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CENTRO DE TECNOLOGIA E GEOCIÊNCIAS
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PROGRAMA DE PÓS-GRADUAÇÃO EM OCEANOGRAFIA

# PESCA E HISTORIA NATURAL DA RAIA-ROXA, *Pteroplatytrygon violacea* (BONAPARTE, 1832), NO ATLÂNTICO OCIDENTAL

DRÁUSIO PINHEIRO VÉRAS

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Dráusio Pinheiro Véras

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Orientador: Prof. Dr. Fábio H. V. Hazin

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*"It's not about how hard you can hit, it's about how hard you can get hit and keep moving forward"* (Rocky Balboa).

Dedico este trabalho, *in memorian*, a minha irmã, Miriam Pinheiro Veras, que nos deixou recentemente.

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## Resumo

A raia-roxa, *Pteroplatytrygon violacea* (Bonaparte, 1832), é a única espécie da família Dasyatidae no ambiente pelágico. O objetivo geral do presente trabalho consistiu em agregar informações sobre a espécie, principalmente no que se refere a sua pesca, seu hábito alimentar, aspectos reprodutivos, distribuição, abundância relativa e preferências de uso do habitat no Oceano Atlântico Ocidental. Para determinar seu hábito alimentar, os estômagos de 106 espécimes foram analisados (69 machos, 26 fêmeas e 11 sem informação de sexo). A importância de cada item alimentar na dieta foi obtida pelo Índice de Importância Relativa (IIR). Foram observados teleósteos, cefalópodes, crustáceos e outras presas que incluíam tunicados, pterópodes e heterópodas. As observações sugerem que a *P. violacea* altera seus itens alimentares de acordo com sua localização geográfica e também mostra como a espécie, apesar de pertencer à família Dasyatidae, é adaptada ao ambiente pelágico. Os hábitos reprodutivos desta espécie são pouco conhecidos. Estudamos a sua biologia reprodutiva, examinando um total de 480 espécimes, 188 fêmeas (39,2%) e 292 machos (60,8%), e proporção sexual de 1,5 macho: 1 fêmea, capturados na pesca de espinhel comercial entre outubro de 2005 e março de 2010. Tamanhos, medidos pela largura do disco ($L_D$), variaram de 28,0-66,0 cm para fêmeas e de 34,0-59,6cm para os machos. Fêmeas foram classificadas como juvenil (n = 42; 22,7%); em maturação (n = 67; 36,2%); pré-ovulatória (n = 28; 15,1%); prenhe estágio 1 (n = 17; 9,2%); prenhe estágio 2 (n = 13; 7,0%); prenhe estágio 3 (n = 2; 1,1%); pós-parto (n = 6; 3,2%) e repouso (n = 10; 5,4%). Fêmeas grávidas em estágios 1-3 (n = 32, 17,3%) variaram entre 48,0-60,0cm $L_D$. O tamanho da primeira maturação sexual foi estimado em 50,0cm $L_D$ para fêmeas e 42,0cm $C_D$ para os machos. A fecundidade do ovário, considerando-se apenas folículos maiores do que> 0,5 cm de diâmetro, variou de 1-17 folículos/fêmea e a fecundidade uterina de embriões em fêmeas prenhes em estágios 2 e 3 variou 1-5 embriões/fêmea. A proporção sexual entre os embriões foi igual (0,9 machos: 1 fêmea) e o tamanho ao nascer foi próximo de 19,0cm $L_D$. A sua distribuição e abundancia relativa foram determinados analisando os dados de captura e esforço de 6.886 lances de espinhel, distribuídos em uma ampla área do Atlântico Ocidental, variando de 15°N e 40°S de latitude e a partir de 010°E a 050°W de longitude, o esforço de pesca atingiu o máximo de 1.200.000 anzóis e a área com a maior concentração de esforço foi localizado entre 5°N-25°S de latitude e 020°-040°W de longitude. A distribuição espacial do esforço de pesca por trimestre mostrou semelhança no primeiro e segundo trimestres, quando comparado com o terceiro e quarto e mostraram duas áreas distintas, com maior esforço, uma localizada entre 5°N-5°S e 025°-040°W e a segunda entre 10°-25°S e 025°-040°W. A distribuição espacial da CPUE mostrou a ocorrência de duas áreas com altos índices de captura (7,8-18,0 raias/1000 anzóis), um mais ao norte, variando de 10°N-10°S a 030°-045°W e outra mais para o sudeste, variando de 20°-35°S a 040°-045°W. Os valores mais baixos de CPUE foram observados entre 10°-20°S e correspondente a 0,8-1,6 raias/1000 anzóis. A distribuição espacial da CPUE por trimestre mostrou capturas elevadas ocorrendo no primeiro (10°N-00° a 030°-045°W), terceiro (25°-35°S a 040°-045°W) e quarto (05°-10°S a 030°-035°W) trimestres. Na distribuição espacial de machos e fêmeas, nenhuma evidência foi encontrada de uma segregação espacial por sexo, os machos não apresentaram padrão de segregação por estágio de maturidade sexual, as fêmeas apresentaram um leve padrão de segregação dos estádios de maturação sexual. Os dados aqui apresentados mostram que os espécimes de *P. violacea* capturados no sudoeste do Atlântico equatorial são compostos em sua maioria (98,8% machos e as fêmeas 79,0%) de indivíduos adultos. No presente estudo, para observações do uso do habitat, foi utilizada uma marca eletrônica, *Pop-up Archival Tag* (PAT). Uma fêmea de raia-roxa, medindo 56,5cm e 48,0cm de largura ($L_D$) e comprimento ($C_D$) de disco respectivamente, capturada em 30 de abril de 2010 foi marcada com uma MiniPAT. O espécime não mostrou nenhum padrão definido de movimento horizontal, movendo-se em muitas direções diferentes em uma área entre 03°-09°N de latitude e 036°-040°W de longitude. Durante os 60 dias com a marca, a raia-roxa moveu-se cerca de 535 km, com um deslocamento diária estimado de 8,92 km. A raia-roxa gastou apenas 9,8% do tempo em águas rasas entre 0-50m de profundidade, com temperaturas entre 23,4 e 28,7°C. Em águas abaixo de 50m, passou 90,2% do tempo, desses, 70% foram em águas abaixo de 75m de profundidade, em temperaturas variando entre 13,0 e 24,5°C. Além disso, durante a maior parte do monitoramento (53%), o espécime ficou em águas entre 100-150m de profundidade, com. A temperatura mínima experimentada pela raia-roxa foi de 10,4°C, correspondendo a 387,5 e 428,0m de profundidades, a última coincidindo com a atividade de mergulho mais marcante da raia-roxa. As diferenças entre o dia e a noite e preferências de profundidade pode indicar padrão de movimento circadiano, ou seja, migram diariamente, geralmente até águas rasas durante a noite e águas profundas durante o dia.

**Palavras chave:** Elasmobrânquios, *Bycatch*, Alimentação, Reprodução, CPUE, PSAT, Dasyatidae, Brasil

## Abstract

The pelagic stingray, *Pteroplatytrygon violacea* (Bonaparte, 1832), is the only species of the batoid family Dasyatidae in the pelagic environment. The aim of this study was to gather information to the knowledge of the species, especially with regard to their fishery, feeding habits, reproductive characteristics, distribution, relative abundance and habitat use preferences in the equatorial and southwestern Atlantic Ocean. To determine its food habits, the stomach of 106 specimens were analyzed (69 males, 26 females, and 11 with no sex information). The importance of each food item in the diet was obtained by the Index of Relative Importance (IRI). Were observed teleost, cephalopods, crustaceans and other prey included tunicates, pteropods and heteropods. The data and comments above suggest that the *P. violacea* alter their food items according to their geographical location and also shows how the species, despite belonging to the Dasyatidae family, is adapted to the pelagic environment. The reproductive habits of this species are poorly known. We studied its reproductive biology in the southwestern Atlantic off Brazil, by examining a total of 480 specimens, 188 females (39.2%) and 292 males (60.8%), and sex ratio of 1.5 male:1 female, taken in the commercial longline fishery between October 2005 and March 2010. Sizes, as measured by disc width ($D_W$), ranged from 28.0-66.0cm for females and from 34.0-59.6cm for males. Females were classified as juvenile (n= 42; 22.7%); maturing (n= 67; 36.2%); pre-ovulatory (n= 28; 15.1%); pregnant stage 1 (n= 17; 9.2%); pregnant stage 2 (n= 13; 7.0%); pregnant stage 3 (n= 2; 1.1%); postpartum (n= 6; 3.2%); and resting (n= 10; 5.4%). Pregnant females in stages 1-3 (n=32, 17.3%) ranged between 48.0-60.0 cm $D_W$. Size at first sexual maturity was estimated at ca. 50.0cm $D_W$ for females and ca. 42.0cm $D_W$ for males. Ovarian fecundity, considering only follicles larger than >0.5cm in diameter, ranged from 1-17 follicles/female and the uterine fecundity of embryos in pregnant females in stages 2 and 3 ranged from 1-5 embryos/female. The sex ratio between the embryos was equal (0.9 male:1 female) and the size at birth was 19.0cm $D_W$. The distribution and their relative abundance were determined by analyzing the catch and effort data from 6,886 longline sets, distributed in a wide area of the equatorial and southwestern Atlantic Ocean, ranging from 15°N to 40°S of latitude and from 010°E to 050°W of longitude, the fishing effort reached the maximum of 1,200,000 hooks and the area with the greatest concentration of effort was located between the 5°N-25°S of latitude and 020°-040°W of longitude. The spatial distribution of fishing effort by quarter showed that the fishing effort was more similar in the 1st and 2nd quarters, when compared to the other and had two distinct areas with highest effort, one located between 5°N-5°S to 025°-040°W and the second between 10°-25°S to 025°-040°W. The spatial distribution of the CPUE showed that occur two catches areas with highest captures (7.8 to 18 stingrays/1000 hooks), one further north, ranging of 10°N-10°S to 030°-045°W and another more to the southeast, ranging of 20°-35°S to 040°-045°W. The lower CPUEs values were observed between 10°-20°S and corresponding to 0.8 to 1.6 stingrays/1000 hooks. The spatial distribution of the CPUE by quarter showed high catches occurring in the 1st (10°N-00° to 030°-045°W), 3rd (25°-35°S to 040°-045°W) and 4th (05°-10°S to 030°-035°W) quarters. In the spatial distribution of males and females, no evidence has been found of a spatial segregation by sex, males showed no segregation pattern by sexual maturity stage, the females showed a slight segregation pattern of sexual maturity stages. The data presented here show that the *Pteroplatytrygon violacea* specimens caught in the southwestern equatorial Atlantic is composed mostly (98.8% males and 79.0% females) of adult individuals. In this study, for observations of habitat use, we used one electronic tag like Pop-up Archival Tag (PAT). One pelagic stingray female, measuring 56.5cm and 48.0cm of disc width ($D_W$) and length ($D_L$) respectively, caught on April 30, 2010 was tagged with MiniPAT. The specimen showed no definite pattern of horizontal movement, moving in many different directions in an area between 03°-09°N latitude and 036°-040°W longitude. During the 60 days of deployment, the pelagic stingray moved about 535 km, with an estimated daily displacement of 8.92 km. It spent just 9.8% of the monitored time in shallow waters, between 0-50m, with temperatures ranging from 23.4 to 28.7°C. The pelagic stingray spent 90.2% of the time below 50m, 70% of which in waters below 75m, in temperatures ranging from 13.0 to 24.5°C. Besides, during most of the monitored time (53%), the specimen stayed in waters between 100-150m. The minimum temperature experienced by pelagic stingray was 10.4°C, corresponding depths of 387.5 and 428.0m, the last one coinciding with the most outstanding diving activity of pelagic stingray. The differences between day and night depth preferences might indicate diel movement pattern, migrate daily, usually up to shallow waters at night and deep waters during the day.

***Keywords***: Elasmobranchs, Bycatch, Feeding, Reproduction, CPUE, PSAT, Dasyatidae, Brazil

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## Sumário

## 1. Introdução

Os tubarões e raias pelágicos são um grupo relativamente pequeno, com reduzida diversidade, representando apenas cerca de 6% das espécies de elasmobrânquios existentes no mundo. Somente sessenta e quatro espécies de tubarões e raias habitam regiões oceânicas, número, portanto, muito baixo se comparado ao das espécies que habitam áreas costeiras (Camhi *et al*., 2009). Amplamente distribuídos em vários oceanos, porém, os elasmobrânquios pelágicos oceânicos possuem comumente distribuição circumglobal (Compagno, 2001). Em comum com as outras espécies de tubarões e raias, apresentam uma baixa taxa de crescimento populacional (Hoenig e Gruber, 1990; Smith *et al*., 1999; Cortés, 2000, 2002; Frisk *et al*., 2005) e um ciclo de vida caracterizado pelo crescimento lento, alta longevidade, maturidade sexual tardia e baixa fecundidade (Hoenig e Gruber, 1990). Por essa razão, são normalmente muito mais vulneráveis à sobrepesca do que os peixes teleósteos (Musick *et al*., 2002; Compagno *et al*., 2005), aspecto que reforça a necessidade de pesquisas sobre o seu ciclo de vida e história natural, de forma a permitir uma adequada avaliação dos seus estoques.

Mundialmente, cerca de um terço de todos os tubarões e raias oceânicos se encontram ameaçados, 6% em risco e 26% vulneráveis, (Camhi *et al*., 2009). Dulvy *et al*. (2008) avaliando a condição de conservação de 21 espécies de elasmobrânquios oceânicos (16 tubarões e 5 raias) capturados regularmente por diferentes pescarias, concluiu que mais da metade se encontrava ameaçada (52%), principalmente em razão de suas elevadas mortalidades por pesca, associadas, na maioria dos casos, a uma completa ausência de medidas de manejo, não havendo frequentemente sequer dados acurados acerca de suas capturas.

As populações de elasmobrânquios estão sendo negativamente impactadas por um conjunto de atividades humanas em todo mundo, encontrando-se, algumas delas, seriamente ameaçadas devido a: 1) estratégias de vida que as tornam particularmente vulneráveis à sobre-explotação, 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 das barbatanas; 5) perda de zonas de berçário e outras áreas costeiras críticas para o seu desenvolvimento; 6) degradação ambiental e poluição (IUCN, 2007). De acordo com a mesma fonte, até as pescarias sujeitas a regimes de manejo são ainda pouco compreendidas ou controladas, havendo, em geral, um baixo esforço de pesquisa sobre a biologia dos elasmobrânquios capturados, com várias das espécies incidentes não sendo sequer identificadas e não havendo, por conseguinte, em muitos casos, qualquer registro de suas capturas.

Desde 1980, um crescimento constante dos desembarques de elasmobrânquios tem sido observado em todo mundo, alcançando, na última década, uma taxa estimada de 5% ao ano (Clarke, 2004), com uma produção atual em torno de 800.000 t (FAO, 2009). Ainda segundo a FAO (2009), em 2007, os tubarões e raias pelágicas representaram cerca de 10% (81.166 t) de todos os desembarques de elasmobrânquios no mundo, 56% dos quais ocorreram no Oceano Atlântico (contra 36% no Pacífico e 8% no Oceano Índico), embora esta porcentagem esteja provavelmente sobrestimada no caso do Atlântico, devido ao melhor nível de informação sobre a captura das espécies neste oceano (Camhi *et al*, 2009).

Entre os métodos de pesca com maior incidência de elasmobrânquios nas capturas inclui-se a pesca de atuns e afins com espinhel, atividade que teve início, no Oceano Atlântico, em 1956, a partir de embarcações japonesas arrendadas, com base Recife-PE, Brasil (Hazin, 1990; Mazzoleni e Schwingel, 2002). Embora a operação dessa frota espinheleira geralmente esteja direcionada para a captura de atuns (*Thunnus* spp.) e do espadarte (*Xiphias gladius*), um considerável montante de elasmobrânquios é capturado como fauna acompanhante (Hazin, 2006). Entre as principais espécies capturadas incluem-se a *Pteroplatytrygon violacea* família Dasyatidae e os tubarões das famílias Lamnidae (*Isurus oxyrinchus*, *Isurus paucus*, *Lamna nasus*), Carcharhinidae (*Prionace glauca, Carcharhinus longimanus, Carcharhinus falciformes e Carcharhinus signatus*), Pseudocarchariidae (*Pseudocarcharias kamoharai*), Alopidae (*Alopias vulpinus* e *Alopias superciliosus*) e Sphyrnidae (*Sphyrna mokarran* e *Sphyrna lewini*), que são consideradas as espécies de tubarões oceânicos mais abundantes do globo (Compagno, 1984; Taniuchi, 1990; Bonfil, 1994).

A organização responsável pela avaliação e manejo dos estoques de tubarões e raias oceânicos, capturados em conjunção com a pesca de atuns e afins no Oceano Atlântico, é a Comissão Internacional para a Conservação do Atum Atlântico (ICCAT- *International Commission for the Conservation of Atlantic Tunas*). Criada em 1966 e constituída atualmente por quase 50 países, a ICCAT é hoje a maior organização regional de ordenamento pesqueiro do mundo. Acompanhando a tendência observada em outros fóruns internacionais, a ICCAT tem aumentado substancialmente, nos últimos anos, a atenção dispensada ao manejo e à conservação dos tubarões. A primeira medida de ordenamento adotada pela Comissão relativa a esse importante grupo zoológico foi a Resolução 95-02, a qual, já em 1995, instou os países membros a aportarem os dados sobre os elasmobrânquios capturados como fauna acompanhante. Desde então, as questões relativas aos elasmobrânquios capturados na área da Convenção têm recebido uma importância crescente, culminando com a realização, em 2004, de uma avaliação dos estoques dos tubarões mako (*Isurus oxyrhinchus*) e azul (*Prionace glauca*), a qual foi seguida por uma segunda e última avaliação, realizada em 2008. Além de monitorar a condição dos estoques das principais espécies de tubarão capturadas no âmbito de sua convenção, a ICCAT tem aprovado, também, uma série de medidas de ordenamento pesqueiro voltadas à sua conservação, incluindo, entre elas, a proibição, em 2004, da prática do descarte de tubarões após a retirada das barbatanas (*finning*) (ICCAT Rec. 04-10). A partir de 2007, porém, sob a presidência do Brasil, a ICCAT intensificou os seus esforços de conservação dos tubarões, aprovando medidas para a proteção do tubarão raposa (*Alopias* spp.), em 2009

(Recomendação 09-07); dos tubarões mako (*Isurus oxyrinchus*) (Rec. 10-06), galha-branca oceânico (*Carcharhinus longimanus*) (Rec. 10-07) e martelo (*Sphyrna* spp.) (Rec. 10-08), em 2010; e do tubarão lombo-preto (*Carcharhinus falciformis*), em 2011 (Rec. 11-08). Tais iniciativas têm sido amplamente apoiadas pelo Brasil, uma vez que o país foi um dos primeiros em todo mundo a banir o *finning*, já em 1998 (Portaria do IBAMA, Nº 121, 24/08/1998), exemplo subsequentemente seguido por outros países, como a África do Sul, os EUA, a Austrália, a Costa Rica e, mais recentemente, a Comunidade Europeia (Shark News, 2002).

Todas as espécies de tubarões acima mencionadas, em maior ou menor grau, têm sido alvo do descarte das carcaças ao mar após a retirada das nadadeiras (*finning*), constituindo-se tal prática um motivo de grande preocupação mundial. Essa mesma preocupação, porém, também existe para as espécies em que a prática do *finning* não ocorre, entre as quais a *P. violacea*. Nesses casos, a principal preocupação está relacionada principalmente à falta de informações biológicas, associada à aguda escassez de dados de captura e esforço, aspecto que levou o Ministério da Pesca e Aquicultura a construir, com o apoio do Subcomitê Científico, do Comitê permanente de Gestão de Atuns e Afins (CPG/ SCC- Atuns) e Universidade Federal Rural de Pernambuco (UFRPE), uma cooperação internacional, objeto do projeto "Tubarões Oceânicos", com o *National Marine Fisheries Service*, dos EUA (NMFS), a *University of Miami* (UM), o *Virginia Institute of Marine Scence* (VIMS), e a *University of Florida* (UF). A coleta de dados e informações biológicas viabilizada por meio dessa cooperação tem permitido um melhor conhecimento da composição específica e estrutura de tamanho das espécies capturadas, do padrão de distribuição espaço-temporal, bem como dos parâmetros biológicos e populacionais de tubarões e raias oceânicas, com ênfase nas espécies sob avaliação da ICCAT, entre as quais se destacam: a raia-roxa (*Pteroplatytrygon violacea*), o tubarão azul (*Prionace glauca*), o tubarão mako (*Isurus oxyrinchus*), o tubarão galha branca oceânico (*Carcharhinus longimanus*), e o tubarão cachorro (*Pseudocarcharias kamoharai*).

Qualquer atividade pesqueira que incida sobre populações de elasmobrânquios, em especial quando os mesmos integram a fauna acompanhante, deve ser sempre acompanhada por pesquisas científicas que abordem os aspectos populacionais e a estratégia de vida, de forma a permitir uma adequada avaliação dos estoques explotados. Dessa maneira, e considerando que no Brasil pouco foi publicado até o momento sobre a espécie (Siqueira e Sant'Anna, 2007; Ribeiro-Prado e Amorim, 2008; Ribeiro-Prado *et al*., 2009, Veras *et al*., 2009), o presente estudo teve o intuito de contribuir para o conhecimento acerca da biologia e dinâmica populacional da *P. violacea*, no Atlântico Ocidental, na expectativa de que os resultados alcançados possam auxiliar na conservação da espécie. Diante deste contexto, foram elaborados quatro artigos científicos visando contribuir para o enriquecimento do conhecimento sobre alguns aspectos ecológicos e pesqueiros da raia-roxa no Atlântico Sul. O primeiro artigo teve como objetivo descrever o hábito alimentar da espécie, por meio da análise de seu conteúdo estomacal e do Índice de

Importância Relativa (IIR). O segundo artigo teve como objetivo estudar a biologia reprodutiva da espécie, definindo o tamanho de primeira maturação sexual, estágios sexuais, época e local de cópula, ovulação e parto, distribuição sazonal dos estágios de maturação, e segregação sexual e por tamanho. O terceiro artigo teve como objetivo avaliar a distribuição, abundância relativa e a composição de tamanhos das capturas da espécie, a partir da análise de dados provenientes da frota atuneira brasileira. O quarto artigo teve como objetivo avaliar o uso do habitat pela raia-roxa, principalmente no que se refere às preferencias de profundidade e temperatura e aos seus movimentos verticais, através do uso de marcas do tipo MiniPAT (Mini *Pop-up Archival Tags*). Espera-se que os resultados gerados possam servir para a elaboração de futuros planos de manejo e conservação da raia-roxa, e que também possam contribuir para que o Brasil ratifique e fortaleça sua participação no âmbito da ICCAT, a partir da proposição de medidas de conservação. Neste sentido, o presente trabalho de pesquisa, além de ter grande relevância ecológica, assume também uma importância sócio-econômica e política significativa.

## 2. Espécie estudada

Diversos trabalhos já foram publicados sobre a raia roxa, *Pteroplatytrygon violacea*, descrevendo sua distribuição (Scott e Tibbo, 1968; Wilson e Beckett, 1970; Iribar e Ibañez, 1977; Nakaya, 1982; Branstetter e McEachran, 1983; Compagno, 1987; Lamilla e Melendez, 1989; Biscoito e Wirtz, 1994; Menni *et al*., 1995; Henderson *et al*., 1999; Bañón, 2000; Mollet, 2002; Mollet *et al*., 2002), abundância (Amorim *et al*., 1998; Mazzoleni e Schwingel, 2002; Domingo *et al*., 2005; Forselledo *et al*., 2008; Ribeiro-Prado e Amorim, 2008; Somvanshi *et al*., 2009; Santana-Hernández *et al*., 2011), dieta (Dávalos-Dehullu e González-Navarro, 2003; Véras et al, 2009), reprodução (Lo Bianco, 1909; Rani e Zezza, 1936; Cavaliere, 1955; Tortonese, 1976; Hemida *et al*., 2003) entre outros (Bigelow e Schroeder, 1962; Nishida e Fujino, 1996; Villavicencio, 1997; Greenwald *et al*, 1997; Bourdon e Mollet, 1999; Ezcurra, 2001; Siqueira e Sant'Anna, 2007; Akhilesh *et al*., 2008; Neer, 2008; Ribeiro-Prado *et al*., 2009). Apesar da literatura relativamente abundante sobre a *P. violacea*, muitas lacunas ainda existem sobre a espécie, particularmente em relação a sua ecologia.

*Pteroplatytrygon violacea* (Bonaparte, 1832) (Fig. 1) é a única espécie da família Dasyatidae que possui hábitos totalmente pelágicos (Wilson e Beckett, 1970). Podendo chegar a 160 cm de comprimento total e 80 cm de largura de disco, possui coloração violeta escuro ou verde-azulado no dorso e ventre purpúreo-acinzentado, com manchas não diferenciadas (Bester *et* al., 2011). Com reprodução ovovivípara (vivípara aplacentária) e período de gestação entre 2 e 4 meses (Mollet, 2002; Hemida *et al*., 2003; Bester *et al*., 2011), os embriões da espécie inicialmente alimentam-se do vitelo, recebendo, posteriormente, uma nutrição adicional da mãe, na forma de um fluido uterino, enriquecido com muco, gordura e proteína, produzido por meio de uma estrutura especializada (Dulvy e Reynolds, 1997), denominada de trofonemata.

A dieta da raia roxa consiste principalmente de crustáceos planctônicos, como eufasiáceos e anfípodas. Outros itens incluem águas-vivas, lulas, polvos, camarões e pequenos peixes pelágicos, como sardinhas (Clupeidae) e cavalinhas (Scombridae) (Last e Stevens, 1994; Bester *et al*., 2011, Veras et al, 2009). Algumas vezes utiliza as largas nadadeiras peitorais para mover o alimento para dentro da boca (Bester *et al*., 2011).

De acordo com Last e Stevens (2009) a espécie, apresenta distribuição mundial, em mares e oceanos tropicais e subtropicais, além de águas temperadas da Austrália e Tasmânia, sendo, contudo, rara em regiões costeiras (Mollet, 2005; Scott e Tibbo, 1968; Wilson e Becket, 1970; Nishida e Nakaya, 1990; Menni *et al*.,1995; Menni e Stehmann, 2000; Mollet, 2002). A presença da espécie já foi registrada para o Mar Mediterrâneo (McEachran e Capapé, 1986; Hemida *et al*., 2003); Mar do Norte (Ellis, 2007); águas oceânicas de Cabo Verde, no Oceano Atlântico Oriental (Debelius, 1998); o Oceano Pacífico Oriental, e em águas do Hawaii (Mollet, 2002; Anon., 1995; Holts, 1994, 1995 e 1996), Canadá (McAllister, 1990), Califórnia (Mollet, 2002, Ezcurra, 2001), México (Branstetter e McEachran, 1983), Chile (Pequeño, 1989), Uruguai (Domingo *et al*., 2005) e Ilhas Galapágos (Grove e Lavenberg, 1997). Outros relatos incluem águas oceânicas das costas meridional e ocidental da África (Compagno *et al*., 1989) e sul do Japão (Masuda *et al*., 1984, Nakaya e Shirai, 1992), bem como Tasmânia, Austrália e Nova Zelândia (Cox e Francis, 1997). No Brasil, ocorre na costa nordeste, sudeste e sul do país (Sadowsky *et al*., 1989; Menni *et al*., 1995; Rincon *et al*., 1997), com seu primeiro registro tendo sido efetuado por Sadowsky e Amorim (1977), na região sul. Mazzoleni e Schwingel (2002) reportaram a presença da *Pteroplatytrygon violacea* entre as espécies capturadas por espinhel pelágico no sudeste, enquanto Menni e colaboradores (1995) fizeram o primeiro registro para o Atlântico Sul equatorial, com um exemplar capturado em latitude próxima ao Estado de Pernambuco. Apesar de ter sua distribuição atualizada em 2009, recentemente foi publicado um trabalho sobre primeira ocorrência da espécie, na costa leste da Índia (Zacharia *et al*., 2011).

**Figura 1**. Foto de um exemplar, macho, da raia-roxa, *Pteroplatytrygon violacea* (Bonaparte, 1832). Fonte: Akhilesh & Manjebrayakath, 2008.

# 3. Artigos científicos

## *3.1. Artigo científico I*

NOTE
BRAZILIAN JOURNAL OF OCEANOGRAPHY, 57(4):339-343, 2009

### STOMACH CONTENTS OF THE PELAGIC STINGRAY (*Pteroplatytrygon violacea*) (ELASMOBRANCHII: DASYATIDAE) FROM THE TROPICAL ATLANTIC

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The pelagic stingray *Pteroplatytrygon violacea* (Bonaparte, 1832) is the only pelagic dasyatid ray occurring in tropical and subtropical waters of the Atlantic, Indian and Pacific Oceans (BIGELOW; SCHROEDER, 1953; MOLLET, 2002; ELLIS, 2007). This poorly known species was originally described from the Mediterranean Sea, and was first reported from the Atlantic by Bigelow & Schroeder (1962). The species has no commercial value, but is fairly abundant off the Southeastern United States representing about 2.5% in number of the catches by pelagic longlines between 1992-2000 (BEERKIRSHER et al., 2004).

The first record in southern Brazilian waters was reported by Sadowski; Amorim (1977) and Mazzoleni; Schwingel (2002) subsequently recorded the pelagic stingray as a bycatch species regularly caught by tuna longliners off southern Brazil. Menni et al. (1995) reported on the presence of the pelagic stingray in northeastern Brazilian waters. Although the pelagic stingray is caught regularly by tuna longliners operating along the Brazilian coast, few biological data are available on the species. In this context, the stomach contents of the pelagic stingray were analyzed to provide more specific information on its feeding habits in the southwestern equatorial Atlantic Ocean.

The sampled area was located between 40°-25°W and 5°N-20°S (Fig. 1). All specimens were caught by the Research Vessel Riobaldo (CEPENE-IBAMA), in the years 1993, 1994 and 1995 through the Ecotuna Project, and by the Brazilian tuna longline fleet, in the years 2005 and 2006 (SEAP, Onboard Observer Program), in waters of 2000 to 5000 m local depth, with hook depth between 50 and 250 m along the longline. The specimens were stored on ice onboard, and at the laboratory, they were sexed and had their disc width measured to the nearest centimeter.

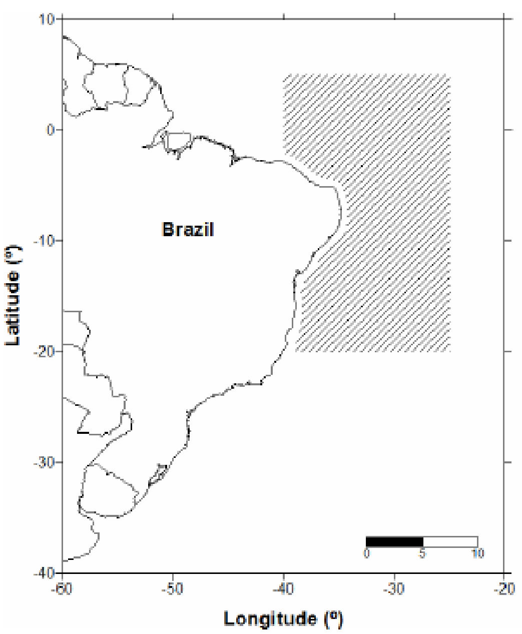


Fig. 1. Sampling area for pelagic stingray in the Southwestern equatorial Atlantic.

A total of 106 specimens were analyzed (69 males, 26 females, and 11 with no sex information). Females were slightly larger, ranging between 40.0 cm and 60.0 cm, with a mean disc width of 49.0 cm. Males varied from 32.0-50.0 cm, with a mean disc width of 43.5 cm (Fig. 2).

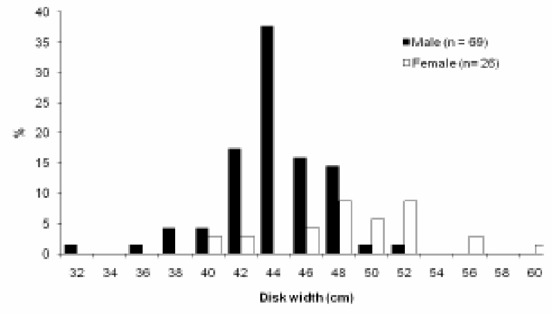


Fig. 2. Size distribution (disc width) for the pelagic stingray.

The stomachs were removed and preserved in 10%formalin, with the food items subsequently identified to the lowest possible taxon. The importance of each food item in the diet was obtained by the Index of Relative Importance (IRI) (PINKAS et al., 1971), utilizing weight data:

$$IRI_i = \%FO_i \times (\%N_i \times \%W_i)$$

Where $\%FO_i$ is the relative frequency of occurrence of each item; $\%N_i$ is the proportion in prey number of each item in the total food; and $\%W_i$ is the proportion in weight of each item in the total food. Longline baits (*Loligo* sp. and *Scomber japonicus*) were not included. Preys in very good condition had their total length measured to investigate preferential prey sizes ingested in the size range of the rays sampled.

Two species of fish were observed (*Diodon hystrix* and *Gempylus serpens*), although most fish remains could not be identified. Various cephalopods were observed, including glass squid (Cranchiidae), ommastrephid squids and the octopod *Japetella diaphana*. Crustaceans were well represented in the diet, especially in terms of hyperiid amphipods (*Phronima sedentaria*, *Phronimopsis* sp., *Phrosina semilunata* and platyscelids), with shrimps (*Heterocarpus ensifer*), brachyuran megalopae, and squillids also consumed. Other prey included tunicates, pteropods and heteropods (Table 1).

The five most important prey were included among the hyperiid amphipods, teleosts, brachyuran megalopae and pteropods. Although prey size ranged from 1.0 to 140.0 mm length, most prey were between 1.0 and 40.0 mm, being represented by small crustaceans, pteropods and heteropods (Fig. 3). The largest prey species were fish, cephalopods and polychaetes.

References in the literature describe the pelagic stingray as epipelagic (SCOTT; TIBBO, 1968; WILSON; BECKETT, 1970; SADOWSKI; AMORIM, 1977; BRANSTETTER; MCEACHRAN, 1983; PRATT et al, 1990; MENNI et al., 1995), although Nakaya (1982) suggested that they may be a benthopelagic species, utilizing both benthic and pelagic habitats, since captures of pelagic stingray were observed between 330 and 381 m depth, with occasional incursions to superficial waters. However, Bañón et al. (1997) had observed and suggested that the *P. violacea* was probably caught in the top 100 m in the bottom trawl fishery, when the bottom trawl at 800 m was hauled up. Siqueira and Sant'Anna (2007) obtained specimens from the artisanal fishery, caught by handline, operating at depths from 30 to 45 m in the adjacent areas of Father Island and Shallow Island, Rio de Janeiro. Therefore, the distribution of *P. violacea* in the water column is probably related to the geographical location and environmental parameters of the region.

Probably due to the hook selectivity of the longline, the smallest individual had 32.0 cm of disc width. The individuals analyzed by Mazzoleni and Schwingel (2002) in Trindade and Martin Vaz islands ranged from 30.0-66.0 cm of disc width, which are, respectively, the smallest and the largest sizes observed for Brazilian waters. Ribeiro-Prado and Amorim (2008) analyzed individuals in São Paulo that ranged from 35.0-65.0cm. Mazzoleni and Schwingel (2002) pointed out that size differences between males and females could be related to reproduction. Although other studies have reported a predominance of females in the sex ratio (MOLLET, 2002), males predominated in this study, corroborating with what was observed by Forselledo et al., (2008), but it is not clear if it is a population characteristic or due to some kind of depth or spatial segregation related to reproduction or feeding habits, or if vertical distribution is in part due to the influence of the sea water temperature. Sexual segregation has been widely observed in sharks by geographical location, intraspecific competition, and requirements of reproductive choices associated with pre- or post-mating strategies (SPRINGER, 1967; MENNI et al., 1979; SIMS et al., 2001; ODDONE et al., 2007). Experiments with captive specimens at the Monterey Bay Aquarium (USA) showed that females reach 20.0 to 30.0 cm more than males at the same age, and that females were more abundant than males (MOLLET et al., 2002).

Table 1. Percentages in number, weight, and frequency of occurrence of food items of *Pteroplatytrygon violacea* in the Southwestern equatorial Atlantic. IRI – Index of Relative Importance, ranging from 1 to 10 in order of importance.

| PREY ITEMS | N | %N | W | %W | FO | %FO | IRI |
|---|---|---|---|---|---|---|---|
| KINGDOM ANIMALIA | | | | | | | |
| **PHYLUM ANNELIDA** | | | | | | | |
| CLASS POLYCHAETE | | | | | | | |
| ORDER ACICULATA | | | | | | | |
| FAMILY ALCIOPIDAE | 7 | 1.10 | 3 | 0.75 | 2 | 3.17 | 8 |
| GENUS *Naiades* | | | | | | | |
| SPECIES *Naiades* sp. | 2 | 0.31 | 1 | 0.25 | 2 | 3.17 | |
| **PHYLUM ARTHROPODA** | | | | | | | |
| SUBPHYLUM CRUSTACEA | | | | | | | |
| SUBCLASS EUMALACOSTRACA | | | | | | | |
| SUPERORDER PERACARIDA | | | | | | | |
| ORDER AMPHIPODA | | | | | | | |
| SUBORDER HYPERIIDEA | | | | | | | |
| SUPERFAMILY PHRONIMOIDEA | | | | | | | |
| INFRAORDER PHYSOCEPHALATA | | | | | | | |
| FAMILY PHRONIMIDAE | | | | | | | |
| GENUS *Phronima* | | | | | | | |
| SPECIES *Phronima sedentaria* (Forskål, 1775) | 364 | 57.14 | 66 | 16.5 | 40 | 63.49 | 1 |
| FAMILY PHROSINIDAE | | | | | | | |
| GENUS *Phrosina* | | | | | | | |
| SPECIES *Phrosina semilunata* Risso, 1822 | 74 | 11.62 | 19 | 4.75 | 8 | 12.70 | 4 |
| FAMILY LESTRIGONIDAE | | | | | | | |
| GENUS *Phronimopsis* | | | | | | | |
| SPECIES *Phronimopsis* sp. | 5 | 0.78 | - | - | 1 | 1.59 | |
| SUPERFAMILY PLATYSCELOIDEA | | | | | | | |
| FAMILY PLATYSCELIDAE | 1 | 0.16 | 1 | 0.25 | 1 | 1.59 | |
| ORDER STOMATOPODA | | | | | | | |
| SUPERFAMILY SQUILLOIDEA | | | | | | | |
| FAMILY SQUILLIDAE | 1 | 0.16 | 1 | 0.25 | 1 | 1.59 | |
| ORDER DECAPODA | 2 | 0.31 | 2 | 0.5 | 2 | 3.17 | |
| SUBORDER PLEOCYEMATA | | | | | | | |
| INFRAORDER BRACHYURA | 87 | 13.66 | 10 | 2.5 | 17 | 26.98 | 3 |
| FAMILY PANDALIDAE | | | | | | | |
| GENUS *Heterocarpus* | | | | | | | |
| SPECIES *Heterocarpus ensifer* Milne-Edwards, 1881 | 1 | 0.16 | 3 | 0.75 | 1 | 1.59 | |
| **PHYLUM CHORDATA** | | | | | | | |
| SUBPHYLUM VERTEBRATA | | | | | | | |
| CLASS OSTEICHTHYES | | | | | | | |
| INFRACLASS TELEOSTEI | | | | | | | |
| ORDER PERCIFORMES | | | | | | | |
| FAMILY GEMPYLIDAE | 1 | 0.16 | 2 | 0.5 | 1 | 1.59 | |
| GENUS *Gempylus* | | | | | | | |
| SPECIES *Gempylus serpens* Cuvier, 1829 | 1 | 0.16 | 8 | 2 | 1 | 1.59 | 10 |
| ORDER TETRAODONTIFORMES | | | | | | | |
| FAMILY DIODONTIDAE | | | | | | | |
| GENUS *Diodon* | | | | | | | |
| SPECIES *Diodon hystrix* Linnaeus, 1758 | 1 | 0.16 | 3 | 0.75 | 1 | 1.59 | |
| UNIDENTIFIED TELEOSTEI | 24 | 3.77 | 262 | 65.5 | 19 | 30.16 | 2 |
| SUBPHYLUM TUNICATE | | | | | | | |
| FAMILY SALPIDAE | 15 | 2.35 | 5 | 1.25 | 6 | 9.52 | 6 |
| **PHYLUM MOLLUSCA** | | | | | | | |
| CLASS GASTROPODA | | | | | | | |
| ORDER PTEROPODA | | | | | | | |
| FAMILY CAVOLINIIDAE | | | | | | | |
| GENUS *Cavolina* | | | | | | | |
| SPECIES *Cavolinia gigas* | 3 | 0.47 | - | - | 2 | 3.17 | |
| SPECIES *Cavolinia uncinata* (Rang, 1829) | 33 | 5.18 | 2 | 0.5 | 9 | 14.29 | 5 |
| ORDER HETEROPODA | 5 | 0.78 | - | - | 4 | 6.35 | 9 |
| CLASS CEPHALOPODA | | | | | | | |
| ORDER OCTOPODA | | | | | | | |
| FAMILY BOLITAENIDAE | | | | | | | |
| GENUS *Japetella* | | | | | | | |
| SPECIES *Japetella diaphana* Hoyle, 1885 (beak) | 1 | 0.16 | - | 0 | 1 | 1.59 | |
| FAMILY OMMASTREPHIDAE (beak) | 3 | 0.47 | - | 0 | 3 | 4.76 | |
| ORDER TEUTHIDA | | | | | | | |
| SUBORDER OEGOPSINA | | | | | | | |
| FAMILY CRANCHIIDAE | 5 | 0.78 | 9 | 2.25 | 4 | 6.35 | 7 |
| UNIDENTIFIED CEPHALOPOD | 1 | 0.16 | 1 | 0.25 | 1 | 1.59 | |
| **TOTAL** | **637** | **100** | **400** | **100** | | | |

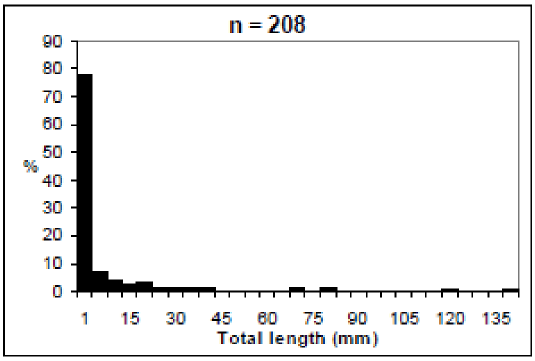


Fig. 3. Prey size distribution of the pelagic stingray.

The pelagic stingray is an epipelagic predator that in the southwestern equatorial Atlantic feeds mainly upon small crustaceans, especially hyperiid amphipods, brachyuran megalopae, and also pteropods, fish and cephalopods. The pelagic feeding habits are further confirmed by the presence of pelagic stingrays in drift gill-net fisheries off southern California (HANAN et al., 1993) and in the Gulf of California (DÁVALOS-DEHULLU; GONZÁLEZ-NAVARRO, 2003).

The stingray catches the bait by wrapping their wings around it and nibbling it until it is gone or until they are hooked (MOLLET, 2002). Bigelow and Schroeder (1962) found two seahorses *Hippocampus* sp., two small shrimps, and fragments of squid in one specimen. SCOTT; TIBBO (1968), found parts of a thalassinoid decapod in a specimen from the northwestern Atlantic, and Wilson and Beckett (1970) found sargassum weed, squid beaks, seahorses, unidentified fish and coelenterates in 16 specimens from the North Atlantic. Two semi-digested skulls of *Scomber japonicus* with a standard length of 235 mm were found in the stomach of a female *P. violacea* in the Gulf of California (DÁVALOS-DEHULLU; GONZÁLEZ-NAVARRO, 2003), although the authors did not comment on the possibility of these *S. japonicus* originating from longline bait. Ribeiro-Prado and Amorim (2008) found mollusca as the most common group, noting also Actinopterygii fishes and Crustaceans in stomachs of *P. violacea*. Siqueira and Sant'Anna (2007) observed only unidentified teleost remains (vertebrae fragments and crystallines).

The dorsal and ventral dark violet color may help to camouflage the pelagic stingrays while they seek pelagic prey in the water column. Besides, the teeth of the pelagic stingray differs from those of most other rays of the Dasyatidae by the presence of cuspidate cutting teeth in both male and female jaws, which contrast with the crushing dentitions of their demersal relatives. These cutting teeth are probably more efficient for grasping small crustaceans. Differences found in the dentition and the swimming behavior of this species, in relation to other *Dasyatis* spp., appear to be autapomorphic (character state that is unique to a particular species or lineage in the group under consideration) functional adaptations to a pelagic lifestyle and a diet of fish and squid (ROSENBERGER, 2001), although prey preferences may vary, as observed in this study, where small crustaceans were more important than fish and squid.

The data and comments above suggest that the *P. violacea* alter their food items according to their geographical location and also shows how the species, despite belonging to the Dasyatidae family, is adapted to the pelagic environment.

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*3.2. Artigo científico II*

# Reproductive Biology of the Pelagic Stingray, *Pteroplatytrygon violacea* (Bonaparte, 1832), in the Equatorial and Southwestern Atlantic Ocean

**ABSTRACT**

We studied its reproductive biology in the equatorial and southwestern Atlantic off Brazil, by examining a total of 480 specimens, 188 females (39.2%) and 292 males (60.8%), with a sex ratio of 1.5 male:1 female, taken in the commercial longline fishery between October 2005 and March 2010. Sizes, as measured by disc width ($D_W$), ranged from 28.0-66.0cm (mean ± S.E. = 50.0 ± 0.4cm $D_W$) for females and from 34.0-59.6cm (mean ± S.E. = 45.5 ± 0.1cm $D_W$) for males. Females were classified as juvenile (n= 42; 22.7%); maturing (n= 67; 36.2%); pre-ovulatory (n= 28; 15.1%); pregnant stage 1 (n= 17; 9.2%); pregnant stage 2 (n= 13; 7.0%); pregnant stage 3 (n= 2; 1.1%); postpartum (n= 6; 3.2%); and resting (n= 10; 5.4%). Pregnant females in stages 1-3 (n=32, 17.3%) ranged between 48.0-60.0 cm $D_W$. Size at first sexual maturity was estimated at ca. 50.0cm $D_W$ for females and ca. 42.0cm $D_W$ for males, since all sampled specimens equal or larger than this size were all already mature. Ovarian fecundity, considering only follicles larger than >0.5cm in diameter, ranged from 1-17 (mean ± S.E. of 5.4 ± 0.3, n= 72) follicles/female and the uterine fecundity of embryos in pregnant females in stages 2 and 3 ranged from 1-5 (mean ± S.E.= 3.5 ± 0.3, n= 15) embryos/female. The sex ratio between the embryos was equal (0.9 male:1 female) and the size at birth was 19.0cm $D_W$. Considering that the pelagic stingray is a common bycatch of worldwide oceanic longline fisheries, the high degree of underreporting of their catches, the likely high mortality of discarded specimens, and the life history parameters of this batoid species, the adoption of specific conservation measures for this species should be considered as a matter of urgency.

***Keywords***: Elasmobranchs, Reproduction, Maturity, Bycatch, Dasyatidae, Brazil

## Introduction

Pelagic sharks and rays form a relatively small group with low diversity, representing about 6% of all living species of elasmobranchs. Only 64 species of sharks and rays inhabit oceanic regions, a number that is very low when compared to elasmobranch biodiversity in coastal areas (Camhi *et al*., 2009). A prominent member of the oceanic community is the pelagic stingray, *Pteroplatytrygon violacea,* which has been reported as an important bycatch species in many of the tuna and swordfish longline fisheries throughout the world (Wilson & Beckett, 1970; Amorim *et al*., 1998; Mollet, 2002; Domingo *et al*., 2005; Joung *et al*., 2005; Somvanshi, *et al*., 2009). It is the only species of the batoid family Dasyatidae that is fully pelagic (Wilson & Beckett, 1970), being distributed in oceanic areas, in relatively shallow waters, up to 100m in depth (Wilson & Beckett, 1970; Last & Stevens, 1994). Tortonese (1956) suggested that this species was abundant only in the Mediterranean Sea, being rare in other places. Several recent papers, however, have shown that pelagic stingrays have a worldwide distribution, with highest abundance in tropical and subtropical regions, but being also found in higher latitudes (Wilson & Beckett, 1970; Last & Stevens, 1994; Mollet, 2002; Hemida *et al*., 2003; Domingo *et al*., 2005; Ellis, 2007; Veras *et al*., 2009; Zacharia *et al*., 2011).

There is no comprehensive information regarding the life history of the pelagic stingray throughout its geographic range. Little is known about the reproductive biology of the species, but some authors (Mollet, 2002; Hemida *et al*., 2003; Bester *et al*., 2005; Neer, 2008) have suggested reproduction and development is viviparous with uterolactation and a gestation period between 2 and 4 months. Captive data suggest that pelagic stingrays have litters of 4-13 young, ranging from 14.0 to 24.0cm at birth, and that ovulation in captivity may occur twice per year (Mollet *et al*., 2002).

Since February 2007, the pelagic stingray has been listed in the low-risk category of "Least Concern" by the IUCN (International Union for Conservation of Nature and Natural Resources), a classification, however, that suffers from a paucity of available life history and fishery data. Information on the reproduction of the pelagic stingray in the wild is particularly limited (Snelson *et al*., 2008). In Brazil, very little has been published so far on the species, with studies of natural history being especially scarce (Siqueira & Sant'Anna, 2007; Ribeiro-Prado & Amorim, 2008; Ribeiro-Prado *et al*., 2009; Veras *et al*., 2009). As a result, the actual status of their stock(s) in the western Atlantic, as in other areas of the world, is still largely unknown. Any fishing activity that results in fishery-related mortality of elasmobranchs, either at-vessel or as catch, whether as a target or especially as poorly recorded bycatch, must always be accompanied by scientific research that address life history and population dynamics in order to allow for proper assessment of the exploited stocks. The present study therefore was undertaken to help fill current gaps in our knowledge of the biology and population dynamics of pelagic stingrays in the southwestern and equatorial Atlantic Ocean.

## Material and Methods

### *Data collection*

A total of 480 specimens of pelagic stingrays were analyzed, of which 292 were male (60.8%) and 188 were females (39.2%). All specimens were collected between October 2005 and March 2010 by onboard observers of the Brazilian National Observer Program monitoring the Brazilian pelagic longline fleet that targets tunas and swordfish. Although the fishing ground was delimited by the square of 09°N, 28°S, 018°W and 053°W, pelagic stingrays were only caught between 06°N, 22°S, 018°W and 037°W (Fig. 1).

Captured specimens were labeled and quickly frozen for days up to months, depending on how long the vessel was at sea. Later, in the laboratory, they were thawed, weighted (g) (total weight: $W_{T,}$ and eviscerated weight: $W_E$) and measured (cm) (disc width: $D_W$; and disc length: $D_L$). It was not possible to measure the total length because, for safety reasons, the tail is cut off onboard.

For females, the liver, ovary, oviducal gland and uteri were removed. Data collected included, liver and ovary weight (LW and OW), and oviducal gland (OG) width, ovary (OV) width and uterus length and width, in cm. The development stage of the ovary was observed macroscopically and the diameter of the largest ovarian follicle (DLOF) was measured (Castro *et al*., 1988; Bridge *et al*., 1998). Ovarian fecundity was estimated by counting the number of ovarian follicles larger than 0.5cm in diameter in each mature female. The uteri were longitudinally sectioned in order to allow the examination of contents. Whenever eggs or embryos were present, they were counted, with embryo sex, total weight, total length, disc width and length being recorded. Uterine fecundity was estimated by counting the number of embryos occurring in each female during pregnancy.

In males, the testes were extracted, weighed ($W_{TES}$) and measured (length and width). The lengths of claspers were also measured (Compagno, 2002) and their calcification stage assessed as flexible, semi-calcified or calcified, the latter generally regarded as an indication of male sexual maturity.

Macroscopic examination allowed for assignment of each specimen to a specific maturity stage. Females were classified based on the dimensions of the ovary, oviducal gland and uterus, and by the uterine contents (eggs or embryos). Males were classified based on the calcification of the claspers and testes development.

All females and males reproductive organs were measured to the nearest 0.1mm using Vernier calipers and weighted using digital scales. All material weighting more than 1,000g were weighted on a scale with 10g accuracy, the material weighting less than 1,000g was weighted on a precision scale with 0.1g accuracy.

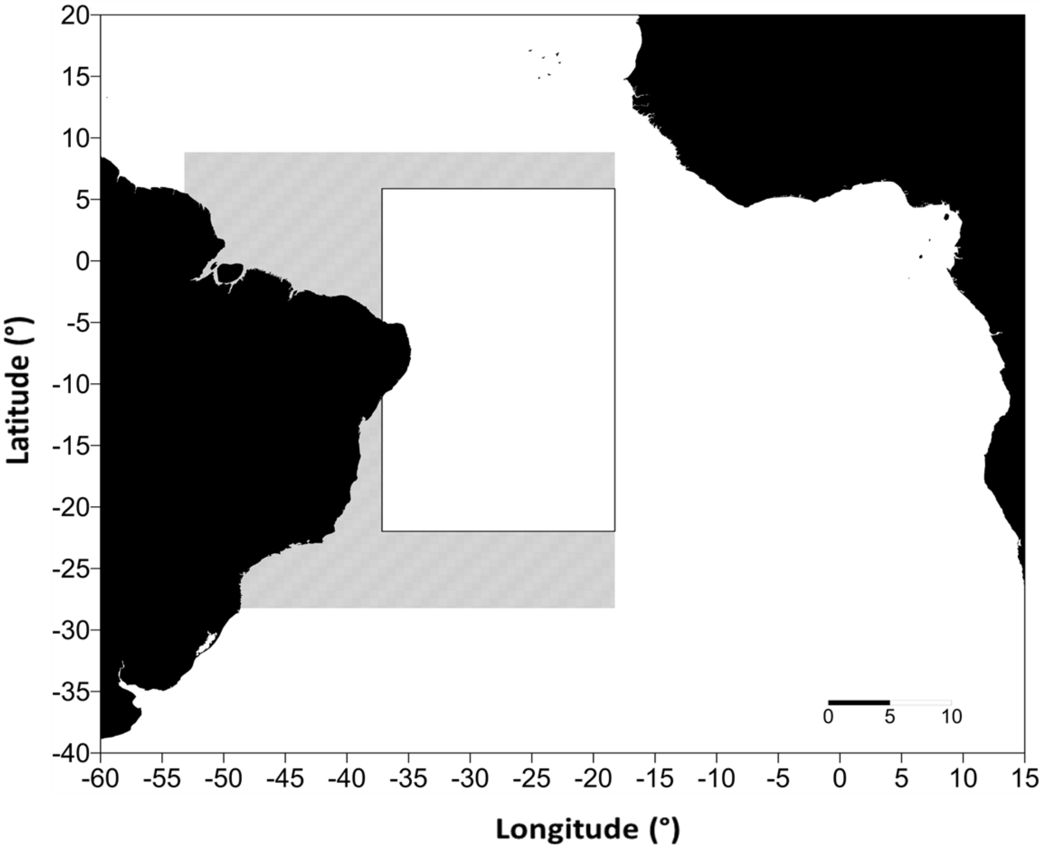


**Figure 1.** Sampling area for pelagic stingray, *Pteroplatytrygon violacea*, in the equatorial and southwestern Atlantic Ocean, highlighted rectangle showing the fishing area and white rectangle showing the area where the pelagic stingrays were caught.

*Maturity Characterization*

The reproductive stages of males and females were assigned using the characteristics defined in Tables 1 and 2. Based on the development of their claspers and testes, males were classified into juvenile, maturing and adult (Table 1). Of the 292 males sampled, in six of them the maturity stage was assigned solely based on the disc width and clasper calcification, since it was not possible to collect the reproductive tract. Depending on the development of the ovary, oviducal gland and uteri, females were separated into six sequential stages: juvenile, maturing, pre-ovulatory, pregnant, postpartum and resting. Juvenile females were characterized by undeveloped and undifferentiated reproductive organs, while maturing individuals had developing ovary with few vitellogenic follicles and little expanded uterus. The pre-ovulatory stage was characterized by developed ovary and enlarged uteri, while pregnant females had completed ovulation and their uteri contained either eggs or embryos (Table 2). For a better understanding, pregnant individuals were classified according to the development of uterine content (eggs and embryos) as: stage 1 (only eggs present), stage 2 (presence of embryos in early and middle development), and stage 3 (embryos approaching parturition) (Table 2). Postpartum females contained a developed ovary and enlarged and empty uteri with well-developed uterine villi present, while resting females had only a slightly enlarged ovary, and enlarged and flaccid uteri (Table 2).

**Table 1.** Characteristics of maturation stages of male pelagic stingray, *Pteroplatytrygon violacea*.

| Stage | Clasper | Testes |
|---|---|---|
| **Juvenile** | Flexible. | Narrow and only slightly enlarged |
| **Maturing** | Calcifying. | Developed, seminal fluid in vas deferens. |
| **Adult** | Fully calcified. | Well developed, seminal fluid in vas deferens. |

**Table 2.** Characteristics of maturation stages of female pelagic stingray, *Pteroplatytrygon violacea*.

| Stage | Ovary | Oviducal gland | Uterus |
|---|---|---|---|
| **Juvenile** | Undeveloped, with translucent follicles. | Undifferentiated or little developed. | Narrow or filiform, uterine villi absent or tiny. |
| **Maturing** | Developing with yellowish follicles. | Developing. | Expanded, developing uterine villi present. |
| **Pre-ovulatory** | Developed with vitellogenic follicles. | Enlarged and developed. | Enlarged, developing and developed uterine villi present. |
| **Pregnant** | | | |
| **Stage 1** | Developed with vitellogenic and translucent follicles. | Developed. | Enlarged, ova presence and early developed uterine villi present. |
| **Stage 2** | Developed with vitellogenic and translucent follicles. | Developed. | Enlarged, embryos presence moderately developed uterine villi present. |
| **Stage 3** | Developed with vitellogenic follicles (2 observations). | Developed, (2 observations). | Enlarged, (2 observations): embryos with totally consumed with yolk sac, highly developed uterine villi present. |
| **Postpartum** | Developed with vitellogenic follicles. | Developed. | Enlarged and empty, well and fully developed uterine villi present. |
| **Resting** | Slightly enlarged, with atresic follicles, presence of corpora lutea. | Enlarged. | Enlarged and flaccid, very small uterine villi present. |

*Data analyses*

Sexual differences in the size (disc width and length) and mass (weight) distribution of the samples between males and females were compared using Mann-Whitney *U*-test. The relationships between $D_W$ x $D_L$ and $W_T$ x $W_E$ between sexes were described using the equations $D_L = a + D_W b$ and $W_E = a + W_T b$ (Ebert & Cowley, 2009). The relationships between lengths ($D_W$) and weights ($W_T$ and $W_E$) of both sexes were calculated with linear regressions. The regressions were estimated separately for males and females using the equations $\ln W_E$

= $\ln a + b\ln D_W$ and $\ln W_T = \ln a + b\ln D_W$, and then compared using Analysis of Covariance (ANCOVA), with the values referring to the weight of individuals being logarithm transformed. A paired Student's t-test was used to test if there was a significant difference between the weights of the left and right testes. Since there was a significant difference, linear regressions between $D_W$ and $W_{TES}$ left and right were calculated and analyzed using ANCOVA, with the data being logarithm transformed. A Chi-Square ($\chi^2$) goodness-of-fit test was used to test the hypothesis of a 1:1 sex ratio among examined specimens and embryos taken from pregnant females in stages 2 and 3.

## Results

### *Size composition and sex ratio*

The sex ratio of the 480 specimens examined was biased towards males (292 males x 188 females) resulting in a sex ratio of 1.5 male: 1 female. Statistical differences ($P < 0.05$) in sex ratios, however, were observed only in the months of January ($\chi^2$ = 0.006), February ($\chi^2$ = 0.003) and July ($\chi^2$ = 0.003). In general, females were larger and heavier than males (Table 3). The most frequent size class of males was 40.0-50.0cm $D_W$, while females had the largest number of individuals included in the 50.0-55.0cm size class (Fig. 2). Significant differences were observed between sexes in terms of $D_W$ (Mann-Whitney *U*-test, $n_{males}$ = 291, $n_{females}$ = 188, $P < 0.05$), $D_L$ (Mann-Whitney *U*-test, $n_{males}$ = 289, $n_{females}$ = 187, $P < 0.05$), $W_T$ (Mann-Whitney *U*-test, $n_{males}$ = 291, $n_{females}$ = 188, $P < 0.05$), and $W_E$ (Mann-Whitney *U*-test, $n_{males}$ = 291, $n_{females}$ = 188, $P < 0.05$). Linear regressions between $D_W$ and $D_L$ and between $W_T$ and $W_E$ separated for males and females are presented in Table 4. There were statistically significant differences in the correlations between weight ($W_T$ and $W_E$) and disc width and length of males and females (ANCOVA, d.f. = 1, 475, $P < 0.05$) (Table 5).

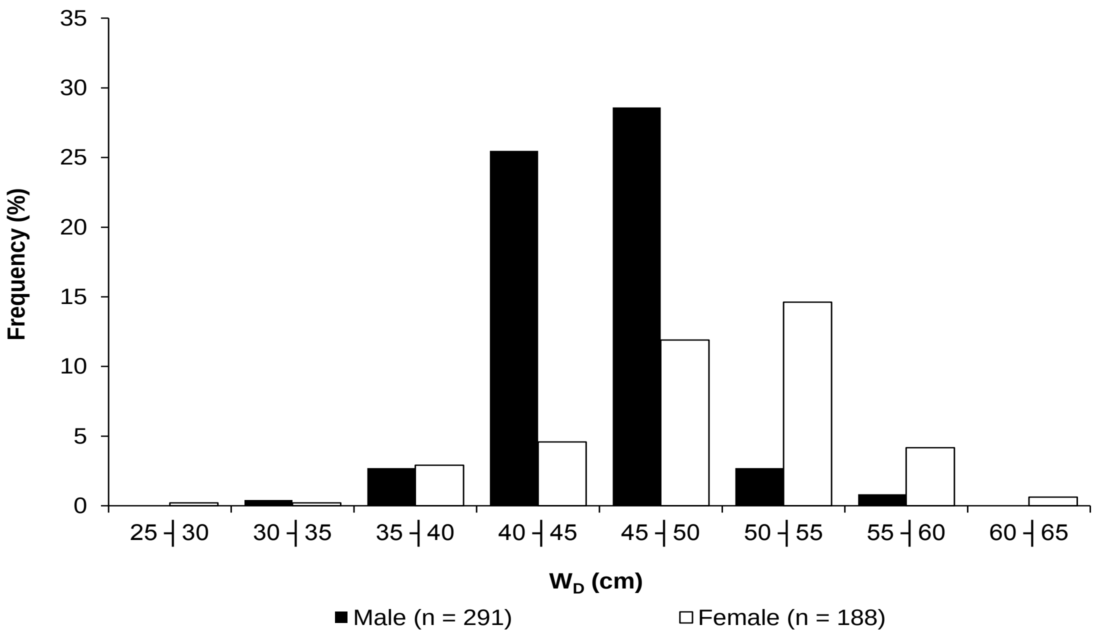


**Figure 2.** Disc width ($D_W$) frequency distribution (5cm intervals) of the pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean.

**Table 3.** Length and weight parameters for males and females of the pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean.

| | Male | | Female | |
|---|---|---|---|---|
| **Parameter** | Range | mean ± | Range | mean ± |
| Disc width (cm) | 34.0-59.6 | S.E.= 45.5 ± 0.1 | 28.0-66.0 | S.E.= 49.4 ± 0.4 |
| Disc length (cm) | 25.0-46.0 | S.E.= 33.8 ± 0.2 | 20.6-50.5 | S.E.= 37.1 ± 0.4 |
| Total weight (g) | 780.0-3,660.0 | S.E.= 1,924.0 ± 25.6 | 380.0-6,420.0 | S.E.= 2,732.0 ± 75.2 |
| Eviscerated weight (g) | 620.0-3,220.0 | S.E.= 1,656.0 ± 22.7 | 340.0-5,400.0 | S.E.= 2,223.0 ± 59.1 |

**Table 4.** Linear regressions for males and females of the pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean.

| **Male**<br>(n= 290, range= 34.0-59.6;<br>mean= 45.5 ± 0.1cm $D_W$) | | **Female**<br>(n= 184, range= 28.0-66.0;<br>mean 49.4 ± 0.4cm $D_W$) | |
|---|---|---|---|
| **Equation** | $r^2$ | **Equation** | $r^2$ |
| $\ln D_L = 1.0659 \ln D_W - 0.5429$ | 0.8183 | $\ln D_L = 1.1126 \ln D_W - 0.7227$ | 0.9154 |
| $\ln W_E = 0.9987 \ln W_T - 0.1414$ | 0.9522 | $\ln W_T = 0.941 \ln W_E + 0.2627$ | 0.9766 |
| $\ln W_T = 2.599 \ln D_W - 2.377$ | 0.7186 | $\ln W_T = 3.1294 \ln D_W - 4.3482$ | 0.8378 |
| $\ln W_E = 2.6446 \ln D_W - 2.7026$ | 0.7104 | $\ln W_E = 2.9591 \ln D_W - 3.8851$ | 0.8263 |
| $\ln W_T = 2.1401 \ln D_L - 0.0032$ | 0.6742 | $\ln W_T = 2.6354 \ln D_L - 1.6755$ | 0.8034 |
| $\ln W_E = 2.1408 \ln D_L - 0.157$ | 0.6442 | $\ln W_E = 2.4882 \ln D_L - 1.3443$ | 0.7904 |

**Table 5.** Correlations between total and eviscerated weights and disc width and length of male and female pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean.

| | Male x female | |
|---|---|---|
| **Relationships** | β x β | α x α |
| | *P* | *P* |
| $W_T$ vs $D_W$ | $6.809359e^{-05}$ | 0.0001192368 |
| $W_E$ vs $D_W$ | 0.01264585 | 0.01455276 |
| $W_T$ vs $D_L$ | $6.961155e^{-05}$ | 0.000158338 |
| $W_E$ vs $D_L$ | 0.004531781 | 0.006228063 |

## *Female Reproductive Cycle*

Only the left ovary, oviducal gland and uterus are functional in the pelagic stingray. The species is characterized by aplacental viviparous reproduction and lecitotrophic embryos with a large yolk sac that is fully absorbed prior to parturition. The uterus has trophonemata, long villous extensions of the uterine epithelium that secrete energy-rich histotrophe or "uterine milk" that is absorbed or ingested by the embryos.

All but three of the 188 examined females could have their reproductive organs analyzed. The females were classified as Juvenile (n= 42; 22.7%); Maturing (n= 67; 36.2%); Pre-ovulatory (n= 28; 15.1%); Pregnant, subclassified into three stages: Pregnant stage 1 (n= 17; 9.2%); Pregnant stage 2 (n= 13; 7.0%) and Pregnant stage 3 (n= 2; 1.1%); Postpartum (n= 6; 3.2%); and Resting (n= 10; 5.4%) (Table 6 e 7).

Based on ovary weight, DLOF and width of the oviducal gland and uterus (Fig. 3, Fig.4, Fig. 5 and Fig. 6), females of the pelagic stingray start to mature at about 45 cm and reach first sexual maturity at about 50.0cm $D_W$, corresponding to 75.7% of the maximum (66,0cm) $D_W$ observed in this study. The first maturing and pregnant females were 45.0 and 48.0 cm $D_W$ respectively and 74.4% of the 188 females analyzed in this study were mature.

**Table 6**. Characteristics of maturity stages of female pelagic stingrays, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean.

| | **Stages** | | | | |
|---|---|---|---|---|---|
| | **Juvenile (42)** | **Maturing (67)** | **Pre-ovulatory (28)** | **Potspartum (6)** | **Resting (10)** |
| **$D_W$ (cm)** | 28.0-47.0 | 45.0-57.7 | 49.2-66.0 | 51.0-63.2 | 50.2-56.5 |
| **mean ±** | S.E. = 41.1 ± 0.05 | S.E. = 50.1 ± 0.01 | S.E. = 53.7 ± 0.1 | S.E. = 55.4 ± 0.8 | S.E. = 52.9 ± 0.2 |
| **OW (g)** | 0.1-1.9 | 0.4-7.0 | 2.1-18.5 | 3.0-4.0 | 0.6-1.8 |
| **mean ±** | S.E.= 0.8 ± 0.01 | S.E.= 2.8 ± 0.04 | S.E.= 9.2 ± 0.2 | S.E.= 3.3 ± 0.08 | S.E.= 1.0 ± 0.05 |
| **DLFO (cm)** | 0.3-0.8 | 0.5-1.2 | 1.2-2.1 | 1.1-1.6 | 0.3-0.8 |
| **mean ±** | S.E.= 0.5 ± 0.0 | S.E.= 0.8 ± 0.0 | S.E.= 1.6 ± 0.01 | S.E.= 1.3 ± 0.03 | S.E.= 0.5 ± 0.02 |
| **OGW (cm)** | 0.4-1.0 | 1.0-1.7 | 1.2-1.9 | 1.3-1.5 | 0.9-1.4 |
| **mean ±** | S.E.= 0.8 ± 0.0 | S.E.= 1.1 ± 0.0 | S.E.= 1.4 ± 0.01 | S.E.= 1.4 ± 0.02 | S.E.= 1.1 ± 0.01 |
| **UW (cm)** | 0.5-3.0 | 2.3-6.0 | 4.3-8.2 | 5.4-7.1 | 2.7-5.5 |
| **mean ±** | S.E.= 1.9 ± 0.01 | S.E.= 3.8 ± 0.01 | S.E.= 5.7 ± 0.04 | S.E.= 6.0 ± 0.1 | S.E.= 4.2 ± 0.09 |

*$D_W$ = disc width; OW = ovary weight; DLFO = diameter of the largest ovarian follicle; OGW = Oviducal gland width; UW = Uterus width

**Table 7**. Characteristics of pregnant stages of female pelagic stingrays, *Pteroplatytrygon violacea* taken in the equatorial and southwestern Atlantic Ocean.

| | **Pregnant (32)** | | |
|---|---|---|---|
| | **Stage 1 (17)** | **Stage 2 (13)** | **Stage 3 (2)** |
| **$D_W$ (cm)** | 48.0-58.0 | 49.1-60.0 | 50.0-54.0 |
| **mean ±** | S.E. = 52.2 ± 0.1 | S.E. = 53.4 ± 0.2 | S.E. = 52.0 ± 1.4 |
| **OW (g)** | 0.6-1.5 | 0.7-8.5 | 3.4-7.0 |
| **OW mean ±** | S.E.= 4.4 ± 0.2 | S.E.= 4.3 ± 0.2 | S.E.= 5.2 ± 1.2 |
| **DLFO (cm)** | 0.5-1.8 | 0.6-1.4 | 1.5-2.0 |
| **mean ±** | S.E.= 0.8 ± 0.02 | S.E.= 0.9 ± 0.03 | S.E.= 1.7 ± 0.1 |
| **OGW (cm)** | 1.0-1.3 | 1.1-1.8 | 1.6-2.0 |
| **mean ±** | S.E.= 1.1 ± 0.01 | S.E.= 1.4 ± 0.02 | S.E.= 1.8 ± 0.1 |
| **UW (cm)** | 3.6-6.4 | 5.8-10.5 | 7.4-12.0 |
| **mean ±** | S.E.= 4.5 ± 0.03 | S.E.= 7.7 ± 0.1 | S.E.= 9.7 ± 1.6 |

*$D_W$ = disc width; OW = ovary weight; DLFO = diameter of the largest ovarian follicle; OGW = Oviducal gland width; UW = Uterus width

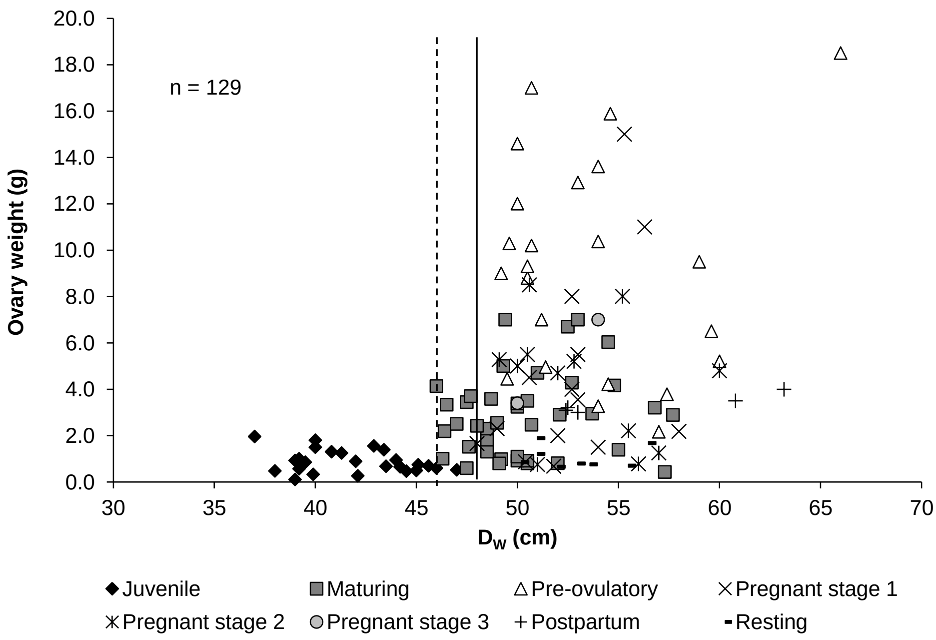


**Figure 3.** Relationship between disc width ($D_W$) and ovary weight for female pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean. The dotted line indicates the first maturing individual and the solid line the first pregnant one.

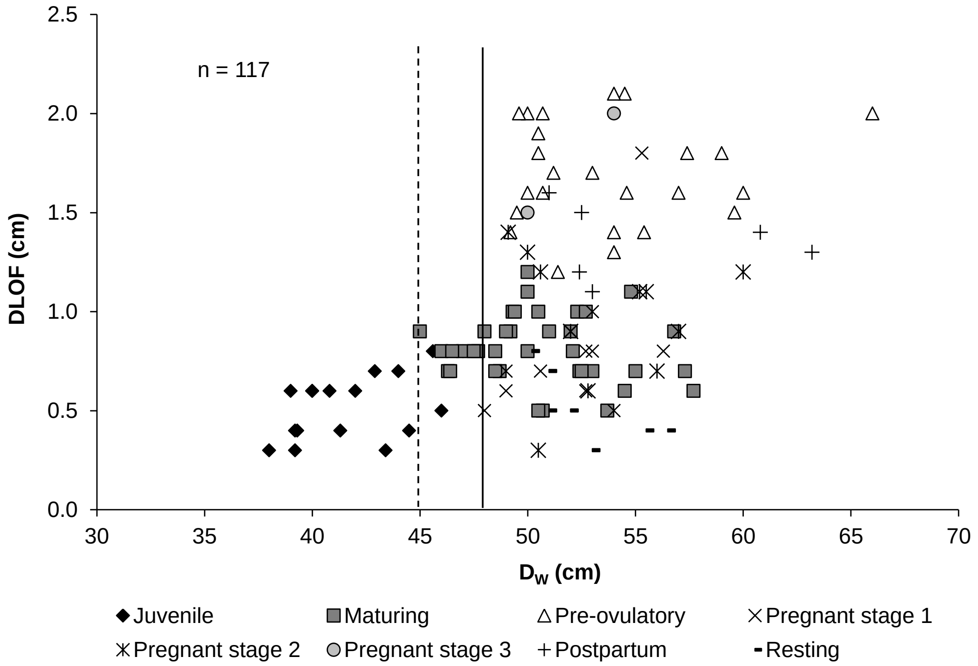


**Figure 4.** Relationship between disc width ($D_W$) and diameter of the largest ovarian follicle (DLOF) for female pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean. Dotted line indicates the first maturing individual and solid line the first pregnant one.

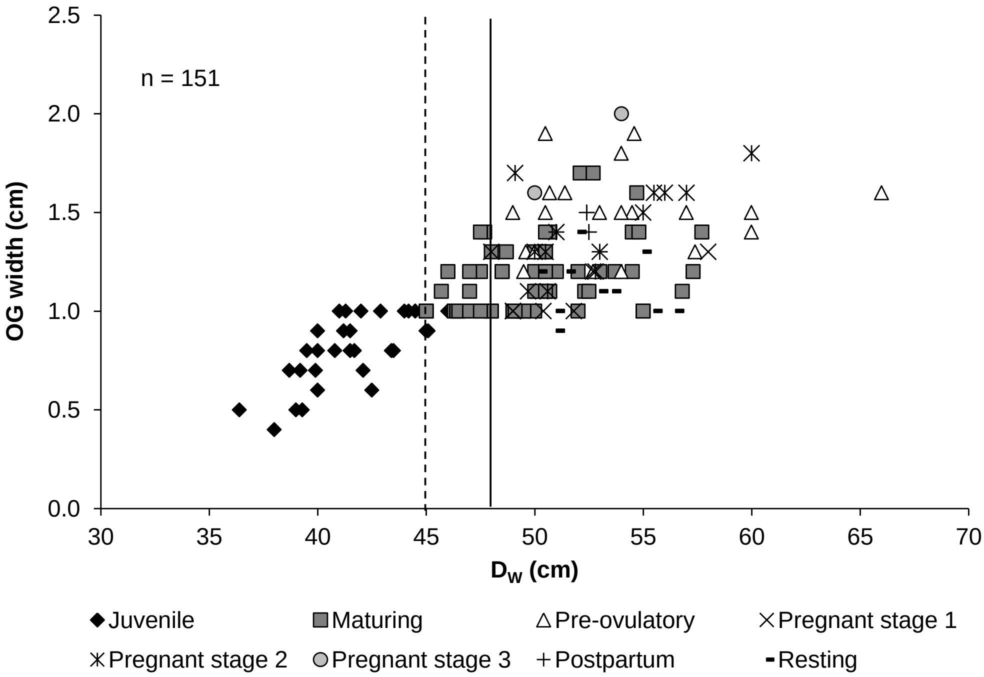


**Figure 5.** Relationship between disc width ($D_W$) and oviducal gland (OG) width for female pelagic stingray *Pteroplatytrygon violacea,* taken in the equatorial and southwestern Atlantic Ocean. Dotted line indicates the first maturing individual and solid line the first pregnant one.

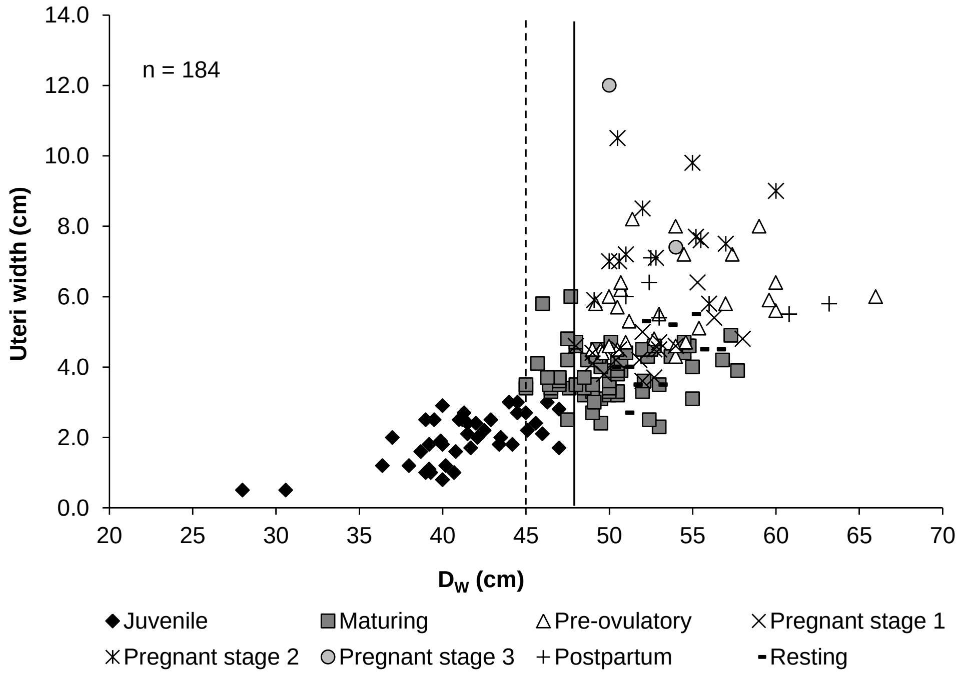


**Figure 6.** Relationship between disc width ($D_W$) and uteri width for female pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean. Dotted line indicates the first maturing individual and solid line the first pregnant one.

Juveniles and pre-ovulatory individuals occurred in all months of the year (Fig.7). Maturing females occurred throughout the year, except in January. Pregnant females (stage 1, 2 and 3) were not encountered in May, August or October, with the highest number (n= 5) of the pregnant stage 1 females being observed in April. The two pregnant stage-3 females with highly developed embryos were observed in June and November. Postpartum females were observed in February, March, August, September and November, while resting females were absent in the first four months of the year.

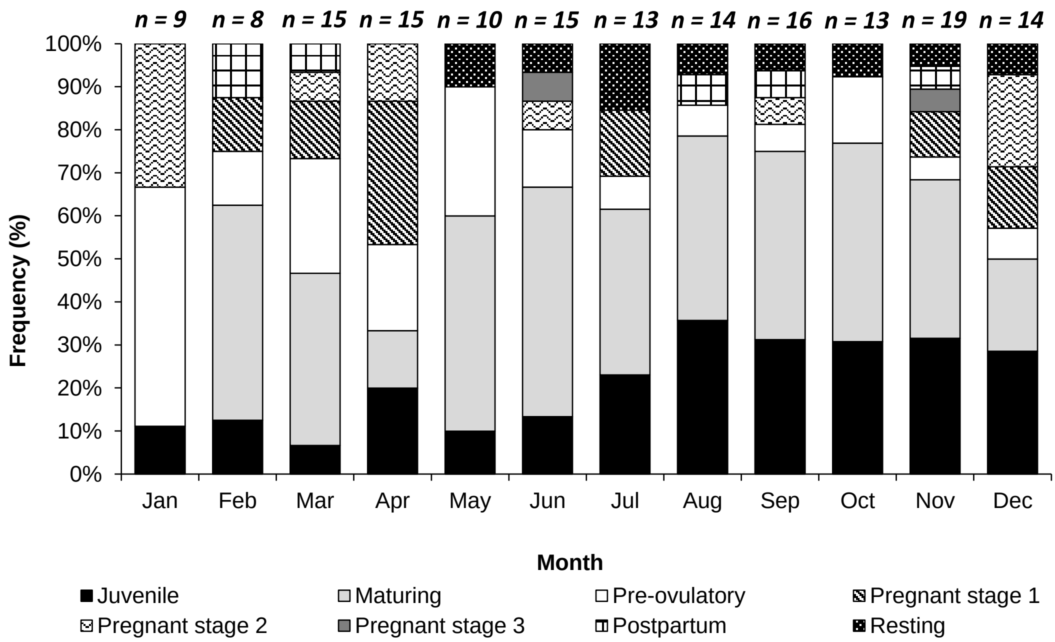


**Figure 7.** Monthly frequency of occurrence of the different maturity stages of female pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean.

*Fecundity and Development*

Ovarian fecundity, based only on follicles larger than 0.5cm in diameter, ranged from 1 to 17 (mean ± S.E.= 5.4 ± 0.3, n= 72). Pre-ovulatory females had the highest number of follicles in the ovary (mean ± S.E.= 6.8 ± 0.7, n= 17). The uterine fecundity of embryos in pregnant females in the stages 2 and 3, ranging between 1 and 5 (mean ± S.E.= 3.5 ± 0.3, n = 15), was lower than ovarian fecundity. There was no relationship between the size of the pregnant female and the number of embryos in the uterus ($r^2 = 0.0094$) (Fig. 8).

The ova inside the uterus were packaged within a cylindrical capsule, while yolk sac-bearing embryos in early and middle development (mean$D_W$ = 4.9-12.2cm, n = 48) were found loose. Full term or near-full term embryos, with the mean $D_W$ at or close to the size at birth (14.2 and 18.8cm, n = 2), had consumed all of the yolk sac, and were positioned in the same direction as their mothers. Embryonic heads were pointed towards the maternal head, and the tips of the pectoral fins were rolled ventrally, resembling the shape of a tube. The embryos also exhibited the characteristic coloration of adult individuals, i.e. a dark purple to blue-green at dorsum and a deep purple to gray ventrally.

Of the 53 observed embryos, 23 were male (43.4%), ranging in mean size from 7.5 to 18.8cm $D_{W,}$ and 25 were female (47.2%), measuring 5.8 to 12.2cm $D_W$. Five (9.4%) 4.9-6.9cm $D_W$ embryos could not be sexed. There was no significant difference in the ratio of male-to-female (0.9:1, $\chi^2 = 0.8$, $P > 0.05$).

The mean disc width ($MD_WE$) of embryos from pregnant stage 2 and 3 females (Fig. 9) did not reveal any seasonal pattern. The smallest embryos (mean = 4.9cm $D_W$) were encountered in April, while larger embryos occurred in March (mean = 12.2cm $D_W$), June (mean = 18.8cm $D_W$, full-term), November (mean = 14.2cm $D_{W,}$ near full-term) and December (mean = 12.2cm $D_W$). Although the relationship between the diameter of the largest ovarian follicle (DLOF) and the embryo mean disc width ($MD_WE$) in pregnant stage 2 and 3, did not show a strong positive relationship ($DLOF = 0.5098 \ln MD_WE - 0.0605$, $r^2 = 0.1932$), the largest $MD_WE$ corresponded to the largest ovarian follicle (Fig. 10).

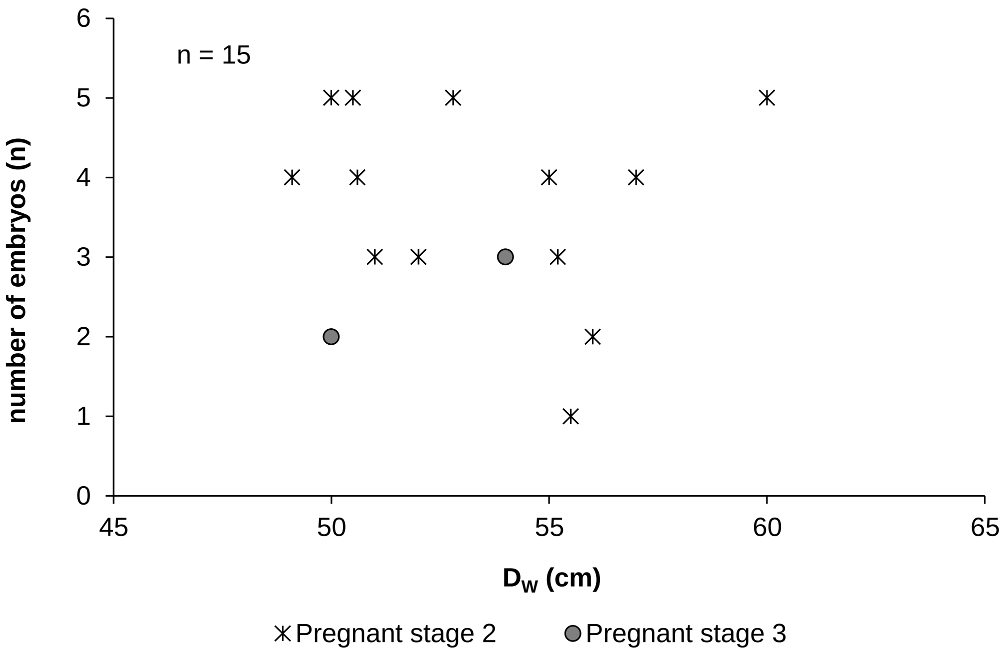


**Figure 8.** Relationship between female pelagic stingray, *Pteroplatytrygon violacea*, disc width ($D_W$) and the number of embryos in uteri in the equatorial and southwestern Atlantic Ocean.

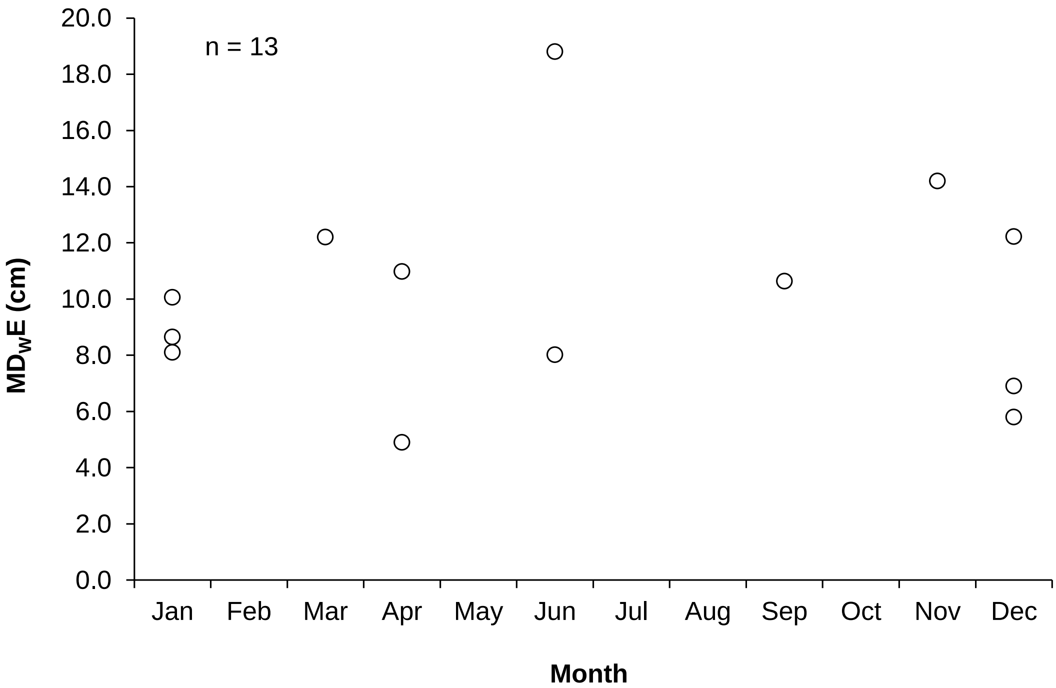


**Figure 9.** Mean disc width ($MD_WE$) of pelagic stingray, *Pteroplatytrygon violacea*, embryos by month, in the equatorial and southwestern Atlantic Ocean.

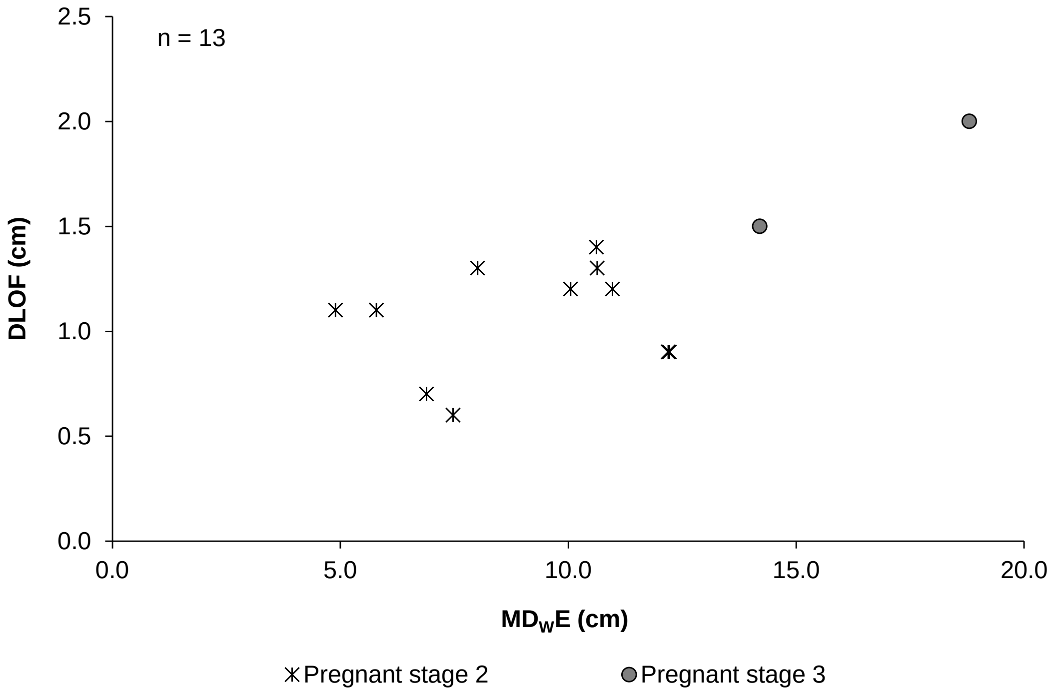


**Figure 10.** Relationship between pelagic stingray, *Pteroplatytrygon violacea*, embryo mean disc width ($MD_WE$) and diameter of the largest ovarian follicle in pregnant stages 2 and 3 females from the equatorial and southwestern Atlantic Ocean.

*Males*

A paired Student's t-test showed a significant difference between the left and right testes weight (t test, $P < 0.05$), but linear regression between disc width and testes weight showed no difference (ANCOVA, P > 0.05).

The collection of the reproductive tract was not possible in six of the 292 males sampled. Males were classified as Juvenile (n= 4; 1.4%); Maturing (n= 15; 5.1%) and Adults (n= 273; 93.5%) (Table 8). Seminal fluid was observed in the vas deferens of both maturing and adult individuals.

Based on sexual parameters, such as clasper length and testes weight in relation to disc width (Fig.11 and 12), males of *P. violacea* reach first sexual maturity at around 42.0cm $D_W$, which corresponds to 63.6% of the maximum $D_W$ observed in this study. The first maturing individual was 37.0cm $D_W$. Based on these results, of the 292 males analyzed in this study, 93.1% were mature.

**Table 8**. Characteristics of maturity stages of male pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean.

| | **Stages** | | |
|---|---|---|---|
| | **Juvenile (4)** | **Maturing (15)** | **Adult(273)** |
| **$D_W$ (cm)** | 34.0-36.0 | 37.3-40.8 | 41.0-59.6 |
| **mean ±** | S.E. = 35.0 ± 0.2 | S.E. = 39.3 ± 0.07 | S.E. = 46.0 ± 0.01 |
| **Clasper length (cm)** | 8.3-8.5 | 8.5-10.0 | 8.8-14.6 |
| **Clasper mean ±** | S.E.= 8.4 ± 0.03 | S.E.= 9.0 ± 0.03 | S.E.= 10.3 ± 0.0 |
| **Test weight (g)** | 0.4-0.9 | 1.3-5.7 | 2.0-16.0 |
| **Test mean ±** | S.E.= 0.6 ± 0.05 | S.E.= 3.2 ± 0.08 | S.E.= 7.2 ± 0.01 |

*$D_W$ = disc width.

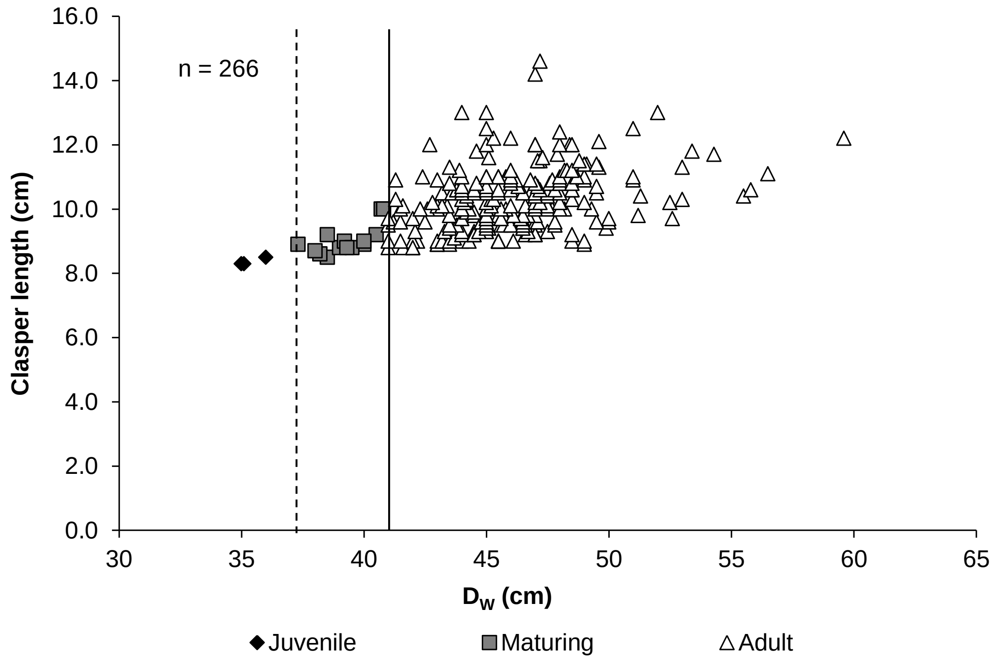


**Figure 11.** Relationship between disc width ($D_W$) and clasper length of male pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean. Dotted line indicates the first maturing individual and solid line the first adult.

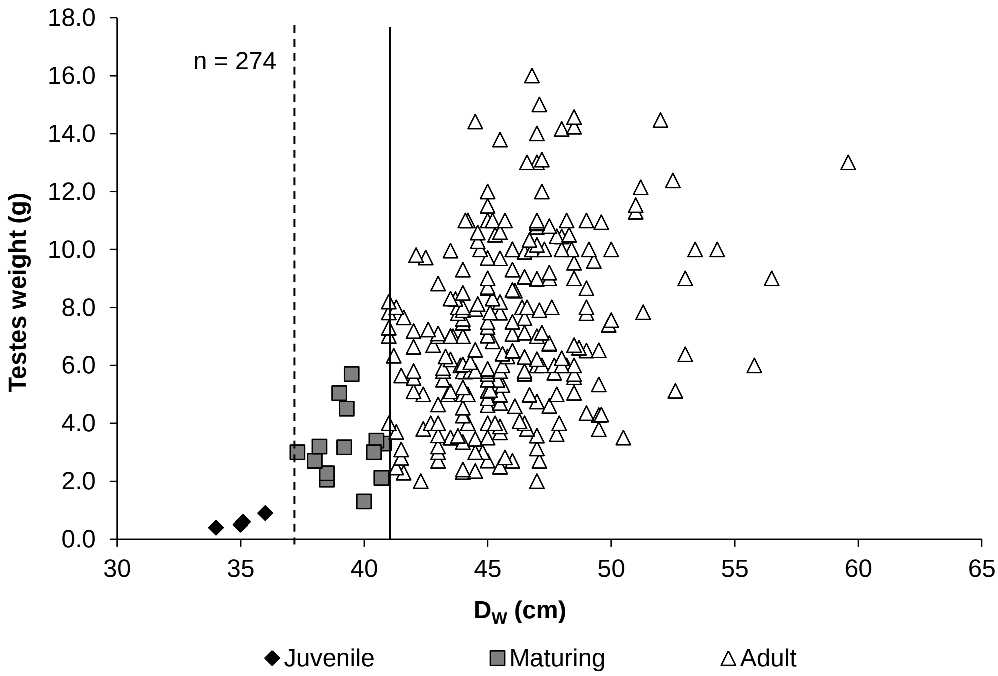


**Figure 12.** Relationship between disc width ($D_W$) and testes weight of male pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean. Dotted line indicates the first maturing individual and solid line the first adult.

Like females, males did not show any seasonal pattern in the frequency of occurrence of maturity stages throughout the year. Adults occurred in all months, with the highest number observed in July (n= 33) (Fig. 13).

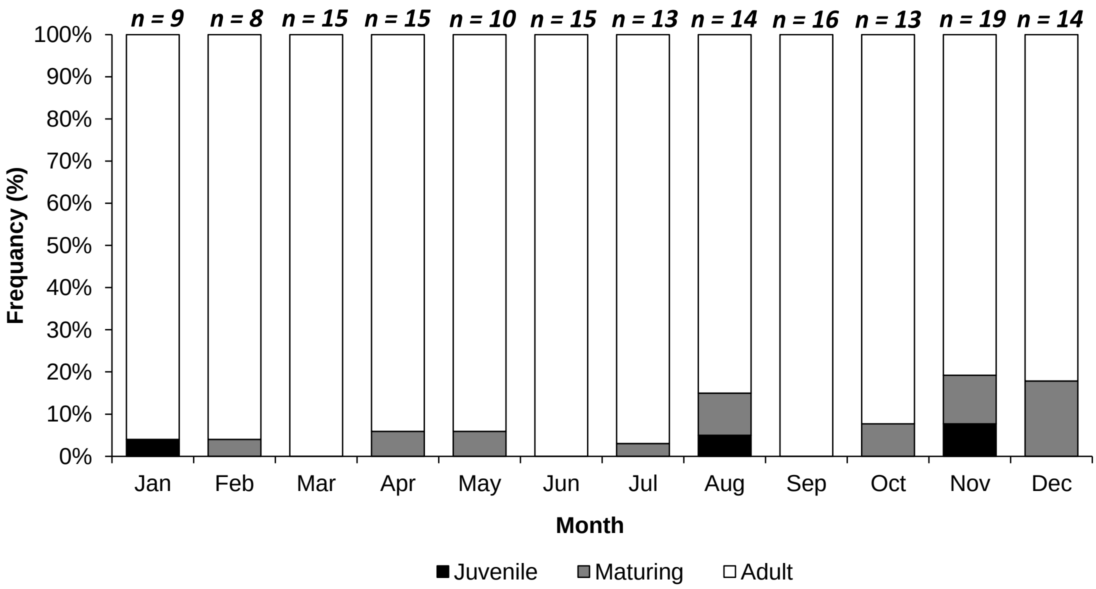


**Figure 13.** Monthly variation of the percentage of occurrence of maturity stages of male pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean.

**Discussion**

Due to the relative scarcity of information regarding the pelagic stingray, some comparisons are made herein with other species of the family Dasyatidae (Table 8). Dasyatids exhibit sexual dimorphism with females maturing and growing to a larger size, and older age, relative to males (Ebert & Cowley, 2009). In the present study, the maximum $D_W$ values (66.0cm) corresponded to 82.5% of the largest $D_W$ (80.0cm) that was previously described in the literature for the species up to 1970 in the Northwest Atlantic (Bigelow & Schroder, 1962; Wilson & Beckett, 1970). Forselledo *et al*. (2008), in the southwestern Atlantic Ocean, based on data collected by the National Observers Program of the Uruguayan Tuna Fleet, subsequently reported the capture of an 84.0cm male and an 82.0cm $D_W$ female. The largest male and female from the present sample were 59.6cm and 66.0 $D_W$, respectively, corresponding to 71.0% and 80.5% of the $D_W$ observed by the referred authors. Mollet *et al*. (2002) cited the largest ever $D_W$ for a female kept in captivity (96.0cm). These differences in size ($D_W$) could be probably related with the capture area.

The smallest free-living individual caught in the present study was a 28.0cm $D_W$ female, equal in size to the smallest female observed by Forselledo *et al*. (2008). The size classes with the highest frequency of males (45.0-50.0cm) and females (50.0-55.0cm) $D_W$ found in the present work were close to the observations of other authors. Mazzoleni and Schwingel (2002), in south regions of Trindade and Martin Vaz islands, Brazil, observed most males and females between 35.0-45.0cm and 50.0-60.0cm $D_W$ respectively; Forselledo *et al*. (2008) found concentrations of males at 40.0-50.0cm and females at 50.0-60.0cm $D_W$; and Neer (2008), in the Southern California Bight region, reported that the majority of males were between 40.0-55.0cm and females between 45.0-60.0cm $D_W$.

The concentration of most individuals in a particular length class is likely related to the method of capture and gear selectivity. Oliveira *et al*. (2010), in the tropical western Atlantic Ocean, offered two hypotheses for the high number of individuals within a small size range: (1) that small specimens were not caught due to size selectivity of the fishing gear; or (2) that small specimens were not caught because they were absent in the study area, suggesting that the juveniles of this species might be occurring either at a different geographical location or at a different depth range than those where the fishery operates. The same alternatives may apply to the pelagic stingray. The smallest specimen observed in this study was almost 10cm larger in $D_W$ than the full-term embryo observed by Hemida *et al*. (2003) from the Mediterranean Sea. Smaller pelagic stingrays off Brazil either inhabit different water depths or regions or are not captured in the fishery. Considering, however, the small size of the mouth of the pelagic stingray, like all dasyatids, and the large size of the hooks (circle hooks (size 18/0, 0◦ offset) and J-style hooks (size 9/0, 10◦ offset) used in the longline tuna fisheries, the second hypothesis seems more plausible.

Females of pelagic stingrays were on average 5.0cm $D_W$ larger and approximately 800.0g heavier than males. Hemida *et al*. (2003) also noted that the size at sexual maturity and maximum size were slightly different between males and females (although different than sizes observed in this study), but they did not find significant differences between the weight of males and females. Other authors also observed a larger size for females of pelagic stingray than for males (Wilson & Beckett, 1970; Tortonese, 1976; Mollet, 2002; Mazzoleni & Schwingel, 2002; Forselledo *et al*., 2008; Neer, 2008; Ribeiro-Prado & Amorim, 2008). This seems to be a characteristic shared by all dasyatids (Table 9).

**Table 9**. Reproductive parameters of the pelagic stingray, *Pteroplatytrygon violacea*, and of other species of the family Dasyatidae.

| Species | Females larger than males | sex ratio (M:F) | $MD_W$ size (cm) (M/F)* | G-P (months) | O-F (nº of oocytes) | U-F (nº of embryos) | Litter disc width at birth (cm) | Local | Author |
|---|---|---|---|---|---|---|---|---|---|
| *Pteroplatytrygon violacea* | Yes | 1.5:1 | 42.0/50.0 | 2-4 | 1-17 | 1-5 | ±19.0 | South Atlantic | Present study |
| *Dasyatis centroura* | Yes | 0.6:1 | 150.0/160.0 | 9-10 | - | 1-6 | 34.0-37.0 | southeastern USA | Struhsaker, 1969 |
| *D. imbricatus* | Yes | 1.05:1 | 16.0/17.0 | 6 | - | 1-2 | 7.5 | Porto Novo | Devadoss, 1978 |
| *D. Sabina* | Yes | 0.4:1 | 20.0/24.0 | 4-4.5 | - | 1-4 | 10.0-13.0 | Mexico | Snelson *et al*., 1988 |
| *D. sayi* | Yes | 0.9:1 | 30.0/50.0 | 9-10 | 1-8 | 1-6 | 15.0-17.0 | Florida | Snelson *et al*., 1989 |
| *D. centroura* | Yes | 0.8:1 | 80.0/100.0 | 4 | 1-5 | 2-8 | 13.7 | Tunisian coasts | Capapé, 1993 |
| *D. longus* | Yes | 1.2:1 | 80.0/110.0 | 10-11 | - | 1-3 | 40.0 | Mexico | Villavicencio-Garayzar *et al*., 1994 |
| *D. Sabina* | Yes | - | 21.0/22.0 | 3-4 | 16 | 1-3 | 10.0 | Florida | Johnson and Snelson, 1996 |
| *D. zugei* | Yes | - | 24.0 (M/F) | 2-4 | - | 1-2 | 8.5-10.0 | India | Devadoss, 1998 |
| *D .jenkinsii* | Yes | - | 40.0/45.0 | 10-12 | - | 2 | 19.0-19.0 | India | Devadoss, 1998 |
| *D. americana* (captive) | Yes | - | 46.0/70.0 | 4.5-7.5 | - | 2-10 | 20.0-34.0 | Captive | Henningson, 2000 |
| *D. pastinaca* | Yes | 1.3:1 | 22.0/24.0 | 5 | - | - | 8.0 | E Mediterranean | Ismen, 2003 |
| *D. marmorata* | Yes | - | 32.9/40.2 | 5 | - | 2-4 | - | Mauritania | Valadou *et al*., 2006 |
| *D. guttata* | Yes | - | - | - | - | 1-2 | 12.0-15.3 | NE Brazil | Yokota and Lessa, 2006 |
| *D. marianae* | Yes | - | - | - | - | 1 | 10.5-13.8 | NE Brazil | Yokota and Lessa, 2006 |
| *D. dipterura* | Yes | 0.4:1 | 46.5/57.3 | - | - | 1-3 | 12.0-16.0 | W Mexico | Smith *et al*., 2007 |
| *D.* cf. *kuhlii* (Java form) | Yes | 0.6:1 | 23.7/23.7 | - | - | - | - | eastern Indonesia | White and Dhamardi, 2007 |
| *D* cf. *kuhlii* (Bali form) | Yes | 0.8:1 | 31.2/35.7 | - | - | 1-2 | 17.2 | eastern Indonesia | White and Dhamardi, 2007 |
| *D. zugei* | Yes | 0.7:1 | 17.2/18.7 | - | - | 1-4 | 7.0-9.0 | eastern Indonesia | White and Dhamardi, 2007 |
| *D. chrysonata* | Yes | 1.3:1 | 39.5/50.5 | 9 | 2-20 | 1-7 | 17.2-18.4 | southern African | Ebert and Cowley, 2009 |
| *Neotrygon kuhlii* | Yes | 0.6:1 | 29.4/31.4 | 4 | - | 1-3 | 11.5-17.0 | Australia | Pierce *et al*., 2009 |

$MD_W$ = Maturity Disc Width; G-P = Gestation period; O-F = Ovarian fecundity; U-F = Uterine fecundity; *males maturing in a disk width less than females

The sex ratio in our study was 1.5:1 (male: female), close to the 1.8:1 ratio encountered by Forselledo (2008) but differing from what was found by Ribeiro-Prado and Amorim (2008) off southern Brazil and Somvanshi *et al*.(2009), in the Indian Exclusive Economic Zone (EEZ), who reported even higher ratios of males (3.4:1 and 3:1, respectively). On the other hand, Mazzoleni and Schwingel (2002) and Hemida *et al*. (2003) found sex ratios of 0.6:1, and Neer (2008) of 0.4:1. It is likely that these varying rates are related to the season of the year, site of capture, or the type of fishing gear employed. Forselledo (2008) suggested that the highest male ratio observed by Ribeiro-Prado and Amorim (2008) could be explained by the fact that their analysis did not include data from the spring. Other dasyatid species also have widely varying male: female sex ratios (Table 9). Sexual segregation is a general characteristic of elasmobranchs populations (Springer, 1967; Klimley, 1987; Sims, 2003; Mucientes *et al*., 2009), with males and females distributed in a different location, depth or feeding area. Veras *et al*. (in press) for *P. violacea*, observed there was no geographical segregation between males and females and their sexual stages of maturity.

Males of pelagic stingray mature at smaller sizes than females. Tortonese (1976), off Italy coast, observed mature males ranging from 37.5-40.2 cm and mature females from 42.5cm $D_W$ on. Wilson and Beckett (1970) observed males ranging from 41.3-70.5cm and females ranging between 42.8 and 80.0cm $D_W$ and reported a size at sexual maturity between 40.0 and 50.0cm $D_W$. Hemida *et al*. (2003) found mature males and females at sizes larger than 40.0 and 45.0cm $D_W$, respectively. Siqueira and Sant'Anna (2007), in the Rio de Janeiro coast, observed eight specimens between 48.0 and 65.5cm $D_{W,}$ all mature. Ribeiro-Prado and Amorim (2008) suggested a size at maturity for males of 43.5 cm and for females of 46.0cm $D_W$. White and Dharmadi (2007), in eastern Indonesia, examining females ranging from 45.2 to 62.3cm and males between 41.0 and 54.2cm $D_W$, estimated a male maturity size of less than 41.0cm $D_W$. They were unable to determine the maturity for females. The sizes at first maturity found in the present work, therefore, equal to 42cm for males and 50cm for females, are close to most of the previous estimates published in the literature, although a little higher for female specimens.

Males of others dasyatids also reach sexual maturity at smaller sizes than females (Table 9). The typically larger size of elasmobranch females in relation to males is related to the need to accommodate the developing embryos during pregnancy, providing more space for embryos and ova, as well as for more muscle mass and a larger liver for energy storage, the latter needed to support the female reproductive processes (Klimley, 1987).

In the present study, villi were absent or small in juveniles, present in maturing females, developing or slightly developed in the pre-ovulatory phase, slightly developed in pregnant stage 1, moderately developed in pregnant stage 2, highly developed in pregnant stage 3, slightly developed during postpartum, and very small in resting females. Wilson and Beckett (1970) also found longer trophonemata in pregnant pelagic stingray. Similarly, Pierce *et al*. (2009), in south-east Queensland, Australia, observed that *Neotrygon kuhlii*, a subtropical dasyatid, postpartum females contained vascularized trophonemata, and Ribeiro *et al*. (2006), in southeastern Brazil, found numerous well-developed trophonemata in the uteri of (probably) mid-pregnancy *Dasyatis hypostigma*.

Reproductive seasonality is one of the most difficult variables to estimate (Oliveira *et al*., 2010). The present data show no clear seasonal or annual pattern in the monthly frequency of different maturity stages, suggesting that parturition occurs throughout much of the year, probably with a rather short reproductive cycle. Forselledo *et al*. (2008)

suggested that pelagic stingray might have a single reproductive cycle per year, in the southwestern Atlantic Ocean. Although it is not possible to infer the gestation period from the present data, it might be sufficiently short to allow for birthing of two litters in a year, assuming a shortened resting period. This seems to be confirmed by the fact that the largest ovarian follicles were found in the two pregnant females with the largest embryos, despite the lack of a strong positive relationship between the diameter of the largest ovarian follicle and mean embryo size of pregnant females in stage 2 and 3. These results also suggest that ovarian development probably speeds up in the later stages of pregnancy, and that females are probably able to reproduce soon after parturition. This condition has been observed in studies of pelagic stingray and other dasyatids (Capapé 1993; Hemida *et al*., 2003; Chapman *et al*., 2003; Janse & Schrama, 2009). A 2-4 month gestation period was observed by Mollet *et al*. (2002) in captive specimens, indicating that pelagic stingrays may give birth even 3 times a year. The reproductive cycle of the pelagic stingray apparently is variable in their areas of occurrence, no doubt a function of local oceanographic variability and food availability. Other dasyatids have gestation periods equal to or greater than those reported for pelagic stingrays (Table 9).

An ovarian fecundity higher than uterine fecundity should be expected since during the ovulation process some oocytes are not ovulated, being reabsorbed by the ovary. Uterine fecundity is also lowered by spontaneous abortion during capture, a phenomenon that has been observed for other dasyatid species (Struhsaker, 1969; Snelson *et al*., 1988; Smith *et al*., 2007; among others). Accordingly, the ovarian fecundity observed for pelagic stingrays in the present study, ranging between 1 and 17, with a mean of 5.4, was higher than the uterine fecundity, ranging from 1 to 5, with a mean of 3.5. Hemida *et al*. (2003) reported an ovarian fecundity for the species from 5 to 10. In their study on captive pelagic stingrays, Mollet *et al*. (2002) documented uterine fecundity from 4 to 13 embryos. A mean uterine fecundity of 5.4 embryos was reported by Mazzoleni and Schwingel (2002) from 11 pelagic stingrays taken in southeastern Brazil. Somvanshi *et al*. (2009) examined a single pelagic stingray bearing three embryos.

The pelagic stingray has larger litter sizes than other, coastal, dasyatid species. Coastal elasmobranchs produce larger, faster-growing young in an environment where food resources are rich and predator avoidance is more important (Snelson *et al*., 2008). In the pelagic environment, by contrast, larger litters with smaller young may be more appropriate because of limited food resources and the evolutionary premium placed on dispersal.

In many species of elasmobranchs there is a positive relationship between fecundity and female size (Conrath, 2005). In theory, as a female grows, the increase in length, disc width and girth results in a larger space in the body cavity to accommodate pups. However, pelagic stingray in this study did not show a positive relationship between the size of the pregnant females and the number of embryos in the uterus. This is consistent with other studies (Hemida *et al*., 2003) addressing pelagic stingray and some other species of dasyatids (Capapé, 1993; Snelson *et al*., 1988, 1989; Johnson & Snelson, 1996; Pierce *et al*., 2009).

Species with late sexual maturity are more vulnerable to overexploitation (Frisk *et al*., 2002). In this study, however, based on the maturity criteria used, 93.1% of the 292 males and 74.4% of the 188 females examined were sexually mature, which is a positive aspect for the sustainability of the stock. Nevertheless, the rise in fishing effort in pelagic fisheries worldwide has resulted in an increase in bycatch and associated bycatch mortality of pelagic stingrays in some areas (Neer, 2008; Baum & Blanchard, 2010), a trend that might be expected to continue. Considering: a) that the pelagic stingray is a common bycatch of worldwide oceanic longline fisheries (O'Brien & Sunada, 1994; Fowler *et al*., 2005; Field *et al*., 2009; Whoriskey *et al*., 2011), b) the high degree of underreporting of their catches (Sauer *et al*., 2003; Fowler *et al*., 2005), c) the likely high mortality of discarded specimens (Domingo *et al*., 2005; Forselledo *et al*., 2008), and d) the life history parameters of this batoid species, the adoption of specific conservation measures for the pelagic stingray should be considered as a matter of urgency.

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*3.3. Artigo científico III*

# Distribution and Catch Rates of pelagic stingray, *Pteroplatytrygon violacea* (Bonaparte, 1832), in the Equatorial and Southwestern Atlantic Ocean

**ABSTRACT**

In this study, the distribution and catch rates of pelagic stingrays in the equatorial and Southwestern Atlantic Ocean were analyzed, based on catch and effort data from 6,886 longline sets carried out by the Brazilian tuna longline boats, from 2006 to 2009. The spatial distribution of the CPUE by years combined showed two areas with highest catch rates of pelagic stingrays (7.8 to 18 stingrays/1,000 hooks), the first one, in the equatorial region, from 10°N to 10°S and from 030° to 045°W, and the second one, in the southeast, from 20° to 35°S and from 040° to 045°W. The spatial distribution of the quarterly mean CPUE showed the highest values occurring from 10°N to 00° and from 030° to 045°W, in the first quarter; from 05°N to 05°S and from 030° to 035°W, in the second quarter; from 25° to 35°S and from 040° to 045°W, in the third; and from 05° to 10°S, and from 030° to 035°W, during the fourth quarter. No evidence has been found of a spatial segregation by sex or, for males, by maturity stages. Females, however, showed a slight segregation pattern by sexual maturity stages. The *Pteroplatytrygon violacea* specimens caught in the equatorial and southwestern Atlantic Ocean is composed mostly of adult individuals (98.8% of males and 79.0% of females).

***Keywords*: Elasmobranchs, CPUE, Bycatch, Dasyatidae, Brazil**

## Introduction

Pelagic sharks and rays are caught by various fishing gears in all oceans of the world, including longline, purse-seine, and gillnet fisheries. Of the 64 species of pelagic sharks and rays known to date, twenty species (32%) are considered threatened and fifteen (24%) near threatened (Camhi *et al*., 2009). Worldwide, about one third of all oceanic sharks and rays are under some level of threat (6% at risk and 26% vulnerable) (Camhi *et al*., 2009). Dulvy *et al*. (2008), evaluating the conservation status of 21 species of pelagic elasmobranchs (16 sharks and 5 rays) taken regularly by various fisheries, concluded that more than half of them were threatened (52%), mainly due to their high fishing mortalities associated, in most cases, with a complete absence of management measures and, often, no accurate data about their catches.

*Pteroplatytrygon violacea* is the only species of the Dasyatidae family that has a fully pelagic behavior (Wilson & Beckett, 1970). It is caught as bycatch in various parts of the world (Kerstetter & Graves, 2006; Neer, 2008; Somvanshi *et al*., 2009; Poisson *et al*., 2010; Piovano *et al*., 2010), mainly by the commercial tuna fishing fleet that uses drifting pelagic longlines as fishing gear (Mollet, 2002; Hemida *et al*., 2003). The species has particularly high catch rates in fisheries targeting swordfish, *Xiphias gladius*, yellowfin tuna, *Thunnus albacares*, bigeye tuna, *T. obesus*, and blue shark, *Prionace glauca* (Forselledo *et al*., 2008). Because they do not have a commercial value, the specimens caught are normally discarded, but often lifeless (Mollet, 2002; Domingo *et al*., 2005).

In spite of the fact that *P. violacea* is not a commercial species, it has been reported as an important bycatch in many of the tuna longline fisheries throughout the world (Wilson & Beckett, 1970; Amorim *et al*., 1998; Mollet, 2002; Domingo *et al*., 2005; Joung *et al*., 2005), a fact that might put their conservation at risk. According to Forselledo *et al*. (2008), catches of *P. violacea* occurred in 52% of 598 pelagic longline sets made in the southwestern Atlantic Ocean. From all stingrays caught, 35% were discarded dead and 50% alive, although the post-release survival rate of the latter is unknown. The remaining 15% were represented by rays released in an unknown condition. Observers on board longliners operating in northeastern Brazil, in turn, observed that although most of the rays were discarded alive, many of them had visible wounds that could compromise their post-release survival (pers. com., 2009), as described by other authors (Dulvy *et al*., 2008; Camhi *et al*., 2009).

Despite the little being yet known in relation to pelagic stingray spatial distribution and relative abundance and the situation about their populations, little information is available on the species, especially in the South Atlantic Ocean. The aim of the present paper, therefore, was to provide information on the catches of pelagic stingrays by Brazilian tuna longliners in the equatorial and southwestern Atlantic Ocean, in order to facilitate the adoption of management measures needed to ensure the conservation of the species, that is since February 2007, listed in the low-risk category of "Least Concern" by the IUCN (International Union for Conservation of Nature and Natural Resources).

**Material and Methods**

Catch and effort data from 6,886 longline sets carried out by Brazilian tuna longline vessels that used 9,617,201 hooks, from 2006 to 2009, were analyzed. The longline sets were distributed in a wide area of the equatorial and southwestern Atlantic Ocean, ranging from 15°N to 40°S of latitude and from 010°E to 050°W of longitude. Data were obtained from the logbooks filled out by on-board observers of the National Observer Program.

The logbooks were made available by the Brazilian Ministry of Fisheries and Aquaculture, throughout of the Special Secretariat of Fisheries and Aquaculture (SEAP). The logbook data included individual records containing the vessel identification, geographic location of fishing ground (latitude and longitude) at the beginning of each set, the number of hooks, time of longline setting, date, and the number of fish caught, by species, in each fishing day.

Catch per unit of effort (CPUE) was calculated as the number of pelagic stingrays caught per 1,000 hooks. The CPUE and the effort were calculated by years combined and by quarters. For the analysis of spatial distribution of CPUE, the catch and effort data were grouped into 5° x 5° squares of latitude and longitude.

Catch by flag was also calculated using only the chartered vessels that captured the pelagic stingray.

Between 2005 and 2011, 513 specimens were collected by observers on board, representing 19.5% of the pelagic stingrays caught (2,634). In the laboratory, the specimens were sexed and measured, in centimeters, for disc width ($D_W$) and length ($D_L$). It was not possible to measure the total length because, for safety reasons, the tail is always cut off immediately after boarding the specimen. For the spatial distribution of the males and females and their maturity stages, the latitude and longitude of each set were used. For the spatial analysis of the disc width distribution, the mean disc width ($D_W$) was calculated for each 5°x5° square. The reproductive stages of males and females were assigned according to Veras *et al*. (in prep.).

## Results

The fishing effort reached the maximum of 1,200.000 hooks and was distributed in a broad area of the Equatorial and South Atlantic Ocean, from 15°N to 40°S and from 010°E to 050°W, with a greater concentration between 5°N- 25°S of latitude and 020°- 040°W of longitude (Fig. 1). The quarterly distribution of the fishing effort shows that the area from 5°N to 5°S had the highest effort in all quarters (Fig. 2). The fishing effort was more similar in the 1st and 2nd quarters, when compared to the later part of the year, and showed two distinct areas with highest effort, the first one located between 5°N and 5°S and from 025° to 040°W, and the second one between 10° and 25°S and from 025° to 040°W. The largest coverage area was observed in the 3rd quarter, when the fishing sets were scattered in an area from 05°N to 35°S and from 010°E to 050°W. The distribution of the fishing effort during the 4th quarter was the narrowest, when compared to the other 3 quarters, being the only one when the fishing effort did not go eastward of 015°W (Fig. 2).

The spatial distribution of the CPUE by years combined showed two areas with higher (7.8 to 18 stingrays/1000 hooks) catch rates, one around the equator, ranging from 10°N to 10°S and from 030° to 045°W, and another one more southward, from 20° to 35°S and from 040° to 045°W (Fig. 3). The lower CPUEs values by years combined were observed between 10°-20°S and corresponding to 0.8 to 1.6 stingrays/1000 hooks.

The spatial distribution of the quarterly mean CPUE showed the highest values occurring from 10°N to 00° and from 030° to 045°W, in the first quarter; from 05°N to 05°S and from 030° to 035°W, in the second quarter; from 25° to 35°S and from 040° to 045°W, in the third; and from 05° to 10°S, and from 030° to 035°W, during the fourth quarter. In all quarters, low (0.8 to 1.6 stingrays/1000 hooks) CPUE values were recorded in the region between 10°-20°S, although fishing effort in this area was relatively high, between 3.000 to 1,200.000 hooks (Fig. 4).

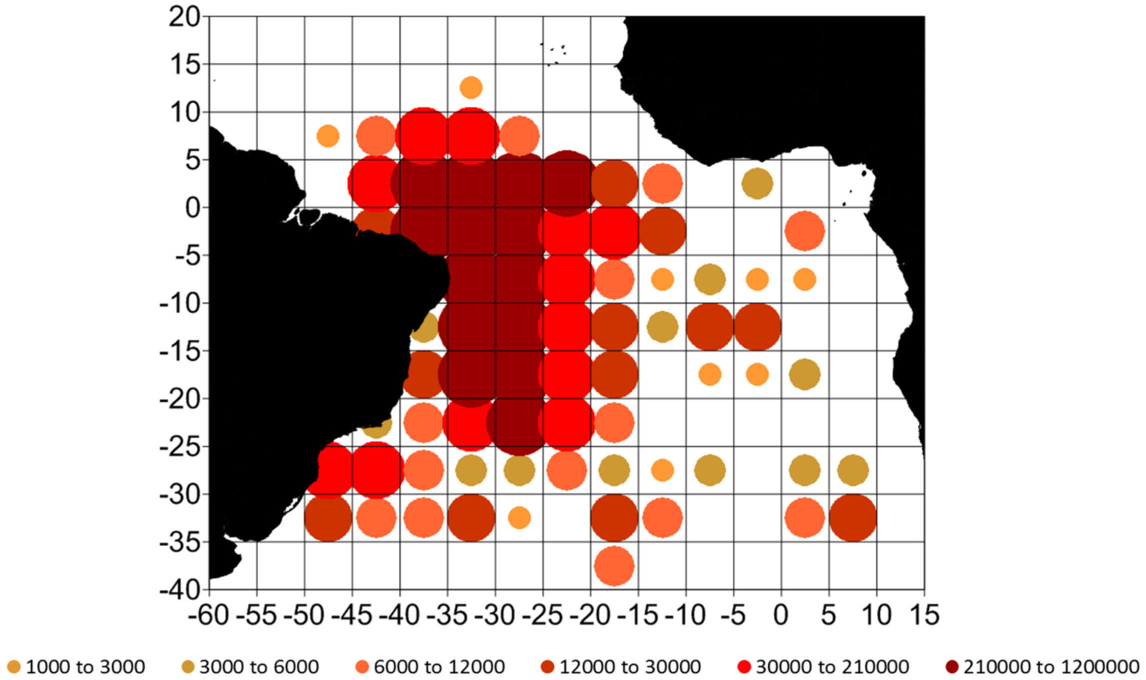


**Figure 1.** Distribution of the fishing effort (in number of hooks), of the Brazilian tuna longline fleet, from 2006 to 2009, in the equatorial and southwestern Atlantic Ocean.

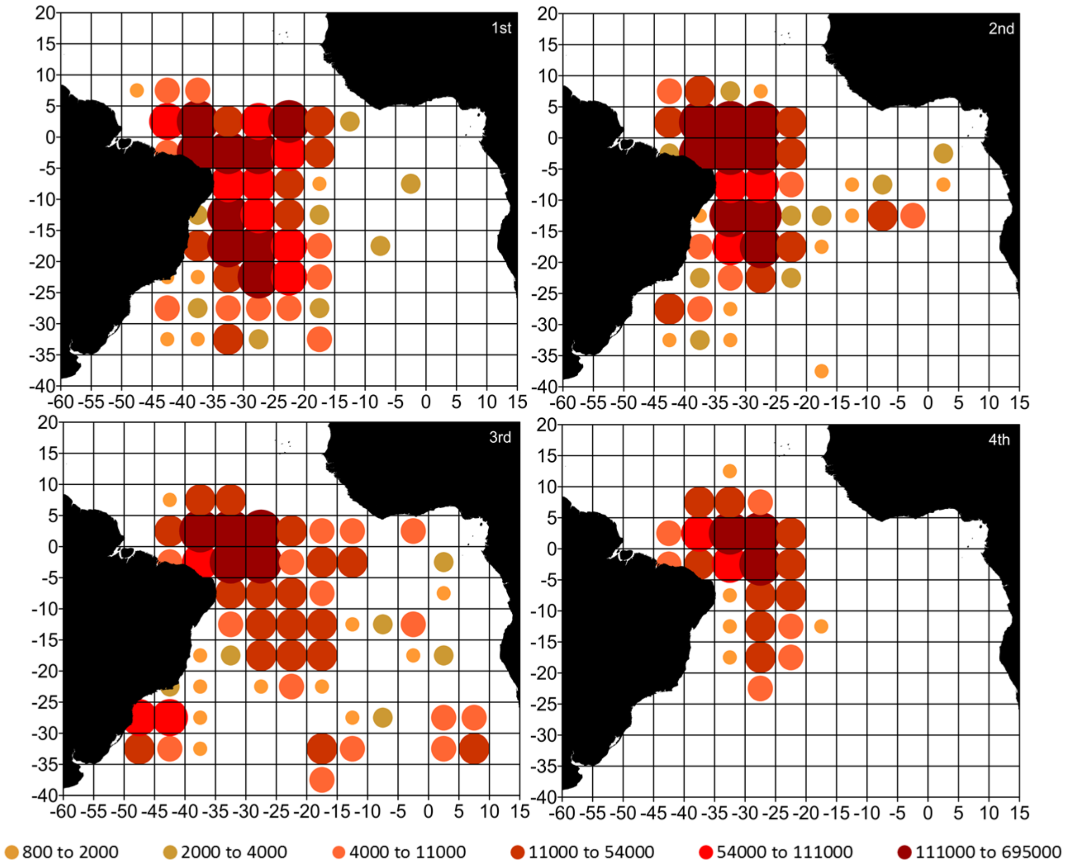


**Figure 2.** Quarterly distribution of the fishing effort (in number of hooks), of the Brazilian tuna longline fleet, from 2006 to 2009, in the equatorial and southwestern Atlantic Ocean.

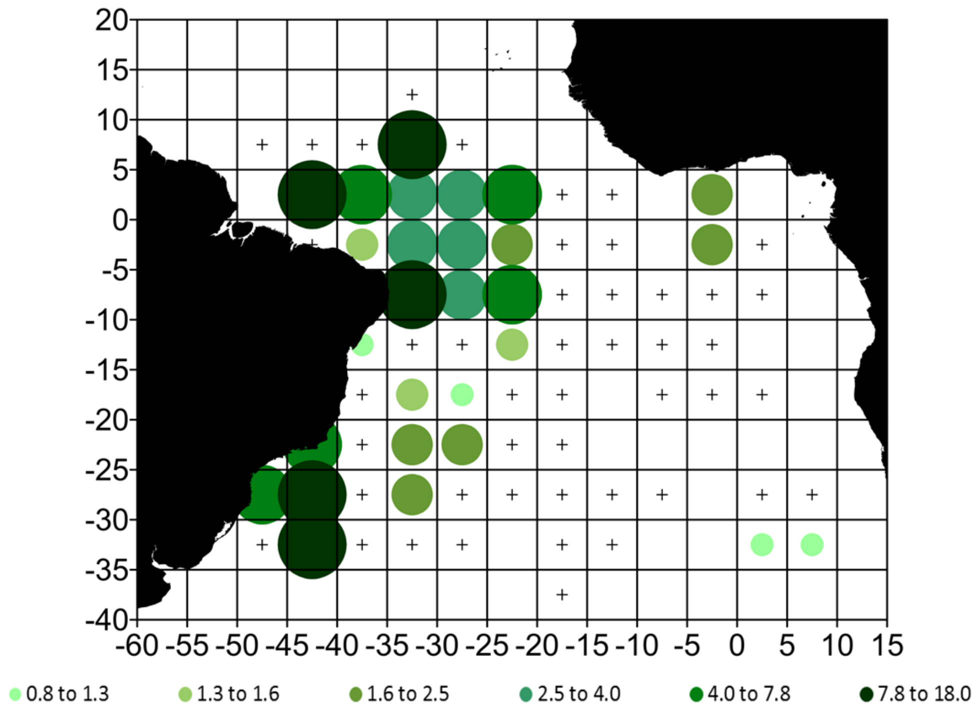


**Figure 3.** Distribution of the CPUE (in number of stingrays/1000 hooks) of the pelagic stingray, *Pteroplatytrygon violacea*, caught by the Brazilian tuna longline fleet, from 2006 to 2009, in the equatorial and southwestern Atlantic Ocean. The crosses represent zero catch.

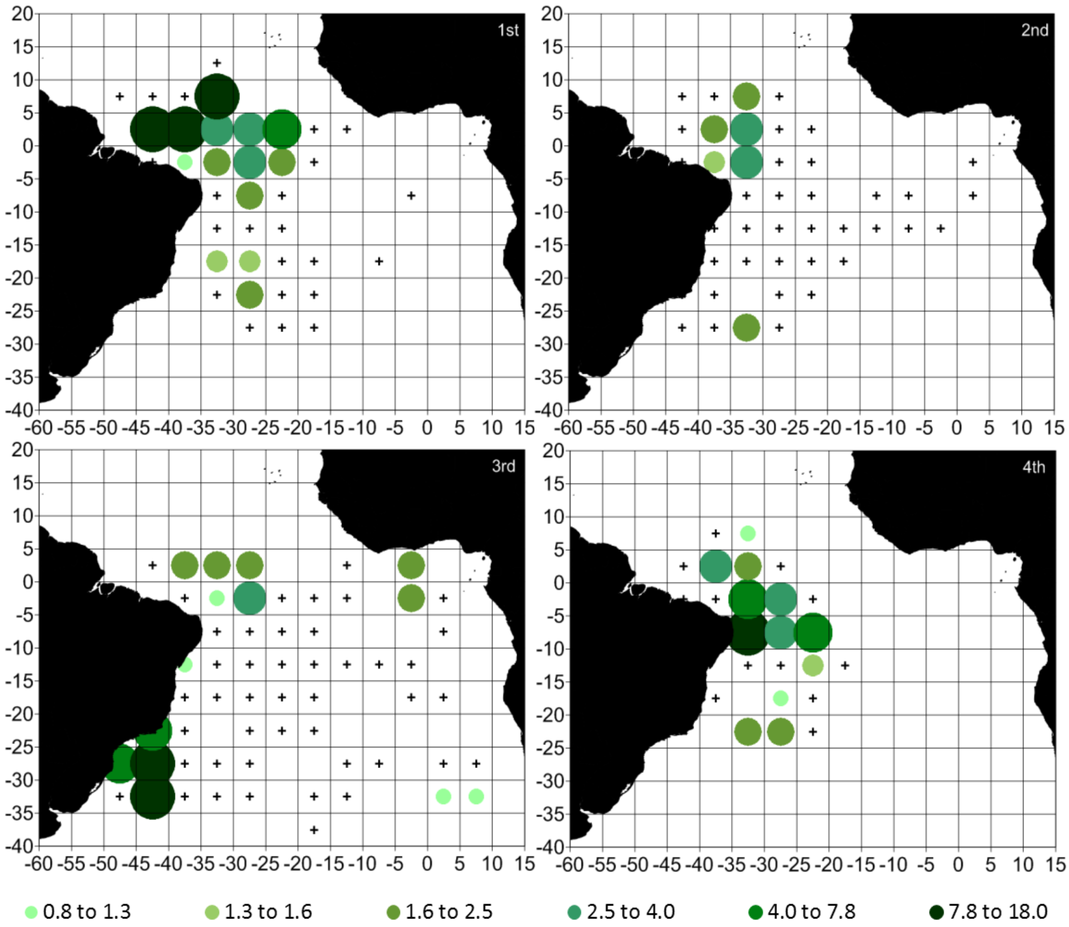


**Figure 4.** Quarterly distribution of CPUE (in number of stingrays/1000 hooks) of the pelagic stingray, *Pteroplatytrygon violacea*, caught by the Brazilian tuna longline fleet, from 2006 to 2009, in the equatorial and southwestern Atlantic Ocean. The crosses represent zero catch.

The proportion of the pelagic stingray in relation to the total catch was very low equaling 0.9% and in relation to the catches of elasmobranches was 5.2% (Fig. 5). The pelagic stingray yearly proportion of the total catch did not exceed 0.4%. Its proportion in relation to the elasmobranch catches showed peaks in 2007 and 2008, 2.5% and 2.3% respectively. In the two remaining years, in relation to the elasmobranch catches, this proportion did not exceed 0.1%.

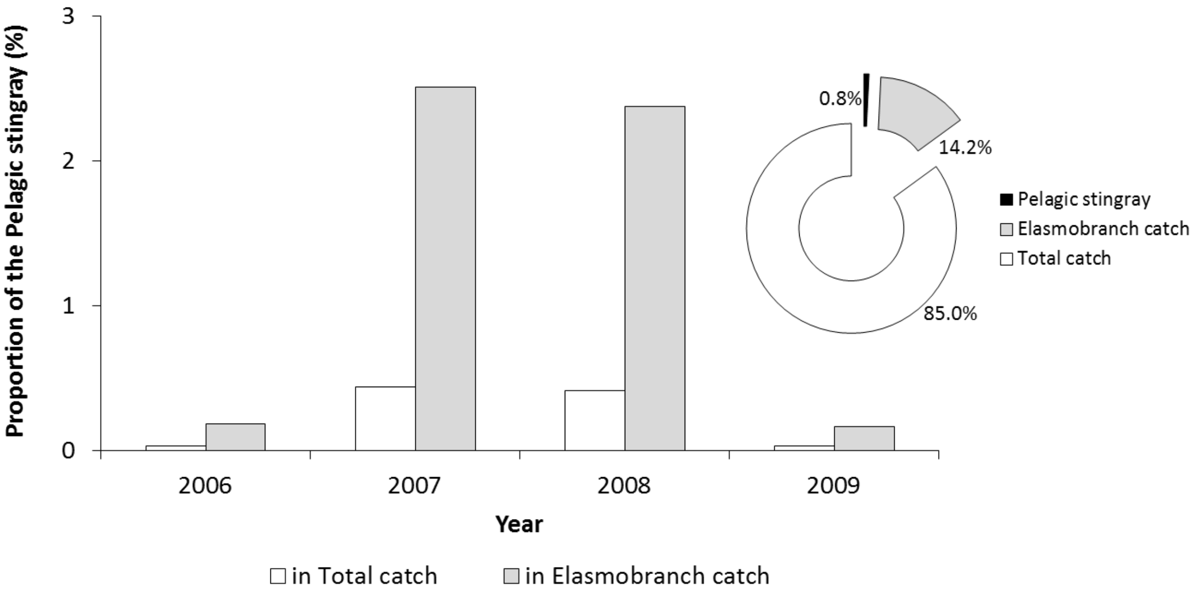


**Figure 5.** Proportion of the pelagic stingray, *Pteroplatytrygon violacea*, in total and elasmobranch catches, of the Brazilian chartered tuna longline fleet, from 2006 to 2009, in the equatorial and southwestern Atlantic Ocean.

The most representative flags in the capture of pelagic stingray from 2006 to 2009 were Spain and Morocco, the late also fishing with Spanish technology. Over the studied years there was a variation in the number of vessels by flag, with a predominance of Spanish boats in the last three years (2007 to 2009). On the catch by flag the Spanish (SPA) boats captured 91.3% of the pelagic stingray in the period, follow by Moroccan (MOR) with 4.6%, Honduran (HON) with 3.9% and UK (ENG) with 0.2% (Fig. 6).

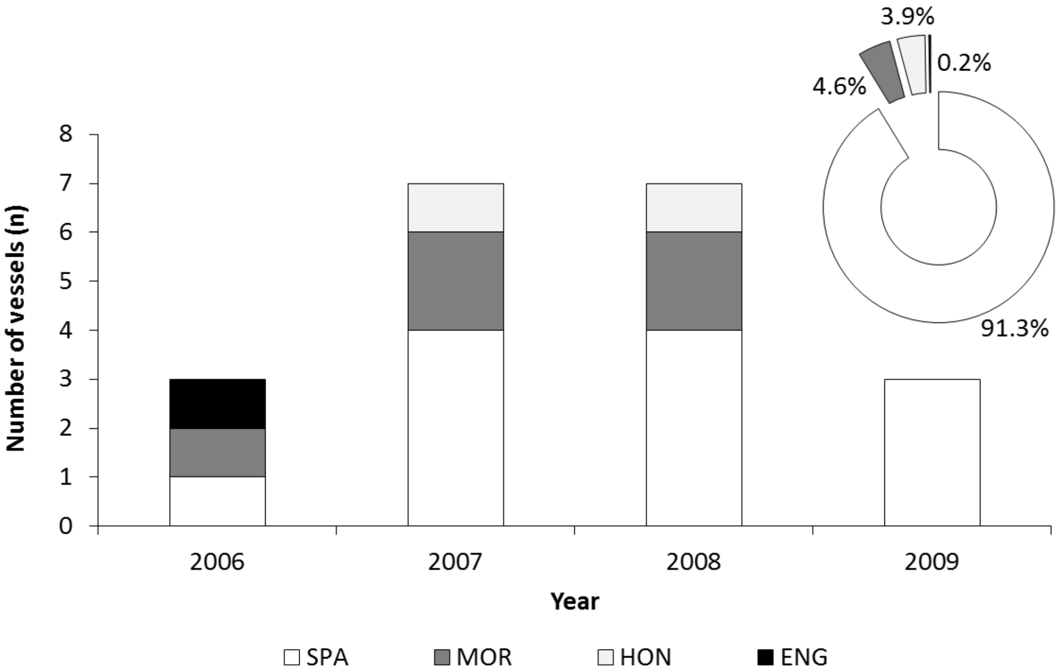


**Figure 6.** Yearly number of chartered longline vessels, by flag, operating in the equatorial and southwestern Atlantic Ocean from 2006 to 2009 that caught the pelagic stingray, *Pteroplatytrygon violacea*.

Of the 513 specimens that were measured, 311 were male (60.6%) and 202 were females (39.4%), resulting in a sex ratio of 1.5:1. Males ranged between 34.0 and 59.6 cm $D_W$ (mean ± S.E. of 45.5 ± 0.1cm $D_W$), while females ranged between 28.0 and 66.0 cm $D_W$ (mean ± S.E. of 50.0 ± 0.4cm $D_W$). The most frequent size class of males was between 40.0 and 50.0cm $D_W$, while females had the largest number of individuals included within the lengths from 50.0 to 55.0cm (Fig. 7).

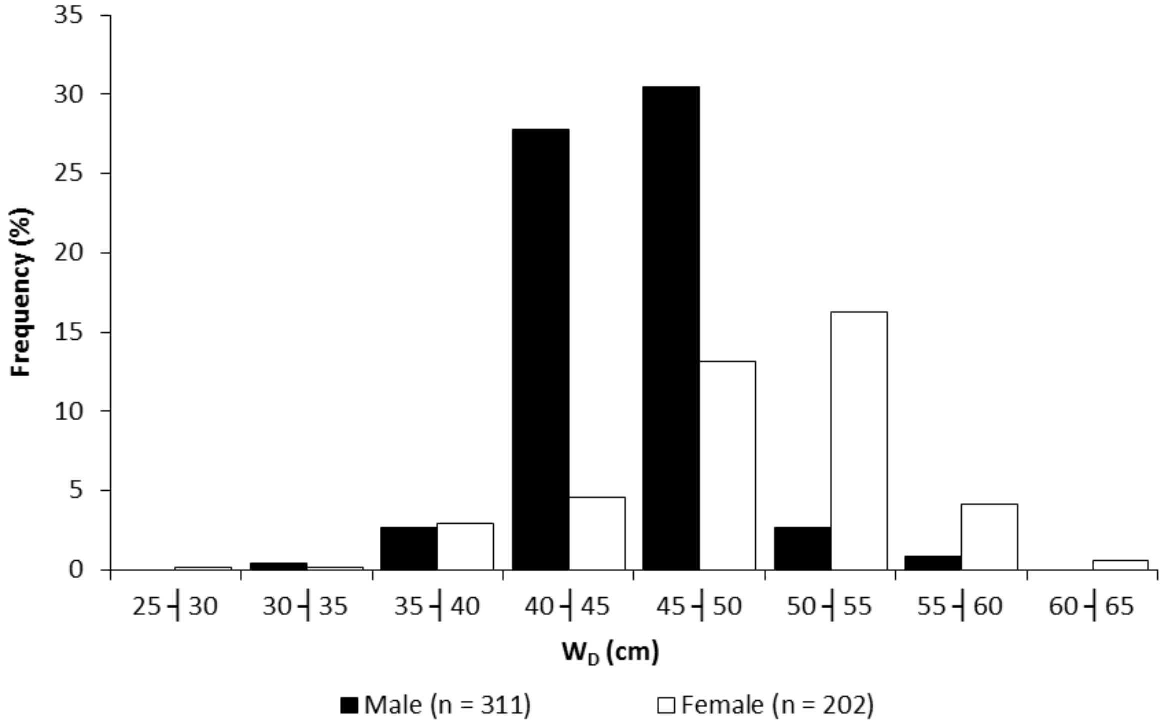


**Figure 7.** Disc width ($D_W$) frequency distribution (5cm intervals) of the pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean.

The spatial distribution of the 5°x5° square mean disc width (Fig. 8) shows a concentration of larger specimens from about 020°W to 040°W and from 5°N to 15°S. The smallest individuals only appeared in the area between 045°W to 050°W and from 25°S to 30°S. The species does not show a striking pattern of size distribution in the study area.

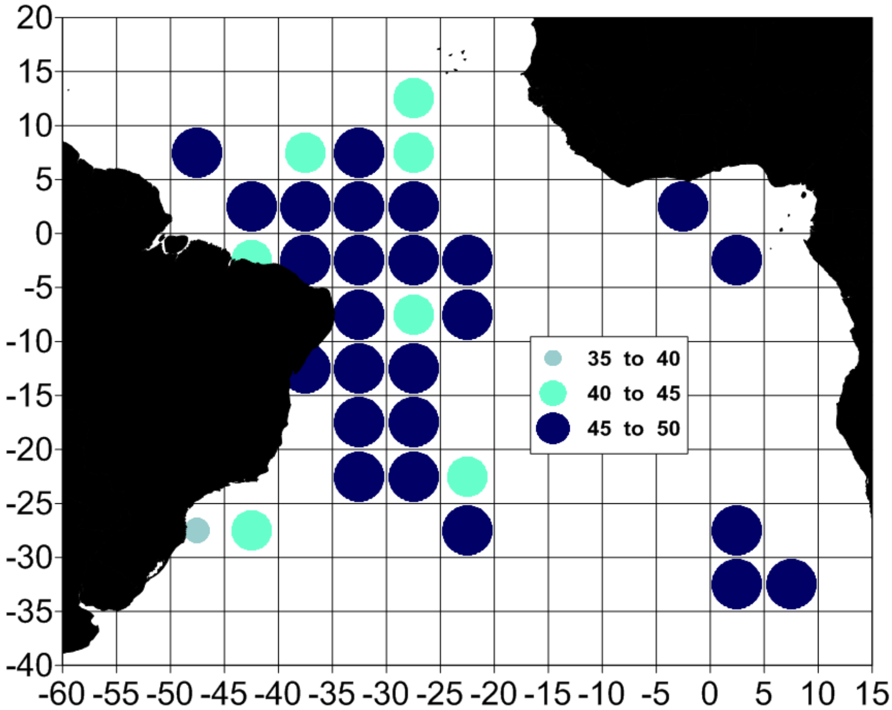


**Figure 8.** Mean disc width ($D_W$), by 5°x5° squares, of the pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean, between 2006 and 2009.

The geographical distribution of 241 males and 157 females caught (Fig. 9) do not show any clear pattern of sexual segregation.

Based on the development of their claspers and testes, males were classified into three categories: juvenile (1.2%), maturing (4.2%) and adult (94.6%). Depending on the development of the ovary, oviducal gland and uterus, females were separated into six stages: juvenile (21.0%), maturing (38.2%), pre-ovulatory (13.4%), pregnant (17.2%), postpartum (3.2%), and resting (7.0%).

Males showed no geographical segregation by maturity stage (Fig. 10). Females, in turn, showed a slight segregation (Fig. 11) with pregnant stages being more concentrated in two areas: between 04°N and 05°S, and from 17°S to 22°S. The presence of pregnant females in stage 3 was only observed in the northern area near the equator, but they were restricted to only 2 specimens.

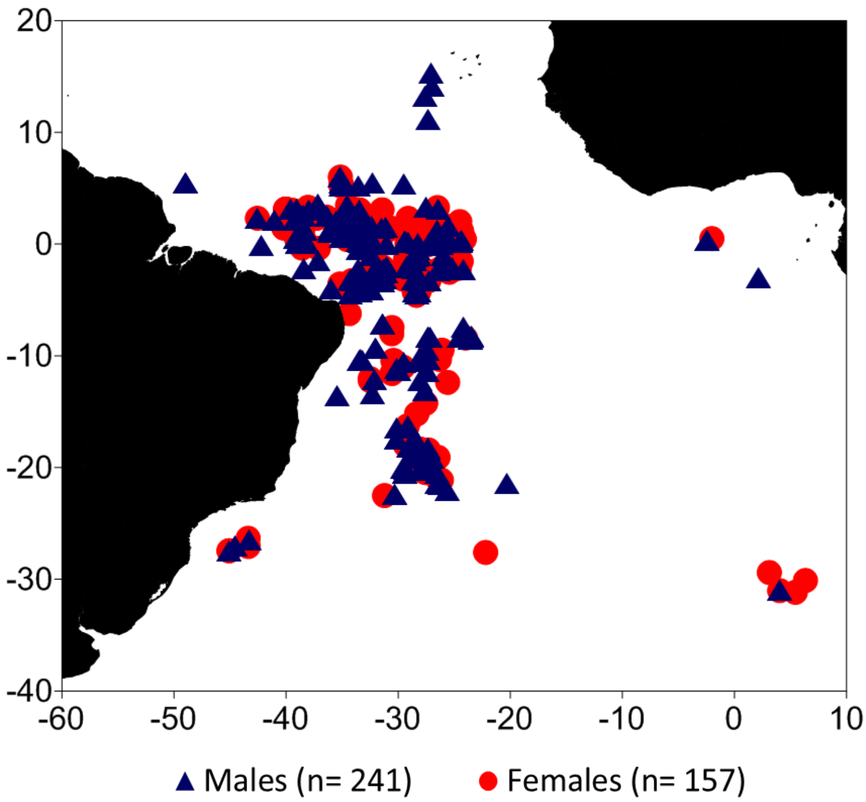


**Figure 9.** Spatial distribution of male and female of the pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean.

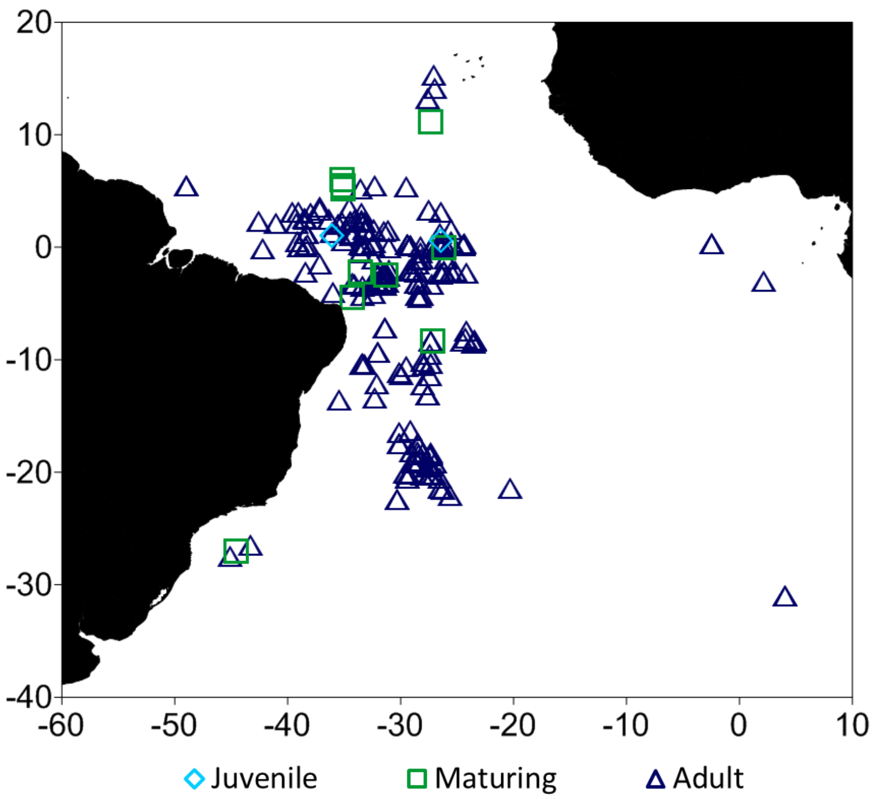


**Figure 10.** Distribution of male of the pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean, by maturity stages.

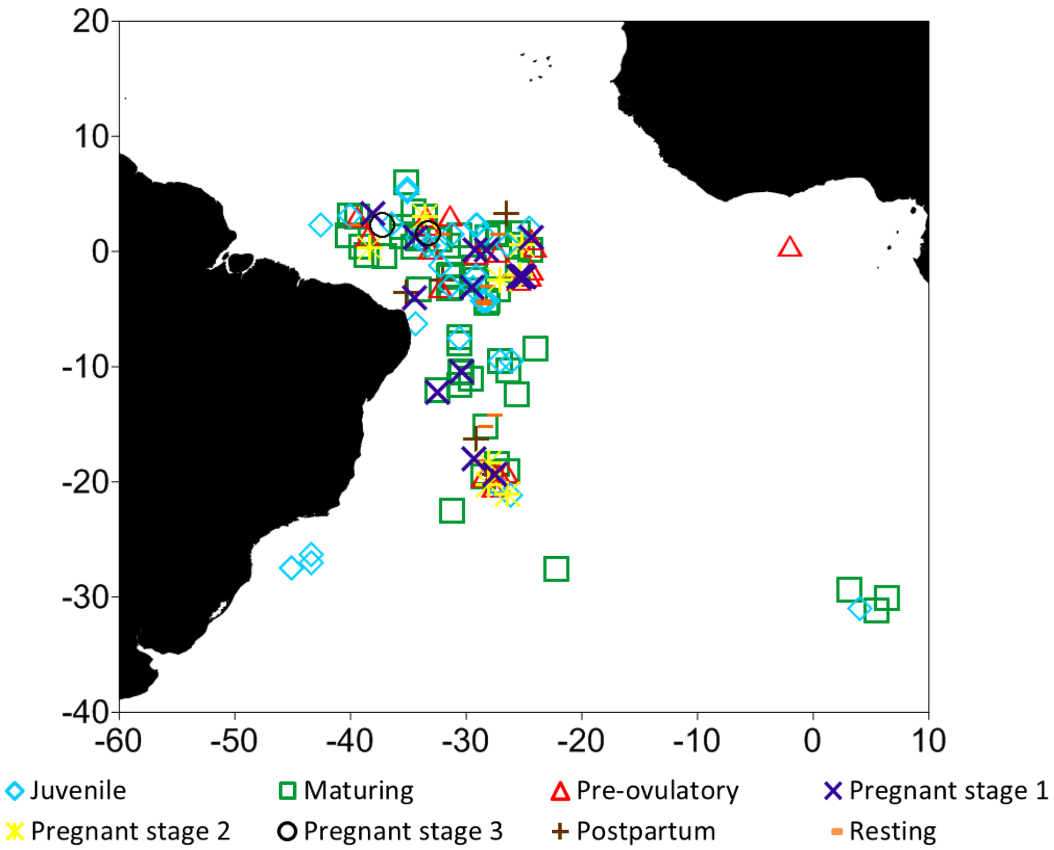


**Figure 11.** Distribution of female of the pelagic stingray, *Pteroplatytrygon violacea*, taken in the equatorial and southwestern Atlantic Ocean, by maturity stages.

## Discussion

The concentration of fishing effort from 5°N to 5°S and from 15°S to 25°S may be related to the presence of seamounts and oceanic islands, in these two regions, including the Archipelago of Saint Peter and Saint Paul, the Fernando de Noronha Island, Rocas Atoll and several seamounts of the North Brazil and Fernando de Noronha Chains, in the first one, and Vitoria-Trindade Chain, in the second one. According to Morato and Clark (2007), seamounts are biologically distinctive open-ocean habitats with unique features, which promote substantial aggregations of mid- and deep-water fish, becoming thus a common target of commercial fisheries. Fishing fleets target seamounts and available catch data indicate that catch per unit effort (CPUE) is higher around seamounts than in adjacent areas of ocean (Fonteneau, 1991; Campbell & Hobday, 2003). Morato *et al*. (2010) also observed increased catch rates of billfishes and tunas, including yellowfin tuna (*Thunnus albacares*), blue marlin (*Makaira nigricans*), and swordfish (*Xiphias gladius*), closer to seamounts. Travassos *et al*. (1999) already showed that many seamounts in that area are characterized by a considerable turbulence and possibly upwellings, which could facilitate primary production. The seamounts of the North Brazil Chain are considered to be an important fishing ground for tuna and tuna-like species off northeast Brazil (Hazin, 1993). According to Hazin *et al*. (1998), catches of gray sharks (*Carcharhinus* spp.) off northeast Brazil were significantly higher around these seamounts. More to the south, around 20°S of latitude, the seamounts of Vitoria-Trindade Chain are also another important fishing area for

Brazilian vessels, manly in the swordfish fishery. According to Mazzoleni and Schwingel (2002), the most caught species in this region are the swordfish, *Xiphias gladius*, the blue shark, *Prionace glauca*, and the pelagic stingray, *Pteroplatytrygon violacea*.

The pelagic stingray is a common component of the bycatch of most pelagic longline fisheries (O'Brien & Sunada, 1994; Whoriskey *et al*., 2011). According to Domingo *et al*. (2005), observing data obtained from the Uruguayan Economic Exclusive Zone (EEZ), the pelagic stingray was the second most commonly observed elasmobranch species in pelagic longline fisheries after the blue shark (*Prionace glauca*). The pelagic stingray in their work was captured in 51% of the sets, with a CPUE reaching 11.5 stingrays/1,000 hooks, with the highest values being recorded between 29°S and 32°S. In the present study, the CPUE values, ranging from 0.8 to 18.0 stingrays/1,000 hooks, were, in general, much higher than those observed by Domingo *et al*. (2005), indicating a much greater abundance of the species in lower latitudes. Forselledo *et al*. (2008), studying the relative abundance of the pelagic stingray in the southwestern Atlantic, observed CPUEs values from 2.3 to 5.6 stingrays/1,000 hooks, also much lower than those found in this study. Despite the differences in CPUE values, the data presented here corroborated the trend observed by Domingo *et al*. (2005) and Forselledo *et al*. (2008), of high catch rates for the species from 25° to 30°S. According to Santos and Andrade (2004), this is an important fishing ground for the yellowfin tuna (*Thunnus albcares*) fisheries, and the presence of this species in the region would be influenced by north-south displacements of the Brazil current. Catches of *P. violacea* in the region, by longline fleets, can also be linked to this displacement of the Brazil current. Forselledo *et al*. (2008) also cited the tropical Brazilian current to explain the higher CPUE observed further south. The author also observed a southward movement of stingrays following the tropical currents.

According to Neer (2008), as the fishing effort offshore has increased, so has the number of rays taken incidentally in these fisheries, a trend that makes the pelagic longline fishery for tunas and swordfish one of the major threats to pelagic stingray populations. The increasing concern with catches of non-target species, including the *Pteroplatytrygon violacea*, in pelagic longline fisheries, has driven the development of possible mitigation measures around the world, such as the use of circle hooks (Promjinda *et al*., 2008; Piovano *et al*., 2010; Curran & Bigelow, 2011; Pacheco *et al*., 2011), with positive results for the pelagic stingray.

The results presented here show that the pelagic stingray is common in the tuna and tuna-like longline fishery realized by the national fleet and that their catch rates are relatively high, largely on vessels with Spanish flags, which carry out a fishing activity directed to the capture of swordfish (*Xiphias gladius*).

The data on disc width of both males and females found in the present work were very close to those observed by Mazzoleni and Schwingel (2002), with most males and females between 35.0-45.0cm and 50.0-60.0cm $D_W$, respectively; and by Forselledo *et al*. (2008), who found males between 40.0-50.0cm and females between 50.0-60.0cm. The spatial distribution of the mean disc width coincides with what was observed by other authors (Mazzoleni & Schwingel, 2002; Domingo *et al*., 2005; Forselledo *et al*., 2008; Ribeiro-Prado & Amorim, 2009) in relation to disc width of specimens captured in the southeastern Atlantic Ocean region. Corroborating with Domingo *et al*. (2005), Forselledo *et al*. (2008) and Ribeiro-Prado and Amorim (2009), in the present study there was no geographical segregation between males and females.

Forselledo *et al*. (2008) observed pregnant females from 19°18'S to 35°58'S and 020°88'W to 047°18'W. Siqueira and Sant'Anna (2007) observed mature and pregnant individuals between 22°58'S and 23°04'S of latitude and 043°03'W and 043°08'W of longitude. In the present study pregnant females were distributed in higher concentrations in two areas: 04°N- 04°S/ 025°W- 040°W; and 16°S- 22°S/ 025°W- 031°W. Although females in advanced pregnancy were only found close to the equator, due to their low number (only two specimens), it was not possible to determine whether the species uses this region as a parturition ground.

The data presented here show that the *Pteroplatytrygon violacea* specimens caught in the southwestern equatorial Atlantic is composed mostly of adult individuals which is positive for their conservation. Considering, however, the increasing participation of the species as bycatch in longline fishing and especially the lack of knowledge about their biology and condition of exploited stocks, more attention should be given to the conservation requirements of this unique oceanic species.

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*3.4. Artigo científico IV*

# Horizontal Movements, Temperature and Depth Preferences of the Pelagic stingray, *Pteroplatytrygon violacea* (Bonaparte, 1832), in the western equatorial Atlantic Ocean


**ABSTRACT**

In the present study, a female specimen of the pelagic stingray was tagged with a Pop-up Archival Tag (PAT). The model chosen was the Wildlife Computers MiniPAT, due to its reduced dimensions, being thus better suited to the small size of the studied species. The tag was programmed to archive data at 60s intervals into 24 hours of 12 bins with a release time of 60 days. The tagged specimen, measuring 56.5cm of disc width ($D_W$) and 48.0cm of disc length ($D_L$), was caught on April 30, 2010, by a longline set done by a commercial fishing boat. The specimen showed no definite pattern of horizontal movement, moving in many different directions in an area between 03°-09°N latitude and 036°-040°W longitude. During the 60 days of deployment, the pelagic stingray moved about 535 km, with an estimated daily displacement of 8.92 km. The tagged specimen showed a preference for waters below 50m deep, in other words, below of the mixed layer. It spent just 9.8% of the monitored time in shallow waters, between 0-50m, with temperatures ranging from 23.4 to 28.7°C. The pelagic stingray spent 90.2% of the time below 50m, 70% of which in waters below 75m, in temperatures ranging from 13.0 to 24.5°C. Besides, during most of the monitored time (53%) the specimen stayed in waters between 100-150m. The minimum temperature experienced by pelagic stingray was 10.4°C, corresponding to depths of 387.5 and 428.0m, the last one coinciding with the deepest dive recorded for the specimen. The diel depth preferences by the tagged pelagic stingray indicate that it stayed mostly at shallower depths, from 50m to 100m, from about 21:00h to 7:000h, and at greater depths, from 100 to 150m, from 8:00h to 20:00h. The data suggest that the species prefers waters below the end of thermocline, between 100-150m deep, spending less time in the mixed layer, particularly when the temperature is above 28.0°C.



***Keywords***: Elasmobranchs, Pop-up satellite archival tag, Distribution, Dasyatidae, Brazil


## Introduction

The pelagic stingray, *Pteroplatytrygon violacea* (Bonaparte, 1832), the only pelagic species of the Dasyatidae family, is widely distributed in tropical and warm temperate oceanic waters (Ellis, 2007). It is a relatively small ray with a maximum disc width of 80cm. There is currently no directed fishing for this species, although it is a common component of the bycatch of most pelagic longline fisheries for tunas, billfishes, and sharks (Domingo *et al*., 2005; Forselledo, *et al*., 2008; Neer, 2008). It is generally caught in the top 100 m over deep water (Serena, 2005), but little is known about its natural history and movement patterns over most of its distribution, mainly because of its oceanic habitat (Neer, 2008).

Recent advances in satellite tagging and tracking technologies have provided important information on the home range and movements of many marine animals (Hammerschlag *et al*., 2011). According to Stevens *et al*. (2010), satellite tracking can inform on habitat use, including temperature and swimming depths, residency times and migratory pathways, which may not only provide valuable insights into the behavior of marine animals, but also on the physical oceanographic properties encountered during their movements (Biuw *et al*., 2007).

Previous studies have been successfully used to determine the movements and environmental preferences of several species of teleosts and elasmobranchs. The observed movement patterns have been attributed to life stages (Bonfil *et al*., 2005; Loher & Seitz, 2006), food search/ availability (Sims *et al*. 2003; Loefer *et al*., 2005; Wilson *et al*., 2005; Hulbert *et al*., 2006), and thermal preferences (Brunnschweiler & Buskirk, 2006; Wilson *et al*., 2007; Brunnschweiler *et al*., 2010; Sepulveda *et al*., 2010; Potter *et al*., 2011). Satellite tags, such as the PAT tags, have a great advantage over conventional tags, since they do not require the recapture of the tagged fish to retrieve the collected data (Le Port *et al*., 2008). Recently, various papers have published results from satellite tagging of pelagic sharks (Domeier and Nasby-Lucas, 2008; Pade *et al*., 2009; Stevens *et al*., 2010; Cartamil *et al*., 2011), but only a few have reported this kind of study on rays and stingrays (Grusha and Patterson, 2005; Le Port *et al*., 2008).

In this context, the present work intends to generate information on the pelagic stingray, *Pteroplatytrygon violacea*, habitat preferences, regarding depth distribution, temperature ranges and horizontal movements, in the western equatorial Atlantic Ocean, through the use of pop-up satellite archival tags (MiniPAT).

## Material and Methods

In the present study, a Pop-up Archival Tag (MiniPAT) manufactured by Wildlife Computers, was used, mainly due to its reduced dimensions, being therefore better suited to the small size of the studied species. The MiniPAT tag measures and stores sea water temperature (from -40°C to +60°C, with a resolution of 0.05°C), depth (from 0 to 1,000m, with a resolution of 0.5m), and brightness level (measured as irradiance at a wavelength of 550nm), for the calculation of geolocation, making it possible to study the vertical and horizontal displacements of the tagged animal, as well as the influence of water temperature on its movements. The tag was programmed to archive data at 60 seconds intervals into 24 hours of 12 bins with a release time of 60 days. The horizontal movement was estimated by processing the data received from the Argos satellites with the manufacturer light-based geolocation software (WC-GPE: Global Position Estimator Program suite, available on: www.wildlifecomputers.com). In order to minimize the errors usually associated to this geolocation estimation the model developed by Tremblay *et al*. (2009) was used. This method consists of bootstrapping random walks and it is an alternative approach to the complicated and time-consuming state-space models.

One female pelagic stingray, measuring 56.5cm of disc width ($D_W$) and 48.0cm of disc length ($D_L$), caught on April 30, 2010, by a commercial fishing boat of the Brazilian tuna longline fleet, was tagged with a MiniPAT. The tag was attached to the fish using the methodology adapted from Le Port *et al*. (2008). The MiniPAT was linked to a piece of polyamide monofilament (nylon) (2.0mm), 1 m long, inserted into a crimp. For fixing the tag, a stainless steel applicator, with a thickness of 2.1mm, was used to insert the nylon filament. The nylon was inserted, through the applicator, dorso-laterally on one side of the tail through the muscle, avoiding the vertebrae, exiting ventrally. Then the monofilament was inserted into a piece of silicone tube in order to minimize the friction that could be generated by the direct contact of the nylon with the tail. Both parts of the monofilament exiting the tail dorsally were then crimped together (Fig. 1).

Tagging location was recorded by using the vessel global positioning system. The total traveled distance was calculated by summing the distances between each consecutive geolocation point, while the daily displacement was estimated by dividing the total traveled distance by the number of days from the deployment period.

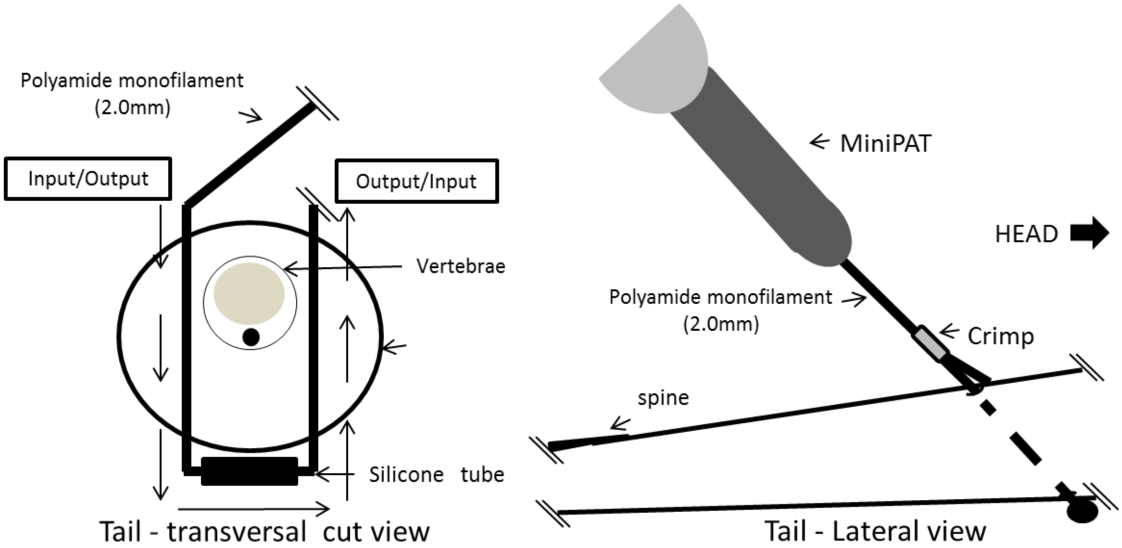


**Figure 1**. Schematic drawing of tag attachment technique applied to a pelagic stingray, *Pteroplatytrygon violacea*, taken by a Brazilian tuna longline vessel, in the western equatorial Atlantic Ocean.

## Results

The female pelagic stingray was tagged in a region near the equator on the western side of the Atlantic Ocean (Fig. 2). During the 60 days of deployment, the pelagic stingray moved about 535 km, with an estimated daily displacement of 8.92 km (Fig. 2). The specimen showed no clear pattern of horizontal movement, and can be divided into three steps, with the following predominant directions: a) strong trend toward the north; b) moving in many different directions; and c) small trend toward the south (Fig. 3).

The tagged specimen showed a preference for waters below 50m deep, in other words, below of the mixed layer (Fig. 4). It spent just 9.8% of the monitored time in shallow waters, between 0-50m, with temperatures ranging from 23.4 to 28.7°C. The pelagic stingray spent 90.2% of the time below 50m, 70% of which in waters below 75m, in temperatures ranging from 13.0 to 24.5°C. Besides, during most of the monitored time (53%), the specimen stayed in waters between 100-150m. The minimum temperature experienced by the pelagic stingray was 10.4°C, corresponding to depths of 387.5 and 428.0m, the last one coinciding with the deepest dive recorded for the specimen (Fig. 5). This deep dive began at 17:15, with the stingray first moving to 194m and then, at 17:20, to 428m, taking 5 minutes, with a speed of approximately 0.78m/s. To swim back to 194m, however, the specimen spent about 35 min. These dives occurred in May 11 (Fig. 5), a day when the specimen spent most of the time at depths ranging from 85 to 428m, with temperatures between 19.1 and 10.4°C (Fig. 4). The pelagic stingray also did a few other incursions below 300m deep, in May 30 and on June 16 and 25. The specimen spent little time at depths ranging from 200 to 300m (3.5% of the time), going below 300m only occasionally (0.08% of the time).

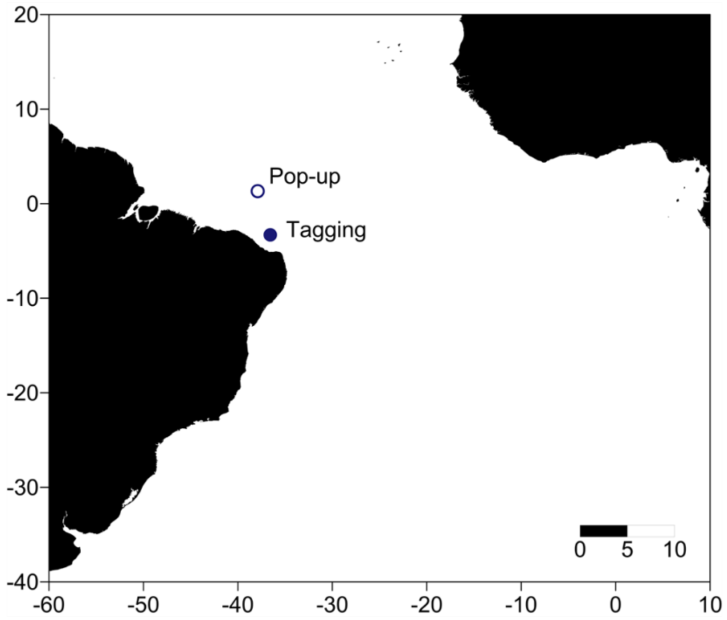


**Figure 2.** Tagging and pop-up positions of a female pelagic stingray, *Pteroplatytrygon violacea*, tagged with a pop-up satellite archival tag (MiniPAT model) in the western equatorial Atlantic Ocean.

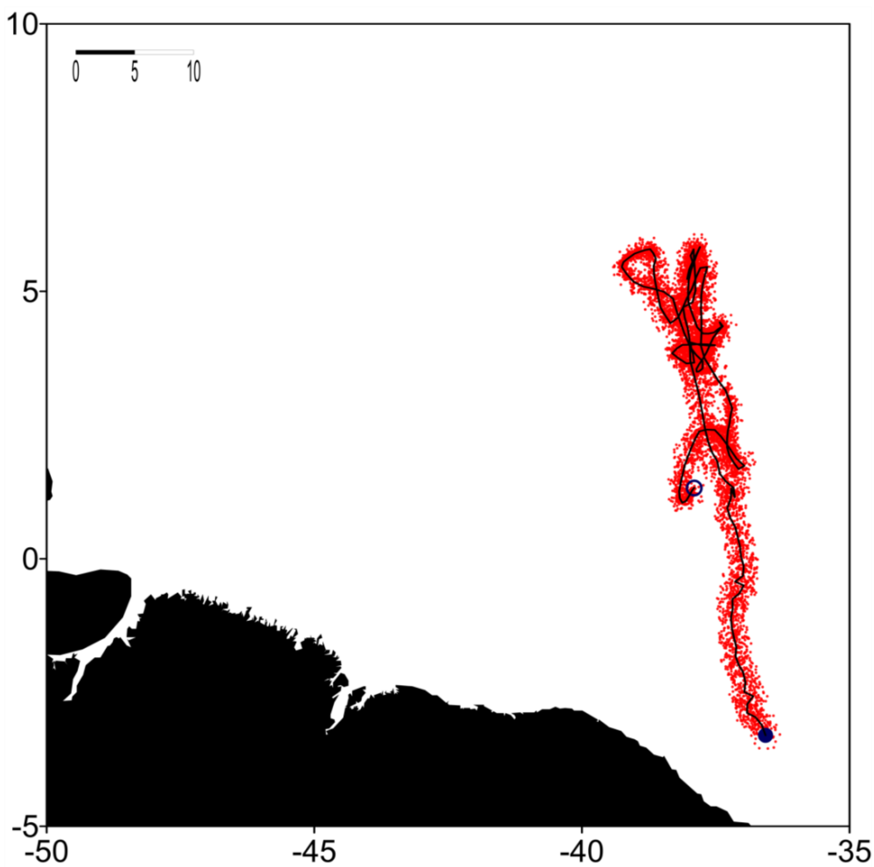


**Figure 3.** Track estimates for a female pelagic stingray, *Pteroplatytrygon violacea*, tagged in the western equatorial Atlantic Ocean. The black line is the estimated track and the red dots are the minimum and maximum extremes of the estimated positions. The blue full dot indicates the beginning of the track while the blue open dot indicates the end.

The diel depth preferences by the tagged pelagic stingray (Fig. 6) indicate that, from about 21:00h to 7:00h, it stayed mostly at shallower depths, from 50m to 100m, being at greater depths, from 100 to 150m, from 8:00h to 20:00h. The data suggest that the species prefers waters below the end of thermocline, between 100-150m deep (Fig. 7), spending less time in the mixed layer, particularly when the temperature is above 28.0°C (Fig. 8).

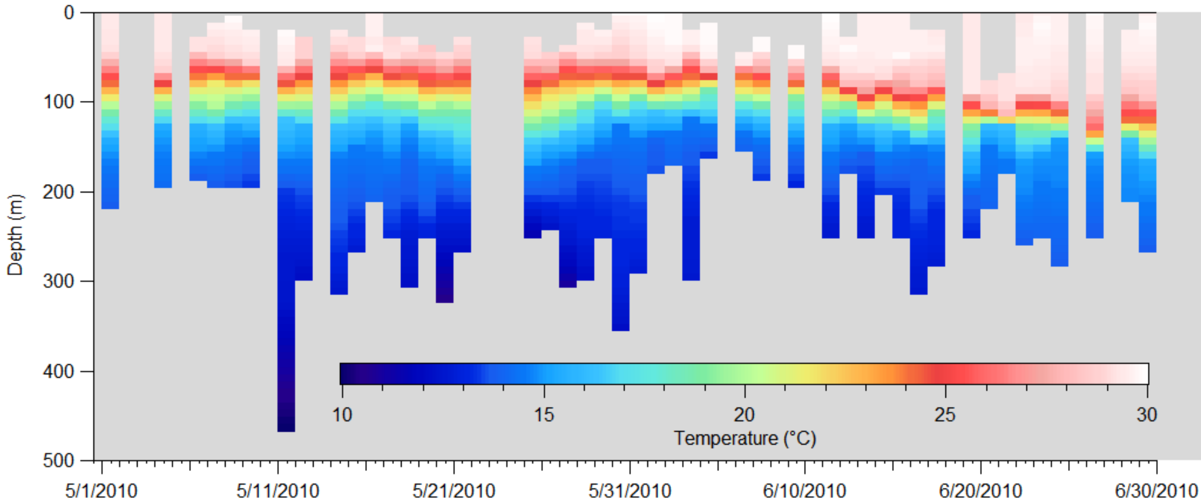


**Figure 4**. Minimum-maximum depths and water temperatures experienced by a female pelagic stingray, *Pteroplatytrygon violacea*, tagged in the western equatorial Atlantic Ocean.

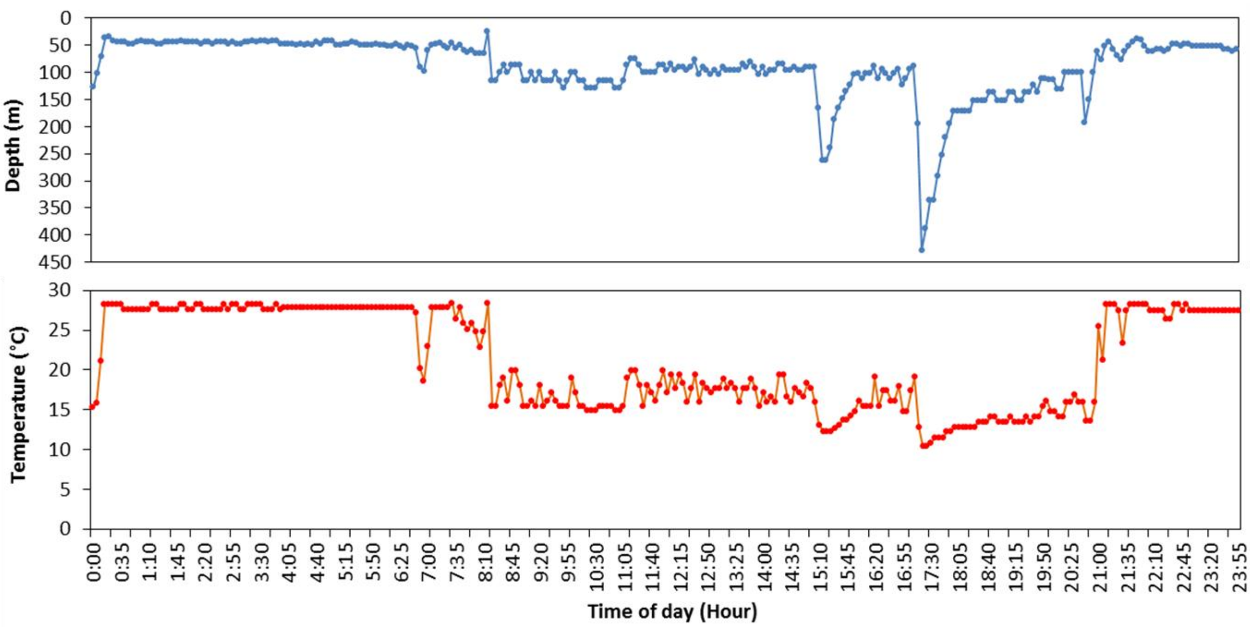


**Figure 5**. Minimum-maximum depths and water temperatures experienced by a female pelagic stingray, *Pteroplatytrygon violacea*, tagged in the western equatorial Atlantic Ocean, throughout the day, in May 11, 2011.

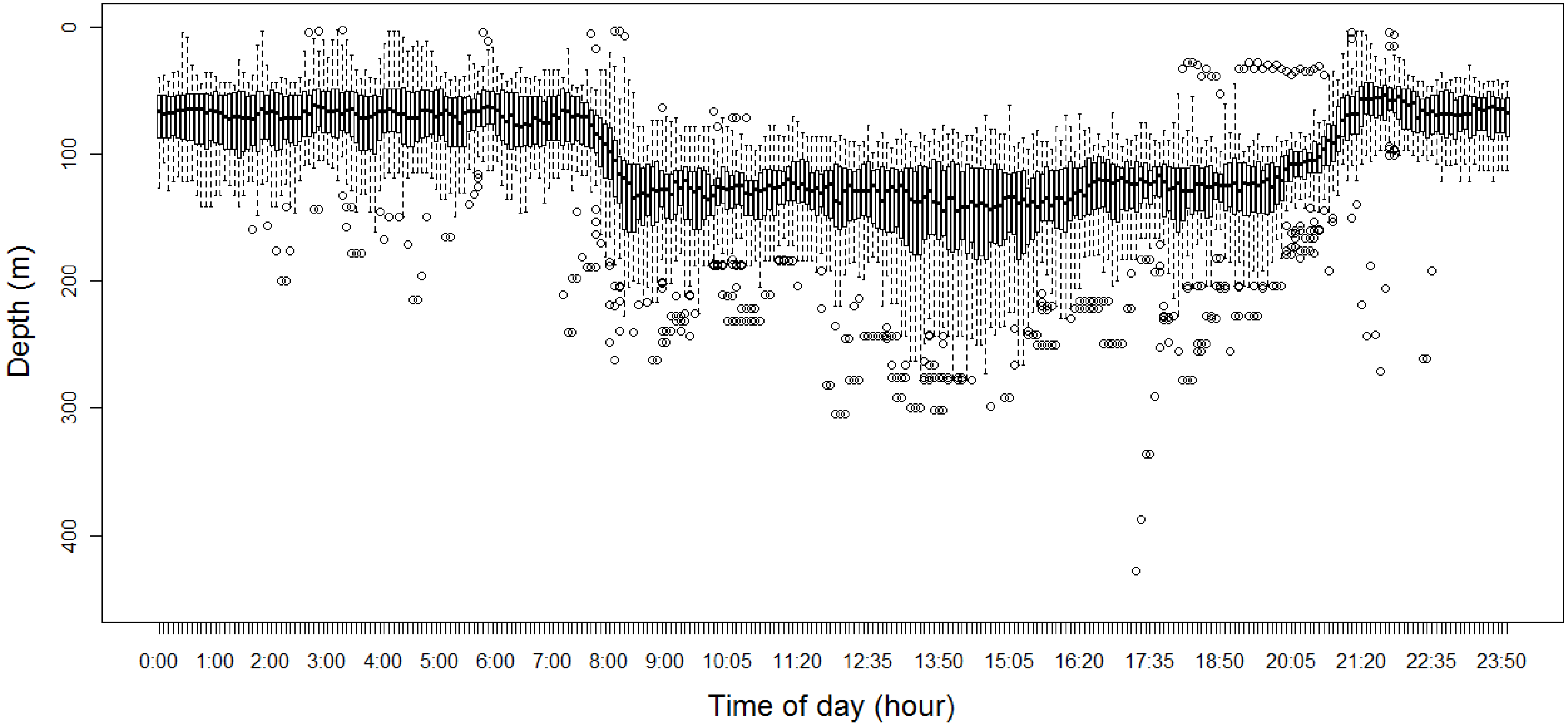


**Figure 6.** Box plots showing the distribution of maximum depths in relation to day and night time to each hour of the day for a female pelagic stingray, *Pteroplatytrygon violacea*, tagged in the western equatorial Atlantic Ocean. Whiskers indicate the 95% confidence intervals; boxes represent the 25th and 75th quartiles, horizontal black lines indicate the median and open circles are the outliers.

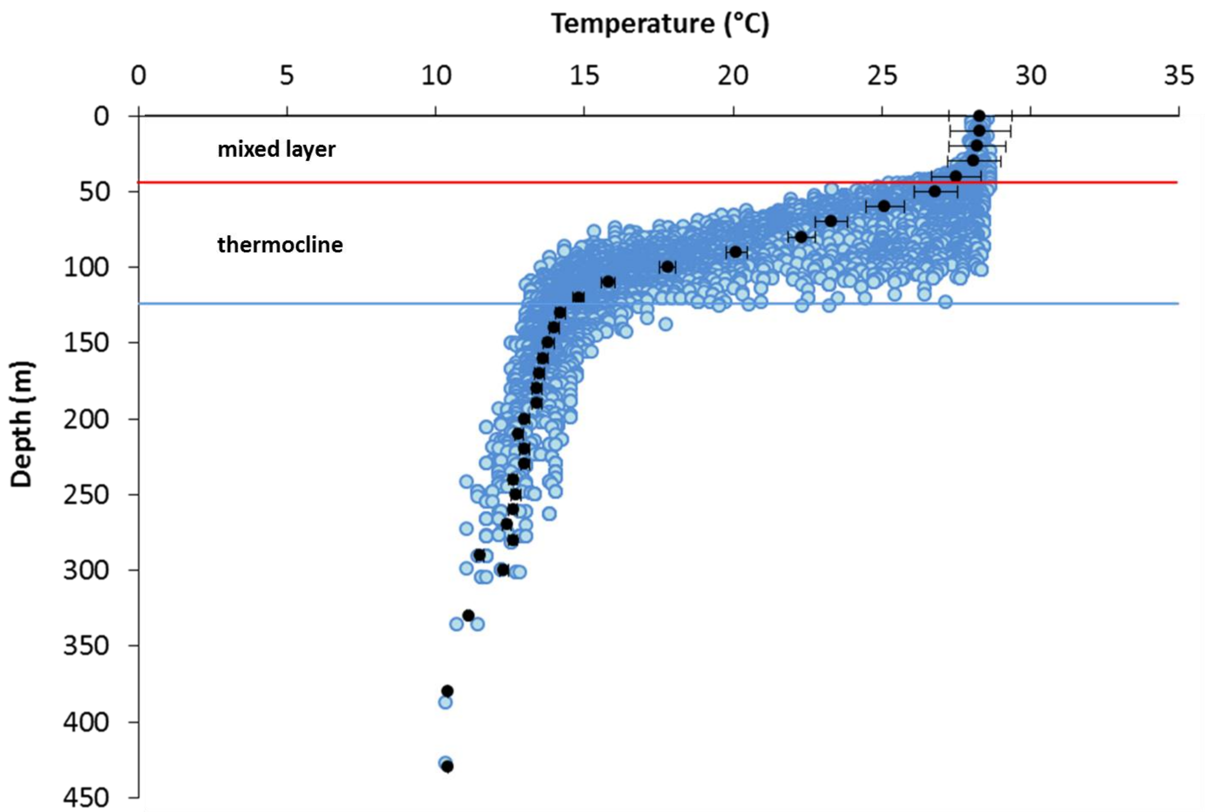


**Figure 7**. Vertical temperature profiles experienced by pelagic stingray, *Pteroplatytrygon violacea*, in the western equatorial Atlantic Ocean, showing the mean temperature ± SE (black dots). The red line indicates the beginning of thermocline, while the blue one indicates the end of it.

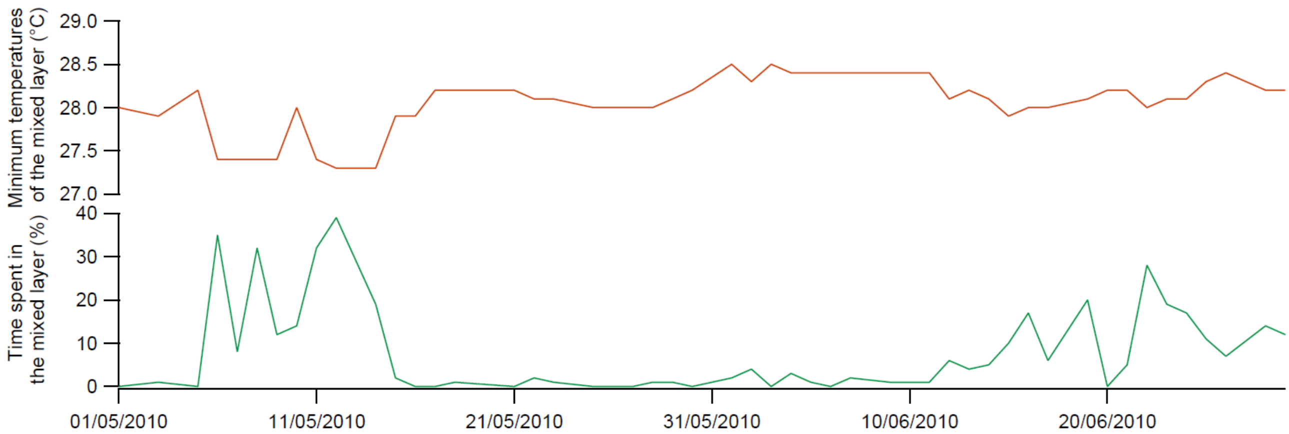


**Figure 8**. Minimum temperatures and time spent in the mixed layer experienced by pelagic stingray, *Pteroplatytrygon violacea*, in the western equatorial Atlantic Ocean.

## Discussion

The average depth (104.2m) frequented by the female pelagic stingray tagged with a MiniPAT tag, in this study, confirms its epipelagic habits (Scott & Tibbo, 1968; Wilson & Beckett, 1970). Although Nakaya (1982) suggested that the species might have a benthopelagic distribution, the data presented here are consistent with most of the findings published by other authors (Akhilesh *et al*., 2008; Zacharia *et al*., 2011; Santana-Hernández *et al*., 2011). However, although the tagged specimen spent only 9.8% of the monitored time in shallow waters, between 0 and 50m deep, other authors have observed pelagic stingray specimens being more common in relatively shallower layers. Ribeiro-Prado and Amorim (2008), for instance, reported for southeastern Brazil, that female pelagic stingrays were most frequent in sets where the fishing gear was placed in low depths (more than 60 m). Ellis (2007) observed, in the North Sea, a mature male caught in water depths of 50-70 m. Siqueira and Sant'Anna (2007), in turn, analyzed pelagic stingray specimens that were obtained from the artisanal fishery landings at Itaipu Beach, Niterói, RJ, caught by handline fishery operating at depths from 30 to 45 m. Finally, Domingo *et al*. (2005) reported catches of pelagic stingrays in longline sets made at depths ranging from 40 to 60 m.

The differences in depth distribution of the pelagic stingray in different regions are likely related to water temperature. The average temperature frequented by the pelagic stingray in this study was 19.6°C, with the specimen spending 64.7% of its time at temperatures ranging from 12 to 22°C. Forselledo *et al*. (2008) observed a temperature range from 9.3 to 28.8°C, with all captures of the species being recorded in waters over 15.3°C. The minimum temperature experienced by the pelagic stingray tagged in this study was 10.4°C. Captive pelagic stingrays at the Zoological Station in Naples often died when the water became too cold (13°C) (Lo Bianco 1909). In the present work, however, the specimen spent 18.2% at temperatures ranging from 12 to 14°C, suggesting that the species might support lower temperatures in the wild, particularly because, in this case, it has the ability to search for warmer, shallower, waters at any time. Mollet (2002), from field and aquaria studies, suggested that pelagic stingrays prefer water temperatures higher than 20°C.

The differences between day and night depth preferences might indicate a diel movement pattern. According to Hutchinson (1967), many taxa of marine zooplankton perform diel vertical migrations with amplitudes from a few to hundreds of meters. Several zooplankton and fish groups feed in the surface waters at night, descending to greater depths during daytime, a movement known as diel vertical migration (DVM) (Luo *et al*., 2000; Cohen and Forward Jr., 2009). Veras *et al*. (2009) observed that the four most important preys for pelagic stingray were hyperiid amphipods, teleosts, brachyuran megalopae and pteropods, with a size between 1.0 and 40.0 mm. The most important prey item was a zooplankton hyperiid, *Phronima sedentaria*, a crustacean which shows a diel pattern of vertical migration (Diebel, 1988; Purcell & Madin, 1991; Laval *et al*., 1992; Cornet & Gili, 1993; Steinberg *et al*., 2000). The diel movement pattern recorded for the pelagic stingray in this study, therefore, may be directly related to the vertical movements of its main preys.

This study has provided new information on the vertical movements and temperature preferences of the pelagic stingray, *Pteroplatytrygon violacea*, indicating that the species might have a remarkable diel vertical migration pattern in the equatorial region, staying in shallow waters during the night and descending to deeper waters during the day. These results may help the assessment of pelagic stingray vulnerability to different gears, fishing at different depths, over the diel period. In order, however, to better understand the species general migratory pattern in this ocean, additional studies on its vertical and horizontal movements are still required.

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## 4. Considerações finais

Até o final da década de 80, a raia-roxa, *Pteroplatytrygon violacea*, era considerada rara (Compagno, 1987). Atualmente, mesmo não havendo nenhuma atividade de pesca dirigida à espécie, a raia roxa é comumente capturada, como fauna acompanhante na pesca de atuns e afins com espinhel pelágico (Forselledo *et al*., 2008; Zacharia *et al*., 2011). Apesar disso, o status das populações da raia-roxa no mundo ainda é desconhecido, particularmente em razão das esparsas informações disponíveis sobre sua pesca, distribuição e biologia.

Parâmetros como o tamanho de primeira maturação sexual, local e época de reprodução, distribuição e uso do habitat são essenciais para o conhecimento da história natural de qualquer espécie e, principalmente, para que se possa avaliar adequadamente o impacto da mortalidade por pesca sobre as suas populações. A expectativa, portanto, é de que as informações geradas pelo presente trabalho possam contribuir para uma melhor avaliação dos estoques de raia-roxa no Oceano Atlântico, com vistas a subsidiar a adoção de medidas de manejo e ordenamento pesqueiro capazes de assegurar a sua conservação.

Na prática, informações geradas em trabalhos com espécies pelágicas já foram efetivamente utilizadas para proteção das espécies de elasmobrânquios pelágicos, a exemplo da proibição de embarque, manutenção a bordo e comercialização do tubarão galha-branca oceânico (*Carcharhinus longimanus*), adotada pela ICCAT (Recomendação 10-07; Tolotti *et al*., in prep.). Esse exemplo ressalta a importância dos resultados gerados em trabalhos científicos com elasmobrânquios, bem como a atenção que vem sendo dada às espécies desse grupo, em comissões internacionais em decorrência da sua vulnerabilidade à crescente pressão pesqueira.

Os resultados apresentados no presente trabalho mostram que a raia-roxa é frequente na pesca de atuns e afins com espinhel realizada pela frota nacional e que suas taxas de captura são relativamente altas. Mostram, também, que a pesca no Atlântico Ocidental incide fortemente sobre a parcela adulta da população (93,7% dos machos e 74,7% das fêmeas) e que a espécie distribui-se preferencialmente entre 12,0 e 22,0°C (com média de 19,6°C), faixa de temperatura na qual o espécime monitorado passou 64,7% do tempo. Essa preferência térmica é próxima daquela exibida pelas principais espécies alvo da pesca, como a albacora bandolim, *Thunnus obesus* (17,0-22,0°C)(Collette et al., 2011) e o espadarte *Xiphias gladius* (18,0-22,0°C) (Collette et al., 2011), aspecto que aumenta a probabilidade da sua captura. Essa característica pode dificultar a implementação de medidas de manejo para a espécie, a exemplo da medida proposta por Bervely *et al*. (2009), que sugeriram a retirada dos anzóis mais rasos como forma de diminuir a sua incidência na pesca de atuns e afins.

No entanto, outras medidas de manejo para a diminuição da captura de fauna acompanhante já vêm sendo testadas, como o uso dos anzóis circulares, embora a sua eficácia ainda não tenha sido totalmente comprovada (Kerstteter e Graves, 2006; Promjinda *et al*., 2008; Pacheco *et al*., 2010; Swimmer *et al*., 2010; Curran e Bigelow, 2011). No caso da raia roxa, particularmente, em razão do seu tamanho relativamente reduzido, é bastante provável que a combinação da forma do anzol (circular) com o seu tamanho (anzóis maiores) contribua significativamente para a redução das capturas da espécie, conforme já demonstrado por outros autores (Piovano *et al*., 2010).

É importante salientar que mesmo gerando informações relevantes e inéditas sobre a raia roxa, na expectativa de que possam ser efetivamente utilizadas na formulação de medidas de manejo para a espécie no futuro, o conhecimento sobre a mesma ainda precisa ser substancialmente aprofundado, principalmente para o Atlântico Sul, onde são ainda raras as informações disponíveis. Sendo assim, sugere-se a continuidade ao monitoramento pesqueiro da espécie e realização de mais experimentos de marcação eletrônica, visando à marcação de exemplares em outras regiões do país.

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