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ASPECTOS DA BIOLOGIA DO CARANGUEJO AFRICANO, *Chaceon gordonae* (Ingle, 1985), (BRACHYURA:GERYONIDAE) NOARQUIPÉLAGO DE SÃO PEDRO E SÃO PAULO.

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PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO

PROGRAMA DE PÓS-GRADUAÇÃO EM RECURSOS PESQUEIROS E AQUICULTURA

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Dissertação apresentada ao Programa de Pós-Graduação em Recursos Pesqueiros e Aquicultura da Universidade Federal Rural de Pernambuco como exigência para obtenção do título de Mestre.

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Rômulo Costa Pires Ferreira

Dissertação julgada adequada para obtenção do título de mestre em Recursos Pesqueiros e Aquicultura. Defendida e aprovada em 07/03/2014 pela seguinte Banca Examinadora.

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Dedico este trabalho aos meus pais,
Roberto e Virgínia (*In memorian***).**

“Viver é um absurdo, e não dá pra passar por isso tão ileso.”
Tati Bernardi

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Resumo

O desenvolvimento de tecnologias para prospecção pesqueira em grandes profundidades possibilitou um estudo acerca dos crustáceos demersais de águas profundas no entorno do Arquipélago de São Pedro e São Paulo (ASPSP), localizado na Dorsal Meso-Atlântica, especificamente do caranguejo africano, *Chaceon gordonae.* Com o objetivo de gerar informações sobre a biologia da espécie, o caranguejo africano *Chaceon gordonae* foi estudado por meio de exemplares coletados com armadilhas de fundo do tipo covo, em profundidades que variaram de 300 a 700 m, no entorno do ASPSP. A estrutura populacional da espécie foi analisada por meio da mensuração dos comprimentos e largura da carapaça dos indivíduos coletados e identificação do sexo, enquanto o estudo da maturidade morfológica incluiu uma análise das principais variáveis morfométricas (comprimento e largura da carapaça, comprimento e largura das quelas esquerda e direita, largura do abdômen para as fêmeas e o peso total dos indivíduos), e a identificação de suas principais características reprodutivas, como o desenvolvimento gonadal e da massa de ovos aderidos aos pleópodos por meio de escala macroscópica de coloração. Um total de 458 indivíduos foram coletados entre 2012 e 2014, ao longo de sete campanhas de pesca exploratória no entorno do ASPSP, entre os quais 252 eram machos e 206 eram fêmeas, configurando uma proporção sexual igual a 1 : 0,82. Os machos apresentaram maior comprimento médio (110,81 ± 14.52 mm comprimento da carapaça, CC) do que as fêmeas (102,37 ± 16.55 mm CC). A análise macroscópica das gônadas identificou seis estágios de maturação, de acordo com a escala de cor, nomeadas: Estágio I (imaturo); Estágio II (em desenvolvimento); Estágio III (intermediário); Estágio IV (avançado); Estágio V (maduro); e Estágio VI (desovado). Com relação ao desenvolvimento da massa de ovos aderidos aos pleópodos através da escala de cor, foi possível identificar cinco estágios, nomeados: Estágio I; Estágio II; Estágio III; Estágio IV; e Estágio V. O tamanho de primeira maturidade morfológica foi estimado em 108.90 mm CC para machos e 84.00 mm CC para fêmeas. Os resultados apresentados estão dentro dos padrões observados para outros caranguejos geryonídeos em relação à estrutura populacional, porém diferem quanto ao tamanho de primeira maturidade morfológica. A análise do desenvolvimento gonadal e da massa de ovos aderidos aos pleópodos se assemelha a outros geryonideos, porém foi criado uma escala única para o *Chaceon gordonae* capturado no ASPSP. Esta análise através da escala de cor pode ser subjetiva, necessitando que mais estudos com analises fisiológicas sejam apresentados para certificar os estágios descritos pela escala de cor.

Palavras chave: *Chaceon gordonae,* biologia reprodutiva, estrutura populacional

Abstract

The development of technologies for exploratory fishing at great depths has enabled a study of crustaceans in the deep waters around the vicinity Saint Peter and Saint Paul Archipelago (SPSPA), located in the Mid-Atlantic Ridge, specifically on African crab *Chaceon gordonae*. In order to generate information on the biology of the species, the African crab *Chaceon gordonae* was studied from specimens collected with bottom traps, at depths comprising 300 to 700 m, surrounding the archipelago. The population structure of the species was analyzed by measuring the length and width of the carapace and identifying the sex of the caught specimens. The study of its biology included an analysis of the main morphometric variables (length and width of the carapace, length and width of the left and right chelae, abdomen maximum width for females and the total weight of individuals), and the identification of its main reproductive traits, including morphometric maturity, common in reproduction studies in crustaceans, and the assessment of gonadal development and egg mass attached to the pleopod, by a macroscopic scale. A total of 458 individuals were collected between 2012 and 2014, during seven exploratory fishing campaigns in the vicinity of the archipelago, among which 252 were males and 206 were females, configuring a sex ratio of 1 : 0,82. Males had a greater average length (110.81 ± 14.52 mm carapace length, CC) than females (102.37 ± 16.55 mm CL). The macroscopic analysis of gonads identified six stages of maturity according to color scale, named: Stage I (immature); Stage II (early development); Stage III (intermediate); Stage IV (advanced); Stage V (mature); and Stage VI (post-spawned). The development of egg mass attached to the pleopods through color scale it was possible to identify five stages, named: Stage I; Stage II; Stage III; Stage IV; and Stage V. The size of the first functional maturity was estimated at 108.90 mm CL for males and 84.00 mm CL for females. The results presented here were within the patterns observed for other geryonid crabs in relation to population structure, but differ in the size of the first morphological maturity. The analysis of gonad development and egg mass attached to the pleopods resembles other geryonids, however, was created a single scale for *Chaceon gordonae* in SPSPA. The analysis of maturity according color scale could be subjective, requiring further studies with physiological analyzes to certify the stages described by the color scale.

Key words: *Chaceon gordonae*, reproduction biology, population structure

Lista de figuras

Revisão de literatura

Artigo científico 1 - First record and preliminary information of the biology of the deep-sea african crab, *Chaceon gordonae* Ingle, 1985 (Brachyura: Geryonidae) caught in Saint Peter and Saint Paul Archipelago - Brazil.

Artigo científico 2 - Seasonal reproduction of female african crab, *Chaceon gordonae* (Ingle, 1985), (Brachyura: Decapoda) collected off Saint Peter and Saint Paul Archipelago.

Lista de tabelas

Artigo científico 1 - First record and preliminary information of the biology of the deep-sea african crab, *Chaceon gordonae* Ingle, 1985 (Brachyura: Geryonidae) caught in Saint Peter and Saint Paul Archipelago - Brazil.

Artigo científico 2 - Seasonal reproduction of female african crab, *Chaceon gordonae* (Ingle, 1985), (Brachyura: Decapoda) collected off Saint Peter and Saint Paul Archipelago.

Sumário

Página

Introdução

O Arquipélago de São Pedro e São Paulo (ASPSP), distante cerca de 510 M (milhas náuticas) da costa brasileira e 282 M do Arquipélago de Fernando de Noronha, constitui um ecossistema raro do ponto de vista geológico e importantíssimo no ciclo de vida de diversas espécies de organismos marinhos, formado por 15 pequenas ilhas que compõem a região emersa de um edifício rochoso, que emerge de profundidades de até 4.000 m (CAMPOS et al., 2005). O ASPSP, em razão do seu posicionamento geográfico estratégico, entre os hemisférios norte e sul e entre os continentes africano e americano, desempenha um papel de grande relevância na distribuição e movimentos migratórios de inúmeras espécies, tanto pelágicas como demersais (VIANA et al., 2010).

Com o desenvolvimento de tecnologias para prospecção do mar profundo, elevados índices de biodiversidade, inclusive de caranguejos, em profundidades superiores a 100 m têm sido reportados em todo mundo (PEREZ et al., 2009). As estimativas de biodiversidade para regiões profundas são projetadas atualmente entre 10 a 100 milhões de espécies (GRASSLE & MACIOLEK, 1992), sendo potencialmente um dos maiores reservatórios de biodiversidade da Terra, comparável com a biodiversidade associada às florestas tropicais e aos recifes coralíneos de água rasas (KITAHARA, 2009).

Estudos sobre os invertebrados bentônicos no ASPSP sugerem a diferenciação do ecossistema marinho em diferentes zonas, por faixa de profundidade, acarretando uma grande limitação na distribuição espacial dessas espécies, particularmente pelo relevo extremamente íngreme do Arquipélago, o que ressalta, ao mesmo tempo, a enorme relevância ecológica e a elevada fragilidade desse ecossistema (VIANA et al., 2010).

Com relação ao grupo dos crustáceos, os estudos realizados nas imediações do ASPSP focaram principalmente no levantamento e na descrição do zooplâncton, assim como em alguns aspectos da biologia do caranguejo *Grapsus grapsus* e da espécie de lagosta *Panulirus echinatus* (PINHEIRO et al., 2003). Nada até o momento, porém, foi estudado sobre crustáceos de águas profundas (mais de

100m), associados a esse ecossistema. Considerando-se, portanto, a incipiência de conhecimentos e a carência de informações básicas sobre esse importante grupo zoológico presente no ASPSP, a Universidade Federal Rural de Pernambuco - UFRPE, a partir de 2011, realizou uma série de prospecções em águas profundas no entorno do ASPSP, durante as quais encontrou uma abundância expressiva de uma espécie de caranguejo da família Geryonidae, identificado como *Chaceon gordonae* (INGLE, 1985) (FERREIRA et al., 2013) (Figura 1). A biologia dos geryonideos em todo o mundo, particularmente aqueles do gênero *Chaceon*, é ainda muito pouco conhecida. No presente estudo, portanto, a biologia do *Chaceon gordonae* coletado no ASPSP foi investigada, com ênfase em sua estrutura populacional e aspectos da sua biologia reprodutiva, com o objetivo de se obter um melhor entendimento acerca da ecologia deste grupo, particularmente em ecossistemas insulares.

Revisão da literatura

A espécie estudada

Até meados da década de 1990, a família Geryonidae era constituída por apenas um gênero, *Geryon,* que agrupava várias espécies. Em 1989, contudo, Manning e Holthuis apresentaram uma nova estrutura sistemática para a família, a qual passou a ter então três gêneros e 31 espécies: *Geryon*, com duas espécies; *Chaceon*, um novo gênero, com 28 espécies; e *Zariquieyon*, outro novo gênero, com apenas uma espécie. Os três gêneros ocorrem em todos os oceanose são encontrados em profundidades que variam entre 100 e 2.800 m, aproximadamente (MANNING, 1990; TAVARES & PINHEIRO, 2011).

O gênero *Chaceon* é representado por todas as espécies que possuem cinco dentes anterolaterais na carapaça, incluindo 11 espécies anteriormente registradas como pertencentes ao gênero *Geryon,* o qual se diferencia do *Chaceon* por apresentar apenas três dentes anterolaterais na carapaça. O terceiro gênero desta família, *Zariquieyon,* também apresenta cinco dentes anterolaterais na carapaça, porém difere dos demais dois gêneros por possuir as margens posterolaterais convexas e a região branquial fortemente inflada (MANNING, 1990).

O *Chaceon* (*Geryon*) *gordonae* foi primeiramente descrito por Ingle (1985), com base em espécimes coletados com armadilhas entre o norte da elevação de Serra Leoa, a oeste da África, até o sul da Islândia. Posteriormente Manning & Houlthuis (1989), revisando a família Geryonidae, se referiram às espécies relatadas por Ingle nos Açores como uma nova espécie, *Chaceon inglei* (MANNING & HOULTHUIS, 1989), mantendo o nome *Chaceon gordonae* para apenas dois machos e duas fêmeas capturadas a uma profundidade de 1.153 m. Afonso-Dias et al. (2008), analisando caranguejos provenientes de pescarias artesanais com uso de armadilhas entre 500 e 1.200 m no Arquipélago de São Tomé e Príncipe, a oeste da África, detectou a presença do *C. gordonae* em quantidades razoáveis, havendo, naquela localidade, uma pescaria voltada para a espécie desde 1980.

Figura 1. *Chaceon gordonae* (Ingle, 1985) capturado no Arquipélago de São Pedro e São Paulo; (a) macho com 83 mm de comprimento da carapaça, e (b) fêmea com 108.9 mm de comprimento da carapaça.

No Brasil, os primeiros registros de caranguejos gerionídeos foram efetuados por Scelzo & Valentini (1974), os quais identificaram indivíduos provenientes de expedições oceanográficas realizadas na plataforma continental e no talude do Brasil, Uruguai e Argentina, como o *Geryon quinquedens.* Entretanto, os referidos autores mencionaram pequenas variações morfológicas e de coloração no material biológico examinado, havendo, basicamente, indivíduos provenientes do talude brasileiro com coloração creme e indivíduos provenientes do sul do Brasil, Uruguai e Argentina com coloração avermelhada. Estes últimos foram atribuídos à nova espécie *Chaceon notialis* por Manning & Holthuis (1989), ficando *Chaceon quinquedens* (ex-*Geryon quinquedens)* restrito ao noroeste do Atlântico, enquanto o morfotipo creme foi atribuído por Manning (1990) a *Chaceon ramosae,* a segunda espécie da família para o Brasil.

No Nordeste do Brasil, Sankarankutty et al.(2001) e Carvalho et al. (2009) descreveram a ocorrência de uma terceira espécie para o país, o *Chaceon fenneri*, a partir de espécimes obtidos pelo Programa REVIZEE (Programa de Avaliação do Potencial Sustentável dos Recursos Vivos na Zona Econômica Exclusiva). Em 2011, porém, Tavares & Pinheiro concluíram que se tratava de uma nova espécie ainda não descrita, identificada posteriormente como *Chaceon linsi*.

Informações morfométricas são de extrema importância para estudos ecológicos em crustáceos, pois podem revelar padrões de crescimento relativo e de maturidade sexual. No decorrer do crescimento ontogenético é habitual que certas dimensões do corpo do caranguejo tenham um crescimento diferente de outras dimensões e que, portanto, haja uma mudança nas relações entre os tamanhos de tais dimensões. Esse crescimento diferenciado é chamado de crescimento relativo ou alométrico (HARTNOLL, 1978). A análise do crescimento relativo é amplamente utilizada nos crustáceos decápodes por uma série de conveniências: eles têm um exoesqueleto quitinoso rígido o qual facilita sua mensuração, sofrem mudas regulares desse exoesqueleto que determinam uma clara subdivisão em sua ontogenia e exibem frequentemente diferenças nas taxas de crescimento tanto entre machos e fêmeas, quanto entre jovens e adultos (HARTNOLL, 1974). Para tal análise geralmente são utilizadas dimensões de estruturas fixas vistas como caracteres sexuais secundários, ou seja, aqueles que são utilizados direta ou indiretamente para a reprodução, como os quelípodos para os machos e o abdome das fêmeas.

A análise do crescimento relativo permite a determinação das diferentes taxas de desenvolvimento de certas estruturas (variáveis dependentes) em relação a outras dimensões do corpo do animal (variável independente), sendo que estas taxas podem promover mudanças nas proporções do seu corpo como um todo (HARTNOLL,1978, 1982, 1985; SOMERTON, 1980). Nessa análise de crescimento relativo é comum a utilização da expressão potencial $Y = \alpha * x^b$, onde *y* é a variável dependente, *x* a variável independente, α é o valor de *y* que a reta corta eixo das abscissas e *b* é o coeficiente de regressão, que indica a inclinação da reta descrita pela equação. Quando esta relação é linearizada e o resultado de *b* fica maior que 1, o crescimento é dado como alométrico positivo, ou seja, a variável dependente cresce mais que a independente durante a ontogenia. Quando *b* é menor que 1, ocorre o inverso: a variável dependente cresce menos que a variável independente, caracterizando um crescimento alométrico negativo. Quando *b* é igual a 1, a variável dependente

cresce de forma proporcionalmente igual à variável independente e o crescimento é chamado isométrico (FONTELES-FILHO, 2011).

Para a determinação do tamanho médio do início da maturidade morfométrica, trabalhos com relações lineares de crescimento entre partes do corpo de geryonideos tem sido frequentemente utilizada (DELGADO & DEFEO, 2004; ERDAMN & BLAKE, 1988; FERNÁNDEZ-VERGAZ et al., 2000; HAEFNER, 1977; HARTNOLL, 1978, 1982, 1985; LÓPEZ ABELLÁN et al., 2002; HALL et al., 2006; SANT'ANA & PEZZUTO 2009; PEZZUTO & SANT'ANA 2009; GUERRERO & ARANA, 2009). Para a realização de uma análise biométrica, as dimensões das quelas para os machos e do abdômen para as fêmeas são mais informativas, sendo analisadas comparativamente essas medidas em relação ao comprimento da carapaça, distância do ponto médio entre as bases dos chifres medianos anterior e da margem posterior da carapaça. Esta é a forma típica de medir o tamanho do corpo de caranguejos de profundidade (LEVINGS et al., 1996; GARDNER, 1997; GOSHIMA et al., 2000; SMITH et al., 2004), e isto supera os problemas da utilização da largura da carapaça, distância compreendida entre o quinto espinho anterolateral da carapaça, quando estas estruturas são particularmente propensos ao desgaste.

O desenvolvimento das gônadas em crustáceos decápodos pode ser acompanhado pelas modificações que ocorrem nos ovários durante o ciclo reprodutivo, onde há multiplicação de células gonadais e crescimento dos gametas para a maturação, ovulação e oviposição (GRASSÉ, 1994). Durante essas fases a gônada feminina sofre modificações, como alteração da cor e tamanho, enquanto a gônada masculina as modificações morfológicas não são tão evidentes (KROL et al., 1992; CAVALLI et al., 2001).

O desenvolvimento das gônadas pode ser acompanhado para determinar o período e tamanho em que o animal atinge a maturidade sexual sendo caracterizada como o conjunto de informações morfológicas e fisiológicas mediante as quais os juvenis ou imaturos alcançam a capacidade de produzir gametas, que podem fecundar ou ser fecundados (MANTELATTO & FRANSOZO, 1997).

As análises das gônadas são importantes para descrever a estrutura das gônadas e servem para caracterizar os estágios de desenvolvimento de uma determinada espécie. Entretanto para os caranguejos Gerionídeos essas pesquisas são escassas, podendo se destacar as desenvolvidas por Haefner (1977) para o *Chaceon* (ex-*Geryon*) *quinquedens*, por Erdam & Blake (1988) para o *Chaceon* (ex-*Geryon*) *fenneri* e por Delgado & Defeo (2004) para o *Chaceon notialis.* Constata-se que as espécies do gênero *Chaceon* são pouco investigadas permanecendo uma lacuna sobre a biologia reprodutiva, principalmente sobre os aspectos histológicos e de fecundidade.

Apesar de apresentar ocorrência no Brasil, restrita as regiões Nordeste e Sul, nenhuma pesquisa foi realizada com os caranguejos de profundidade do gênero *Chaceon* sob o aspecto da dinâmica da reprodução. Visando contribuir com informações sobre a biologia reprodutiva dessa espécie no Brasil, particularmente em regiões insulares, pretende-se, portanto, com dados relacionados à maturidade morfométrica, a descrição e as observações macroscópicas sobre a dinâmica do desenvolvimento das gônadas e da massa de ovos aderidos aos pleópodos, aportar as primeiras informações acerca da biologia reprodutiva do *Chaceon gordonae* no Arquipélago de São Pedro e São Paulo.

Estas análises são importantes para um estudo mais aprofundado do ciclo reprodutivo da espécie e, desta forma, de vital importância para subsidiar medidas de manejo necessárias para assegurar a conservação de suas populações.

Área de Estudo

O Arquipélago de São Pedro e São Paulo (ASPSP) (Figura 2) é constituído por um pequeno grupo de ilhas (15) e diversas pontas de rochas que se situam nas proximidades da Dorsal Meso-Atlântica, distando cerca de 100 km ao norte do equador, na posição de 00º55'"N e 29º20'"W (VIANA et al., 2010). O ASPSP é o resultado de um afloramento da falha transformante no manto suboceânico, emergindo de profundidades abaixo de 4.000 m (MABESSONE e COUTINHO, 1970). Com uma área total emersa de cerca de 17.000 m^2 e uma distância entre os pontos extremos de 420 m,

o ASPSP está inserido no Sistema Equatorial de Correntes Marinhas, sofrendo a influência direta da corrente sul equatorial (CSE), que flui superficialmente no sentido E→W, com limite inferior de 200m, e da corrente equatorial submersa (CES), que flui no sentido contrário (W→L), a uma profundidade de aproximadamente 70 m (CAMPOS et al., 2005). Encontra-se, ainda, sob a influência direta da Zona de Convergência Intertropical, cuja dinâmica influencia o regime de chuvas na costa nordeste do Brasil e Atlântico equatorial, razão pela qual o ASPSP é uma das áreas de maior índice pluviométrico em todo o oceano Atlântico, apresentando, consequentemente, uma reduzida salinidade superficial (VIANA et al., 2010). Em função do seu posicionamento geográfico estratégico, localizado entre os dois hemisférios e ainda entre os continentes africano e americano (cerca de 530 milhas náuticas de Natal-RN, Brasil, e 985 milhas náuticas da Guiné-Bissau, África), o ASPSP exerce uma forte influência no ciclo de vida de várias espécies migratórias, possuindo uma grande importância como local de reprodução e alimentação para várias delas (VIANA et al., 2010).

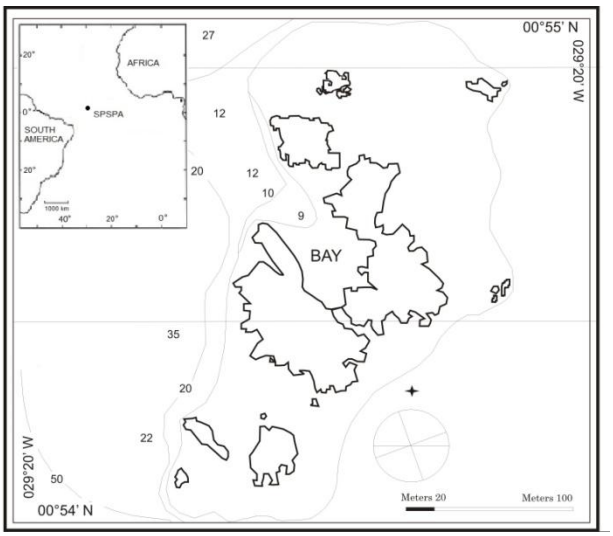

Figura 2. Localização do Arquipélago de São Pedro e São Paulo.

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Artigo científico 1

First record and preliminary information of the biology of the deep-sea african crab, *Chaceon gordonae* Ingle, 1985 (Brachyura: Geryonidae) in Saint Peter and Saint Paul Archipelago - Brazil.

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Abstract: Seven exploratory deep-water fishing surveys were carried out at Saint Peter and Saint Paul Archipelago between 2012 and 2014 at depths ranging from 300 to 700 m. During surveys the presence of a deep-sea crab, identified as *Chaceon gordonae* (Ingle, 1985), was recorded, with 458 specimens being caught. Of the sampled specimens, 252 were males and 206 were females. The carapace length (CL) of sampled crabs measured, on average, 110.81 ± 14.52 mm for males and 102.00 ± 16.55 mm for females, with males being therefore a bit larger. In general, the β_1 parameter of the length-weight relationship indicates a positive allometric growth. A comparison of linear regression between the carapace length and right chela length and width for males revealed physical maturity between 108.90 and 111.00 mm CL, respectively, whereas the regression between carapace length and abdomen width with the presence of ovigerous specimens in females revealed a physical maturity at 84.00 mm CL.

Primer registro y información preliminar de la biogía del cangrejo de alta mar, *Chaceon gordonae* Ingle, 1985 (Brachyura: Geryonidae) en São Pedro e São Paulo Archipiélago – Brasil.

Resumen: Siete campañas de pesca exploratória en aguas profundas se realizaron entre 2011 y 2014, entre 300 y 700 m, en las proximidades del archipiélago de São Pedro y São Paulo. Durante los reconocimientos se registró la presencia del cangrejo de profundidad, identificado el *Chaceon gordonae* (Ingle, 1985) . De los 458 especímenes capturados, 252 eran machos y 206 eran hembras. Se registraron las medidas de longitud de caparazón (LC) de los cangrejos, con machos que hayan presentado talla pormedia (LC= 110,81 ± 14,52 mm) mayor que de las hembras (LC= 102,00 ± 16,55 mm). En general, el parámetro β_1 de la relación entre lalongitud y el peso mostraron un patrón de crecimiento alométrico positivo. Mediante la comparación de regresiones lineales entre el longitude de caparazón y la anchura y la longitude de la quela derecha para machos revelo una talla de madurez morfológica entre 108,90 y 111,00 mm LC. La comparación de la regresión lineal entre lalongitud Del carapazón y ancho del abdômen con la presencia ovígeras, revelaron una talla de madurez morfológica de 84,00 mm LC para hembras.

Key-words: size distribution, reproduction, crab biology, allometric growth, decapoda, oceanic island

Introduction

Chaceon is the most numerous genus of the Family Geryonidae, including 28 species, which are widely distributed around the continental slopes and seamounts of the world oceans, except in the eastern Pacific, northward of Chile, in depths from 100 to more than 2.800 m (Manning & Houlthuis, 1989; Tavares & Pinheiro, 2011).

Chaceon gordonae (Fig. 1) was previously reported by Ingle (1985), with a distribution from Sierra Leone Ridge, off western Africa, to southern Iceland, for only two males and two females from a depth of 1,153 m. Later, Afonso-Dias et al. (2008), analyzing collections of São Tomé e Príncipe Archipelago, off western Africa, found *C. gordonae* in reasonable quantities that sustain a small artisanal fishery since 1980, configuring the second record of the specie in the North Atlantic Ocean.

In the South Atlantic Ocean, the first records of geryonid crabs were made by Scelzo & Valentini (1974), which identified individuals from oceanographic expeditions conducted on the continental shelf and slope in Brazil, Uruguay and Argentina. In northeastern Brazil, Sankarankutty et al.(2001) and Carvalho et al. (2009) reported the occurrence of *Chaceon,* initially reported as *Chaceon fenneri*. In 2011, however, Tavares & Pinheiro argued that those specimens belonged to a yet unknown species, later described as *Chaceon linsi*.

Morphometric information is important for ecological studies and in brachyuran crabs the analysis of relative growth to assess maturity is widely used because it may exhibit changes along their ontogeny, indicating that there are differences in growth not only between sexes, but also between pre- and post-pubertal moult (Hartnoll 1974, 1978; Fernández-Vergas et al., 2000). For this kind of analysis, the dimensions of fixed structures, which are directly or indirectly used for reproduction, such as the chelae for males and the abdomen for females (Hartnoll, 1974), are often used. Data related to sexual maturity are crucial for the study of the reproductive cycle and are thus vitally important to guide the adoption of fisheries management measures required to ensure the conservation of exploited species.

Through a research project developed by the Universidade Federal Rural de Pernambuco- UFRPE, the presence of a crab species of the Geryonidae family, identified as *Chaceon gordonae* (Ingle, 1985), was recorded around Saint Peter and Saint Paul Archipelago (SPSPA) (Ferreira et al., 2013). Therefore, this paper represents the first record of the Geryonid crab *C. gordonae* at SPSPA (Central-Equatorial Atlantic) and estimate morphological maturity, as well to describe size structure and depth pattern of its local population. An evaluation on sex ratio are also presented. The findings reported here add new information to the few studies, particularly with *C. gordonae* in oceanic islands, with possible use at management programmes.

Material and methods

The Saint Peter and Saint Paul Archipelago (Fig 2) is a small group of rocky islands located in the Mid-Atlantic Ridge, between the northern and southern hemispheres and the African and the American continents (00°55' N; 029°20' W). It is about 510 NM far from the Brazilian coast and 282 NM far from Fernando de Noronha Archipelago (Viana et al. 2010).

The examined specimens were caught between January 2012 and April 2014 by bottom traps, during seven research cruises at depths comprising from 300 to 700 m. A vernier calliper with 0.01 mm precision was used to measure the key variables: carapace width (CW), carapace length (CL), left and right chela width (LCHW and RCHW), left and right chela length (LCHL and RCHL), and female maximum abdomen width (AW). The wet weight (W g) of both males and females was recorded to establish a length-weight relationship.

The size frequency distribution was obtained by grouping the measurements of carapace length (CL) in 10-mm intervals. To compare the proportion of males and females, a chi-square test was applied, while a Student-T test was used for the comparison of carapace width, carapace length and weight. To assess if the values of carapace length in males and females showed significant differences ($p < 0.05$), a Shapiro-Wilkwas applied to test the normality. Because the data did not show normal distribution (for males: $W = 0{,}88979$, and for females: $W = 0{,}88349$), was then tested a nonparametric ANOVA followed by Kurkal-Wallis test for the surveys.

Due to loss of appendages of some specimens, a sub-sample was used to establish the length-weight relationship, measuring the total wet weight (g) and the carapace length (mm) of the specimens. The standard power function was applied, in which W is the body wet weight of an individual crab of CL, β_0 is the intercept, and β_1 is the growth factor parameter.

$$W = \beta_0 CL^{\beta_1}$$

The parameters were obtained by minimizing the sum of the difference of the logarithmic least-square regression. Student´s t test was used to establish the type of relative growth (allometric or isometric) with 3 for growth parameter for this relationship (Fonteles-Filho, 2011).

The morphometric maturity of *C. gordonae* was studied by analyzing the relative growth pattern of the key variables (RCHL, LCHL, RCHW, LCHW, and AW for females) against carapace length (CL), as an independent variable. An allometric equation, using the standard power function, was fitted to the data by least square regression, and the transition points (*i.e.* changes in slope/or elevation), determined by the less value of the parameter β_1.The change in direction of the regression was taken as an indication of sexual maturity, since it shows the beginning of allometric growth probably due to the need for an anatomical adaptation to perform mating or hatching eggs (Hartnoll, 1974). The growth

parameter which defines if this relationship is isometric or allometric is 1. Males chela who was in process to regeneration were exclude to the analysis.

Results

Length and weight distributions and sex ratio

Of the 458 crabs measured, 252 were males and 206 were females. Male *Chaceon gordonae* ranged from 40.60 to 137.10 mm CL, with a higher mean CL (110.81 ± 14.52 mm) and a heavier mean weight (650.39 ± 236.26 g) than females, which had a greater size range, from 41.60 to 139.80 mm CL, but a smaller mean CL (102.00 ± 16.55 mm), as well as a lighter mean weight (387.42 ± 151.89 g) (Table 1). Male size-frequency distribution was unimodal, with a mode around 110 mm CL, while female most frequent size was more spread out, with a bimodal size-frequency distribution between 100 to 120 mm CL (Fig 3). Significant differences in the distributions of carapace length were observed between surveys (Kruskal-Wallis ANOVA, $H = 65.00$, N = 458, $p < 0.001$): crabs caught in January being larger than the others from the rest of the surveys, and those caught in October were the smallest ones (Fig 4).

The length-weight relationship of *C. gordonae*, based on a subsample of 284 crabs (127 males and 157 females), describes a positive allometric growth. However, when individuals were analysed by sex, the β_1 parameter for females showed a negative allometric growth, and for males the β_1 parameter showed a positive allometric growth (Table 2).

The sex ratio recorded overall was 1:0.82 in favor of males. When this analysis were made by month, males showed more frequent than females in March, June, October and December, whereas females predominated in April and May. In January, the sex-ratio was equivalent for both sexes ($\chi^2 = 1.79$), and in October just one female was caught (Table 3).

Depth distribution

Chaceon gordonae specimens were caught in a depth range from 300 to 700 m. Although the crabs were caught in all depth strata, they were more abundant from 400 m to 600 m. Males were caught more frequently than females over most of their range, except for 600 m strata, where females predominated (Table 4).

Morphometric analysis

The comparison between length and width chelae measurements for males showed that right chela had a greater increase than the left chela (Table 5). Hence the morphometric maturity for males was calculated with the relationship between right chela measurements against CL, while for females this

relationship was calculated between AW against CL. The maximum inflection points that determine physical maturity was estimated as 108.90 mm CL (based on Right chela width) and 111.00 mm CL (based on Right chela length) for males (Fig 5) and 84.00 mm CL for females (Fig 6), based on the abdomen width.

Discussion

Ingle (1985) described *Geryon gordonae* from only two males (CL 118 and 119 mm) and two females (CL 81 and 89 mm), from a depth of 1,153 m, reporting a distribution for the species from the Sierra Leone Ridge, off West Africa, to southern Iceland. Afonso-Dias et al.(2008) reported the occurrence of *C. gordonae* in São Tomé Island with a CL range between 77 to 129 mm for males and 75 to 119 mm for females. Here we report the first occurrence for this species to Brazil, particularly to the Saint Peter and Saint Paul Archipelago, a rare insular ecosystem, which plays a very important role in the life cycle of several species of marine organisms (Viana et al. 2010). That is the fourth geryonid crab occurring in Brazilian waters, and it's a yet poorly unknown specie worldwide.

The size range in the present study was wider compared to previously described, including specimens from 40.60 to 137.10 mm CL for males and 41.60 to 139.80 mm CL for females. Males were more frequent than females in the present study, concurring with most studies on geryonids (Fernández-Vergaz et al., 2000; Pinho et al., 2001; López Abellán et al., 2002; Guerrero & Arana 2009; Pezzuto & Sant'Ana 2009; Castro et al., 2010). This trend, however, might be a result of fishing procedure. The use of traps often results in more males being caught, particularly when females are ovigerous, because of their tendency to avoid traps while brooding eggs (Taggart et al., 2004). Additionally, sampling bias probably also exists with regard to male size, since smaller crabs are less likely to enter traps when large males are present (Taggart et al., 2004).

The bathymetric range of the species in Saint Peter and Saint Paul Archipelago, from 300m to 700m, the maximum depth where traps operated, appears to be typical for geryonids, with males being more abundant in shallower depths (Melville-Smith, 1988; Pinho et al., 2001; Gutiérrez et al., 2011).

In brachyuran crabs, chela in males and abdomen in females are considered as secondary characters because of their functions in reproduction (Hartnoll, 1978). The male crab uses its chela for territorial defense, combat, mating and courtship as well as in carrying and holding the female during copulation. The abdomen in adult females forms an incubation chamber for the developing eggs, which are attached to the pleopods. The increase in relative growth of the male chela and female abdomen at the puberty moult brings these structures to full functional size at maturity (Melville-Smith, 1988). Hence the relative growth of chela in males and abdomen in females has been used to determine size at which puberty moult occurs or functional maturity attained. The present results based on morphometric

features, such as the use of some physical trait, are often used (Somerton, 1980; Fernández-Vergaz et al., 2000; López-Abellan et al., 2002; Guerrero & Arana, 2009; Pezzuto & Sant'Ana, 2009; Sant'Ana & Pezzuto, 2009). The choice of the carapace length to assess morphometric maturity in *Chaceon gordonae* caught in SPSPA, as the reference measure, was given by observing that they have the fifth anterolateral teeth as long spines, and is prone to wear to be very sharp. Within this fact, the carapace width of the caught species in SPSPA may not represent the real growth. Some individuals present this teeth in different length in comparison with the right and left side (visually observation), and when we transport to the laboratory, some of 5^{th} anterolateral teeth was broken, invalidating the measure. In males, the relationship between carapace length against right chela length and width showed a maximum inflexion from 108.90mm CL (142.4 mm CW) to 111.00 mm CL (134.4 mm CW) mm, respectively. For females, the size at first sexual maturity, with the relationship between carapace length against abdomen width, was 84.00 mm CL (116.8 mm CW). This length for both males and females, differ to estimates made by various authors for other *Chaceon* species (Haefner, 1977; Melville-Smith, 1987; Fernandez-Vergaz et al., 2000; López-Abellan et al., 2002; Guerrero & Arana, 2009; Pezzuto & Sant'Ana, 2009; Sant'Ana & Pezzuto, 2009), attained higher values.

To conclude, that first analysis with deep-sea crabs in Saint Peter and Saint Paul Archipelago were within the patterns observed in other *Chaceon* studies in relation to depth and size structure, but outside in relation to morphometric maturity. However, the need for more effort is required to better understand the ecology of this important group of crustaceans in the archipelago. Techniques other than trap, such as the use of BRUV's (Baited Remote Underwater Video), may be therefore necessary to better understand the movements, spatial distribution, and life history of this species at Saint Peter and Saint Paul Archipelago.

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Tables and figures

Figure 1. *Chaceon gordonae* (Ingle, 1985). Male with 83 mm CL, 110 mm CW, collected off Saint Peter and Saint Paul Archipelago at 330 m depth.

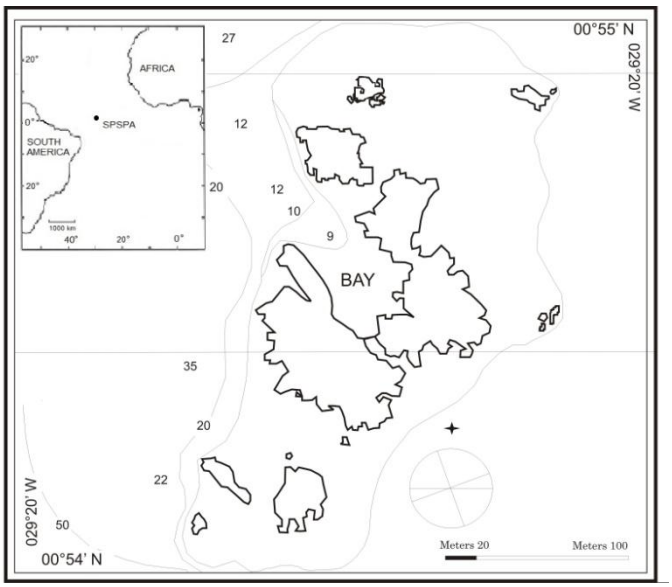

Figure 2. Location of the Saint Peter and Saint Paul Archipelago, Brazil.

Table 1. Sample size (N), range, mean ± standard deviation (SD) between sexes in carapace length, and weight of the deep-sea african crab, *Chaceon gordonae* (Ingle, 1985) measured and weighed during fishing surveyed carried out off Saint Peter and Saint Paul Archipelago.

Variables		**N**	**Range**	**Mean** ± SD	**t-test***
CL (mm)	Males	252	40.60 - 137.10	110.81 ± 7.26	t = 6.06
	Females	206	41.60 - 139.80	102.00 ± 8.27	p < 0.0001
	Total	458	40.60 - 139.80	106.85 ± 8.03	
Weigth (g)	Males	127	177.00 - 1420.00	650.39 ± 118.13	t = 6.63
	Females	157	19.00 - 675.00	387.42 ± 75.94	p < 0.0001
	Total	284	19.00 - 1420.00	505.01 ± 116.96	

* Student T-test

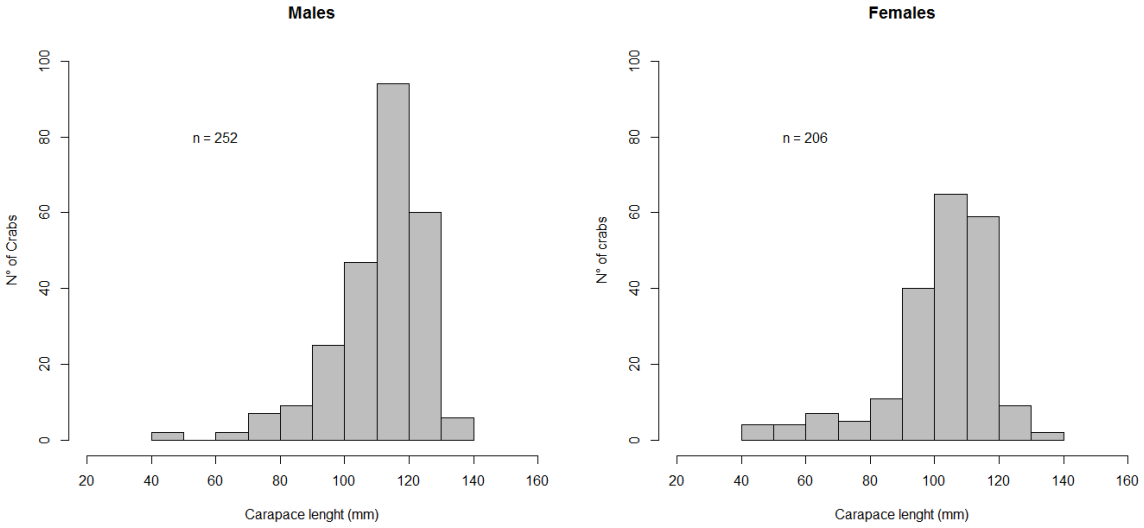

Figure 3. Length frequency distribution by sex for the deep-sea african crab, *Chaceon gordonae* (Ingle, 1985), caught around the Saint Peter and Saint Paul Archipelago.

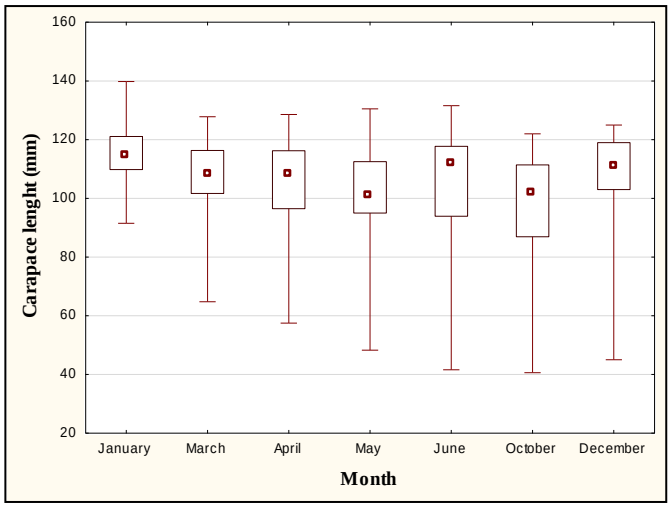

Figure 4. Length range of the deep-sea african crab, *Chaceon gordonae* (Ingle, 1985) caught at each survey (sample size for each month: January = 127; March = 73; April = 64; May = 73; June = 53; October = 38; December = 30).

Table 2. Length-weight relationship parameters for male and female of deep-sea African crab *Chaceon gordonae* caught off SPSPA. Intercept (β_0), Growth parameter (β_1), Standard deviation of a mean (SE), Correlation coefficient (r^2), Sample size (n).

	β_0	β_1	SE(β_1)	r^2	n	t-test	*p*	SE estimate
Females	0.0009	2.79	± 0.09	0.85	157	29.99	<0.0001	± 0.235
Males	0.0002	3.17	± 0.17	0.72	127	18.29	<0.0001	± 0.209
Total	0.0003	3.07	± 0.08	0.83	284	37.54	<0.0001	± 0.245

*****Student T-test

Table 3. Sex-ratio of deep-sea African crab *Chaceon gordonae* caught off SPSPA, by month (* presence of ovigerous female).

Survey	N° Males	N° Females	Sex-ratio	χ^2
January	55	72*	1 : 1,31	1.79
March	57	16*	1 : 0,28	31.54
April	12	52*	1 : 4,33	39.06
May	21	52*	1 : 2,47	18.03
June	42	11	1 : 0,26	34.21
October	37	1	1 : 0,03	89.75
December	28	2	1 : 0,07	75.11
Total	252	206	1 : 0,82	1.01

Table 4. Sex-ratio of the deep-sea African crab *Chaceon gordonae* caught off SPSPA, by depth intervals (*presence of ovigerous female)

Depth range (m)	N° Males	N° Females	Sex-ratio	χ^2
300 - 399	31	7	1 : 0,22	39.89
400 - 499	77	67*	1 : 0,87	0.48
500 - 599	44	43*	1 : 0,98	0.01
600 - 699	1	13*	1 : 13,00	73.47
700 - 799	37	1	1 : 0,03	89.75
Total	190	131	1 : 0,69	3.38

Table 5. Sample size (N), mean± standard deviation (SD), for the key variables (LCHL, RCHL, LCHW, RCHW) of the deep-sea african crab, *Chaceon gordonae* (Ingle, 1985) measured during fishing surveyed carried out off Saint Peter and Saint Paul Archipelago.

		N	Mean ± SD	F-ratio	Test-t	p
LCHL	Males	243	96.75 ± 15.72	1.8	17.76	<0.0001
	Females	191	72.55 ± 11.72			
RCHL	Males	243	99.11 ± 16.42	1.94	17.57	<0.0001
	Females	189	74.27 ± 11.78			
LCHW	Males	244	33.29 ± 5.72	2.19	19.9	<0.0001
	Females	191	23.69 ± 3.86			
RCHW	Males	243	35.33 ± 6.6	2.56	18.64	<0.0001
	Females	189	25.12 ± 4.12			

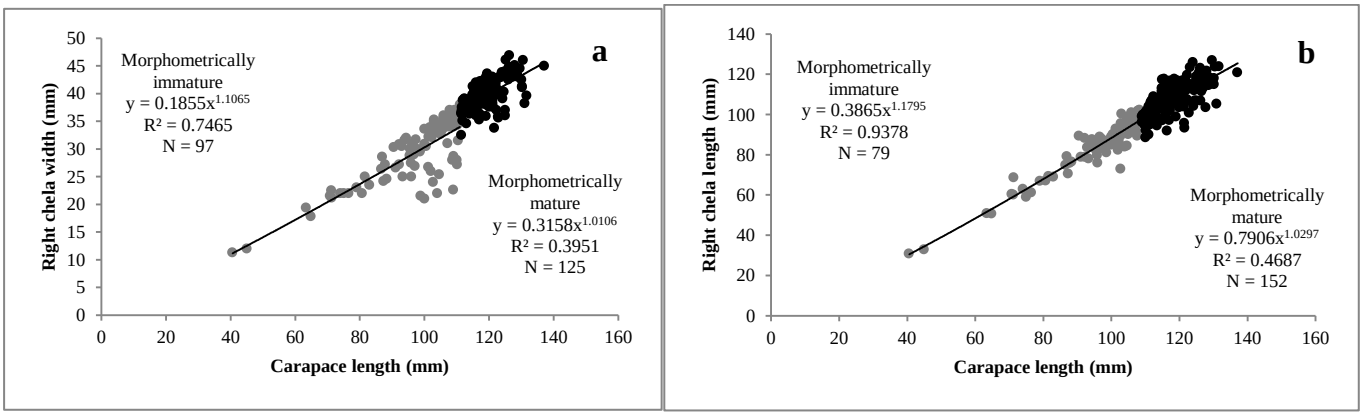

Figure 5. *Chaceon gordonae* bivariate scatter plots of secondary sexual characters and lines fitted to each group of points representing morphometric mature stages of males: a; Right chela width (RCHW), b; Right chela length (RCHL).

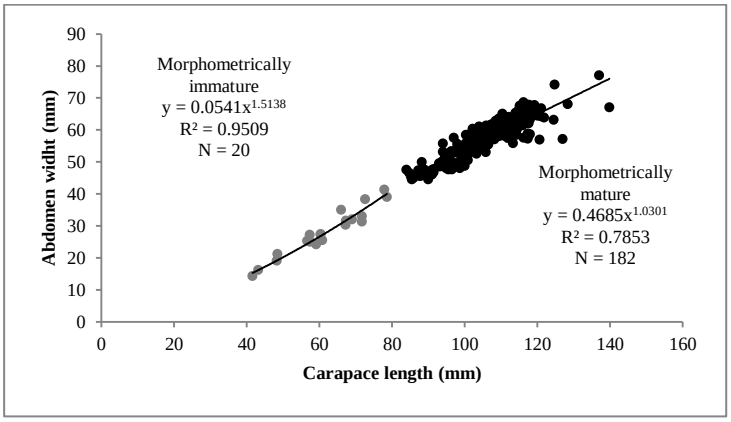

Figure 6. *Chaceon gordonae* bivariate scatter plots of secondary sexual characters and lines fitted to each group of points representing morphometric mature stages of females.

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Artigo científico 2

Seasonal reproduction of female african crab, *Chaceon gordonae* (Ingle, 1985), (Brachyura: Decapoda) collected off Saint Peter and Saint Paul Archipelago.

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Abstract: The goal of this work was to elaborate on seasonal reproductive knowledge of female deep-sea african crab, *Chaceon gordonae*, off the Saint Peter and Saint Paul Archipelago by providing information regarding its gonadal and eggs development according color scale and size at first physical maturity. Four exploratory deep-water fishing surveys were carried out at depths comprising from 300 to 700 m, being caught a total of 131 specimens. The carapace length (CL) of sampled crabs measured, on average was 96,70 ± 17.34 mm CL. Six color stages in gonad development were categorized, with five stages of color for the egg mass. A comparison of linear regression between carapace length and abdomen width with the presence of ovigerous female revealed a physical maturity at 84.00 mm CL. Estimate maturity in females crabs according color changes in ovary could often be subjective, being necessary histologic analysis to accurately certificate the stage of maturation.

Resumen: El objectivo de este estúdio fue desarrollar el conocimiento sobre la madurez sexual del cangrejo africano, *Chaceon gordonae*, capturados en el São Pedro y São Paulo archipiélago, proporcionando información sobre el desarrollo gonadal y del huevos, según la escala de color, y la estimación del talla de primera madurez física. Cuatro campañas exploratorios de pesca de águas profundas se llevaron a cabo a profundidades que comprenden 300 a 700 m, siendo capturado un total de 131 especímenes. La longitud del caparazón (CL) de los cangrejos fue, em el pormedio, de 96.70 ± 17.34 mm CL. Seis clases de color en el desarrollo de las gônadas se classificaron, y cinco clases de color para la masa de huevos. Una comparación de la regressión lineal entre la longitud de carapazón y ancho del abdômen, com la presencia de hembras ovígeras mostró uma madurez física a 84.00 mm CL. Estimar la madurez de los cangrejos hembras según los câmbios de color en el ovário podrían ser subjectivos, siendo el análisis histológico necesario para certificar la madurez em estos animales.

Keys words: female, geryonidae, morphometric maturity, color scale, oceanic island.

Introduction

Geryonid crabs are widely distributed around the continental slopes and seamounts of the world oceans, except in the eastern Pacific, northward of Chile. *Chaceon* is the most numerous genus of the Geryonidae family, including 31 species, occurring in depths from 100 to more than 2.800 m (Manning & Houlthuis, 1989; Tavares & Pinheiro, 2011). Through a research project developed by the Universidade Federal Rural de Pernambuco – UFRPE, the presence of a crab species of the Geryonidae family, identified as *Chaceon gordonae* (Ingle, 1985), was recorded around Saint Peter and Saint Paul Archipelago (SPSPA) (Ferreira et al., 2013), a small group of rocky islands located in the Mid-Atlantic Ridge, (0°55' N; 29°20' W), in the equatorial Atlantic Ocean (Viana et al., 2010) (Fig. 1).

The paucity of knowledge and the lack of basic information about this important group of deep-sea crab in SPSPA, generated the need for biological information to be used in ecological investigations. Among this information, the knowledge of reproductive dynamics is one of the most important to ensure efficient management programs. In decapod crustaceans, such as those from geryonid family, the reproductive development can be accompanied along their ontogeny, through morphometric features such as size at first morphological maturity (Fernández-Vergaz et al., 2000; Pezzuto & Sant'Ana, 2009; Sant'Ana & Pezzuto, 2009; Guerrero & Arana, 2009; Castro et al., 2010), and by changes that occur in the ovaries during reproductive cycle, such as in color and size (Haefner, 1977; Melville-Smith, 1987; Erdam & Blake, 1988). In addition, egg development also studied once some authors suggest that these species may not spawn annually, due to long intermoult (Hines, 1988; Tuset et al., 2011).

The comparison of macroscopic traits, such as color changes in stages of gonadal maturation and egg mass, to the morphological features allows creating a chromatic scale to characterize the stage of sexual maturation on the female gonad and eggs attached in pleopods. Ovarian maturation stages, egg development, as well as the length at first maturity are vital to understand the reproductive dynamics of *C. gordonae,* particularly in the Saint Peter and Saint Paul

Archipelago. Thus, the aim of this paper is to describe the sequential stages in the development of *C. gordonae* ovaries and egg development, creating an accurate chromatic scale, and to estimate the size at first sexual maturity.

Material and methods

Between May 2012 and April 2014, female *Chaceon gordonae* were caught in the vicinity of Saint Peter and Saint Paul Archipelago by bottom traps at depths comprising from 300 to 700 m. At the site, all collected females were measured for short carapace length (CL, midline distance from the diastema between the rostral teeth to the posterior carapace edge), and maximum abdomen width (AW) using a caliper with 0.01 mm precision. The total wet weight (W) was recorded with 0,01 g precision. Then, the carapace of each female was removed to access the ovary. Ovarian developmental stage was then assessed on the basis of macroscopic criteria following the maturation scales described by other *Chaceon* species (Haefner, 1977; Erdman & Blake, 1988; Fernández-Vegaz et al., 2000). Females of *C. gordonae* were classified according to the size and color of fresh gonad. The predominant color of each maturity stage was compared with a catalog of colors (Pantone®) to establish a point of chromatic reference.

To determine the morphological size at maturity, the AW data were plotted against CL, as an independent variable. An allometric equation, using the standard power function, was fitted to the data by least square regression, and the transition points (*i.e.* changes in slope/or elevation), determined by the less value of the parameter β_1.The change in direction of the regression was taken as an indication of sexual maturity, since it shows the beginning of allometric growth probably due to the need for an anatomical adaptation to perform mating or hatching eggs (Hartnoll, 1974). The allometric level (β_1 *value*) obtained from the regression lines was tested for significant difference from 1 (β_1 # 1) by means of a *t*-test (Zar, 1999).

To define the egg development through color scale, berried females was described and classified according color changes of the egg mass considering previous studies in *Chaceon* spp. (Haefner,

1978; Erdman & Blake, 1988; Tusset et al., 2011), and then compared to a catalog of colors (Pantone®).

Results

Four exploratory fishing deep-water surveys were carried out at Saint Peter and Saint Paul Archipelago, in the first semester of each year, with131 females of *Chaceon gordonae* caught. The collected crabs ranged from 41.60 to 120.00 mm in CL, with a mean 96.70 ± 17.34 mm, and from 19.0 to 675.0 g in weight, with a mean 363.76 ± 173.34 g. *C. gordonae* specimens were caught in a depth range from 300 to 700 m. Although the crabs were caught in all depth strata, they were more abundant from 400 m to 500 m strata. Ovigerous females were observed between 400 and 600 m range of depths, except for 300 m and 700 m.

The female gonad of *Chaceon gordonae* is formed by paired and parallel lobes located on carapace. The anterior region is surrounded by the stomach and the posterior region is located lateral to the hepatopancreas. Six different stages of development of the female gonads were identified according color scale, named stage I (immature), stage II (early development), stage III (intermediate), stage IV (advanced), stage V (mature) and stage VI (post-spawning).

Stage I (immature): ovary is very small and colourless to white translucent (Pantone 5875C) and is difficult to distinguish in the carapace. Lobes of the ovary are not developed and are reduced to the posterodorsal part of the stomach. Stage II (early development): the ovary is clearly better developed, when compared to stage I. Small and color ranges from ivory to light orange (Pantone 116 CS). The start of vitellogenesis is observed. Stage III (intermediate): ovary well development with a medium size and presents colors ranging from yellow-orange to dark orange (Pantone 137 CS). Stage IV (advanced): ovary occupying a large space in the visceral cavity. The color rages from orange to red-orange (Pantone 1665). Stage V (mature): ovaries are brown (Pantone 175 CS), appears to decrease in size of posterior lobes and greatly swollen anterior

lobes. Stage VI (post-spawning): the post-spawning stage is usually similar to early-development, except for the presence of furrowed and flaccid lobes, indicating that partial spawning may occur for this species. The color ranges from brownish to ivory (Pantone 1225) (Fig. 2).

For the egg mass attached to the pleopods, five development stages were observed and correlated with the color scale: stage I, dark orange or red-orange colour (Pantone 1665), apparently fully filled with yolk; stage II, brownish color (Pantone 1675), probably absorbing the yolk; stage III, burgundy color (Pantone 1815); stage IV, purple-black color (Pantone 1817); and stage V, brownish-black color (Pantone 4975). Egg development seems to be not completely synchronous and sometimes two colour patterns can be observed simultaneously, one in the inner part, and another in the outer part of the egg mass (Fig. 3).

The linear relationship between CL and AW adding second sexual characteristics, such as the presence of eggs in pleopods, showed that the first morphometric maturity occurs at 84.00 mm CL (Fig. 4).

Discussion

The size at which decapod crustaceans are physiologically mature can be determined through the study of reproductive characteristics, as macro and micro observation of the gonads, while the morphometric methods indicate allometric changes in growth related to morphological maturity, in which an individual is able to mate (Mantellato et al., 2009). The differences in the morphology of crustaceans, arising from changes of puberty, evident in the relationship between the dimensions of the carapace, are consequences of the development of the gonads. This may be related to the fact that the puberty moult occurs with an abrupt growth of the abdomen, since females would direct the energy available to first develop morphologically for the incubation of eggs and only then complete their gonadal development.

Our analysis in the female *Chaceon gorodnae* ovary collected off Saint Peter and Saint Paul Archipelago, showed that is similar in location to that of *C. quinquedens* (Haefner, 1977), and *C. maritae* (Melville-Smith, 1987), being a typical design for geryonid crabs. It consists of two sections united by a bridge, assuming an H shape, if viewed dorsally. Macroscopic observations on gonad development according color scale, corroborated by previous work in female *Chaceon* spp. (Haefner, 1977; Melville-Smith, 1987; Erdman & Blake, 1988; Fernández-Vergaz et al., 2000; Pinho et al., 2001) (Fig. 4).

The present results were based on combined information on morphometric characteristics, by analyzing the relationships between carapace length and abdomen width, including the presence of eggs attached in pleopods, and then compared to macroscopic development of the gonads and egg mass, according color scale. Size at first physical maturity, estimated by the traditional method based on a logistic curve, was 84.00 mm CL. These results are in accordance with the size range reported for other geryonid species (Fernández-Vergaz et al., 2000; López-Abellan et al., 2002; Pinho et al., 2001; Guerrero & Arana, 2009; Sant'Ana & Pezzuto, 2009).

So, spawning could probably occur in the first semester, coinciding with other works on *Chaceon* reproductive cycle (Fernández-Vergaz et al., 2000; López-Abellan et al., 2002; Pinho et al., 2001). These results support an annual reproductive cycle of *C. gordonae* which seems to be different from a continuous cycle reported for *C. maritae* and *C. quinquedens* (Melville-Smith, 1988; Haefner, 1977) but similar to that of *C. fenneri* (Erdman & Blake, 1988) and *C. affinis* (Pinho et al., 2001).

The determination of maturity stages by macroscopic observation of the ovary colour could often be subjective. In further studies, a wider range of gonads in other stages of development should be used for histological analysis, in order to find a possible correlation with a colour scale. Additional studies are necessary to allow the acquisition of more information on the reproduction

of *Chaceon gordonae* around the world, specifically in Saint Peter and Saint Paul Archipelago and other insular ecosystems.

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Tables and Figures

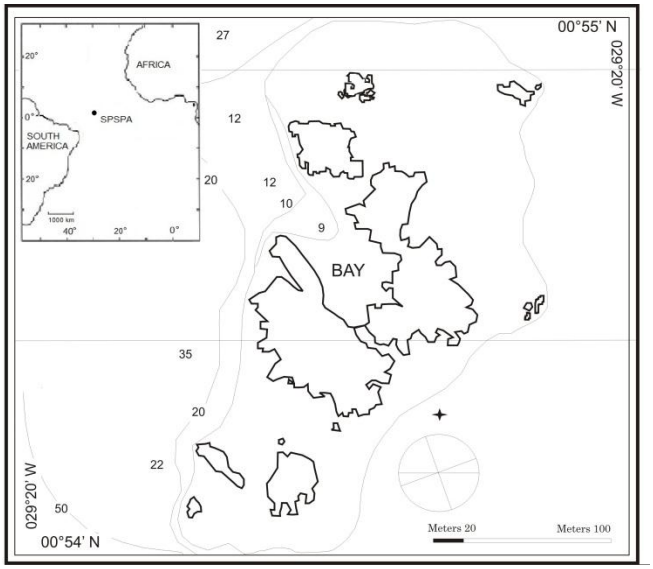

Figure 1. Location of the Saint Peter and Saint Paul Archipelago

Table 1. Number of female *Chaceon gordonae* and of ovigerous individuals by depth.

Depth	Nº Females	Ovigerous
300 - 399	6	0
400 – 499	66	15
500 – 599	44	12
600 – 699	13	4
700 - 799	1	0
Total	131	31

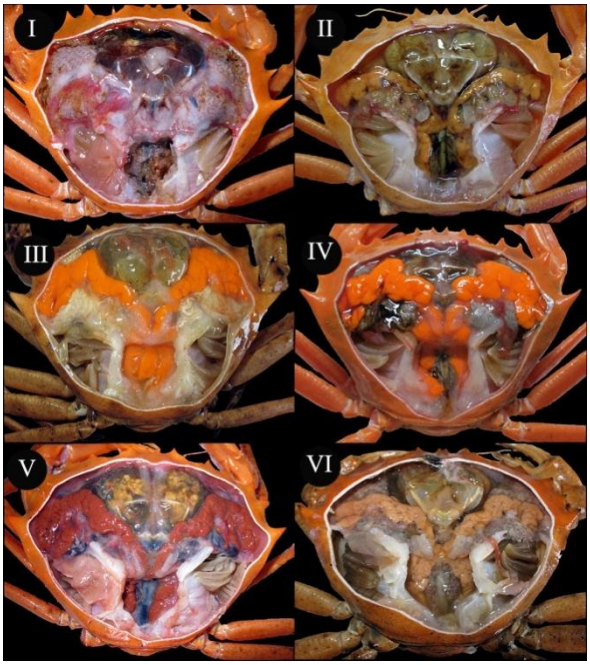

Figure 2. Chromatic variation of female *Chaceon gordonae* ovary caught at SPSPA: (I) immature; (II) early; (III) intermediate; (IV) advanced; (V) mature; and (VI) post-spawning.

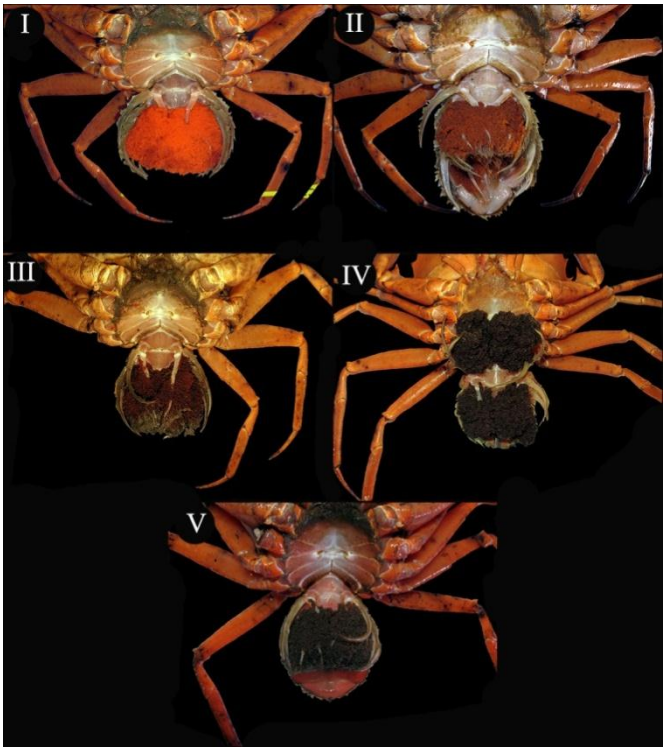

Figure 3. Chromatic variation of eggs attached to pleopods until their hatching: (I) red-orange; (II) brownish; (III) burgondy; (IV) purple-black; and (V) brownish-black.

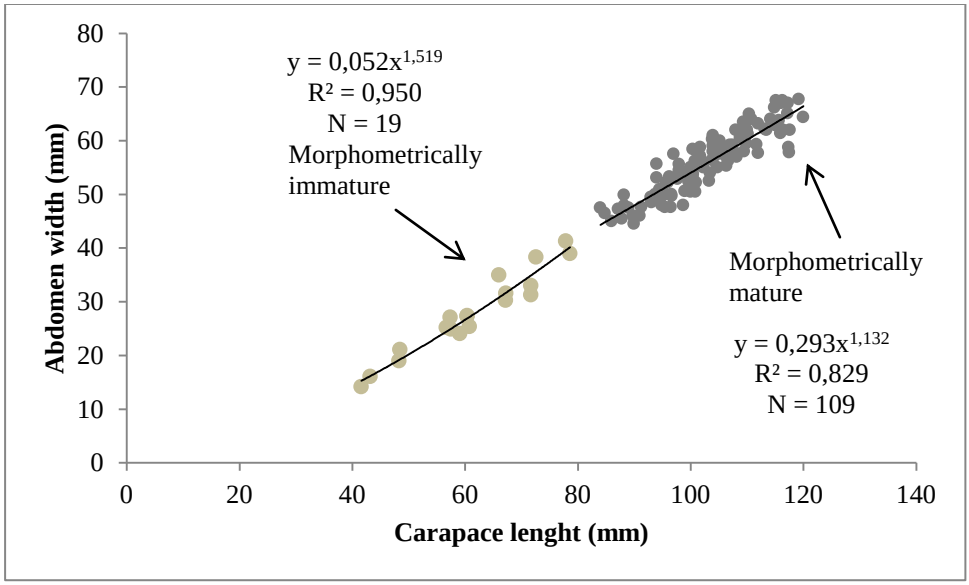

Figure 7. *Chaceon gordonae* bivariate scatter plots of secondary sexual characters and lines fitted to each group of points representing morphometric maturity stages of females.

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5. **Normas da revista**

Latin American Journal of Aquatic Resources

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- Results
- Discussion
- Conclusions (optional)
- Acknowledgements

References:
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- Coelho,V., R.A. Cooper & S. Rodrigues. 2000. Burrow morphology and behaviour of the mud shrimp Upogebia omissa (Decapoda, Thalassinidea, Upogebiidae). Mar. Ecol. Progr. Ser., 200: 229-240.

b) Book references should indicate: Author(s). Year of publication. Book title. Editorial, City, Pages.

- Thurman, H. & A. Trujillo. 2002. Essentials of oceanography. Prentice Hall, New Jersey, 524 pp.

c) Articles published in books should indicate: Author(s). Year of publication. Article title. Editor(s). Book title. Editorial, City, Pages.

- Brummet, R.E. & B.A. Costa-Pierce. 2002. Village-based aquaculture ecosystems as a model for sustainable aquaculture development in Sub-Saharan Africa. In: B. Costa-Pierce (ed.). Ecological aquaculture: evolution of the blue revolution. Blackwell Science, Oxford, pp. 145-160.

d) Articles published on Internet should indicate: Author(s). Year of publication. Article title. Web site. Date reviewed.

- Walker, J.R.1997. MLA-Style citations of Internet sources. [http://www.cas.usf.edu/english/walker/janice.html]. Reviewed: 24 January 2008.

e) References to articles or books published in CD-Rom should indicate: author(s), year of publication, (CD-ROM), article or book titles, editorial, city.

- Retamal, M.A. 2000. (CD-ROM). Decápodos de Chile. ETI-Universidad de Concepción. Springer-Verlag, Berlin.

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6. Considerações finais

Embora apresentem uma distribuição circunglobal, são poucas as informações sobre a biologia dos caranguejos geryonideos em todo o mundo. O estudo focou a identificação e aspectos da biologia, como estrutura populacional e reprodução do caranguejo-africano capturado no entorno do Arquipélago de São Pedro e São Paulo, situado no oceano Atlântico Equatorial.

Os resultados mostraram um padrão nas informações sobre estrutura populacional e distribuição batimétrica dos espécimens coletados no Arquipélago de São Pedro e São Paulo quando comparados aos coletados em outras partes de mundo, como as Ilhas Canárias e Ilha de Cabo Verde no Nordeste do Atlântico, no Arquipélago de Juan Fernandez situado no Pacífico Sul, e Golfo do México. Em relação aos dados gerados sobre a reprodução, o *Chaceon gordonae* capturado no ASPSP apresentou tamanhos de primeira maturação morfológica superior aos registrados para outras espécies de geryonideos, tornando necessário o desenvolvimento de mais pesquisas com análises histológicas para certificar os dados apresentados nesta dissertação.

Esta foi a primeira iniciativa para se compreender aspectos populacionais, bem como aspectos da reprodução do caranguejo-africano no Atlântico Equatorial e terá continuidade na expectativa de alcançar um conhecimento mais aprofundado acerca de sua população e biogeografia, que são aspectos essenciais para a construção de estratégias adequadas de conservação.