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Biologia reprodutiva dos tubarões *Carcharhinus falciformis*, *C. plumbeus*, *Pseudocarcharias kamoharai* e ocorrências do *Rinichodon typus*, no Atlântico Tropical e ecologia da raia *Dasyatis americana*, na Rebio Rocas – Brasil.

Paulo Guilherme Vasconcelos de Oliveira

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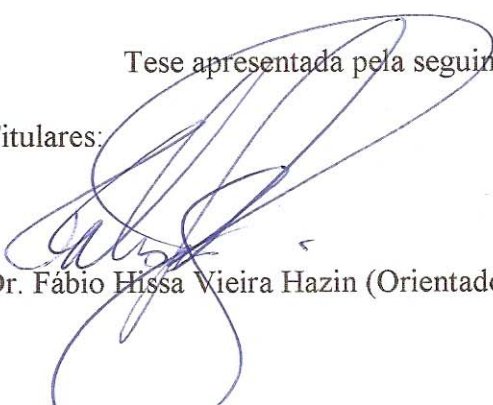
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*“Andei pelos oceanos deixando
rastros de espuma por onde passei, a
luz da lua emprestava às minhas
andanças um ar de capitão solitário,
nessas noites senti-me como uma alma
do mar”.*

Paulinho.

*Aos meus pais, Wlisses e Maria do Carmo,
que desde o início ensinaram-me a amar o mar e
respeitar a vida. Obrigado por vocês existirem.*

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RESUMO

O presente trabalho relata a biologia de 3 espécies de tubarões, o *Carcharhinus falciformis*, *Carcharhinus plumbeus* e o *Pseudocarcharias kamoharai*, além da ecologia da raia prego, *Dasyatis americana*. Primeiramente foi estudada a biologia reprodutiva do *C. falciformis*, sendo examinado um total de 96 indivíduos, sendo 48 machos e 48 fêmeas, capturados na região Equatorial do Oceano Atlântico, nas proximidades do Arquipélago de São Pedro e São Paulo (0°55'10"N;29°20'33"W). O comprimento total (CT) dos indivíduos variou entre 83,0 e 272,0cm, para as fêmeas e entre 75,0 e 295,0 para os machos. Estes dados sugerem um tamanho de primeira maturação sexual para o tubarão lombo-preto, em águas equatoriais, de aproximadamente 230,0cm, para as fêmeas e de 210,0 a 230,0cm para os machos. A distribuição mensal das fases sexuais ao longo do ano das fêmeas, não apresentaram uma tendência clara, sugerindo que pelo menos, na área estudada, esta espécie, não apresenta um ciclo gestacional anual claro. A proporção sexual dos embriões foi igual a 1:1,4 (macho:fêmea), com uma fecundidade de 4 a 15 embriões por período gestacional. Outra espécie que também teve os aspectos da sua biologia reprodutiva investigados foi o *C. plumbeus*, que durante o período de dezembro de 1994 a janeiro de 1996, teve, um total de 28 tubarões, sendo 11 machos e 17 fêmeas, capturados na região Nordeste do Brasil, na área de talude continental, em frente à costa do Estado de Pernambuco. O CT variou entre 154,0 e 196,0cm para os machos e entre 108,5 e 208,0cm para as fêmeas. A distribuição mensal dos estágios sexuais demonstraram que o parto e a ovulação ocorrem nos mesmos meses, sugerindo um ciclo de gestacional de 12 meses, em anos alternados. O número de embriões por fêmea grávida, variou entre 7 e 10 indivíduos, com um valor médio de 8,6, apresentando os mesmos uma proporção sexual de 1:1,4(macho:fêmea). Uma terceira e última espécie ainda teve a biologia reprodutiva investigada, no período de fevereiro de 2005 a setembro de 2007 foram capturados, por barcos da frota comercial arrendada, 490 exemplares de tubarão cachorro, *Pseudocarcharias kamoharai*, no Atlântico Tropical (06° 45' N e 23° 36' S e 018° 44' W e 053° 13'W). Em laboratório, os indivíduos capturados foram identificados e tiveram seus principais comprimentos aferidos, e seus aparelhos reprodutores coletados e fixados em formol a 10%. Dos 490 espécimes de tubarão cachorro analisados, 313 (63,9%) eram fêmeas, com CT variando de 75,0 a 122,0 cm, e 177(36,1%) eram machos, com CT entre 65,5 e 109,0 cm. As fêmeas apresentaram 6 classes de estágios maturacionais, enquanto que os machos apenas 2 classes. A distribuição de frequência de comprimento apresentou uma moda para as fêmeas de entre 90,1 e 100,0 cm, sendo igual para os machos. O peso médio da glândula oviducal nos jovens apresentou diferença estatisticamente significantes em relação aos outros estágios (Kruskal-Wallis, $F=2.34$; $P = 0.004$). As fêmeas classificadas como adultas, exibiam todo o aparelho reprodutor desenvolvido, contudo, sempre, com peso do ovário e largura dos úteros menores que os outros estágios, excetuando-se as juvenis. As fêmeas prenhes, cujo CT variou entre 87,5 e 118,6 cm, foram classificadas em quatro estágios distintos, prenhe I, II, III e IV (a termo), pois, embora estivessem na mesma condição, exibiam características particulares, principalmente no que tange as condições dos úteros e ovários. As fêmeas classificadas como prenhe II apresentavam os ovários com características semelhantes aos da prenhe I, contudo com um peso médio um pouco maior e com intensa atividade vitelogênica. Os espécimes classificados como prenhe III, continham em seus úteros apenas embriões, com comprimento total sempre inferior a 30 cm. Os espécimes classificados no estágio de prenhes IV (a termo) exibiam os ovários nitidamente em processo de reabsorção, não se encontrando mais em ovulação, o que pode ser verificado pela diminuição de seu peso. Apresentavam ainda em ambos os úteros embriões com CT superior a 30,0 cm. As relações

para um tamanho de 1^a maturação sexual em torno de 90,0 cm de CT. Entre os 177 machos examinados 37 (20,9%) encontravam-se juvenis, com CT variando entre 65,5 – 94,0 cm e 140 (70,1%), eram adultos, exibindo CT entre 80,0 – 109,0 cm. As relações entre CT e a largura, comprimento e peso do aparelho reprodutor da espécie, apontam para um tamanho de primeira maturação sexual entre 80,0 e 94,0 cm de CT. Também foi realizado um estudo de ocorrência do *Rhynchodon typus* no Arquipélago de São Pedro e São Paulo, por se tratar de um importante local de concentração de tubarões-baleia. Os animais foram vistos ao longo de todo ano, próximos às embarcações de pesca nas adjacências das ilhas. Em avistagens registradas entre fevereiro de 2000 e novembro de 2005, os comprimentos dos indivíduos variaram entre 1,8 m e 14 m. As causas destas concentrações no arquipélago ainda não são claras, uma vez que não há ressurgências e grandes concentrações de plâncton no arquipélago, e também não foram observadas atividades reprodutivas. No entanto, podem estar associadas ao período de desova dos peixes-voadores, marcadamente no primeiro semestre, quando as aparições são mais frequentes. Finalizando, foi realizado na Reserva Biológica do Atol das Rocas o trabalho de ecologia populacional e uso do habitat da *Dasyatis americana*, sendo avistadas 184 raias, durante as incursões subaquáticas, no período de agosto de 2003 a dezembro de 2005. O tamanho dos indivíduos variou entre 29,0 e 113,0 cm de largura de disco (LD). A maioria dos espécimes observados encontravam-se na faixa de 80,0 a 89,0 cm de LD, representando cerca de 25% do total. As fêmeas foram mais abundantes que os machos, com uma proporção sexual de 5,7♀:1♂ (fêmea:macho). O tamanho da população foi estimada em 99,2±17,1 e 94,4±10,3 indivíduos, utilizando Petersen-Bayley e Jolly-Saber, como estimadores probabilísticos, respectivamente. Os espécimes observados apresentaram comportamentos de alimentação e movimentação altamente relacionados com o severo ciclo de mares imposto pelo Atol.

Palavras-Chave: Oceanografia biológica; tubarões; biologia reprodutiva

ABSTRACT

The present work aims to describe the biology of 3 species of sharks, *Carcharhinus falciformis* (silky shark), *Carcharhinus plumbeus* (sandbar shark) and the *Pseudocarcharias kamoharui* (crocodile shark), furthermore the ecology of the southern stingray, *Dasyatis americana*, at the Atol das Rocas Marine Biological Reserve. Firstly, was studied the reproductive biology of the *C. falciformis*, a total of 96 silky sharks, 48 males and 48 females, caught in the equatorial region, close to the Archipelago of Saint Peter and Saint Paul (0°55'10"N; 29°20'33"W) were examined, with a view to study their reproductive biology. Total length (TL) ranged from 83.0 to 272.0 cm, for males, and from 75.0 to 295.0 cm, for females. The present data suggest a size at first sexual maturity for the silky shark in the equatorial Atlantic of about 230 cm, for females, and from 210 to 230 cm, for males. The monthly distribution of female sexual stages do not show any clear trend, suggesting that, at least close to the equator, the species might not have a clear seasonal cycle of gestation. Litter size ranged from 4 to 15, with a sex ratio of embryos equal to 1:1.4 (male: female). The other species that had reproductive aspects investigated was the *C. plumbeus*, a total of 28 sandbar sharks, 11 males and 17 females, caught off the coast of Pernambuco, northeast Brazil, from December 1994 to January 1996, were examined. Total length (TL) ranged from 154.0 to 196.0 cm, for males, and from 108.5 to 208.0 cm, for females. All specimens were already adults. The monthly distribution of sexual stages shows that parturition and ovulation happen in the same months, suggesting a 12-month gestation cycle, in alternate years. Litter size ranged from 7 to 10, with a mean value of 8.6, and the sex ratio of embryos was 1:1.4 (male: female). The third, and last, species studied regarding the reproductive biology was the crocodile shark. During the period between February 2005 and september 2007, 490 specimens were caught by boats from the Brazilian longline fleet in the Equatorial Atlantic Ocean (06° 45' N e 23° 36' S e 018° 44' W e 053° 13' W). 313 (63,9%) were females, with TL ranging between 75,0 and 122,0, and 177(36,1%) were males, with TL between 65,5 and 109,0 cm. Females were found with the reproductive tract in six different life stages, and males just two stages. Mean weight of the shell gland in the juveniles showed differences statistically significant in relation to other life stages. Females classified as adults, had the entire reproductive tract in advanced stage of development, however, always, with the weight of ovary and lenght of utero lower than other life stages. The results pointed to a size of first maturity about 90.0 cm TL. The last chapter of the present thesis is a study carried out at the Atol das Rocas Biological Marine Reserve to investigate the population structure and use of

habitat of the Southern stingrays (*Dasyatis Americana*). Rays (n = 184) ranged in size from 29–113 cm in disk width (DW). With greatest abundance (25%) in the 80-89 cm size class. The frequency of occurrence was higher for females than males (5.7:1). Population size was estimated to be 99.2 ± 17.1 individuals using the Petersen-Bayley likelihood estimator and 94.4 ± 10.3 with the Jolly-Seber estimator. The central lagoon was the only site in which the mean occurrence per unit of effort (OPUE) was significantly greater at high tide than at low tide. All other sampled areas showed the highest number of *D. americana* at low tide. Females segregated by size and water depth with the largest individuals (> 80 cm DW) found in depths greater than 1.5 m, and smaller individuals (20 - 62 cm DW) restricted to shallower areas. Rays of undetermined sex were associated with shallowest depths (< 0.5 m). Adult males (50 - 67 cm DW) occupied depths ranging from 3.5 - 4.5 m.

Key-words: Biological oceanography; sharks; reproductive biology

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APRESENTAÇÃO

A Classe Chondrichthyes é formada por peixes de esqueleto cartilaginoso que surgiram durante o Período Siluriano, há mais de 450 milhões de anos, mas a diversidade atual ocorreu a partir do Jurássico (200 a 145 milhões de anos atrás) (Silva, 2001). Atualmente a Classe Chondrichthyes é formada por duas Subclasses Elasmobranchii e Holocephalii. A Subclasse Holocephalii é representada pelas quimeras, com cerca de 50 espécies conhecidas. (Last & Stevens, 1994).

A Subclasse Elasmobranchii, em geral são animais marinhos, que podem ser encontrados desde regiões mais profundas até regiões costeiras entrando em estuários e rios, neste grupo de animais encontramos as raias e tubarões (Last & Stevens, 1994). Os tubarões estão entre os grupos de animais de maior sucesso em termos de evolução, pois sobrevivem há centenas de milhões de anos, graças à manutenção de sua diversidade (Silva, 2001).

Dentro da Subclasse Elasmobranchii são encontradas uma única ordem de raias (Rajiformes) e 8 ordens de Tubarões: Heterodontiformes, Orectolobiformes, Carchariniformes, Lamniformes, Hexanchiformes, Squaliformes, Squatiniformes e Pristiophoriformes. (Silva, 2001).

Os Chondrichthyes apresentam fecundação interna, fecundidade relativamente baixa e uma grande diversidade de estratégias reprodutivas, (Last & Stevens, 1994). Todas as espécies de tubarões possuem reprodução sexuada com fertilização interna. Algumas espécies são ovíparas enquanto outras apresentam viviparidade, podendo esta ser lecitotrófica - o embrião alimentando-se exclusivamente do vitelo, ou matotrófica - o embrião é nutrido pela mãe, incluindo-se nesta categoria tanto a oofagia, em que os embriões alimentam-se dos ovos produzidos pelo ovário materno, como a nutrição por placenta do saco vitelínico (Almeida, 1999).

Os Elasmobrânquios são considerados k-estrategistas, apresentando uma maturação sexual tardia, um baixo potencial reprodutivo, um ciclo de vida longo e uma recuperação lenta à redução dos seus estoques (Oliveira, 2001). Os tornando bem mais suscetíveis a sobrepesca do que os peixes teleósteos, neste sentido, é indispensável que toda a atividade de pesca de tubarões seja acompanhada por um estudo sobre o potencial reprodutivos das espécies capturadas (Hazin *et al*, 1995).

Capturas de mundiais de peixes cartilaginosos, representando 1% do total capturado pelas pescarias mundiais, o que equivale à 700.000 a 800.000 toneladas; aproximadamente 70-100 milhões de animais. Dos quais os tubarões representam 60% das capturas (Compagno *et al*, 2005).

A maioria dos tubarões desempenha um importante papel nos ecossistemas marinhos, pois consomem uma grande variedade de organismos, colaborando com a manutenção das taxas populacionais de suas presas, além de auxiliarem no controle da qualidade genética destas populações, eliminando os indivíduos menos ativos, sendo vitais para a manutenção da biodiversidade marinha, pois a depleção ou remoção destes pode acarretar um aumento ou declínio de outras espécies, trazendo consequências imprevisíveis ao ecossistema (Silva, 2001).

O presente trabalho consiste na compilação de cinco artigos científicos publicados e a publicar acerca da ecologia e biologia de elasmobrânquios no Atlântico Sudoeste Equatorial.

CAPÍTULO 1. BIOLOGIA REPRODUTIVA DO TUBARÃO CACHORRO, *Pseudocarcharias kamoharai* (MASUBARA, 1936) NO ATLÂNTICO SUDOESTE EQUATORIAL.

BIOLOGIA REPRODUTIVA DO TUBARÃO CACHORRO, *Pseudocarcharias kamoharai* (MASUBARA, 1936) NO ATLÂNTICO SUDOESTE EQUATORIAL.

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Resumo

No período de fevereiro de 2005 a setembro de 2007 foram capturados, por barcos da frota comercial arrendada, 490 exemplares de tubarão cachorro, *Pseudocarcharias kamoharai*, no Atlântico Tropical (06° 45' N e 23° 36' S e 018° 44' W e 053° 13'W). Em laboratório, os indivíduos capturados foram identificados e tiveram seus principais comprimentos aferidos, e seus aparelhos reprodutores coletados e fixados em formol a 10%. Dos 490 espécimes de tubarão cachorro analisados, 313 (63,9%) eram fêmeas, com CT variando de 75,0 a 122,0 cm, e 177(36,1%) eram machos, com CT entre 65,5 e 109,0 cm. As fêmeas apresentaram 6 classes de estágios maturacionais, enquanto que os machos apenas 2 classes. A distribuição de frequência de comprimento apresentou uma moda para as fêmeas de entre 90,1 e 100,0 cm, sendo igual para os machos. O peso médio da glândula oviducal nos jovens apresentou diferença estatisticamente significantes em relação aos outros estágios (Kruskal-Wallis, $F=2.34$; $P = 0.004$). As fêmeas classificadas como repouso, exibiam todo o aparelho reprodutor desenvolvido, contudo, sempre, com peso do ovário e largura dos úteros menores que os outros estágios, excetuando-se as juvenis. As fêmeas prenhes, cujo CT variou entre 87,5 e 118,6 cm, foram classificadas em quatro estágios distintos, prenhe I, II, III e IV (a termo), pois, embora estivessem na mesma condição, exibiam características particulares, principalmente no que tange as condições dos úteros e ovários. As fêmeas classificadas como prenhe II apresentavam os ovários com características semelhantes aos da prenhe I, contudo com um peso médio um pouco maior e com intensa atividade vitelogênica. Os espécimes classificados como prenhe III, continham em seus úteros apenas embriões, com comprimento

total sempre inferior a 30 cm. Os espécimes classificados no estágio de prenhes IV (a termo) exibiam os ovários nitidamente em processo de reabsorção, não se encontrando mais em ovulação, o que pode ser verificado pela diminuição de seu peso. Apresentavam ainda em ambos os úteros embriões com CT superior a 30,0 cm. As relações entre o comprimento total e a largura dos úteros e o peso das glândulas oviducais apontam para um tamanho de 1º maturação sexual em torno de 90,0cm de CT. Entre os 177 machos examinados 37 (20,9%) encontravam-se juvenis, com CT variando entre 65,5 –94,0 cm e 140 (70,1%), eram adultos, exibindo CT entre 80,0 – 109,0 cm. As relações entre CT e a largura, comprimento e peso do aparelho reprodutor da espécie, apontam para um tamanho de primeira maturação sexual entre 80,0 e 94,0 cm de CT

Abstract

The third, and last, species studied regarding the reproductive biology was the crocodile shark. During the period between February 2005 and september 2007, 490 specimens were caught by boats from the Brazilian longline fleet in the Equatorial Atlantic Ocean (06° 45' N e 23° 36' S e 018° 44' W e 053° 13'W). 313 (63,9%) were females, with TL ranging between 75,0 and 122,0, and 177(36,1%) were males, with TL between 65,5 and 109,0 cm. Females were found with the reproductive tract in six different life stages, and males just two stages. Mean weight of the shell gland in the juveniles showed differences statistically significant in relation to other life stages. Females classified as adults, had the entire reproductive tract in advanced stage of development, however, always, with the weight of ovary and lenght of utero lower than other life stages. The results pointed to a size of first maturity about 90.0 cm TL. The last chapter of the present thesis is a study carried out at the Atol das Rocas Biological Marine Reserve to investigate the population structure and use of habitat of the Southern stingrays (*Dasyatis Americana*. Rays (n = 184) ranged in size from 29–113 cm in disk width (DW). With greatest abundance (25%) in the 80-89 cm size class. The frequency of occurrence was higher for females than males (5.7:1). Population size was estimated to be 99.2 ± 17.1 individuals using the Petersen-Bayley likelihood estimator and 94.4 ± 10.3 with the Jolly-Seber estimator. The central lagoon was the only site in which the mean occurrence per unit of effort (OPUE) was significantly greater at high tide than at low tide. All other sampled areas showed the highest number of *D. americana* at low tide. Females segregated by size and water depth with the largest individuals (> 80 cm DW) found in depths greater than 1.5 m, and smaller individuals (20 - 62 cm DW) restricted to shallower areas. Rays of undetermined sex were associated with shallowest depths (< 0.5 m). Adult males (50 - 67 cm DW) occupied depths ranging from 3.5 - 4.5 m.

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1. Introdução

Os tubarões constituem um importante recurso pesqueiro, sendo capturados em várias partes do mundo por diversas artes de pesca (Chovan e Crump, 1990 *apud* Fischer, 2003). Grande parte de sua captura ocorre de forma acidental, como fauna acompanhante na pesca de outros recursos pesqueiros, de forma que o volume total de tubarões capturados é certamente superior ao total desembarcado, em função da prática comum do descarte (Russel, 1993; Hanfee, 1996; Trent, *et al.* 1997 *apud* Gadig, 1994).

Desde 1980 tem havido um crescimento constante dos desembarques de elasmobrânquios, em todo mundo, alcançando, na última década, uma taxa estimada de 5% ao ano (Clarke, 2004). O Brasil está incluído no grupo dos seis países que mais capturam elasmobrânquios, na categoria de "major shark-fishing state" (IUCN, 2002).

De acordo com o Grupo de Especialistas em Tubarões- SSG (1996), as populações de elasmobrânquios estão sendo negativamente impactadas por um conjunto de atividades humanas, encontrando-se, algumas delas, seriamente ameaçadas devido a: 1) Estratégias de vida, referidas acima, que as tornam particularmente vulneráveis à exploração, dificultando a sua recuperação quando em depleção; 2) rápido crescimento de pescarias não regulamentadas nas quais as mesmas incidem tanto como espécie-alvo, como fauna acompanhante; 3) altos índices de captura e mortalidade; 4) estímulo à captura "incidental" e ao descarte, devido ao alto preço de subprodutos, especialmente das barbatanas; 5) perda de zonas de berçário e outras áreas costeiras críticas para o seu desenvolvimento; 6) degradação ambiental e poluição.

Entre as espécies cujo conhecimento é particularmente limitado, estão as oceânicas, para as quais a coleta de dados é especialmente dificultada por constituírem, na maioria, a captura "incidental". Essas espécies, embora assim designadas, são capturadas, em muitos

casos, com o auxílio de adaptações dos aparelhos de pesca, como, no caso do espinhel pelágico, o uso da linha terminal de aço (estropo).

Entre essas, incluem-se os tubarões da família Lamnidae (*Isurus oxyrinchus*, *I. paucus*, *Lamna nasus*), da família Carcharhinidae (*Prionace glauca*, *Carcharhinus longimanus* e *Carcharhinus signatus*), Pseudocarchariidae (*Pseudocarcharias kamoharai*), Alopiidae (*Alopias vulpinus* e *Alopias superciliosus*) e Sphyrnidae (*Sphyrna mokarran* e *S. lewini*). Entre essas, as espécies da família Carcharhinidae constituem cerca de 40-50% das capturas obtidas com espinhel pelágico (Hazin et al, 1990).

Todas as espécies acima, algumas das quais se encontram, inclusive, listadas como espécies ameaçadas ou sobre-explotadas (ver I.N. 05, 21/05/2004; IUCN, 2000) (Silva, 2001), em maior ou menor grau, têm sido alvo do descarte das carcaças ao mar após a retirada das nadadeiras (*finning*), constituindo-se tal prática em motivo de grande preocupação, ao nível mundial, particularmente em função da escassez de dados de captura, associada a um esforço de pesca crescente.

Tubarão cachorro

Na ordem Lamniformes são conhecidas 7 famílias e cerca de 15 espécies, As quais são em geral tubarões de grande porte com exceção da Pseudocarchariidae (Compagno, 1984; Lessa, 1991; Barreto *et al*, 1993 e Lessa, 1999). A família Pseudocarchariidae é representada por apenas um gênero e uma espécie, a *Pseudocarcharias kamoharai*, vulgarmente conhecida como tubarão cachorro, que apresenta um porte pequeno, não ultrapassando 110cm de comprimento total (Compagno, 1984), olhos muito grandes, sem membrana nictitante, dentes finos e longos, com bordas lisas, pedúnculo caudal com quilha dérmica, coloração marrom uniforme e nadadeiras com margens claras (Last, 1994; Nelson, 1994 e Menezes 2003).

É uma espécie circumtropical, ocorrendo inclusive em águas brasileiras, da superfície até mais de 300m de profundidade (Carvalho-Filho, 1999). Distribui-se pela zona oceânica epipelágica e, possivelmente, mesopelágica de todos os oceanos, com maior número de registros no Pacífico Sul (Compagno, 1984; Cigala-Fulgosi 1992; Long, 1997). No Atlântico, no início, era conhecido apenas na margem oriental, leste e sul das Ilhas de Cabo Verde, Guiné Bissau, Guiné, Angola e África do Sul (Cadenat, 1963).

O primeiro registro desta espécie na margem ocidental se deu na costa brasileira, com base no exemplar capturado no litoral de Santa Catarina (Sadowsky, *et al.*, 1987). O hábito alimentar inclui pequenos peixes da família Gonostomatidae e Myctophidae, assim como pequenos camarões (Compagno, 1984).

A reprodução, ainda pouco estudada, se dá por viviparidade matrotófica, com embriões nutrindo-se de ovos fertilizados (oofagia) (Dulvey, 1997), com fecundidade uterina de quatro embriões e nascimento ocorrendo com comprimento total (CT) entre 40- 43cm (Bass, 1975; Fujita, 1981).

Devido, em parte, ao seu pequeno porte e ao seu baixo valor comercial, que estimula a prática do descarte, a espécie *Pseudocarcharias kamoharai* encontra-se atualmente na lista vermelha das espécies ameaçadas de extinção da IUCN (International Union for the Conservation of Nature and Natural Resources) (IUCN, 2005).

O conhecimento das características biológicas, entre elas a reprodução, é fator determinante para a conservação das espécies exploradas pela pesca comercial, uma vez que a mortalidade excedente, infligida pela pesca, pode comprometer irreversivelmente a capacidade de recuperação dos estoques, em decorrência da estreita relação entre estoque e recrutamento (Holden, 1974). Ainda, segundo o mesmo autor, modelos clássicos de gerenciamento de pesca não se adequam aos elasmobrânquios, pois assumem que o recrutamento e o tamanho do estoque são independentes, enquanto a estratégia de vida desses

peixes faz com que os mesmos estejam intimamente relacionados. Esse aspecto torna-se particularmente grave no caso de espécies rotineiramente descartadas, em função do seu baixo valor comercial, como no caso do tubarão cachorro, em relação às quais a obtenção de dados que permitam avaliar a mortalidade resultante da atividade pesqueira é extremamente dificultada.

Nesse contexto, portanto, no intuito de melhor avaliar a vulnerabilidade dos estoques de tubarão cachorro à sobrepesca decorrente da atividade pesqueira, aspecto essencial para a sua conservação, o presente estudo pretendeu adicionar informações importantes sobre a história natural desses animais, especificamente quanto ao seu comportamento reprodutivo.

2. Objetivo

2.1 Geral

O presente trabalho pretende elucidar aspectos da biologia reprodutiva da espécie *Pseudocarcharias kamoharai* no Atlântico Tropical, a partir de exemplares capturados por barcos atuneiros da frota comercial arrendada em operação no Nordeste brasileiro.

2.2 Específicos

- ✓ Descrever os estágios maturacionais de machos e fêmeas;
- ✓ Determinar a fecundidade uterina;
- ✓ Determinar o tamanho da primeira maturação sexual;
- ✓ Determinar época e local de parto.

3. Material e Métodos

No período de fevereiro de 2005 a setembro de 2007 foram coletados 490 exemplares de tubarão cachorro, capturados por barcos da frota comercial arrendada. A área de atuação dos barcos localizou-se entre os meridianos de latitudes 06° 45' N e 23° 36' S e as longitudes

018° 44' W e 053° 13' W (Figura 01), utilizando como aparelho de pesca o espinhel pelágico de deriva, em profundidades aproximadas entre 100 e 300m.

Conservados a bordo em câmaras de congelamento ou em gelo, os animais amostrados foram acondicionados inteiros e etiquetados, tendo sido conduzidos, após o desembarque, ao Laboratório de Oceanografia Pesqueira (LOP) da Universidade Federal Rural de Pernambuco (UFRPE). Posteriormente, já em laboratório, todos os animais foram mensurados quanto aos seus comprimentos total (CT), furcal (CF), interdosal (ID) e pré-caudal (CID) (Figura 02), aferindo-se igualmente os pesos total (PT) e eviscerado (PE).

Em seguida, os mesmos foram dissecados para a retirada dos aparelhos reprodutores dos machos (testículos, epidídimos e ampolas do ducto deferente) (Figura 03) e das fêmeas (ovários, glândulas oviducais e útero) (Figura 04), os quais foram pesados e medidos quanto a sua largura e comprimento. Todo material coletado foi preservado em solução de formol a 10%, tendo sido em seguida transferido para solução de álcool etílico a 70%.

Nas fêmeas, o estágio de desenvolvimento dos ovários e glândulas oviducais foram observados e o peso dos mesmos mensurado. Foi observada também a presença de marcas de mordidas ou cicatrizes nas fêmeas, uma vez que as mesmas podem ser uma indicação positiva de cópula (Stevens, 1974). Os úteros foram seccionados longitudinalmente para permitir o exame de seu conteúdo. Encontrando-se ovos ou embriões, os mesmos foram, quando possível, contados, medidos e sexados, sendo em seguida preservados em solução de formalina a 10% e posteriormente transferidos para solução de álcool etílico a 70%.

Nos machos, as ampolas do ducto deferente foram dissecadas e o seu conteúdo verificado. O comprimento e largura dos cláspers foram mensurados, avaliando-se, também, o seu estado de calcificação.

Com base nas informações obtidas foi possível identificar o estágio de maturação sexual dos indivíduos capturados, assim como diversas características da biologia reprodutiva

dos mesmos, incluindo tamanho de primeira maturação sexual, época de cópula e fertilização dos ovos, e número de filhotes por período gestacional.

3.1 Análise estatística

Para análise dos dados foram utilizados testes estatísticos univariados através do Software SAS (v. 9.0; SAS Institute, Cary, NC, USA). A homocedasticidade das variâncias dos pesos médios da glândula oviducal, do ovário, e da largura média do útero, entre os diferentes estágios das fêmeas, foi verificada através do teste de Levene.

Em seguida, para se avaliar se a variável resposta era significativamente diferente, foi utilizada uma análise de variância uni-fatorial (One-way ANOVA) (no caso de homocedasticidade da variância) e o teste não-paramétrico de Kruskal-Wallis (no caso de heterocedasticidade das variâncias). Para os testes e análises estatísticas realizados, o nível de significância adotado para rejeitar a hipótese nula (H_0) foi de 5% ($\alpha = 0,05$).

Para os exemplares de tubarão cachorro capturados, foram ajustadas as relações por meio de regressões lineares, entre o CT e os diversos comprimentos e pesos mensurados. As equações foram estimadas separadamente para machos e fêmeas, tendo sido os mesmos posteriormente comparadas por meio de uma análise de Co-variância (ANCOVA).

A não-normalidade da curva de distribuição dos dados não foi considerada como empecilho para o uso do método paramétrico ANOVA. Underwood (1997) indica que a análise de variância (ANOVA) é robusta quanto a não-normalidade da curva de distribuição dos dados e que tal premissa não tem obrigatoriedade de ser obedecida. Sendo assim, optou-se por considerar apenas a homocedasticidade das variâncias dos dados como pré-requisito para a aplicação da ANOVA.

4. Resultados

Dos 490 espécimes de tubarão cachorro analisados, 313 eram fêmeas, representando 63,9% das amostras, com CT variando de 75,0 a 122,0 cm e 177 (36,1%) eram machos, com CT entre 65,5 e 109,0 cm. As fêmeas apresentaram 6 classes de estágios maturacionais, enquanto os machos apenas 2 classes (Tabela 01).

A distribuição de frequência de comprimento, tanto para machos como para fêmeas, apresentou uma moda entre 90,1 e 100,0 cm (Figura 05). Os pesos eviscerados dos exemplares examinados variaram de 0,44 a 3,68 kg, para os machos, e de 0,90 a 5,12 kg, para as fêmeas. A relação de peso eviscerado e comprimento total de machos e fêmeas, não apresentaram diferenças significativas ($P < 0.05$) (Figura 06).

4.1. Fêmeas

De acordo com o desenvolvimento dos aparelhos reprodutores, as 313 fêmeas amostradas foram classificadas em 6 estágios maturacionais distintos, a saber: juvenil, prenhe I, prenhe II, prenhe III, prenhe IV(a termo) e em repouso (Tabela 02).

Os exemplares juvenis exibiam aparelho reprodutor pouco desenvolvido, com glândulas oviducais e úteros filiformes, pouco diferenciados do oviduto, ovários sem ovócitos visíveis ou com ovócitos diminutos e transparentes, sem atividade vitelogênica.

O peso médio da glândula oviducal nas fêmeas jovens apresentou diferença estatisticamente significativa em relação aos outros estágios (Kruskal-Wallis, $F=2.34$; $P = 0.004$) (Figura 7), assim como o peso médio do ovário e a largura média do útero (Kruskal-Wallis, $F=2.88$; $P < 0.001$) (Figuras 8 e 9).

As fêmeas em repouso exibiam glândulas oviducais, bem diferenciadas do oviduto, úteros largos e compridos, apresentando-se, em alguns casos, flácidos e com pregas longitudinais, indicando um parto recente (Figura 10). Os ovários, apesar de claramente

adultos, aparentavam se encontrar em repouso, com ovócitos em processo de reabsorção, presença de cicatrizes, *cópora lutea*, provavelmente de gestações anteriores, porém sem atividade vitelogênica (Figura 11). Tanto o peso do ovário como a largura do útero das fêmeas em repouso foram significativamente menores do que o das fêmeas nos outros estágios, exceto as que se encontravam no estágio juvenil (Kruskal-Wallis, $F=3.04$; $P=0.027$) (Figuras 08 e 09).

As fêmeas prenhes, cujo CT variou entre 87,5 e 118,6 cm, foram classificadas em quatro estágios distintos, prenhe I, II, III e IV (a termo), pois embora estivessem na mesma condição, exibiam características particulares, principalmente no que tange as condições dos úteros (Figura 12) e ovários (Figura 13) (Tabela 03).

As fêmeas prenhe I encontravam-se em início de gestação, com apenas ovos nos úteros, ovários em desenvolvimento, pesando cerca de 120,0 g, com folículos vitelogênicos de coloração amarelada e glândulas oviducais desenvolvidas (Figura 14).

As fêmeas classificadas como prenhe II apresentavam os ovários com características próximas aos das prenhes I, com um peso médio, contudo, bem maior (cerca de 250,0 g) e intensa atividade vitelogênica. Encontravam-se em um processo mais avançado de prenhes, já exibindo ovos, cerca de 16 por útero, e embriões, nos quais a sexagem contudo, não pôde ser realizada, devido ao seu pequeno tamanho, em média, igual a 7,8 cm de CT. As glândulas oviducais encontravam-se bem desenvolvidas e dilatadas. Foi observada a presença de ovos percorrendo o oviduto, tanto na porção entre as glândulas oviducais e os úteros como no ostium, ou seja, entre o ovário e as glândulas oviducais (Figura 15).

No estágio de Prenhes III, os úteros desses animais também continham ovos e embriões desenvolvidos, embora com um comprimento total sempre inferior a 30,0 cm, tendo sido possível, conseqüentemente a sexagem de todos eles. Os ovários, assim como, no estágio de prenhes II, também se encontrava bem desenvolvido com intensa atividade vitelogênica,

exibindo ovócitos bem amarelados. As glândulas oviducais e os ovidutos, apresentavam características semelhantes às das fêmeas em estágio de prenhes I e II. Os embriões, nesse estágio já apresentavam uma grande reserva vitelínica armazenada em seus estômagos (Figura 16).

Os indivíduos classificados no estágio de prenhe IV (a termo), exibiam apenas embriões bem desenvolvidos nos úteros, com comprimentos próximos ao tamanho de nascimento, sempre superior a 30,0 cm (Figura 17). O ovário já se encontrava em nítido processo de reabsorção, não se encontrando mais em ovulação, o que pode ser verificado pela redução de seu peso. As glândulas oviducais se apresentavam desenvolvidas, porém menos dilatadas do que as encontradas nas fêmeas prenhes II e III.

As características do ovário das fêmeas prenhes a termo foram muito próximas às das fêmeas em repouso, além de bem diferentes das fêmeas prenhes em estágio I, indicando que as fêmeas de tubarão cachorro possivelmente entrem em um período de repouso após o parto, embora a duração do mesmo seja difícil de presenciar com base nos dados presentes. A fecundidade uterina variou entre 3 e 4 (1 a 2 embriões por útero) com média igual a 3,8 embriões por fêmea prenhe. A proporção sexual total dos embriões foi de aproximadamente 1♂:1♀.

As relações entre o comprimento total e o peso do ovário e a largura dos úteros (Figuras 12 e 13) apontam para um tamanho de 1º maturação sexual em torno de 90,0cm de CT.

Indivíduos juvenis apareceram em todos os trimestres, com a sua frequência média mensal não apresentando diferença significativa ao longo do ano (Kruskal-Wallis, $F = 4.88$; $P < 0.06$). A frequência média de fêmeas prenhes I capturadas no terceiro trimestre foi significativamente menor em relação aos outros períodos do ano (Kruskal-Wallis, $F = 2.28$; $P < 0.001$) (Figura 18).

As fêmeas classificadas como Prenhe II, por sua vez, foram significativamente mais freqüentes no primeiro trimestre do ano (Kruskal-Wallis, $F = 3.14$; $P < 0.03$) (Figura 18), enquanto as fêmeas prenhes III foram significativamente menos freqüentes no primeiro trimestre (Kruskal-Wallis, $F = 3.14$; $P < 0.03$) (Figura 18).

Tanto as fêmeas em repouso quanto a termo, foram mais capturadas, no 2º e 3º trimestres do ano, quando a sua freqüência de ocorrência foi significativamente maior (Kruskal-Wallis, $F = 3.11$; $P < 0.04$) (Kruskal-Wallis, $F = 2.09$; $P < 0.001$), respectivamente (Figura 18).

Estes dados sugerem que, embora o Tubarão cachorro, *Pseudocarcharias kamoharai*, no Atlântico Tropical, se reproduza durante todo o ano, parece haver um pico de atividade de parto no 3º trimestre particularmente no mês de julho, quando foi observado o maior número de fêmeas a termo (Figura 19).

4.2. Machos

Entre os 177 indivíduos examinados 37 encontravam-se juvenis representando 20,9% do total, com CT variando entre 65,5 – 94,0 cm. A grande maioria (140; 70,1%), eram adultos, exibindo CT entre 80,0 – 109,0 cm..

Os indivíduos classificados como juvenis exibiam cláspers flexíveis e de tamanho reduzido, medindo entre 5,0 e 10,6 cm (Figura 20), testículos filiformes e pouco diferenciados do órgão epigonal (Figura 21), sempre com largura inferior a 2,0 cm, e por fim, ampolas do ducto deferente sem conteúdo.

Os exemplares no estágio adulto apresentavam cláspers desenvolvidos e rígidos, com comprimento sempre superior a 7,0 cm e normalmente maior que 10,0 cm (Figura 20), testículos completamente desenvolvidos (Figuras 21 e 22) e a ampola do ducto deferente sempre contendo líquido seminal espesso, de coloração branca.

As relações entre CT e o comprimento do cláster (Figura 20) e a largura, comprimento e peso do testículo (Figuras 21, 22 e 23), apontam para um tamanho de primeira maturação sexual entre 80,0 e 94,0cm de CT.

5. Discussão

Referências na literatura acerca da biologia reprodutiva do tubarão cachorro, *Pseudocarcharias kamoharai* (Abe, 1969; Bass et al., 1975; Fujita, 1981; Hamlett, 2005 e White, 2007), são ainda muito escassas, devendo-se tal fato, provavelmente, ao descarte que é realizado pela frota pesqueira industrial, uma vez que a referida espécie exibe um comprimento reduzido, não apresentando valor comercial (Stevens, 2000).

A predominância de fêmeas nas amostras coletadas (63,9%) também é registrada em outros estudos (White, 2007), embora o tamanho dos espécimes examinados no presente trabalho tenha apresentado um intervalo de comprimento maior que o do citado autor.

O intervalo de tamanho de primeira maturação sexual para as fêmeas sugerido pelos presentes dados, 90,0 cm CT, é igual ao tamanho proposto por Stevens (1994), se aproximando, também, dos valores sugeridos por Compagno (1984), entre 89,0 e 102,0 cm, e por Abe (1969) e Fujita (1981) que propuseram, respectivamente, um tamanho de primeira maturação de 98,0 e 99,0 cm.

No caso dos machos, o tamanho de primeira maturação sexual estimado pelo presente trabalho, 94,0 cm foi maior do que o sugerido por Stevens (1994), igual a 74,0 cm de CT, embora esteja inserido no intervalo proposto por Compagno (1984), de 74,0 a 110,0cm.

Os dados sugerem que ao longo da gestação, o ovário encontrava-se sempre ovulando até os embriões atingirem um tamanho próximo do nascimento, com uma importante reserva protéica ficando retida no estômago dos mesmos. A partir daí o ovário parece entrar em um processo de reabsorção, passando a nutrição embrionária a ocorrer exclusivamente a partir do vitelo que já se encontrava no estômago dos embriões. Esta reserva vai sendo consumida até o momento do nascimento, sendo este fato observado para a mesma espécie por Fujita (1981), Hamlett (2005) e Compagno (2005), assim como para outros lamniformes, como o *Isurus*

oxyrinchus, (Branstetter, 1981), *Carcharodon carcharias*, *I. paucus*, *I. oxyrinchus*, *Alopias superciliosus* e *vulpinus* (Gilmore, 1993).

A proporção sexual dos embriões, igual a 1:1, com uma fecundidade muito próxima a 2 embriões por útero, também foi observada por Bass et al (1975), Fujita (1981), Stevens (1994), Hamlett (2005) e White (2007).

O comprimento de nascimento dos embriões, acima de 30,0cm, também concorda com Stevens (1994), Fujita (1981), Compagno (1984), Hamlett (2005) e White (2007) que citam um CT de nascimento em torno de 40,0cm.

A diminuição no peso dos ovários, aliada à condição dos mesmos nas fêmeas prenhes a termo e em repouso, provavelmente indicam que o *P. kamoharai* na área estudada não inicia uma nova gestação logo após o parto.

A distribuição mensal dos estágios sexuais, portanto, indicam que a época de parto e o início de gestação acontecem durante todos os meses do ano, não havendo uma sazonalidade marcada. O fato do número de fêmeas prenhes (125) haver sido levemente superior ao de fêmeas em repouso (89) sugere que esse período seja um pouco mais curto que a do ciclo gestacional. Em função da ovulação e parto, entretanto, ocorrerem ao longo de todo o ano, sem uma sazonalidade marcada, impedem uma estimativa da duração dos mesmos.

Diante da elevada vulnerabilidade da espécie ao esforço de pesca exercido pela frota comercial que opera na captura de atuns com espinhel no Atlântico, é urgente a implementação de medidas que possam reduzir a sua mortalidade por pesca, tal premência torna, particularmente aguda quando se considera que a espécie não apresenta valor comercial, o que implica que a sua total extirpação do meio poderá ocorrer sem que haja qualquer impacto comercial na atividade pesqueira.

Além disso, a espécie possui uma fecundidade baixa, entre 3 e 4 embriões por gestação, um ciclo reprodutivo provavelmente longo, como é comum entre os laminídeos,

particularmente em função do período de repouso necessário à recuperação do ovário, em um tamanho de primeira maturação sexual muito próximo do seu comprimento total. A expectativa, portanto, é de que os dados gerados no presente trabalho possam estimular e subsidiar a adoção de medidas necessárias à conservação do tubarão cachorro no oceano Atlântico. Cabe destacar, por fim, a necessidade igualmente urgente, de que outros aspectos da sua biologia tais como o seu crescimento e hábito alimentar, sejam também investigados.

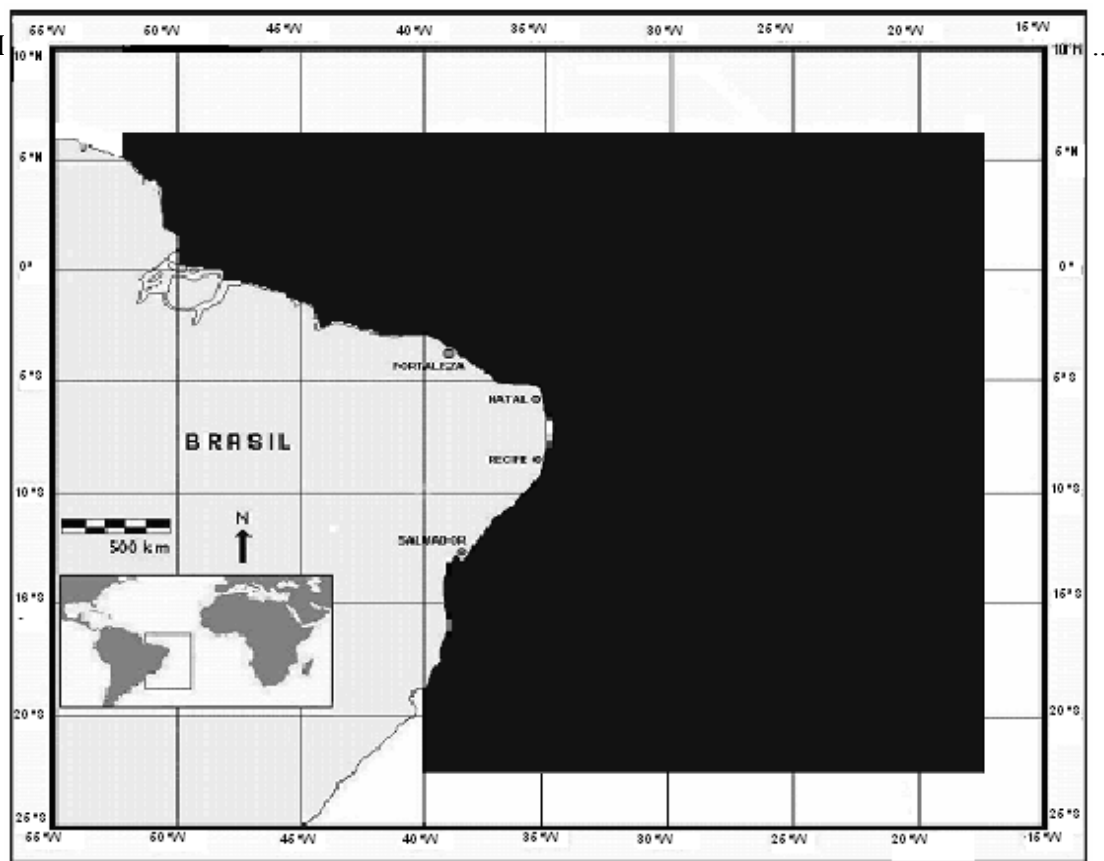


Figura 01. Área de atuação das embarcações arrendadas. Localizada entre os meridianos de latitudes $06^{\circ} 45' N$ e $23^{\circ} 36' S$ e as longitudes $018^{\circ} 44' W$ e $053^{\circ} 13' W$.

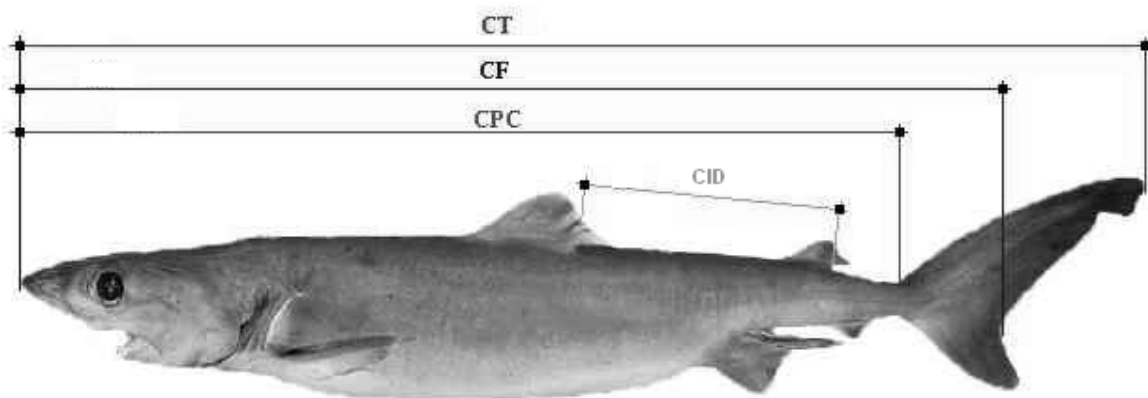


Figura 02. Medidas aferidas em cada exemplar amostrado. **CT** (Comprimento Total), **CF** (Comprimento Furcal), **CPC** (Comprimento Pré-caudal) e **CID** (Comprimento interdorsal).

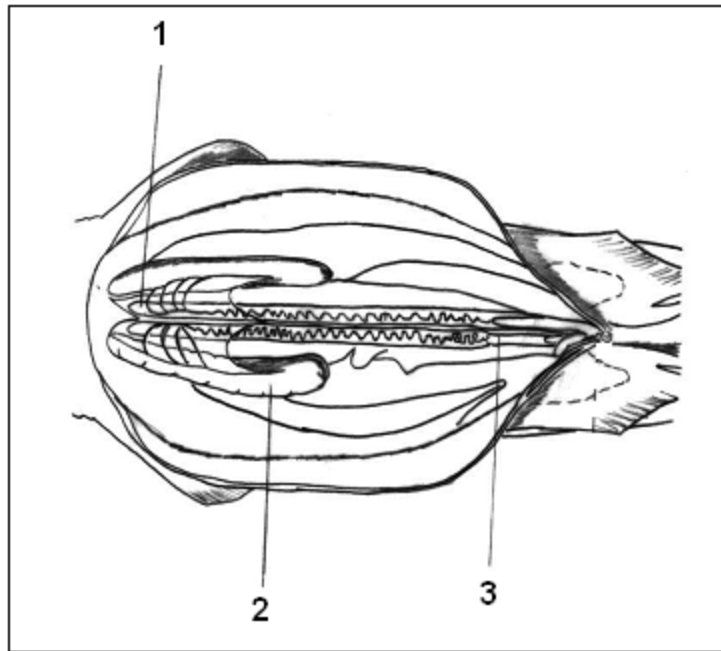


Figura 03. Desenho esquemático das estruturas coletadas do aparelho reprodutor masculino.
(1) Epididimo, (2) Testículo e (3) Ampola do Ducto Deferente.

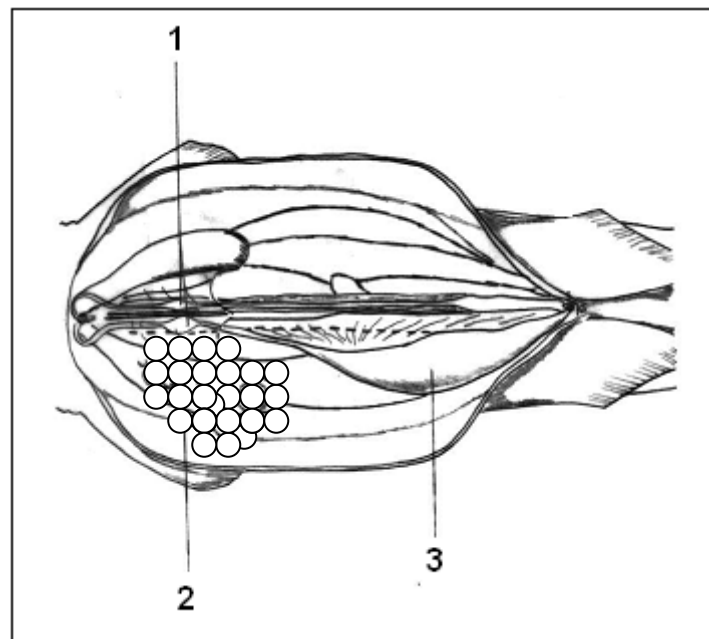


Figura 04. Desenho esquemático das estruturas coletadas do aparelho reprodutor feminino.
(1) Glândula Oviducal, (2) Ovário e (3) Útero.

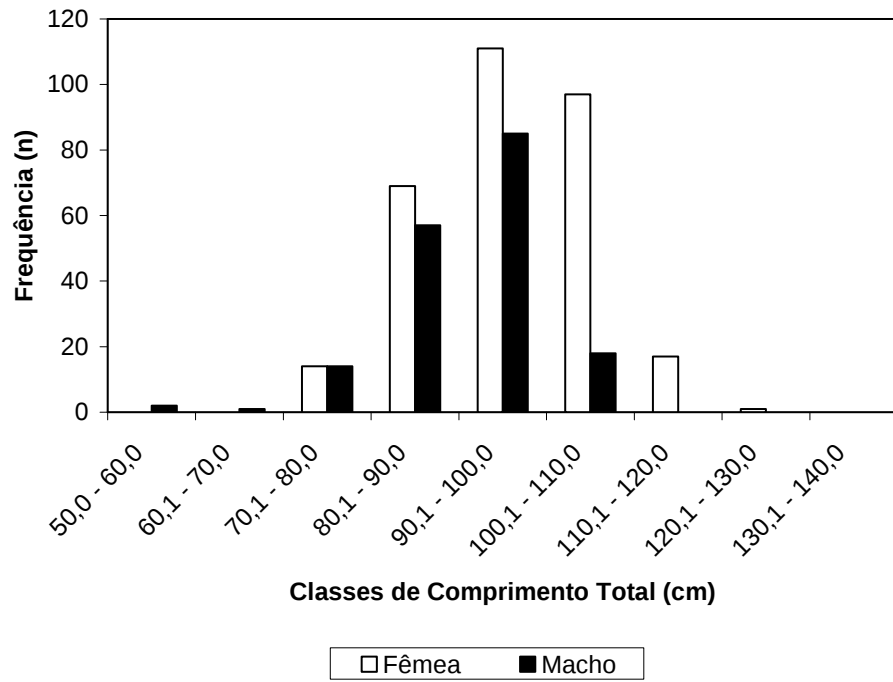


Figura 05. Distribuição de frequência de comprimento total dos machos e fêmeas de *P. kamoharai*, capturados no Atlântico Tropical.

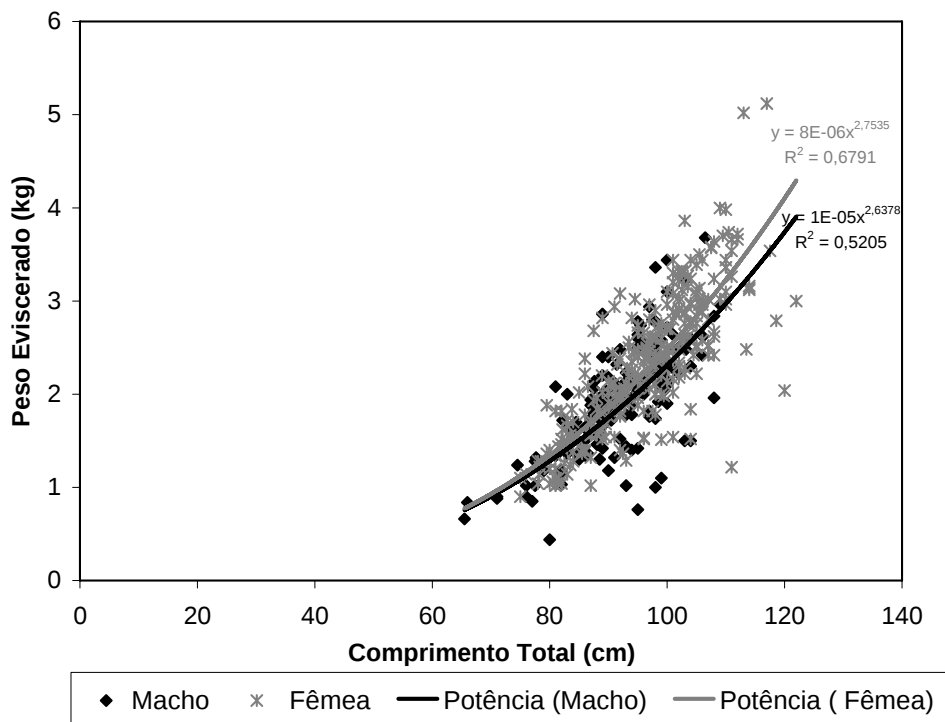


Figura 06. Relação entre o comprimento total e o peso eviscerado de machos e fêmeas de *P. kamoharai*, capturados no Atlântico Tropical.

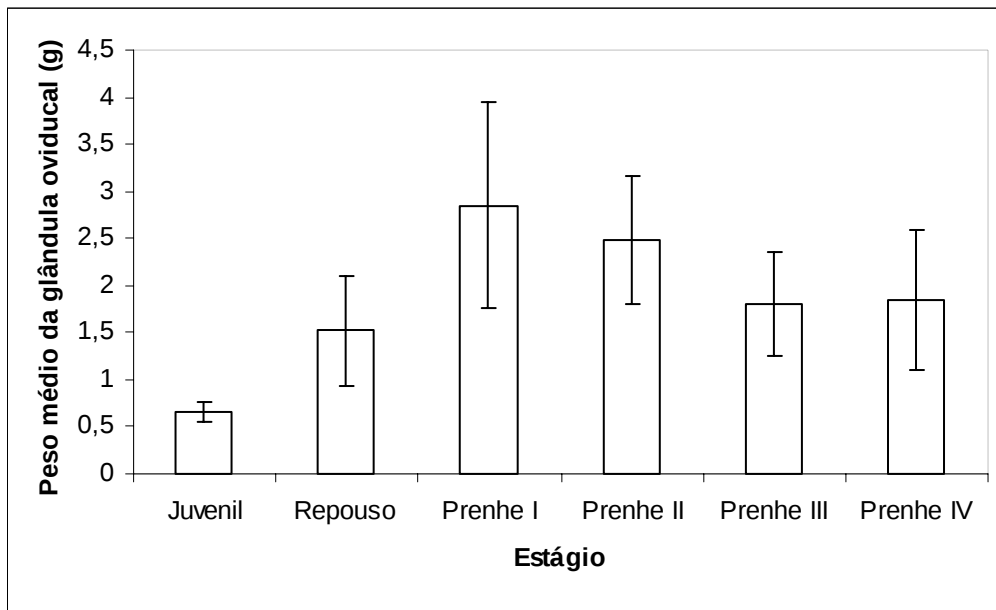


Figura 07. Relação entre o peso da glândula oviducal e os estágios maturacionais das fêmeas de *P. kamoharai*, capturados no Atlântico Tropical.

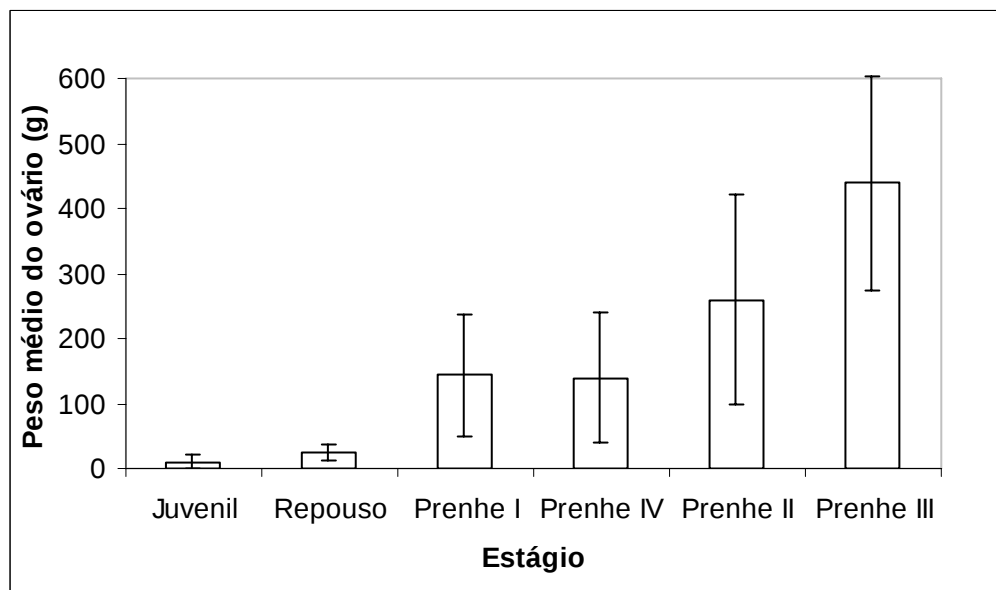


Figura 08. Relação entre o peso do ovário e os estágios maturacionais das fêmeas de *P. kamoharai*, capturados no Atlântico Tropical.

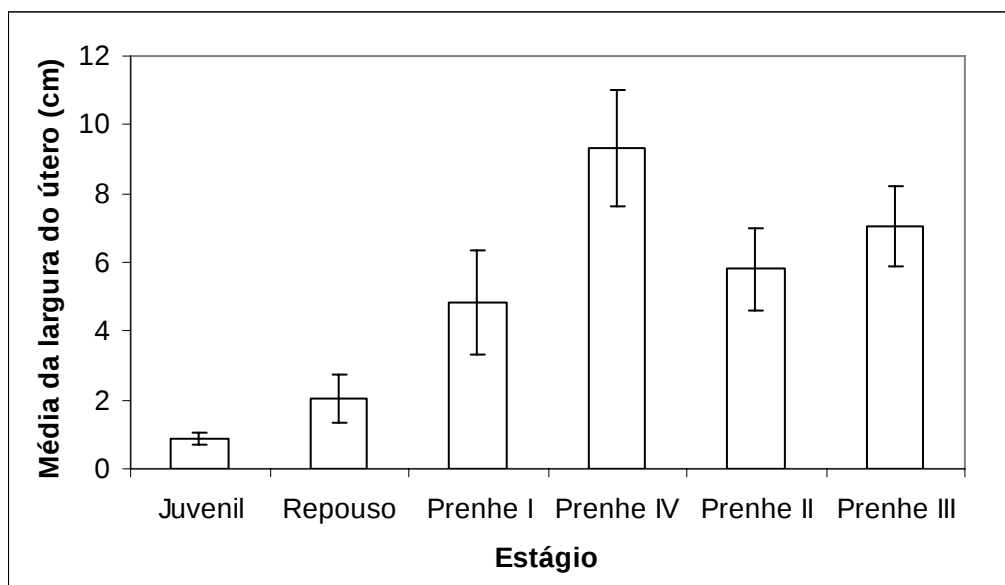


Figura 09. Relação entre a média da largura dos úteros e os estágios maturacionais das fêmeas de *P. kamoharai*, capturados no Atlântico Tropical.

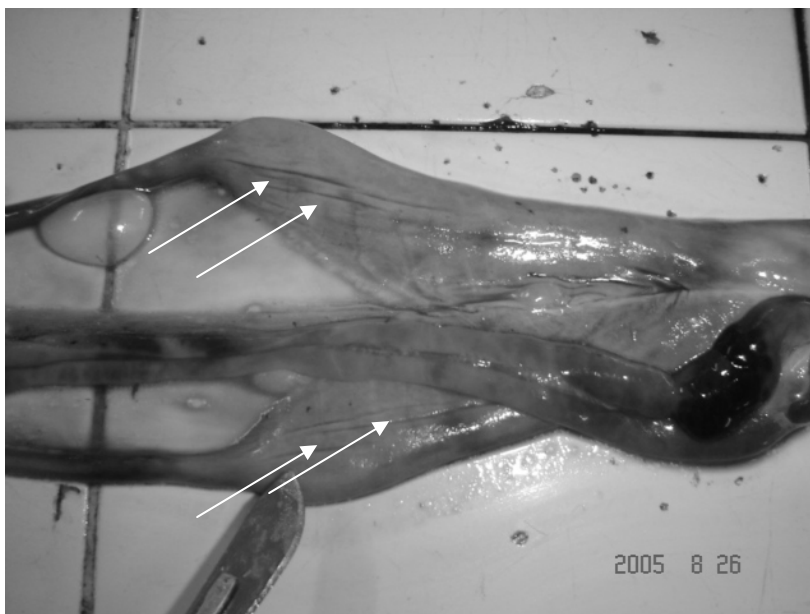


Figura 10. Pregas longitudinais no útero (setas) das fêmeas de *P. kamoharai*, capturadas no Atlântico Tropical. Evidência para as fêmeas pós-parto.

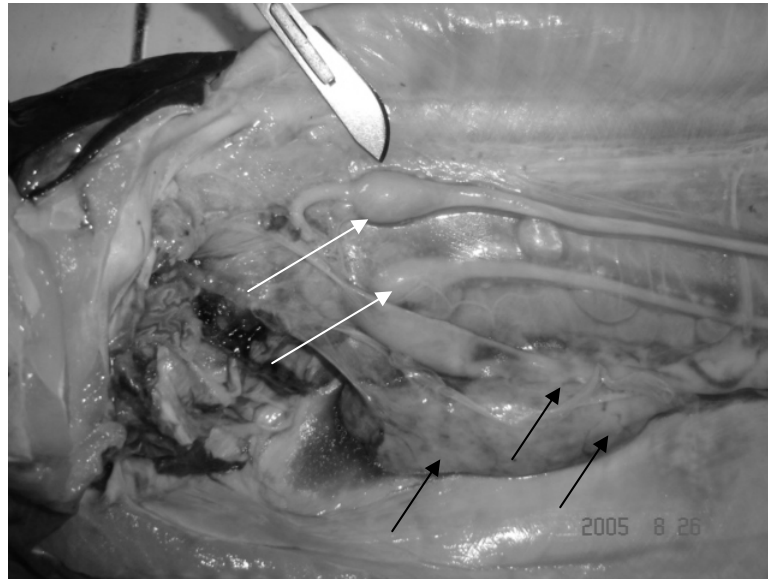


Figura 11. As glândulas oviduais delineadas (setas claras) e a presença de *corpora lútea* (setas escuras) das fêmeas *P. kamoharai*, capturadas no Atlântico Tropical. Representando cicatrizes de gestações passadas.

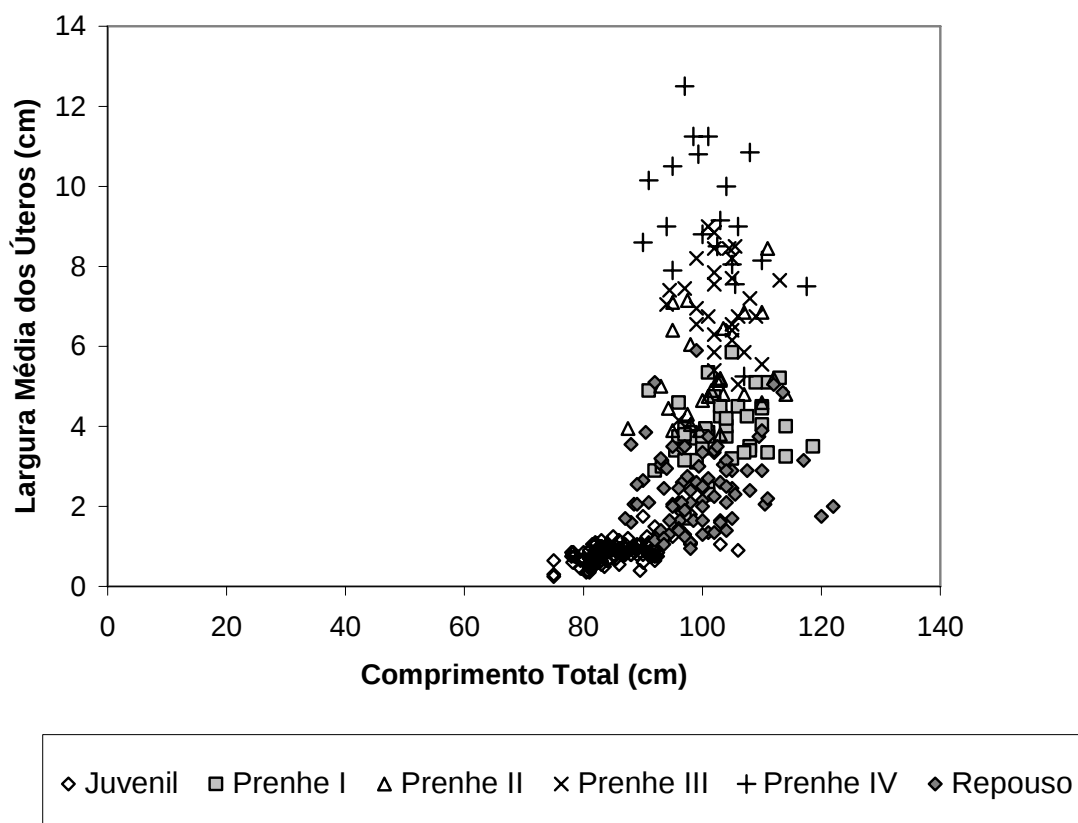


Figura 12. Relação entre a largura do útero e o comprimento total das fêmeas de *P. kamoharai*, capturados no Atlântico Tropical.

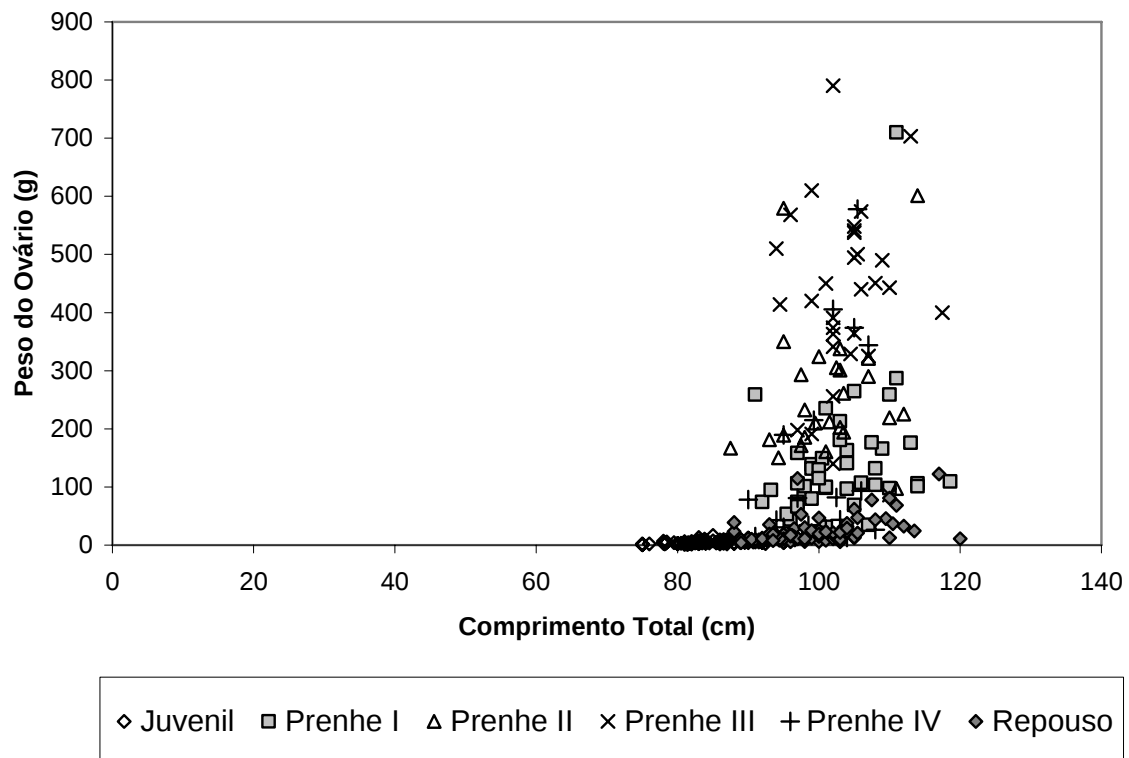


Figura 13. Relação entre o peso do ovário e o comprimento total das fêmeas de *P. kamoharai*, capturados no Atlântico Tropical.



Figura 14. Presença de ovos nos úteros (setas claras) e ovários com ovócitos amarelados (setas escuras) nas fêmeas de *P. kamoharai*, capturadas no Atlântico Tropical.

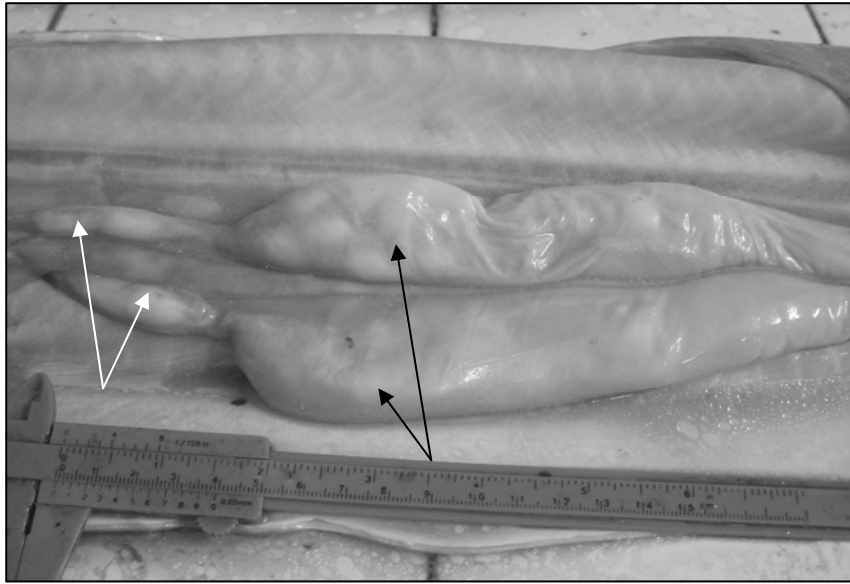


Figura 15. Presença de ovos nos ovidutos (setas claras) e úteros (setas escuras) das fêmeas de *P. kamoharai*, capturadas no Atlântico Tropical.

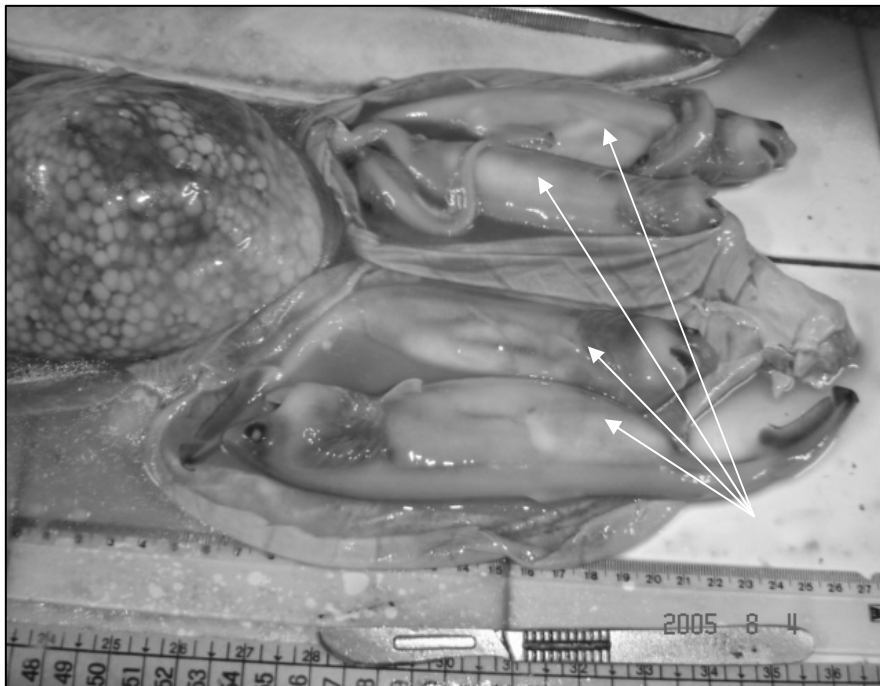


Figura 16. Embriões com estômago rico em vitelo (setas claras) das fêmeas de *P. kamoharai*, capturadas no Atlântico Tropical.

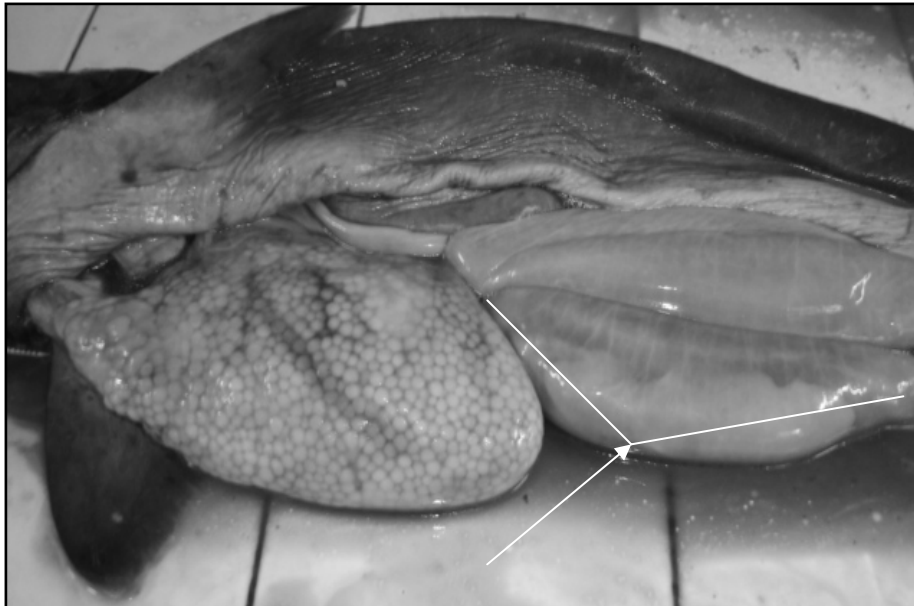


Figura 17. Ovario de uma fêmea prenhe a termo e úteros contendo embriões com CT próximo ao tamanho de nascimento de fêmeas de *P. kamoharai*, capturados no Atlântico Tropical.

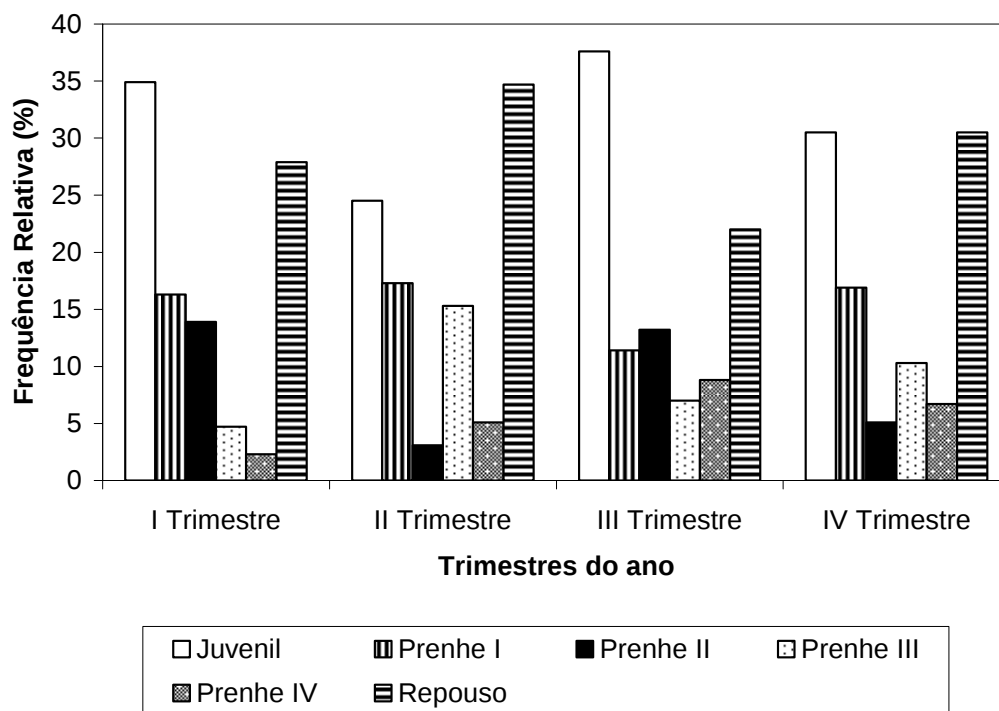


Figura 18. Distribuição trimestral de frequência dos estágios sexuais de fêmeas de *P. kamoharai*, capturados no Atlântico Tropical.

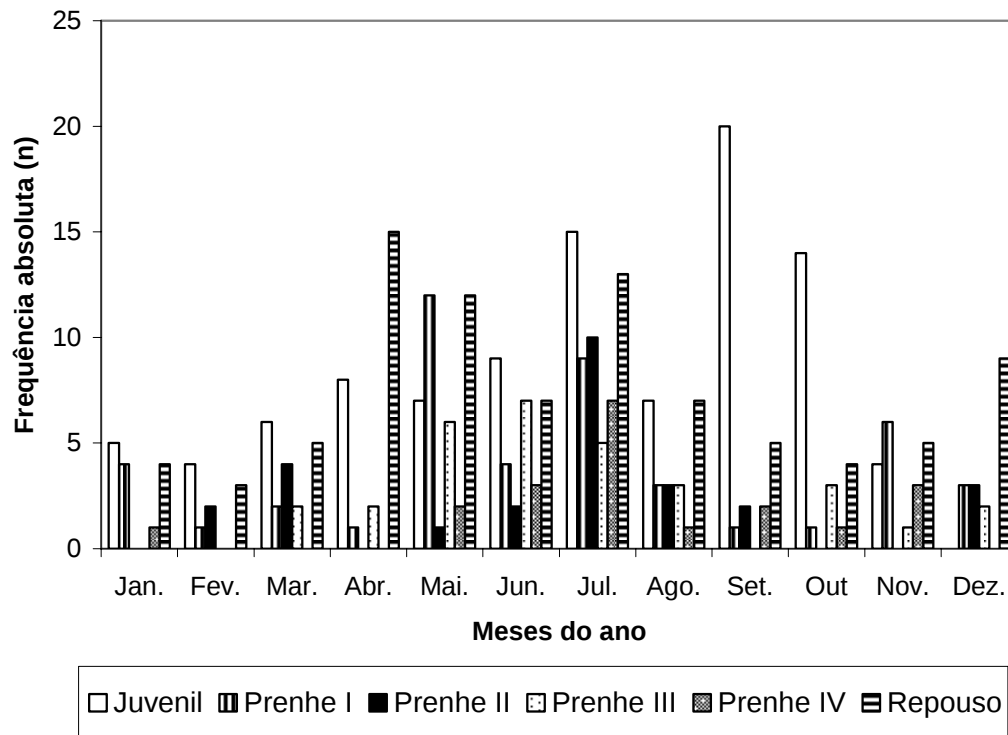


Figura 19. Distribuição mensal de frequência dos estágios sexuais de fêmeas de *P. kamoharai*, capturados no Atlântico Tropical.

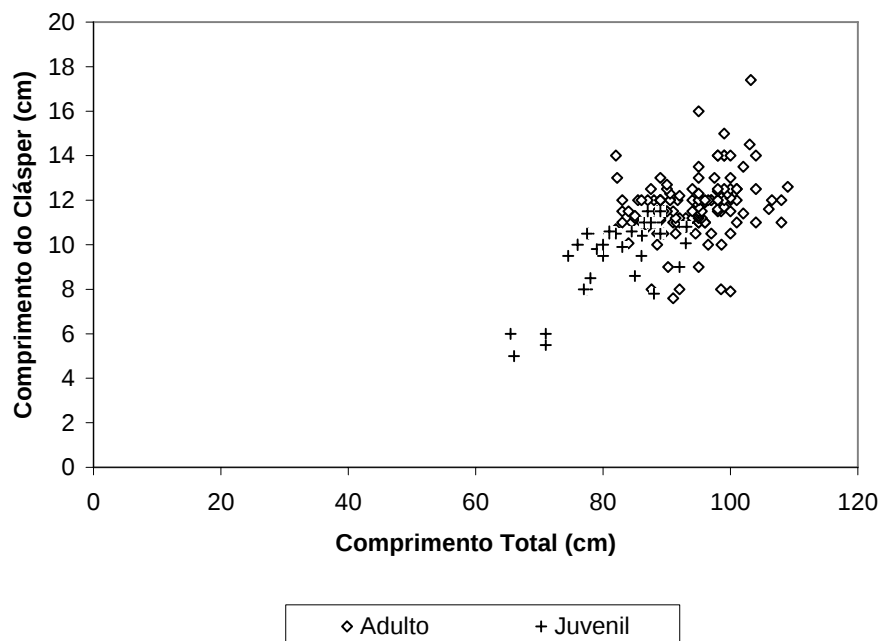


Figura 20. Relação entre o comprimento do cláster e o comprimento total dos machos de *P. kamoharai*, capturados no Atlântico Tropical.

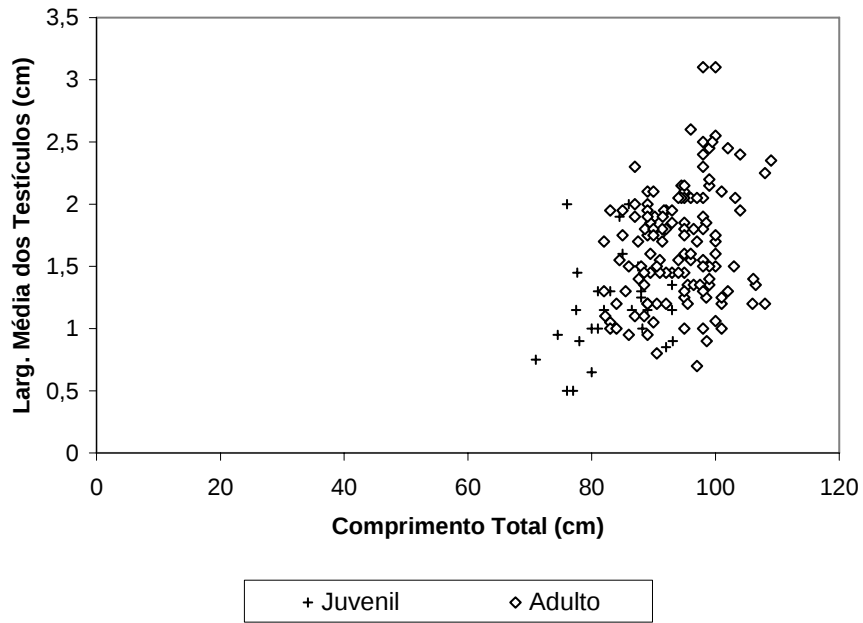


Figura 21. Relação entre a largura do testículo e o comprimento total dos machos de *P. kamoharai*, capturados no Atlântico Tropical.

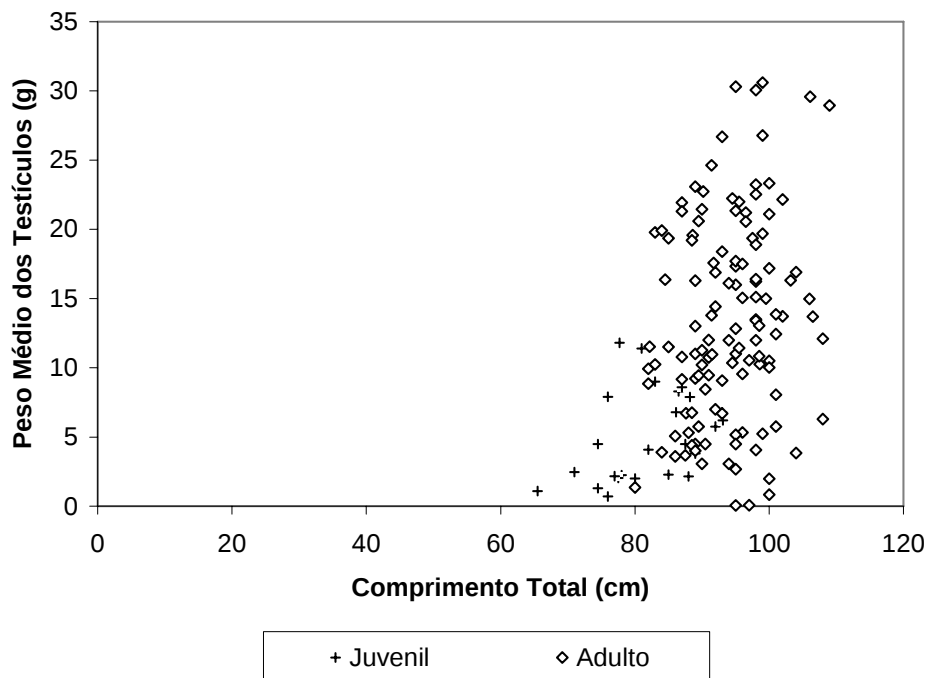


Figura 22. Relação entre o peso dos testículos e o comprimento total dos machos de *P. kamoharai*, capturados no Atlântico Tropical.

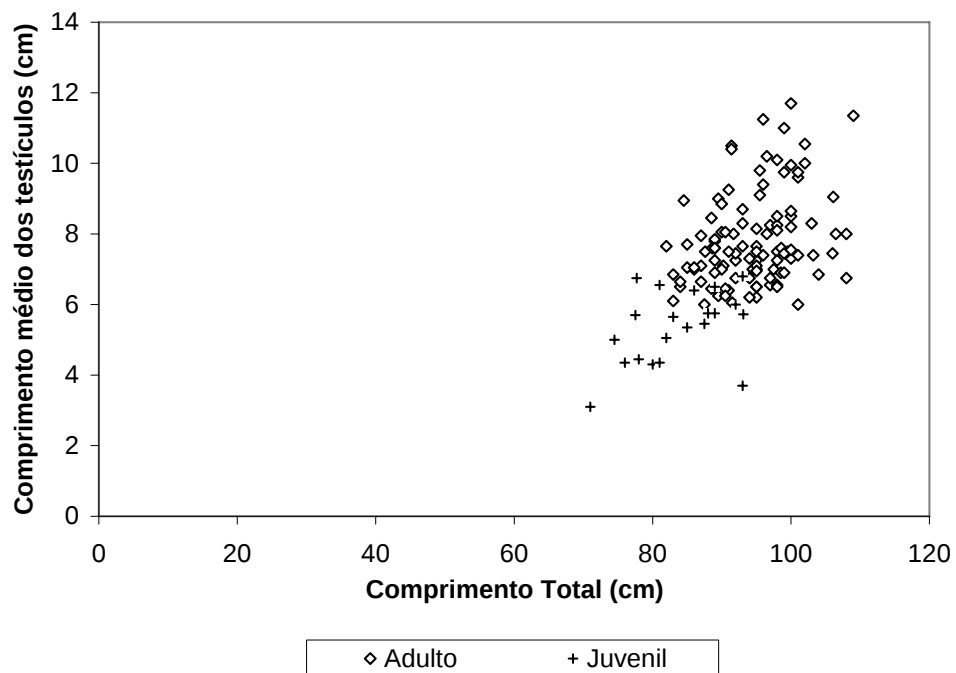


Figura 23. Relação entre o comprimento do testículo e o comprimento total dos machos de *P. kamoharai*, capturados no Atlântico Tropical.

Tabela 1 – Sexo e estágio de maturidade sexual, por mês, do tubarão cachorro capturado no Atlântico Sudeste Equatorial (ou seria Atlântico Tropical)

	Jan.	Fev.	Mar.	Abr.	Mai.	Jun.	Jul.	Ago.	Set.	Out.	Nov.	Dez.	Total
Juv (♂)	3		2	5	3	4	4	5	3	4	2	2	37
Adulto (♀)	10	7	23	20	10	11	25	15	7	5	5	2	140
Sub-total	13	7	25	25	13	15	29	20	10	9	7	4	177
Juvenil (♀)	5	4	6	8	7	9	15	7	20	14	4		99
Repouso (♀)	4	3	5	15	12	7	13	7	5	4	5	9	89
Prenhe I (♀)	4	1	2	1	12	4	8	3	1	1	6	3	46
PrenheII (♀)		2	4		1	2	10	3	2			3	27
Prenhe III (♀)			2	2	6	7	5	4		3	1	2	32
Prenhe IV (♀)	1				2	3	7	1	2	1	3		20
Sub-total	14	10	19	26	40	32	58	25	30	23	19	17	313
Total	27	17	44	51	53	47	87	45	40	32	26	21	490

Tabela 2 – Características gerais dos estágios maturacionais das fêmeas de tubarão cachorro, capturados no Atlântico tropical.

	CT (cm)	LU (cm)	PO (g)	LGO (cm)	PGO (g)
Juvenil	75,0 – 106,0	0,3 – 2,05	0,57 – 16,5	0,18 – 1,25	0,03 – 1,84
Repouso	87,0 – 122,0	0,9 – 5,9	4,0 – 122,3	0,45 – 3,75	0,45 – 6,22
Prenhe I	91,0 – 118,6	1,7 – 5,8	31,3 – 71,0	0,6 – 5,3	0,3 – 8,04
Prenhe II	87,5 – 114,0	3,8 – 8,4	97,1 – 601,0	1,15 – 327,0	1,02 – 4,35
Prenhe III	94,0 – 113,0	4,15 – 9,0	86,0 – 790,0	1,1 – 2,43	0,07 – 3,13
Prenhe IV (a termo)	90,0 – 110,0	5,25 – 12,5	12,7 – 578,0	0,8 – 1,84	0,9 – 2,7

Tabela 3 – Características gerais, por mês, das fêmeas prenhes de tubarão cachorro, capturados no Atlântico Tropical.

	Comprimento médio dos embriões (cm)	Peso médio dos ovários
Jan.	21,8	146
Fev.	4,1	165
Mar.	16,2	255
Abr.	25,5	265
Mai.	29,4	244
Jun.	20,7	258
Jul.	23,4	240
Ago.	15,6	218
Set.	21,8	277
Out.	27,8	471
Nov.	25,2	157
Dez.	17,2	250

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CAPÍTULO 2. OCCURRENCES OF WHALE SHARK (*Rhincodon typus* SMITH, 1828) IN THE SAINT PETER AND SAINT PAUL ARCHIPELAGO, BRAZIL

TITLE

OCCURRENCES OF WHALE SHARK (*Rhincodon typus* Smith, 1828) IN THE SAINT PETER AND SAINT PAUL ARCHIPELAGO, BRAZIL

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PALAVRAS-CHAVE: Tubarão-baleia, Arquipélago de São Pedro e São Paulo

TÍTULO ABREVIADO: Whale sharks in the Saint Peter and Saint Paul Archipelago

ABSTRACT

The Saint Peter and Saint Paul Archipelago in the central tropical Atlantic, is an important ground of whale sharks that are commonly sighted along the year close to the fishing boats in the adjacencies of the islands. In sightings reported between February 2000 and November 2005, the lengths of the individuals ranged between 1.8 to 14.0 m. The cause of these concentrations in the archipelago are still unclear, once there is no upwellings and plancton concentration for feeding, and no reproductive activities were reported. Nevertheless, it could be associated to the spawning period of the abundant flying fishes, mainly in the first semester, when sightings were more frequent.

RESUMO

Título: Ocorrências de Tubarão-Baleia (*Rhincodon typus* Smith, 1828) no Arquipélago de São Pedro e São Paulo, Brasil

O Arquipélago de São Pedro e São Paulo situado na área central tropical do Atlântico, é um importante local de concentração de tubarões-baleia, que são vistos ao longo de todo ano, próximos às embarcações de pesca nas adjacências das ilhas. Em avistagens registradas entre fevereiro de 2000 e novembro de 2005, os comprimentos dos indivíduos variaram entre 1,8 m e 14 m. As causas destas concentrações no arquipélago ainda não são claras, uma vez que não há ressurgências e grandes concentrações de plâncton no arquipélago, e também não foram observadas atividades reprodutivas. No entanto, podem estar associadas ao período de desova dos peixes-voadores, marcadamente no primeiro semestre, quando as aparições são mais frequentes.

INTRODUCTION

The whale shark, *Rhincondon typus* is the biggest fish of the world, inhabiting all tropical and subtropical oceans, with records in warm tropical waters, except in Mediterranean (Compagno, 1984; Colman, 1997). Although whale shark have a wide distribution, the knowledge of its biology and ecology is still limited (Jones & Kaly, 1995). In general, occurrences of whale sharks are sporadic and not expected, that can be associate with the limited knowledge on its ecology (Colman, 1997).

According Gudger (1922, 1923) cited by Soto (2001), the first record of a whale shark in Brazilian waters was in the coast of Bahia. Since then about 63 records of whale shark are known to Brazilian waters (Bertoncini & Sampaio, 2002), ranging from 1.8 m to 14 m (Edwards & Lubbock, 1982; Gaelzer, 1985; Gadig, 1991, 1994, 1997 e 2005; Soto, 1995; Alecrim-Santos *et al.*, 1988; Amorim & Ferreira, 2002, Campos *et al.*, 2005).

Due to the strategic position of the Saint Peter and Saint Paul Archipelago (SPSPA) between the two hemispheres, and between the Atlantic and African continents, the archipelago is an important concentration ground of migratory species such as tunas, billfishes, turtles, dolphins and the whale sharks. It is one of the smallest, most isolated group of oceanic islands in the world. The rocky islands are particularly interesting from the population biology and biogeographical perspectives because of their very small size and isolation. They are uniquely influenced by both the superficial Southern Equatorial Current flowing eastward, and the Equatorial Undercurrent flowing westward. The area has been visited by scientific expeditions since 1799 when the inhospitable nature and inaccessibility of the archipelago prevented detailed biological studies. However, since the establishment of a scientific research station by the Brazilian Navy, in July 1998, researchers have been able to visit the island periodically and continually.

Records of whale shark in the SPSPA were reported by Edwards & Lubbock (1982), Gadig (1994), and Rangel (1998). Since the beginning of the scientific researches in the SPSPA in 1998, whale shark has been frequently sighted around the islands.

The aim of this study is compile the existent data of sightings of the whale sharks recorded in the SPSPA, localize the sighting points, estimate the lengths of individuals, and observe the sightings frequency along the year.

MATERIAL AND METHODS

The Saint Peter and Saint Paul Archipelago is a very small group of rocky islands located on the mid-Atlantic Ridge, just north of the Equator (00°55'N; 29°21'W), 1,000 km from the Brazilian coast, and 1,890 km from Senegal, Africa (Fig. 1). Data were obtained between February 2000, and November 2005, as a result of a filing card, besides interviews and informations provided by fishermen and researches that utilize the scientific station. Total length was obtained by visual estimative, or using a metric cable when appropriate. A χ^2 test was used to compare sightings with moon phase.

RESULTS

In the present study, 54 observations of whale shark were made in the SPSPA (Table 1). Total length ranged from 1.8 m to 14 m, although precise lengths have been collected only in one occasion with a metric cable, in June 2001 (Fig. 2). The maximum length of 14 m at march 27th 2000 was estimated comparing the fish to the length of the fishing boat once the whale shark remained for 10 minutes by the side of the boat. Most sightings were made in the morning (25), and in the afternoon (16). In January 2004, four sharks were seen at night, one of them remained for 360 min beside the boat. Sightings times ranged between 1 minute to 360 min, with no correlation between moon phase (χ^2 ; $p < 0.001$). The sex determination of all

individuals was not possible due to most of the sightings were made from the fishing boats and, not from dive. In the SPSPA, the whale shark did not presented a clearly period of occurrence, but the sightings were more common mainly during the first semester (Fig. 3).

Twenty three sightings were reported at the buoy 1, eighteen at buoy 2 where fishing boats are commonly moored and ten was not described (Fig. 4). Buoys 1 and 2 are localized in the downstream side, and are protected from the wind. Only two sightings were recorded in the east side, and in one occasion very close to the rocks. Probably the sightings of June 18, 19, and 20th 2000, were of the same individual with 8 m TL. The same situation may have occurred with the sighting recorded in March 27 and 28th 2002, both for individuals with 5 m TL. Two whale sharks presented some remarkable characteristics, one shark (5 m TL) had the top of the caudal fin cutted, and another shark (8 m TL) did not presented the first dorsal fin, both were photographed.

DISCUSSION

The movements of the whale sharks can be related with productivity and invertebrate eggs deposition (Compagno 1984; Colman, 1997), commonly associated with turbulence around oceanic islands, as in the SPSPA. Gunn *et al.* (1992) pointed out the association between whale sharks and tunas in the Coral Sea, where the sharks concentrate for predation upon the lantern fishes during the reproduction period of these fishes. In the case of SPSPA, schools of yellowfin tuna (*Thunnus albacares*), concentrate around the islands, from October on, to feed upon the flying fish (*Cypselurus cyanopterus*), that reproduce in the area mainly between December and March (Lessa *et al.*, 1998; Lessa *et al.*, 1999; Vaske-Jr, *et al.*, 2003; Vaske Jr., *et al.*, 2005). Although no filter feeding activity have been reported during sightings, eggs and larvae of flying fish are the most abundant planktonic item in the adjacencies of the SPSPA, that could be the main food item for whale sharks in this period. The SPSPA do not

present upwellings or high primary productivity in the adjacencies (Travassos *et al.*, 1999) that could explain the concentrations of whale sharks as observed by Arnborn & Papastravrou (1988) in the Galapagos Islands. Thus, if the whale shark utilize the SPSPA for feeding, it is probable that the more frequent sightings in the first semester could be associated with the more abundance of eggs and larvae of the flying fish. No reproductive activities were reported or observed, so the whale shark could also utilize the archipelago as a resting point in their migratory routes in the Atlantic, that remain unknown.

The sighting time was variable, which means that sharks are not annoyed with the presence of the boats, on the contrary, maybe they are attracted by the boats.

Future studies are necessary to the knowledge if the whale shark in the SPSPA, including telemetry as used by Eckert & Stewart (2001), to elucidate the migratory routes, and observe if the individuals of the SPSPA come from another points of the oceans, or if they are part of a resident population.

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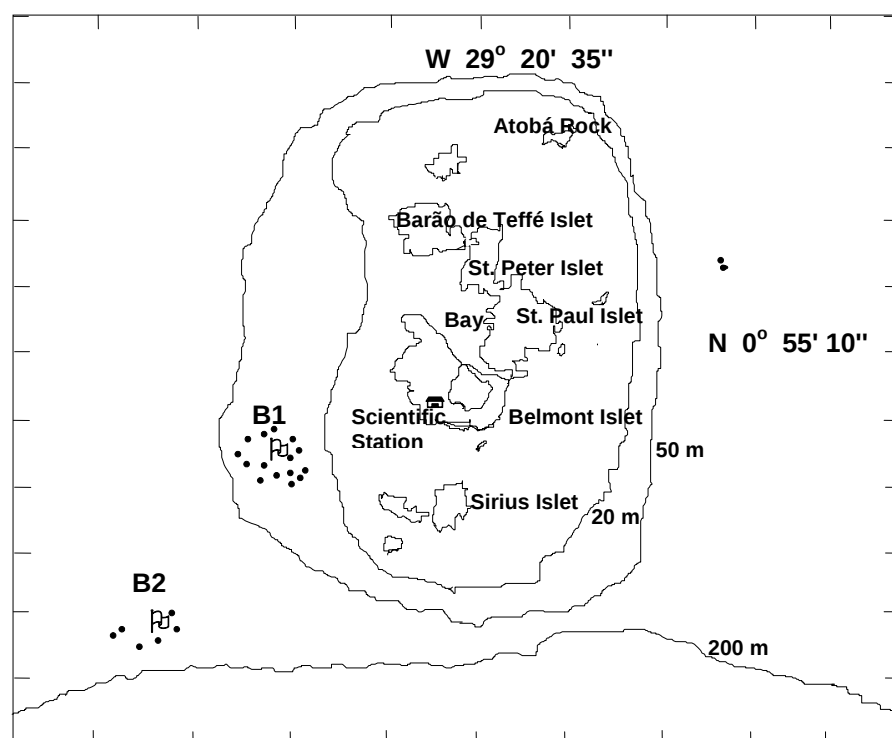


Figure 1 – Saint Peter and Saint Paul Archipelago in the central Atlantic with isobaths. B1 – buoy 1; B2 – buoy 2.

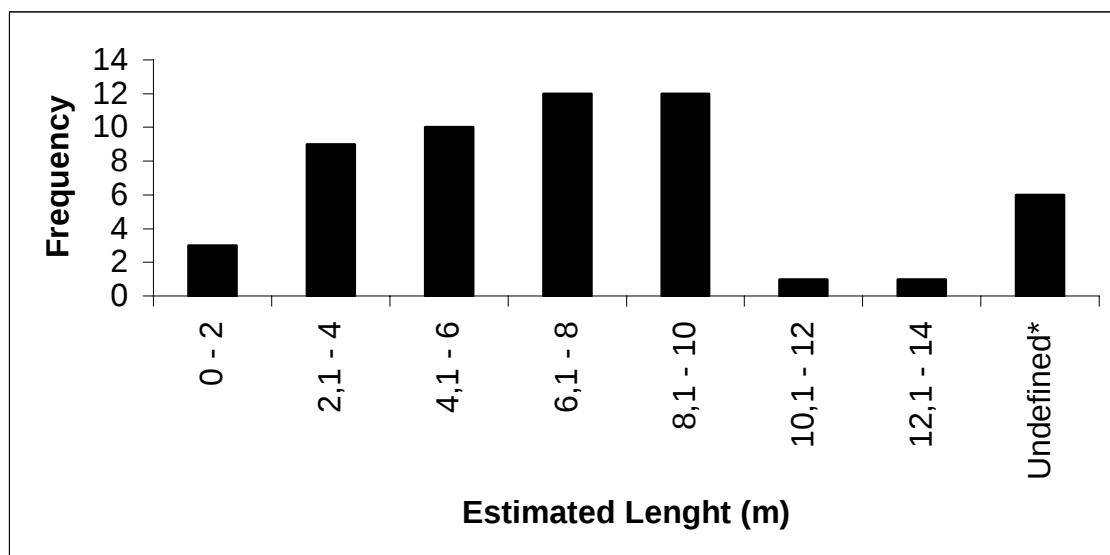


Figure 2 - Length distribution of whale sharks sighted in the Saint Peter and Saint Paul Archipelago between February 2000 and November 2005.

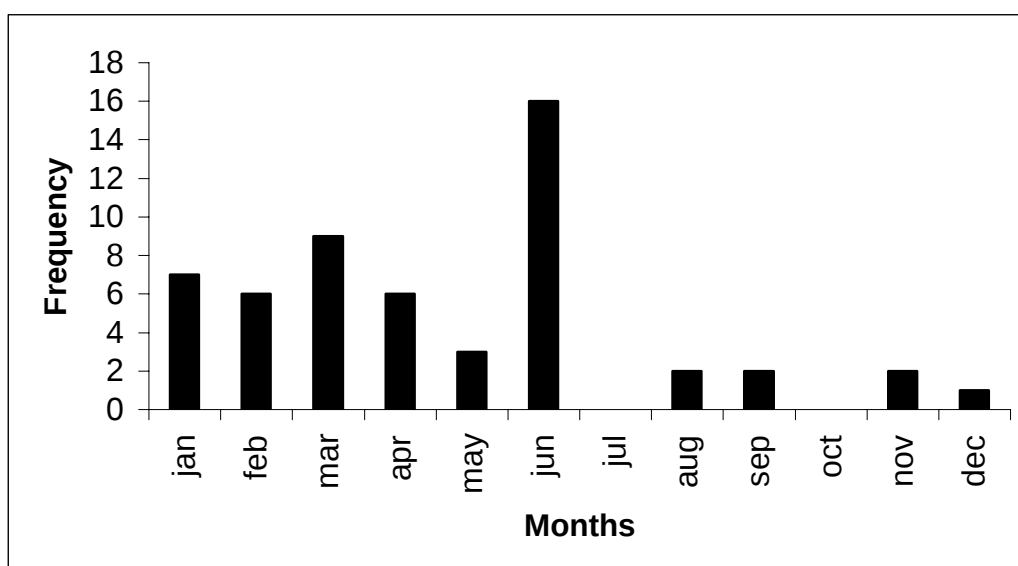


Figure 3 - Monthly frequencies of sightings of whale shark in the Saint Peter and Saint Paul Archipelago.

Table 1 - Whale shark occurrences in Saint Peter and Saint Paul Archipelago.

N	Date	Est. Length (m)	Sex	Day hour	Sight. time (min)	Moon
1	fev/00	9	-	morning	10	-
2	11/03/2000	6	-	-	-	first quarter
3	19/03/2000	10	-	8 a.m.	45	full
4	27/03/2000	14	-	6 p.m.	10	last quarter
5	aug/2000	-	-	-	-	-
6	04/03/2001	8	-	afternoon	15	first quarter
7	24/03/2001	5	-	1 p.m.	15	new
8	april/2001	8	-	-	-	-
9	18/04/2001	-	-	12 a.m.	-	last quarter
10	12/06/2001	7,8	F	10 to 11 a.m.	60	last quarter
11	12/06/2001	12	M	10 to 11 a.m.	60	last quarter
12	aug/2001	-	-	-	-	-
13	20/09/2001	3	-	7 a.m.	20	new
14	mar/02	-	-	-	-	-
15	27/03/2002	5	-	12 a.m.	15	full
16	28/03/2002	5	-	7 a.m.	5	full
17	01/06/2002	10	-	morning	2	last quarter
18	02/06/2002	10	-	-	-	last quarter
19	02/06/2002	3	-	-	-	last quarter
20	18/06/2002	8	-	3 p.m.	30	first quarter
21	19/06/2002	8	-	6 a.m.	15	first quarter
22	20/06/2002	8	-	1 p.m.	15	first quarter
23	23/12/2002	-	-	morning	-	full-first quarter

24	25/01/2003	6	-	afternoon	30	last quarter
25	09/02/2003	6	-	morning	40	first quarter
26	13/02/2003	10	-	morning	20	full
27	23/02/2003	2	-	afternoon	40	last quarter
28	19/01/2004	8	-	2 a.m.	1	new
29	21/01/2004	4	-	20h42min	1	new
30	22/01/2004	1,8	-	8 p.m.	2	new
31	24/01/2004	10	-	22h35min	8	new
32	25/01/2004	7	-	5 p.m.	10	new
33	29/01/2004	7	-	23hs to 05hs	360	first quarter
34	31/03/2004	8	-	5 p.m.	0,40	first quarter
35	04/04/2004	9	-	6 p.m.	2	full
36	02/06/2004	4	-	6 p.m.	15	full
37	03/06/2004	4	-	6 a.m.	10	full
38	04/06/2004	4	-	5 p.m.	15	full
39	05/06/2004	4	-	6 a.m.	1	full
40	06/06/2004	4	-	9:30a.m.	15	full-first quarter
41	19/02/2005	2	-	14h35min	-	first quarter
42	19/02/2005	6	-	14h35min	38	first quarter
43	12/04/2005	6	-	7h43min	-	first quarter
44	18/04/2005	9	-	9h30min	-	first quarter
45	25/04/2005	7	-	11h10min	20	full
46	06/05/2005	7	-	11h20min	40	new
47	11/05/2005	10	-	11 a.m.	60	new
48	11/05/2005	-	-	11 a.m.	-	new

49	03/06/2005	10	-	11h30min	-	new
50	06/06/2005	3	-	10h20min	-	new
51	06/06/2005	10	-	10h20min	-	new
52	21/09/2005	8	-	6h30min	5	full
53	25/11/2005	5	M	11h25min	1	last quarter
54	27/11/2005	5	M	05h45min	4	last quarter-new

CAPÍTULO 3. POPULATION STRUCTURE AND HABITAT UTILIZATION OF THE SOUTHERN STINGRAY, *Dasyatis americana* (HILDEBRAND & SCHROEDER, 1928), AT THE ATOL DAS ROCAS BIOLOGICAL RESERVE, BRAZIL.

POPULATION STRUCTURE AND HABITAT UTILIZATION OF THE SOUTHERN STINGRAY, *Dasyatis americana* (HILDEBRAND & SCHROEDER, 1928), AT THE ATOL DAS ROCAS BIOLOGICAL RESERVE, BRAZIL.

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Andrew Piercy³ & George Burgess³**

Abstract.

Specimens (N=184) of *Dasyatis americana* were sighted during underwater observations at the Atol das Rocas Biological Reserve in northeastern Brazil. These rays ranged in size from 29–113 cm in disk width (DW). *D. americana* in the 80-89 cm size class were in greatest abundance (25 %). The relative frequency was higher for females than males and a sex ratio of 5.7:1 was observed. Population size was estimated to be 99.2 ± 17.1 individuals obtained through the Petersen-Bayley likelihood estimator and 94.4 ± 10.3 individuals through the Jolly-Seber estimator. Among the environments sampled, the central lagoon was the only site in which the mean occurrence per unit of effort (OPUE) was significantly greater at high tide. All other sample areas showed significantly higher number of *D. americana* individuals at low tide than at high tide. Ray activity level was correlated with tide, with activity levels higher at high tide. These data also demonstrates a significant difference in the distribution of the DWs of female individuals in relation to the depths of the sampling sites. Females with DWs of over 80 cm were found in depths greater than 1.51 m, whereas individuals with DWs of up to 62 cm were observed in depths that did not surpass 1.5 m. Individuals of undetermined sex were associated to shallower environments with depths not surpassing 0.5 m. Adult males preferred environments with depths ranging from 3.51 to 4.5 m

Key words: Southern stingray, population size, behavior, *Dasyatis Americana*.

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1. Introduction

Elasmobranch (sharks, skates, and rays) are generally characterized by low fecundity, late maturity and slow growth, and are highly vulnerable to exploitation (Hoening & Gruber, 1990). The group of stingrays has been undergoing a decline in its populations, as has been reported by some authors in different parts of the world as Falkland Islands (Agnew, 1999), Southwestern of Atlantic Ocean (Guerrero & Piola 1997) and Caribbean sea (Pequeno & Lamilla, 1993). Thus, studies about population structure, habitat use and life-history are important and should be encouraged.

Feeding habits, reproductive biology, movement patterns and population structures are known for some species of the genus *Dasyatis*, such as *D. chrysonata* (Hess, 1961), *D. centroura* (Struhsaker, 1969; Capape, 1993), *D. lata* (Cartamil *et al.*, 2003), *D. longus* (Garayazar *et al.*, 1994), *D. pastinaca* (Ismen, 2002), *D. sabina* (Piercy *et al.*, 2006, Kajiura *et al.*, 2000, Snelson & Johnson, 1996, Snelson *et al.*, 1988), *D. guttata* (Carqueija *et al.*, 1995; Thorson, 1983; Silva *et al.*, 2001) and *D. sayi*, (Snelson *et al.*, 1989).

The southern stingray, *Dasyatis americana*, is a common species to tropical and subtropical waters of the West Atlantic, and is distributed from New Jersey (USA) to Rio de Janeiro (Brazil) (Bigelow & Schroeder, 1953). Menni & Stehmann (2000) reported that this species occurs along practically the entire Brazilian coast. *D. americana* is also frequently observed in the Fernando de Noronha Archipelago and at the Atol das Rocas Biological Reserve.

Despite previous studies on the reproductive behavior (Broockmann, 1975; Henningsen, 2000; Chapman *et al.*, 2003), interactions with other species (Snelson *et al.*, 1990), distribution (Menni & Stehmann, 2000) and basic biology (Bigelow & Schroeder, 1953) of *D. Americana*, gaps in knowledge still remain for other aspects of the ecology of this species. In Brazil, for example, little is known of the population structure and behavior of

these marine animals. Thus, the aim of the present study was to contribute to the knowledge of population parameters of *D. americana* at the Atol das Rocas Biological Reserve, including habitat use.

1.1 Study area

Atol das Rocas is an unique atoll in the South Atlantic Ocean and was the first marine reserve in Brazil (created in June 1979). Since that time, fishery and tourism activities have been prohibited in the reserve. Atol das Rocas is located 144 nautical miles from the city of Natal – RN on the northeast coast of Brazil (Oliveira-Filho & Ugadim, 1979). It has an internal area of 7.2 km² (Kikuchi & Leão, 1997). Two islands, Farol island and Cemiterio island, become connected at low tide, and a large number of tidal pools are formed around them. Some of these pools are isolated on the reef top (inner pools), while others (outer pools) have connections with the open sea (Rosa and Moura, 1997). At high tide, the atoll waters are renewed and a central lagoon is formed, with depths ranging from 0.3 to 4.5 m. (Fig. 1).

2. Material and Methods

2.1 Data collection

From August 2003 to December 2005, 12 surveys, with mean of 18 days each, were carried out on the Atol das Rocas Biological Reserve. The surveys dates were 08/03 and 10/01 2003, 01/04, 02/01, 04/02, 06/05, 09/04 and 11/03 2004 and 03/04, 05/01, 07/05 and 12/04 2005. We conducted visual censuses in the different environments that make up the Atol das Rocas to study the population structure and use of habitat by *D. americana*. Censuses were standardized by sampling the same places with the same number of snorkeling dives and same observation time for each one. Divers performed intensive searches at a constant speed along a pre-defined route at each local, recording the individuals sighted. Sites were sampled at both low and high tide during the day time in a total of 1.092 snorkeling dives (946 hours and 40 minutes). Sampling of the external portions of the atoll and the outer pools could not be

carried out due to a lack of autonomous diving equipment that would allow divers to reach greater depths. Collection sites were grouped into two main environments: a) Inner pools: six temporary pools of different sizes that become isolated from other areas of the atoll at low tide. b) Central lagoon: permanent lagoon in the central portion of the atoll.

The following aspects were recorded: duration of each dive; depth of the site, number of rays observed, sex, behavior (swimming, feeding and resting) and disk width (DW). Disk width was either visually estimated for moving rays or both estimated and measured to a precision of one cm with a tape measure. We evaluated the presence of natural marks and scars commonly found on the pectoral and pelvic fin, as well as other parts of the body (Carrier *et al.* 1994; Klimley & Anderson, 1996). These marks were then drawn, photographed and recorded, together with other data, on underwater PVC notebooks with respect to type and position of the mark. We photographed every ray observed in the field (Samsung V8 digital camera with underwater box proof). Photographs, including the entire body, were analyzed in the laboratory to detect additional distinctive marks not observed in the field. These marks were also drawn on paper and catalogued. Analysis of such marks was used for the individual identification of the rays and to determine if a re-sighted animal was photographed during different sampling events.

Occurrence per unit of effort (OPUE) was used as the relative abundance index in terms of the number of individuals sighted per diving time. All dives were performed during the slack tides. Dive duration at each sampling site was approximately consistent throughout the sampling period. Thus, there was no need for standardization of the occurrence per unit of effort (OPUE).

2.2 Estimating the population size (N)

To estimate population size of *D. americana*, we employed probabilistic estimators commonly used in capture-recapture studies of tagged animals. Essentially, estimation size is

based on the probability that an animal caught on an initial survey will be recaptured on a second survey. In the present study, the population size of *D. americana* at Atol das Rocas was estimated from the analysis of the re-sighting of rays in the different surveys.

Rays were considered “captured” if they were observed and photographed, and had any distinctive mark. "Recapture" was based on the re-sighting of previously photographed and/or individualized rays. Thus, we considered n_1 as the number of individualized animals among those sighted in the first survey (t_1), n_2 as the number of rays in the second survey (t_2) and m_2 the number of re-sightings in the second survey (t_2). Individuals without distinctive marks were not used in the estimations.

We assumed that the probability of finding animals with some distinct mark did not vary among the surveys because the sampling effort was uniform and all rays were photographed. Two estimators were used to determine the population size (N). The first, was proposed by Bailey (1951) as a modification of the Petersen estimator, the estimator is given by:

$$N = \frac{n_1 \cdot (n_2 + 1)}{(m_2 + 1)}$$

The standard error of this estimate is given by:

$$SE = \sqrt{\frac{n_1^2 \cdot (n_2 + 1) \cdot (n_2 - m_2)}{(m_2 + 1)^2 \cdot (m_2 + 2)}}$$

Distinct PB estimates for the *D. americana* population size were obtained from the March-May and May-July 2005 data. The choice of these months if gave for the fact that to te adequate use of PB probabilistic estimator is necessary a minimum of three sucessives events with the same interval between them. The short interval of one month between samplings also reduces the chances of variations in the number of individuals of the population through birth and death, with no alterations to the composition of the population structure as a whole. It

should be mentioned that the population size estimate refers to part of the population, which may or may not be the entire population. In the present study, no newborn individuals were observed. Thus, values obtained in the estimates did not consider this age class or, consequently, the recruitment of young individuals. The total population size (N) was calculated as the average of the two estimates (as in Cliff, 1996) thus:

$$\overline{N} = \frac{\sum NI}{(S-1)}$$

Where S is the number of samples.

When using the Petersen estimator, a number of assumptions must be obeyed in order to validate the estimates, including the following: a) the population studied has to be closed, that is, its size must remain unaltered throughout the period of investigation; b) all animals have the same probability of being caught in the first sampling; c) the marks do not affect the catchability of the animals; d) the second sampling is random; and f) all marks recovered in the second sampling are recorded (Abuabara & Petrere Jr. 1997)

The second estimator Jolly-Seber estimator (Seber, 1982) was used as a complement. The Jolly-Seber estimator was proposed for open populations (accounting for mortality, births, immigration and emigration) and is well known as an improved estimator that uses the same basic reasoning as Petersen's (Fernandez, 1995). The calculation of population size is not estimated between two sampling events, as in Petersen-Bayley, but through the entire sequence of sampling events. Based on the data obtained from the whole sampling, a single N value and its standard error can be obtained, rendering the calculation of the averages between estimates unnecessary. Thus: n_i = total number of animals "captured" in sample i ; m_i = number of marked animal "captured" in sample i ; R_i = number of animals that are released after the i th sample; r_i = number of n_i animals released at sample time i that are re-sighting at

one or more future sample times; Z_i = number of individuals marked before sample i , not caught in sample i , but caught in some sample after sample i .

The first step in using the Jolly-Seber estimator is to calculate M_i , that is, the estimate size of the “captured” population before the sample i . Thus, M_i is given by:

$$M_i = m_i + \frac{R_i + Z_i}{r_i}$$

Population size (N_i) is given by:

$$N_i = \frac{n_i \cdot M_i}{m_i}$$

The standard error of this estimate is given by:

$$SE.N_i = \sqrt{N_i(N_i - M_i) \left\{ \frac{M_i - m_i + r_i}{M_i} \left[\frac{1}{Z_i} - \frac{1}{r_i} \right] + \frac{1}{m_i} + \frac{1}{n_i} \right\}}$$

This method also presupposes assumptions such as random sampling; all individuals have the same probability of being caught; every marked individual has the same probability of survival; individuals do not lose their marks during the sampling period; and marks are not overlooked in the capture (Krebs, 1999).

3. Results

3.1 Population Structure

A low proportion of the sighted *D. americana* could not be sexed (7 individuals, 3.8 %). This occurred due to the fact that claspers (intromittent male sex organs) could only be visually detected on individuals with a DW larger than 45 cm in our conditions. Therefore, only individuals this size or larger were identified with regard to gender. Sexed rays included 161 females (87.5 %) and 16 males (8.7 %). The greatest abundance on each excursion, as well as for the overall sampling period, was of individuals in the 80 – 89 cm size class (Fig. 2). The Chi-square (χ^2) test revealed that the sex ratio found on all expeditions and throughout the overall sampling period were significantly different from 1:1, favoring females (Table 1).

3.2 Population Size.

Among the 184 rays sighted throughout the study period, 157 (85.3%) presented some distinguishing mark, which was recorded photographically and sketched (Figure 3). Based on the Petersen (PB) estimate, estimated population sizes between the first and second events (March-May) and the second and third (May-July) were 101.4 ± 21.2 and 97.2 ± 18.3 , respectively. Using these data, the average population size was calculated as 99.2 ± 17.1 , meaning the estimated population of *D. americana* ranged from 82.1 to 116.3 individuals (Table 2). The Jolly-Seber estimate of the population size was 94.4 ± 10.3 individuals thus, the population ranged from 84.1 to 104.7.

3.3 Use of Habitat

Among the environments sampled, the central lagoon was the only site in which the mean occurrence per unit of effort (OPUE) was significantly greater at high tide (Kruskal-Wallis, $P = 0.019$) (Fig. 4). All pools sampled presented a significantly higher number of *D. americana* individuals at low tide than at high tide (Kruskal-Wallis, $P = 0.023$) (Fig. 5). The majority of individuals sighted in the pools at low tide were not sighted in the immediately following high tide. However, in the same pools during the subsequent low tide, sightings of the same individuals as the previous low tide were common, often occupying the same spots in these pools. Rays were found at rest at low tide (Kruskal-Wallis, $P = 0.013$) (Fig. 6), whereas most rays were found swimming or feeding at high tide (Kruskal-Wallis, $P = 0.011$) (Fig. 7). The analysis of these data demonstrates a significant difference in the size distribution of the female individuals in relation to the depths of the sampling sites. Females with DWs of over 80 cm were found in depths greater than 1.51 m, whereas individuals with DWs of up to 62 cm were observed in depths that did not surpass 1.5 m (Kruskal-Wallis, $P = 0.021$). Individuals of undetermined sex ($DW \leq 45$ cm) were associated to shallower environments with depths not surpassing 0.5 m. Adult males preferred environments with

depths ranging from 3.51 to 4.5 m (Fig 8). It is difficult to determine the use of habitat for juvenile males (sizes 46 to 50 cm), as there were just one individual from this age class observed throughout the sampling.

4. Discussion

4. 1 Population Structure

Multiple size classes of rays were observed throughout the study. According to Bigelow & Schroeder (1953), *D. americana* are born at an average disk width of 20 cm, and females and males mature to disk widths of 75 - 80 cm and 51 cm, respectively. In the present work the difficulty in determining the gender of young individuals is attributed to the fact that many bathyal species exhibit an abrupt transition in the clasper/disk width ratio (with a larger growth rate of the clasper) upon nearing maturity size (Struhsaker, 1969; Thorson, 1983; and Snelson *et al.*, 1988). Therefore, young males exhibit small claspers that are undetectable through our casual visual sampling, whereas adult individuals with a larger clasper/disk width ratio are easier to identify with regard to gender.

The greater proportion of females in the sightings is in agreement with the observations of Snelson *et al.* (1989) for *D. sayi* and Struhsaker (1969) for *D. centroura*, caught off Florida and southern Georgia (USA). The latter author, however, did not detect a significant difference in the sex ratio of the species off South Carolina and other parts of Georgia (USA). A 1:1 sexual ratio was found for other species of rays, including other dasyatidae (Snelson *et al.* 1988), as well as for embryos of *D. sayi* (Snelson *et al.*, 1989) and *D. sabina* (Snelson *et al.*, 1996). According to data obtained in captivity, Henningsen (2000) reported a sex ratio for *D. americana* newborns that was not significantly different from 1:1. However, as observed in the present study, this sex ratio may not remain constant in the adult population, as was observed also for *D. sayi* (Snelson *et al.*, 1989). This could result from either gender

segregation by habitat or a greater mortality rate among males throughout ontogenetic development (Snelson *et al.*, 1989).

Spatial segregation is a common event among elasmobranches (Thorson, 1983; Snelson *et al.*, 1989; Hoening & Gruber, 1990). Therefore, the sex ratio found for *D.americana* may be a result of environments that are predominantly occupied by female individuals, though it was not possible to sample all parts of the Atol das Rocas and inability to discern young males. However, it may also be a seasonal event. At specific times, such as reproductive periods, there is a normal tendency toward the grouping of individuals from both genders, resulting in a more balanced sexual proportion. This is maybe related to a reproductive strategy, since elasmobranches exhibit internal fertilization (Carrier *et al*, 1994).

One mating event observation was made on 18 September 2004 in approximately 4m of water on the central lagoon. Three rays, one adult female and two adults males, were initially seen swimming side by side. Some minutes later one of the males grasped the right side of the females pectoral disc in his mouth and attempted to copulate. The sequence of this mating event could not be seen by the fact that the divers decided not to cause any interference in the event so stopped following the rays. However, the sexual ratio remained significantly different from 1:1 throughout all the sampling months. Therefore, other seasonal samplings are needed throughout the environments that make up the Atol das Rocas to determine whether the sexual ratio encountered is due to spatial and/or temporal sexual segregation.

4. 2 Population size

The data obtained in the present study indicate a relatively high number of rays sighted when compared to results from other studies on rays in different locations using catches for population sampling, often over much longer sampling periods. The number of rays with natural distinguishing marks (87.5 %) was rather high when compared to results obtained by

Pratt & Carrier (2001) for studies on nurse sharks (*Ginglymostoma cirratum*), who found just 10% of animals with such marks.

The first step in analyzing the results of a population size estimate is to assess the adequacy of the estimator employed. With the Petersen estimator and its modifications, a number of presuppositions must be followed in order to validate the estimates, one of which is considered crucial: the number of individuals of the population must remain unaltered throughout the study period. Therefore, particular attention was given to the experimental design for the use of this estimator; the experiment was carried out within a short period of time (3 months), thereby reducing the variations in the number of individuals in the population studied, mainly due to the migrations that are common to natural populations. The southern stingray is a species known for its low migration capacity (Bigelow & Schroeder, 1953). The population at the Atol das Rocas is certainly geographically isolated from other populations due to considerable dispersion barriers, such as depths greater than 1000 meters and large distances.

Mortality is another important parameter with regard to alterations in the number of individuals in a population. However, Abuabara & Petrere Jr. (1997) point out that natural deaths may occur among samples without affecting the estimation if tagged and untagged specimens have the same chance of dying. As photographic records of natural distinguishing marks do not require any type of handling, capture or other procedure that may alter the chances of survival, it can be assumed that the mortality of photographed and non-photographed individuals has the same probability and therefore did not affect estimates.

Another presupposition regarding the loss of natural marks deserves special attention. The accuracy of the estimate depends upon the identification of distinguishing marks that naturally appear on the rays. Thus, new marks could appear in the intervals between sampling events, thereby invalidating the identification of a given individual, which could then be taken

as two separate individuals. Throughout the present study, however, only four rays presented an increase in previously recorded marks. As many of the animals exhibit more than one distinguishing mark on different parts of the body (pelvic fins, pectoral fins, lower caudal lobe), alterations in natural marks become easier to detect and record, thereby minimizing errors. Another point that merits attention in the data analysis concerns the sampling of only a sub-area used by the population. As the sampling was limited to the inner sections of the atoll, it can be supposed that a significant portion of the population was not sampled. Considering that in one discovery scuba dive made at the external portions of the atoll in october 2003 was obtained $OPUE = 0.47$ and that this value is very similar of the mean $OPUE$ value obtained for the centrall lagoon during the high tides, it is reasonable to assume that the estimated population size should be higher than the actual number of sighted rays.

Another point that merits attention is the low variation of the values obtained by both estimation methods, especially with regard to the upper range limits of the estimate. Abuabara & Petrere Jr. (1997) point out that obtaining estimates through more than one method is extremely valid. Cailliet (1996) has also encouraged the use of Petersen estimators for those who use the Jolly-Seber estimator, and vice-versa.

4. 3 Use of habitat

Data were collected at both low and high tide, and sampling was concentrated in the inner portions of the atoll. At low tide, the formation of different environments was evident, as was the consequent difference in the use of these environments by the species studied. The distribution of *D. americana* in the different environments of the Atol das Rocas generally proved to be closely related to the characteristics of the species.

Bigelow & Schroeder (1953) described the southern stingray as a species with sedentary habits, having found individuals at rest during intervals between periods of characteristically diurnal activity. At the Atol das Rocas, the vast majority of sampling

occurred during the day, when the species is considered active. However, it was observed that the periods of activity for *D. americana* was closely related to tide cycles. At low tide, most rays were observed at rest in the inner pools, whereas at high tide, most were observed in activity in the central lagoon. This behavior may reflect an adaptation on the part of the southern stingray to the profound alterations imposed by the tidal regimen of the Atol das Rocas. As some of the environments are isolated at low tide, it would not be advantageous for a ray to remain at a foraging activity during this time, since the inner pools do not present abundance of mollusks (Barros, J. N, 2003), on which *D. americana* feeds (Bigelow & Schroeder, 1953). At high tide, on the other hand, a series of environments becomes accessible, requiring greater exploratory activity. From the standpoint of strategies to avoid predation, isolated environments would be better protected, requiring less safeguarding activity and favoring a state of rest, whereas high tide makes the environments exposed to the presence of large predators and would hinder the rest of individuals.

A possible explanation for the fact that most *D. americana* were sighted mainly in the central lagoon during periods of activity is that this site presents a large diversity of mollusks of different sizes. The species may therefore use it for both feeding and mating (Barros, J. N, 2003), mollusks on which *D. americana* feeds (Bigelow & Schroeder, 1953). Gillivam & Sullivan (1993) state that the tide influences the movement and foraging patterns of *D.americana*. This characteristic would be related to an increased availability of habitats at high tide for the search for benthic prey. Movement patterns under the influence of the tide are also described for *Aetabus narinari* (Silliman & Gruber, 1999), *D.sabina* (Teaf, 1978 apud Ackerman *et al*, 2000) and *Triakis semifasciata* (Ackerman *et al*, 2000).

Juveniles females of *D. americana* (around 75 cm in DW) in the Atol das Rocas Biological Reserve commonly occur in depths to 2.0 m. Adult females and males (from 80 cm and 51 cm in DW, respectively) are commonly associated with greater depths. Segregation of

spatial distribution between young and adult individuals has been amply reported in the literature for both bony fish and elasmobranchs alike (Jones & McCormick, 2002). It is known that for some species, young and smaller fish seek out environments that are more protected from predation, commonly known as nurseries. Under conditions of strong pressure from predation, the availability of such protected environments may even influence the abundance of the species (Nagelkerken *et al*, 2000; Jones & McCormick, 2002). It is also well known that nurseries for young sharks are characterized by shallow regions (bays, estuaries, mangroves) that are protected from predation by other larger sharks (Branstetter, 1990; Wetherbee *et al.*, 1990; Castro, 1993). Segregation by habitat has a direct influence on feeding, as nurseries are also considered locations of a high abundance of food sources (Simpfendorfer & Milward, 1993). The ontogenetic change in feeding habits accompanies the exiting of animals from nurseries toward deeper regions as they grow in size. The diet of some shark species indicates that young individuals have a restricted diet associated to particular habitats, such as nurseries, which reduces competition with conspecifics in different life stages (Wetherbee *et al.* 1990; Lowe *et al.* 1996). A number of studies on elasmobranchs have suggested that the ontogenetic change in feeding is also related to the capacity of larger individuals in gaining access to prey that are more difficult to obtain or are inaccessible to smaller individuals (Smith & Merriner, 1985). Thus, juveniles of *D. americana* may be using shallower environments as a refuge from predator as well as for feeding. As they grow, they seek out deeper regions where they come across other types of prey. This change in environment probably alters feeding habits and foraging strategies, consequently impeding competition for food sources between young and adult individuals.

Spatial segregation between young and adult individuals has also been described for other species of *Dasyatis*. Elbert & Cowley (2003) state that *D. crysonota* occupies different

habitats throughout life and the proportion of different food items varies considerably between the different size classes.

The Atol das Rocas is located in an oceanic region with surrounding deep waters. Taking into account that the species *D. americana* is characterized by occupying shallow, coastal areas and that there are individuals at the atoll from all age classes that possibly use the region for feeding, reproduction and nurseries, we suggest that the local population is closed from an ecological standpoint. Thus, there is the possibility that *D. americana* individuals remain in the atoll waters throughout their entire life cycle. The region may therefore be considered extremely important for *D. americana*, which it would directly depend upon local resources to complete its biological cycle. There is an evident need to maintain permanent studies that supplement effective conservation and management actions regarding the Atol das Rocas Biological Reserve and the species *D. americana*

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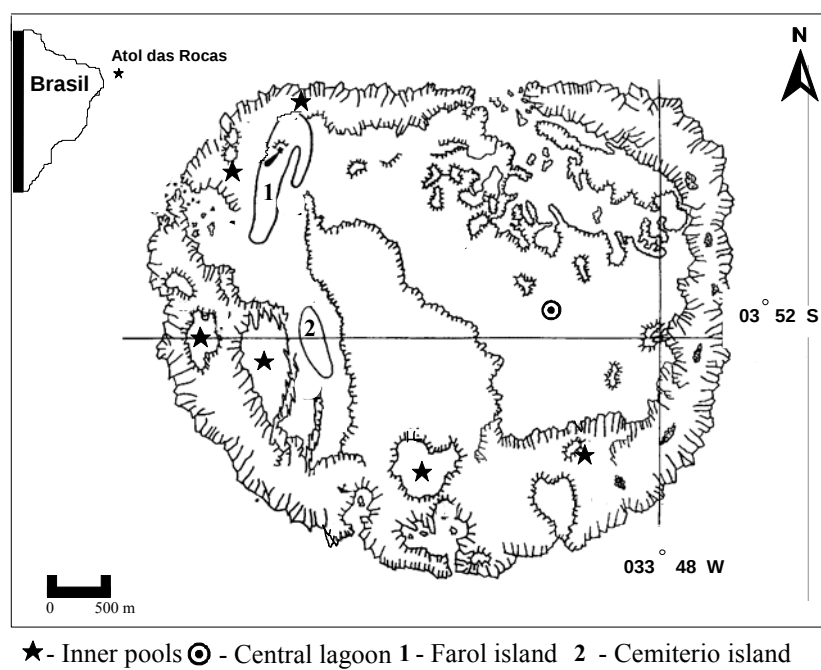


Figure 1. Schematic map with main environments of Atol das Rocas Biological Reserve

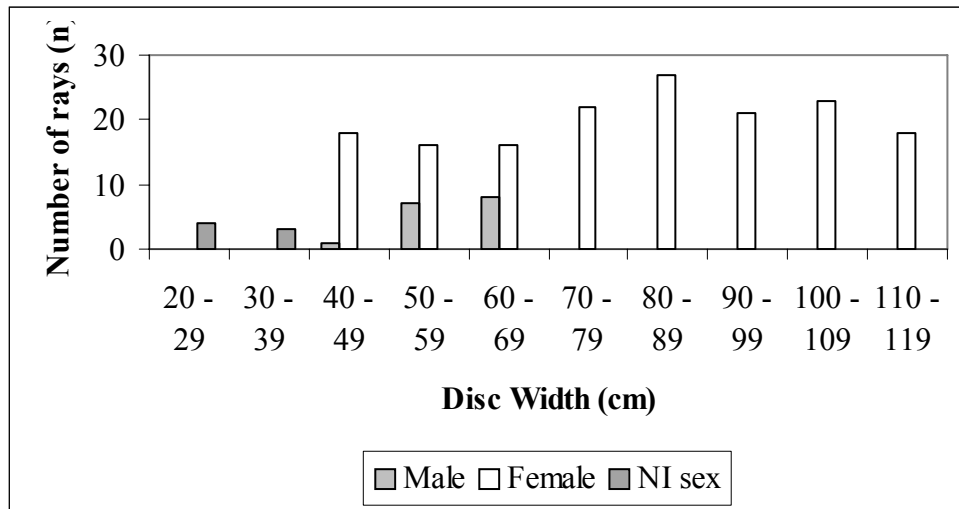


Figure 2. Frequency distribution of disk width (DW) of individuals by sex.

Month	Nº Females	Nº Males	Sex Ratio	X ² (0,05;1)	P
Jan	14				
Feb	12				
Mar	22	6	3.6 : 1	8,3	0.0023
Apr	13				
May	10	1	10 : 01	19,7	0.0002
Jun	11				
Jul	10				
Ago	11				
Sep	21	7	3 : 01	6,8	0.0039
Oct	13	2	6.5 : 1	14,6	0.00017
Nov	12				
Dec	12				
Total	161	16	5.7 : 1	49.4	0.0001

Table 1. Number of females and males, gender proportion, χ^2 and “p” values per month throughout the sampling period.

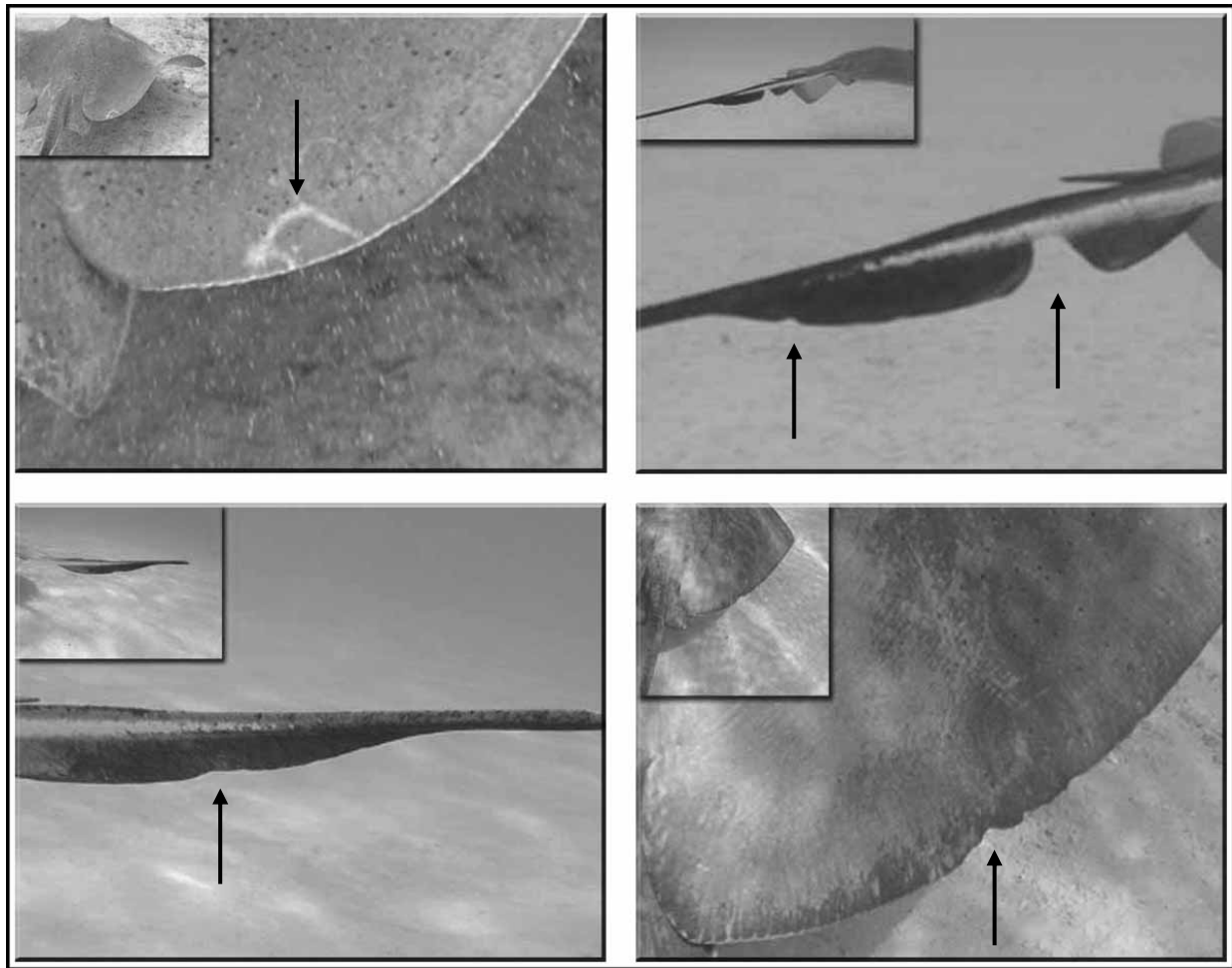


Figure 3. Photographs of some natural marks used in individual identification. Arrow indicates the natural mark.

Events (i)	N_i	$n_{(i+1)}$	$m_{(i+1)}$	N	$N \text{ Total}$
March/05	25	14	4		
May/05	16	11	5	$101.4 \pm 21,2$	
July/05	11	-	-	$97.2 \pm 18,3$	99.2 ± 17.1

N_i = n° of individualized rays in sample i ; $n_{(i+1)}$ = n° of individualized in sample $(i+1)$;
 $m_{(i+1)}$ = n° of sighted rays in sample $(i+1)$ already observed in sample i ; N = estimated population size.

Table 2. Summary of re-sightings and Petersen estimates for the *D. americana* population at the Atol das Rocas Biological Reserve.

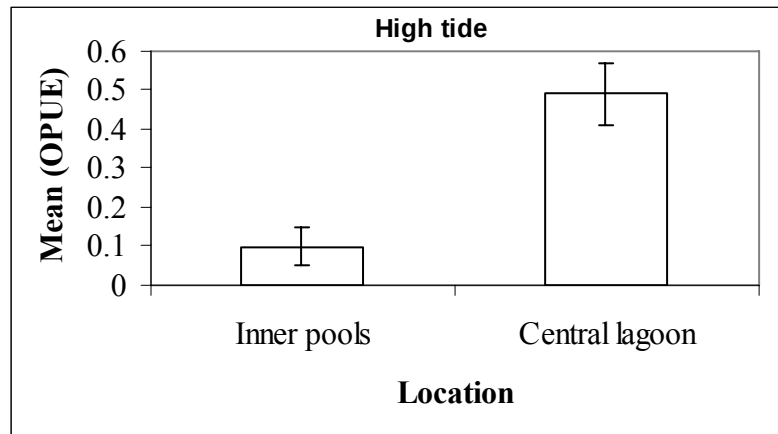


Figure 4. Mean occurrence per unit effort (OPUE) of *Dasyatis americana* at different sampling sites at high tide. Values are means $\pm$ 1 SE.

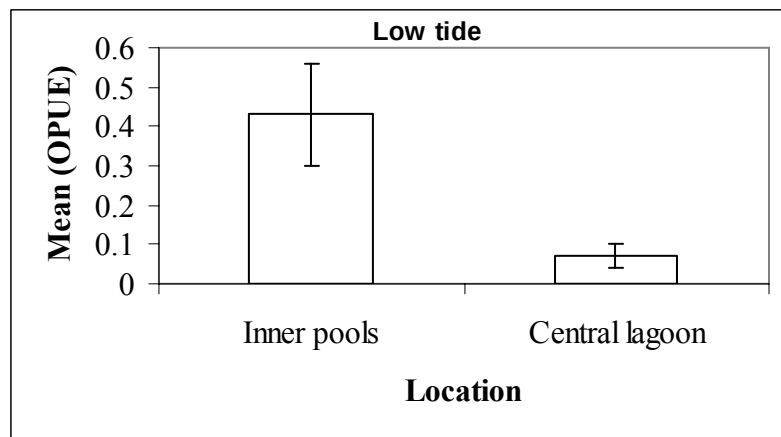


Figure 5. Mean occurrence per unit effort (OPUE) of *Dasyatis americana* at different sampling sites at Low tide. Values are means $\pm$ 1 SE.

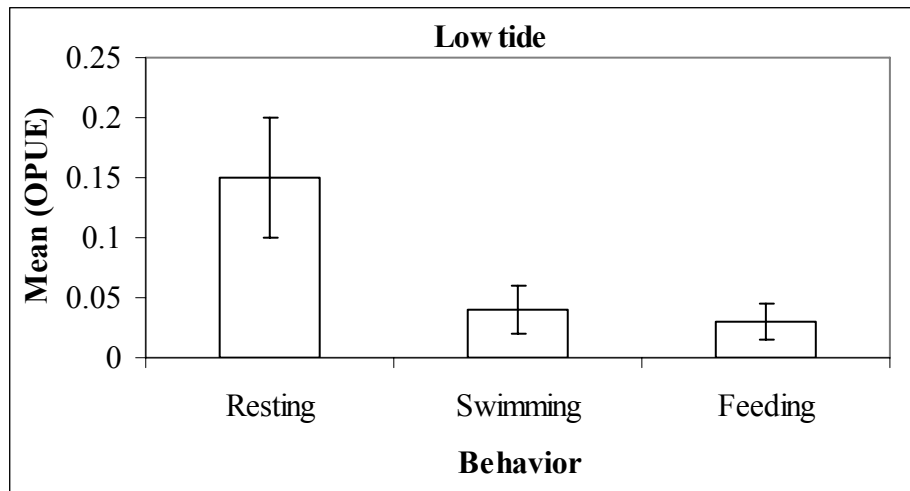


Figure 6. Mean occurrence per unit effort (OPUE) of *Dasyatis americana* at different types of behavior at low tide. Values are means $\pm$ 1 SE.

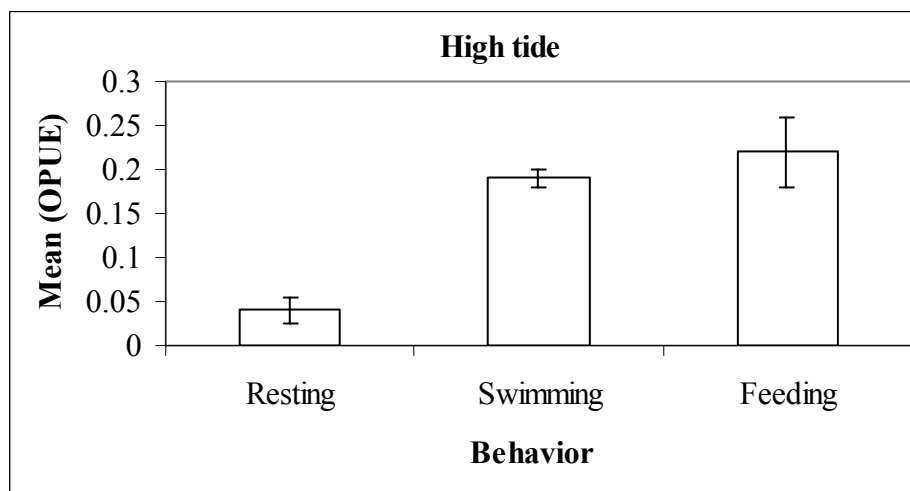


Figure 7. Mean occurrence per unit effort (OPUE) of *Dasyatis americana* at different types of behavior at high tide. Values are means $\pm$ 1 SE..

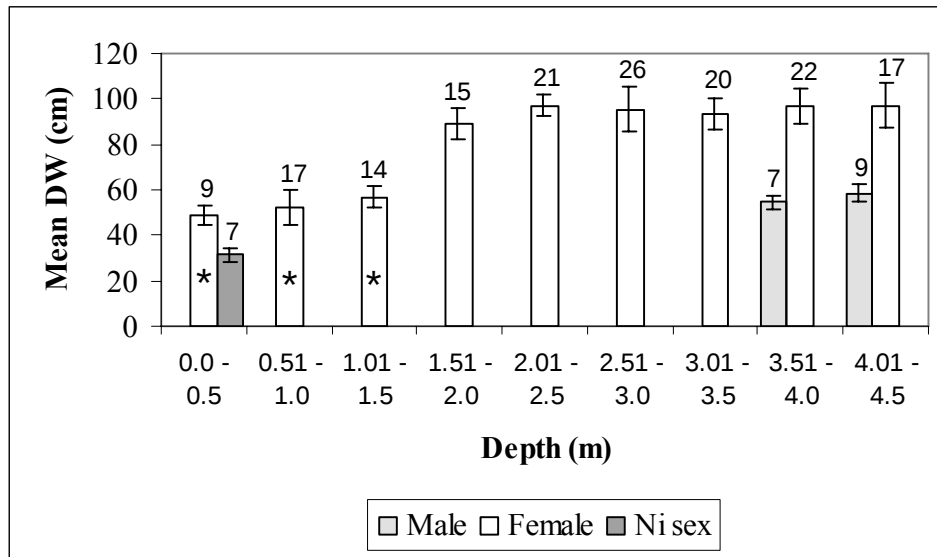


Figure 8. Mean distribution of disk width (DW) of individuals by depth. Depths with (*) are significantly different, to the females, from other depths. Numbers above the bars refer to sample sizes. Values are means $\pm$ 1 SE

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CONCLUSÃO

Os dados obtidos nos artigos indicam:

Capítulo 1 - Que as fêmeas de *Pseudocarcharias kamoharai* (Matsubara, 1936), ficam prenhas indiferente da época do ano, mas tendo alguns períodos de picos como o mês de maio para prenhe intermediária. A espécie não apresentou diferenciação para o desenvolvimento dos úteros e observou-se também que à medida que o ovário se desenvolve é comprovada uma relação com o desenvolvimento do útero.

Capítulo 2 - Que durante as mares baixas, a maioria das raias, permanecem em repouso. Mesmo durante o dia, observaram-se muitas raias em repouso nas marés baixas. Tal fato nos leva a crer que esta seria uma adaptação das raias prego as profundas alterações impostas pelo severo regime de mares do Atol das Rocas. Assim sendo, como parte dos ambientes estão isolados durante as marés baixas, não seria vantajoso para um animal manter-se, por exemplo, em atividade de forrageamento, uma vez que todo o ambiente seria prontamente percorrido. Durante as mares altas, uma série de ambientes tornaram-se acessíveis, demandando uma maior atividade exploratória. Mesmo do ponto de vista das estratégias para evitar a predação, os ambientes isolados seriam protegidos e necessitariam de menor atividade de guarda, favorecendo o repouso. Por outro lado, as marés altas tornariam todos os ambientes expostos a presença de grandes predadores, o que dificultaria o repouso dos indivíduos.

Capítulo 3 – Que o tubarão baleia no Arquipélago de São Pedro e São Paulo ocorrem com maior frequência no primeiro semestre do ano, onde são avistados em maior número durante o período da manhã, com comprimentos variando entre 2 e 10 metros, e uma maior distribuição entre 2 e 4 metros. Os indivíduos registrados no ASPSP apresentam-se, provavelmente, em sua maioria, imaturos. As avistagens foram mais frequentes nas fases de lua cheia e nova.

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ANEXOS

ASPECTS OF THE REPRODUCTIVE BIOLOGY OF THE SILKY SHARK, *Carcharhinus falciformis* (NARDO, 1827), IN THE VICINITY OF ARCHIPELAGO OF SAINT PETER AND SAINT PAUL, IN THE EQUATORIAL ATLANTIC OCEAN.

**ASPECTS OF THE REPRODUCTIVE BIOLOGY OF THE SILKY SHARK,
CARCHARHINUS FALCIFORMIS (NARDO, 1827), IN THE VICINITY OF
ARCHIPELAGO OF SAINT PETER AND SAINT PAUL,
IN THE EQUATORIAL ATLANTIC OCEAN**

Fábio H. V. Hazin¹; Paulo G. V. Oliveira¹; Bruno C. L. Macena¹

SUMMARY

A total of 96 silky sharks, 48 males and 48 females, caught in the equatorial region, close to the Archipelago of Saint Peter and Saint Paul (0°55'10"N; 29°20'33"W) were examined, with a view to study their reproductive biology. Total length (TL) ranged from 83.0 to 272.0 cm, for males, and from 75.0 to 295.0 cm, for females. The present data suggest a size at first sexual maturity for the silky shark in the equatorial Atlantic of about 230 cm, for females, and from 210 to 230 cm, for males. The monthly distribution of female sexual stages do not show any clear trend, suggesting that, at least close to the equator, the species might not have a clear seasonal cycle of gestation. Litter size ranged from 4 to 15, with a sex ratio of embryos equal to 1:1.4 (male: female)

RÉSUMÉ

Un total de 96 requins soyeux, 48 mâles et 48 femelles, capturés dans la région équatoriale à proximité de l'archipel de St Pierre et St Paul (0°55'10"N; 29°20'33"W) ont été examinés dans l'objectif d'étudier leur biologie de reproduction. La longueur totale s'est établie entre 83,0 et 272,0 cm pour les mâles et entre 75,0 et 295,0 cm pour les femelles. Les données présentes suggèrent une taille à la première maturité sexuelle pour le requin soyeux dans l'Atlantique équatorial d'environ 230 cm pour les femelles, et entre 210 et 230 cm pour les mâles. La répartition mensuelle des stades sexuels femelles n'indique aucune tendance claire, ce qui suggère qu'au moins près de l'équateur, l'espèce n'a peut-être pas un cycle de gestation saisonnier clairement établi. La taille de la portée va de 4 à 15, avec un sex-ratio d'embryons égal à 1 : 1,4 (mâle : femelle).

RESUMEN

Se examinó un total de 96 tiburones jaquetón, 48 machos y 48 hembras, capturados en la región ecuatorial, cerca del Archipiélago de Saint Peter y Saint Paul (0°55'10"N; 29°20'33"W), para estudiar su biología reproductiva. La longitud total (TL) osciló entre 83,0 y 272,0 cm, para las hembras y entre 75,0 y 295,0 para los machos. Estos datos sugieren una talla de primera madurez para el tiburón jaquetón en aguas ecuatoriales de aproximadamente 230 cm, para las hembras y de 210 a 230 cm, para los machos. La distribución mensual de las fases sexuales de las hembras no mostraba ninguna tendencia clara, lo que sugiere que, al menos en las zonas cercanas al Ecuador, esta especie podría no tener un ciclo de gestación estacional claro. El tamaño de las camadas osciló entre 4 y 15 crías, con una ratio de sexos de embriones de 1:1.4 (macho: hembra)

KEYWORDS

Reproductive cycle, *Carcharhinidae*, *Carcharhinus falciformis*,
silky shark, Equatorial Atlantic Ocean

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1. Introduction

The silky shark, *Carcharhinus falciformis*, is an abundant oceanic species, which occurs in equatorial and tropical areas around the globe. It has an epipelagic distribution, being commonly found near the edge of continental shelves, as well as in the proximity of oceanic Islands (Bigelow and Schroeder, 1948; Bass *et al.*, 1973; Compagno, 1984). Common in the southwestern Atlantic Ocean, it is often caught by tuna longliners targeting tunas and swordfish (Hazin *et al.*, 1991). Off the Brazilian northeast coast, it is particularly abundant in the vicinity of the Archipelago of Saint Peter and Saint Paul (ASPSP), where it is caught by hand line and longline.

Located at about 600 nautical miles away from the Brazilian coast, the ASPSP has a permanent research station, which serves as a platform for the development of several researches on insular fauna and flora of the Equatorial Atlantic. Its remote location, between the northern and southern hemispheres, as well as between the African and South American continents, makes it a strategic site for the study of pelagic species of the Atlantic Ocean. Since the middle eighties, several fishing vessels based in the Brazilian northeast coast, from Recife to Fortaleza, often cover the long distance separating the ASPSP from the mainland, in order to exploit the abundant fisheries resources present in its vicinity. Although yellowfin tuna, wahoo, flying fish and the rainbow runner are the main targets, silky sharks are also commonly caught.

Despite the silky shark is a common species along the entire Brazilian coast (Gadig and Moreira-Júnior, 1992), information on its biology is virtually non-existing as yet. The objective of the present work was thus to provide preliminary data on the reproductive biology of silky sharks caught in the equatorial Atlantic, close to the Archipelago of Saint Peter and Saint Paul.

2. Material and methods

From September 1998 to April 2004, 96 silky sharks caught by commercial longline operations in the vicinity of the Archipelago of Saint Peter and Saint Paul (0°55'10"N; 29°20'33"W) were examined. Sharks were dissected and examined immediately after being boarded. The reproductive organs of both males and females were collected and preserved in 10% sea-water formalin solution. From females, both oviducal glands and the ovary were collected, weighted and measured, and the stage of ovarian development was observed. The number of vitellogenic follicles was counted and the diameter of the largest one was measured using a Vernier caliper. Both uteri were measured and their contents observed, following dissection. Whenever there were eggs or embryos present, they were counted, measured, weighted, and sexed (embryos). Male testes were also collected and measured, including width, length and weight. Clasper length was recorded and its calcification stage observed.

3. Results and discussion

The silky shark was the most abundant shark species in the fishing operations carried out by the longliners, yellowfin tuna being the most frequent fish caught. Of the 96 specimens examined, 48 were females and 48 males, resulting in a sex ratio (male:female) of 1:1, which is close to the ratio of 1:1.2 found by Branstetter (1987) in the Gulf of Mexico, from a sample of 119 specimens. Total length (TL) ranged from 83.0 to 272.0 cm, for males, and from 75.0 to 295.0 cm, for females (Figure 1). Males were found in 3 different sexual stages: juvenile (n= 26/ 54%); Maturing (n= 13/ 27%); and Adult (n= 9/ 19%). Juvenile males, with a TL up to 186 cm, had flexible and uncalcified claspers, measuring up to 12.0 cm. Maturing specimens ranged from 185 to 210 cm TL, with a clasper length from 13 to 24 cm. Adult specimens had fully calcified claspers, with more than 27 cm. Their TL ranged from 234 to 272 cm (Figure 2). Females, in turn, were found in four different sexual stages: Juvenile (n= 24/ 50%), with a TL ranging from 75.0 to 180.0 cm; Maturing (n= 6/ 12%), TL from 210 to 225 cm; Pre-ovulatory (n= 8/ 18%), TL from 245 to 295 cm; and Pregnant (n= 10/ 20%), TL from 237 to 270 cm. Juvenile females had undeveloped sexual organs with thin uteri and oviducal gland (less than 1.0 cm in width). Maturing females were approaching sexual maturity for the first time. They already had well developed oviducal glands and wider uteri (up to 5 cm), as well as some vitellogenic follicles in the ovary, but with less than 2.0 cm in diameter. The 8 pre-ovulatory specimens were clearly adult, with large vitellogenic follicles in the ovary, with more than 2.5 cm in width. The present data suggest a size at first sexual maturity for the silky shark in the equatorial Atlantic of about 230 cm, for females, and from 210 to 230 cm, for males, which are similar to those found by Branstetter (1987), for silky shark specimens from the northwestern Gulf of Mexico.

The total length of females showed 3 different modes, corresponding, respectively, to juvenile (140 to 160 cm), Maturing (200 to 220 cm), and adult specimens, including both pregnant and pre-ovulatory (260 to 280 cm) (Figure 1). No females were found within the 30-cm gap, from 180 to 210 cm, which separates immature from maturing specimens, suggesting the occurrence of a size segregation. A similar trend was also found for males, with no specimen measuring from 210cm to 234 cm TL, a 24 cm gap, which separates maturing specimens from the adults (Figures 1 and 2).

Litter size in the 10 pregnant females varied from 4 to 15 embryos, with a sex ratio (male: female) of 1: 1.17. Only one female, caught in October, was in early gestation, with embryos measuring from 12.5 to 15.0 cm TL. In other 5 pregnant females, embryos ranged roughly from about 35 to 50 cm, being thus in mid-term, since size at birth is about 75 cm (Compagno, 1984; Springer, 1960). In the remaining 4 pregnant specimens, however, the embryo size was not recorded. Embryos collected by the fishermen during January and February, ranged from 11.0 to 77.5 cm, although no information on the mother was provided. Such a wide range of embryo size in similar periods of the year suggests that silky sharks might not have a marked seasonal gestation cycle, as already reported by several authors (Strasburg, 1958; Bane, 1966; Bass *et al.*, 1973). This seems to be supported by the monthly distribution of female sexual stages, since all stages seem to be indistinctively present throughout the year (Figure 3). This differs from Branstetter (1987), however, who suggested a seasonal gestation period for the species in the Gulf of Mexico. The much narrower seasonal amplitude of sea surface temperature close to the equator, in the present case, when compared to the Gulf of Mexico, above of 20°N of latitude, may account for such a difference.

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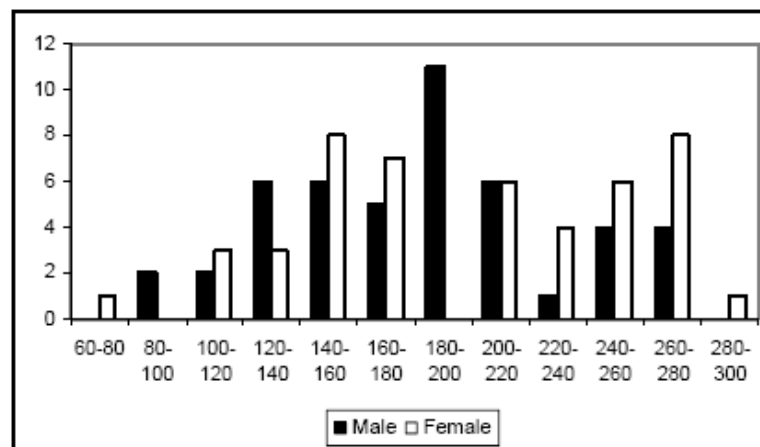


Figure 1. Length-frequency distribution of male (n=48) and female (n=48) silky sharks caught in the equatorial Atlantic, in the vicinity of the Archipelago of Saint Peter and Saint Paul.

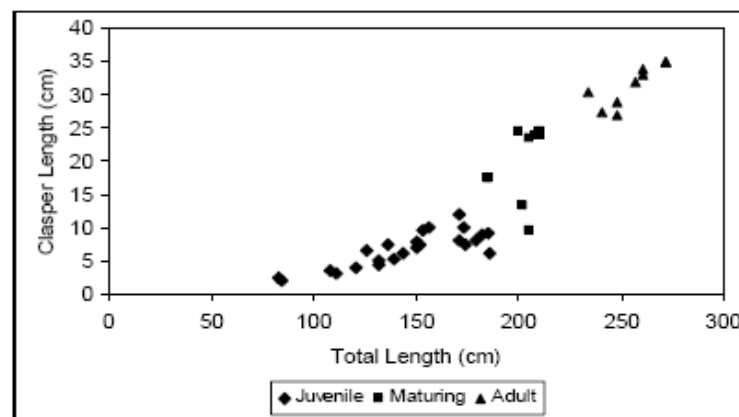


Figure 2. Relationship between total length and clasper length, in male silky sharks caught in the equatorial Atlantic, in the vicinity of the Archipelago of Saint Peter and Saint Paul.

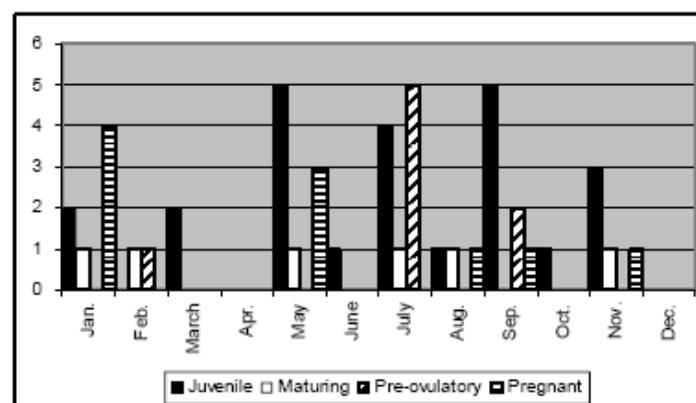


Figure 3. Monthly frequency distribution of sexual stages of female silky sharks caught in the equatorial Atlantic, in the vicinity of the Archipelago of Saint Peter and Saint Paul.

ASPECTS OF THE REPRODUCTIVE BIOLOGY OF THE SANDBAR SHARK,
Carcharhinus plumbeus (NARDO, 1827), IN COASTAL WATERS OFF PERNAMBUCO,
BRAZIL.

ASPECTS OF THE REPRODUCTIVE BIOLOGY OF THE SANDBAR SHARK,
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OFF PERNAMBUCO, BRAZIL

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SUMMARY

A total of 28 sandbar sharks, 11 males and 17 females, caught off the coast of Pernambuco, northeast Brazil, from December 1994 to January 1996, were examined. Total length (TL) ranged from 154.0 to 196.0 cm, for males, and from 108.5 to 208.0 cm, for females. All specimens were already adults. The monthly distribution of sexual stages shows that parturition and ovulation happen in the same months, suggesting a 12-month gestation cycle, in alternate years. Litter size ranged from 7 to 10, with a mean value of 8.6, and the sex ratio of embryos was 1:1.4 (male: female).

RÉSUMÉ

Un total de 28 requins gris, 11 mâles et 17 femelles, capturés au large de la côte de Pernambuco, Nord-Est du Brésil, de décembre 1994 à janvier 1996, ont été examinés. La longueur totale s'est établie entre 154,0 et 196,0 cm pour les mâles et entre 108,5 et 208,0 cm pour les femelles. Tous les spécimens avaient déjà atteint le stade adulte. La répartition mensuelle des stades sexuels indique que la parturition et l'ovulation surviennent au cours des mêmes mois, ce qui suggère un cycle de gestation de 12 mois, au cours d'années alternées. La taille de la portée fluctuait entre 7 et 10, avec une valeur moyenne de 8,6 et le sex-ratio des embryons s'établissait à 1 : 1,4 (mâle : femelle).

RESUMEN

Desde diciembre de 1994 hasta enero de 1996 se examinó un total de 28 tiburones tordo, 11 machos y 17 hembras, capturados en las aguas situadas frente a costa de Pernambuco, nordeste de Brasil. La longitud total osciló entre 154,0 y 196,0 cm para los machos y entre 108,5 y 208,0 cm para las hembras. Todos los ejemplares eran ya adultos. La distribución mensual de las fases sexuales muestra que el parto y la ovulación se producen en los mismos meses, lo que sugiere un ciclo de gestación de 12 meses, en años alternos. El tamaño de las camadas osciló entre 7 y 10 crías, con un valor medio de 8,6, y la ratio de sexos de los embriones fue 1:1.4 (macho: hembra).

KEYWORDS

Reproductive cycle, *Carcharhinidae*, *Carcharhinus plumbeus*,
sandbar shark; Pernambuco, Brazil

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1. Introduction

The genus *Carcharhinus* has the largest number of species among all shark genus: 29 species, 10 of which are present in the Southwestern Equatorial Atlantic Ocean. The sandbar shark, *Carcharhinus plumbeus* (Nardo, 1827), is a medium-sized grey shark, viviparous with a yolk-sac placenta, found in continental and insular shelves, as well as in deep waters adjacent to them (Compagno, 1984). Being present in the entire Brazilian coast, they are highly migratory, with reported movements of over 2,900 km (Merson and Pratt, 2001).

Data on the distribution, biology and reproduction of the sandbar shark have been reported from USA (Bigelow and Schroeder, 1948; Springer, 1960; Clark and von Schmidt, 1965; Branstetter, 1981), Hawaii (Wass, 1978), China (Taniuchi, 1971), South Africa (Bass *et al.*, 1973), Australia (Mcauley *et al.*, 2005), Chinese Taipei (Joung and Chen, 1995) and Mediterranean (Saïdi *et al.*, 2005). In Brazil, however, only Amorim *et al.* (1998) have provided, so far, biological information on the species.

Mattos and Hazin (1997) examined sharks caught in the coast of Pernambuco, northeast Brazil, between September 1994 and May 1996 and identified the presence of 9 species. Of these, the blacknose shark, *Carcharhinus acronotus*, and the sandbar shark, *Carcharhinus plumbeus*, were the most abundant ones, accounting together to about 70% of all specimens. Besides, Wanderley Jr. *et al.* (1998), studying the distribution of sharks in the same area, identified a pattern of species segregation by depth, with a clear predominance of the sandbar shark in deeper areas (between 50 and 60 m), next to the continental slope, whilst the blacknose shark showed a much shallower distribution, being common only in waters with less than 20-m depth. The higher abundance of the sandbar shark in the continental slope, as well as in the adjacent oceanic waters, results in its sporadic catch by longliners targeting tunas and swordfish off Brazilian coast. Nevertheless, the lack of a targeted fishery for the species in Brazil, associated to its seldom occurrence in the longline catches, make the study of its biology very difficult. Aiming at filling this gap, at least in part, in the present paper preliminary information on the reproductive biology of *C. plumbeus* specimens caught by bottom longline in the coast of Pernambuco has been provided.

2. Material and methods

A total of 28 sandbar sharks, 11 males and 17 females, caught in the coast of Pernambuco (7° to 10°S; 34° to 35°W), from December 1994 to January 1996, were examined. All specimens were caught with a bottom longline, close to the edge of the continental shelf and slope. Sharks were dissected and examined immediately after capture. The reproductive organs of both males and females were collected and preserved in 10% sea-water formalin solution. From females, both oviducal glands and the ovary were collected, weighted and measured, and the stage of ovarian development was observed. The number of vitellogenic follicles was counted and the diameter of the largest one was measured using a Vernier caliper. Both uteri were measured and their contents observed, following dissection. Whenever there were eggs or embryos present, they were counted, measured, weighted, and sexed (embryos). Male testes were also collected and measured, including width, length and weight. Clasper length was measured and the calcification stage was observed.

3. Results and discussion

Total length (TL) of the sandbar sharks examined ranged from 154.0 to 196.0 cm, for males, and from 108.5 to 208.0 cm, for females, with females being consistently larger than males (Figure 1). Maximum reported total length for males and females is 224 cm and 234 cm, respectively, with females, therefore, also attaining a larger size (Compagno, 1984). All males examined seem to be adult, with fully developed sexual organs and well calcified claspers (Table 1). Females were separated into 5 different sexual stages, according to distinctive characteristics of their reproductive organs (Table 2), as follows: maturing, pre-ovulatory, pregnant, post-partum and resting. The only maturing female already had vitellogenic follicles in the ovary, but their relatively small size, with the largest one measuring less than 2.0 cm in width, indicated that it was not yet ready to ovulate. Pre-ovulatory females, in turn, had ripe ova, with the largest oocyte measuring 2.7 and 2.8 cm, for both specimens, respectively, being thus very close to ovulation, since ovulation happens at an oocyte diameter from about 3.0 cm (Springer, 1960). Pregnant females had either eggs or embryos in their uteri. All of them, however, irrespective of embryo size, had very small ovarian follicles, with the largest one measuring 0.5 to 0.6 cm, and no sign of vitellogenesis. Post-partum females had ovaries in a similar condition to those of pregnant females. Their uteri, however, were empty, flaccid and dilated, with signs of a recent parturition. Resting females, in turn, showed no sign of sexual activity, showing an undeveloped ovary and thin uteri.

Size at first sexual maturity for the species has been provided by numerous authors (Bigelow and Schroeder, 1948; Springer, 1960; Clark and von Schmidt, 1965; Bass *et al.*, 1973; Branstetter, 1981; Saidi *et al.*, 2005), ranging, in general, from about 160 to 185 cm, for males, and from 170 to 190 cm, for females. This information confirms that most of the examined specimens were already adults.

Pregnant females were caught from December to May. Litter size ranged from 7 to 10, with a mean value of 8.6 (Table 3). Amorim *et al.* (1998) found an identical range for the number of embryos per litter, in 15 females caught off southern Brazil. These figures are also pretty much within the range of litter size reported in the literature: 9, in North Carolina (Springer, 1960); 4 to 11, with a mean of 9, in Florida (Clark and von Schmidt, 1965); 4-12, in South Africa (Bass *et al.*, 1973); 6-11, in Gulf of Mexico (Branstetter, 1981); 1-8, with a mean of 5, in Hawaii (Wass, 1973); 2-10, mean of 5.6, in China Sea (Taniuchi, 1971); 4-10, mean of 6.9, in the Gulf of Gabès (Saidi *et al.*, 2005); 4-12, mean of 7.5, in Taiwan (Joung and Chen, 1995); 4-10, mean of 6.5, in Australia (Mcauley *et al.*, 2005).

Most of the specimens (5) had well developed embryos, the largest one in each litter measuring more than 50.0 cm, up to 57.0 cm. These embryos were probably near term, since size at birth ranges from about 56 to 75 cm (Compagno 1984). One female had only eggs in the uteri, another one had both eggs and embryos of a maximum TL of 10.0 cm, and a third one had relatively small embryos, with TL ranging from 14.0 to 17.0 cm. Sex ratio (male: female) was 1: 1.4, with a predominance of females, which was very similar to the sex ratio of the adult specimens caught (1: 1.5). Amorim *et al.* (1998) found a similar sex ratio of embryos (1:1.4), off southern Brazil. In North Carolina and Central Gulf of Florida, however, females seem to outnumber males in a much larger proportion, with sex ratios of 1:5 (Springer, 1960) and 1:6 (Clark and von Schmidt, 1965), respectively, being reported. Springer (1960), nevertheless, suggested that the much larger number of females in U.S. coast could be due to a feeding inhibition by males. In northeast Taiwan, in turn, a sex ratio very close to the present case, 1:1.6, was described by Joung and Chen (1995). Wass (1973), on the other hand, reported a sex ratio for the sandbar shark from Hawaiian waters very close to 1.

The monthly distribution of sexual stages (Figure 2) shows that parturition and ovulation happens in similar months, from December to March, during austral summer, suggesting thus a 12-month gestation cycle. In Hawaii, mating, ovulation and parturition also seem to occur in the same period, between July and September, coinciding thus with summer in the northern Hemisphere. A similar cycle seems also to happen in the east coast of USA (Springer, 1960). In that region, pregnant females of sandbar shark usually invade lagoons and bays of shallow waters to give birth to pups (Castro, 1993). It's likely, therefore, that Pernambuco coast also constitutes a parturition and nursery ground for the species. The presence of resting females, together with a maturing specimen in August, provide some indication that gestation might happen in alternate years, or even every 3 years. The fact that pregnant, post-partum and resting females show small ovarian follicles (Figure 3) indicates that vitellogenesis is not concurrent with embryo development, giving further support to a two or three years reproductive cycle. Off Hawaii, Wass (1973) also noted that only about half of adult females was pregnant, suggesting a two year reproductive cycle for the species, with alternate gestations each year. A two-year reproductive cycle for the sandbar shark has also been supported by several other authors (Springer 1960; Wass 1973; Bass *et al.* 1973; Branstetter 1981; Joung and Chen 1995; Castro 1996; Saidi *et al.* 2005).

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Table 1. Monthly distribution of sexual stages of male and female sandbar sharks, caught off Pernambuco, northeast Brazil, from December 1994 to January 1996.

Sexual Stage		Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Total
Males	Adult	3	2	-	2	-	1	2	-	1	11
	Maturing	-	-	-	-	-	-	-	-	1	1
	Pre-ovulatory	-	-	2	-	-	-	-	-	-	2
Females	Pregnant	2	1	1	2	-	2	-	-	-	8
	Post partum	-	-	-	1	-	3	-	-	-	4
	Resting	-	-	-	2	-	-	-	-	-	2
	Subtotal	2	1	3	5	0	5	0	0	1	17
Total		5	3	3	7	0	6	2	0	2	28

Table 2. Main characteristics of sexual stages of female sandbar sharks, caught off Pernambuco, northeast Brazil.

	Maturing	Pre-ovulatory	Pregnant	Post-partum	Resting
Number of specimens	1	2	8	4	2
Uterus width	4.0	5.6 and 5.5	7.1 - 27.5	4.7 - 6.5	2.3 and 2.5
Oviducal gland width	2.8	4.5 and 4.0	2.4 - 4.0	2.5 - 2.9	2.7
Ovary width	7.5	7.2 and 10.7	5.0 - 7.5	4.9 - 6.2	5.0
Largest ovarian follicle diameter	1.8	2.7 and 2.8	0.5 - 0.6	0.5 - 1.0	0.5 and 0.6
TL (cm)	204.0	195.0 and 197.7	193.0 - 208.0	180.5 - 202.0	194.5 and 204.0

Table 3. Litter size, sex ratio and range of total length of embryos of 8 pregnant females, caught off Pernambuco, northeast Brazil, from December 1994 to January 1996.

	Month	Litter Size/ Sex Ratio (males: females)	TL range (cm)
1	December	9/ 5: 4	50.0 - 56.0
2	December	9/ 4: 5	49.0 - 55.0
3	January	9/ 5: 4	52.0 - 54.0
4	February	-	Egg
5	March	8/ 3: 5	53.0 - 56.0
6	March	7/ 2: 5	53.5 - 57.0
7	May	10/ 4: 6	14.0 - 17.0
8	May	8/ 2: 6	Egg - 10.0

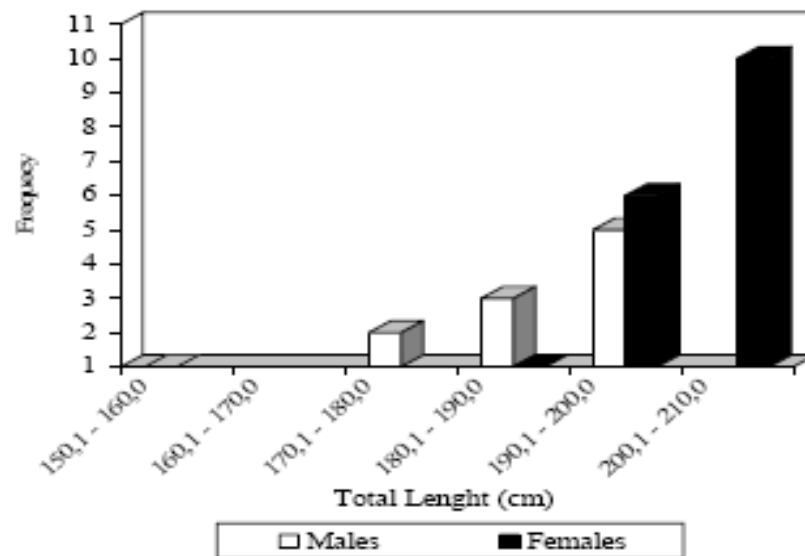


Figure 1. Length-frequency distribution of male and female sandbar sharks, caught off Pernambuco, northeast Brazil, from December 1994 to January 1996.

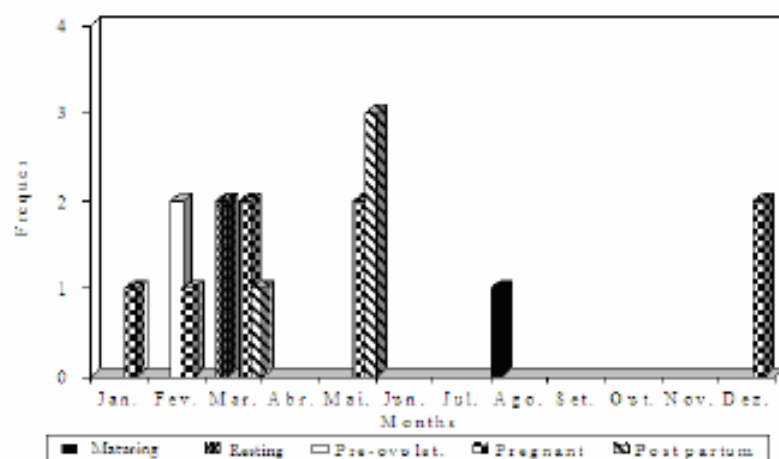


Figure 2. Monthly distribution of sexual stages of female sandbar sharks caught off Pernambuco, northeast Brazil.

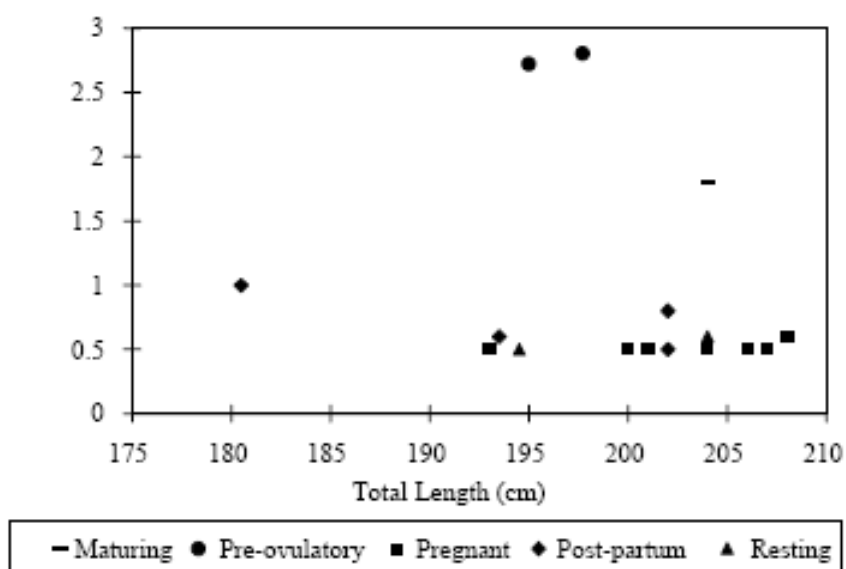


Figure 3. Relationship between largest ovarian follicle diameter and total length of female sandbar sharks, by sexual stages.