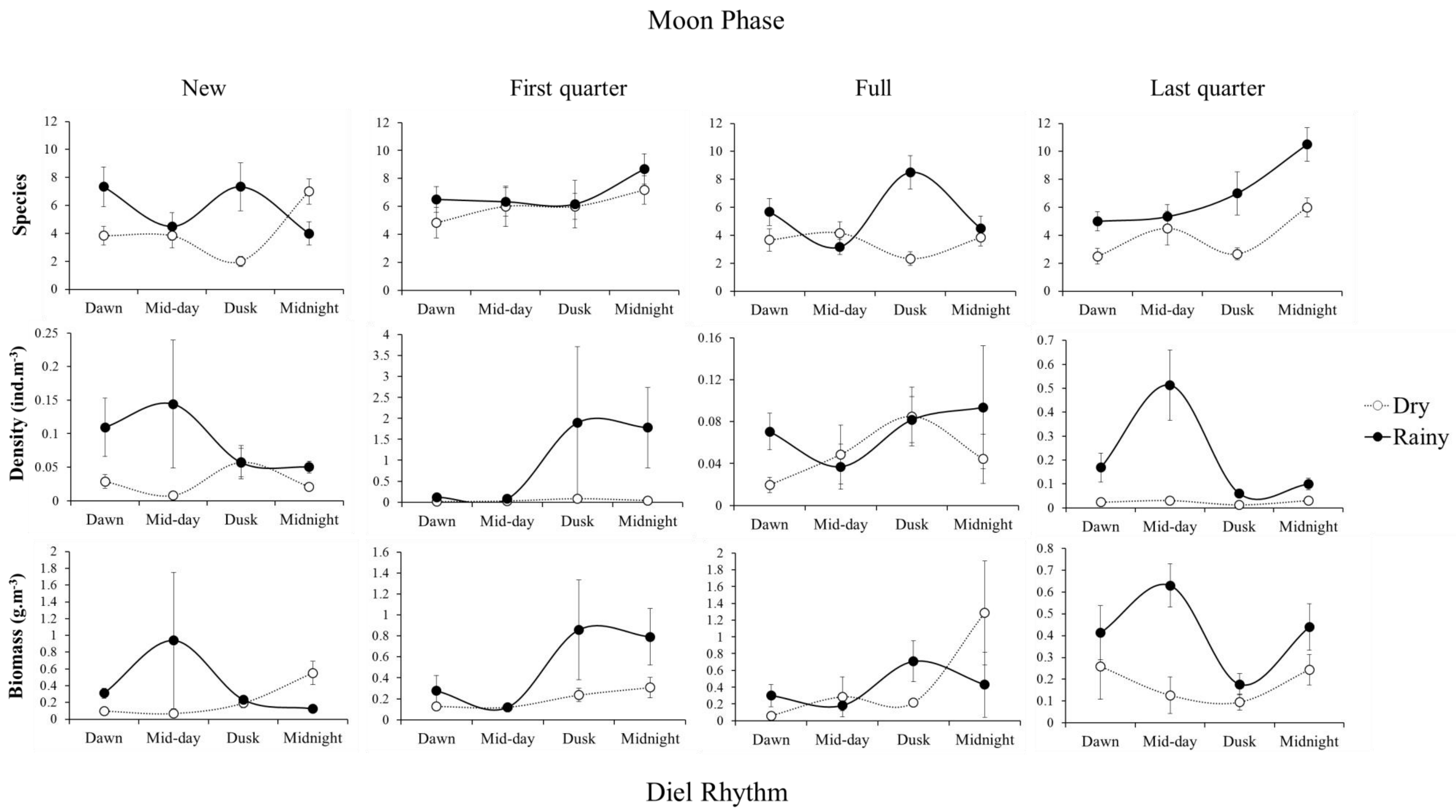

Moon Phase
New
First quarter
Full
Last quarter
Species
Density (ind.m⁻³)
Biomass (g.m⁻³)
Dawn
Mid-day
Dusk
Midnight
Dry
Rainy
Diel Rhythm

Fig 4

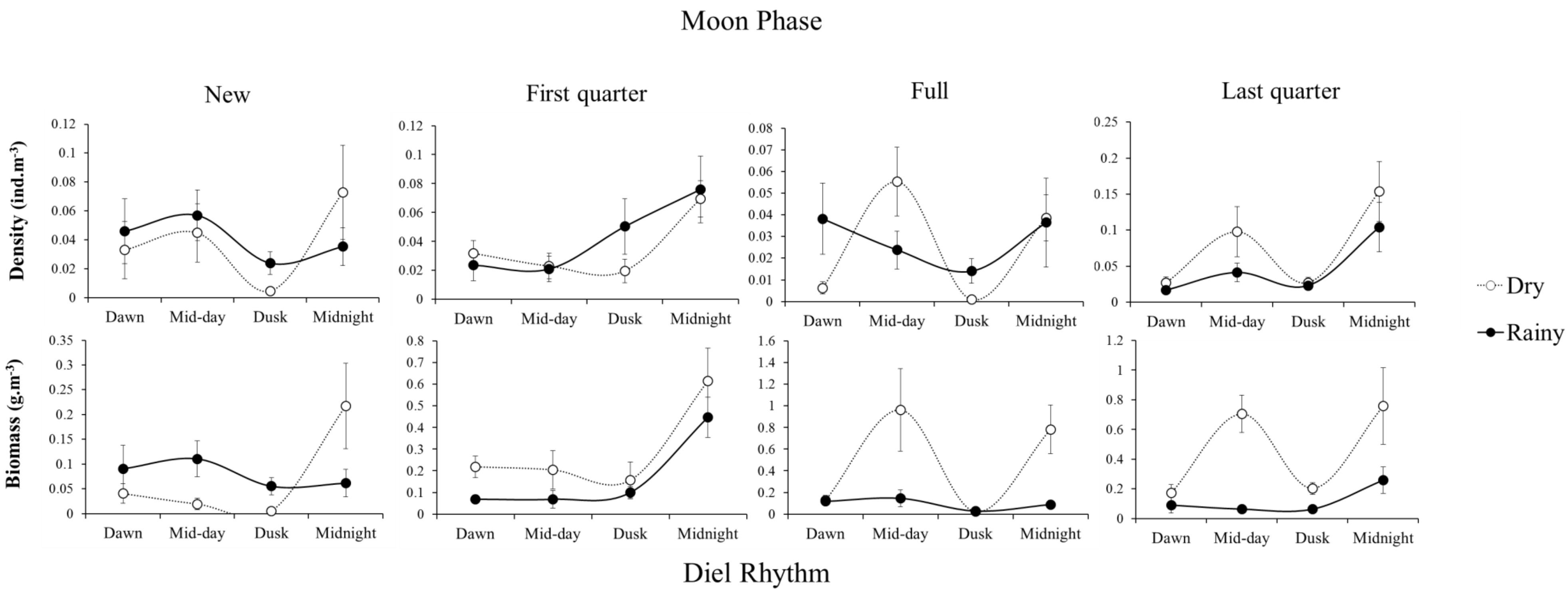

Moon Phase
New
First quarter
Full
Last quarter
Density (ind.m-3)
Biomass (g.m-3)
Dawn
Mid-day
Dusk
Midnight
Dry
Rainy
Diel Rhythm

Fig 5

Dry season

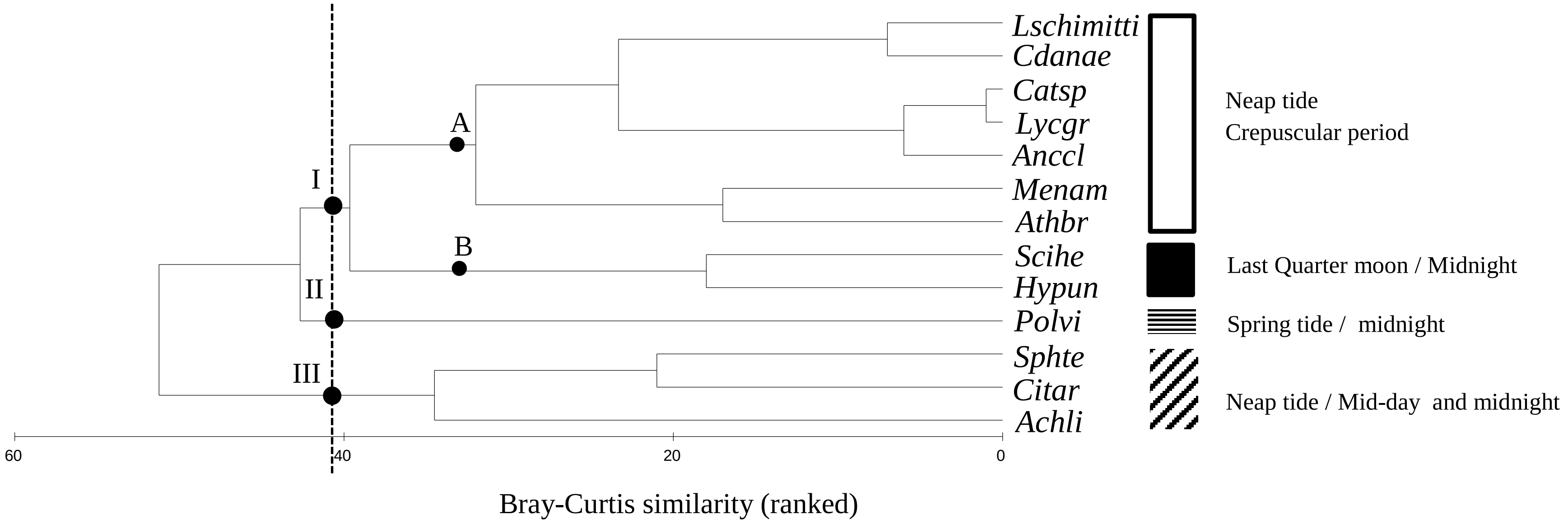


Fig 6a

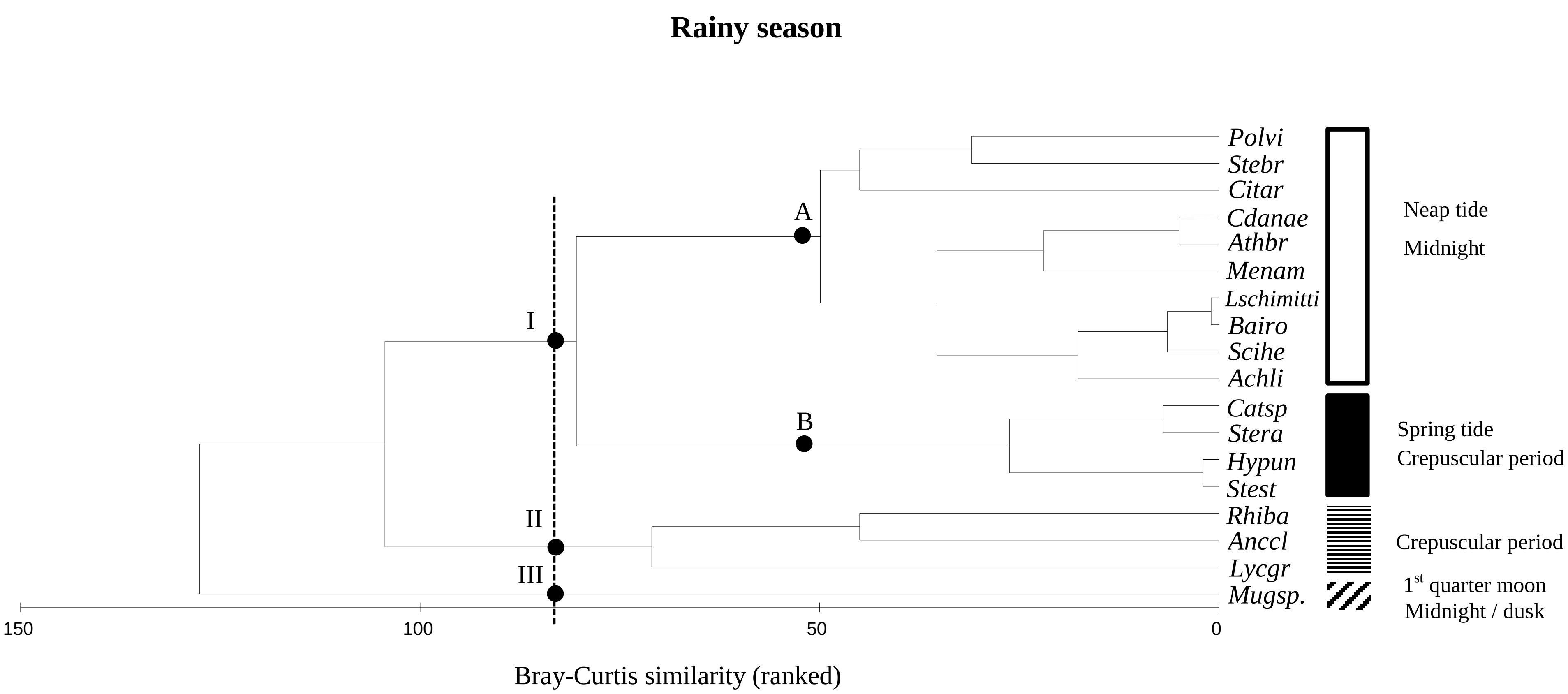

Rainy season
A
B
I
II
III
Polvi
Stebr
Citar
Cdanae
Athbr
Menam
Lschimitti
Bairo
Scihe
Achli
Catsp
Stera
Hypun
Stest
Rhiba
Anccl
Lycgr
Mugsp.
Neap tide
Midnight
Spring tide
Crepuscular period
Crepuscular period
1st quarter moon
Midnight / dusk
150
100
50
0
Bray-Curtis similarity (ranked)

Fig 6b

Dry season

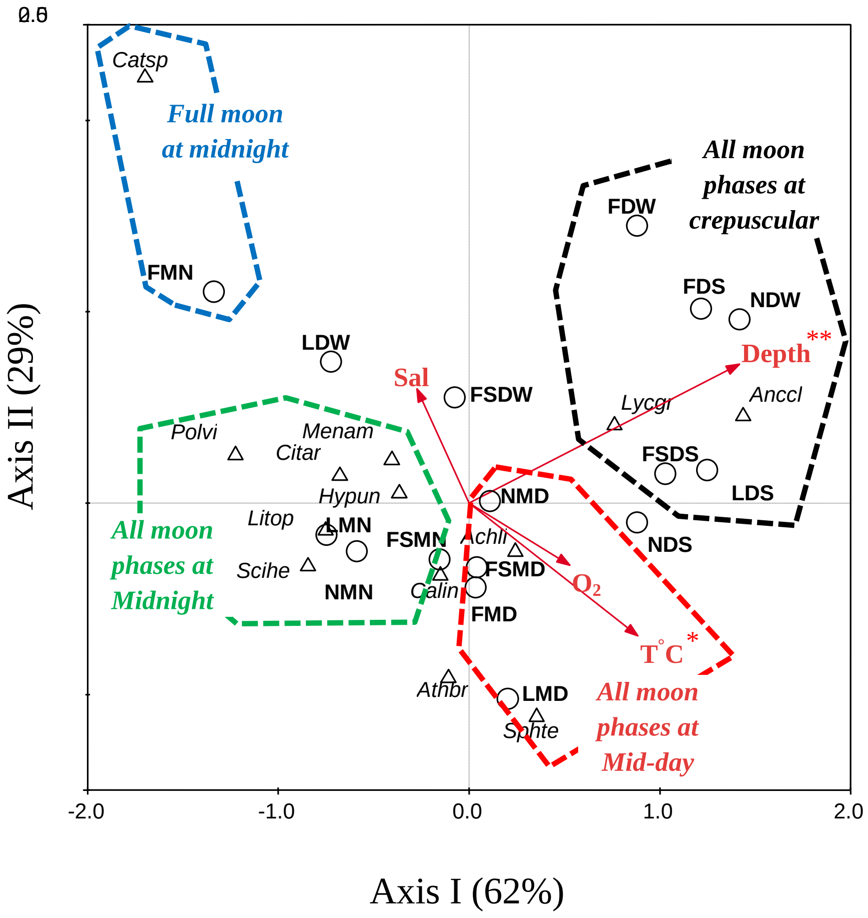


Fig 7a

Rainy Season

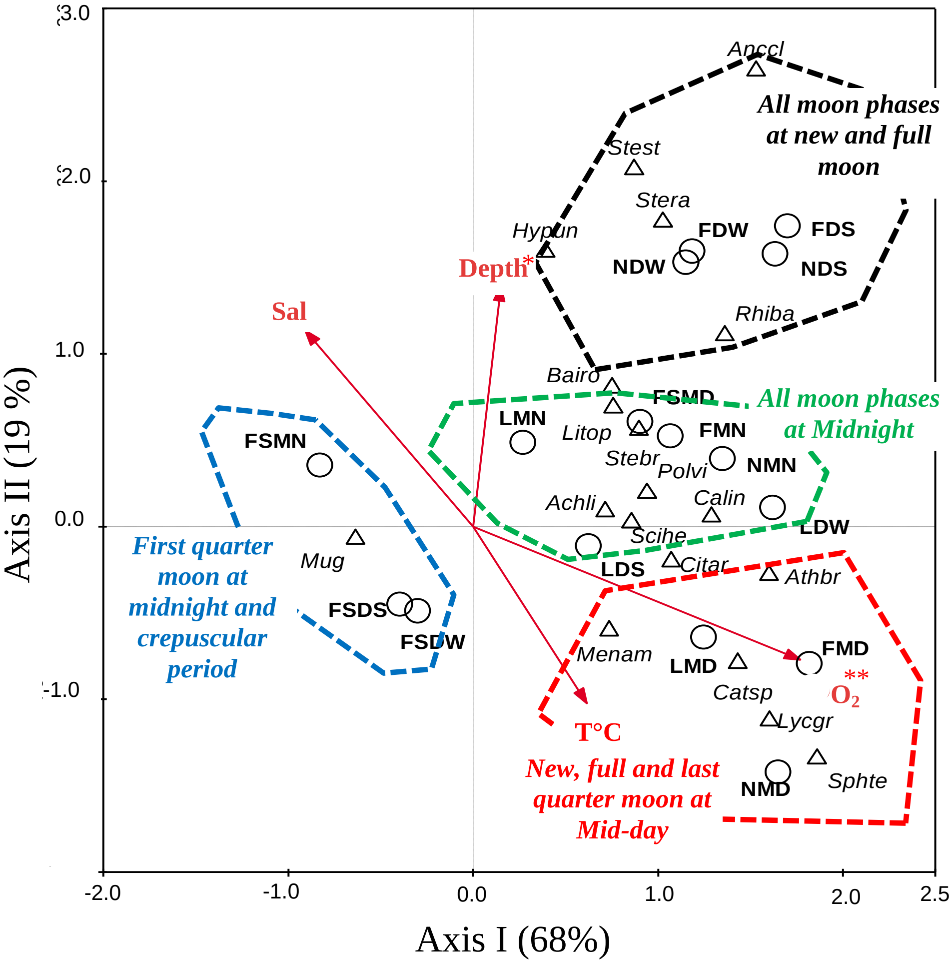


Fig 7b

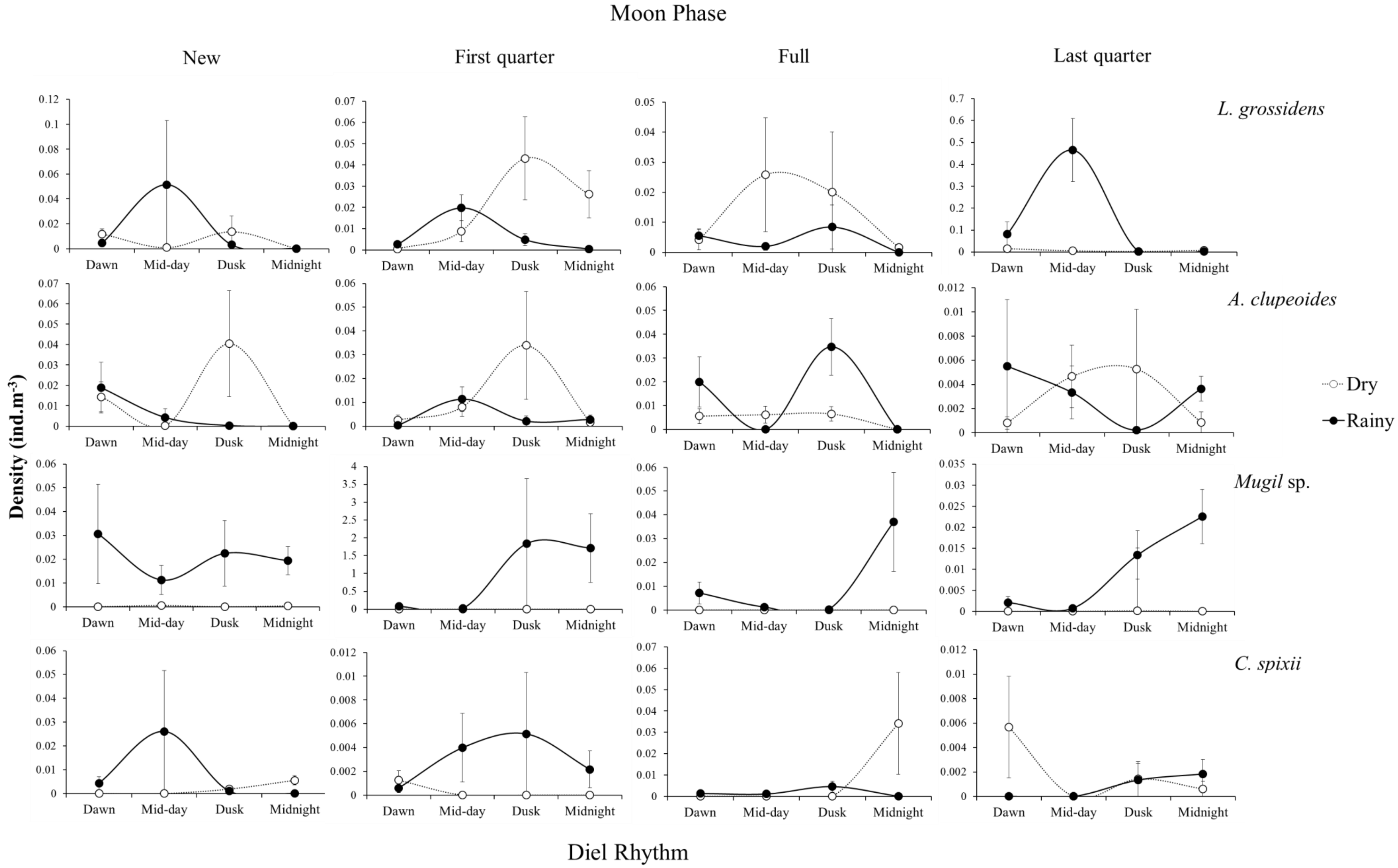
Appendix 1

						Moon phase																				
						Rainy season (%)										Dry season (%)										
						First quarter		Full		Last quarter		New		Mean Length	Length range	First quarter		Full		Last quarter		New		Mean Length	Length range	Total Length
Species	Dens	Acum (%)	Bio	Acum (%)	Freq. (%)	Dens	Bio	Dens	Bio	Dens	Bio	Dens	Bio	(cm±SD)	(cm)	Dens	Bio	Dens	Bio	Dens	Bio	Dens	Bio	(cm±SD)	(cm)	mean (cm)±SD
1 *Mugil* sp.	0.1196	63.7	0.0496	13.1	37.0	94.38	51.61	14.62	2.83	4.49	1.70	22.98	4.49	3.1±0.5	(1-13)					0.10	1.98	0.88	25.15	20±0.2	(16-24)	11±0.3
2 *Lycengraulis grossidens*	0.0263	77.7	0.0446	25.0	50.0	0.72	5.64	5.09	3.33	63.94	31.97	16.20	3.85	5.2±2.2	(3-18)	45.78	35.75	25.55	5.66	31.26	12.36	21.11	7.59	7.3±2.7	(3-14)	6.2±2.4
3 *Anchovia clupeoides*	0.0075	81.6	0.0144	28.8	40.6	0.43	0.68	17.47	4.60	1.48	1.37	6.44	5.06	5±2.2	(3-15)	26.86	10.27	9.03	2.35	11.90	3.49	44.72	7.07	6.1±2.4	(3-14)	5.5±2.3
4 *Bairdiella ronchus*	0.0041	83.8	0.0052	30.1	22.9	1.13	1.61	5.04	2.14	3.01	2.27	12.38	3.33	4.2±2	(1-15)					0.24	0.44					4.2±2
5 *Stellifer brasiliensis*	0.0034	85.6	0.0035	31.1	18.8	0.57	1.25	13.76	2.63	5.16	2.43			3.8±1.9	(1-13)			0.09	0.01							3.8±1.9
6 *Cathorops spixii*	0.0032	87.3	0.0720	50.1	26.6	0.31	2.02	2.22	7.37	0.37	0.53	8.62	24.75	8.9±2.9	(4-23)	0.73	3.89	16.84	58.25	6.44	33.67	5.81	23.21	13.6±3.6	(3-24)	11.2±3.3
7 *Atherinella brasiliensis*	0.0030	89.0	0.0094	52.6	34.9	0.14	1.00	5.36	1.17	1.91	3.02	8.06	5.99	6.3±2.5	(2-12)	2.10	1.11	3.00	0.95	19.70	10.64	0.49	0.25	7.6±2.7	(2-11)	7±2.6
8 *Anchoa tricolor*	0.0025	90.3	0.0041	53.7	9.4	0.01	0.05	0.08	0.01	5.15	3.18	0.24	0.04	7±2.6	(3-6)	0.92	0.66	15.79	3.35			0.56	0.33	11±3.3	(5-11)	9±2.9
9 *Stellifer stellifer*	0.0013	91.0	0.0108	56.6	15.6	0.14	1.91	2.62	3.84	2.22	10.00	2.35	4.21	8.8±2.9	(5-13)											8.8±2.9
10 *Stellifer rastrifer*	0.0023	92.2	0.0177	61.3	18.2	0.46	5.95	8.63	13.47	1.42	5.20	4.59	8.00	8.4±2.9	(6-15)											8.4±2.9
11 *Rhinosardinia bahiensis*	0.0017	93.1	0.0053	62.7	18.2	0.15	0.85	0.63	0.44	2.98	5.15	4.80	3.02	7.5±2.7	(5-9)	0.75	0.56					0.33	0.14	8.2±2.8	(7-9)	7.8±2.8
12 *Menticirrhus americanus*	0.0010	93.6	0.0143	66.5	29.2	0.24	2.49	0.98	1.32	0.64	0.63	0.79	1.40	6.7±2.6	(3-14)	1.39	5.48	3.11	11.53	2.40	7.29	0.62	1.61	12.6±3.5	(8-19)	9.6±3.1
13 *Polydactylus virginicus*	0.0009	94.1	0.0066	68.2	23.4	0.12	0.96	2.20	1.22	1.04	1.23	0.29	0.16	6.3±2.5	(3-10)	0.80	1.94	0.96	2.13	1.78	3.20	2.95	4.69	11.8±3.4	(6-14)	9.1±2.9
14 *Anchoa lyolepis*	0.0009	94.6	0.0018	68.7	5.7	0.01	0.02					0.25	0.09	5.8±2.4	(3-8)	0.17	0.03	13.08	2.85	0.66	0.01			6.5±2.5	(3-8)	6.1±2.4
15 *Sciades herzbergii*	0.0009	95.1	0.0033	69.6	21.9	0.14	0.88	1.21	0.80	0.46	0.86	1.62	1.32	7.9±2.8	(4-11)	1.40	0.57	0.40	0.21	3.45	2.18	1.48	0.81	8.4±2.9	(6-11)	8.1±2.8
16 *Pellona harroweri*	0.0008	95.5	0.0012	69.9	4.2			4.38	0.67	1.42	1.47	0.06	0.08	5.1±2.2	(4-9)											5.1±2.2
17 *Achirus lineatus*	0.0008	95.9	0.0093	72.3	21.4	0.20	6.16	0.41	0.71	0.71	2.64	1.98	4.86	7.6±2.7	(5-15)	0.58	2.70	0.13	0.04	0.61	0.83	0.23	0.02	7.1±2.6	(3-12)	7.3±2.7
18 *Bathygobius soporator*	0.0007	96.3	0.0049	73.6	9.4	0.22	4.37	1.77	1.14	0.85	2.47			6.4±2.5	(2-10)	0.41	0.25									6.4±2.5
19 *Hyporhamphus unifasciatus*	0.0007	96.7	0.0077	75.7	28.6	0.10	1.80	0.39	0.78	0.46	1.99	0.58	1.48	15.3±3.9	(4-19)	2.44	6.36	0.78	1.60	3.38	4.34	1.76	1.01	14.9±3.8	(3-18)	15.1±3.8
20 *Sphoeroides testudineus*	0.0007	97.0	0.0186	80.6	17.7	0.05	4.05	3.48	13.17	0.19	12.92	0.29	1.12	12.5±3.5	(3-25)	1.10	2.97	0.13	0.03	3.41	2.73	0.77	0.06	5.2±2.2	(2-13)	8.8±2.9
21 *Citharichthys arenaceus*	0.0007	97.4	0.0019	81.1	19.3	0.09	0.20	1.32	0.21	0.37	0.16	1.68	0.66	4.5±2.1	(3-10)	1.41	2.52	0.29	0.26			1.85	0.84	8.6±2.9	(4-11)	6.6±2.5
22 *Larimus breviceps*	0.0005	97.7	0.0165	85.4	8.9	0.04	0.99	1.29	9.34	0.06	0.79	2.41	20.82	11.7±3.4	(4-16)	0.36	0.03							6.3±2.5	(3-13)	9±2.9
23 *Lile piquitinga*	0.0004	97.8	0.0024	86.1	8.9			0.27	0.10			0.06	0.04	7.5±2.7	(7-8)	0.46	0.58	3.42	2.40	0.24	0.27	1.98	1.49	8.8±2.9	(7-10)	8.1±2.8
24 *Pomadasys corvinaeformis*	0.0003	98.0	0.0033	87.0	9.9											2.93	5.59	2.26	2.27	0.75	0.51	0.19	0.57	8.5±2.9	(4-15)	8.5±2.9
25 *Eucinostomus gula*	0.0003	98.2	0.0016	87.4	6.3			1.64	0.95							0.46	0.29	0.26	0.19			3.03	2.13	7.7±2.7	(3-11)	7.7±2.7
26 *Strongylura marina*	0.0003	98.3	0.0053	88.8	13.0	0.02	1.60	0.29	0.01	0.15	2.23	0.11	0.79	21.8±4.6	(5-38)	1.77	2.37	0.11	0.01	1.73	7.72	0.67	0.29	21.4±4.6	(8-37)	21.6±4.6
27 *Symphurus tessellatus*	0.0003	98.5	0.0006	89.0	8.3	0.10	0.23	1.03	0.19	0.15	0.49			6.3±2.5	(4-11)	0.18	0.47									6.3±2.5
28 *Sphoeroides greeleyi*	0.0003	98.6	0.0006	89.1	9.4			0.09	0.02							0.79	0.24	1.40	0.31	3.12	1.22	0.80	0.23	4.4±2.1	(2-8)	4.4±2.1
29 *Citharichthys spilopterus*	0.0002	98.7	0.0022	89.7	10.9	0.02	0.93			0.04	0.99	0.54	0.77	11.3±3.3	(4-16)	0.53	0.31	0.53	0.47	1.37	1.05			8.4±2.9	(6-11)	9.8±3.1
30 *Gobionellus oceanicus*	0.0002	98.8	0.0001	89.7	5.2	0.06	0.05			0.08	0.02	1.08	0.12	3.3±1.8	(2-5)											3.3±1.8
31 *Trachinotus falcatus*	0.0002	98.9	0.0007	89.9	8.3											0.55	0.40	0.51	0.23	3.73	1.46	0.35	0.25	6±2.4	(4-10)	6±2.4
32 *Eucinostomus melanopterus*	0.0002	99.0	0.0012	90.2	9.4	0.01	0.21							8	8	0.65	0.64	0.20	0.08	0.88	1.03	2.14	1.25	7.3±2.7	(4-10)	7.3±2.7
33 *Cynoscion acoupa*	0.0002	99.1	0.0020	90.8	7.8	0.03	0.20	0.45	2.29	0.20	0.18	0.35	1.22	16.4±4.1	(3-23)											16.4±4.1
34 *Cynoscion microlepidotus*	0.0002	99.2	0.0005	90.9	2.6			1.03	0.58	0.21	0.30			5.5±2.3	(2-10)											5.5±2.3
35 *Dasyatis guttata*	0.0001	99.3	0.0188	95.9	4.7			1.17	22.99	0.06	1.61	0.05	1.12	43.5±6.9	(27-67)							0.25	12.59	65	65	54.2±6.1
36 *Ophioscion punctatissimus*	0.0001	99.4	0.0001	95.9	5.7	0.02	0.03			0.32	0.13	0.05	0.01	3.8±1.8	(2-4)							0.33	0.01	3	3	3.2±1.7
37 *Selene vomer*	0.0001	99.4	0.0003	96.0	6.3			0.38	0.05	0.04	0.01			3±1.7	-2.40	1.26	0.74					0.23	0.03	4.8±2.2	(3-6)	3.9±1.9
38 *Ctenogobius stigmaticus*	0.0001	99.5	0.0001	96.0	3.1	0.01	0.01			0.11	0.11	0.72	0.14	5±2.2	(4-16)											5±2.2
39 *Etropus crossotus*	0.0001	99.5	0.0006	96.2	3.1	0.07	0.38			0.13	0.59			6.4±2.5	(4-11)											6.4±2.5
40 *Oligoplites saurus*	0.0001	99.6	0.0001	96.2	6.3											0.51	0.09	0.18	0.04	0.47	0.03	0.90	0.14	5±2.2	(3-6)	

Appendix 1. Continued

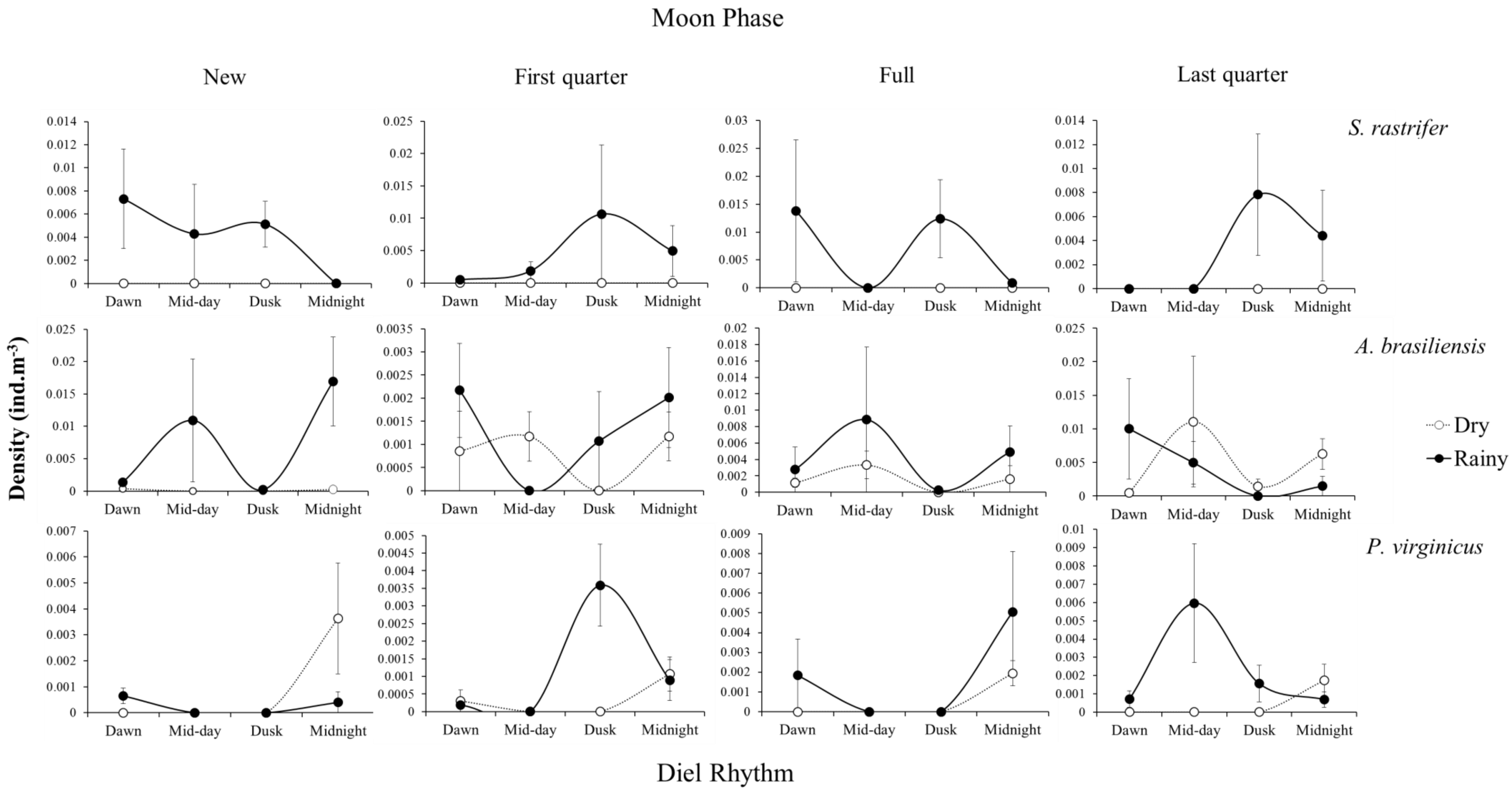
Species	Dens	Acum (%)	Bio	Acum (%)	Freq. (%)	Moon phase – Rainy season (%) – First quarter Dens	First quarter Bio	Full Dens	Full Bio	Last quarter Dens	Last quarter Bio	New Dens	New Bio	Mean Length (cm±SD)	Length range (cm)	Dry season (%) – First quarter Dens	First quarter Bio	Full Dens	Full Bio	Last quarter Dens	Last quarter Bio	New Dens	New Bio	Mean Length (cm±SD)	Length range (cm)	Total Length mean (cm)±SD
41 *Albula vulpes*	0.0001	99.6	0.0005	96.3	2.6											0.54	0.45					1.31	0.90	9.8±3.1	(5-17)	9.8±3.1
42 *Cynoscion leiarchus*	0.0001	99.7	0.0017	96.8	4.2	0.02	1.43	0.53	1.52			0.04	0.03											11.8±3.4	(6-21)	11.8±3.4
43 *Caranx latus*	0.0001	99.7	0.0008	97.0	5.7							0.10	0.09	7	7	0.32	0.16	0.30	0.22	0.63	2.20	0.19	0.12	7.8±2.8	(5-12)	7.4±2.6
44 *Chaetodipterus faber*	0.0001	99.7	0.0008	97.2	7.3											0.78	0.73	0.25	0.42	0.24	0.06	0.14	0.80	5.2±2.2	(2-12)	5.2±2.2
45 *Cetengraulis edentulus*	0.0001	99.8	0.0007	97.4	3.1											0.23	0.57					1.44	1.24	10.5±3.2	(9-12)	10.5±3.2
46 *Eucinostomus argenteus*	0.0001	99.8	0.0008	97.6	2.6													0.80	1.19			0.33	0.20	9.6±3.1	(8-11)	9.6±3.1
47 *Chirocentrodon bleekerianus*	<0.0001	99.8	0.0001	97.6	2.1			0.27	0.10					7	7	0.08	0.08			0.42	0.20			8.6±2.9	(8-9)	7.8±2.5
48 *Eugerres brasilianus*	<0.0001	99.9	0.0021	98.2	3.1													0.14	2.48			0.83	1.47	13.2±3.6	(8-23)	13.2±3.6
49 *Synghnathus scovelli*	<0.0001	99.9	<0.0001	98.2	1.0					0.12	0.03			9	9											9
50 *Guavina guavina*	<0.0001	99.9	0.0003	98.3	1.6							0.17	0.42	10	10	0.11	0.36							12	12	11±1.4
51 *Synodus foetens*	<0.0001	99.9	0.0002	98.3	2.6											0.31	0.05					0.17	0.37	5.3±2.3	(5-6)	5.3±2.3
52 *Peprilus paru*	<0.0001	99.9	0.0001	98.4	1.6													0.37	0.21					7.5±2.7	(7-8)	7.5±2.7
53 *Paralichthys brasiliensis*	<0.0001	99.9	0.0002	98.4	1.0															0.63	0.81			9	9	9
54 *Conodon nobilis*	<0.0001	99.9	0.0004	98.5	2.1		0.07							8	8							0.19	0.79	14	14	11±4.2
55 *Erotelis smaragdus*	<0.0001	99.9	<0.0001	98.5	0.5							0.11	0.07	6±2.4	(4-8)											6±2.4
56 *Rypticus randalli*	<0.0001	99.95	0.0007	98.7	1.0																	0.33	1.59	16	16	16
57 *Sciades proops*	<0.0001	99.96	0.0012	99.0	1.0											0.19	4.20							26	26	26
58 *Archosargus rhomboidalis*	<0.0001	99.96	<0.0001	99.0	1.0																	0.25	0.02	4	4	4
59 *Odontesthes bonariensis*	<0.0001	99.97	<0.0001	99.0	1.0																	0.23	0.03	6±2.4	(5-7)	6±2.4
60 *Genyatremus luteus*	<0.0001	99.97	0.0007	99.2	1.0					0.03	1.29			17	17											17
61 *Ophichthus ophis*	<0.0001	99.98	0.0019	99.7	1.0											0.16	6.59							7	7	7
62 *Anisotremus surinamensis*	<0.0001	99.98	0.0003	99.8	1.0																		0.67	13	13	13
63 *Lagocephalus laevigatus*	<0.0001	99.98	0.0001	99.8	1.0					0.03	0.09													5	5	5
64 *Diapterus rhombeus*	<0.0001	99.99	<0.0001	99.8	1.0															0.24	0.06			12	12	12
65 *Hippocampus reidi*	<0.0001	99.99	0.0001	99.8	1.0															0.24	0.21			11	11	11
66 *Lutjanus jocu*	<0.0001	99.99	0.0002	99.9	1.0													0.10	0.26					4	4	4
67 *Sciades couma*	<0.0001	99.997	0.0002	99.9	1.0	0.005	0.36							18	18											18
68 *Centropomus undecimalis*	<0.0001	100	0.0002	100	0.5							0.05	0.43	17	17											17
Total Fish	**0.1878**		**0.3777**			**0.97**	**0.52**	**0.08**	**0.42**	**0.22**	**0.44**	**0.09**	**0.41**			**0.04**	**0.23**	**0.05**	**0.48**	**0.02**	**0.19**	**0.03**	**0.35**			
Crustaceans																										
69 *Callinectes danae*	0.019		0.221			0.004	0.09	0.004	0.04	0.01	0.05	0.01	0.02	4.2±2	(1-19)	0.02	0.24	0.02	0.47	0.05	0.43	0.03	0.43	3.2±1.8	(1-11)	3.7±1.9
70 *Litopenaeus schimitti*	0.022		0.046			0.04	0.08	0.02	0.05	0.04	0.07	0.03	0.06			0.01	0.05	0.003	0.01	0.03	0.03	0.001	0.01			
Total	**0.041**		**0.267**			**0.04**	**0.17**	**0.03**	**0.10**	**0.05**	**0.12**	**0.04**	**0.08**			**0.04**	**0.30**	**0.03**	**0.47**	**0.08**	**0.46**	**0.03**	**0.44**			
Total Fish & Crustaceans	**0.229**		**0.645**			**1.01**	**0.69**	**0.11**	**0.51**	**0.26**	**0.55**	**0.13**	**0.48**			**0.08**	**0.53**	**0.08**	**0.95**	**0.10**	**0.65**	**0.07**	**0.79**			
Wrack			**3.863**				**0.88**		**2.09**		**0.99**		**0.10**				**16.64**		**0.87**		**0.99**		**8.34**			

Appendix 2

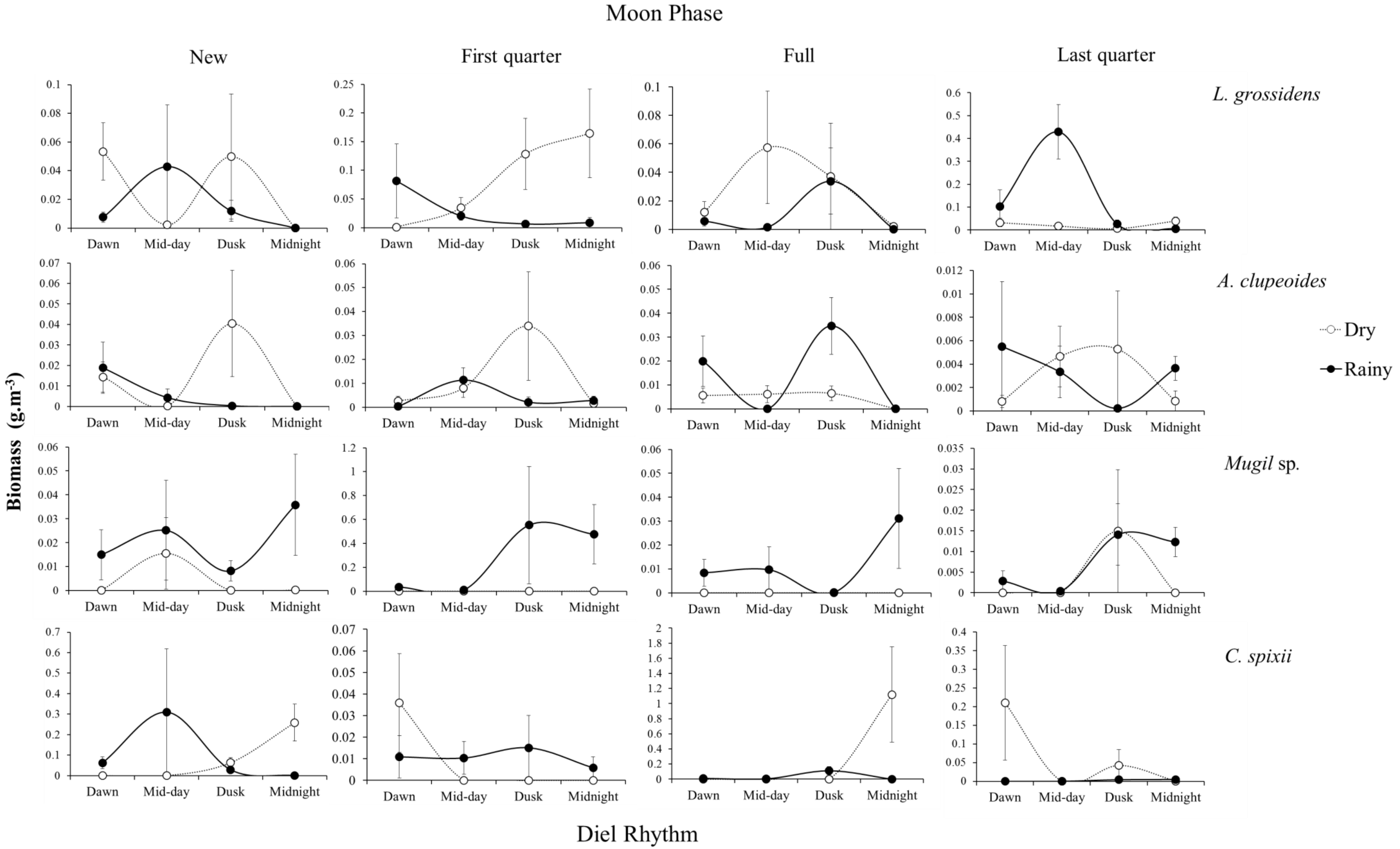


Moon Phase
New
First quarter
Full
Last quarter
L. grossidens
A. clupeoides
Mugil sp.
C. spixii
Dry
Rainy
Density (ind.m-3)
Dawn
Mid-day
Dusk
Midnight
Diel Rhythm

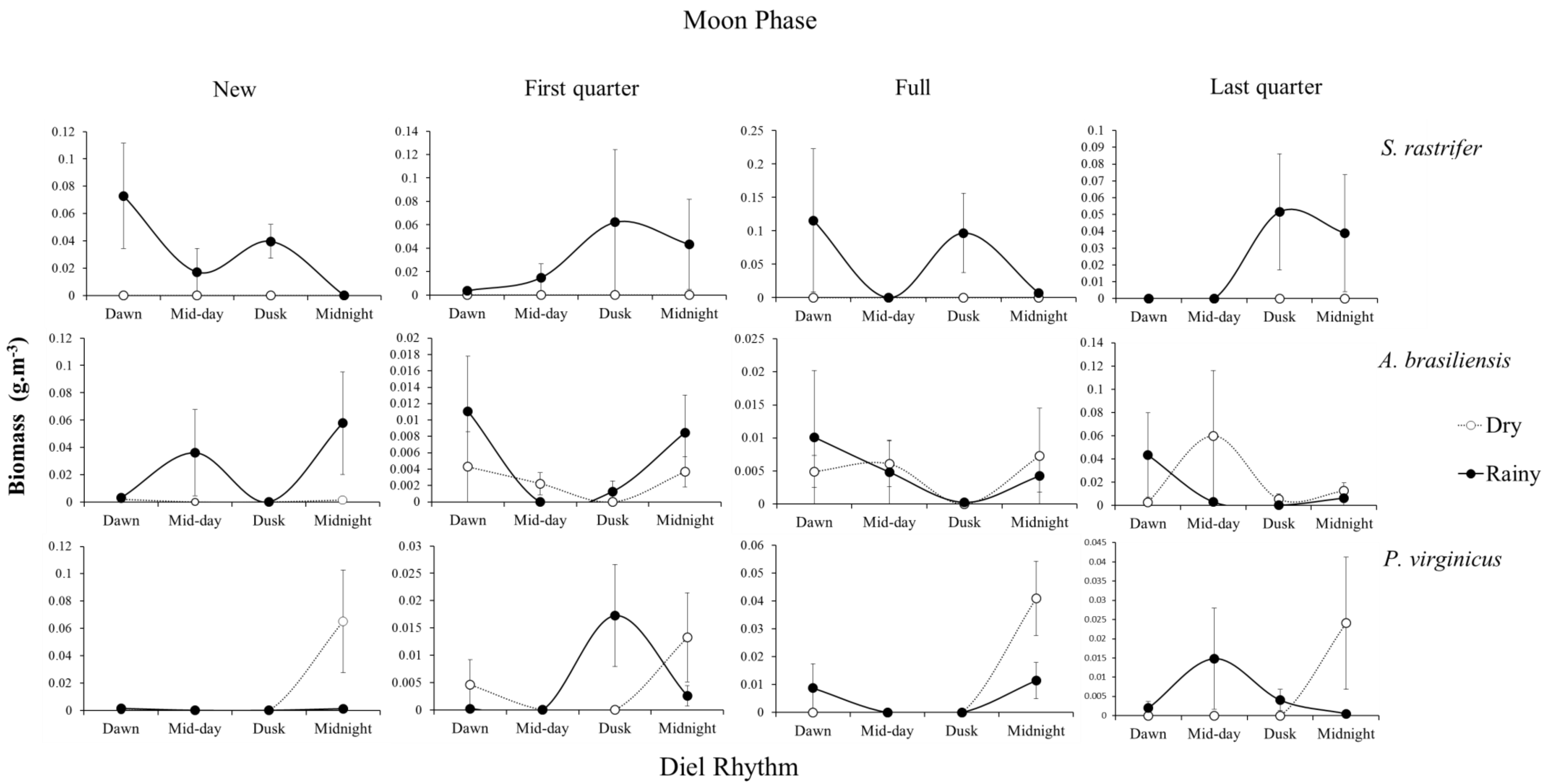
Appendix 2. Continued



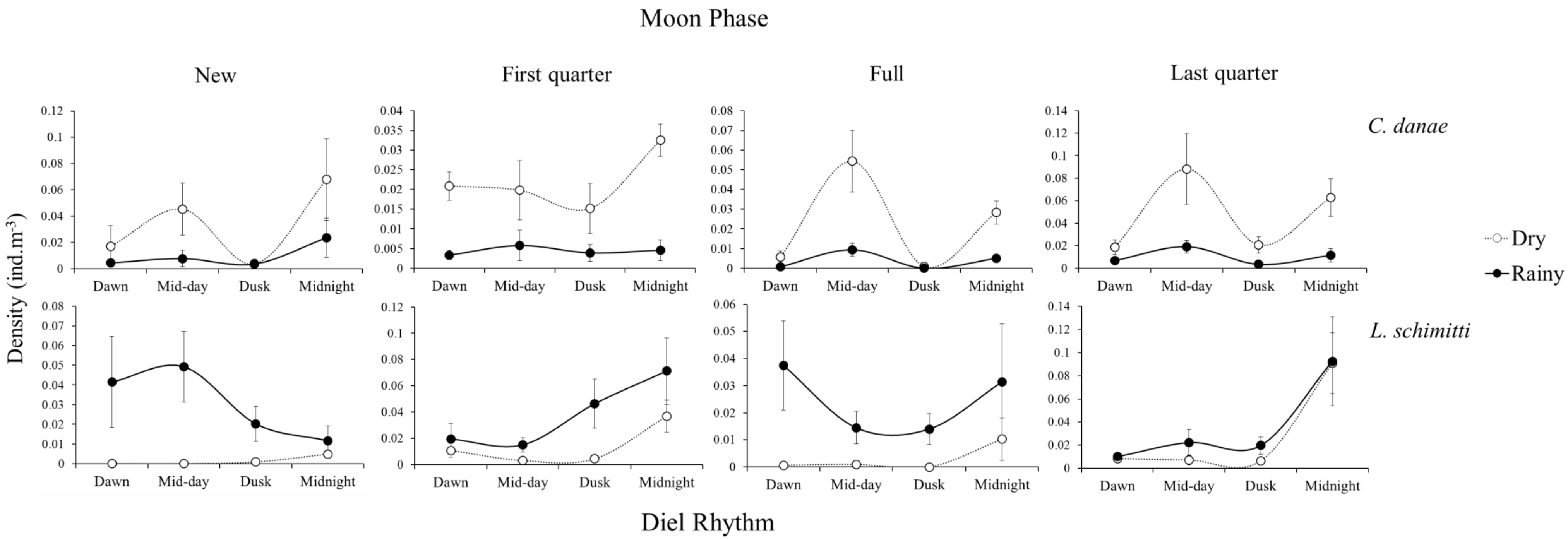
Appendix 3


Moon Phase
New
First quarter
Full
Last quarter
L. grossidens
A. clupeoides
Mugil sp.
C. spixii
Dry
Rainy
Biomass (g.m-3)
Dawn
Mid-day
Dusk
Midnight
Diel Rhythm

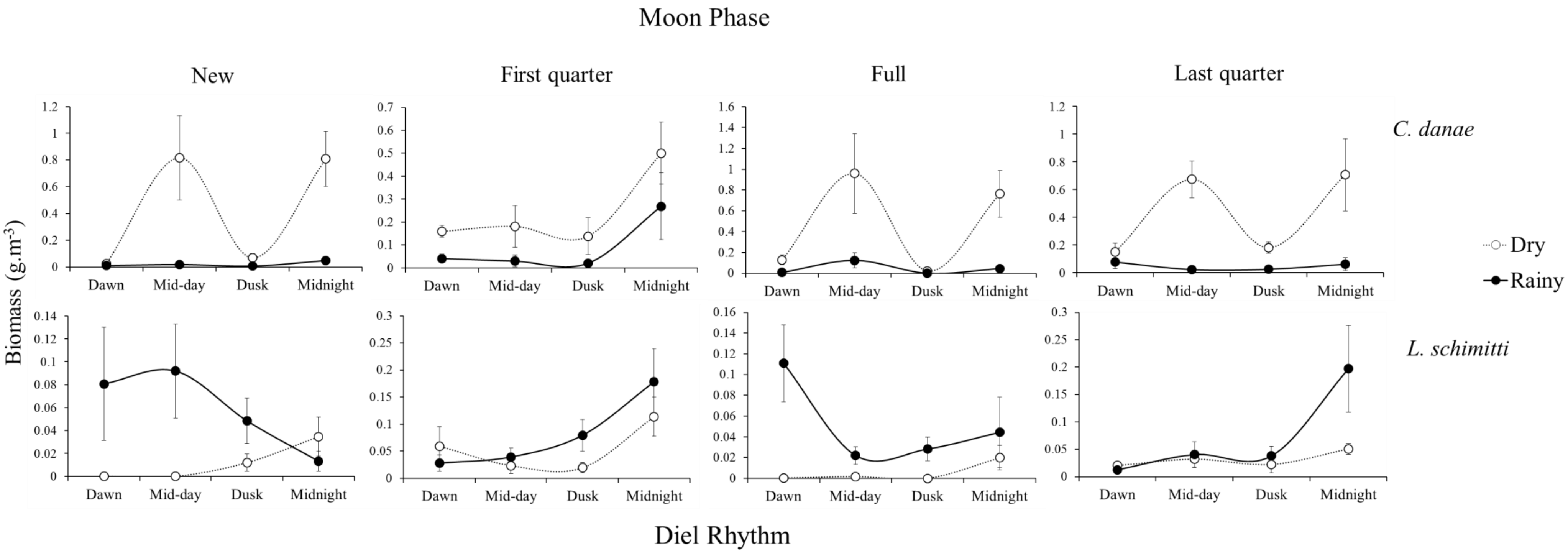
Appendix 3. Continued



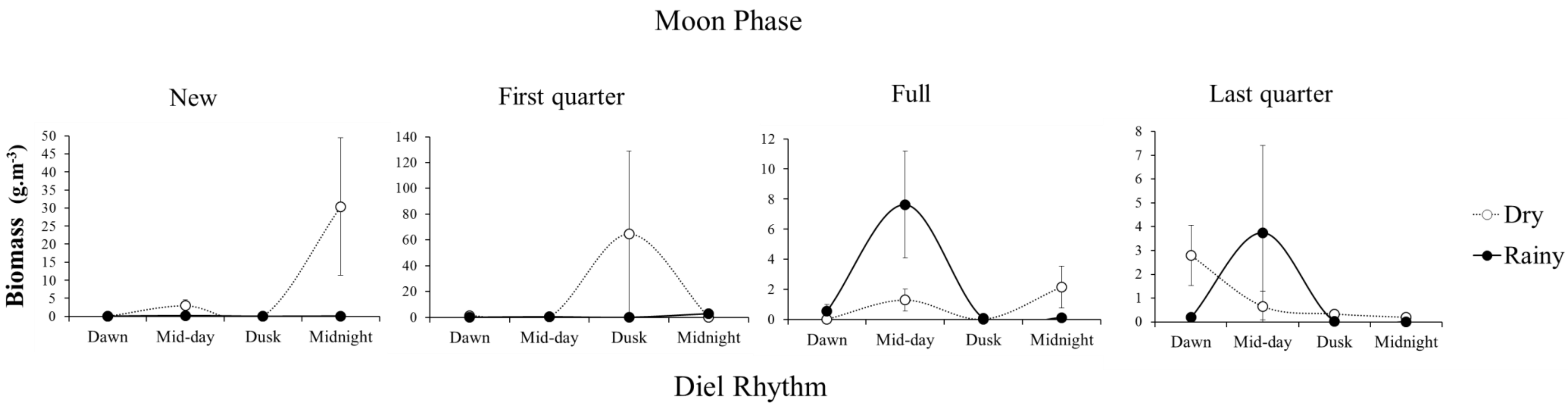
Appendix 4


Moon Phase
New
First quarter
Full
Last quarter
C. danae
L. schimitti
Dry
Rainy
Density (ind.m-3)
Dawn
Mid-day
Dusk
Midnight
Diel Rhythm

Appendix 4. Continued



Appendix 5



Moon Phase
New
First quarter
Full
Last quarter
Biomass (g.m-3)
Dawn
Mid-day
Dusk
Midnight
Dry
Rainy
Diel Rhythm

Capítulo 3

Spatial and seasonal variations of intertidal community in estuarine sandy beaches

Spatial and seasonal variations of intertidal community in estuarine sandy beaches

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Running title: Spatial-temporal patterns on fish assemblages

ABSTRACT

The use of intertidal sandy beaches by fish and macrocrustaceans was studied to identify the patterns on habitat use in space and time. With a beach seine net, samples were taken between October 2010 and September 2011. Fish assemblage (density, biomass, number of species and trophic guilds) and the biomass of wrack showed significant interactions among all studied factors (shore, season and distance from the river mouth). Differences in the river discharge between shores lead to spatial and temporal patterns in the environmental variables (salinity, water temperature, Relative Tidal Range and $CaCO_3$ %) and faunal community (total density, biomass, number of species and trophic guilds) . This habitat showed great importance to the early stages of marine and estuarine species of fishes, which dominated this environmental seasonally, suggesting an important habitat cycle, increasing the connection among the adjacent habitats (main channel, mangrove forest and coastal waters).

Keywords: crustaceans, ecological guilds, fish assemblage, low tide terrace, young-of-the-year

INTRODUCTION

Surrounded by the growing population increase, coastal environments are the regions that most suffer the anthropogenic pressures, while promoting several services (*e.g.* protein, transport, tourism, industries and port activities) to human society. In the same time, coastal ecosystems are broadly recognized as important transition zones, with high productive and numerous habitats valuable for aquatic community, supporting fundamental ecological links with other environments (Blaber *et al*., 1995; Costanza *et al*., 1997; Nagelkerken *et al*., 2000; Beck *et al*., 2001; Barletta & Blaber, 2007; Barletta *et al*., 2008; Vasconcelos *et al*., 2010). More than ever, scientific researches evidence habitat loss and decreasing living researches availability for the aquatic life which require these ecosystems (Barletta & Costa, 2009; Barletta *et al*., 2010; Newtom *et al*., 2012).

Amid different habitats present in an estuarine ecosystem, intertidal sandy/mud beaches located in adjacent areas are dynamic environments and essential habitat for various types of fauna (Defeo & McLachlan, 2005; Mclachlan & Brown, 2006). Such environments, usually behave under strong influence of several environmental factors as tidal regime (moon and diel cycle) and river discharge (nutrients, sediment, pollution and freshwater). Juveniles of fishes species can spend their first years of life in these habitats, enhanced their fitness until recruitment, under favorable conditions as better feeding researches, optimal growth, refuge opportunities and connectivity with other habitats (Blaber *et al*., 1989, 1995; Miller *et al*., 1991; Elliot & Dewailly, 1995; Beck *et al*., 2001; Barletta & Blaber, 2007; Vasconcelos *et al*., 2010).

Studies realized on sand/mud beaches in tropical (Pessanha & Araújo, 2003; Gaelzer & Zalmon, 2008; Inui *et al*., 2010), subtropical (Lima & Vieira, 2009; Lercari *et al*., 2010; Mont´Alverne *et al*., 2012) and temperate (Lastra *et al*., 2006; Dolbeth *et al*., 2008; Franco *et al*., 2008) regions, showed many habitat features as salinity, water temperature, seasonal cycle and distance from the river mouth, affecting the availability of nutrients and preys in such environments, leading a different patterns on habitat use by faunal communities.

In tropical coastal ecosystems, the proximity and connective among different high productive environments (*e.g.* mangrove, main channel, sea grass meadows, coral reefs and coastal waters), can assign essential key functions for intertidal coastal habitats. In the Northeast Brazilian coast, ecological studies are scarce (Ramos *et al*., 2011; Oliveira & Pesanha, 2014) and the information about the use of intertidal habitats by fishes assemblages are rare. The present study aims to identify spatial (distance from river mouth), temporal (seasons) and environmental factors (salinity, dissolved oxygen, water temperature, Relative Tidal Range and $CaCO_3$ on sediment) which can affect the use of intertidal sandy/mud beaches by the macro faunal community, in the adjacent area of a tropical estuary. Moreover, the knowledge about the ecological functions of these intertidal habitats can assist fishery and nature conservation managers, in their planning of coastal habitats use.

MATERIALS AND METHODS

STUDY AREA

Sandy beaches located in the adjacent area of the Goiana River estuary (Northeast Brazil) were study (Fig. 1). The Goiana River main channel, cross a tide terrace along the south shore of the estuary. A detailed description about the Goiana Estuary and adjacent area, and seasonal definitions adopted in the present study [ED, *early dry season* (September-November); LD, *late dry season* (December-February); ER, *early rain season* (March-May); LR, *late rain season* (June-August)] followed Barletta & Costa (2009). Local winds (available from Centro de Previsão de Tempo e Estudos Climáticos - CPTEC/INPE, on www.cptec.inpe.gov.br, PCD Goiana) showed the predominance from East and Northeast during the dry season, and most intensity winds from South during the rainy season (Appendix 1). The rainfall local regime was available from National Institute of Meteorology (INMET, Curado-82900, on www.inimet.gov.br) (Fig. 2).

Since 2007, the Goiana River Estuary became part of a Marine Conservation Unity (MCU) of the type Extractive Reserve (RESEX Acaú-Goiana), covering an area of 4700 ha, including the Goiana River main channel and adjacent areas (e.g. flooded mangrove forests, coastal habitats and fisher's settlements).

SAMPLING METHODS

Before each sampling, environmental variables as water temperature (°C), salinity and dissolved oxygen ($mg.L^{-1}$) were taken (oximeter Cell Ox 340 WTW, Germany; hand refractometer Atago S/Mill-E, Japan). In similar way, wave height (Hb) was measured visually, with a graduated ruler, for the calculation of the Relative Tidal Range (RTR= tidal range / Hb), and a sediment sample, for the estimation of $CaCO_3$ percentage. Sandy/mud beaches on both shores (north and south) of the Goiana Estuary were sampled. Three sample areas (A1, A2 and A3) located at different distances from the mouth of Goiana River were studied (Fig. 1). Between October 2010 and September 2011, three replicates were taken in each sample area during the first quarter moon of each month (N = 216 samples).

The beach community was sampled with a beach seine net 10 m long, which had 7 meters of opening and consisted of 10 mm mesh-size (between knots) in the body and 5 mm in the cod-end. All samples lasted five minutes and the start and end positions were recorded by GPS (Garmin GPS 12 Navigation, Olathe, KS, U.S.A.) for subsequent calculation of the swept volume (V), which was calculated from:

$$V = DLm \quad (1)$$

where, D is the average depth, L is the swept distance (m) and m is the length of net opening which is equal to the width of the path swept by the beach seine net. The capture per united effort (CPUE) was used for estimation of density (eq. 2) and biomass (eq. 3) (Sparre & Venema, 1997).

$$\text{Density} = individuals*V^{-1}\ (\text{ind.m}^{-3})\ (2)$$

$$\text{Biomass} = grams*V^{-1}\ (\text{g.m}^{-3})\ (3)$$

Fish and crustaceans were identified until the species level (in the most cases) (Figueiredo & Menezes, 1978, 1980; Fischer, 1978; Menezes & Figueiredo, 1980, 1985; Cervigón 1985, 1991, 1993, 1994,1996; FAO, 2002, Humann & Deloach, 2002) counted, weighed and the standard length (*L*s) were measured. Fishes and crustaceans species were classified in ecological guilds (trophic and functional) based on Barletta & Blaber (2007), Elliott *et al*. (2007) and Potter *et al.* (2013).

STATISTICAL ANALYSIS

A factorial analysis of variance (Three-Way ANOVA), was used to identify differences in community features (number of fish species, density and biomass of fish and crustaceans, biomass of wrack and trophic guilds) and environmental variables (salinity, water temperature, dissolved oxygen, RTR and $CaCO_3$ concentration on sediment) among the factors shore, season and area. When necessary, the data were standardized (Box & Cox, 1964) to increase normality. In the case of significant differences identified by ANOVA, the Bonferroni test at 5% probability to determine the difference between means was applied (Quinn & Keough, 2003). Similarity matrices were computed using PRIMER (Clarke & Warwick, 1994). Preceding the analysis, the original data matrix (total biomass) was reduced (maintained the twenty fish species best ranking in the variables density, biomass and frequency of occurrence) to remove any undue effects of rare species on the analysis (Gauch, 1982). The clusters were determined using ranked similarities with Bray-Curtis index for species biomass (*R*-mode analyzes) and Euclidian distance for environmental variables (*Q*-mode analyses).

Canonical correspondence analysis (CCA) (CANOCO for Windows 4.5) was used to measure ecological interactions among the total mean biomass of intertidal community (dependent variable) and environmental variables (independent variables) for each season (dry and rainy) (ter Braak & Smilauer, 2002). CCA is a direct gradient analysis where the species composition, or distribution, is directly related to environmental variables (Palmer, 1993). To perform a CCA, a multiple least-squares regression was computed with the site scores (derived from weighted averages of species) (ter Braak, 1986; Palmer, 1993). The biomass data of beach community were analyzed to extract patterns of variation in relation to the environmental data (direct gradient analysis). These analyses focused on symmetric and biplot scaling, and a Monte-Carlo permutation test was used to determine which environmental variables were significant to the variability of the dependent variables. The CCA was run with 100 iterations with randomized site locations to facilitate Monte-Carlo tests (between the eigenvalues and species–environment correlations). The CCA produces a biplot where environmental variables are represented as arrows (eigenvectors) radiating from the origin of the ordination. The length of the environmental vector, is related to the strength of the relationship between the environmental variable that the vector represents, and the species assemblages analyzed for each season (ter Braak, 1986).

RESULTS

ENVIRONMENTAL VARIABLES

The three-way ANOVA showed significant interactions among the factors shores, season and area, for salinity, water temperature and $CaCO_3$ (Table I). High values ($P<0.05$) of salinity (36), water temperature (32.2°C) and dissolved oxygen (17.7 $mg.L^{-1}$) occurred during the dry season (Table I; Fig. 3). The major values of $CaCO_3$ (~85%) and RTR (33) were recorded during the ER, in the south shore of the estuary. Even more, lowest values of $CaCO_3$ and water temperature were founded on the A3

(3.05% and 24.7°C respectively), on both shores (Table I; Fig. 3). Cluster analysis of the abiotic data differentiated three main groups (Fig. 4). The first group was subdivided in two subgroups. The subgroup I.A. represented the south shore of the estuary, mainly in the A1, and was subdivided in more two subgroups, representing the LD ($I.A_1$) and the rainy season ($I.A_2$). The subgroup I.B. represent the north shore of the estuary, and was subdivided in two subgroups, representing the dry ($I.B_1$) and rainy ($I.B_2$) seasons. The second group represents the south shore, and was subdivided in two subgroups representing the ED (II.A) and ER (II.B) seasons. Finally, the last group (III) was represented by the A3 in the ED.

INTERTIDAL FAUNAL COMMUNITY

Eighty-eight fish species distributed in thirty five families were recorded. The fish assemblage contributed for 74.1% and 83.4% of the total fauna (fish and crustaceans) mean density (0.224±0.01 ind.m^{-3}) and biomass (0.764±0.02 g.m^{-3}), respectively (Appendix 2). The species *Lycengraulis grossidens* (Spix & Agassiz 1829), *Anchovia clupeoides* (Swainson 1839), *Stellifer stellifer* (Bloch 1790), *Polydactylus virginicus* (L. 1758), *Larimus breviceps* (Cuvier 1830), *Cathorops spixii* (Spix & Agassiz 1829) and *Pomadasys corvinaeformis* (Steindachner 1868) were the most important species of fish in number (79.8 % of total fishes density) and represented 64.1% of total fish biomass (Appendix 2). In the crustaceans community, two species of *Callinectes* spp. were taken, with large dominance of *C. danae* (Smith 1869), as well as, Penaeidae species, most represented by *Litopenaeus schimitti* (Burkenroad 1938), the most important crustacean in number (93.1%) and weigh (72.5%). The mean biomass of wrack representing 97% of the total biomass caught (Appendix 2).

SEASONAL AND SPATIAL VARIATIONS IN THE INTERTIDAL COMMUNITY

Significant interactions (Three-Way ANOVA) were detected among shore *vs.* season *vs.* area for total density and biomass of fauna (fishes and crustaceans), total fish density and wrack biomass (Tables II, III; Appendices 3, 4). The highest biomass of total faunal community (0.02±0.01 $g.m^{-3}$), as well as, the major abundance of crustaceans (0.03±0.001 $ind.m^{-3}$; 0.06±0.01 $g.m^{-3}$) was observed during the rainy season, with lowest values in the A1, independent of shore factor. During this season, high abundance (density and biomass) of species as *C. spixii*, *L. schimitti* and *S. stellifer* was caught. During the dry season, *L. grossidens*, *P. corveneiformis*, *M. americanus* and *P.virgynicus* (biomass) showed highest abundance, mostly on south shore of the estuary (except *P. corveneiformes*) (Tables II, III; Appendices 3, 4). A major density of fish community (total mean) was also observed on the south shore, as well as, highest abundance of *Mugil* spp., *C. danae*, *A. clupeoides* (density) and *L. breviceps* (biomass) (Tables II, III; Appendices 3, 4). In the A1, on both shores, the lowest abundance of total fauna, total crustaceans and wrack (biomass) were observed (Tables II, III; Appendices 3, 4).

Guild Approach

The great majority of fish species were classified as marine immigrants (78%), and although the estuarine species represented only 15% of the fish assemblage (number of species), them represented 56% of the total fish biomass (Appendix 5). In the intertidal habitat, zooplanktivorous (3 spp.) and detritivorous (3 spp.) were the most important trophic guilds in number (62%), and benthophagous (35 spp.) and hyperbenthophagous (20 spp.) in weigh (54%) (Appendix 5).

Zooplanktivorous fish species dominated (density and biomass) the south shore of the estuary during the dry season, with lowest values in the A1 (Table IV, Figs. 5, 6), while benthophagous and detritivorous preferred the north shore, mostly in the A1 (Figs. 5, 6). During the rainy season, this pattern extends into the south shore and a highest biomass of detritivorous was caught. Carnivorous species were not found in the A3 on both shores of the estuary (Table IV, Figs. 5, 6).

PATTERNS ON THE INTERTIDAL COMMUNITY IN RELATION TO SPATIAL, TEMPORAL AND ENVIRONMENTAL FACTORS

The variations on intertidal community, and their interactions among study factors, became clear in the cluster analysis. For the biomass values of the most important species, the *R*-mode cluster analysis differentiated two main groups (Fig. 7). The first group represented the rainy season, and was subdivided in two subgroups, representing the estuarine species ($I.A_1$) and the north shore ($I.A_2$). The second group represented the dry season and was subdivided in north (II.A) and south (II.B) shore (Fig. 7). For the main trophic guilds (biomass) identified in the intertidal community, the *R*-mode cluster analysis differentiated three main groups (Fig. 8). The first group was represented by the north shore, mostly during the rainy season. The second group represented the south shore, mostly during the dry season, and the group III, the south shore during the rainy season principally (Fig. 8).

The CCA ordination (biplot diagrams) of species scores (Fig. 9), and regression analysis (Table V), permitted to analyze the distribution of community groups per season (dry and rain), in relation to fluctuations of the environmental variables. For both seasons, the first axis best explained the distribution of intertidal community, being formed negatively by the eigenvector $CaCO_3$ (P=0.049) on the dry season, and dissolved oxygen (P=0.049) and water temperature (positively, P=0.019) on the rainy season (Table V; Fig. 9).

During the dry season, a spatial division in the faunal community became clearly in the CCA ordination [Fig. 9(a)]. South shore species (*e.g. L. grossidens*, *M. americanus*, *Mugil* sp., *C. danae*) were correlated negatively (Axis I) with the majors environmental variables (except salinity), while others species as *R. bahiensis*, *O. punctatissimus*, *E. melanopterus* and *L. schimitti* seems to prefer the north shore of the estuary, with a positive correlation with salinity [Fig. 9(a)]. On the rainy season ordination of CCA [Fig. 9(b)], spatial patterns on faunal community were also detected. For instance, benthophagous species (*e.g. A. lineatus*, *C. nobilis*, *E. melanopterus*, *P. corveneiformis*) and *L. schimitti* (detritivorous), preferred the north shore of the estuary during the LR, correlating negatively with the most environmental variables (except dissolved oxygen). In the same way, estuarine species (*e.g. A. lineatus, R. bahiensis*, *S. herzbergii*, *S. brasiliensis*) seems to prefer the north shore of the estuary [Fig. 9(b)].

DISCUSSION

THE ROLE OF FLOWING RIVER ON THE ABIOTIC VARIABLES

During the rainy season, the freshwater input and lowest solar radiation, decreasing the salinity and water temperature in the sandy beaches adjacent to Goiana Estuary, which reaching their lowest values on the LR. The southward discharge from the Goiana main channel, intensified the river dominance (*e.g.* input of freshwater and nutrients) in the south shore of the estuary on areas closely to the river mouth. On both shores, the A3 showed minor effect from river discharge. According to Masselink & Short (1993), the values of RTR classify this intertidal environment as a low tide terrace, and the lowest values of this variable on the north shore of the estuary, is probably related to the north boundary of the terrace, located in the A3. In the cluster analysis of the abiotic data, the spatial factors (shore and area) dominated the criteria of grouping by the analysis, while the seasonality was responsible for the subgroups arrangement.

The $CaCO_3$ (%) in the sediment, came by biogenic detritus (mostly *Halimeda* spp.), and the patterns found, suggest the influence of different features of the habitat (and their interactions), as beach rocks located front of the north shore, most intensive winds from south during the rainy season, the pattern of river discharge (nutrients) and mesofauna productivity. Complementary studies in this habitat (Lacerda *et al*., *in press*) showed a strong influence of tide regime in the environmental patterns, with large oscillations along the seasonal, diel and moon cycles.

SPATIAL AND SEASONAL FACTORS ON COMMUNITY DEFAULTS

Like others estuarine systems around the world (Elliot & Dewailly, 1995; Beck *et al*., 2001; Pessanha & Araújo, 2003; Barletta & Blaber, 2007; Nicolas *et al*., 2007; Zhang, 2013), the most individuals were represented by juveniles of marine immigrants and estuarine species, with patterns (spatial and temporal) stimulated by interactions between biotic and abiotic factors (*e.g.* salinity, water temperature, distance from river mouth, reproduction and recruitment).

The intertidal community captured in the external portion of the Goiana Estuary, was basically formed by transient fish species (Horn *et al*., 1999) and macrocrustaceans. The fish assemblage composition in the present study showed great similarity with others sandy beaches along the Brazilian coast, dominated by juveniles and YOY of Engraulidae and Clupeidae species (also some Mugilidae, Gerreidae and Atherinopridae), as in Mamanguape Estuary fifty-two miles northward (Oliveira & Pessanha, 2014), Sepetiba Bay in the Southeast coast (Pessanha & Araújo, 2003; Pessanha *et al*., 2003), Pontal do Sul (Spach *et al*., 2004) and Babitonga Bay (Souza-Conceição *et al*., 2013) in the Southern coast. In most cases, spatial (distance from river mouth) and temporal (season) patterns in the composition of fish assemblages were reported, principally related to fluctuations on salinity, water temperature (South coast) and transparency.

On the south shore of the Goiana Estuary, the low tide terrace is crossed by the Goiana River main channel. This fact leads spatial differences in the distribution of mainland nutrients and freshwater input, increasing the river influence southward. Under these conditions, a significant increase of zooplanktivorous occurs in the south shore during the dry season, probably related to the increase on the primary production stimulated by the highest water temperature, transparency and solar radiation. Moreover, differences in the sediment composition ($CaCO_3$ %) can affect (spatially and seasonally) the prey availability between shores (Nicolas *et al*., 2007; Lercari *et al*., 2010), and the trophic strategies of the different species, as the benthophagous which showed high abundance in the north shore of the estuary (more silt concentration in the sediment).

Other spatial difference in the distribution of fish species occurred with carnivorous, which only occurred close to the river mouth and mostly during the rainy season. During this period, high densities of estuarine and nursery species came to occupy the sandy/mud beaches closely to the river mouth (Lacerda *et al.*, in press). On the other hand, detritivorous showed high abundance in the farther area from the river mouth, following the major wrack concentration.

The guild distribution in the intertidal community, showed similar outcomes to those found by Barletta & Blaber (2007) using the same guild classification source (Elliot *et al*., 2007), for a comparison between tropical estuarine systems. The authors showed a dominance of marine immigrants (66%) in Embley Estuary (Northern Australia), with large numbers of benthophagous (41%) in the sandy/mud beaches habitats. However, in the Caeté Estuary (Northern Brazil), the major contribution for the total biomass came from estuarine (75%) benthophagous (90%) fish species. This difference in the predominance of estuarine (Caeté Estuary) and marine (Embley Estuary) juveniles, found by Barletta & Blaber (2007), showed the strong effect of salinity on assemblages in the different reaches of the two systems. Bearing in mind also others surveys on Orinoco Delta, Venezuela (Cervigón, 1985), Cayenne River estuary, French Guiana (Morais & Morais, 1994) and in the coastal areas of Guyana (Lowe-McConnell, 1962), Barletta & Blaber (2007) generalized the patterns of fish species distribution (movements) induced by salinity gradients and seasonal fluctuations, as well as, fish assemblages feeding mode functional groups, for Northern South America. On temperate regions, other studies in coastal shallow waters and estuarine systems (Santos & Nash, 1995; Potter *et al*., 2001; Ibarra *et al*., 2003; Kellnreitner *et al*., 2012), showed similar patterns on guild composition. However, in such latitudes, water temperature oscillations showed an important role in the faunal community patterns.

In the present study, the cluster analyses showed that the seasonality was the most important factor in the criteria of intertidal community grouping, while the spatial factors showed their importance in the subgroups arrangement. Moreover, this pattern does not match those found an approach by trophic guilds, when the spatial factors seems to be more significant in the clusters arrangement. In the canonical correspondence analyses, the projection of eigenvectors (environmental variables) followed the river course discharge and sediment features, and showed high correlation with the community distribution. The salinity fluctuation between seasons was the most important factor for the fish assemblage variance.

THE SEASONAL CYCLE AND HABITAT CONNECTIVITY

Supporting the results found in complementary studies (Lacerda *et al*., *in press*), this intertidal sandy/mud beaches places himself as protected shallow waters, and proved to be an important ecotone between the coastal waters and the internal portion of the estuary, as tidal creeks, already recognized as important nursery habitats for marine migrants fishes species (*e.g.*,, Koch *et al*., 2005; Krumme *et al*., 2005; Barletta & Blaber 2007; Ramos *et al*., 2011). Moreover, like others shallow coastal and estuarine habitats (Blaber *et al*., 1995; Nagelkerken *et al*., 2000; Barletta & Blaber, 2007; Vasconcelos *et al*., 2010; Potter *et al*., 2013; Souza-Conceição *et al*., 2013), this low tide terrace can harbor the juveniles and YOY of many species before being recruited to the sub adult populations, and present itself as an alternative nursery and feeding site for faunal species (Lacerda *et al*., *in press*).

The patterns observed on faunal community and environmental variables in the intertidal sandy beaches, pointed the important function of the seasonal cycle, in the connective role between adjacent habitats. The great majority of fishes species were classified as marine immigrants (~80%), but the dominance (abundance) of this guild only occurs during the dry season, when the habitat lies under dominance of coastal waters (*e.g.* water temperature, transparency, salinity and wrack). During the rainy season, when estuarine conditions (*e.g.* freshwater input, water temperature and turbidity) prevailing in the habitat, estuarine species (~15% of the total species) showed high abundance. Besides others factors (*e.g.* river and coastal integrity), the regular pattern of the rainfall regime was critical to create a habitat cycle that contemplates a high number of species, as well as, different fish assemblages. During the seasonal cycle, sandy beach habitat is made up different temporal niches (*e.g.* wrack, sediment type, primary production, space heterogeneity and size, nursery species) which contribute to the connectivity (energy flow) with the adjacent habitats, marked by species replacement. A conceptual model was proposed to illustrate the dynamic of the habitat features and faunal community between seasons, in the external portion of the Goiana estuary (Fig. 10).

The ecological functions mentioned have shown to be rather sensitive to changes in the environmental patterns (predictability of the seasonal cycle) as well as the rainfall regime and the integrity of the river system, which makes this habitat endangered front of a developing nation. The great productivity and livelihood importance of the Goiana River Estuary were responsible for the creation of a MCU of the type Extractive Reserve (RESEX), here hundreds of families rely of this ecosystem to survive, ensuring the maintenance, and security, of traditional and alternative lifeway. The integrity and productive of the estuarine system were in conflict with the surrounding sugarcane plantations, cement factories, aquiculture, deforestation and industrial activities which are not included in the MCU area. Really, all data highlight the importance of the integrity of this kind of habitat for the maintenance of the biodiversity, local productivity and ecological functions of the estuarine system. Therefore, the recognition of beaches and shallow coastal areas as integral parts of the estuarine-coastal continuum is an urgent matter to be dealt by the nature conservation managers in their planning of coastal habitats uses.

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FIGURES AND APPENDICES CAPTIONS

Fig 1. Study area. The low portion of Goiana River Estuary and adjacent area.

Fig 2. Rainfall data between October 2010 and September 2011. Historical rainfall pattern (red line, from National Institute of Meteorology-INMET, Curado-82900, on www.inimet.gov.br).

Fig 3. Variations on salinity, water temperature (°C), dissolved oxygen ($mg.L^{-1}$), Relative Tidal Range (RTR) and the concentration of $CaCO_3$ (%) in the sediment on both shores of the estuary, during the dry and rainy season.

Fig 4. Cluster dendogram of the environmental variables (salinity, water temperature, dissolved oxygen, Relative Tidal Range-RTR and $CaCO_3$) in the adjacent area of Goiana River Estuary. Shore: N, north; S, south; Seasons: ED, early dry; LD, late dry; ER, early rain; LR, late rain; Area represented by numbers 1, 2 and 3.

Fig 5. Variations on the mean density values ($ind.m^{-3}$) of trophic guilds identified in the intertidal fish community, on both shores of the estuary during the dry and rainy seasons.

.**Fig 6.** Variations on the mean biomass values ($g.m^{-3}$) of trophic guilds identified in the intertidal fish community, on both shores of the estuary during the dry and rainy seasons.

Fig 7. Cluster dendogram of the most abundant species on beach samples in the adjacent area of Goiana River Estuary. Samples clustered by group average of ranked Bray-Curtis similarity index based on biomass values. Species: Cyaco, *C. acoupa*; Stste, *S. stellifer*; Caspx, *C. spixii*; Penaei, L. schimitti; M.O. total (g), total mean biomass of wrack; Mugil, *Mugil* sp.; Rhbah, *R. bahiensis*; Conob, *C. nobilis*; Povir, *P. virginicus*; Anclu, *A. clupeoides*; Lygro, *L. grossidens*; Pocor, *P. corveneiformes*; Callinec, *Callinectes danae*; Meame, *M. americanus*; Labre, *L. breviceps*.

Fig 8. Cluster dendogram of the most important trophic guilds identified on the intertidal faunal community. Samples clustered by group average of ranked Bray-Curtis similarity index based on biomass values.

Fig 9. Canonical correspondent analysis ordination biplot showing species centroids in relation to environmental variables (T°C, water temperature; O_2, dissolved oxygen; SAL, salinity; RTR, Relative Tide Range; $CaCO_3$, percentage of $CaCO_3$ in the sediment) during both seasons, dry (a) and rainy (b). Δ, species: Mugil, *Mugil* sp.; Svomer, *S. vomer*; Lgross, *L. grossidens*; Aclup, *A. clupeoides*; Stestudi, *S. testudineus*; Alinea, *A. lineatus*; Bronchus, *B. ronchus*; Sstell, *S. stellifer*; Rbahiens, *R. bahiensis*; Srastrif, *S. rastrifer*; Hunifasc, *H. unifasciatus*; Cacoupa, *C. acoupa*; Pcroco, *P. croco*; Clattus, *C. lattus*; Cspixii, *C. spixii*; Sherzber, *S. herzberguii*; Opunctat, *O. punctatissimus*; Sbrasili, *S. brasiliensis*; Arhomboi, *A. rhomboidalis*; Cnobilis, *C. nobilis*; Emelano, *E. melanopterus*; Lbrevi, *L. breviceps*; Stessela, *S. tesselatus*; Abrasili, *A. brasiliensis*; Lpiquiti, *L. piquitinga*; Pcorvene, *P. corvinaeformis*; Cundes, *C. undecimalis*; Mamerica, *M. americanus*; Pvirgin, *P. virginicus*; Cdanae, *C. danae*; Lschmitti, *L. schmitti*. Seasons: ED, early dry; LD, late dry; ER, early rain; LR, late rain. Shore: N, north; S, south. Area: A1, area 1; A2, area 2; A3, area 3.

Fig 10. Conceptual model representing the community and habitat features during the dry (a) and rainy (b) seasons.

Appendix 1. Wind patterns along the study period. Wind-Rose graph projected by the software WRPLOT View – *Freeware* (version 7.0). Dada available from DCP Goiana on www.cptec.inpe.gov.br .

Appendix 2. Total mean of density (ind.m^{-3} and %), biomass (g.m^{-3} and %), frequency of occurrence (%) and standard length (*L*s ± SD) of fish and main crustaceans species, during the study period. Trophic guilds (1, planktivorous; 2, detritivorous; 3, herbivorous; 4, carnivorous; 5, benthophagous; 6, hyperbenthophagous; 7, zooplanktivorous) and Functional guilds (1, marine straggler; 2, marine immigrants; 3, estuarine species; 4, anadromous; 5, amphidromous; 6, freshwater stragglers) considered in this study.

Appendix 3. Variations on density values of the main fish species on both shores of the estuary during the dry and rainy seasons.

Appendix 4. Variations on biomass values of the main fish species on both shores of the estuary during the dry and rainy seasons.

Appendix 5. Total mean of density (ind.m^{-3} and %) and biomass (g.m^{-3} and %) of the most important trophic guilds identified in the intertidal community.

TABLE I. Summary of the three-way ANOVA and Bonferroni test results for the environmental variables (salinity, temperature, dissolved oxygen, Relative Tidal Range and CaCO3 percentage). Differences among shores, seasons and area were indicated by underlined (_). S, south shore; N, north shore; ED, early dry season; LD, late dry season; ER, early rain season; LR, late rain season; A1, area 1; A2, area 2; A3, area 3; *ns*, non-significant (P>0.05).* P<0.05; **P<0.01.

	Source of Variance			
Environmental variables	**Shore (1)**	**Season (2)**	**Area(3)**	**Interactions**
Salinity	N S *	LR ER ED LD **	*ns*	1 x 2 x 3 **
Temperature (T°C)	*ns*	LR ED ER LD **	A3 A2 A1 **	1 x 2 x 3 **
Dissolved oxigen ($mg.L^{-1}$)	*ns*	ER LD LR ED **	*ns*	*ns*
RTR	N S **	ED LR LD ER	*ns*	1x2 **
$CaCO_3$ (%)	N S **	LR LD ED ER **	A3 A1 A2 **	1 x 2 x 3 **

TABLE II. Summary of the three-way ANOVA and Bonferroni test results for number of fish species, total density (fish and crustaceans) and density values of the most important species of fishes and crustaceans. Differences among shores, seasons and area were indicated by underlined (_). S, south shore; N, north shore; ED, early dry season; LD, late dry season; ER, early rain season; LR, late rain season; A1, area 1; A2, area 2; A3, area 3; *ns*, non-significant (*P*>0.05).* *P*<0.05; ***P*<0.01.

	Source of Variance						
Variables	**Shore (1)**		**Season (2)**		**Area(3)**		**Interactions**
Number of species	*ns*		LD ED LR ER	**	*ns*		1 x 2 ** 2 x 3 **
Fish Density (ind.m^{-3})							
Total	N S	*	LR ED LD ER	*	*ns*		1 x 2 x 3 *
L. grossidens	N S	**	LR ER ED LD	**	A1 A3 A2	*	1 x 2 x 3 *
A. clupeoides	N S	*	*ns*		*ns*		ns
L. breviceps	*ns*		ED LD LR ER	**	*ns*		1 x 2 x 3 **
S. stellifer	*ns*		LD ED LR ER	**	*ns*		*ns*
P. virgynicus	*ns*		*ns*		A1 A2 A3	*	ns
C. spixii	*ns*		LD ED LR ER	**	*ns*		1x3 **
P. corveneiformes	*ns*		LR ER ED LD	**	*ns*		*ns*
R. bahiensis	*ns*		LD ED ER LR	*	*ns*		*ns*
Mugil sp.	N S	*	LD ER ED LR	*	A3 A2 A1	*	*ns*
M. americanus	N S	**	LR ER ED LD	**	*ns*		1 x 2 *
Crustaceans Density (ind.m^{-3})							
Total	*ns*		LD ED ER LR	**	A1 A2 A3	**	*ns*
Callinectes danae	N S	*	LR ED LD ER	*	*ns*		*ns*
Litopenaeus schimitti	*ns*		LD ED ER LR	**	A1 A2 A3	**	*ns*
Total density of fauna (ind.m^{-3}) (fishes and crustaceans)	*ns*		*ns*		A1 A3 A2	*	1 x 2 x 3 **

TABLE III. Summary of the three-way ANOVA and Bonferroni test results for biomass values of fish species, total biomass (fish and crustaceans) and wrack biomass. Differences among shores, seasons and area were indicated by underlined (_). S, south shore; N, north shore; ED, early dry season; LD, late dry season; ER, early rain season; LR, late rain season; A1, area 1; A2, area 2; A3, area 3; *ns*, non-significant (P>0.05).* P<0.05; **P<0.01.

	Source of Variance						
Variables	**Shore (1)**		**Season (2)**		**Area(3)**		**Interactions**
Fish Biomass (g.m^{-3})							
Total	*ns*		LR ED ER LD	**	A3 A1 A2	*	1 x 2 ** 1 x 3 **
L. grossidens	N S	**	LR ER ED LD	**	A1 A3 A2	*	1 x 2 x 3 *
A. clupeoides	*ns*		*ns*		*ns*		*ns*
L. breviceps	N S	**	*ns*		*ns*		1 x 2 x 3 **
S. stellifer	*ns*		LD ED LR ER	**	A3 A1 A2	**	1 x 3 ** 2 x 3 *
P. virgynicus	N S	**	LR ER ED LD	**	A1 A2 A3	**	1 x 2 x 3 **
C. spixii	*ns*		LD ED ER LR	**	*ns*		1x3 **
P. corveneiformes	*ns*		LR ED ER LD	**	*ns*		*ns*
R. bahiensis	*ns*		LD ER ED LR	**	*ns*		*ns*
Mugil sp.	N S	*	LD ER LR ED	*	*ns*		*ns*
M. americanus	N S	**	LR ER ED LD	**	*ns*		1 x 2 ** 2 x 3 *
Crustaceans Biomass (g.m^{-3})							
Total	*ns*		LD ED ER LR	**	A1 A2 A3	*	1 x 2 **
Callinectes danae	N S	*	LR ED LD ER	**	*ns*		*ns*
Litopenaeus schimitti	*ns*		LD ED ER LR	**	A1 A2 A3	**	*ns*
Total biomass of fauna (g.m^{-3}) (fishes and crustaceans)	*ns*		LD ED ER LR	*	A1 A3 A2	**	1 x 2 x 3 **
Wrack Biomass (g.m^{-3})	*ns*		LR LD ER ED	*	A1 A2 A3	**	1 x 2 x 3 **

TABLE IV. Summary of the three-way ANOVA and Bonferroni test results for density and biomass values of the main trophic guilds identified in the fish community. Differences among shores, seasons and area were indicated by underlined (_). S, south shore; N, north shore; ED, early dry season; LD, late dry season; ER, early rain season; LR, late rain season; A1, area 1; A2, area 2; A3, area 3; *ns*, non-significant (P>0.05).* P<0.05; **P<0.01.

	Source of Variance							
Trophic guilds	**Shore (1)**		**Season (2)**		**Area(3)**		**Interactions**	
Density (ind.m^{-3})								
Benthophagous	S N	**	*ns*		A3 A2 A1	**	1 x 2 x 3	*
Detritivorous	S N	**	*ns*		A3 A2 A1	**	1 x 2 x 3	*
Herbivorous	*ns*		*ns*		A1 A2 A3	*	1 x 3	*
Hyperbenthophagous	*ns*		LD ED LR ER	**	*ns*		1 x 3	*
Carnivorous	*ns*		*ns*		A3 A2 A1	*	1 x 2 x 3	*
Planktivorous	*ns*		LD ED ER LR	**	A3 A1 A2	*	1 x 2	**
Zooplanktivorous	N S	**	LR ER ED LD	**	A1 A3 A2	*	1 x 2 x 3	*
Biomass (g.m^{-3})								
Benthophagous	S N	*	*ns*		*ns*		1 x 2 x 3	**
Detritivorous	*ns*		LD ED ER LR	**	*ns*		1 x 2	**
Herbivorous	*ns*		*ns*		*ns*		*ns*	
Hyperbenthophagous	*ns*		ED LR LD ER	*	A1 A3 A2	*	1 x 2 x 3	*
Carnivorous	*ns*		*ns*		A3 A1 A2	*	1 x 2 x 3	*
Planktivorous	*ns*		*ns*		A3 A2 A1	*	1 x 2	*
Zooplanktivorous	N S	**	LR ER ED LD	**	A1 A3 A2	*	1 x 2 x 3	**

TABLE V. Results of canonical correspondence analysis. * $P<0.05$

a. Dry season	Axis 1	Axis 2	
Eigenvalue	0.221	0.159	
Species-environmental correlation	0.971	0.936	
Cumulative % variance			
of species data	22.7	39.1	
of species environmetal relation	41.9	72.0	
Correlation with environmental variables			*p*-value
RTR	-0.7120	0.1285	0.2574
$CaCO_3$ (%)	-0.8342*	0.0240	0.0495
Salinity	0.3092	0.6330	0.1782
Water temperature (°C)	-0.2218	-0.5922	0.8713
Dissolved oxygen ($mg.L^{-1}$)	0.1749	0.3953	0.2079

b. Rainy season	Axis 1	Axis 2	
Eigenvalue	0.210	0.134	
Species-environmental correlation	0.912	0.964	
Cumulative % variance			
of species data	26.5	43.4	
of species environmental relation	46.7	76.5	
Correlation with environmental variables			*p*-value
RTR	-0.2530	-0.6253	0.3861
$CaCO_3$ (%)	0.0525	-0.6537	0.3168
Salinity	-0.4157	-0.4452	0.2772
Water temperature (°C)	0.0545*	-0.7788	0.0198
Dissolved oxygen ($mg.L^{-1}$)	-0.5849*	0.3890	0.0495

Fig 1


0º
South America
Atlantic Ocean
3
2
1
North Shore
Goiana River
Atlantic Ocean
Mangrove Forest
1
2
3
South Shore
Goiana Estuary
N
300
1200
0
600
m

Fig 2

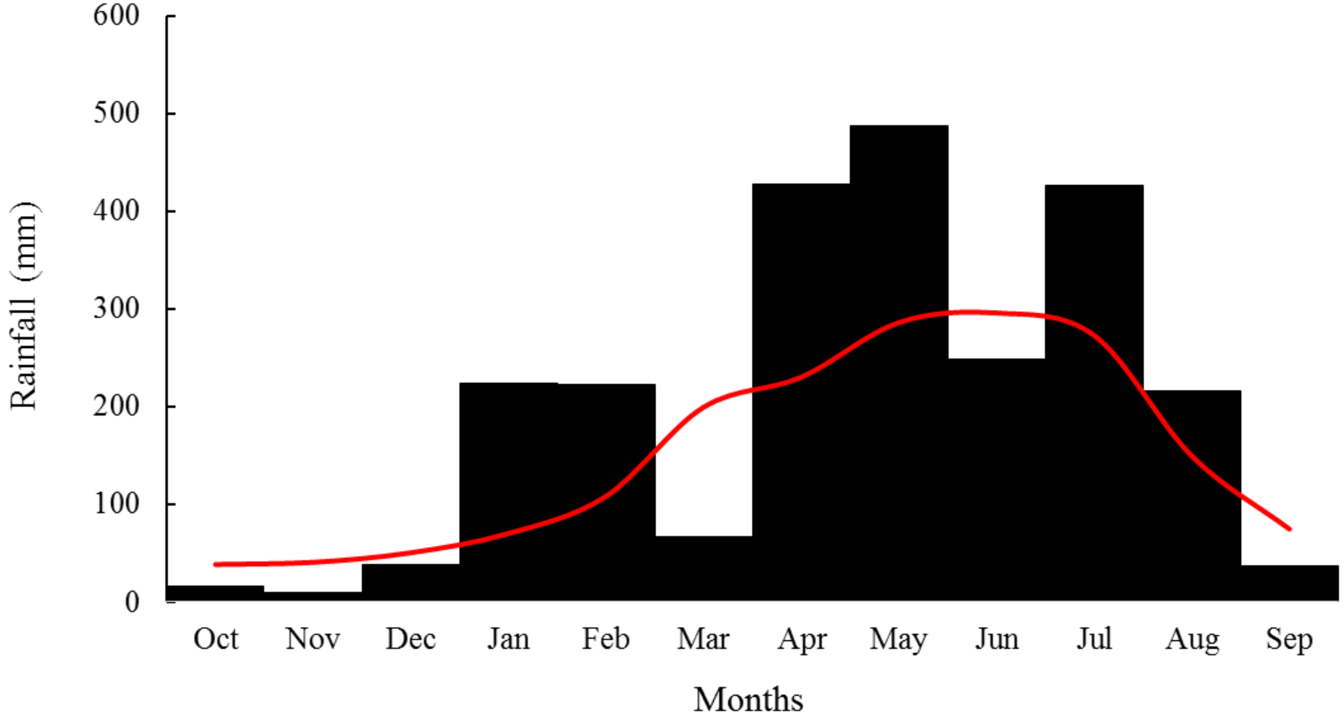
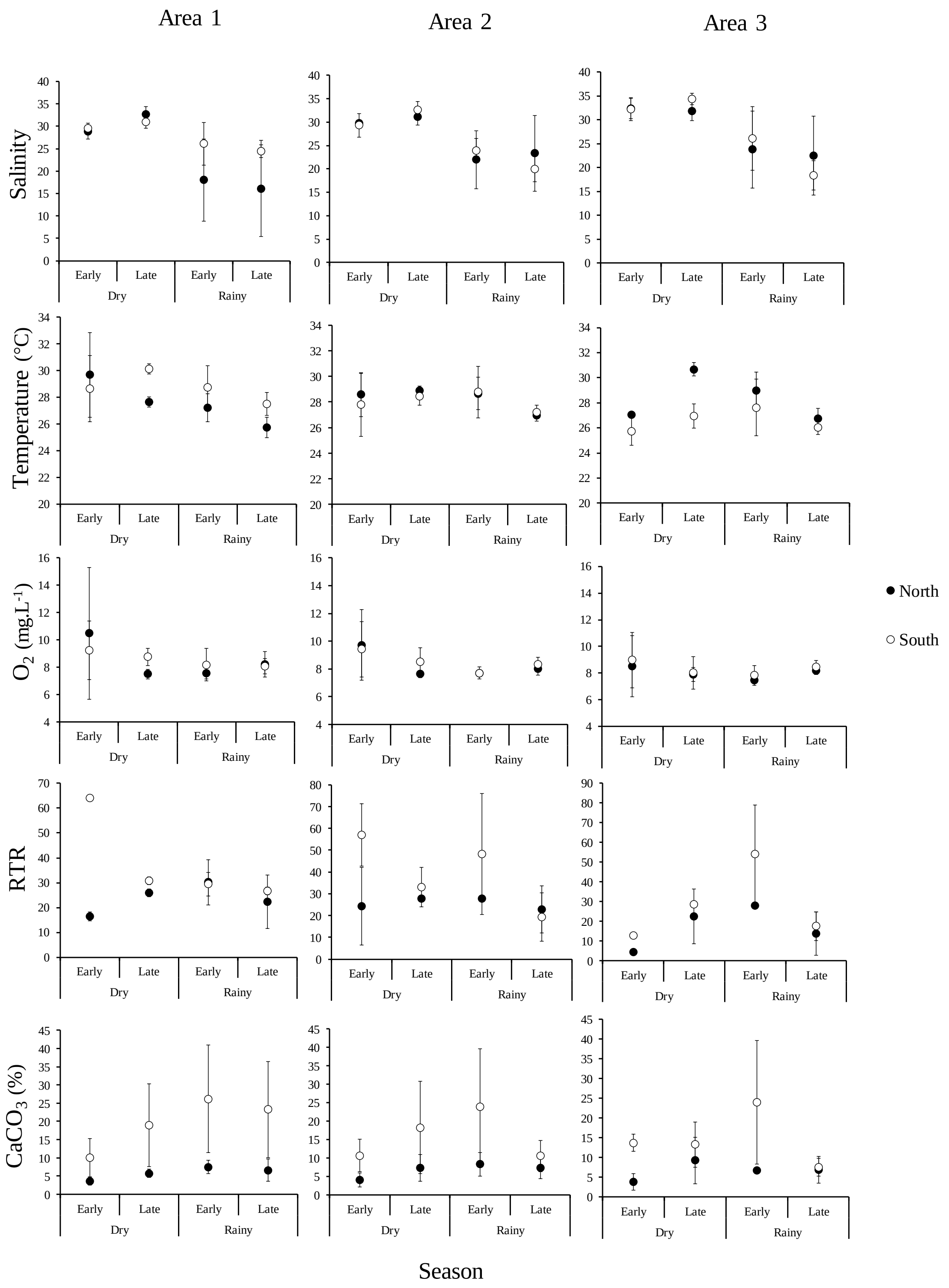
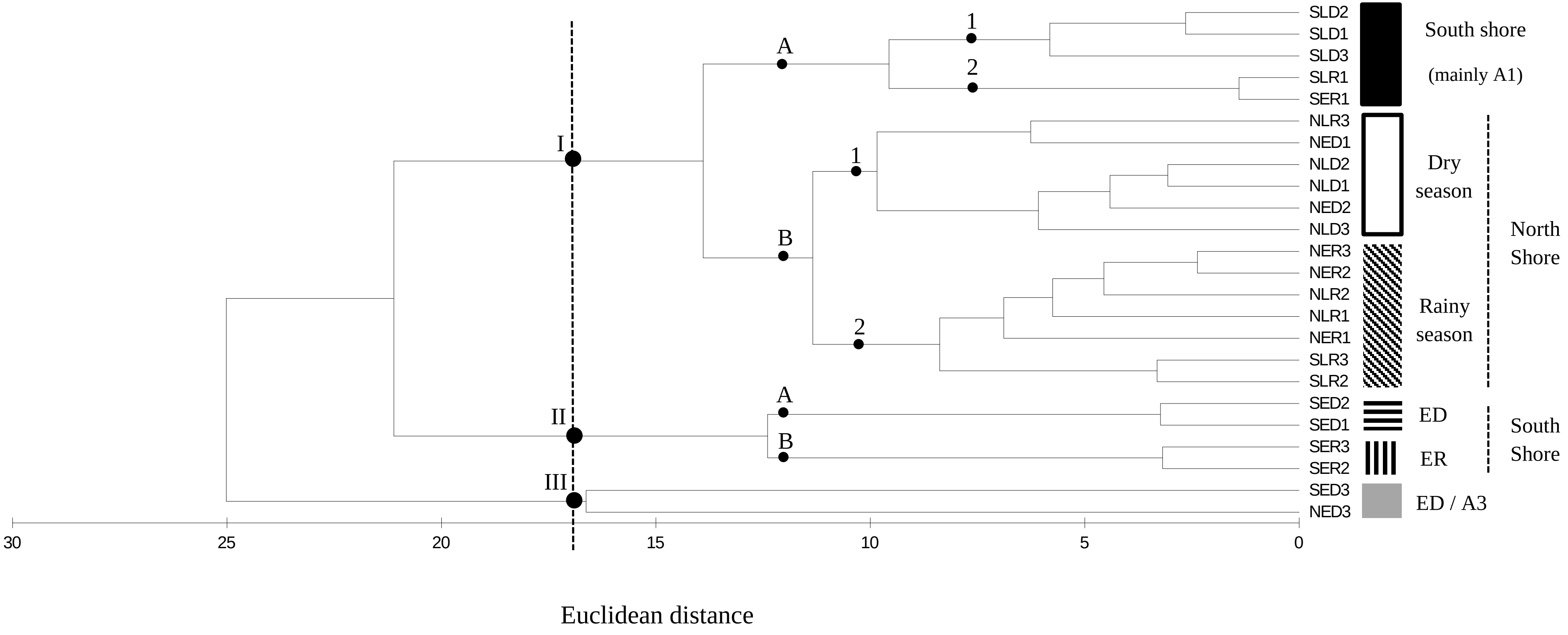

600
500
400
300
200
100
0
Rainfall (mm)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Months

Fig 3



Area 1
Area 2
Area 3
Salinity
Temperature (°C)
O2 (mg.L-1)
RTR
CaCO3 (%)
Early
Late
Dry
Rainy
North
South
Season

Fig 4



SLD2
SLD1
SLD3
SLR1
SER1
NLR3
NED1
NLD2
NLD1
NED2
NLD3
NER3
NER2
NLR2
NLR1
NER1
SLR3
SLR2
SED2
SED1
SER3
SER2
SED3
NED3
I
II
III
A
B
A
B
1
2
1
2
South shore
(mainly A1)
Dry
season
Rainy
season
North
Shore
ED
ER
South
Shore
ED / A3
30
25
20
15
10
5
0
Euclidean distance

Fig 5a

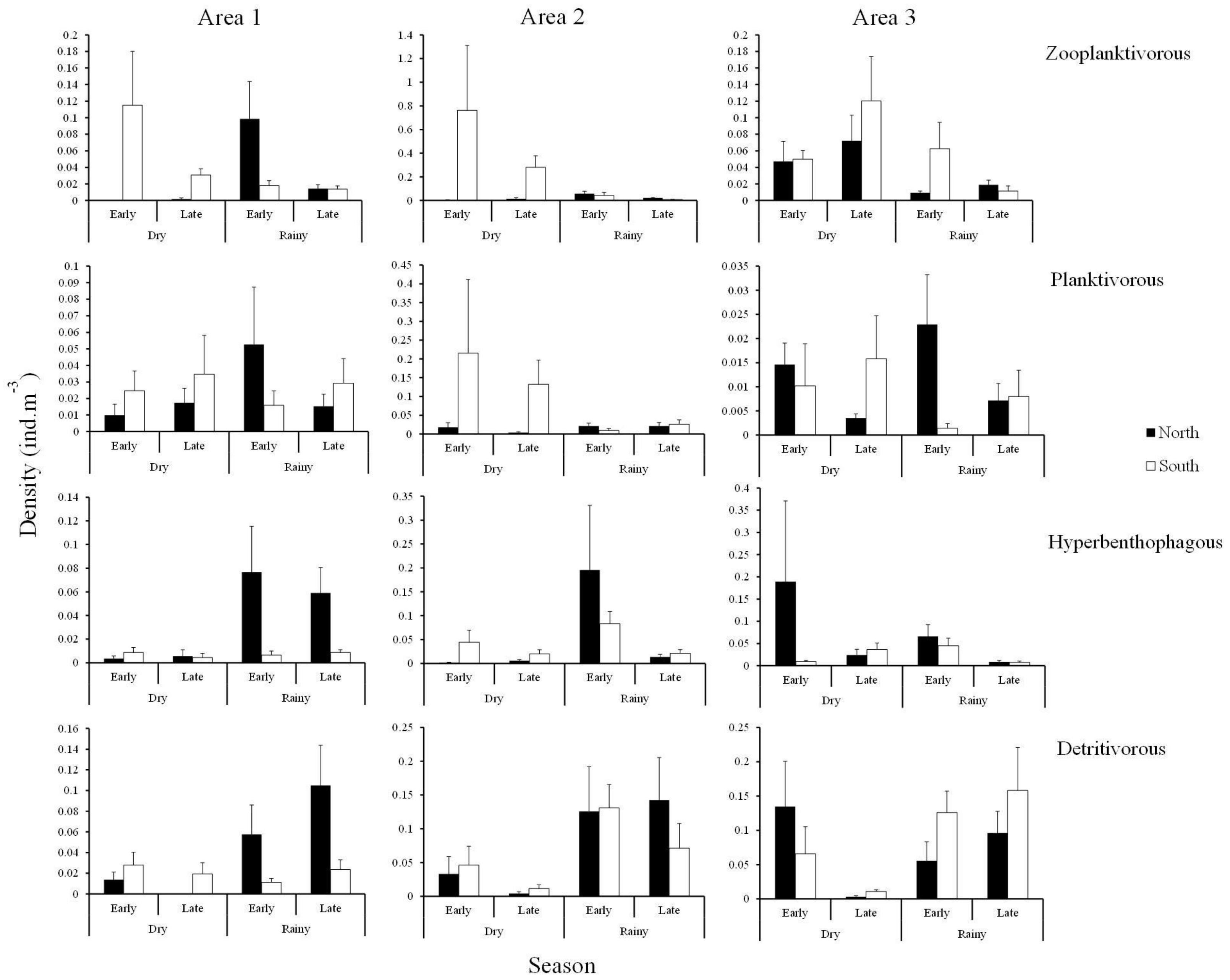
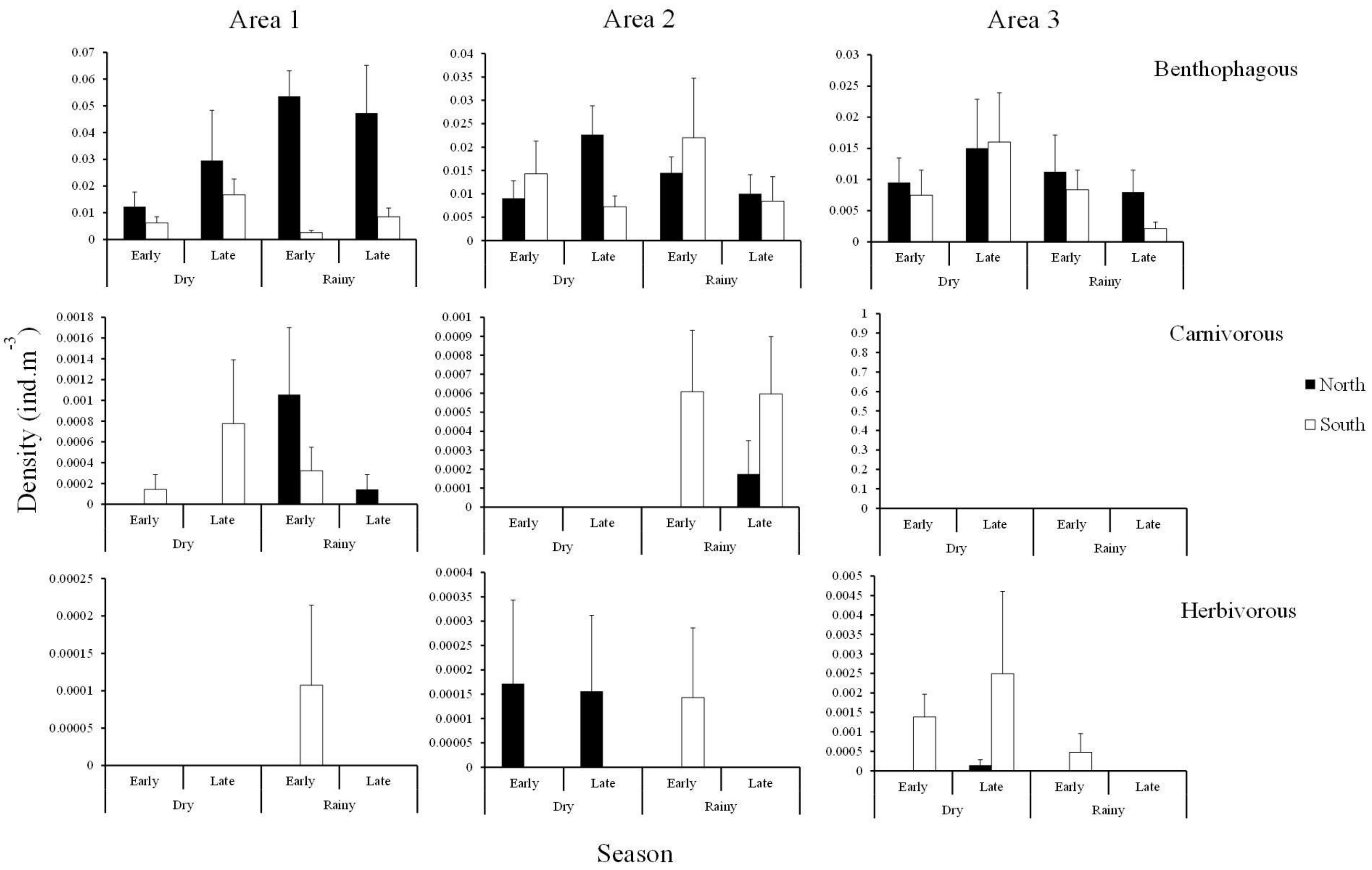
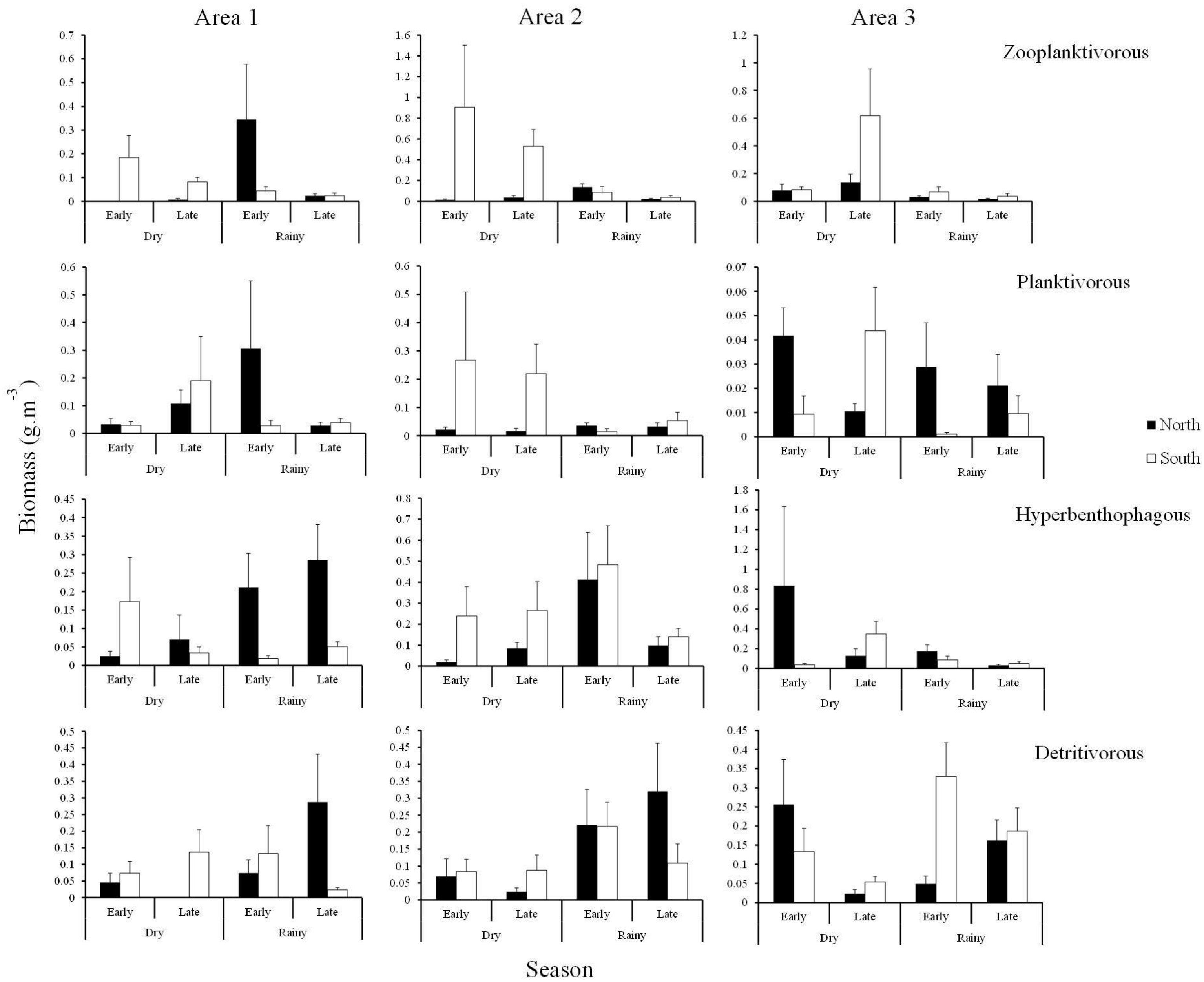

Area 1
Area 2
Area 3
Zooplanktivorous
Planktivorous
Hyperbenthophagous
Detritivorous
North
South
Density (ind.m^{-3})
Season
Early
Late
Dry
Rainy

Fig 5b



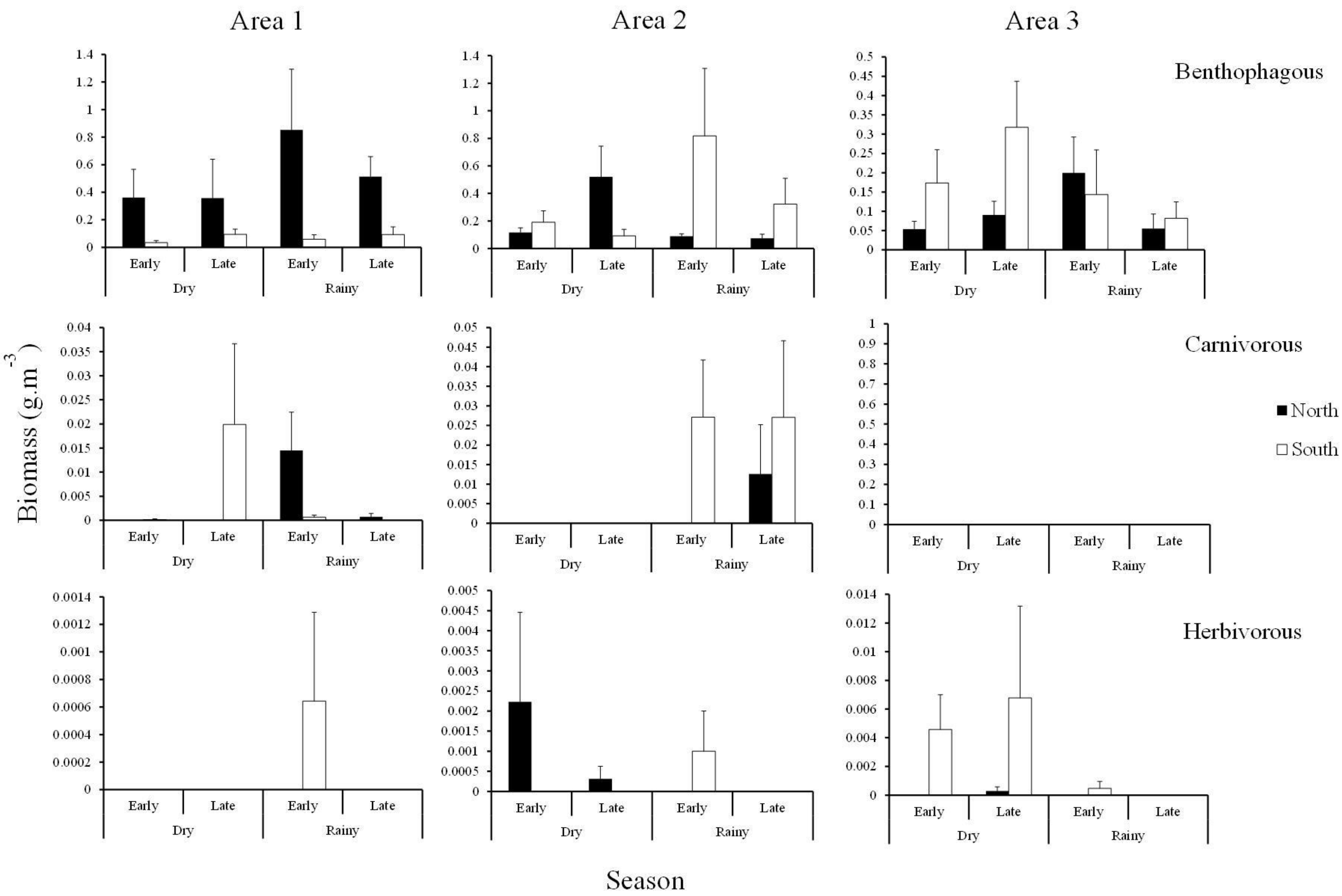
Area 1
Area 2
Area 3
Benthophagous
Carnivorous
Herbivorous
North
South
Density (ind.m^-3)
Season
Early
Late
Dry
Rainy

Fig 6a



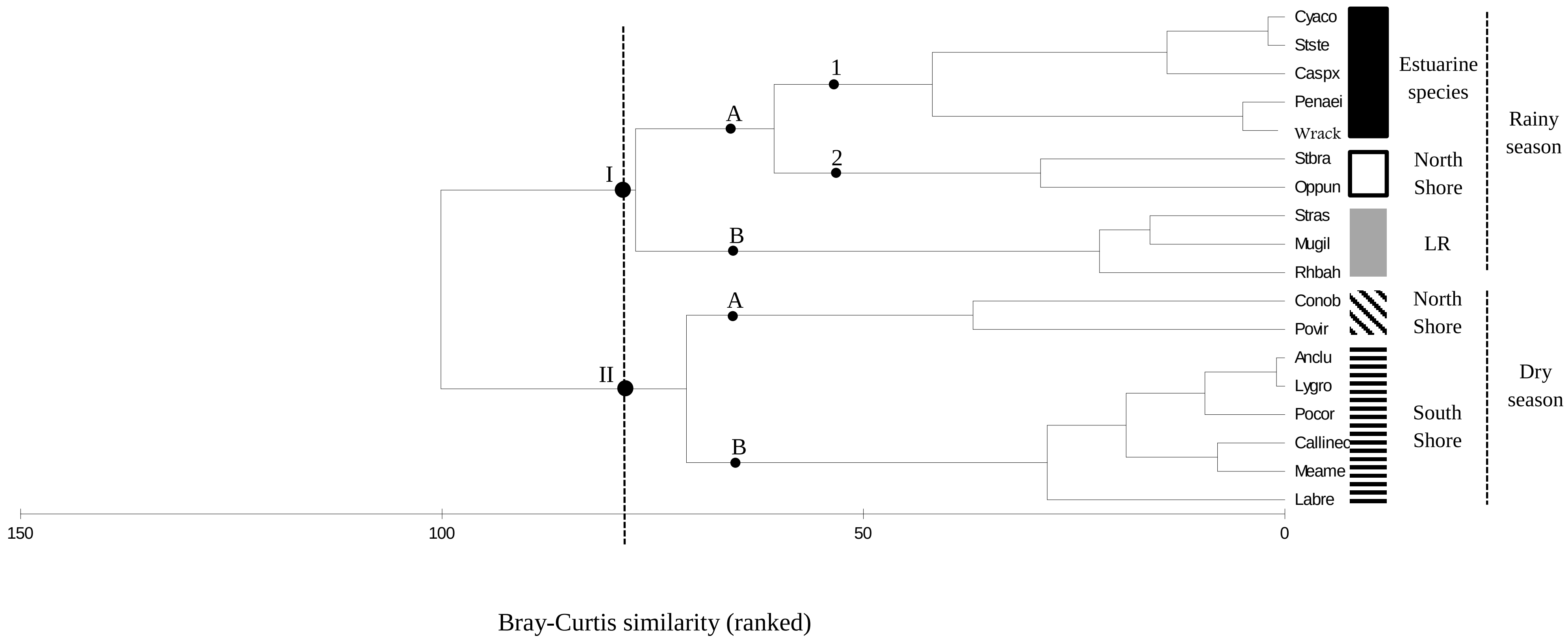
Area 1
Area 2
Area 3
Zooplanktivorous
Planktivorous
Hyperbenthophagous
Detritivorous
North
South
Biomass (g.m -3)
Early
Late
Dry
Rainy
Season

Fig 6b



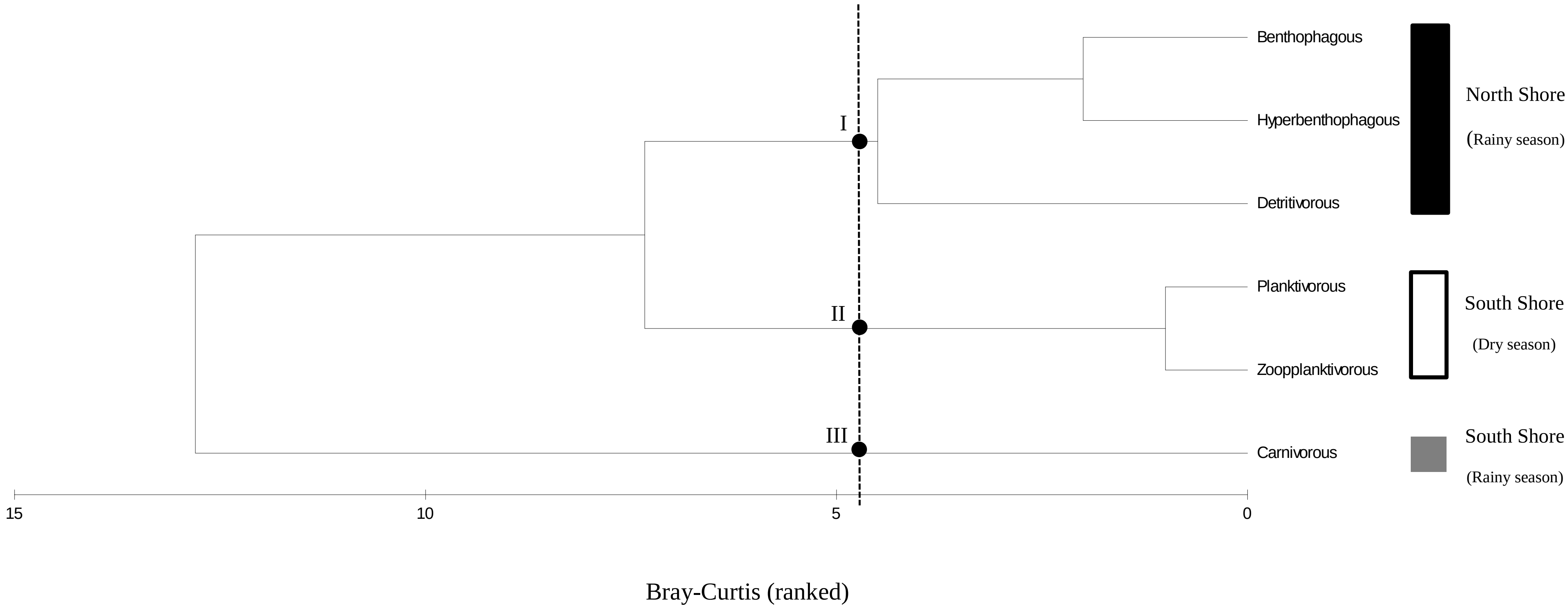
Area 1
Area 2
Area 3
Benthophagous
Carnivorous
Herbivorous
North
South
Biomass (g.m-3)
Early
Late
Dry
Rainy
Season

Fig 7



Cyaco
Stste
Caspx
Penaei
Wrack
Stbra
Oppun
Stras
Mugil
Rhbah
Conob
Povir
Anclu
Lygro
Pocor
Callinec
Meame
Labre
Estuarine species
North Shore
LR
North Shore
South Shore
Rainy season
Dry season
I
II
A
B
A
B
1
2
150
100
50
0
Bray-Curtis similarity (ranked)

Fig 8



Benthophagous
Hyperbenthophagous
Detritivorous
Planktivorous
Zoopplanktivorous
Carnivorous
I
II
III
North Shore
(Rainy season)
South Shore
(Dry season)
South Shore
(Rainy season)
15
10
5
0
Bray-Curtis (ranked)

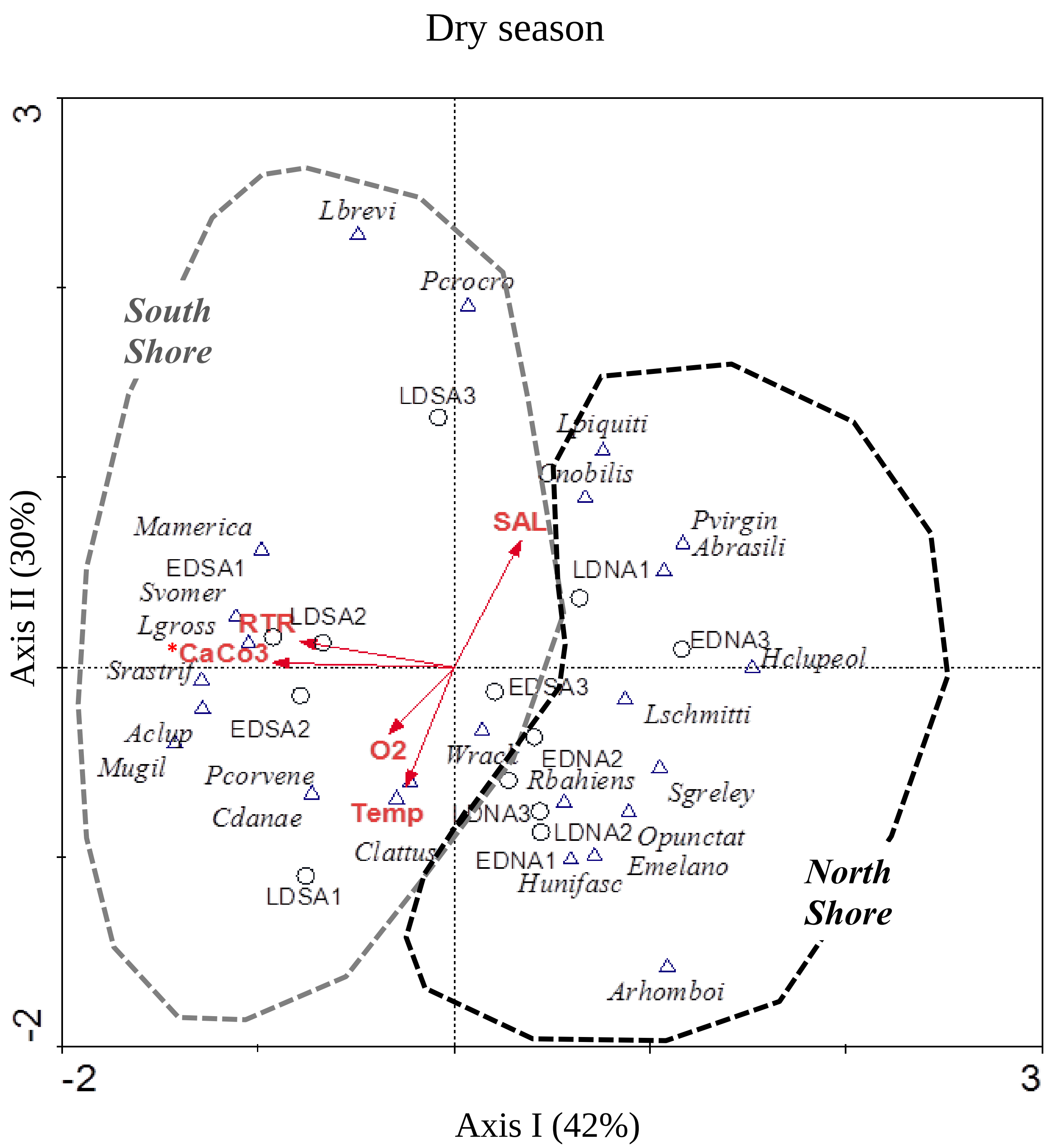

Dry season
Axis II (30%)
Axis I (42%)
3
-2
-2
3
South Shore
North Shore
Lbrevi
Pcrocro
LDSA3
Lpiquiti
Cnobilis
SAL
Pvirgin
Abrasili
Mamerica
EDSA1
Svomer
LDNA1
Lgross
RTR
LDSA2
*CaCo3
EDNA3
Hclupeol
Srastrif
EDSA3
Lschmitti
Aclup
EDSA2
O2
Mugil
Wrack
EDNA2
Pcorvene
Rbahiens
Sgreley
Cdanae
Temp
LDNA3
LDNA2
Opunctat
Clattus
EDNA1
Emelano
Hunifasc
LDSA1
Arhomboi

Fig 9a

Rainy season

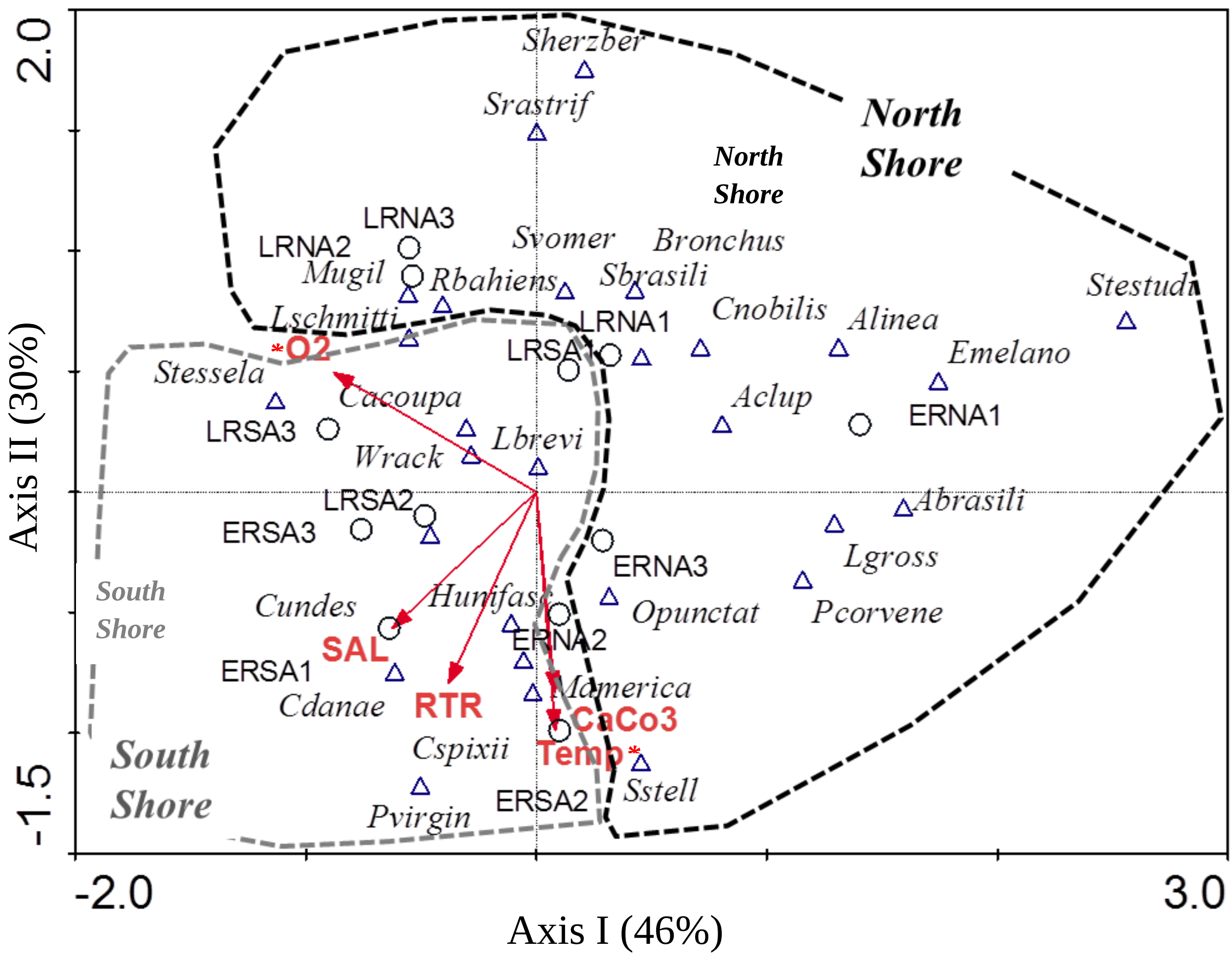


Fig 9b

Dry Season

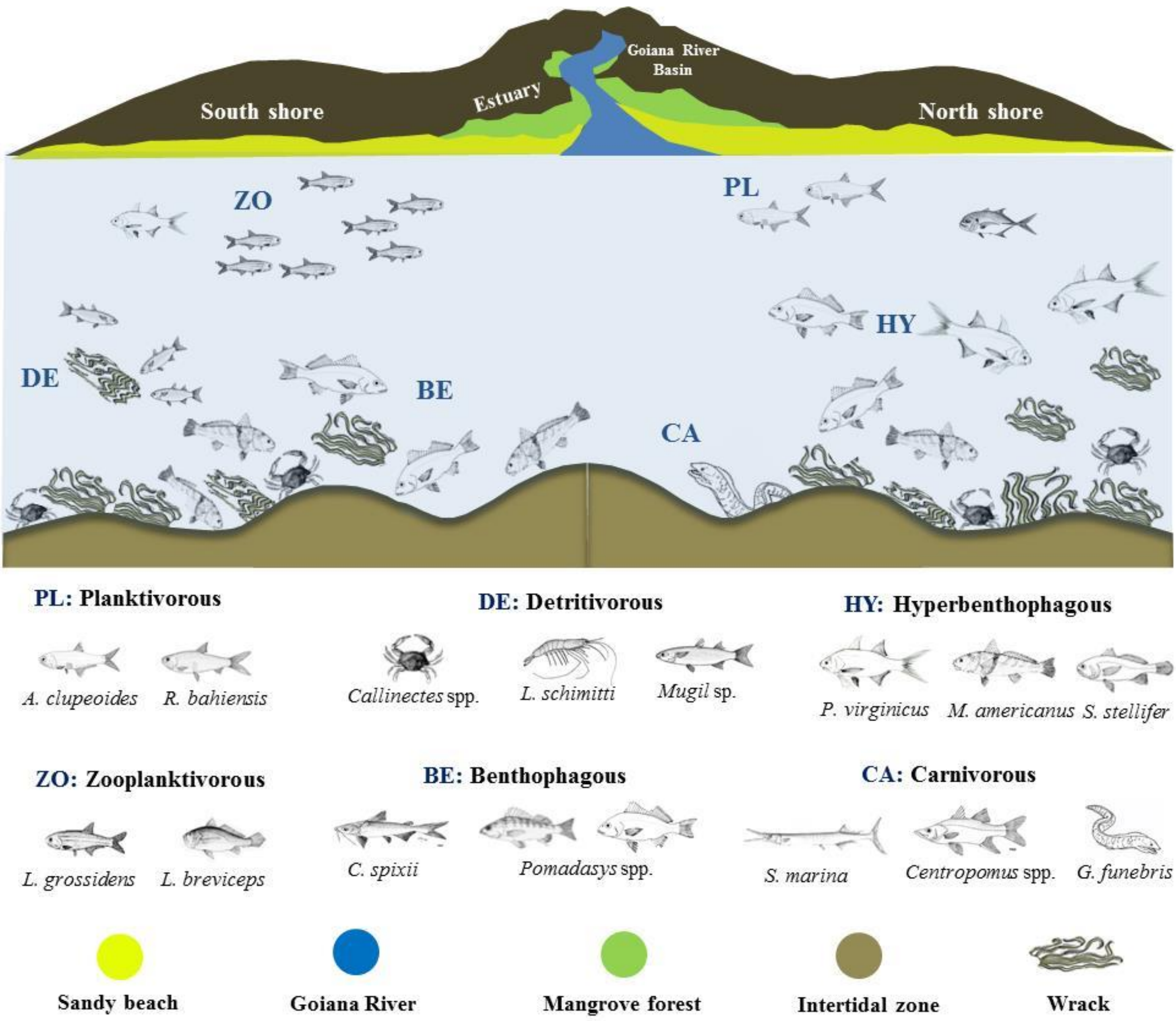


Fig 10a

Rainy season

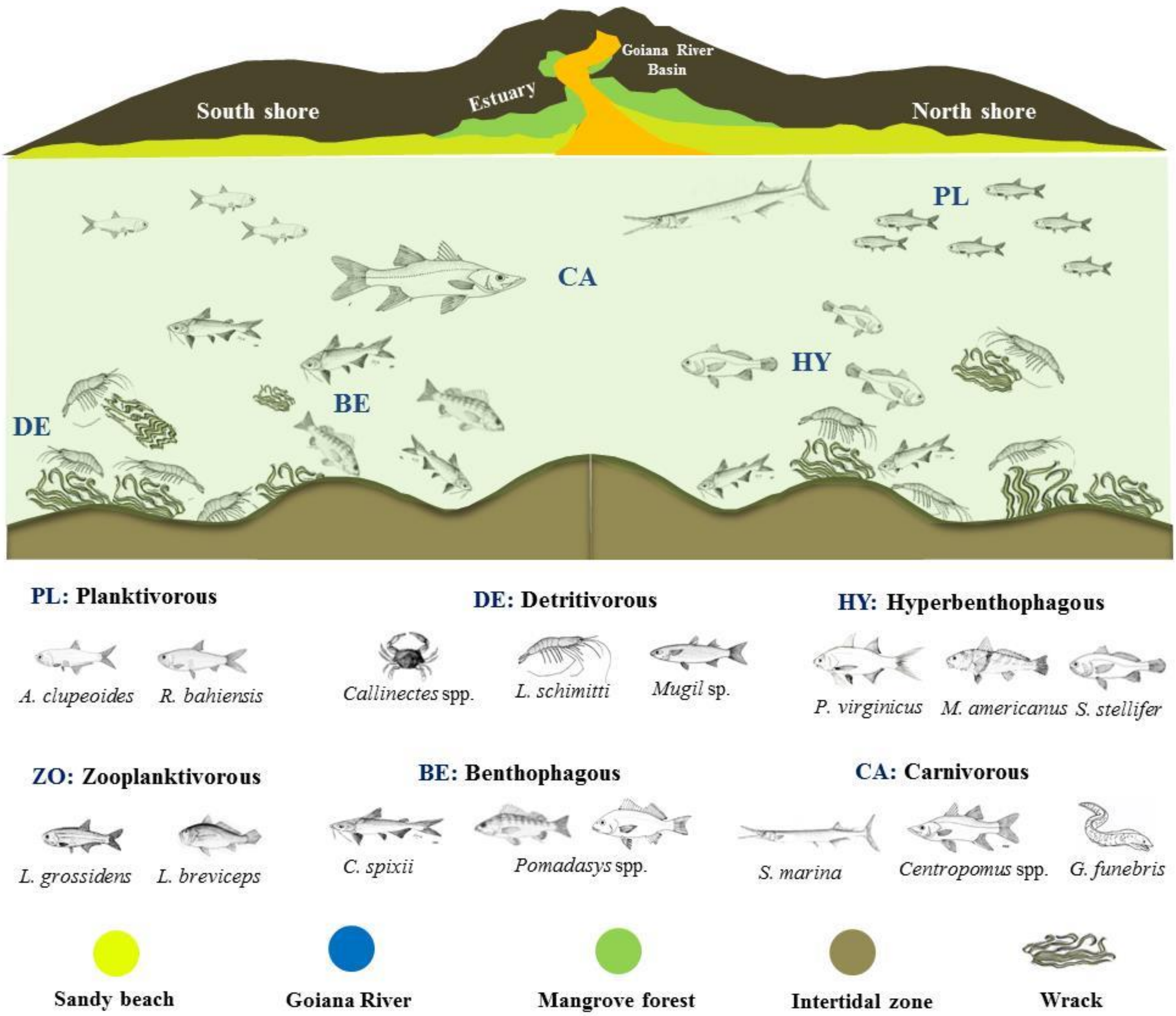
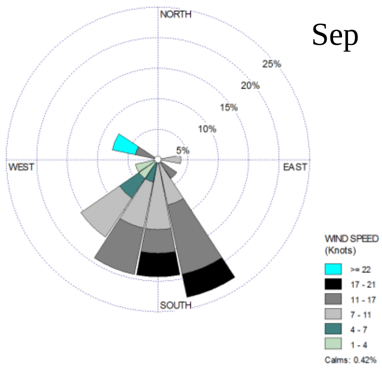
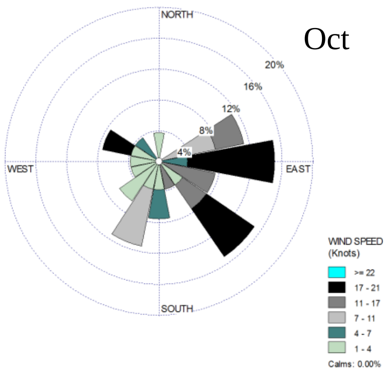


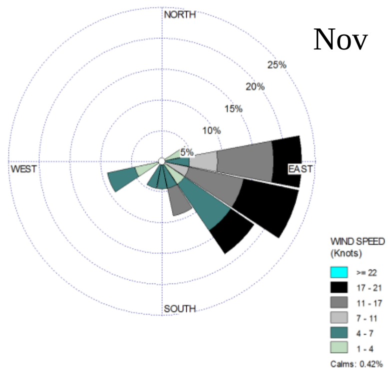
Fig 10b

Appendix 1

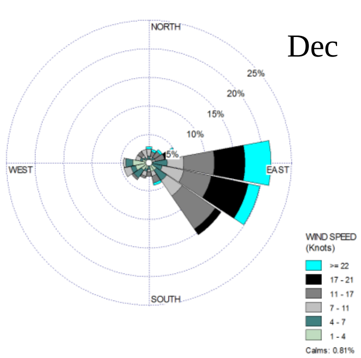
Early Dry

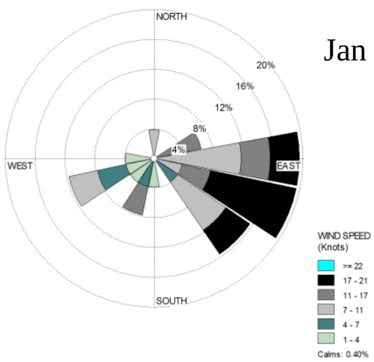


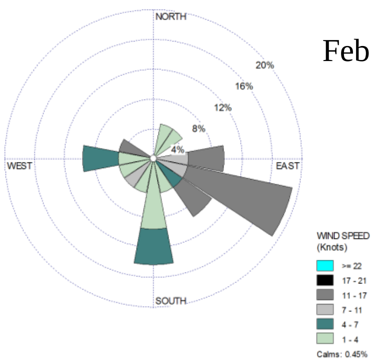




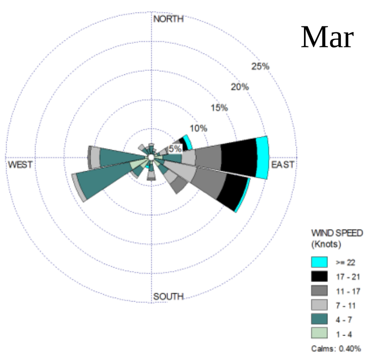
Late Dry

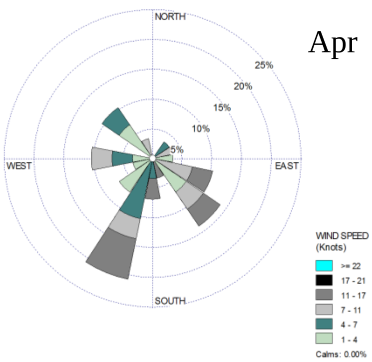


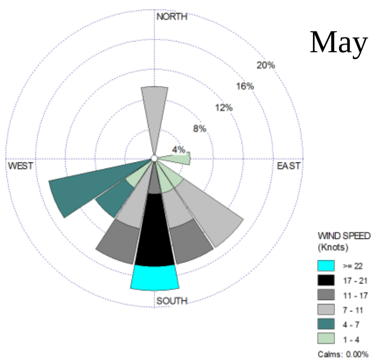




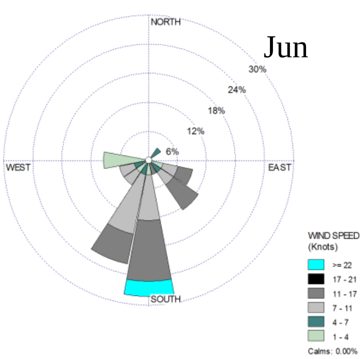
Early Rain

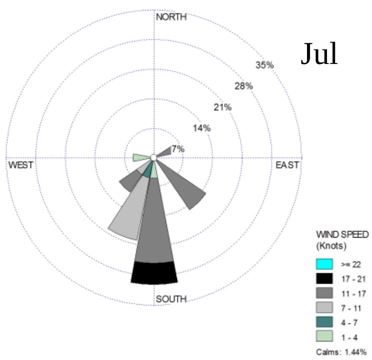


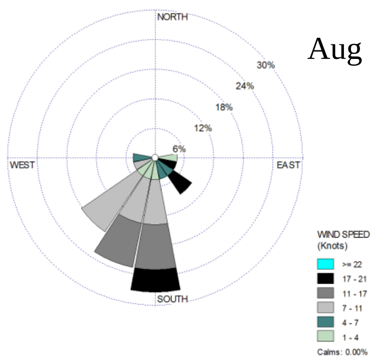




Late Rain







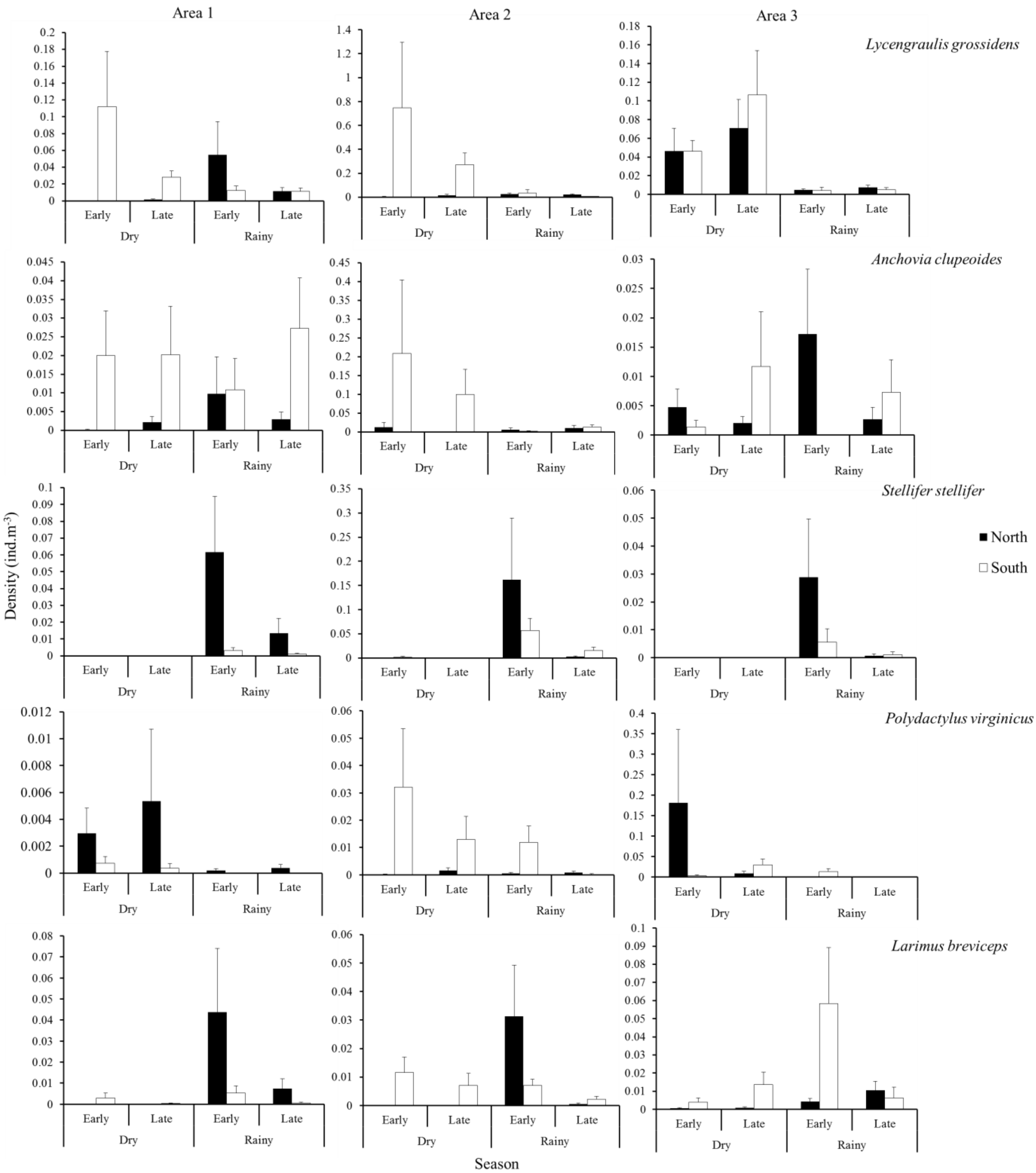
Appendix 2

							Density (%)						Biomass (%)								
	Ecological Guilds		Mean Density		Mean Biomass		North			South			North			South			Frequenci of	Mean	Min-Max
Species	Functional	Trophic	ind. m^{-3}	% cumulative	g. m^{-3}	% cumulative	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3	occurence (%)	*L* s (mm)	*L* s (mm)
Fish (a)																					
1 *Lycengraulis grossidens*	3	7	0.068594	41.2	0.11602	18.2	9.844	8.437	15.778	39.686	53.790	2.727	8.159	7.666	9.670	19.978	27.147	12.447	69.0	4.9±2.2	(2-14)
2 *Anchovia clupeoides*	2	1	0.020581	53.6	0.02734	22.5	2.192	3.976	3.286	18.985	17.426	2.626	2.495	1.354	2.126	6.745	6.625	0.882	31.9	4.8±2.2	(2-14)
3 *Stellifer stellifer*	3	6	0.014769	62.5	0.04804	30.0	1.961	22.218	3.613	1.627	5.469	0.854	5.585	13.540	2.261	0.998	9.835	1.950	18.5	4.2±2.1	(1-11)
4 *Polydactylus virginicus*	2	6	0.012888	70.2	0.06379	40.0	1.322	0.439	23.528	0.265	2.473	6.312	2.976	0.793	34.438	0.293	5.758	1.335	32.9	5.7±2.4	(2-14)
5 *Larimus breviceps*	2	7	0.009111	75.7	0.03086	44.9	7.459	4.297	2.296	2.214	1.775	1.598	1.551	1.153	0.926	2.313	2.687	16.953	40.3	3.8±1.9	(1-18)
6 *Cathorops spixii*	3	5	0.004000	78.1	0.10190	60.9	5.663	0.699	0.853	1.828	1.422	0.728	16.577	1.728	6.323	6.354	23.226	1.179	28.2	8.7±2.9	(2-21)
7 *Pomadasys corvinaeformis*	2	5	0.002840	79.8	0.02059	64.1	0.629	1.998	2.555	3.360	0.628	0.560	1.256	5.274	4.516	5.592	1.513	1.972	26.4	6.0±2.4	(1-11)
8 *Rhinosardinia bahiensis*	3	1	0.004217	82.3	0.00854	65.4	3.373	3.456	2.091	2.217	1.203	0.365	1.707	1.608	1.744	1.466	1.207	0.164	31.0	5.5±2.3	(3-8)
9 *Mugil sp.*	2	2	0.003157	84.2	0.00245	65.8	1.553	0.457	0.275	7.258	1.134	0.592	0.151	0.384	0.699	0.879	0.639	0.165	24.1	2.4±1.5	(1-8)
10 *Cynoscion acoupa*	2	6	0.002332	85.6	0.00486	66.6	1.537	1.215	0.975	0.372	0.624	2.455	0.885	0.842	0.248	0.633	0.273	1.428	17.1	3.3±1.8	(1-14)
11 *Stellifer rastrifer*	2	6	0.002580	87.2	0.01326	68.7	5.748	1.393	0.652	1.245	0.314	0.314	3.573	2.456	1.437	2.137	0.724	0.443	17.1	5.3±2.3	(2-10)
12 *Ophioscion punctatissimus*	2	6	0.001945	88.4	0.00315	69.2	0.126	2.230	2.835		0.267	0.249	0.224	0.595	2.139		0.153	0.417	16.2	3.2±1.8	(1-9)
13 *Sardinella brasiliensis*	2	1	0.001183	89.1	0.00810	70.4	3.967		0.175	0.237	0.944		4.668		0.118	0.484	0.164		3.2	6.8±2.6	(5-9)
14 *Sciades herzbergii*	3	5	0.001738	90.1	0.00759	71.6	4.389	0.918	0.359	0.325	0.779	0.578	3.260	1.743	0.265	0.226	0.685	0.558	13.0	6.2±2.4	(3-13)
15 *Conodon nobilis*	2	5	0.001570	91.1	0.02420	75.4	2.826	0.269	0.194	0.138	0.337	1.182	8.357	0.823	0.442	0.366	1.350	5.753	18.1	6.8±2.6	(2-13)
16 *Menticirrhus americanus*	2	6	0.001404	91.9	0.02480	79.3	0.285	0.676	0.775	1.738	0.332	0.885	0.337	2.986	1.696	12.516	3.113	4.161	31.0	7.3±2.7	(1-17)
17 *Bairdiella ronchus*	2	6	0.001173	92.6	0.00572	80.2	0.925	0.354	1.338	0.220	0.464	0.843	0.839	0.680	2.875	0.154	0.237	0.127	13.0	5.3±2.3	(2-10)
18 *Anchoa tricolor*	2	1	0.001387	93.4	0.00440	80.9		0.174	0.646	0.157	1.497	1.429		0.234	0.844	0.849	1.745	0.234	3.2	6.7±2.6	(4-9)
19 *Pomadasys crocro*	6	5	0.000776	93.9	0.00807	82.2	0.533	0.232	0.564	0.773		0.715	1.573	0.542	0.915	1.183		3.539	8.8	5.9±2.4	(2-13)
20 *Sphoeroides greeleyi*	2	5	0.001021	94.5	0.00606	83.1	2.433	0.731	0.389	0.326		0.113	2.472	1.584	0.219	0.978		0.913	10.2	5.7±2.4	(3-9)
21 *Stellifer brasiliensis*	3	6	0.000954	95.1	0.00439	83.8	0.916	0.193	0.736	0.628	0.956	0.655	0.957	0.914	2.986	0.180	0.860	0.256	15.3	5.8±2.4	(2-10)
22 *Lile piquitinga*	2	1	0.000656	95.5	0.00307	84.3	1.252		0.180	0.139	0.189	0.236	1.216		0.133	0.849	0.150	0.457	7.4	6.2±2.5	(5-8)
23 *Anchoa lyolepis*	2	1	0.000366	95.7	0.00087	84.4	0.799			0.736	0.283		0.434			0.238	0.183		2.3	5.2±2.3	(3-8)
24 *Atherinella brasiliensis*	2	1	0.000485	96.0	0.00245	84.8	0.877	0.345	0.353	0.278	0.496	0.657	0.984	0.569	0.118	0.192	0.448	0.181	10.2	6.4±2.5	(3-10)
25 *Selene vomer*	2	6	0.000420	96.3	0.00178	85.1	0.139	0.421	0.362	0.391	0.138	0.254	0.479	0.328	0.154	0.726	0.445	0.212	12.5	3.9±2.0	(2-10)
26 *Archosargus rhomboidalis*	2	5	0.000426	96.5	0.00407	85.7	0.280	0.741	0.344				0.365	3.244	0.487				6.0	5.6±2.4	(4-7)
27 *Eucinostomus melanopterus*	2	5	0.000352	96.7	0.00211	86.1	0.372	0.599	0.992	0.743	0.142	0.263	0.641	0.595	0.142	0.230	0.383	0.181	10.2	5.5±2.3	(1-10)
28 *Haemulon aurolineatum*	2	5	0.000275	96.9	0.00071	86.2	0.963						0.425						0.5	3.8±1.9	(2-7)
29 *Cetengraulis edentulus*	2	1	0.000558	97.2	0.00720	87.3			0.194	2.937	0.566				0.554	9.937	0.400		2.8	9.0±2.9	(7-11)
30 *Harengula clupeola*	2	1	0.000374	97.4	0.00144	87.5	0.342	0.212	0.123	0.381	0.138		0.392	0.219	0.467	0.472	0.947		5.6	5.7±2.4	(2-10)
31 *Sphoeroides testudineus*	2	5	0.000333	97.6	0.04154	94.0	0.689	0.277	0.481	0.270	0.142	0.742	13.433	15.578	1.448	0.248	0.444	1.532	9.7	10.7±3.3	(1-20)
32 *Achirus lineatus*	3	5	0.000355	97.9	0.00671	95.1	0.882	0.499	0.525	0.321	0.142	0.182	2.242	0.232	0.745	0.145	0.822	1.643	9.7	6.8±2.6	(3-10)
33 *Caranx latus*	2	6	0.000389	98.1	0.00209	95.4	0.139	0.489	0.145		0.276	0.670	0.168	1.948	0.353		0.236	0.891	6.5	5.3±2.3	(4-8)
34 *Platanichthys platana*	7	1	0.000315	98.3	0.00233	95.8	0.289	0.248	0.175		0.566	0.188	0.365	0.363	0.592		0.312	0.534	3.2	6.7±2.6	(5-8)
35 *Lutjanus jocu*	2	6	0.000273	98.4	0.00360	96.3	0.337	0.458				0.113	0.699	2.500				0.913	5.1	7.1±2.7	(4-9)
36 *Pomadasys ramosus*	2	5	0.000126	98.5	0.00186	96.6				0.614	0.283					1.455	0.552		1.4	6.3±2.5	(5-17)
37 *Lutjanus analis*	2	6	0.000151	98.6	0.00098	96.8	0.165	0.579	0.257				0.168	0.252	0.447				4.2	4.3±2.1	(3-7)
38 *Symphurus tessellatus*	2	5	0.000217	98.7	0.00148	97.0	0.313	0.125	0.139	0.233	0.113	0.223	0.539	0.970	0.415	0.923	0.657	0.269	9.3	5.4±2.3	(3-11)
39 *Etropus crossotus*	2	5	0.000128	98.8	0.00167	97.3	0.284	0.322	0.151	0.743	0.378		0.779	0.579	0.816	0.943	0.842		4.6	7.8±2.8	(3-11)
40 *Hyporhamphus unifasciatus*	2	3	0.000157	98.9	0.00100	97.4	0.278	0.195	0.813	0.153	0.222	0.684	0.287	0.381	0.199	0.298	0.586	0.695	8.8	11.4±3.3	(3-16)
41 *Albula vulpes*	6	5	0.000181	99.0	0.00154	97.7		0.130	0.353	0.149	0.425	0.238		0.832	0.532	0.182	0.822	0.448	3.2	7.5±2.7	(2-14)
42 *Odontesthes incisa*	3	1	0.000145	99.1	0.00021	97.7	0.139	0.275	0.353		0.212		0.239	0.138	0.118		0.274		3.7	5.2±2.2	(4-6)
43 *Sciades couma*	2	5	0.000116	99.2	0.00117	97.9	0.254					0.138	0.718					0.894	0.9	11.2±3.3	(7-16)
44 *Chaetodipterus faber*	2	3	0.000193	99.3	0.00062	98.0		0.232	0.175	0.270		0.542		0.937	0.118	0.424		0.415	4.6	3.3±1.8	(2-5)
45 *Pellona harroweri*	2	7	0.000080	99.3	0.00010	98.0		0.322	0.166		0.189			0.116	0.564		0.173		4.6	3.5±1.9	(3-5)
46 *Citharichthys spilopterus*	2	5	0.000074	99.4	0.00058	98.1	0.139	0.386	0.167	0.462		0.345	0.196	0.695	0.143	0.126		0.192	2.8	6.4±2.5	(1-10)
47 *Haemulon steindachneri*	2	5	0.000127	99.5	0.00039	98.2		0.414						0.395					0.9	4.6±2.1	(3-6)
48 *Eucinostomus argenteus*	2	5	0.000058	99.5	0.00025	98.2	0.149	0.322	0.175				0.796	0.232	0.148				2.8	5.4±2.3	(4-8)
49 *Cathorops agassizii*	3	5	0.000051	99.5	0.00073	98.3		0.113		0.321		0.345		0.254		0.479		0.342	1.4	5.8±2.4	(3-16)
50 *Oligoplites saurus*	2	6	0.000069	99.6	0.00010	98.3	0.447	0.717			0.378		0.769	0.413			0.235		1.9	4.8±2.2	(3-7)

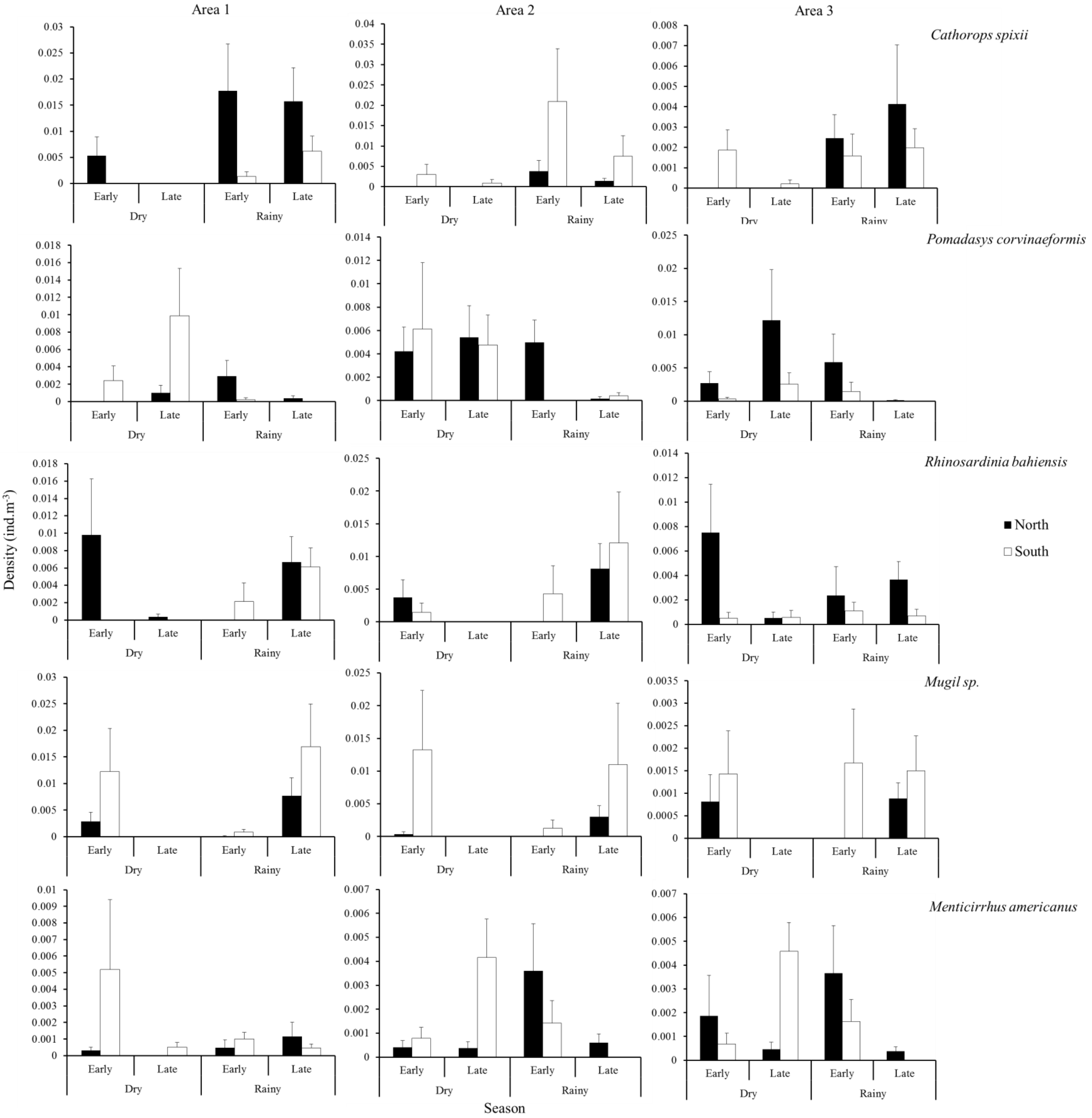
Appendix 2. Continued

		Ecological Guilds		Mean Density		Mean Biomass		Density (%)						Biomass (%)								
								North			South			North			South			Frequenci of	Mean	Min-Max
	Species	Functional	Trophic	ind. m^{-3}	% cumulative	g. m^{-3}	% cumulative	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3	occurence (%)	*L* s (mm)	*L* s (mm)
	Fish (a)																					
51	*Chilomycterus spinosus*	2	5	0.000046	99.6	0.00014	98.4	0.614	0.223	0.175			0.497	0.183	0.416	0.177			0.441	2.8	2.8±1.7	(2-5)
52	*Umbrina coroides*	2	6	0.000041	99.6	0.00080	98.5			0.755		0.189				0.319		0.219		0.9	8.0±2.8	(5-11)
53	*Gymnothorax funebris*	2	4	0.000036	99.6	0.00036	98.5	0.126						0.218						1.4	19.7±4.4	(18-21)
54	*Eugerres brasilianus*	2	5	0.000047	99.7	0.00162	98.8	0.165						0.979						1.4	10.7±3.3	(7-13)
55	*Rypticus randalli*	1	4	0.000037	99.7	0.00080	98.9	0.278				0.448		0.146				0.259		1.9	10.0±3.2	(9-12)
56	*Odontognathus mucronatus*	3	1	0.000036	99.7	0.00009	98.9			0.323	0.347	0.333				0.566	0.377	0.264		1.9	5.0±2.2	(2-7)
57	*Cynoscion leiarchus*	2	6	0.000030	99.7	0.00001	98.9		0.966						0.695					0.5	2.0±1.4	(1-3)
58	*Eucinostomus gula*	2	5	0.000035	99.8	0.00038	99.0		0.695		0.297		0.263		0.174		0.218		0.580	1.4	7.2±2.7	(5-10)
59	*Bathygobius soporator*	3	5	0.000042	99.8	0.00017	99.0	0.322			0.158	0.944		0.338			0.186	0.274		1.9	4.7±2.2	(2-6)
60	*Genyatremus luteus*	2	5	0.000028	99.8	0.00002	99.0		0.579				0.365		0.122				0.846	1.4	2.2±1.5	(2-3)
61	*Diapterus rhombeus*	2	5	0.000017	99.8	0.00006	99.0	0.612						0.349						1.4	4.0±1.2	(3-4)
62	*Strongylura marina*	2	4	0.000036	99.8	0.00015	99.1				0.293						0.240			1.4	11.7±3.4	(6-18)
63	*Trinectes microphthalmus*	2	5	0.000014	99.8	0.00003	99.1			0.478						0.344				0.9	3.5±1.9	(3-4)
64	*Citharichthys arenaceus*	2	5	0.000027	99.9	0.00006	99.1	0.256	0.236		0.743			0.440	0.228		0.552			1.4	5.2±2.3	(4-6)
65	*Hemiramphus brasiliensis*	2	3	0.000018	99.9	0.00006	99.1		0.217			0.944	0.172		0.131			0.192	0.476	1.4	10.7±3.3	(8-14)
66	*Syngnathus pelagicus*	2	1	0.000015	99.9	0.00002	99.1	0.348	0.166					0.598	0.516					0.9	8.5±2.9	(7-10)
67	*Microphis brachyurus*	4	1	0.000014	99.9	0.00001	99.1	0.487						0.838						0.9	10.0±2.3	(9-11)
68	*Opisthonema oglinum*	2	1	0.000011	99.9	0.00002	99.1			0.175		0.944				0.177		0.249		0.9	5.0±2.2	(4-6)
69	*Centropomus undecimalis*	5	4	0.000015	99.9	0.00108	99.3		0.236			0.142			0.530			0.253		0.9	15.5±3.9	(15-16)
70	*Paralonchurus brasiliensis*	2	6	0.000017	99.9	0.00049	99.3					0.189						0.227		0.5	12.4	12.4
71	*Erotelis smaragdus*	3	5	0.000014	99.9	0.00010	99.4		0.232				0.197		0.649				0.272	0.9	6.5±2.4	(5-7)
72	*Trachinotus falcatus*	2	6	0.000019	99.9	0.00017	99.4	0.165				0.779		0.635				0.274		0.9	6.5±2.5	(5-8)
73	*Elops saurus*	2	4	0.000007	99.9	0.00070	99.5				0.396						1.112			0.5	22.3	22.3
74	*Scomberomorus cavalla*	2	4	0.000006	99.9	0.00003	99.5				0.347						0.472			0.5	8.8	8.8
75	*Hippocampus reidi*	2	1	0.000009	99.9	0.00001	99.5						0.276						0.770	0.5	6.1	6.1
76	*Trachinotus goodei*	2	6	0.000018		0.00072	99.6					0.113						0.329		0.5	11.2	11.2
77	*Synodus foetens*	2	4	0.000009		0.00001	99.6				0.522						0.141			0.5	6.6	6.6
78	*Lagocephalus laevigatus*	2	5	0.000005		0.00000	99.6			0.142						0.473				0.5	3.1	3.1
79	*Sciades proops*	2	5	0.000009		0.00107	99.8				0.522						1.698			0.5	26.0	26
80	*Thalassophryne nattereri*	3	6	0.000006		0.00001	99.8		0.193						0.695					0.5	2.5	2.5
81	*Hypostomus sp.*	6	5	0.000010		0.00001	99.8						0.365						0.846	0.5	2.0	2.0
82	*Centropomus mexicanus*	2	4	0.000006		0.00032	99.8					0.944						0.145		0.5	14.2	14.2
83	*Myrophis punctatus*	2	5	0.000005		0.00011	99.8			0.151						0.164				0.5	36.7	36.7
84	*Chloroscombrus chrysurus*	2	5	0.000003		0.00000	99.8				0.198						0.539			0.5	2.2	2.2
85	*Peprilus paru*	2	6	0.000006		0.00004	99.9						0.172						0.333	0.5	6.2	6.2
86	*Centropomus parallelus*	5	4	0.000007		0.00083						0.779						0.382		0.5	17.3	17.3
87	*Ophichthus ophis*	2	5	0.000004		0.00010				0.117						0.985				0.5	46.2	46.2
	total			**0.1664**		**0.6374**		**2.820**	**2.658**	**2.911**	**3.858**	**4.150**	**1.355**	**3.942**	**3.309**	**3.548**	**3.505**	**3.992**	**2.767**			
	Crustaceans (b)																					
88	*Litopenaeus schimitti*	2		0.054193	93.1	0.09184	72.5	24.456	38.338	34.239	4.765	11.008	42.999	8.804	20.846	18.839	5.028	6.872	16.553	55.1	2.6±2.9	(0.7-6)
89	*Callinectes danae*	2		0.003992		0.03485		0.770	2.516	0.976	5.624	0.964	2.811	1.778	5.807	1.337	16.952	2.012	8.267	30.6	3.1±1.8	(1-10)
	total			**0.0582**		**0.1267**	**0.491**	**1.008**	**1.632**	**1.407**	**0.415**	**0.478**	**1.830**	**0.423**	**1.065**	**0.806**	**0.878**	**0.355**	**0.992**			
	Wrack (c)					**25.0267**	**97.037**							**15.75**	**13.65**	**9.88**	**0.37**	**23.17**	**34.22**			
	Total biomass (a+b+c)					**25.7908**																

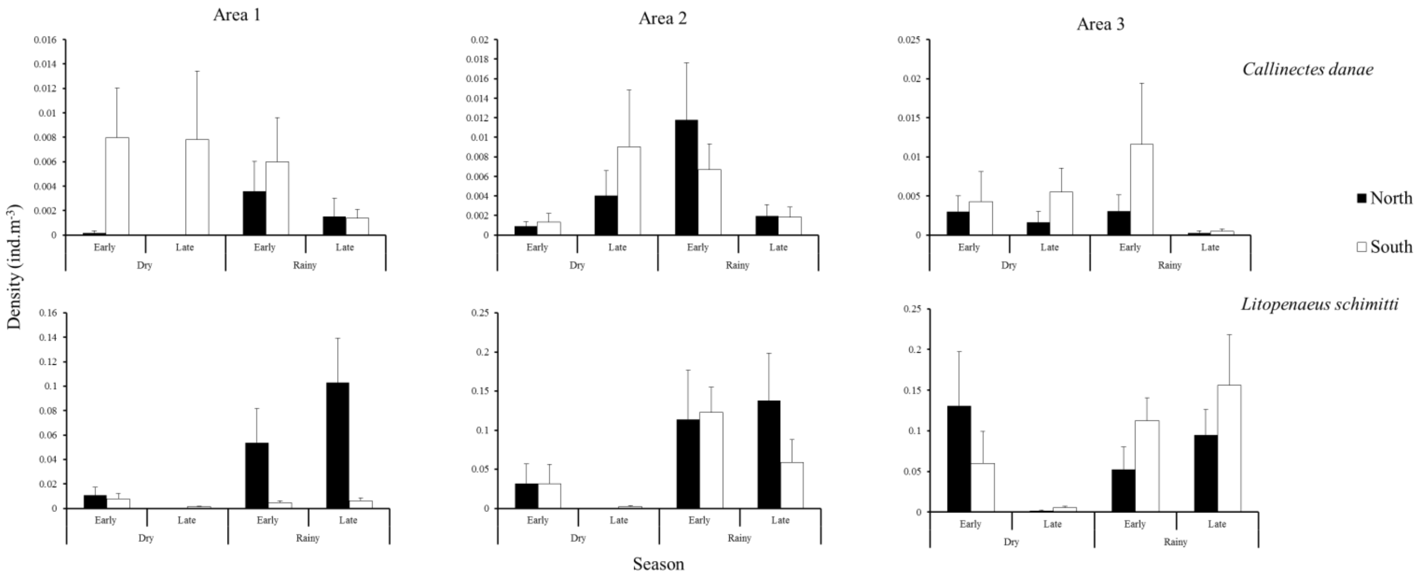
Appendix 3


Area 1
Area 2
Area 3
Lycengraulis grossidens
Anchovia clupeoides
Stellifer stellifer
Polydactylus virginicus
Larimus breviceps
North
South
Density (ind.m-3)
Season
Early
Late
Dry
Rainy

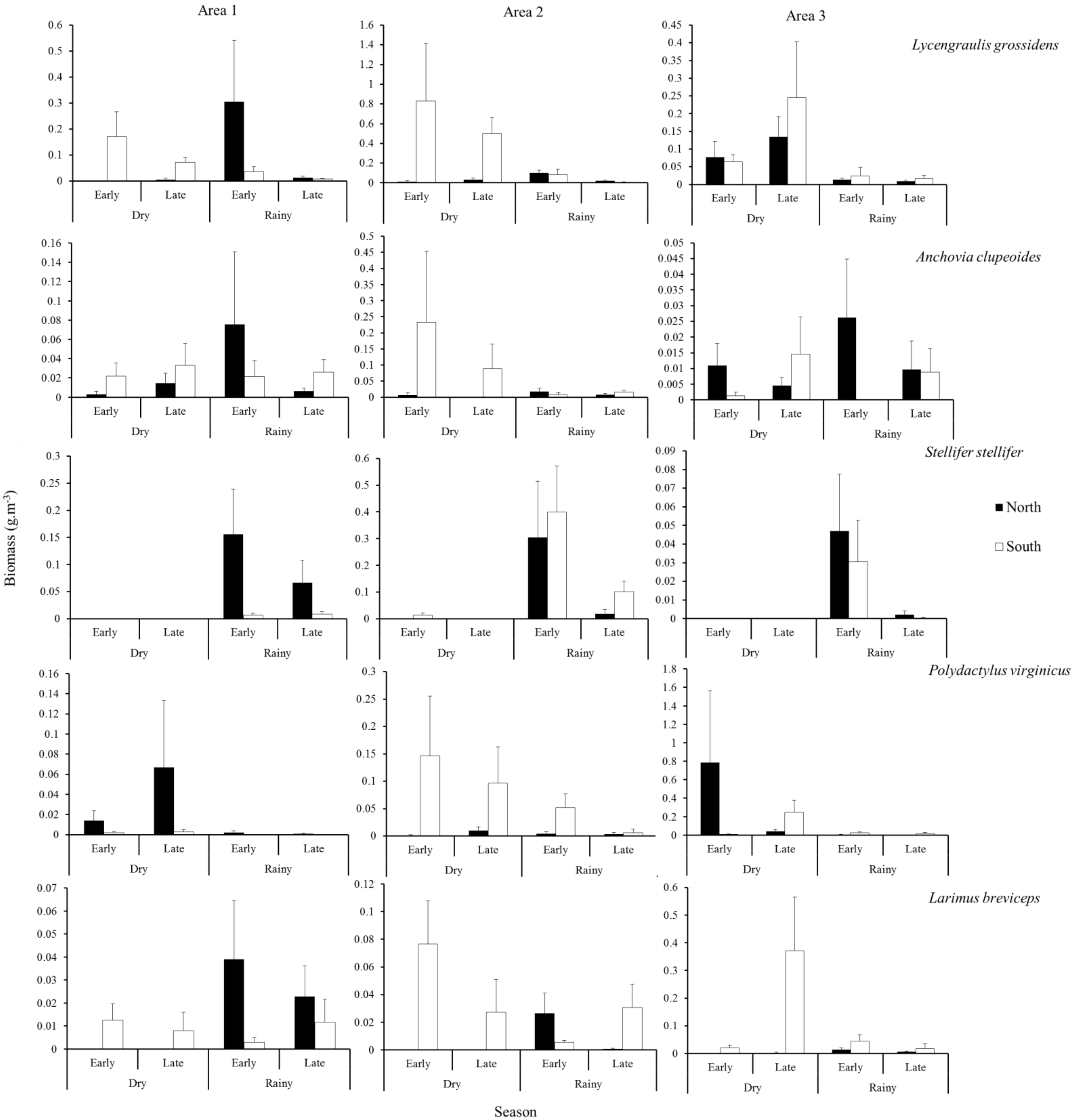
Appendix 3. Continued



Appendix 3. Continued

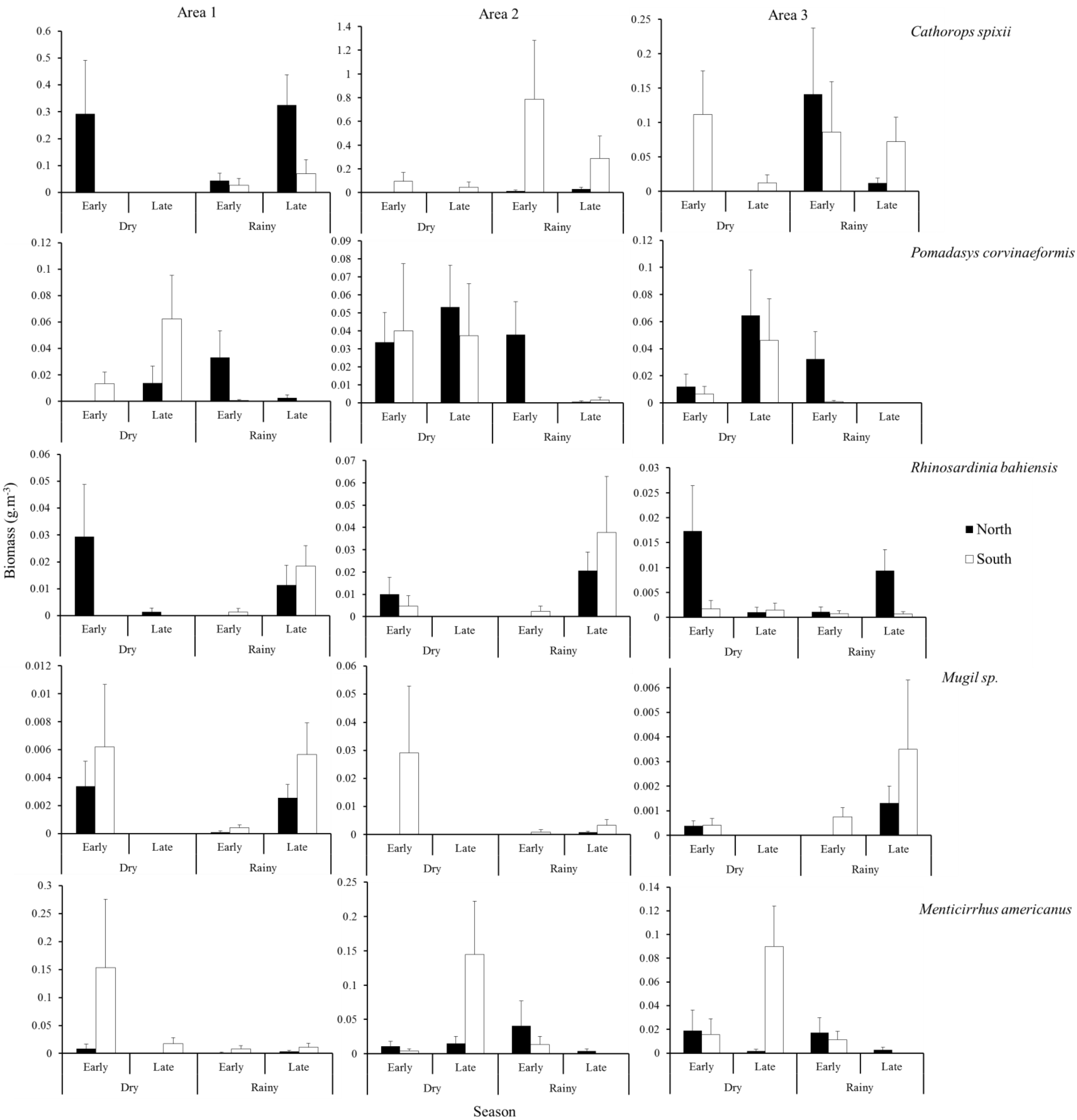


Appendix 4

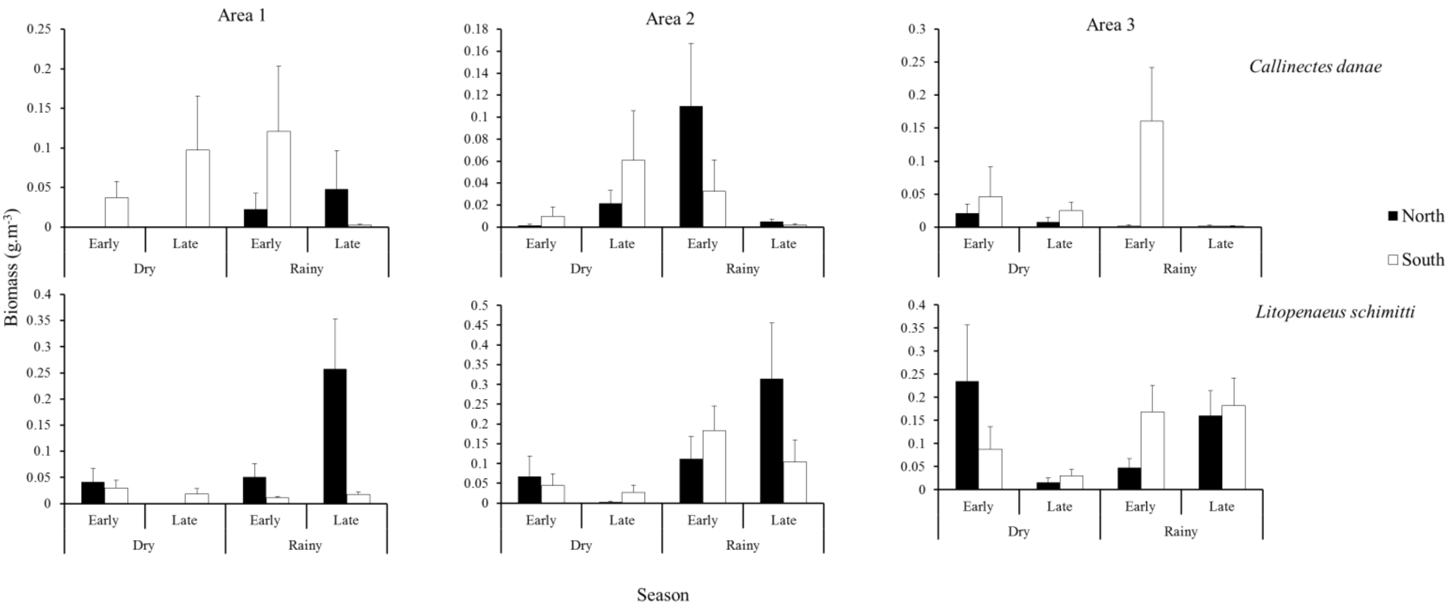


Area 1
Area 2
Area 3
Lycengraulis grossidens
Anchovia clupeoides
Stellifer stellifer
Polydactylus virginicus
Larimus breviceps
North
South
Biomass (g.m-3)
Early
Late
Dry
Rainy
Season

Appendix 4. Continued



Appendix 4. Continued



Appendix 5.

Trophic Guilds	Mean Density ind. m^{-3}	Mean Density % cumulative	Mean Biomass g. m^{-3}	Mean Biomass % cumulative	Total Density (%) North A1	Total Density (%) North A2	Total Density (%) North A3	Total Density (%) South A1	Total Density (%) South A2	Total Density (%) South A3	Total Biomass (%) North A1	Total Biomass (%) North A2	Total Biomass (%) North A3	Total Biomass (%) South A1	Total Biomass (%) South A2	Total Biomass (%) South A3
Zooplanktivorous	0.0780	34.7390	0.1481	19.3819	17.3756	13.0319	18.0281	32.2302	55.8005	31.3933	9.7387	8.6514	10.8507	15.5264	29.9251	28.6120
Planktivorous	0.0304	48.2556	0.0661	28.0324	13.1881	8.6946	5.8936	22.1125	19.5564	4.5478	11.6743	4.4901	4.2258	17.1254	10.6510	2.2630
Hyperbenthophagous	0.0394	65.8072	0.1787	51.4176	21.6696	29.3082	35.2787	13.0587	8.6410	12.7261	15.1597	25.8609	48.1826	13.1301	21.6158	18.3117
Detritivorous	0.0613	93.1230	0.1291	68.3193	26.7795	41.3113	35.4222	17.0607	13.2755	46.4018	10.7333	26.6911	20.2459	10.6799	9.5227	24.9857
Benthophagous	0.0151	99.8350	0.2371	99.3513	20.8331	7.5861	5.3599	15.2358	2.6578	4.3715	52.3304	33.6697	16.4833	42.6902	27.2291	25.4075
Carnivorous	0.0002	99.9059	0.0043	99.9110	0.1541	0.0236	0.0000	0.2894	0.0615	0.0000	0.3637	0.5298	0.0000	0.8330	1.0371	0.0000
Herbivorous	0.0002	100.0000	0.0007	100.0000	0.0000	0.0442	0.0175	0.0127	0.0073	0.5595	0.0000	0.1069	0.0118	0.0149	0.0192	0.4200

Conclusões

Conclusões

A partir dos diferentes desenhos amostrais executados, todos os objetivos propostos foram alcançados. O habitat praia, estabelecido às margens da desembocadura do estuário do Rio Goiana foi pela primeira vez estudado de forma ecológica, e muitas informações importantes a respeito desse ambiente, protegido por lei, passam a ser conhecidas.

Na porção externa do estuário do Rio Goiana, praias arenosas encontram-se ligadas a um extenso terraço de baixa-mar. Apesar de ser um ambiente modificado pela maré, o Rio Goiana exerce enorme influencia na composição física (morfodinâmica e sedimentos), química (salinidade) e biológica (matéria orgânica e comunidade biótica) das praias adjacentes. Dessa forma, ao atravessar o terraço de baixa-mar pela margem sul do estuário, o canal principal do Rio Goiana é responsável pelas diferenças espaciais encontradas nos diferentes estudos apresentados. Esse ambiente raso, frequentemente emerso e com alto acúmulo de matéria orgânica vegetal, abriga grande abundancia de peixes e crustáceos, em sua maioria representados por indivíduos em fase inicial de desenvolvimento. Por apresentar proteção contra predadores (aguas rasas, turvas e com complexidade estrutural fruto do acumulo de macroalgas), recursos alimentares (invertebrados associados à matéria orgânica) e conexão com outros habitats, as praias adjacentes ao estuário representam uma importante alternativa de berçário para diferentes espécies de peixes e crustáceos.

Localizadas entre habitats (estuário e recifes costeiros) de grande importância e produtividade biológica, as praias também desenvolvem um importante papel na conexão entre os habitats adjacentes. Durante a estação seca, o terraço de baixa-mar apresenta-se propício para juvenis de espécies costeiras terem acesso aos canais de maré e florestas de mangue, na porção interna do estuário. Por outro lado, durante a estação chuvosa, também permite que espécies estuarinas explorem recursos da região costeira adjacente. Dessa forma, o aporte de agua doce durante a estação das chuvas tem grande importância ecológica no habitat, permitindo que o mesmo contemple um maior número de espécies, sendo o fator principal na variância da comunidade.

Inserida em uma Reserva Extrativista, as praias adjacentes a desembocadura do estuário são utilizadas diariamente por famílias tradicionais. As águas rasas e bancos arenosos expostos promovem fácil acesso a fontes proteicas de qualidade. Dessa forma, as praias são habitats de extrema importância para Resex Acaú-Goiana, devendo ter sua integridade mantida de forma prioritária, pois além de ser acessível e fornecer alimento para inúmeras famílias, também apresenta papel crucial na manutenção da biodiversidade local e de habitats adjacentes, podendo garantir um melhor funcionamento e produtividade do complexo estuarino-costeiro, essencial à sustentabilidade da Reserva.

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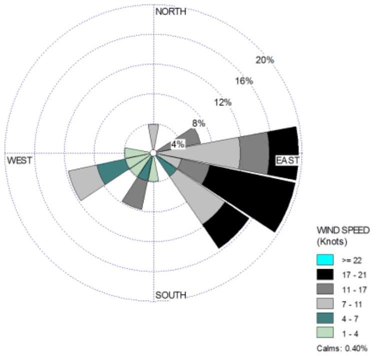
Apêndices

A informação entre parênteses é referente aos compartimentos da Tese. Apresentação (*Ap*) e capítulos (1,2 e 3).

Apêndice 1 (*Ap*)

Janeiro



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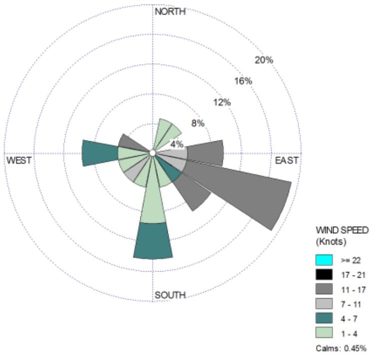

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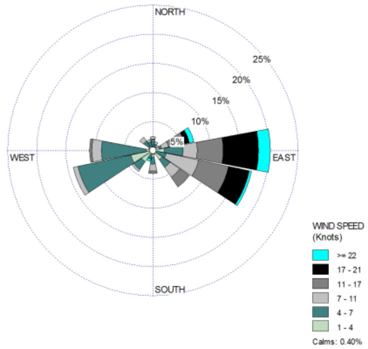

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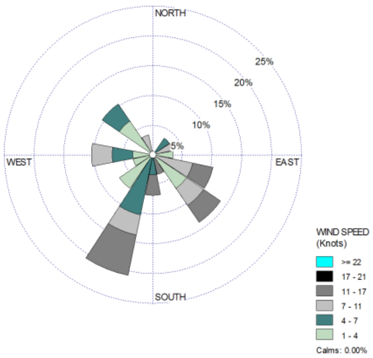

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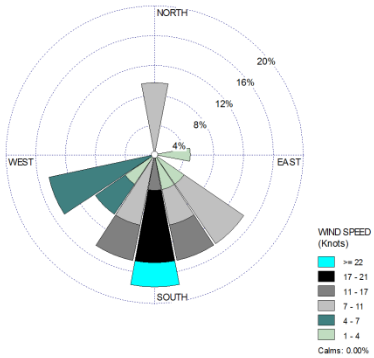

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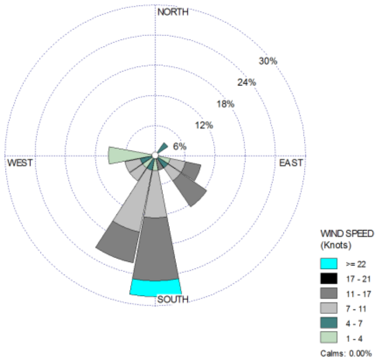

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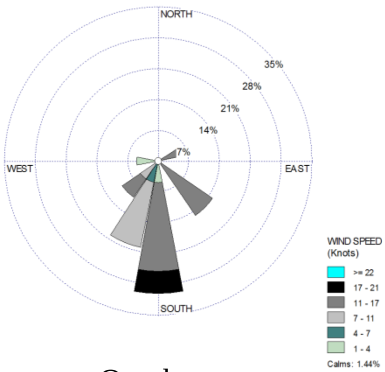

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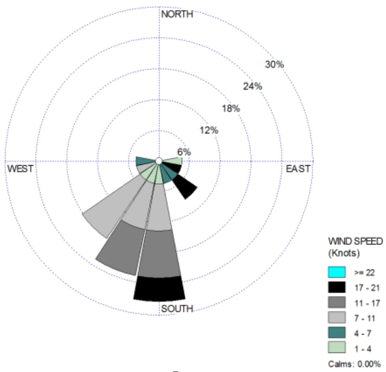

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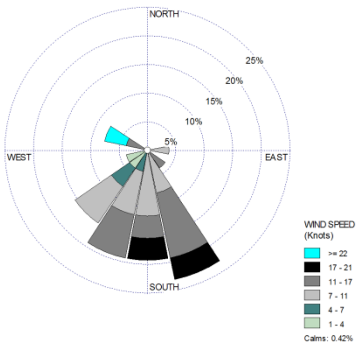

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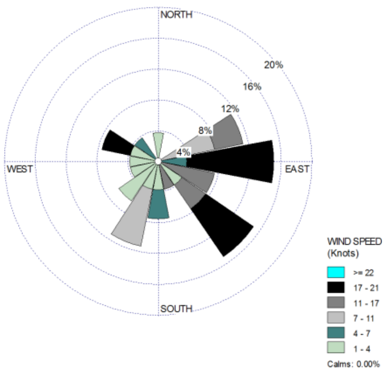

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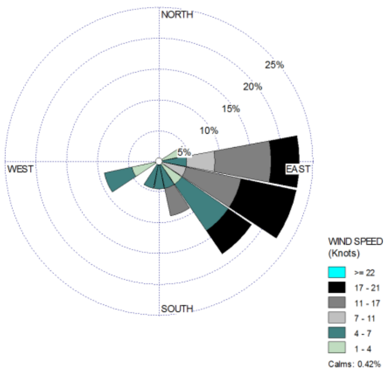

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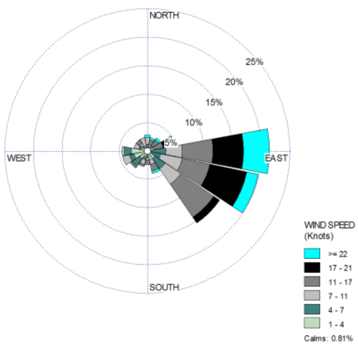

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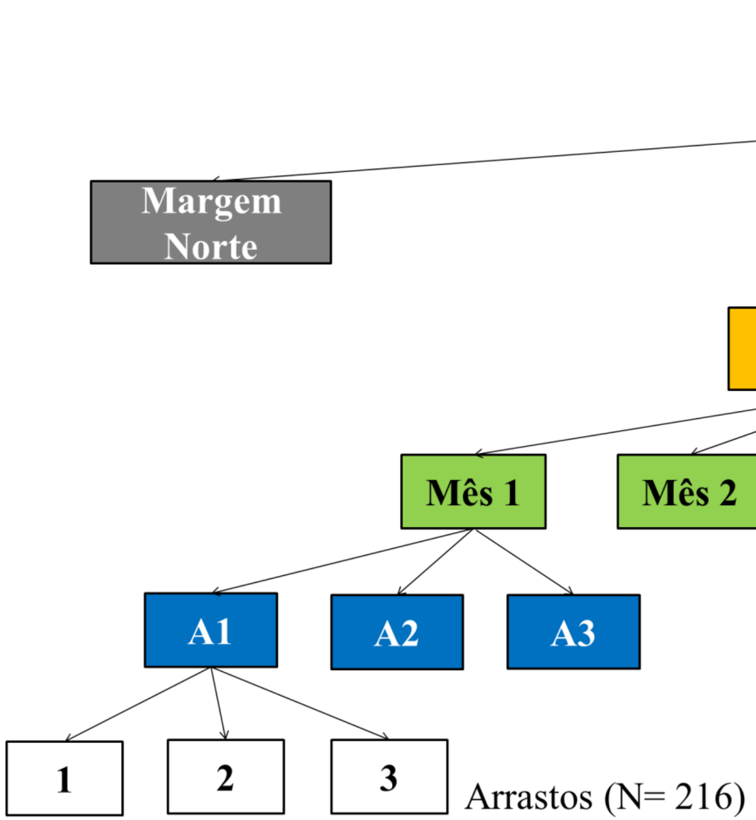

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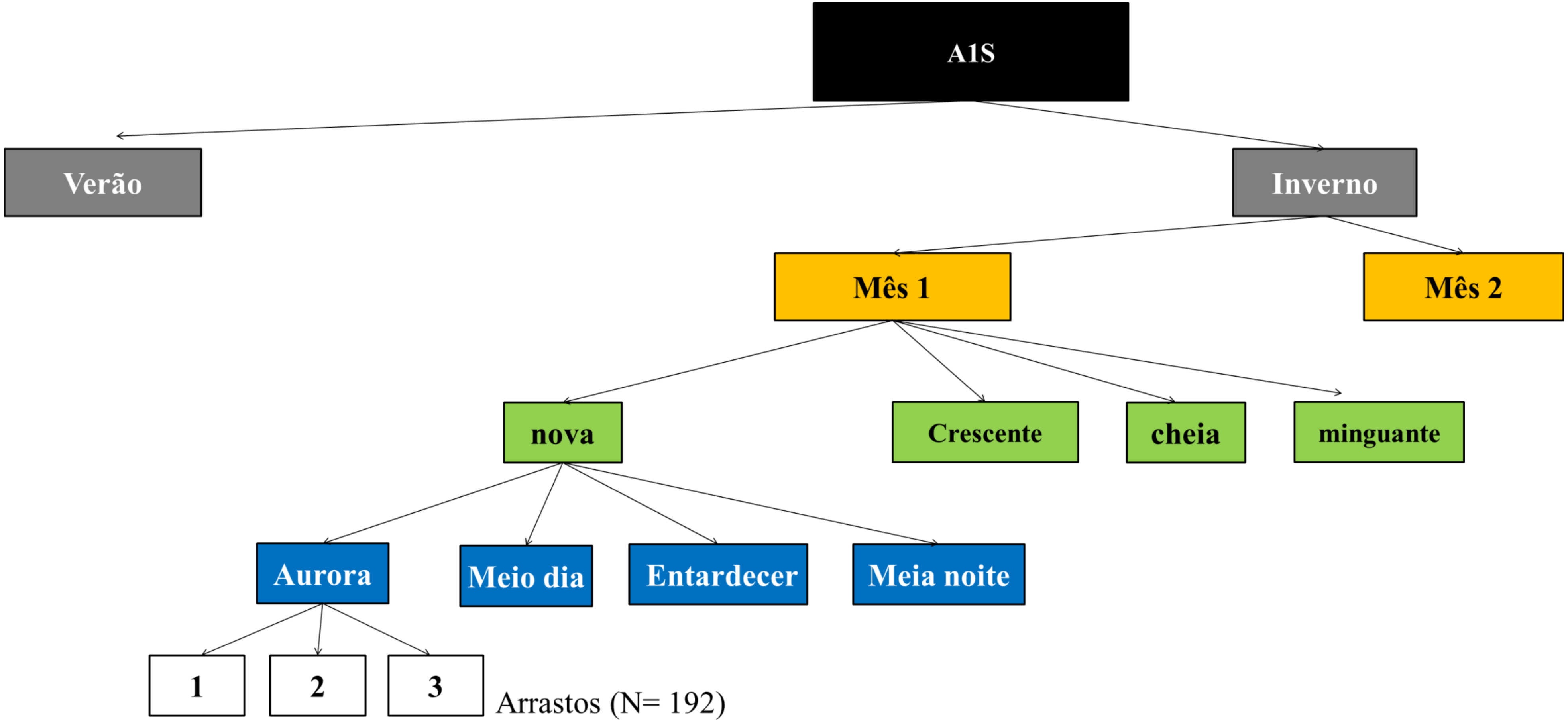

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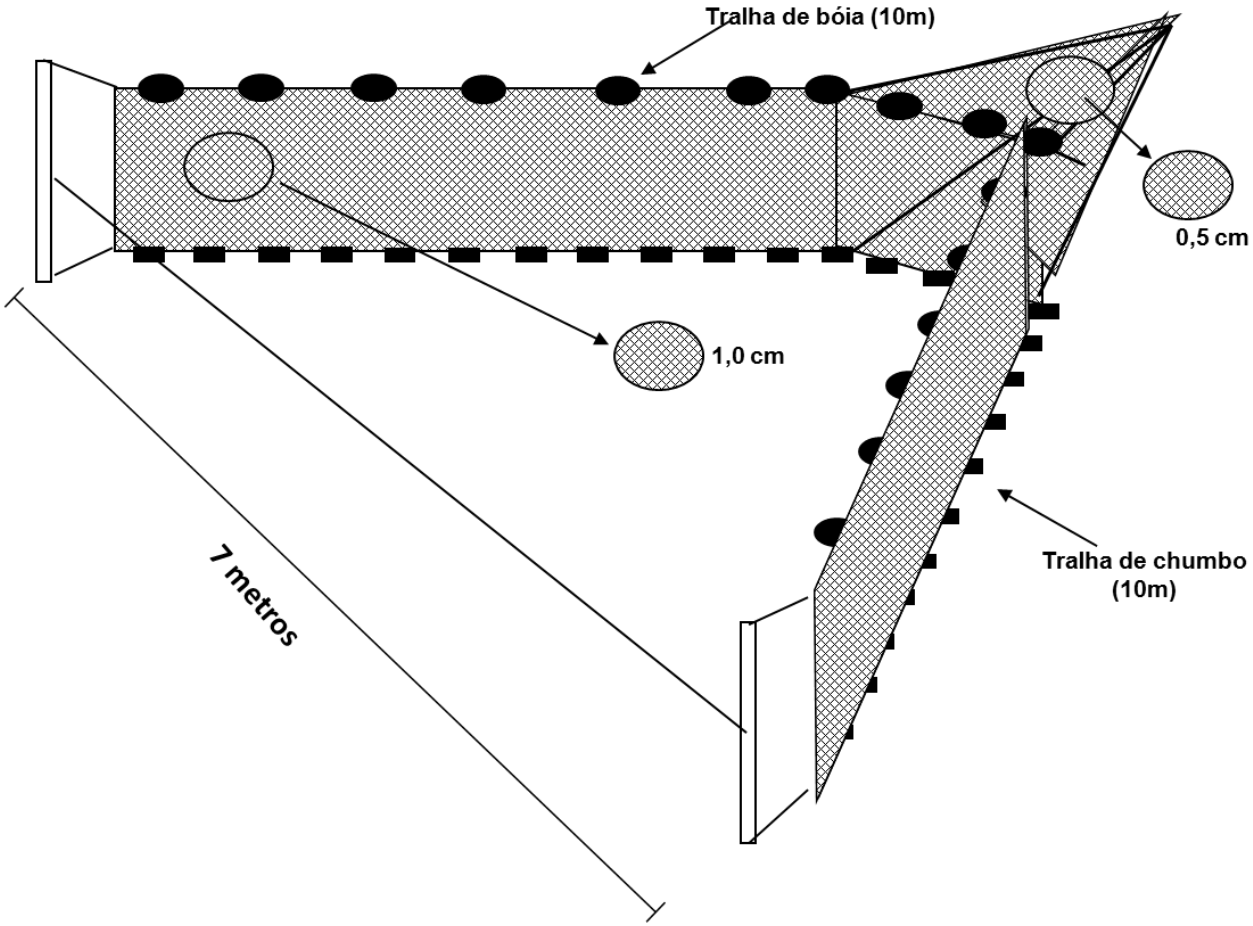


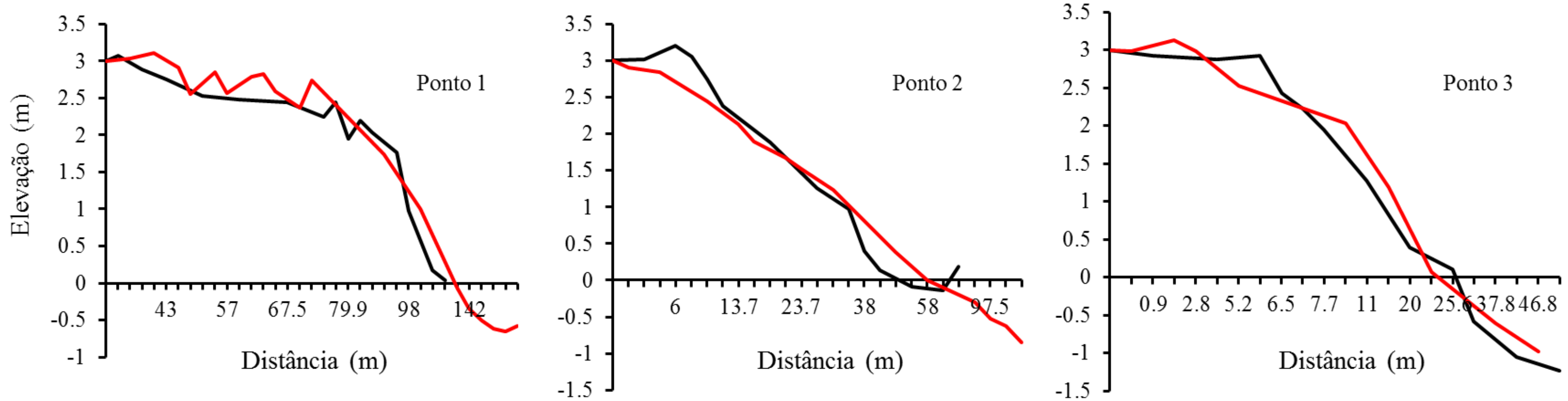
Apêndice 1 (1)

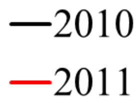



Apêndice 2 (1)

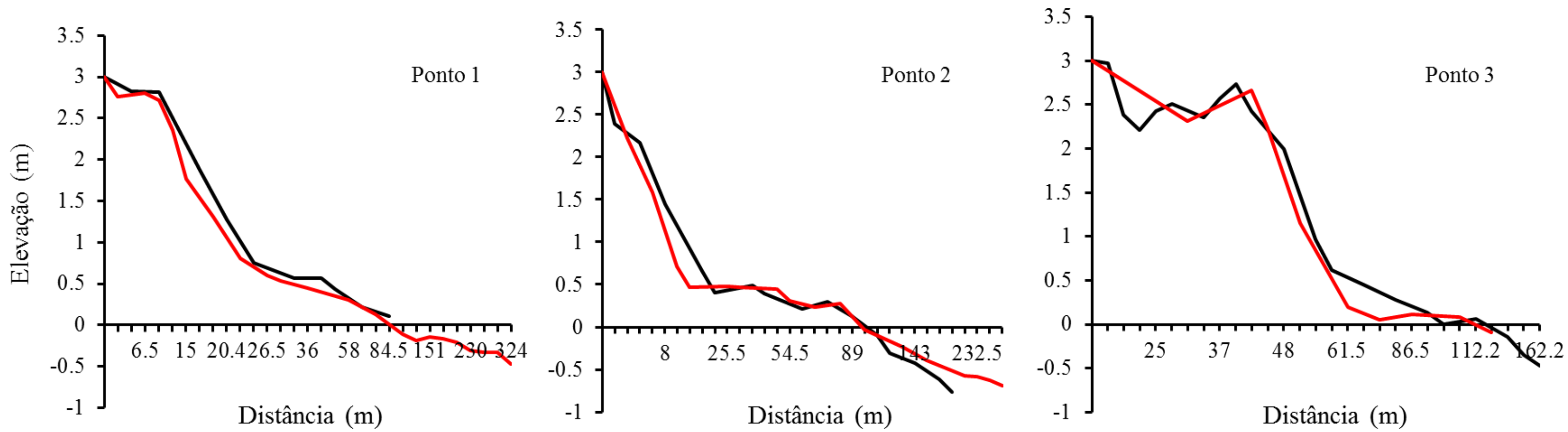
Apêndice 3 (1)

Margem Norte – Praia de Acaú





Margem Sul – Praia de Carne de Vaca



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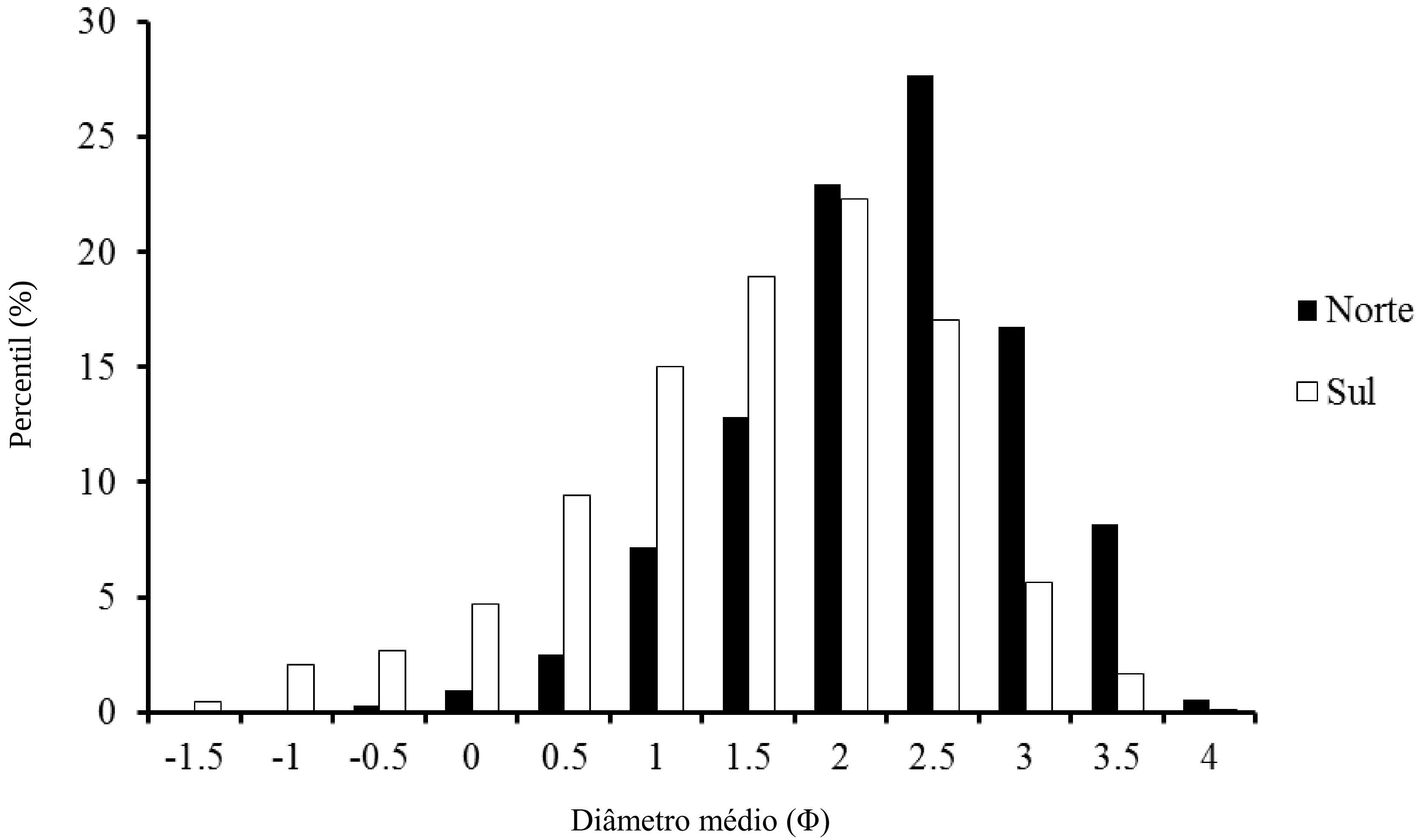
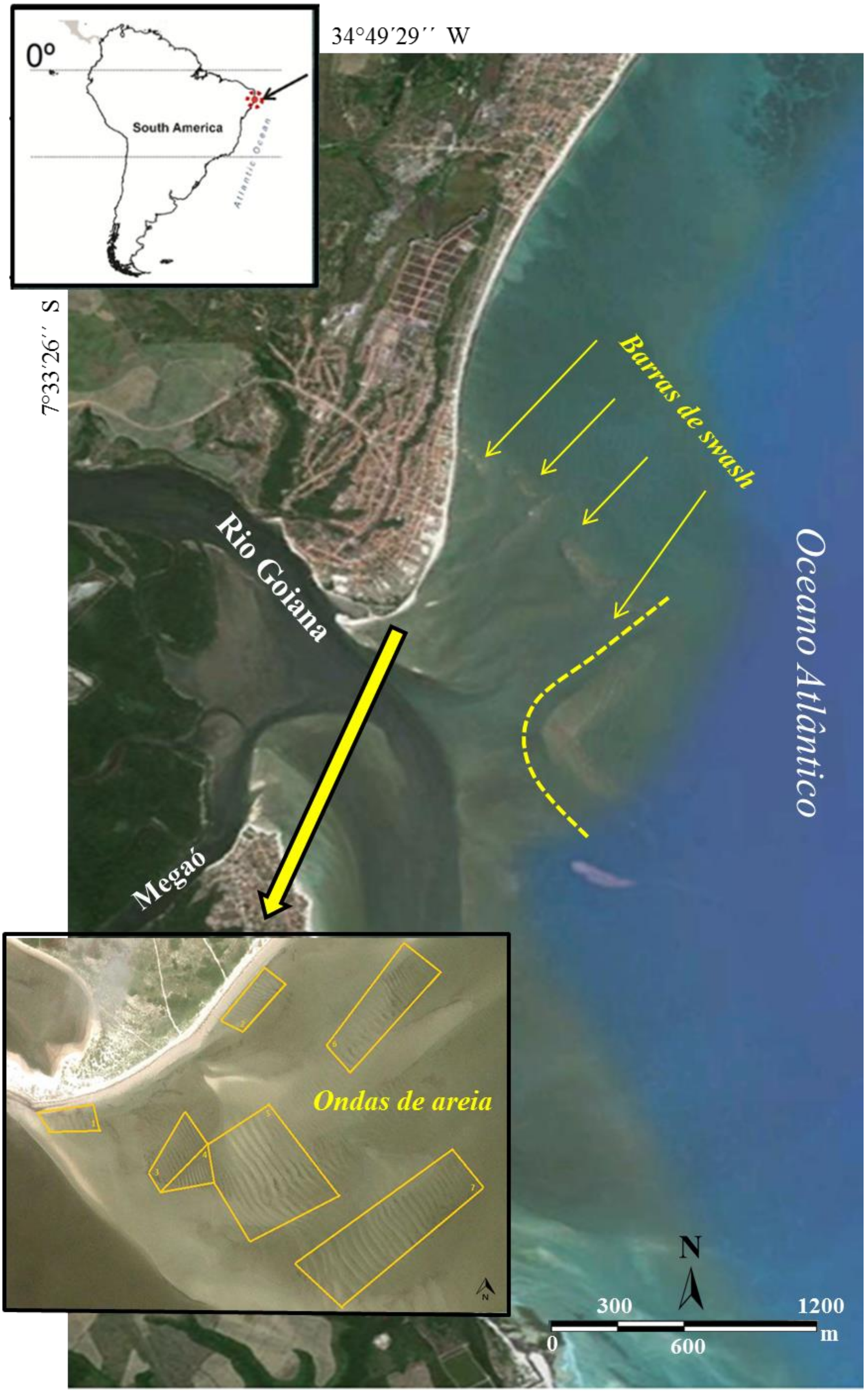


30
25
20
15
10
5
0
Percentil (%)
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
Diâmetro médio (Φ)
Norte
Sul

Apêndice 5 (1)


34°49′29′′ W
7°33′26′′ S
0°
South America
Atlantic Ocean
Barras de swash
Oceano Atlântico
Rio Goiana
Megaó
Ondas de areia
N
300
1200
0
600
m

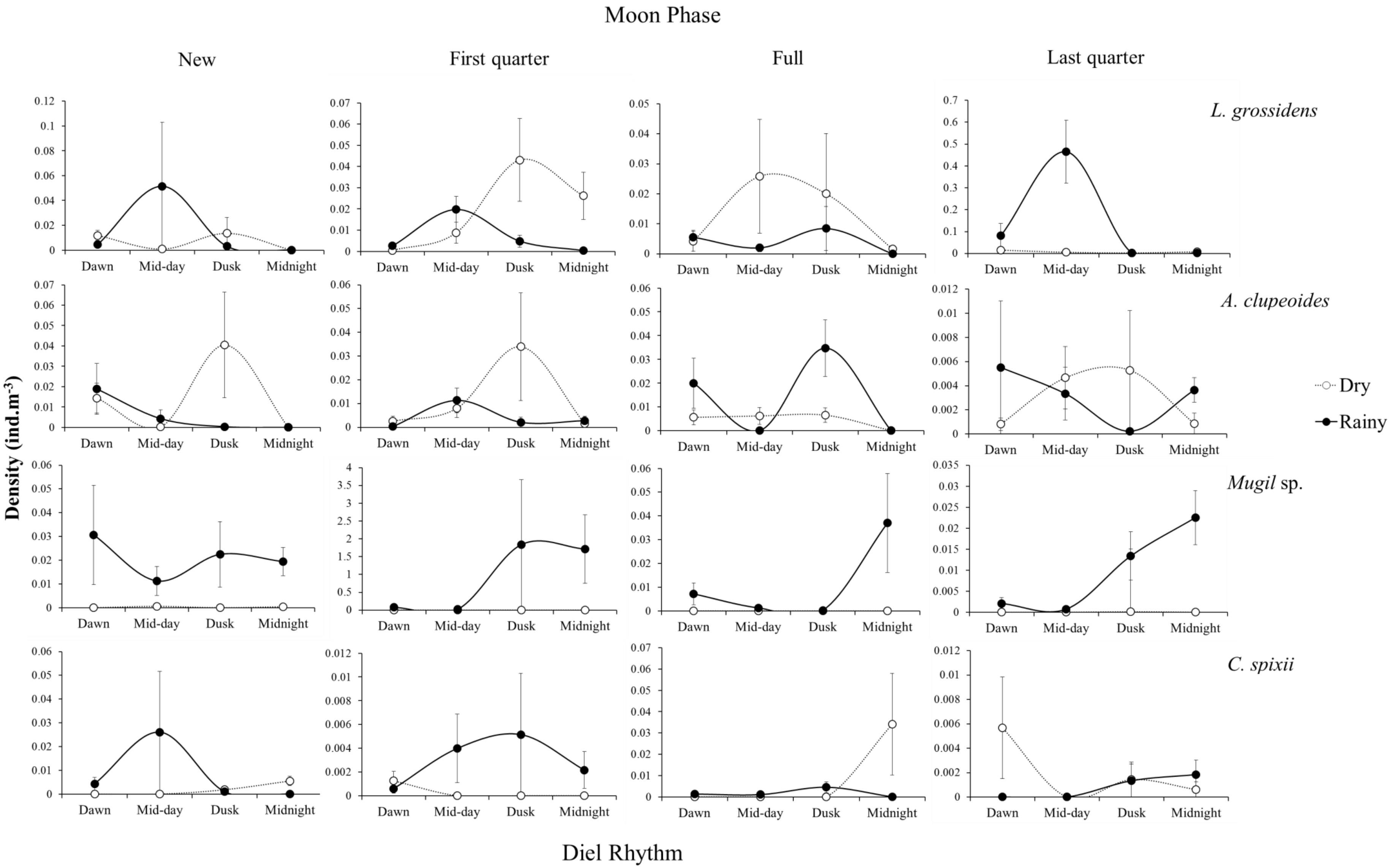
Apêndice 1 (2)

							Moon phase																				
							Rainy season (%)										Dry season (%)										
							First quarter		Full		Last quarter		New		Mean Length	Length range	First quarter		Full		Last quarter		New		Mean Length	Length range	Total Length
	Species	Dens	Acum (%)	Bio	Acum (%)	Freq. (%)	Dens	Bio	Dens	Bio	Dens	Bio	Dens	Bio	(cm±SD)	(cm)	Dens	Bio	Dens	Bio	Dens	Bio	Dens	Bio	(cm±SD)	(cm)	mean (cm)±SD
1	*Mugil* sp.	0.1196	63.7	0.0496	13.1	37.0	94.38	51.61	14.62	2.83	4.49	1.70	22.98	4.49	3.1±0.5	(1-13)					0.10	1.98	0.88	25.15	20±0.2	(16-24)	11±0.3
2	*Lycengraulis grossidens*	0.0263	77.7	0.0446	25.0	50.0	0.72	5.64	5.09	3.33	63.94	31.97	16.20	3.85	5.2±2.2	(3-18)	45.78	35.75	25.55	5.66	31.26	12.36	21.11	7.59	7.3±2.7	(3-14)	6.2±2.4
3	*Anchovia clupeoides*	0.0075	81.6	0.0144	28.8	40.6	0.43	0.68	17.47	4.60	1.48	1.37	6.44	5.06	5±2.2	(3-15)	26.86	10.27	9.03	2.35	11.90	3.49	44.72	7.07	6.1±2.4	(3-14)	5.5±2.3
4	*Bairdiella ronchus*	0.0041	83.8	0.0052	30.1	22.9	1.13	1.61	5.04	2.14	3.01	2.27	12.38	3.33	4.2±2	(1-15)					0.24	0.44					4.2±2
5	*Stellifer brasiliensis*	0.0034	85.6	0.0035	31.1	18.8	0.57	1.25	13.76	2.63	5.16	2.43			3.8±1.9	(1-13)			0.09	0.01							3.8±1.9
6	*Cathorops spixii*	0.0032	87.3	0.0720	50.1	26.6	0.31	2.02	2.22	7.37	0.37	0.53	8.62	24.75	8.9±2.9	(4-23)	0.73	3.89	16.84	58.25	6.44	33.67	5.81	23.21	13.6±3.6	(3-24)	11.2±3.3
7	*Atherinella brasiliensis*	0.0030	89.0	0.0094	52.6	34.9	0.14	1.00	5.36	1.17	1.91	3.02	8.06	5.99	6.3±2.5	(2-12)	2.10	1.11	3.00	0.95	19.70	10.64	0.49	0.25	7.6±2.7	(2-11)	7±2.6
8	*Anchoa tricolor*	0.0025	90.3	0.0041	53.7	9.4	0.01	0.05	0.08	0.01	5.15	3.18	0.24	0.04	7±2.6	(3-6)	0.92	0.66	15.79	3.35			0.56	0.33	11±3.3	(5-11)	9±2.9
9	*Stellifer stellifer*	0.0013	91.0	0.0108	56.6	15.6	0.14	1.91	2.62	3.84	2.22	10.00	2.35	4.21	8.8±2.9	(5-13)											8.8±2.9
10	*Stellifer rastrifer*	0.0023	92.2	0.0177	61.3	18.2	0.46	5.95	8.63	13.47	1.42	5.20	4.59	8.00	8.4±2.9	(6-15)											8.4±2.9
11	*Rhinosardinia bahiensis*	0.0017	93.1	0.0053	62.7	18.2	0.15	0.85	0.63	0.44	2.98	5.15	4.80	3.02	7.5±2.7	(5-9)	0.75	0.56					0.33	0.14	8.2±2.8	(7-9)	7.8±2.8
12	*Menticirrhus americanus*	0.0010	93.6	0.0143	66.5	29.2	0.24	2.49	0.98	1.32	0.64	0.63	0.79	1.40	6.7±2.6	(3-14)	1.39	5.48	3.11	11.53	2.40	7.29	0.62	1.61	12.6±3.5	(8-19)	9.6±3.1
13	*Polydactylus virginicus*	0.0009	94.1	0.0066	68.2	23.4	0.12	0.96	2.20	1.22	1.04	1.23	0.29	0.16	6.3±2.5	(3-10)	0.80	1.94	0.96	2.13	1.78	3.20	2.95	4.69	11.8±3.4	(6-14)	9.1±2.9
14	*Anchoa lyolepis*	0.0009	94.6	0.0018	68.7	5.7	0.01	0.02					0.25	0.09	5.8±2.4	(3-8)	0.17	0.03	13.08	2.85	0.66	0.01			6.5±2.5	(3-8)	6.1±2.4
15	*Sciades herzbergii*	0.0009	95.1	0.0033	69.6	21.9	0.14	0.88	1.21	0.80	0.46	0.86	1.62	1.32	7.9±2.8	(4-11)	1.40	0.57	0.40	0.21	3.45	2.18	1.48	0.81	8.4±2.9	(6-11)	8.1±2.8
16	*Pellona harroweri*	0.0008	95.5	0.0012	69.9	4.2			4.38	0.67	1.42	1.47	0.06	0.08	5.1±2.2	(4-9)											5.1±2.2
17	*Achirus lineatus*	0.0008	95.9	0.0093	72.3	21.4	0.20	6.16	0.41	0.71	0.71	2.64	1.98	4.86	7.6±2.7	(5-15)	0.58	2.70	0.13	0.04	0.61	0.83	0.23	0.02	7.1±2.6	(3-12)	7.3±2.7
18	*Bathygobius soporator*	0.0007	96.3	0.0049	73.6	9.4	0.22	4.37	1.77	1.14	0.85	2.47			6.4±2.5	(2-10)	0.41	0.25									6.4±2.5
19	*Hyporhamphus unifasciatus*	0.0007	96.7	0.0077	75.7	28.6	0.10	1.80	0.39	0.78	0.46	1.99	0.58	1.48	15.3±3.9	(4-19)	2.44	6.36	0.78	1.60	3.38	4.34	1.76	1.01	14.9±3.8	(3-18)	15.1±3.8
20	*Sphoeroides testudineus*	0.0007	97.0	0.0186	80.6	17.7	0.05	4.05	3.48	13.17	0.19	12.92	0.29	1.12	12.5±3.5	(3-25)	1.10	2.97	0.13	0.03	3.41	2.73	0.77	0.06	5.2±2.2	(2-13)	8.8±2.9
21	*Citharichthys arenaceus*	0.0007	97.4	0.0019	81.1	19.3	0.09	0.20	1.32	0.21	0.37	0.16	1.68	0.66	4.5±2.1	(3-10)	1.41	2.52	0.29	0.26			1.85	0.84	8.6±2.9	(4-11)	6.6±2.5
22	*Larimus breviceps*	0.0005	97.7	0.0165	85.4	8.9	0.04	0.99	1.29	9.34	0.06	0.79	2.41	20.82	11.7±3.4	(4-16)	0.36	0.03							6.3±2.5	(3-13)	9±2.9
23	*Lile piquitinga*	0.0004	97.8	0.0024	86.1	8.9			0.27	0.10			0.06	0.04	7.5±2.7	(7-8)	0.46	0.58	3.42	2.40	0.24	0.27	1.98	1.49	8.8±2.9	(7-10)	8.1±2.8
24	*Pomadasys corvinaeformis*	0.0003	98.0	0.0033	87.0	9.9											2.93	5.59	2.26	2.27	0.75	0.51	0.19	0.57	8.5±2.9	(4-15)	8.5±2.9
25	*Eucinostomus gula*	0.0003	98.2	0.0016	87.4	6.3			1.64	0.95							0.46	0.29	0.26	0.19			3.03	2.13	7.7±2.7	(3-11)	7.7±2.7
26	*Strongylura marina*	0.0003	98.3	0.0053	88.8	13.0	0.02	1.60	0.29	0.01	0.15	2.23	0.11	0.79	21.8±4.6	(5-38)	1.77	2.37	0.11	0.01	1.73	7.72	0.67	0.29	21.4±4.6	(8-37)	21.6±4.6
27	*Symphurus tessellatus*	0.0003	98.5	0.0006	89.0	8.3	0.10	0.23	1.03	0.19	0.15	0.49			6.3±2.5	(4-11)	0.18	0.47									6.3±2.5
28	*Sphoeroides greeleyi*	0.0003	98.6	0.0006	89.1	9.4			0.09	0.02							0.79	0.24	1.40	0.31	3.12	1.22	0.80	0.23	4.4±2.1	(2-8)	4.4±2.1
29	*Citharichthys spilopterus*	0.0002	98.7	0.0022	89.7	10.9	0.02	0.93			0.04	0.99	0.54	0.77	11.3±3.3	(4-16)	0.53	0.31	0.53	0.47	1.37	1.05			8.4±2.9	(6-11)	9.8±3.1
30	*Gobionellus oceanicus*	0.0002	98.8	0.0001	89.7	5.2	0.06	0.05			0.08	0.02	1.08	0.12	3.3±1.8	(2-5)											3.3±1.8
31	*Trachinotus falcatus*	0.0002	98.9	0.0007	89.9	8.3											0.55	0.40	0.51	0.23	3.73	1.46	0.35	0.25	6±2.4	(4-10)	6±2.4
32	*Eucinostomus melanopterus*	0.0002	99.0	0.0012	90.2	9.4	0.01	0.21							8	8	0.65	0.64	0.20	0.08	0.88	1.03	2.14	1.25	7.3±2.7	(4-10)	7.3±2.7
33	*Cynoscion acoupa*	0.0002	99.1	0.0020	90.8	7.8	0.03	0.20	0.45	2.29	0.20	0.18	0.35	1.22	16.4±4.1	(3-23)											16.4±4.1
34	*Cynoscion microlepidotus*	0.0002	99.2	0.0005	90.9	2.6			1.03	0.58	0.21	0.30			5.5±2.3	(2-10)											5.5±2.3
35	*Dasyatis guttata*	0.0001	99.3	0.0188	95.9	4.7			1.17	22.99	0.06	1.61	0.05	1.12	43.5±6.9	(27-67)							0.25	12.59	65	65	54.2±6.1
36	*Ophioscion punctatissimus*	0.0001	99.4	0.0001	95.9	5.7	0.02	0.03			0.32	0.13	0.05	0.01	3.8±1.8	(2-4)							0.33	0.01	3	3	3.2±1.7
37	*Selene vomer*	0.0001	99.4	0.0003	96.0	6.3			0.38	0.05	0.04	0.01			3±1.7	-2.40	1.26	0.74					0.23	0.03	4.8±2.2	(3-6)	3.9±1.9
38	*Ctenogobius stigmaticus*	0.0001	99.5	0.0001	96.0	3.1	0.01	0.01			0.11	0.11	0.72	0.14	5±2.2	(4-16)											5±2.2
39	*Etropus crossotus*	0.0001	99.5	0.0006	96.2	3.1	0.07	0.38			0.13	0.59			6.4±2.5	(4-11)											6.4±2.5
40	*Oligoplites saurus*	0.0001	99.6	0.0001	96.2	6.3											0.51	0.09	0.18	0.04	0.47	0.03	0.90	0.14	5±2.2	(3-6)	

Apêndice 1 (2). Continuação

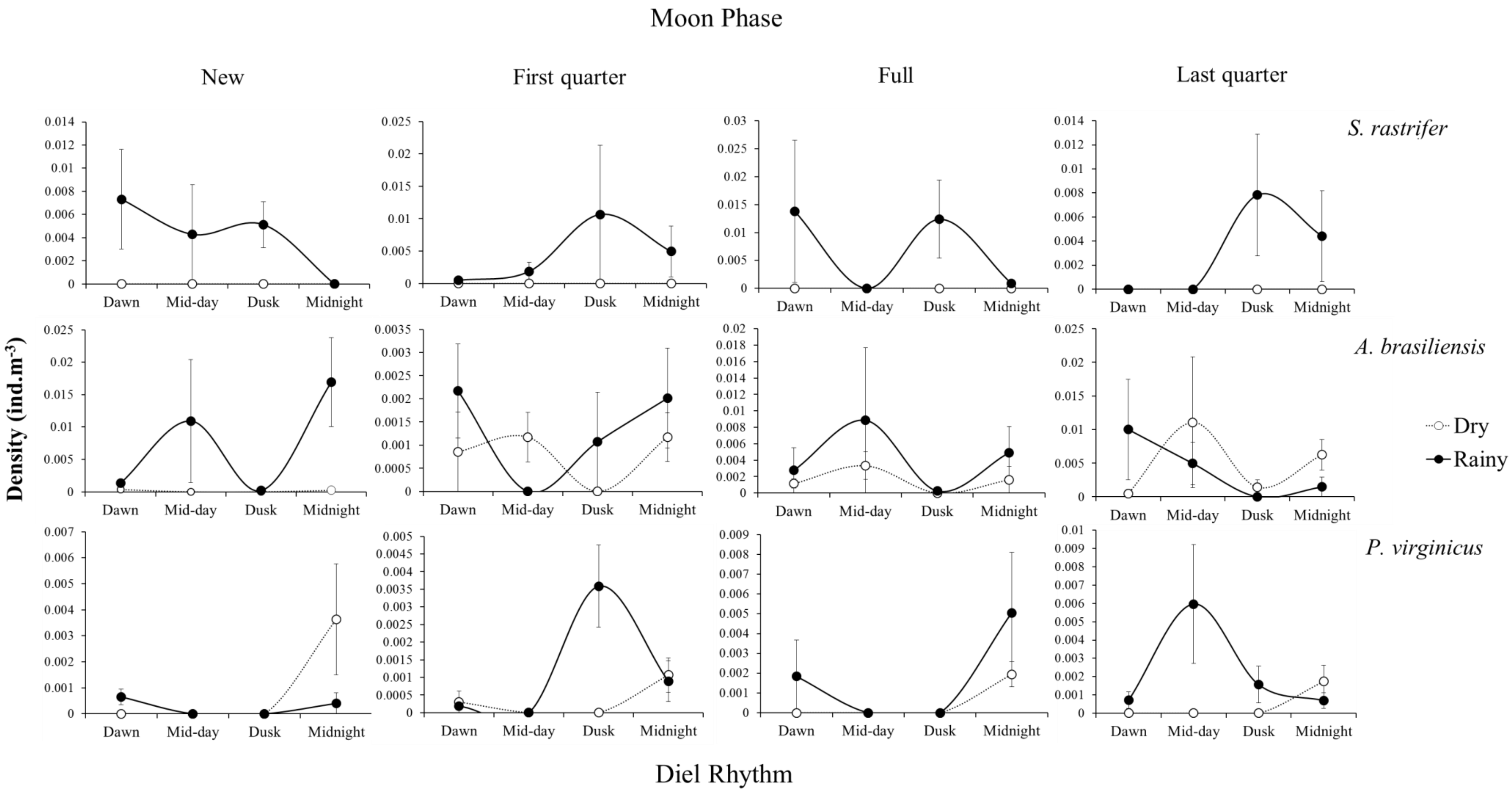
						Moon phase																				
						Rainy season (%)										Dry season (%)										
						First quarter		Full		Last quarter		New		Mean Length	Length range	First quarter		Full		Last quarter		New		Mean Length	Length range	Total Length
Species	Dens	Acum (%)	Bio	Acum (%)	Freq. (%)	Dens	Bio	Dens	Bio	Dens	Bio	Dens	Bio	(cm±SD)	(cm)	Dens	Bio	Dens	Bio	Dens	Bio	Dens	Bio	(cm±SD)	(cm)	mean (cm)±SD
41 *Albula vulpes*	0.0001	99.6	0.0005	96.3	2.6											0.54	0.45					1.31	0.90	9.8±3.1	(5-17)	9.8±3.1
42 *Cynoscion leiarchus*	0.0001	99.7	0.0017	96.8	4.2	0.02	1.43	0.53	1.52			0.04	0.03											11.8±3.4	(6-21)	11.8±3.4
43 *Caranx latus*	0.0001	99.7	0.0008	97.0	5.7							0.10	0.09	7	7	0.32	0.16	0.30	0.22	0.63	2.20	0.19	0.12	7.8±2.8	(5-12)	7.4±2.6
44 *Chaetodipterus faber*	0.0001	99.7	0.0008	97.2	7.3											0.78	0.73	0.25	0.42	0.24	0.06	0.14	0.80	5.2±2.2	(2-12)	5.2±2.2
45 *Cetengraulis edentulus*	0.0001	99.8	0.0007	97.4	3.1											0.23	0.57					1.44	1.24	10.5±3.2	(9-12)	10.5±3.2
46 *Eucinostomus argenteus*	0.0001	99.8	0.0008	97.6	2.6													0.80	1.19			0.33	0.20	9.6±3.1	(8-11)	9.6±3.1
47 *Chirocentrodon bleekerianus*	<0.0001	99.8	0.0001	97.6	2.1			0.27	0.10					7	7	0.08	0.08			0.42	0.20			8.6±2.9	(8-9)	7.8±2.5
48 *Eugerres brasilianus*	<0.0001	99.9	0.0021	98.2	3.1													0.14	2.48			0.83	1.47	13.2±3.6	(8-23)	13.2±3.6
49 *Synghnathus scovelli*	<0.0001	99.9	<0.0001	98.2	1.0					0.12	0.03			9	9											9
50 *Guavina guavina*	<0.0001	99.9	0.0003	98.3	1.6							0.17	0.42	10	10	0.11	0.36							12	12	11±1.4
51 *Synodus foetens*	<0.0001	99.9	0.0002	98.3	2.6											0.31	0.05					0.17	0.37	5.3±2.3	(5-6)	5.3±2.3
52 *Peprilus paru*	<0.0001	99.9	0.0001	98.4	1.6													0.37	0.21					7.5±2.7	(7-8)	7.5±2.7
53 *Paralichthys brasiliensis*	<0.0001	99.9	0.0002	98.4	1.0															0.63	0.81			9	9	9
54 *Conodon nobilis*	<0.0001	99.9	0.0004	98.5	2.1		0.07							8	8							0.19	0.79	14	14	11±4.2
55 *Erotelis smaragdus*	<0.0001	99.9	<0.0001	98.5	0.5							0.11	0.07	6±2.4	(4-8)											6±2.4
56 *Rypticus randalli*	<0.0001	99.95	0.0007	98.7	1.0																	0.33	1.59	16	16	16
57 *Sciades proops*	<0.0001	99.96	0.0012	99.0	1.0											0.19	4.20							26	26	26
58 *Archosargus rhomboidalis*	<0.0001	99.96	<0.0001	99.0	1.0																	0.25	0.02	4	4	4
59 *Odontesthes bonariensis*	<0.0001	99.97	<0.0001	99.0	1.0																	0.23	0.03	6±2.4	(5-7)	6±2.4
60 *Genyatremus luteus*	<0.0001	99.97	0.0007	99.2	1.0					0.03	1.29			17	17											17
61 *Ophichthus ophis*	<0.0001	99.98	0.0019	99.7	1.0											0.16	6.59							7	7	7
62 *Anisotremus surinamensis*	<0.0001	99.98	0.0003	99.8	1.0																		0.67	13	13	13
63 *Lagocephalus laevigatus*	<0.0001	99.98	0.0001	99.8	1.0					0.03	0.09													5	5	5
64 *Diapterus rhombeus*	<0.0001	99.99	<0.0001	99.8	1.0															0.24	0.06			12	12	12
65 *Hippocampus reidi*	<0.0001	99.99	0.0001	99.8	1.0															0.24	0.21			11	11	11
66 *Lutjanus jocu*	<0.0001	99.99	0.0002	99.9	1.0													0.10	0.26					4	4	4
67 *Sciades couma*	<0.0001	99.997	0.0002	99.9	1.0	0.005	0.36							18	18											18
68 *Centropomus undecimalis*	<0.0001	100	0.0002	100	0.5							0.05	0.43	17	17											17
Total Fish	**0.1878**		**0.3777**			**0.97**	**0.52**	**0.08**	**0.42**	**0.22**	**0.44**	**0.09**	**0.41**			**0.04**	**0.23**	**0.05**	**0.48**	**0.02**	**0.19**	**0.03**	**0.35**			
Crustaceans																										
69 *Callinectes danae*	0.019		0.221			0.004	0.09	0.004	0.04	0.01	0.05	0.01	0.02	4.2±2	(1-19)	0.02	0.24	0.02	0.47	0.05	0.43	0.03	0.43	3.2±1.8	(1-11)	3.7±1.9
70 *Litopenaeus schimitti*	0.022		0.046			0.04	0.08	0.02	0.05	0.04	0.07	0.03	0.06			0.01	0.05	0.003	0.01	0.03	0.03	0.001	0.01			
Total	**0.041**		**0.267**			**0.04**	**0.17**	**0.03**	**0.10**	**0.05**	**0.12**	**0.04**	**0.08**			**0.04**	**0.30**	**0.03**	**0.47**	**0.08**	**0.46**	**0.03**	**0.44**			
Total Fish & Crustaceans	**0.229**		**0.645**			**1.01**	**0.69**	**0.11**	**0.51**	**0.26**	**0.55**	**0.13**	**0.48**			**0.08**	**0.53**	**0.08**	**0.95**	**0.10**	**0.65**	**0.07**	**0.79**			
Wrack			**3.863**				**0.88**		**2.09**		**0.99**		**0.10**				**16.64**		**0.87**		**0.99**		**8.34**			

Apêndice 2 (2)



Moon Phase
New
First quarter
Full
Last quarter
L. grossidens
A. clupeoides
Mugil sp.
C. spixii
Dry
Rainy
Density (ind.m-3)
Dawn
Mid-day
Dusk
Midnight
Diel Rhythm

Apêndice 2 (2). Continuação



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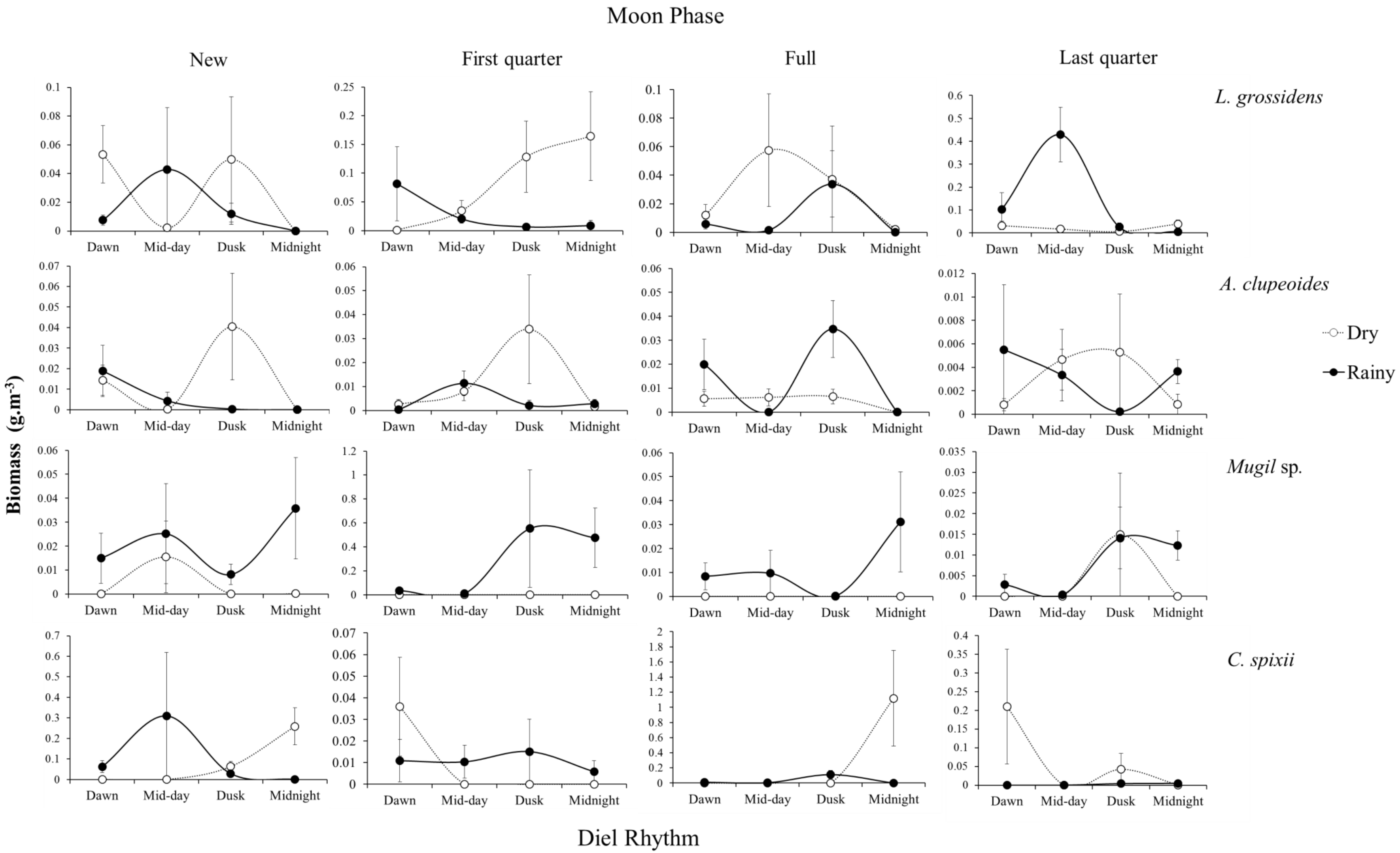
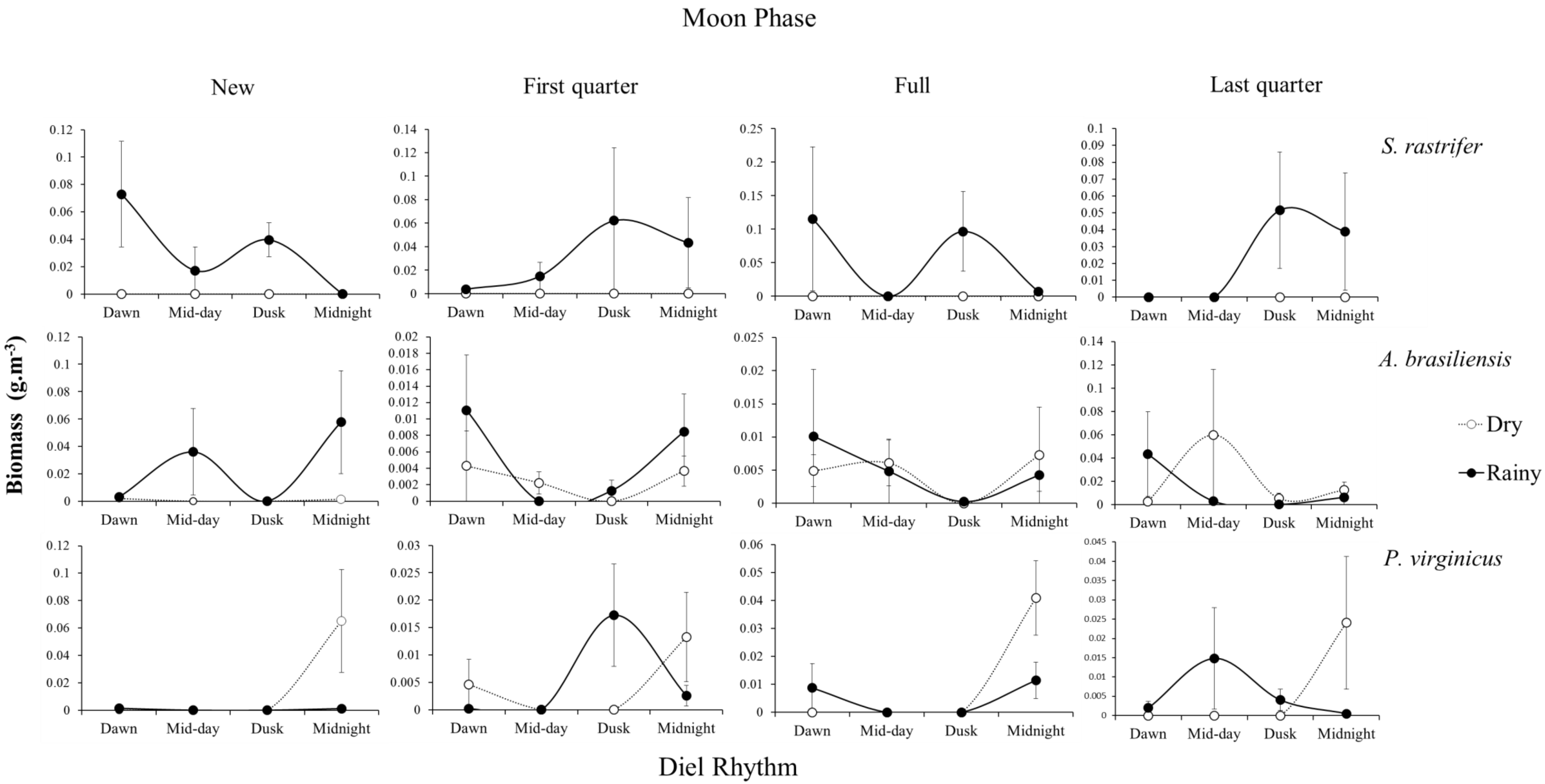
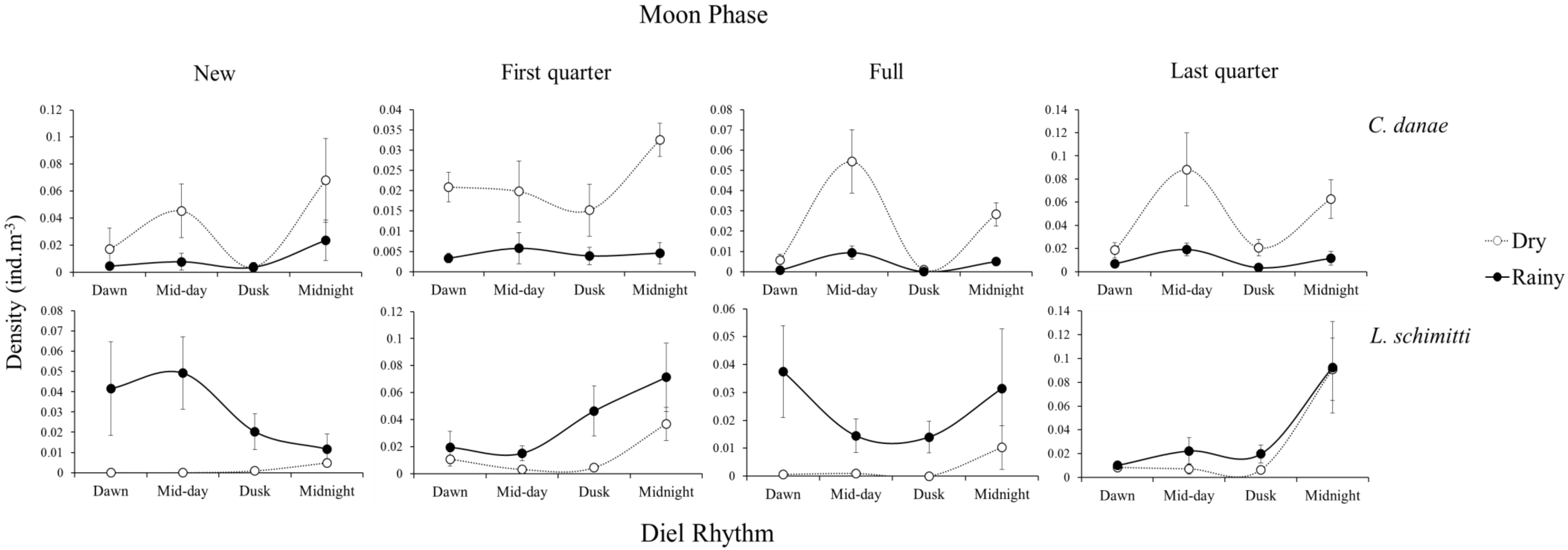

Moon Phase
New
First quarter
Full
Last quarter
L. grossidens
A. clupeoides
Mugil sp.
C. spixii
Dry
Rainy
Biomass (g.m-3)
Dawn
Mid-day
Dusk
Midnight
Diel Rhythm

Apêndice 3 (2). Continuação

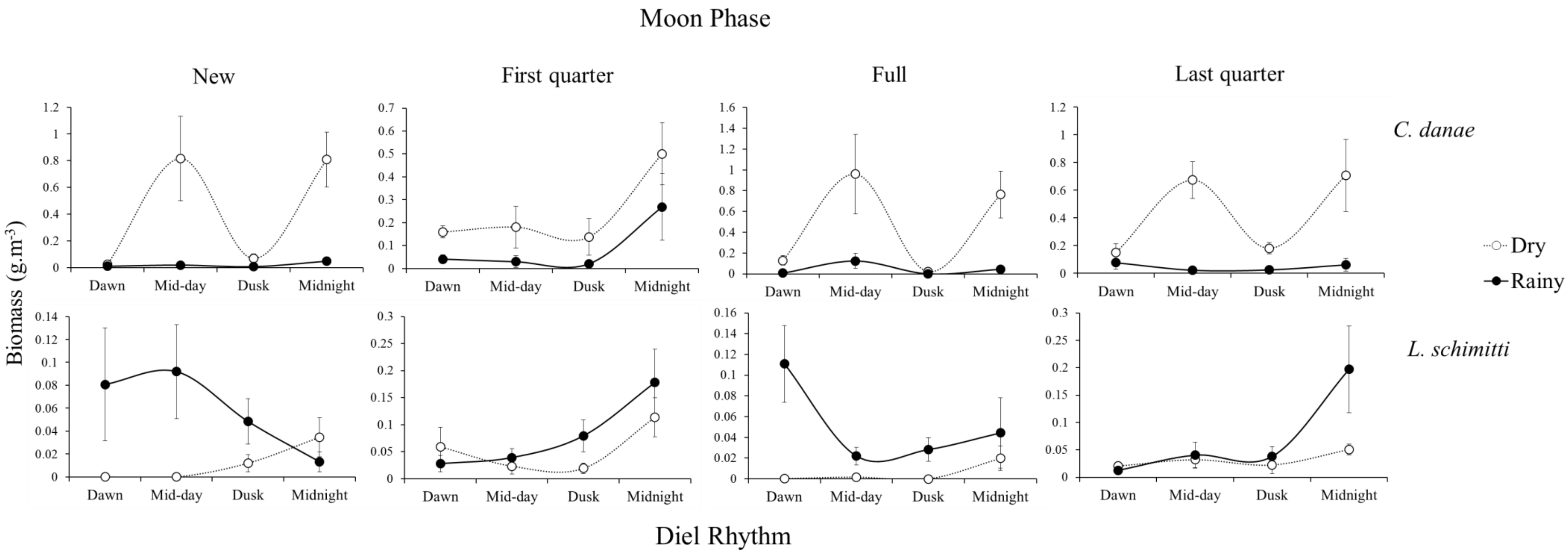


Apêndice 4 (2)

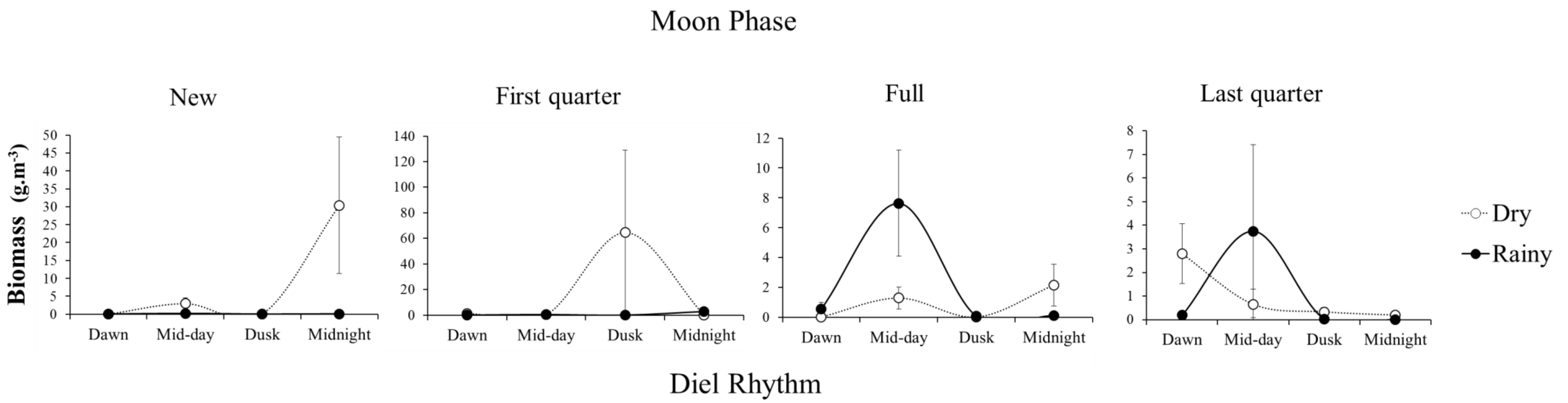


Moon Phase
New
First quarter
Full
Last quarter
C. danae
L. schimitti
Dry
Rainy
Density (ind.m-3)
Dawn
Mid-day
Dusk
Midnight
Diel Rhythm

Apêndice 4 (2). Continuação

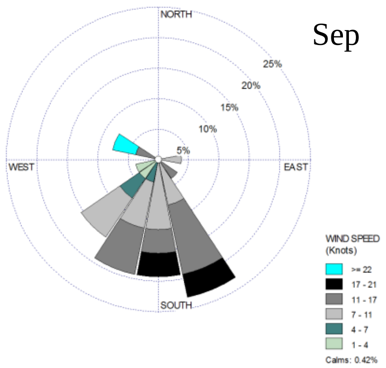


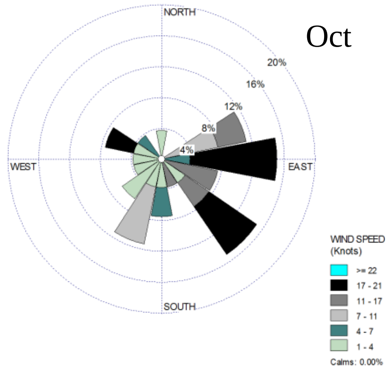
Apêndice 5 (2)

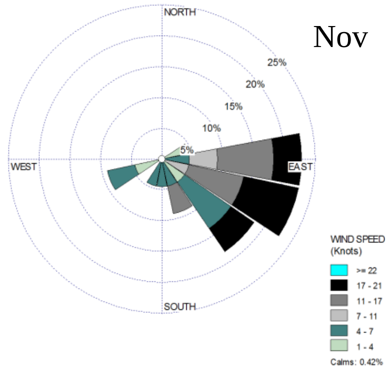

Moon Phase
New
First quarter
Full
Last quarter
Biomass (g.m-3)
Dawn
Mid-day
Dusk
Midnight
Dry
Rainy
Diel Rhythm

Apêndice 1 (3)

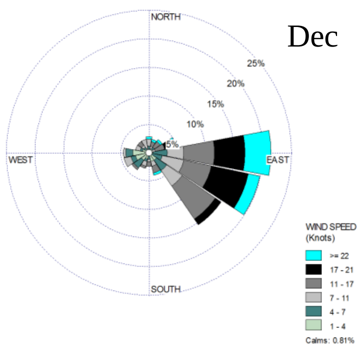
Early Dry

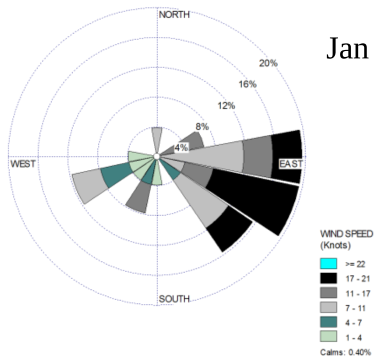


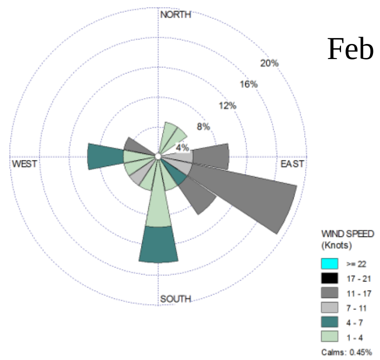




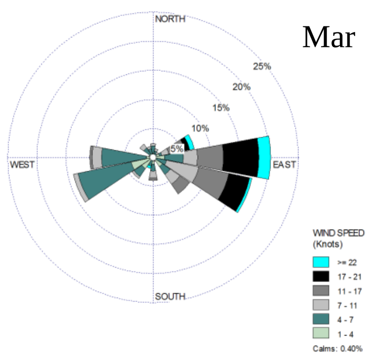
Late Dry

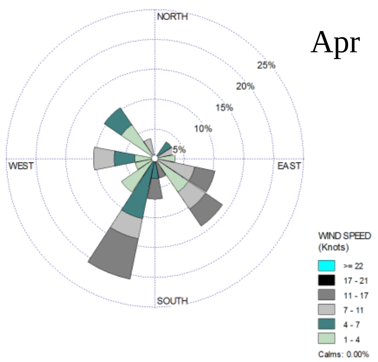


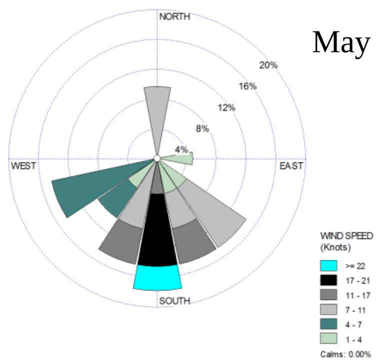




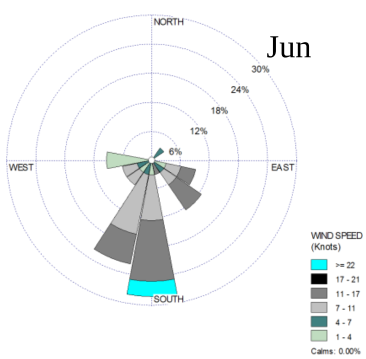
Early Rain

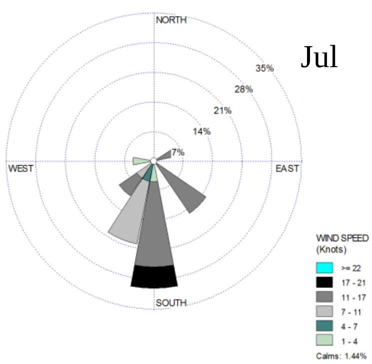


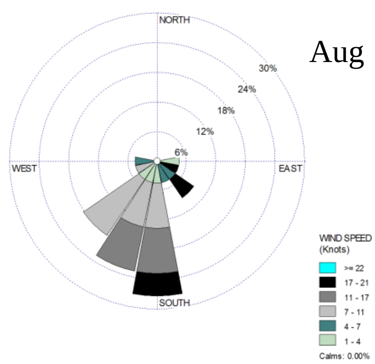




Late Rain







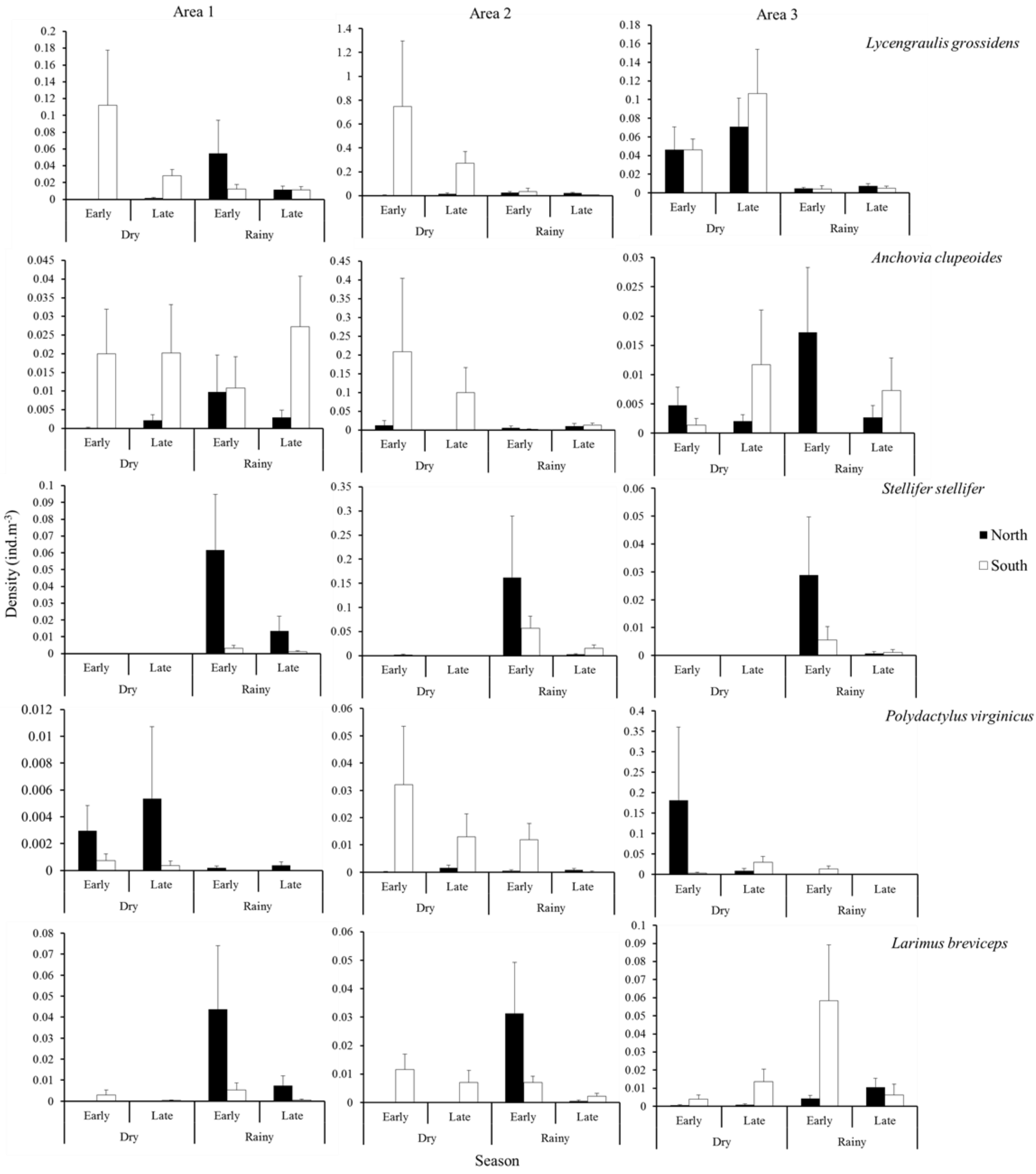
Apêndice 2 (3)

Species	Ecological Guilds		Mean Density		Mean Biomass		Density (%)						Biomass (%)						Frequenci of	Mean	Min-Max
							North			South			North			South					
Species	Functional	Trophic	ind. m^{-3}	% cumulative	g. m^{-3}	% cumulative	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3	occurence (%)	*L* s (mm)	*L* s (mm)
Fish (a)																					
1 *Lycengraulis grossidens*	3	7	0.068594	41.2	0.11602	18.2	9.844	8.437	15.778	39.686	53.790	2.727	8.159	7.666	9.670	19.978	27.147	12.447	69.0	4.9±2.2	(2-14)
2 *Anchovia clupeoides*	2	1	0.020581	53.6	0.02734	22.5	2.192	3.976	3.286	18.985	17.426	2.626	2.495	1.354	2.126	6.745	6.625	0.882	31.9	4.8±2.2	(2-14)
3 *Stellifer stellifer*	3	6	0.014769	62.5	0.04804	30.0	1.961	22.218	3.613	1.627	5.469	0.854	5.585	13.540	2.261	0.998	9.835	1.950	18.5	4.2±2.1	(1-11)
4 *Polydactylus virginicus*	2	6	0.012888	70.2	0.06379	40.0	1.322	0.439	23.528	0.265	2.473	6.312	2.976	0.793	34.438	0.293	5.758	1.335	32.9	5.7±2.4	(2-14)
5 *Larimus breviceps*	2	7	0.009111	75.7	0.03086	44.9	7.459	4.297	2.296	2.214	1.775	1.598	1.551	1.153	0.926	2.313	2.687	16.953	40.3	3.8±1.9	(1-18)
6 *Cathorops spixii*	3	5	0.004000	78.1	0.10190	60.9	5.663	0.699	0.853	1.828	1.422	0.728	16.577	1.728	6.323	6.354	23.226	1.179	28.2	8.7±2.9	(2-21)
7 *Pomadasys corvinaeformis*	2	5	0.002840	79.8	0.02059	64.1	0.629	1.998	2.555	3.360	0.628	0.560	1.256	5.274	4.516	5.592	1.513	1.972	26.4	6.0±2.4	(1-11)
8 *Rhinosardinia bahiensis*	3	1	0.004217	82.3	0.00854	65.4	3.373	3.456	2.091	2.217	1.203	0.365	1.707	1.608	1.744	1.466	1.207	0.164	31.0	5.5±2.3	(3-8)
9 *Mugil sp.*	2	2	0.003157	84.2	0.00245	65.8	1.553	0.457	0.275	7.258	1.134	0.592	0.151	0.384	0.699	0.879	0.639	0.165	24.1	2.4±1.5	(1-8)
10 *Cynoscion acoupa*	2	6	0.002332	85.6	0.00486	66.6	1.537	1.215	0.975	0.372	0.624	2.455	0.885	0.842	0.248	0.633	0.273	1.428	17.1	3.3±1.8	(1-14)
11 *Stellifer rastrifer*	2	6	0.002580	87.2	0.01326	68.7	5.748	1.393	0.652	1.245	0.314	0.314	3.573	2.456	1.437	2.137	0.724	0.443	17.1	5.3±2.3	(2-10)
12 *Ophioscion punctatissimus*	2	6	0.001945	88.4	0.00315	69.2	0.126	2.230	2.835		0.267	0.249	0.224	0.595	2.139		0.153	0.417	16.2	3.2±1.8	(1-9)
13 *Sardinella brasiliensis*	2	1	0.001183	89.1	0.00810	70.4	3.967		0.175	0.237	0.944		4.668		0.118	0.484	0.164		3.2	6.8±2.6	(5-9)
14 *Sciades herzbergii*	3	5	0.001738	90.1	0.00759	71.6	4.389	0.918	0.359	0.325	0.779	0.578	3.260	1.743	0.265	0.226	0.685	0.558	13.0	6.2±2.4	(3-13)
15 *Conodon nobilis*	2	5	0.001570	91.1	0.02420	75.4	2.826	0.269	0.194	0.138	0.337	1.182	8.357	0.823	0.442	0.366	1.350	5.753	18.1	6.8±2.6	(2-13)
16 *Menticirrhus americanus*	2	6	0.001404	91.9	0.02480	79.3	0.285	0.676	0.775	1.738	0.332	0.885	0.337	2.986	1.696	12.516	3.113	4.161	31.0	7.3±2.7	(1-17)
17 *Bairdiella ronchus*	2	6	0.001173	92.6	0.00572	80.2	0.925	0.354	1.338	0.220	0.464	0.843	0.839	0.680	2.875	0.154	0.237	0.127	13.0	5.3±2.3	(2-10)
18 *Anchoa tricolor*	2	1	0.001387	93.4	0.00440	80.9		0.174	0.646	0.157	1.497	1.429		0.234	0.844	0.849	1.745	0.234	3.2	6.7±2.6	(4-9)
19 *Pomadasys crocro*	6	5	0.000776	93.9	0.00807	82.2	0.533	0.232	0.564	0.773		0.715	1.573	0.542	0.915	1.183		3.539	8.8	5.9±2.4	(2-13)
20 *Sphoeroides greeleyi*	2	5	0.001021	94.5	0.00606	83.1	2.433	0.731	0.389	0.326		0.113	2.472	1.584	0.219	0.978		0.913	10.2	5.7±2.4	(3-9)
21 *Stellifer brasiliensis*	3	6	0.000954	95.1	0.00439	83.8	0.916	0.193	0.736	0.628	0.956	0.655	0.957	0.914	2.986	0.180	0.860	0.256	15.3	5.8±2.4	(2-10)
22 *Lile piquitinga*	2	1	0.000656	95.5	0.00307	84.3	1.252		0.180	0.139	0.189	0.236	1.216		0.133	0.849	0.150	0.457	7.4	6.2±2.5	(5-8)
23 *Anchoa lyolepis*	2	1	0.000366	95.7	0.00087	84.4	0.799			0.736	0.283		0.434			0.238	0.183		2.3	5.2±2.3	(3-8)
24 *Atherinella brasiliensis*	2	1	0.000485	96.0	0.00245	84.8	0.877	0.345	0.353	0.278	0.496	0.657	0.984	0.569	0.118	0.192	0.448	0.181	10.2	6.4±2.5	(3-10)
25 *Selene vomer*	2	6	0.000420	96.3	0.00178	85.1	0.139	0.421	0.362	0.391	0.138	0.254	0.479	0.328	0.154	0.726	0.445	0.212	12.5	3.9±2.0	(2-10)
26 *Archosargus rhomboidalis*	2	5	0.000426	96.5	0.00407	85.7	0.280	0.741	0.344				0.365	3.244	0.487				6.0	5.6±2.4	(4-7)
27 *Eucinostomus melanopterus*	2	5	0.000352	96.7	0.00211	86.1	0.372	0.599	0.992	0.743	0.142	0.263	0.641	0.595	0.142	0.230	0.383	0.181	10.2	5.5±2.3	(1-10)
28 *Haemulon aurolineatum*	2	5	0.000275	96.9	0.00071	86.2	0.963						0.425						0.5	3.8±1.9	(2-7)
29 *Cetengraulis edentulus*	2	1	0.000558	97.2	0.00720	87.3			0.194	2.937	0.566				0.554	9.937	0.400		2.8	9.0±2.9	(7-11)
30 *Harengula clupeola*	2	1	0.000374	97.4	0.00144	87.5	0.342	0.212	0.123	0.381	0.138		0.392	0.219	0.467	0.472	0.947		5.6	5.7±2.4	(2-10)
31 *Sphoeroides testudineus*	2	5	0.000333	97.6	0.04154	94.0	0.689	0.277	0.481	0.270	0.142	0.742	13.433	15.578	1.448	0.248	0.444	1.532	9.7	10.7±3.3	(1-20)
32 *Achirus lineatus*	3	5	0.000355	97.9	0.00671	95.1	0.882	0.499	0.525	0.321	0.142	0.182	2.242	0.232	0.745	0.145	0.822	1.643	9.7	6.8±2.6	(3-10)
33 *Caranx latus*	2	6	0.000389	98.1	0.00209	95.4	0.139	0.489	0.145		0.276	0.670	0.168	1.948	0.353		0.236	0.891	6.5	5.3±2.3	(4-8)
34 *Platanichthys platana*	7	1	0.000315	98.3	0.00233	95.8	0.289	0.248	0.175		0.566	0.188	0.365	0.363	0.592		0.312	0.534	3.2	6.7±2.6	(5-8)
35 *Lutjanus jocu*	2	6	0.000273	98.4	0.00360	96.3	0.337	0.458				0.113	0.699	2.500				0.913	5.1	7.1±2.7	(4-9)
36 *Pomadasys ramosus*	2	5	0.000126	98.5	0.00186	96.6				0.614	0.283					1.455	0.552		1.4	6.3±2.5	(5-17)
37 *Lutjanus analis*	2	6	0.000151	98.6	0.00098	96.8	0.165	0.579	0.257				0.168	0.252	0.447				4.2	4.3±2.1	(3-7)
38 *Symphurus tessellatus*	2	5	0.000217	98.7	0.00148	97.0	0.313	0.125	0.139	0.233	0.113	0.223	0.539	0.970	0.415	0.923	0.657	0.269	9.3	5.4±2.3	(3-11)
39 *Etropus crossotus*	2	5	0.000128	98.8	0.00167	97.3	0.284	0.322	0.151	0.743	0.378		0.779	0.579	0.816	0.943	0.842		4.6	7.8±2.8	(3-11)
40 *Hyporhamphus unifasciatus*	2	3	0.000157	98.9	0.00100	97.4	0.278	0.195	0.813	0.153	0.222	0.684	0.287	0.381	0.199	0.298	0.586	0.695	8.8	11.4±3.3	(3-16)
41 *Albula vulpes*	6	5	0.000181	99.0	0.00154	97.7		0.130	0.353	0.149	0.425	0.238		0.832	0.532	0.182	0.822	0.448	3.2	7.5±2.7	(2-14)
42 *Odontesthes incisa*	3	1	0.000145	99.1	0.00021	97.7	0.139	0.275	0.353		0.212		0.239	0.138	0.118		0.274		3.7	5.2±2.2	(4-6)
43 *Sciades couma*	2	5	0.000116	99.2	0.00117	97.9	0.254					0.138	0.718					0.894	0.9	11.2±3.3	(7-16)
44 *Chaetodipterus faber*	2	3	0.000193	99.3	0.00062	98.0		0.232	0.175	0.270		0.542		0.937	0.118	0.424		0.415	4.6	3.3±1.8	(2-5)
45 *Pellona harroweri*	2	7	0.000080	99.3	0.00010	98.0		0.322	0.166		0.189			0.116	0.564		0.173		4.6	3.5±1.9	(3-5)
46 *Citharichthys spilopterus*	2	5	0.000074	99.4	0.00058	98.1	0.139	0.386	0.167	0.462		0.345	0.196	0.695	0.143	0.126		0.192	2.8	6.4±2.5	(1-10)
47 *Haemulon steindachneri*	2	5	0.000127	99.5	0.00039	98.2		0.414						0.395					0.9	4.6±2.1	(3-6)
48 *Eucinostomus argenteus*	2	5	0.000058	99.5	0.00025	98.2	0.149	0.322	0.175				0.796	0.232	0.148				2.8	5.4±2.3	(4-8)
49 *Cathorops agassizii*	3	5	0.000051	99.5	0.00073	98.3		0.113		0.321		0.345		0.254		0.479		0.342	1.4	5.8±2.4	(3-16)
50 *Oligoplites saurus*	2	6	0.000069	99.6	0.00010	98.3	0.447	0.717			0.378		0.769	0.413			0.235		1.9	4.8±2.2	(3-7)

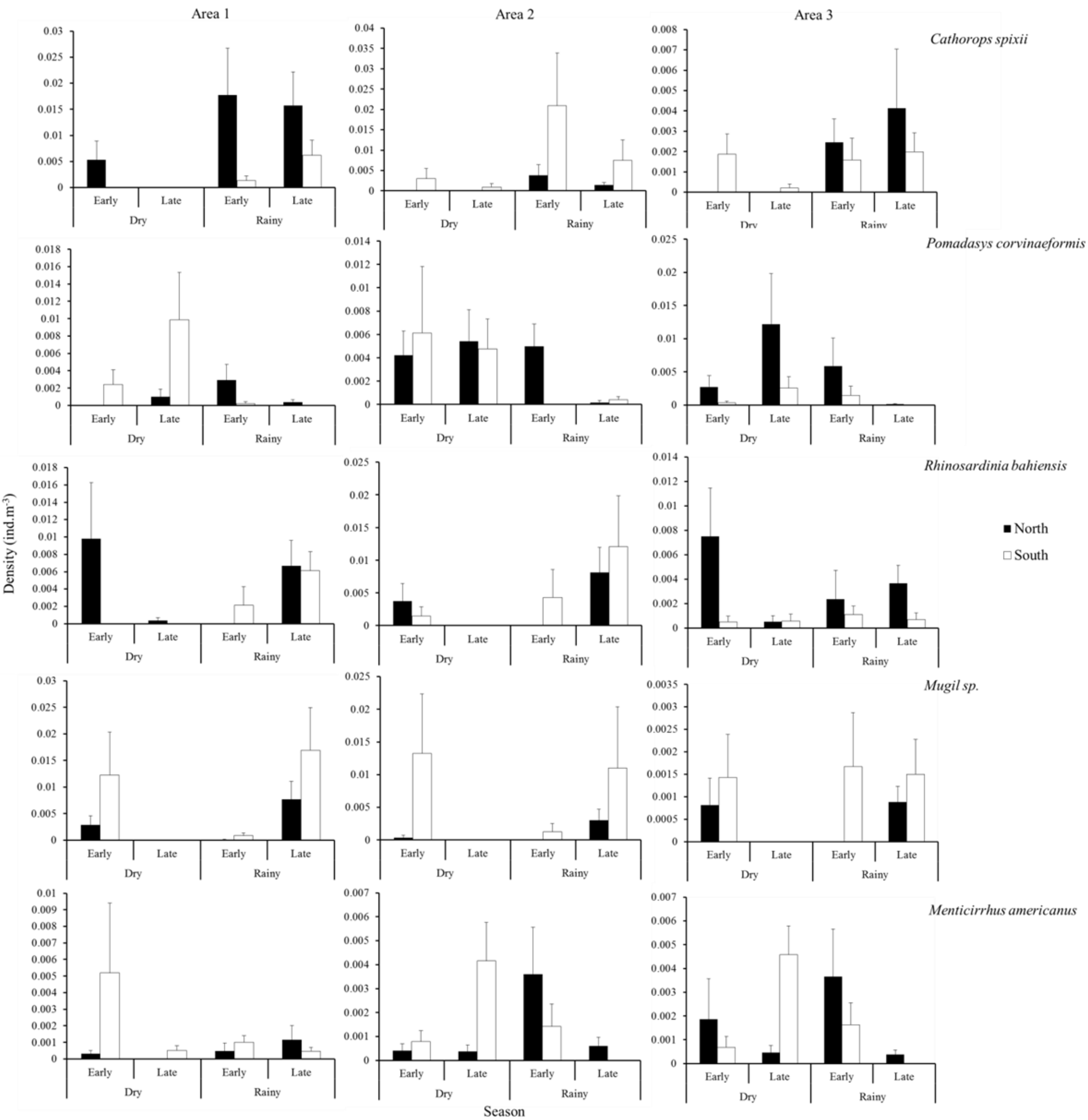
Apêndice 2 (3). Continuação

							Density (%)						Biomass (%)								
	Ecological Guilds		Mean Density		Mean Biomass		North			South			North			South			Frequenci of	Mean	Min-Max
Species	Functional	Trophic	ind. m^{-3}	% cumulative	g. m^{-3}	% cumulative	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3	occurence (%)	*L* s (mm)	*L* s (mm)
Fish (a)																					
51 *Chilomycterus spinosus*	2	5	0.000046	99.6	0.00014	98.4	0.614	0.223	0.175			0.497	0.183	0.416	0.177			0.441	2.8	2.8±1.7	(2-5)
52 *Umbrina coroides*	2	6	0.000041	99.6	0.00080	98.5			0.755		0.189				0.319		0.219		0.9	8.0±2.8	(5-11)
53 *Gymnothorax funebris*	2	4	0.000036	99.6	0.00036	98.5	0.126						0.218						1.4	19.7±4.4	(18-21)
54 *Eugerres brasilianus*	2	5	0.000047	99.7	0.00162	98.8	0.165						0.979						1.4	10.7±3.3	(7-13)
55 *Rypticus randalli*	1	4	0.000037	99.7	0.00080	98.9	0.278				0.448		0.146				0.259		1.9	10.0±3.2	(9-12)
56 *Odontognathus mucronatus*	3	1	0.000036	99.7	0.00009	98.9			0.323	0.347	0.333				0.566	0.377	0.264		1.9	5.0±2.2	(2-7)
57 *Cynoscion leiarchus*	2	6	0.000030	99.7	0.00001	98.9		0.966						0.695					0.5	2.0±1.4	(1-3)
58 *Eucinostomus gula*	2	5	0.000035	99.8	0.00038	99.0		0.695		0.297		0.263		0.174		0.218		0.580	1.4	7.2±2.7	(5-10)
59 *Bathygobius soporator*	3	5	0.000042	99.8	0.00017	99.0	0.322			0.158	0.944		0.338			0.186	0.274		1.9	4.7±2.2	(2-6)
60 *Genyatremus luteus*	2	5	0.000028	99.8	0.00002	99.0		0.579				0.365		0.122				0.846	1.4	2.2±1.5	(2-3)
61 *Diapterus rhombeus*	2	5	0.000017	99.8	0.00006	99.0	0.612						0.349						1.4	4.0±1.2	(3-4)
62 *Strongylura marina*	2	4	0.000036	99.8	0.00015	99.1				0.293						0.240			1.4	11.7±3.4	(6-18)
63 *Trinectes microphthalmus*	2	5	0.000014	99.8	0.00003	99.1			0.478						0.344				0.9	3.5±1.9	(3-4)
64 *Citharichthys arenaceus*	2	5	0.000027	99.9	0.00006	99.1	0.256	0.236		0.743			0.440	0.228		0.552			1.4	5.2±2.3	(4-6)
65 *Hemiramphus brasiliensis*	2	3	0.000018	99.9	0.00006	99.1		0.217			0.944	0.172		0.131			0.192	0.476	1.4	10.7±3.3	(8-14)
66 *Syngnathus pelagicus*	2	1	0.000015	99.9	0.00002	99.1	0.348	0.166					0.598	0.516					0.9	8.5±2.9	(7-10)
67 *Microphis brachyurus*	4	1	0.000014	99.9	0.00001	99.1	0.487						0.838						0.9	10.0±2.3	(9-11)
68 *Opisthonema oglinum*	2	1	0.000011	99.9	0.00002	99.1			0.175		0.944				0.177		0.249		0.9	5.0±2.2	(4-6)
69 *Centropomus undecimalis*	5	4	0.000015	99.9	0.00108	99.3		0.236			0.142			0.530			0.253		0.9	15.5±3.9	(15-16)
70 *Paralonchurus brasiliensis*	2	6	0.000017	99.9	0.00049	99.3					0.189						0.227		0.5	12.4	12.4
71 *Erotelis smaragdus*	3	5	0.000014	99.9	0.00010	99.4		0.232				0.197		0.649				0.272	0.9	6.5±2.4	(5-7)
72 *Trachinotus falcatus*	2	6	0.000019	99.9	0.00017	99.4	0.165				0.779		0.635				0.274		0.9	6.5±2.5	(5-8)
73 *Elops saurus*	2	4	0.000007	99.9	0.00070	99.5				0.396						1.112			0.5	22.3	22.3
74 *Scomberomorus cavalla*	2	4	0.000006	99.9	0.00003	99.5				0.347						0.472			0.5	8.8	8.8
75 *Hippocampus reidi*	2	1	0.000009	99.9	0.00001	99.5						0.276						0.770	0.5	6.1	6.1
76 *Trachinotus goodei*	2	6	0.000018		0.00072	99.6					0.113						0.329		0.5	11.2	11.2
77 *Synodus foetens*	2	4	0.000009		0.00001	99.6				0.522						0.141			0.5	6.6	6.6
78 *Lagocephalus laevigatus*	2	5	0.000005		0.00000	99.6			0.142						0.473				0.5	3.1	3.1
79 *Sciades proops*	2	5	0.000009		0.00107	99.8				0.522						1.698			0.5	26.0	26
80 *Thalassophryne nattereri*	3	6	0.000006		0.00001	99.8		0.193						0.695					0.5	2.5	2.5
81 *Hypostomus sp.*	6	5	0.000010		0.00001	99.8						0.365						0.846	0.5	2.0	2.0
82 *Centropomus mexicanus*	2	4	0.000006		0.00032	99.8					0.944						0.145		0.5	14.2	14.2
83 *Myrophis punctatus*	2	5	0.000005		0.00011	99.8			0.151						0.164				0.5	36.7	36.7
84 *Chloroscombrus chrysurus*	2	5	0.000003		0.00000	99.8				0.198						0.539			0.5	2.2	2.2
85 *Peprilus paru*	2	6	0.000006		0.00004	99.9						0.172						0.333	0.5	6.2	6.2
86 *Centropomus parallelus*	5	4	0.000007		0.00083						0.779						0.382		0.5	17.3	17.3
87 *Ophichthus ophis*	2	5	0.000004		0.00010				0.117						0.985				0.5	46.2	46.2
total			**0.1664**		**0.6374**		**2.820**	**2.658**	**2.911**	**3.858**	**4.150**	**1.355**	**3.942**	**3.309**	**3.548**	**3.505**	**3.992**	**2.767**			
Crustaceans (b)																					
88 *Litopenaeus schimitti*	2		0.054193	93.1	0.09184	72.5	24.456	38.338	34.239	4.765	11.008	42.999	8.804	20.846	18.839	5.028	6.872	16.553	55.1	2.6±2.9	(0.7-6)
89 *Callinectes danae*	2		0.003992		0.03485		0.770	2.516	0.976	5.624	0.964	2.811	1.778	5.807	1.337	16.952	2.012	8.267	30.6	3.1±1.8	(1-10)
total			**0.0582**		**0.1267**	**0.491**	**1.008**	**1.632**	**1.407**	**0.415**	**0.478**	**1.830**	**0.423**	**1.065**	**0.806**	**0.878**	**0.355**	**0.992**			
Wrack (c)					**25.0267**	**97.037**							**15.75**	**13.65**	**9.88**	**0.37**	**23.17**	**34.22**			
Total biomass (a+b+c)					**25.7908**																

Apêndice 3 (3)

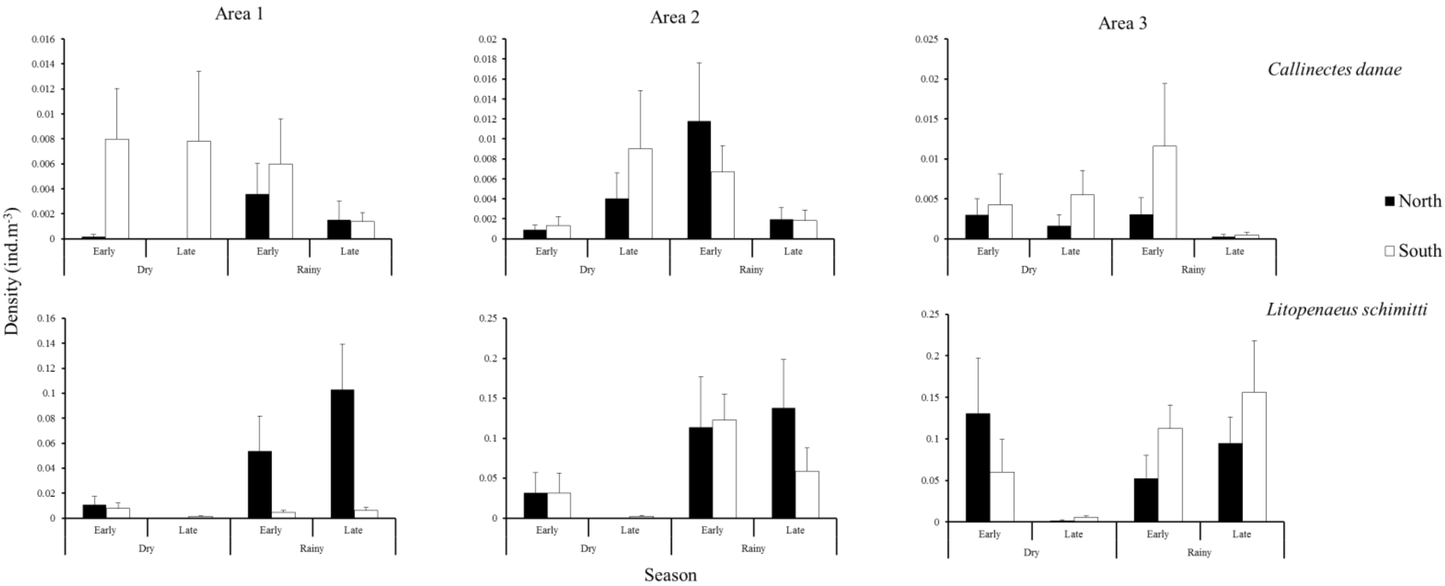


Area 1
Area 2
Area 3
Lycengraulis grossidens
Anchovia clupeoides
Stellifer stellifer
Polydactylus virginicus
Larimus breviceps
North
South
Density (ind.m-3)
Early
Late
Dry
Rainy
Season

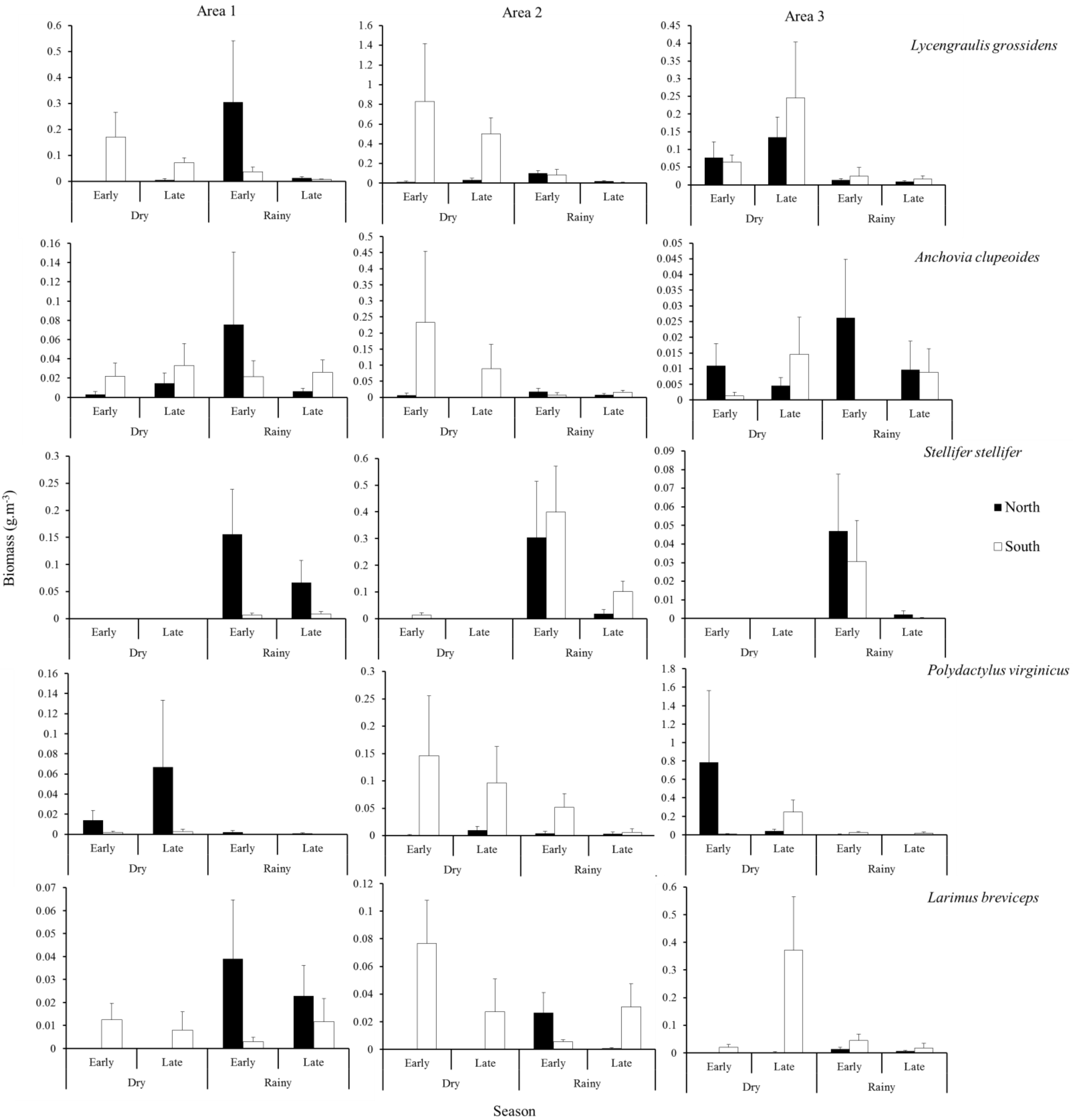


Area 1
Area 2
Area 3
Cathorops spixii
Pomadasys corvinaeformis
Rhinosardinia bahiensis
Mugil sp.
Menticirrhus americanus
Density (ind.m-3)
Season
Early
Late
Dry
Rainy
North
South

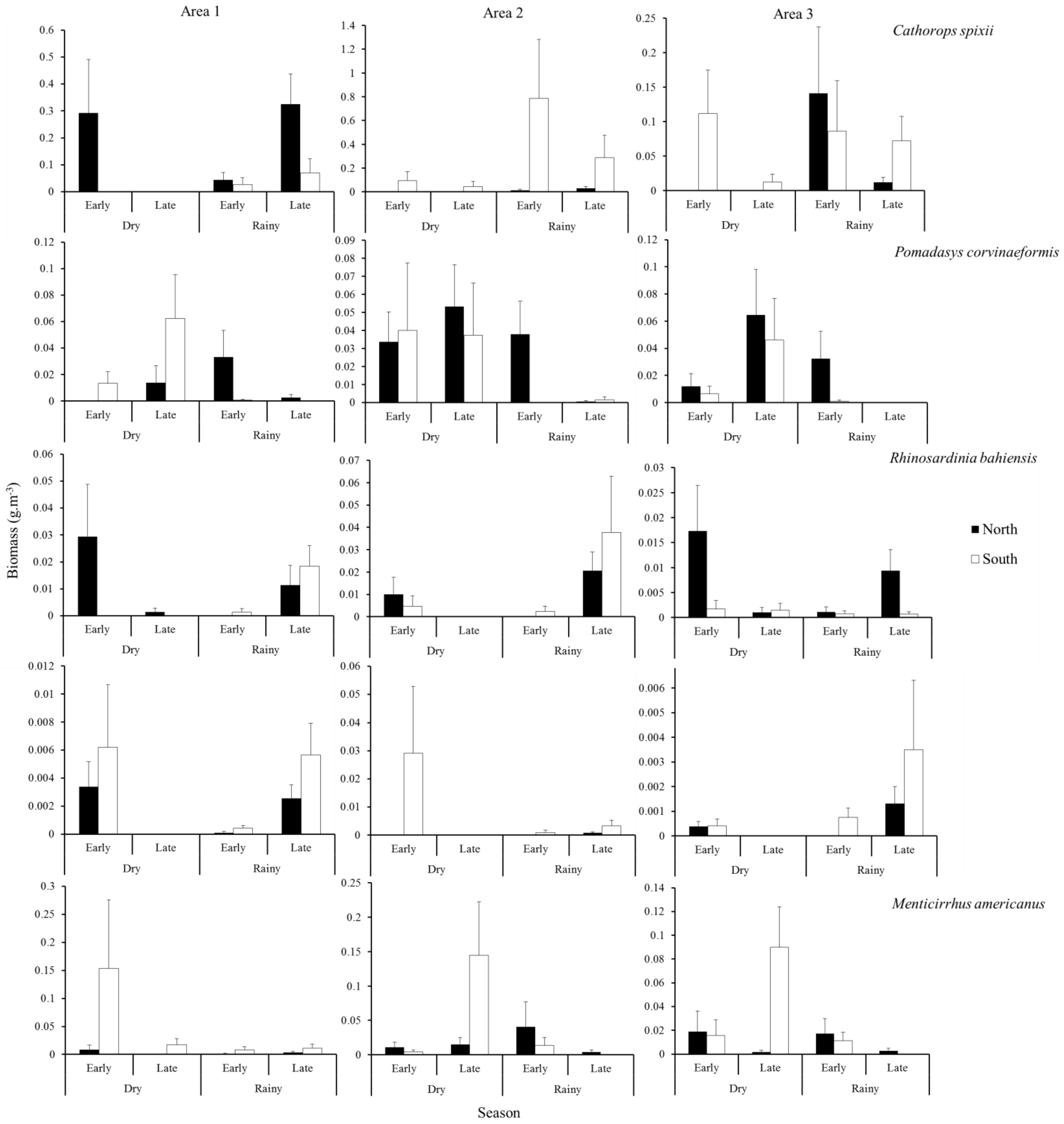
Apêndice 3 (3). Continuação



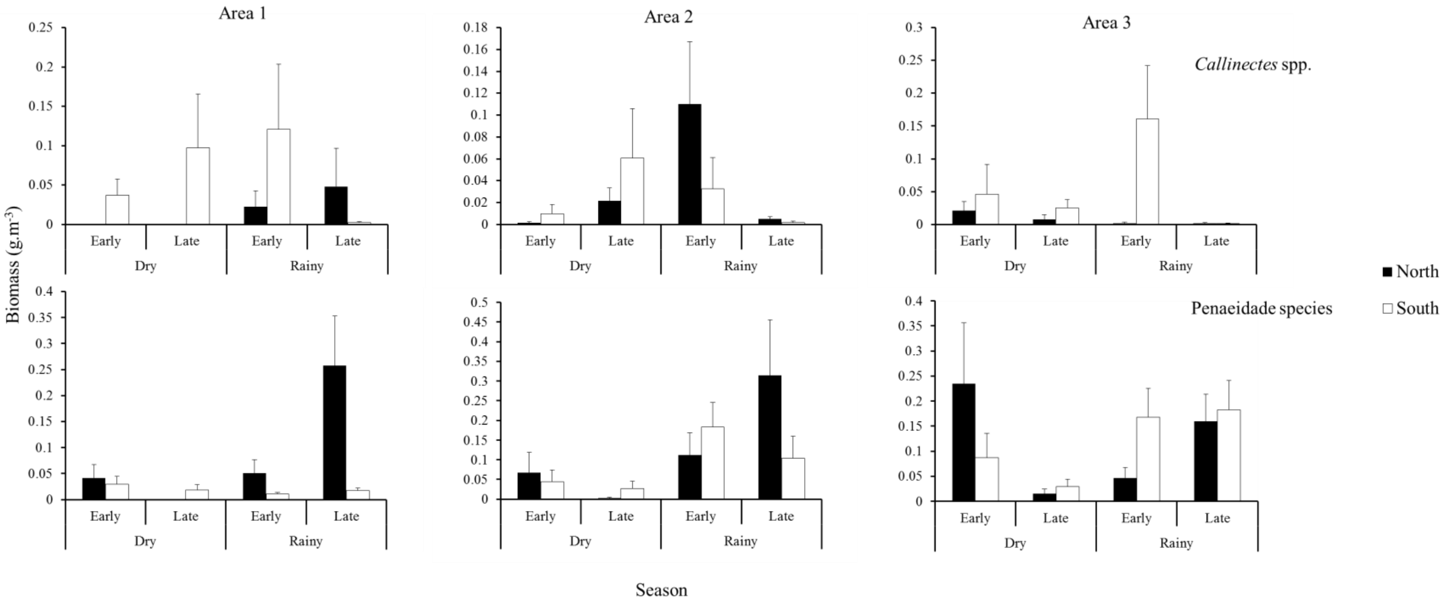
Apêndice 4 (3)


Area 1
Area 2
Area 3
Lycengraulis grossidens
Anchovia clupeoides
Stellifer stellifer
Polydactylus virginicus
Larimus breviceps
North
South
Biomass (g.m-3)
Early
Late
Dry
Rainy
Season

Apêndice 4 (3). Continuação



Apêndice 4 (3). Continuação



Apêndice 5 (3)

	Mean Density		Mean Biomass		Total Density (%)						Total Biomass (%)					
					North			South			North			South		
Trophic Guilds	ind. m^{-3}	% cumulative	g. m^{-3}	% cumulative	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3
Zooplanktivorous	0.0780	34.7390	0.1481	19.3819	17.3756	13.0319	18.0281	32.2302	55.8005	31.3933	9.7387	8.6514	10.8507	15.5264	29.9251	28.6120
Planktivorous	0.0304	48.2556	0.0661	28.0324	13.1881	8.6946	5.8936	22.1125	19.5564	4.5478	11.6743	4.4901	4.2258	17.1254	10.6510	2.2630
Hyperbenthophagous	0.0394	65.8072	0.1787	51.4176	21.6696	29.3082	35.2787	13.0587	8.6410	12.7261	15.1597	25.8609	48.1826	13.1301	21.6158	18.3117
Detritivorous	0.0613	93.1230	0.1291	68.3193	26.7795	41.3113	35.4222	17.0607	13.2755	46.4018	10.7333	26.6911	20.2459	10.6799	9.5227	24.9857
Benthophagous	0.0151	99.8350	0.2371	99.3513	20.8331	7.5861	5.3599	15.2358	2.6578	4.3715	52.3304	33.6697	16.4833	42.6902	27.2291	25.4075
Carnivorous	0.0002	99.9059	0.0043	99.9110	0.1541	0.0236	0.0000	0.2894	0.0615	0.0000	0.3637	0.5298	0.0000	0.8330	1.0371	0.0000
Herbivorous	0.0002	100.0000	0.0007	100.0000	0.0000	0.0442	0.0175	0.0127	0.0073	0.5595	0.0000	0.1069	0.0118	0.0149	0.0192	0.4200

“Minha jangada vai sair pro mar

Vou trabalhar, meu bem querer

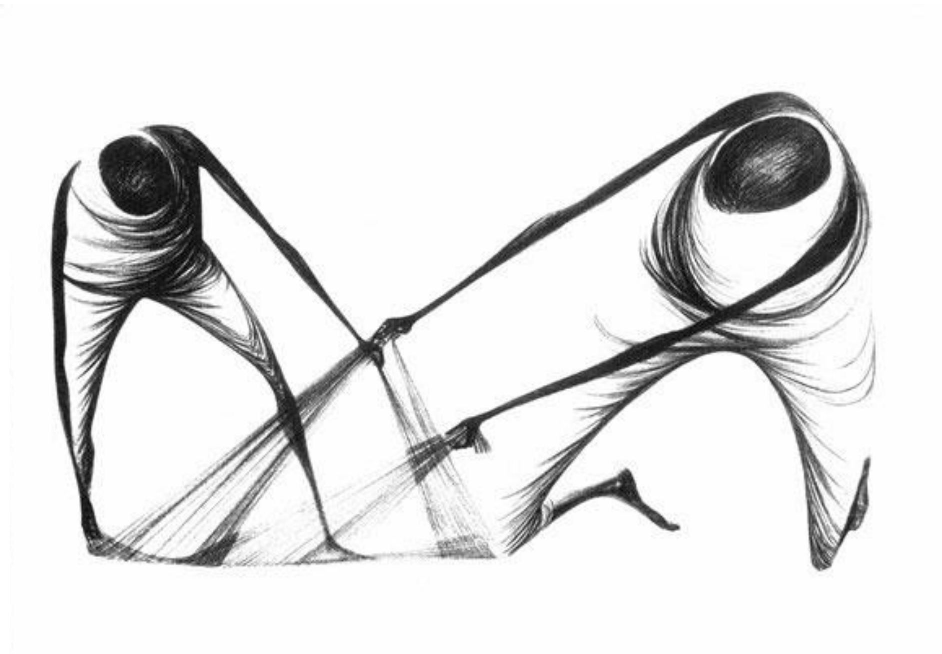
Se Deus quiser quando eu voltar do mar

Um peixe bom eu vou trazer

Meus companheiros também vão voltar

E a Deus do céu vamos agradecer...”

(*Dorival Caymmi*)



Arte: Enrico Bianco