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DISTRIBUIÇÃO, SAZONALIDADE DAS CAPTURAS, UTILIZAÇÃO DO HABITAT E MOVIMENTAÇÃO DO TUBARÃO LIXA *Ginglymostoma cirratum* (Bonnaterre 1778) NA COSTA DO RECIFE, BRASIL

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Luciana Cerqueira Ferreira

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Mestrado em Oceanografia

Luciana Cerqueira Ferreira

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What is a scientist after all? It is a curious man looking through a keyhole, the keyhole of nature, trying to know what's going on.

Jacques Yves Cousteau

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Resumo

O presente trabalho teve por objetivos analisar a abundância relativa, a distribuição de tamanhos, a proporção sexual, os padrões de movimentação, a utilização do habitat e o padrão de residência do tubarão lixa, G*inglymostoma cirratum*, na costa do Recife. Apesar de a espécie possuir uma ampla distribuição no litoral brasileiro, ainda muito pouco se sabe sobre a sua biologia, com a maioria dos trabalhos tendo sido realizados nas costas da Florida e do Caribe. No primeiro capítulo desta dissertação foram analisados os dados de captura provenientes de excursões de pesca semanais realizadas de 2004 a 2010 pelo barco de pesquisa (BPq.) Sinuelo, da Universidade Federal Rural de Pernambuco, no litoral do Recife, atuando, principalmente, nas áreas em frente às praias de Boa Viagem/ Piedade e Paiva. As capturas foram realizadas com a utilização de dois espinhéis de fundo e 23 linhas de espera, lançadas após o canal existente em frente às referidas praias, e com mais alguns lances do espinhel em águas mais profundas (em torno de 30 m). A CPUE (Captura por Unidade de Esforço), em termos do número de indivíduos capturados por 1.000 anzóis, foi utilizada para se estimar a abundância relativa. O tubarão lixa foi a segunda espécie mais frequente entre os elasmobrânquios capturados no espinhel lançado em frente às praias de Boa Viagem/ Piedade e Paiva e foi a espécie mais capturada nas linhas de espera e no espinhel ocasionalmente lançado em profundidades maiores. O comprimento total dos tubarões variou entre 107 e 300 cm. Durante o período chuvoso, as capturas foram dominadas por fêmeas que representaram 72,7% dos tubarões lixa capturados entre abril e setembro. Os machos foram mais abundantes em outubro e janeiro, quando representaram 63,3% e 83,3% das capturas, respectivamente. De uma maneira geral, a CPUE dos machos foi maior entre outubro e abril, período no qual a salinidade, temperatura e transparência da água também estiveram mais altas. A CPUE das fêmeas apresentou uma oscilação mensal entre 0,05 e 0,58, mas sem padrão sazonal aparente. No segundo capítulo foram utilizados dados do monitoramento acústico e de marcação-recaptura para avaliar a residência e os movimentos de tubarões lixa na costa do Recife. O monitoramento acústico dos tubarões foi realizado por meio de uma série de receptores com áreas de detecção não sobrepostas dispostos ao longo da costa do Recife, de janeiro de 2010 a janeiro de 2011. Nove por cento dos tubarões marcados foram recapturados após, em média, 209 dias de liberdade em locais distantes 0,04 a 6,23 km do local de marcação. Um tubarão macho foi considerado semi-residente, apresentando "home ranges" diários pequenos e uma área de atividade restrita às estações localizadas ao sul do rio Jaboatão, apesar de ter demonstrado longo período de completa ausência de detecções na área monitorada Duas fêmeas apresentaram o mesmo padrão de movimentação restrita com evidências de fidelidade local a algumas áreas. Todos os tubarões foram mais detectados durante a noite, sendo que dois deles nunca foram detectados durante o dia, sugerindo o uso da área monitorada como possível local de alimentação no período noturno.

Palavras-chave: *Ginglymostoma*, CPUE, comprimento, marcação, telemetria acústica, residência, Pernambuco

Abstract

The overall objective of the present work was to analyze the relative abundance, size distribution, sex ratio, movement patterns, habitat use and residence of the nurse shark, G*inglymostoma cirratum*, caught off the coast of Recife. Although the species is widely distributed along the Brazilian coast, very little is still known on its biology, with most of the studies being carried out at the Caribbean and Florida coasts. In the first chapter, catch data from weekly fishing cruises conducted off the coast of Recife, from 2004 to 2010, by the research vessel Sinuelo, from the Universidade Federal Rural de Pernambuco, were analyzed. The surveys covered mostly the areas off the beaches of Boa Viagem/ Piedade and Paiva and used, as a fishing gear, two bottom longlines and 23 drum lines set in front of the two referred beaches, with occasional longline sets being also done at greater depths (30 m in average). CPUE (Capture per unit of effort) as the number of individuals caught per 1,000 hooks was used to assess relative abundance. Nurse sharks were the second most frequent species from all elasmobranchs caught by the longline deployed off Boa Viagem/Piedade and Paiva beaches and it was the most frequent species in the drumlines and the longline occasionally deployed at greater depths. The total length of the specimens caught varied between 107 and 300 cm. During the rainy period, catches were dominated by females, which corresponded to 72.7% of catches from April to September. Males were more abundant during October and January when they represented 63.6% and 83.3% of catches, respectively. Male nurse shark CPUE was higher from October to April, period in which, in general, salinity, temperature and water transparency were also higher. Female CPUE showed a monthly oscillation from 0.05 to 0.58, but with no clear seasonal trend. On the second chapter, data from tag-recapture and acoustic monitoring were used to evaluate residency and movement patterns of nurse shark off the coast of Recife. Acoustic monitoring was carried out with a non-overlapping receiver array deployed throughout the coast of Recife from January 2010 to January 2011. Nine per cent of all tagged sharks were recaptured, in average, after 209 days in liberty in sites located 0.04 to 6.23 km from the tagging site. A male shark was considered to be semi-resident, displaying small daily home ranges and an area of activity confined to the stations located to the south of Jaboatão River, although it showed a long period of absence with no detections in the monitored area. Two females exhibited the same restricted movement pattern with evidence of site fidelity to some areas. All sharks were more detected during the night and two of them were never detected during daytime, suggesting that this area may be used as a forage ground during nighttime.

Keywords: *Ginglymostoma*, CPUE, length, tagging, acoustic telemetry, residency, Pernambuco

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Sumário

1. Introdução

Existem, hoje, aproximadamente 1.200 espécies de Chondrichthyes que incluem 50 espécies de quimeras (Ordem Chimaeriformes), mais de 600 espécies de batoides (Ordem Rajiformes) e quase 500 espécies de tubarões, esses últimos distribuídos em 10 Ordens, 60 Famílias e 186 Gêneros (Compagno, 2001).

Os elasmobrânquios (tubarões e raias) são caracterizados por apresentarem crescimento lento, maturação tardia e potencial reprodutivo baixo, o que os torna particularmente vulneráveis a sobrepesca (Musick et al., 2000; Sims, 2010). A pressão de pescarias costeiras aumentou rapidamente após a década de 1950, com o início da utilização de redes baratas de monofilamento. A depleção e o provável desaparecimento de algumas espécies costeiras de tubarões provavelmente também começaram nessa mesma época (Compagno et al., 2005).

Atualmente, a maior prioridade nos estudos sobre elasmobrânquios é o aporte de informações sobre sua biologia e ecologia, habitats críticos, estrutura populacional, idade e crescimento, reprodução e tendências na CPUE. Em muitos casos, o conhecimento sobre a diversidade e distribuição de espécies de tubarões é extremamente inadequado devido à falta de levantamentos científicos básicos e de monitoramento das pescarias (Compagno et al., 2005).

Uma das ferramentas mais utilizadas já há algum tempo no estudo dos elasmobrânquios, em particular de sua estrutura populacional, distribuição e migração, tem sido a marcação e recaptura. A técnica de marcação e recaptura consiste em marcar um grande número de peixes de um modo que os mesmos possam ser identificados individualmente e liberados, em seguida, no seu ambiente natural para que possam ser recapturados posteriormente em operações de pesca, sejam comerciais ou de pesquisa. A partir das recapturas é possível se obter informações extremamente valiosas sobre características de dispersão, migrações de larga escala, taxas de crescimento e estimativas populacionais (Klimley & Nelson, 1984; Heupel & Bennett, 1997; Sims, 2010), razão pela qual a marcação e recaptura tem se constituído em uma importante ferramenta na avaliação de recursos pesqueiros.

A despeito de ser uma técnica utilizada até os dias atuais, porém, a técnica de marcação- recaptura apresenta uma série de limitações, sendo, por isso, cada vez mais utilizada em conjunção com técnicas de telemetria em estudos de movimentos e migrações de tubarões (Nelson, 1990; Kohler & Turner, 2001).

A habilidade de localizar remotamente no ambiente e de se estudar a fisiologia e comportamento de animais de vida livre por meio de técnicas de telemetria resultaram em um grande avanço na compreensão e manejo de populações de animais selvagens (Fancy et al., 1988). Essa técnica permite a obtenção de inúmeras informações acerca de uma determinada população, de forma detalhada, aprimorando o conhecimento sobre preferências de habitat, área de atividade e variações sazonais nos padrões de movimentação de indivíduos (Nelson, 1990).

A telemetria acústica tem sido amplamente utilizada para o monitoramento de várias espécies de elasmobrânquios. A distribuição de receptores acústicos autônomos ao longo da costa permite uma "recaptura eletrônica" dos animais, possibilitando um monitoramento em longo prazo (>1 ano), independentemente das condições climáticas e sem que haja necessidade de esforço de pesca contínuo (Voegeli et al., 2001)

Existem dois métodos de inserção de transmissores acústicos: interno ou externo, ambos com vantagens e desvantagens que dependem do tipo de transmissor, da espécie, de suas características comportamentais e do tipo de dados a serem adquiridos. A marcação externa envolve a fixação do transmissor por meio de aplicadores musculares ou alças nas nadadeiras dorsais enquanto a marcação interna é realizada pela inserção do transmissor pelo esôfago para dentro do estomago (forçado ou por meio de alimentação) ou a inserção na cavidade abdominal por meio de procedimento cirúrgico. A marcação externa é comumente usada em espécies que não podem ser facilmente trazidas a bordo ou cuja morfologia impossibilita procedimentos cirúrgicos (e.g., linguados). Apesar de ser mais rápida e simples, a marcação externa pode ter efeitos adversos no comportamento e fisiologia da natação dos animais marcados devido ao arrasto causado pelo transmissor. Transmissores implantados no estômago, por outro lado, apresentam uma grande possibilidade de perda devido à regurgitação, enquanto que a marcação por meio de procedimento cirúrgico exige treinamento adequado para reduzir a taxa de mortalidade dos animais marcados (Reine, 2005).

No caso do tubarão lixa, as marcas externas não são adequadas, já que o mesmo é um animal de comportamento bentônico que se encontra em frequente contato com formações recifais (Carrier, 1985). Como o risco de regurgitação com a inserção pelo estômago é também elevado, a técnica mais indicada para a marcação com transmissores acústicos nesses animais é, portanto, a utilização de procedimento cirúrgico para inserção de transmissores na cavidade abdominal.

Entre as informações geradas pela telemetria acústica, a utilização do habitat pelos animais marcados é uma das mais importantes. O conhecimento da utilização do espaço por um indivíduo, ao longo de um dia, mês ou ano, é vital para o entendimento da sua biologia e história de vida, sendo importante tanto para o conhecimento dos aspectos biológicos como para o manejo e conservação da espécie (Holland *et al*., 1993; Heupel *et al.*, 2006). O grande número de estudos sobre os padrões de movimentação e utilização do habitat de várias espécies de tubarões por meio da telemetria acústica indica o sucesso dessa técnica em fornecer informações que possibilitem um maior entendimento da ecologia e comportamento das espécies em seu ambiente natural (Holland *et al.*, 1993; Morrissey & Gruber, 1993; Heupel *et al*., 2004; Garla, 2004; Garla *et al.*, 2006; Heupel *et al.*, 2006).

Embora um grande número de espécies de tubarões esteja presente em ambientes costeiros, descrições sobre a distribuição e o uso do habitat por essas espécies tendem a serem vagas e demasiadamente generalizadas. A avaliação das populações de tubarões, por outro lado, sejam oceânicos ou costeiros, é severamente prejudicada pela falta de informações apropriadas sobre sua biologia e de dados provenientes da pesca. Séries temporais longas de dados de captura e esforço raramente se encontram disponíveis para as diversas espécies de tubarões (Cortes, 1998; Knip et al., 2010). Tal carência se torna particularmente acentuada no caso de tubarões e raias que são pescadas como *by-catch*, em pescarias multi-específicas (Muisck et al, 2000), como é o caso do tubarão lixa. O tubarão lixa não é uma espécie com elevado valor comercial, não sendo, consequentemente, alvo de uma pescaria específica. Apesar disso, a espécie é comumente capturada acidentalmente em várias pescarias, tanto artesanais como industriais (Bonfil, 1997; Carrier & Pratt, 1998; Compango 2001, Rosa et al., 2005), aspecto que torna a avaliação do estado de sua população extremamente difícil.

Os poucos trabalhos realizados com captura- marcação- recaptura de indivíduos de tubarão-lixa, além de terem fornecido dados importantes para o estudo de sua idade e crescimento (Carrier & Luer, 1990), demonstraram que a espécie apresenta movimento migratório relativamente restrito, pequena área de distribuição e alta fidelidade ao local em que são capturados (Carrier & Luer, 1990; Garla, 2004). Tais aspectos tornam a metodologia de monitoramento com telemetria acústica altamente recomendável para o estudo da espécie.

Apesar do IBAMA listar o tubarão lixa como "ameaçado de extinção" (IBAMA, 2004), encontrando-se, portanto, protegido por lei, o mesmo ainda é freqüentemente capturado como fauna acompanhante, particularmente pela pesca artesanal (Carrier & Pratt, 1998; Compango, 2001, Rosa et al 2005). Tal situação gera a necessidade de uma melhor compreensão da utilização espacial e temporal do habitat pela espécie, informações essas de extrema importância para seu manejo e conservação.

O objetivo dessa dissertação, portanto, foi o de estudar a biologia do tubarão lixa, G*inglymostoma cirratum*, na costa de Recife, incluindo informações sobre a sua abundância relativa, distribuição de tamanho, proporção sexual, padrões de movimentação, utilização do habitat e residência, no intuito de fornecer subsídios que possam auxiliar na adoção de medidas de manejo visando à conservação da espécie. A dissertação encontra-se estruturada na forma de dois artigos científicos. O primeiro teve como objetivo avaliar a abundância relativa, proporção sexual, distribuição de tamanho e suas flutuações sazonais de tubarões lixas capturados na costa de Recife com base nos dados coletados pelo Projeto de Pesquisa e Monitoramento de Tubarões na Costa do Estado de Pernambuco (PROTUBA). O segundo artigo teve como objetivo avaliar o uso do habitat, residência e padrões de movimentação do tubarão lixa por meio da telemetria acústica com instalação de uma série de receptores ao longo da costa do Recife.

2. Espécie estudada

O tubarão-lixa *Ginglymostoma cirratum* (Figura 1) é uma espécie que habita a região costeira de plataformas continentais e insulares, em águas tropicais e subtropicais do Oceano Atlântico, onde está presente em ambos os lados, e no leste do oceano Pacífico, desde o golfo da Califórnia até o Peru. Na margem ocidental do Atlântico, a

espécie se distribui desde Rhode Island (EUA) até o sudeste do Brasil. Sendo frequentemente encontrado em fundos rochosos, recifes de coral e em canais fluviais de mangues, o tubarão-lixa ocorre desde águas bastante rasas até 130 m de profundidade (Bigelow & Schroeder, 1948; Compagno, 2001; Soto, 2001).

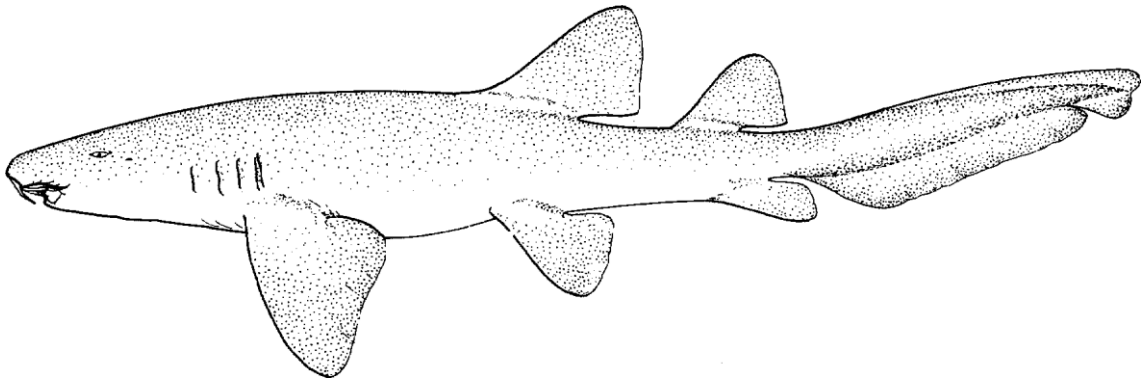

Figura 1. Figura esquemática do tubarão lixa *Ginglymostoma cirratum* (Compagno, 2001).

Apesar da abundância relativamente elevada de *G. cirratum* em águas costeiras, o seu comportamento e ecologia ainda são pouco estudados, particularmente nas populações do Atlântico Sul e Pacífico, com a maioria dos trabalhos sobre a espécie tendo sido realizados nas costas da Florida e do Caribe. Apesar de a espécie possuir uma ampla distribuição na costa do Brasil, muito pouco ainda se sabe sobre sua biologia em águas brasileiras (Castro & Rosa, 2005).

Klimley (1980) fez observações do comportamento de tubarões lixa durante a cópula em um aquário do Miami Sea Aquarium. Carrier & Luer (1990), por sua vez, estudaram as taxas de crescimento da espécie em indivíduos em cativeiro e em indivíduos selvagens, por meio de um programa de marcação e recaptura, com os dois grupos tendo exibido taxas de crescimento muito similares. Motta & Wilga (1999) e Motta et al. (2002) estudaram a morfologia bucal da espécie e sua capacidade de sucção, enquanto Matott et al. (2005) mostraram que, apesar da especialização do aparelho bucal, a espécie não apresenta uma dieta especializada.

Carrier et al. (1994) fizeram observações em campo do comportamento reprodutivo de tubarões lixa no Parque Nacional de Dry Tortugas, Florida, enquanto Carrier & Pratt (1998), subsequentemente, propuseram o fechamento do mesmo durante o período reprodutivo para proteção da espécie, com base nas observações do seu comportamento durante esse período. Castro (2000) fez uma revisão da biologia da

espécie na costa leste da Flórida e nas Bahamas, com informações sobre parâmetros reprodutivos, como tamanho de maturação, período de gestação e ciclo reprodutivo, além de informações sobre habitat, tamanho máximo, dieta e importância econômica.

Mais recentemente, Pratt & Carrier (2001) utilizaram informações sobre a espécie como estudo de caso para trabalhos sobre a reprodução de elasmobrânquios. Saville et al. (2002) indicaram a ocorrência de paternidade múltipla em juvenis de tubarão lixa, utilizando métodos de análise de DNA, sugerindo que tal estratégia reprodutiva poderia ser um meio de garantir a variabilidade genética da espécie, uma vez que seu movimento migratório é relativamente limitado.

Em estudos realizados no Brasil, Castro & Rosa (2005) avaliaram a estrutura populacional do tubarão lixa na Reserva Biológica do Atol das Rocas por meio de fotografia de marcas naturais, estimando um tamanho populacional de 339 a 368 indivíduos. Santander-Neto et al. (2010), por sua vez, descreveram a estrutura populacional da espécie por meio da análise de indivíduos capturados pela pesca artesanal no estado do Ceará.

3. Artigos científicos

3.1. Artigo científico I

Relative abundance, size distribution, sex ratio and seasonality in catch rates of the nurse sharks *Ginglymostoma cirratum* (Bonnaterre 1778) off Recife Coast, Northeast Brazil

Luciana C. Ferreira & Others

Abstract

Nurse sharks are a highly abundant species in coastal waters in both sides of the tropical and subtropical Atlantic. In spite of that, the knowledge on its biology and ecology is still very limited, especially along the Brazilian coast. This study investigates the abundance, sex ratio, size distribution and seasonal fluctuations of the abundance of nurse sharks off Recife, Northeastern Brazil. Nurse sharks were the second most frequent elasmobranch species in the shallower longlines (30.9%) and had the highest CPUE of sharks caught in drumlines and in deeper longlines. The total length of the specimens caught ranged from 107 to 300 cm. During the rainy season the sex ratio was biased towards females (2.67♀:1♂), while during the dry season it didn't differ from 1:1. Females dominated catches from April to September (72.7%) while males were more abundant only in October (63.6%) and January (83.3%). Male nurse shark CPUE was higher from October to April, period in which, in general, salinity, temperature and water transparency were also higher. Female nurse shark CPUE fluctuated monthly from 0.05 to 0.58, but with no clear seasonal trend.

Keywords: *Ginglymostoma, CPUE, seasonal, total length*

Introduction

From June 1992 to September 2006, a sudden shark attack outbreak was recorded in a 20 km stretch of coastline off Recife, Pernambuco, Brazil, including the beaches of Paiva, Candeias, Piedade, Boa Viagem, and Pina (Hazin et al., 2008). In 2004, a local committee (CEMIT- Comitê Estadual de Monitoramento de Incidentes com Tubarões/ the State Committee for the Monitoring of Shark Incidents) was

established in order to mitigate the problem. Since its inception, the CEMIT adopted several measures including the monitoring of the beaches by the Life Guard Department, actions aiming at environmental restoration, the implementation of an environmental education and outreach program, and the research and monitoring program of the shark species responsible for the attacks.

In this context, the Shark Monitoring Program off Recife was initiated with the objective of gathering information about the distribution, abundance and biology of coastal sharks, particularly potentially aggressive species such as tiger sharks *Galeocerdo cuvier* and bull sharks *Carcharhinus leucas*. Six years after the program started a great deal of information has been gathered on the shark species that inhabit this area, not only regarding aggressive species but also species that are relatively abundant and consequently frequently caught during the survey, such as the southern stingray *Dasyatis americana*, the blacknose shark *Carcharhinus acronotus* and the nurse shark *Ginglymostoma cirratum*.

The nurse shark, *Ginglymostoma cirratum* (Bonnaterre 1778), is a coastal species found in both sides of the tropical and subtropical Atlantic, ranging, in the western side of this ocean, from North Carolina to southern Brazil and, in the eastern side, from Cape Verde to northwestern Africa (Bigelow & Schroeder, 1948; Compagno, 2001; Soto, 2001).

Despite the relatively high abundance of nurse sharks in shallow waters of continental shelves and islands, knowledge on its biology and ecology is still rather limited, with most of the studies being restricted to the Caribbean and Florida coast (Klimley, 1980; Carrier, 1985; Carrier & Luer, 1990; Carrier et al.1994; Carrier & Pratt, 1998; Castro, 2000; Pratt & Carrier 2001; Chapman et al., 2005). Although the species is widely distributed along the Brazilian coast, there are insufficient data available regarding important aspects of its biology (Castro & Rosa, 2005), such as abundance, distribution, habitat utilization, population status and fishing impact on its population.

The nurse shark is considered as an endangered species by the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA- Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis), which prohibited, consequently, its fishing in Brazil. In spite of that, nurse sharks are regularly caught by various artisanal fisheries as an incidental *by-catch* (Carrier & Pratt, 1998; Compagno, 2001,

Rosa et al, 2005), generating thus an urgent need for a better understanding of the biology and ecology of this species in the Brazilian coast.

The present paper aims, therefore, at providing information on the relative abundance, sex ratio, size distribution and seasonal fluctuations of nurse sharks off Recife, based on the results obtained by the shark monitoring program conducted by the State Committee for the Monitoring of Shark Incidents (CEMIT).

Materials and Methods

Recife has a coastline of about 20 km, and seawater temperatures ranging from about 24°C, during winter, to 30°C, during summer. All beaches included in the area of high risk of shark attack are under the influence of the Jaboatão River estuary (Hazin et al., 2008). There are two seasons clearly defined in the region: a rainy season, from March to August, and a dry season, from September to February. The continental shelf is relatively plain and short, being only 18 to 20 miles long adjacent to Recife, with its shelf break at 60 to 80 m depth (Kempf, 1970; Araújo et al., 2004).

A total of 239 fishing cruises were conducted between May 2004 and October 2010, each of them averaging five days (sd= 0.72) and encompassing four fishing sets (sd= 0.77). In each set, two bottom longlines and 23 drumlines were deployed.

Each longline consisted of a multifilament polyamide mainline (with 8 mm for the first 3 years and then changed to a 6 mm), with 4 km length subdivided in 4 sections, each bearing 25 baited hooks, summing 100 hooks. After September 2005, all hooks were suspended to midwater by buoys in order to reduce the *bycatch.* Sampling effort was divided into two standard fishing sites comprising the beaches where most of the shark attacks have taken place (Hazin et al., 2008): the first longline was deployed off Boa Viagem/ Piedade beaches and the second one off Paiva beach (Figure 1). Longlines were set at depths averaging 13 m off Boa Viagem/ Piedade and Paiva beaches (sd = 1.01 m and 0.87 m, respectively), outside a channel that runs along them (Hazin et al., 2008). After March 2008, occasional longlines sets were also deployed at the middle of the continental shelf adjacent to Recife, in depths over 30 m.

The drumlines were equipped with two hooks placed at midwater and also deployed in both sampling sites. Differently from the longlines, however, the drumlines

were set in shallower waters, inside the channel, approximately 500 m from shore (Hazin et al., 2008).

Both drumlines and longlines were baited regularly with moray-eel (*Gymnothorax* sp.), although oilfish (*Ruvettus pretiosus*), and mackerel (*Scomber japonicus)* were also occasionally used. The fishing gears were always set at dusk and retrieved at dawn in both fishing sites to maintain an even soaking time during the whole sampling period.

Catch per unit of effort (CPUE), as the number of individuals caught per 1,000 hooks, was used to access relative abundance. Since the longlines off Boa Viagem/ Piedade and Paiva beaches were identical during all years there was no need for any standardization of the effort. The CPUE for the longlines deployed at the standard fishing sites and the CPUE for the occasional longline sets done in the middle of the continental shelf were analyzed separately due to the difference in effort and fishing ground.

From 2004 to 2007, information on the size and sex of the nurse sharks caught was not obtained and only the CPUE is available. After November 2007, all specimens were identified, measured, sexed and tagged. Environmental parameters were recorded at each sampling site at the beginning and end of the deployment and hauling of each longline. Measurements of salinity and sea surface temperature were recorded utilizing an YSI 556 Multiparameter, while water transparency was recorded with a Secchi Disc.

After testing the data of sharks total length for normality and homocedasticity with a Lillefors normality test ($p<0.05$), an ANOVA test ($p<0.05$) was conducted to assess the existence of seasonal differences in mean TL for both sexes at each quarter of the year. The ANOVA test was also performed to compare monthly averages of physical water parameters between the two fishing sites. Chi-square goodness-of-fit tests ($p < 0.05$) were used to test for monthly and seasonal differences in sex ratios.

To test whether environmental factors (temperature, salinity and transparency) had significant effects on nurse shark CPUE, a Linear Regression test ($p < 0.05$) was performed, using free code software R version 2.10.1 (The R Foundation for Statistical Computing). Monthly CPUE data for each set were log-transformed [log(CPUE+1)] to normalize the data.

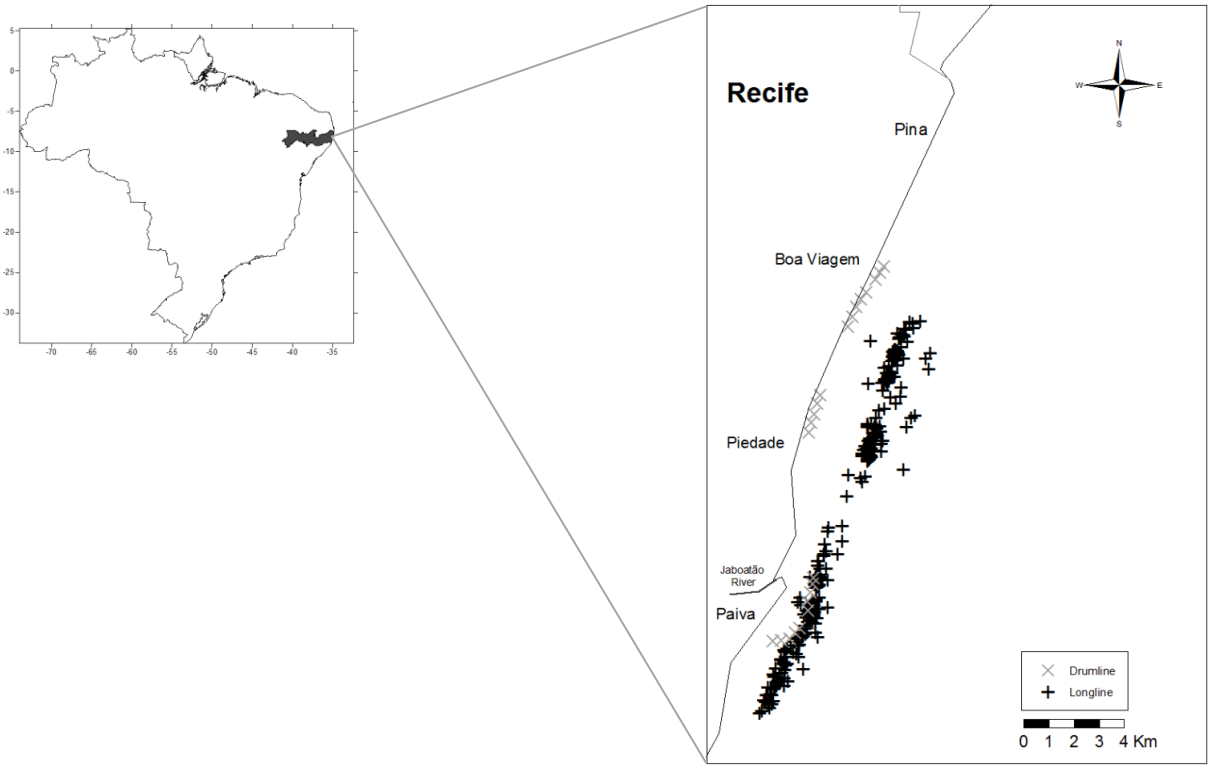

Figure 1. Location of the drumlines and standard longlines sets deployed by the Shark Monitoring Program, off Recife, Brazil.

Results

Teleosts accounted for the majority of the catches (62%) for the longlines and drumlines at the standard fishing sites, with catfishes (*Sciades proops*, *Bagre marinus*, *Bagre* sp.) being the most numerous species, comprising 75.5% of the group. The moray-eel (*Gymnothorax* sp) was the second most common teleost, accounting for 15.0% of teleost catches. Other species sporadically caught were the goliath grouper (*Epinephelus itajara*), snappers (*Lutjanus* sp.), the french angelfish (*Pomacanthus paru*), the tarpon (*Megalops atlanticus*) and shark suckers (*Echeneis naucrates*). During the monitoring program, 5 green turtles (*Chelonia mydas*) were caught and all of them were released alive and with good vital conditions.

A total of 362 elasmobranches were caught by the standard longline and drumlines sets comprising 37.5% of the total catch. The blacknose shark (*Carcharhinus acronotus*) was the most common species, comprising 33.1% of elasmobranch catches. The nurse shark (*Ginglymostoma cirratum*) was the second most frequent species and corresponded to 30.9% of the elasmobranches. Batoids stood for 22.4%, including four species: the southern stingray *Dasyatis americana*, the manta ray *Manta birostris* and

Mobula sp, and the spotted eagle ray *Aetobatus narinari*. Other shark species had lower abundance, such as the tiger shark (*Galeocerdo cuvier*), the bull shark (*Carcharhinus leucas*), the blacktip shark (*Carcharhinus limbatus*), the great hammerhead (*Sphyrna mokarran*), the silky shark (*Carcharhinus falciformis*) and the Caribbean reef shark (*Carcharhinus perezi*).

The standard longline CPUE was equal to 1.99 for elasmobranches and the nurse sharks were the second most abundant elasmobranch species, with a CPUE of 0.60 (Table 1). All sharks showed higher longline CPUE at Boa Viagem/ Piedade beaches than at Paiva beach, while most teleosts showed an opposite trend, with higher longline CPUE at Paiva beach.

Similarly to the standard longlines catches, most species had higher CPUE for the drumlines off Boa Viagem/ Piedade beaches (Table 1). For both the drumlines and the occasional longline sets done at the mid-continental shelf, nurse sharks represented the highest CPUE for all shark species (Table 1).

Nurse sharks ranged in size between 107 and 300 cm total length (TL) (Figure 2). Average female TL was 182 cm (sd= 47.2 cm) and average male TL was 178 cm (sd= 36.5 cm), with no significant difference in TL between sexes (p= 0.83, NS). Most of the sharks were under the maturation size estimated for the species (Castro, 2000; females= 227 cm TL, males= 214 cm TL) (χ^2= 10.7, df= 1, $p < 0.01$ for males; and χ^2= 15.5, df= 1, $p < 0.01$, for females). Size distribution of nurse sharks exhibited significant monthly variations (F= 7.44, df= 11, $p < 0.01$). Variations in mean TL were also observed on each quarter of the year for both males and females (Figure 3). Mean TL of females were slightly larger during the third and fourth quarters (July to December), while the TL of males showed an opposite trend, with smaller sizes during the second half of the year.

Table 1. Catch per Unit of Effort (CPUE) for elasmobranch and teleost species caught by the Shark Monitoring Program off Recife (2004-2010), at the standard fishing sites and mid continental shelf by longline and drumline. Numbers in parentheses represent the number of animals caught.

	Longline				Drumline		
Species	Boa Viagem/ Piedade	Paiva	**Total**	Mid Continental Shelf	Boa Viagem/ Piedade	Paiva	**Total**
Catfishes	1.75 (154)	3.15 (271)	2.44 (425)		0.98 (13)	1.2 (14)	1.09 (27)
C. acronotus	0.91 (80)	0.38 (33)	0.65 (113)	2.00 (8)	0.38 (5)	0.17 (2)	0.28 (7)
G. cirratum	0.67 (59)	0.52 (45)	0.60 (104)	2.25 (9)	0.45 (6)	0.17 (2)	0.32 (8)
Gymnothorax sp.	0.67 (59)	0.29 (25)	0.48 (84)	0.25 (1)	0.30 (4)	0.17 (2)	0.24 (6)
D. Americana	0.47 (41)	0.33 (28)	0.40 (69)	0.50 (2)	0.15 (2)	0.09 (1)	0.12 (3)
G. cuvier	0.22 (19)	0.09 (8)	0.16 (27)	0.25 (1)	0 (0)	0.09 (1)	0.04 (1)
Lutjanus sp.	0.16 (14)	0.26 (22)	0.21 (36)		0.08 (1)	0 (0)	0.04 (1)
C. leucas	0.08 (7)	0.02 (2)	0.05 (9)		0.08 (1)	0 (0)	0.04 (1)
Mobula sp.	0.08 (7)	0.02 (2)	0.05 (9)				
C. limbatus	0.06 (5)	0 (0)	0.03 (5)				
A. narinari	0.03 (3)	0.02 (2)	0.03 (5)				
M. atlanticus	0.06 (5)	0 (0)	0.03 (5)				
C. falciformis	0.02 (2)	0.01 (1)	0.02 (3)	0.25 (1)			
P. paru	0.02 (2)	0.01 (1)	0.02 (3)				
E.naucrates	0 (0)	0.03 (3)	0.02 (3)	0.25 (1)			
E. itajara	0 (0)	0.03 (3)	0.02 (3)		0.45 (6)	0 (0)	0.24 (6)
S. mokarran	0.03 (2)	0 (0)	0.01 (2)				
C. perezi	0.01 (1)	0 (0)	0.01 (1)				
C. porosus				0.25 (1)			

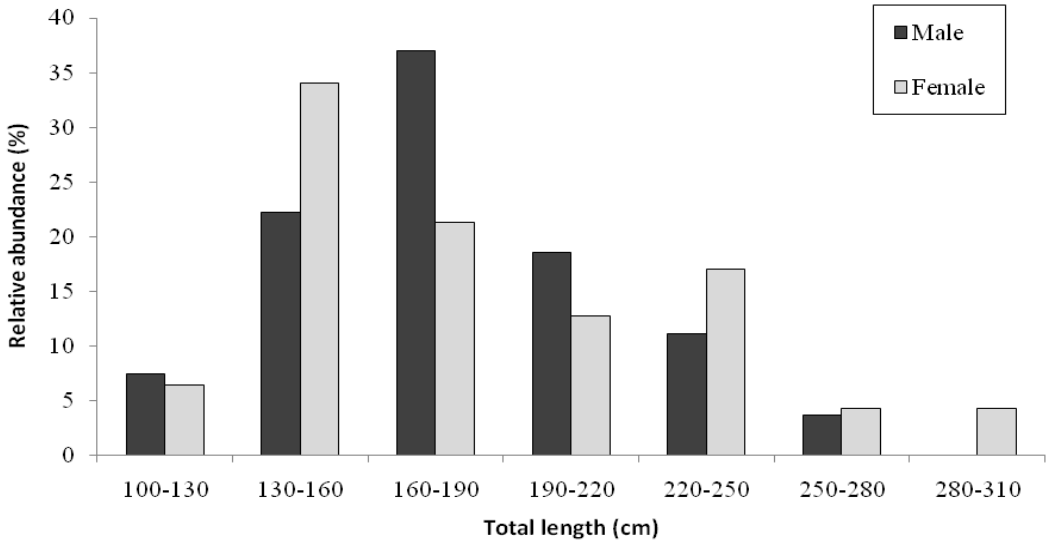

Figure 2. Size distribution of male and female nurse sharks caught off Recife in all longlines and drumlines sets, from November 2007 to October 2010.

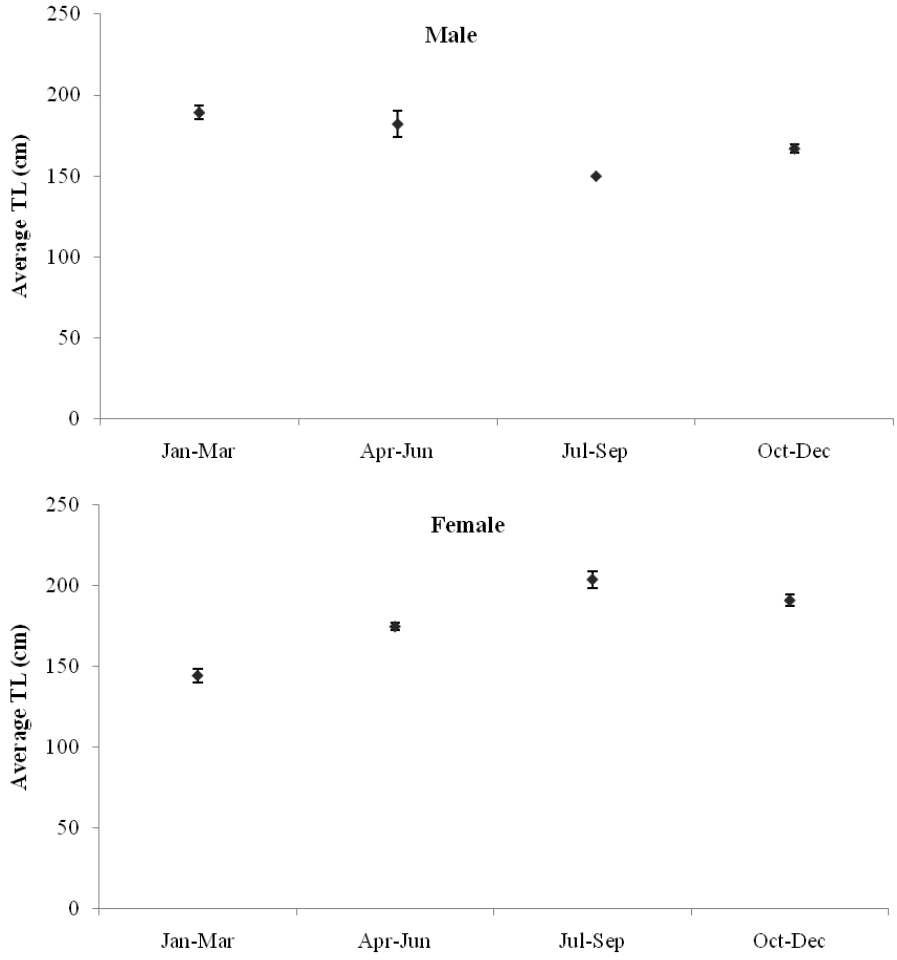

Figure 3. Average total length (± SE) for each quarter of the year for male and female nurse sharks caught off Recife on all longlines and drumlines sets, from November 2007 to October 2010.

Although the overall sex ratio for nurse sharks was 1.35♀:1♂, it showed a strong seasonal variation (Figure 4). Females were significantly predominant in the catches during the second (April to June) and third (July to September) quarters of the year (χ^2 = 5 df = 1, $p < 0.05$ and χ^2 = 9.9 df = 1, $p < 0.05$, respectively), accounting for 75.0% and 85.7% of nurse shark catches, respectively. Males were more abundant during the first quarter of the year (January to March), peaking in January, when they comprised 71.4% of catches. There was also a peak in male's abundance during October, but the sex ratio wasn't significantly different from 1♀:1♂ on the fourth quarter (p = 1.0, NS).

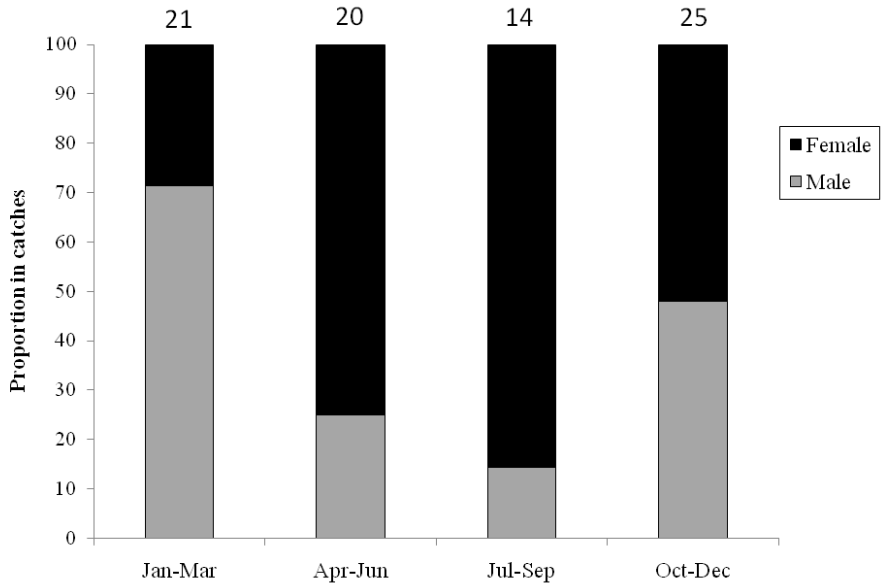

Figure 4. Seasonal changes in the proportion of females and males in catches. Number above bars represent total number of shark caught each month.

There was no significant difference in the monthly average sea surface temperature, salinity and transparency between Boa Viagem/ Piedade and Paiva beaches (F= 0.01 p= 0.91; F= 0.03 p = 0.85; F= 0.0003 p= 0.98, respectively). Notwithstanding, all parameters exhibited a seasonal oscillation (Figure 5). Monthly average temperature demonstrated a seasonal pattern between summer (dry season) and winter months (rainy season) with temperatures ranging between 25.3º and 30.9ºC. Salinity oscillated from 33.1 to 38.9, averaging 35.9 during the dry season and 35.0 during the rainy season. Water transparency was higher during dry months (4.6 m) and lower during rainy months (1.3m).

The CPUE of m Males exhibited a similar pattern, to the environmental parameters showing higher abundance during dry months, when temperature, salinity

and transparency were also higher. However, there was no significant influence of physical parameter on the CPUE of male nurse sharks (Temperature p = 0.18, NS; Salinity p = 0.07, NS; Transparency p = 0.32, NS). Relative abundance of females fluctuated monthly, but with no clear seasonal trend (Figures 5).

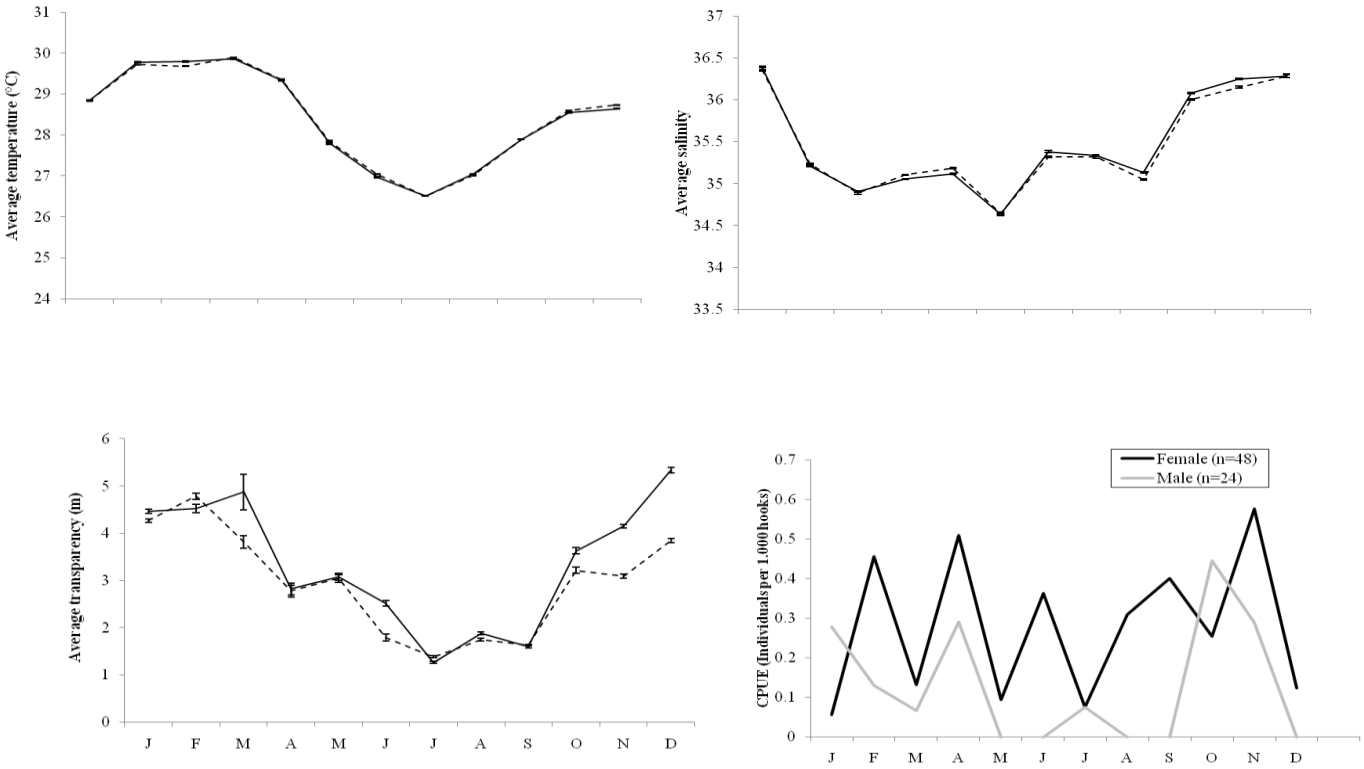

Figure 5. Monthly average water temperature, salinity and transparency (±SE), full lines represent Boa Viagem beach and dotted lines represent Paiva beach; and monthly mean CPUE for male and females.

Discussion

Nurse sharks were caught throughout the sampling period, suggesting a year-round occurrence in the study area. A high frequency for the species has been previously reported in the Everglades, Florida (Wiley & Simpfendorfer, 2007), in Ceará, Northeastern Brazil (Santander-Neto et al., 2010), and in Atol das Rocas Biological Reserve, Brazil (Agra, 2009).

The higher abundance of this species, in Boa Viagem/ Piedade beaches, observed in the present study, was previously noticed by Fischer et al. (2009), who also recorded the occurrence of other shark species such as the hammerhead shark, the tiger shark, the bull shark, the blacktip shark and the blacknose shark.

The physical parameters monitored in the present study exhibited no differences between both fishing areas, suggesting that water temperature, salinity and turbidity were probably not responsible for the differences in abundance between them.

Based on the size at maturation estimated for the species (females= 227, males= 214 cm TL; Castro, 2000), most of the nurse sharks examined were juveniles, although no specimen under 100 cm TL was caught. The absence of neonates is possibly related to the selectivity of the hook size, which may have prevented smaller sharks from biting the hook.

Castro (2000) proposed a maximum size for the nurse shark of 280 cm. However, in the present work, one shark caught off Paiva beach measured 300 cm TL and another one captured off Boa Viagem/ Piedade beach had 290 cm TL, both females. These results are close to the maximum length of 305 cm, found by Castro & Rosa (2005) in the Atol da Rocas Biological Reserve, Brazil. Interestingly, both maximum sizes over 280 cm were found for nurse shark populations from the tropical south Atlantic which may be a first indication of a difference from the species population between hemispheres.

The observed overall sex ratio 1.35♀:1♂ is similar to the ratio found in the coast of Ceará, Northeast Brazil (Santander-Neto et al., 2010; 1.19♀:1♂). The seasonal changes in the sex ratio by quarters observed in the present study were also recorded at Atol das Rocas Biological Reserve, by Castro & Rosa (2005), who also found a lower abundance of males during winter months. They also recorded a dominance of females during August who appeared to be gravid and aggregating. In the present case, however, visual observation during the monitoring period hasn't provided much evidence on the state of maturation of females (gravid or not), making it impossible to infer the influence of the reproductive cycle on the seasonal changes in the sex ratio of nurse sharks off Recife.

Wiley & Simpfendorfer (2007) reported a preference of nurse sharks for certain marine areas following temperature and salinity electivity patterns. Accordingly, they would avoid waters with salinity < 30°C and temperature < 25°C or > 29°C. Since temperature and salinity off Recife were always higher than 25 and 32, respectively, it is plausible that this habitat offers adequate physical conditions for nurse sharks throughout the year which can explain the year-round presence of females.

The results of this study show that nurse sharks are a resident species in the monitored area off Recife and are represented mostly by immature specimens. However, the seasonal variations in the abundance of males nurse sharks could suggest a seasonal migration of males away from this area, during the rainy season. Further studies on the reproductive cycle and movement patterns of nurse sharks off Recife are necessary to fully understand the reasons for some of the results obtained by this study.

Acknowledgments

This work was part of the Shark Monitoring Program conducted by the CEMIT (the State Committee for the Monitoring of Shark Incidents) and was made possible by funding from the State Government of Pernambuco. The authors would like to acknowledge the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for providing a scholarship to L. C. Ferreira. The authors are thankful to the crew of R.V. Sinuelo and R.V. Pedrinho and all interns form Laboratório de Tecnologia Pesquira (LATEP-UFRPE) for assisting with field work.

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3.2. Artigo científico II

Residency and movement patterns of nurse sharks, *Ginglymostoma cirratum* (Bonaterre 1778), in coastal waters off Recife, northeastern Brazil

Luciana C. Ferreira & Others

Abstract

The nurse shark *Ginglymostoma cirratum* is an abundant coastal species widely distributed on both sides of the tropical and subtropical Atlantic Ocean, including the Brazilian coast. Despite it is considered as an endangered species in Brazil, information on biological and ecological aspects of this species in Brazilian waters is still very limited with little detailed studies available. In the present work, acoustic monitoring and tag-recapture data were used to evaluate residency and movements of nurse sharks in coastal waters off Recife. To that aim, a non-overlapping array of receivers was deployed to track the movement of nurse sharks from January 2010 to January 2011. About 9% of tagged sharks were recaptured after an average of 209 days at liberty, in places located between 0.04 and 6.23 km from the original tagging site. The tagged sharks showed different movement patterns. One male was considered as resident with small daily home ranges and an area of activity almost restricted to the stations south of the Jaboatão River, although it also showed a seasonal migratory pattern. Two females displayed a more disperse pattern of movement but with evidences of site fidelity to some areas. All sharks were more detected during the night and two were almost never detected during daylight hours, suggesting the use of this area as a possible foraging ground at night time. Although further studies with a greater sample size for nurse sharks are still necessary, the results of the present study suggest that the activity space and movement pattern for this species is considerably variable with apparent seasonal changes which can affect how management actions should be established to ensure its conservation.

Keywords

Ginglymostoma, tagging, recapture, acoustic telemetry, habitat use

Introduction

The nurse shark *Ginglymostoma cirratum* is a coastal species widely distributed in continental and insular shelf waters in both sides of the tropical and subtropical Atlantic (Bigelow & Schroeder, 1948; Compagno 2001). Despite its abundance in shallow waters, there is still little information on the species ecology, with most studies being restricted to the coast of Florida and the Caribbean (Carrier, 1985; Carrier & Luer, 1990; Carrier et al., 1994; Castro, 2000; Pratt & Carrier, 2001; Chapman et al., 2005). The knowledge on biological and ecological aspects of this species in Brazilian waters, however, is still very limited, with few detailed studies available (Garla, 2004; Castro & Rosa, 2005; Agra, 2010; Santander-Neto et al., 2010).

Although the nurse shark is considered as an endangered species by the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA-Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis), which prohibited, consequently, its fishing in Brazilian waters, the species is still frequently caught as *by-catch* by local artisanal fisheries (Rosa et al., 2005).

Tagging studies may provide valuable knowledge on many aspects of the biology and ecology of elasmobranches, enabling the collection of information on population size, life history parameters and behavior, including distribution and migratory patterns (Heupel & Bennett, 1997; Kohler & Turner, 2001). Conventional tagging studies, however, are often characterized by low percentage of tag returns and irregular return times (Nelson, 1990). One important aspect of the biology and life history of a species, for both biological and management purposes, is the understanding of how much area one individual uses over different periods of time (Heupel et al., 2006). The development of passive acoustic telemetry has enabled long term studies that were much less expensive and time consuming than the more conventional active tracking done in the past (Voegeli et al., 2001). This technology has allowed the simultaneous monitoring of a higher proportion of a population, making it possible, therefore, to study the changes in movement patterns in a population level, over a long period of time (Heupel et al., 2004; Simpfendorfer et al., 2002). Many inshore or reef sharks are primarily home ranging, making long term telemetry studies possible, with relatively limited resources (Nelson, 1990). Acoustic passive monitoring is usually applied for species that are easily accessed and confined to a well enclosed geographic region with the use of an overlapping array of receivers (Heupel et al., 2006). The

utilization of an overlapping array in an open coastal environmental, however, in many instances is not economically feasible, making it necessary, such as in the present case, to use a non-overlapping array, to cover a larger area (Simpfendorfer et al., 2002).

The purpose of this research was thus to investigate the habitat use, residency and movement patterns of nurse sharks trough the employment of a non-overlapping array of receivers, in the coastal waters off Recife, Brazil. The expectation is that the data presented may help to build management measures more adequate and effective to ensure the conservation of this important shark species.

Material and Methods

Recife is a rather large city located in northeast Brazil, with a population of 1.5 million and a coastline of about 20 km. Seawater temperatures range from about 24°C, during winter, to 30°C, during summer, while salinity oscillates from 34.5 to 38.5, being highly influenced by the Jaboatão River estuary, located to the south of Recife (Hazin et al., 2008). There are two clearly defined seasons in the region: a rainy season (winter), from March to August, and a dry season (summer), from September to February. The continental shelf is relatively plain and short, with the shelf break at depths from 60 to 80 m (Kempf, 1970; Araújo et al., 2004). The study site comprised four beaches from the Recife metropolitan area (Pina, Boa Viagem, Piedade, and Candeias) located to the north of the Jaboatão River and one to the south of it (Paiva).

A series of 25 VR2W acoustic omnidirectional hydrophones (Vemco) were deployed in a non-overlapping array within the study site (Fig.1), from January 2010 to January 2011. Receivers were deployed in different periods and not all receivers were in the water at the same time until August 2010. Receivers were deployed in depths between 8 to 14 m moored to the seafloor with a 20 kg cement plate which was connected to a 40 kg cement block and two 15 kg anchors with an 8 mm polyamide multifilament to prevent drifting. The receiver was held upright in the middle of the water column by a subsurface float. Preliminary field testing indicated a detection range for the receivers between 250-300 m.

Sharks were collected under the research carried out by the Shark Monitoring Program off Recife. Bottom longline fishing cruises to catch and tag sharks were conducted weekly from October 2007 to January 2011. Each longline was equipped

with a hundred 18/0 circle hooks deployed parallel to the coastline at the isobaths from 8 to 14 m. Longlines were always set at dusk and retrieved at dawn to standardize soaking time. All hooked sharks were carefully brought onboard, restrained on deck and received a continuous flow of water. All sharks were measured (Total length- TL), sexed and externally tagged with a stainless steel dart-tag (Floytag & Mfg., Inc.)

Acoustic tagging was performed in five nurse sharks, which were hooked cleanly in the mouth, had no significant injury and showed good vital conditions. In all cases, the coded acoustic transmitters (V16, Vemco) were implanted surgically, in the abdominal cavity, trough a 5 cm incision made in the ventral surface just anterior to the origin the pelvic fins. During surgery, sharks had their eyes covered and received a continuous flow of water. Once the insertion was concluded, the incision was closed with a nylon suture. The sharks were then returned to water and held close to the boat until they were able to swim on their own. Transmitters were implanted into four females and one male ranging from 151 to 240 cm TL (mean=192.8 cm TL). All but one female were considered juvenile, based on estimated size at maturity by Castro (2000) (Approximately 227 cm TL for males and 214 cm TL for females).

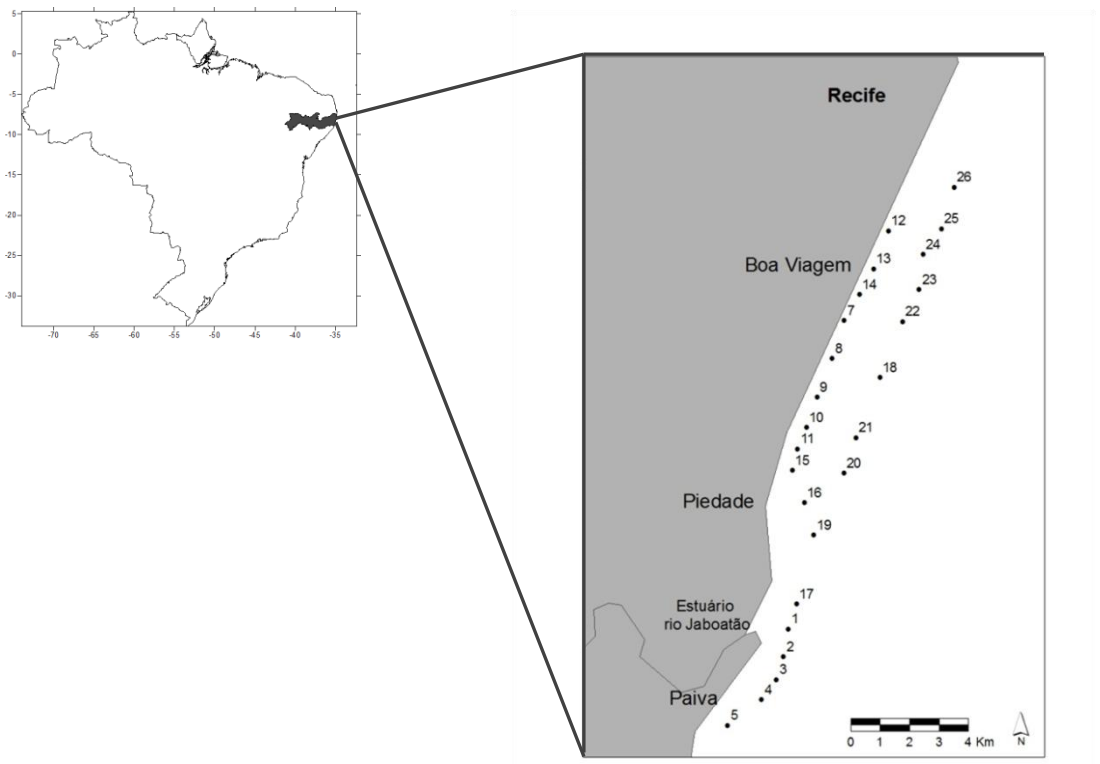

Figure 1. Coast of Recife metropolitan area, northeast Brazil. Points indicate the location of acoustic receiver stations within the study site.

The period of liberty of recaptured sharks was calculated and the distance between the points of tagging and recapture estimated and plotted in a map, using ArcView 3.2. Detection records were counted for each receiver from the date of deployment to the date of download. For each receiver station, the total number of records (all sharks combined) per day was used to calculate the density of detections. Records from each receiver were also sorted by transmitter identity, date and time. For each shark the total number of detections anywhere inside the array was plotted in a time series to conservatively evaluate residency time. To assess site fidelity, the number of detections from individual sharks at every receiver was collated and the proportion of detection on each receiver was calculated. A "primary site" (receiver closest to the point of capture and tagging) was designated to assist in the evaluation of site fidelity and movement pattern. Minimum linear distances were defined as the straight-line distance between the two most distant receivers in the array which detected the shark. The proportion of detection of each shark at each hour of the day was calculated to examine diel patterns of activity. A comparison of the number of detections of each shark was made between months during the whole monitoring period to verify the presence of any seasonal changes. Home ranges for individual sharks were calculated using two methods: minimum convex polygon (MCP) and 95% fixed kernel. MCP provides an estimate of the extent of the home range while kernel estimates provide information on the utilization of the space within the home range (Heupel et al., 2004). Both home range estimates were made using the Animal Movement Extension (Hooge & Eichenlaub, 2000) for ArcView 3.2. Chi-square tests ($p < 0.05$) were performed to examine significant differences in the number of detection between each hour of the day for each shark and also between detections at the primary site and adjacent sites.

Results

Seventy eight nurse sharks were caught and tagged, including 40 females, 35 males and three specimens with unrecorded sex. The size of the sharks ranged from 125 to 258 cm TL (mean= 189 cm TL, s.d.= 34.9 cm), for males, and from 119 to 300 cm TL, for females (mean= 187 cm TL, s.d.= 49.8 cm).

Seven out of the 78 tagged sharks (about 9%) were recaptured after 30 to 469 days at liberty, with a mean of 209 days (Fig. 2). One shark was recaptured twice, 177

days after the first release, at 0.64 km from the first tagging site, and 287 days after the second release, at 1.76 km from the second tagging site. The distance between the tagging and recapture sites for all sharks ranged from 0.04 to 6.23 km, with a mean of 2.2 km. The shark with the longest time at liberty showed the greatest distance, while the shark with the shortest time at liberty showed the smallest displacement.

Of the five sharks that were acoustically tagged (Table 1), three were detected by the acoustic receivers array, yielding a total of 5,178 detections during the entire study. Shark 1 (S1) was a male with 170 cm TL tagged in October 2009; Shark 2 (S2) was a female with 151 cm TL tagged in July 2010; and Shark 3 (S3) was a female with 240 cm TL, probably the only mature shark that was fitted with a transmitter, tagged on August 2010. The two females had a more similar pattern of detections, when compared to the one shown by the male, which was considerably different.

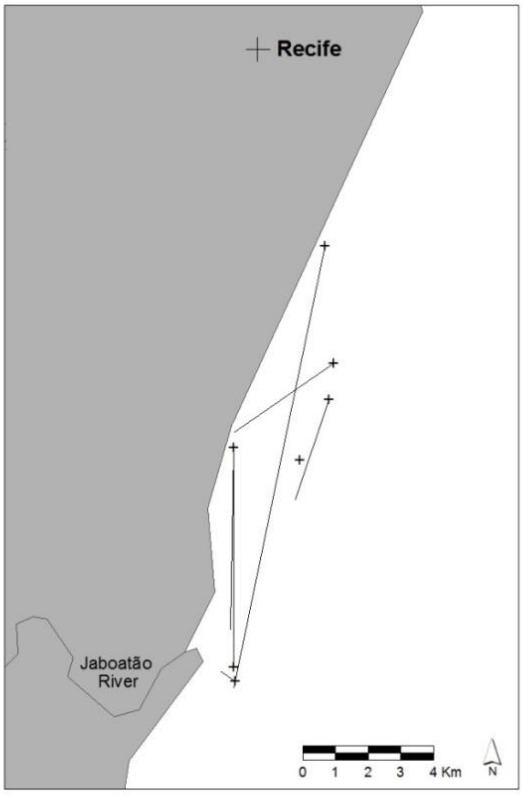

Figure 2. Map of location of tagging (+) and release points, as well as, the shortest route to recapture point (line) for the all nurse sharks recaptured off Recife.

Table 1. Nurse sharks monitored off Recife. ID indicates sharks identification; date of tagging; total length (cm); number of detections.

ID	Date	TL	Sex	Detections	Point of capture	
					Latitude	Longitude
S1	10/03/2010	170	M	5031	8° 13’ 57.5 S	34° 54’ 38.4 W
S2	07/31/2010	151	F	196	8° 09’ 40.5 S	34° 52’ 57.2 W
S3	08/16/2010	240	F	88	8° 13’ 15.0 S	34° 54’ 27.7 W
S4	11/02/2010	203	F	0	8° 13’ 26.4 S	34° 54’ 33.3 W
S5	11/22/2010	200	M	0	8° 13’ 58.8 S	34° 54’ 37.4 W

All three sharks when present in the monitored area stayed for a significant amount of time close to at least one receiver during consecutive days (Figure 3). S1 presented two different periods of detection separated by a period of complete absence from the array that lasted for five months. During the first period, S1 was detected in at least two of the receivers on an almost daily basis, while during the second period detections were lower and less frequent. S2 was also detected almost daily during the first two months following its capture and tagging but detections were sharply diminished from November 2010 to January 2011. S3 was detected for only two months, presenting a high daily density in detections when present in the monitored area. S1 was detected in 26.3% of the days after it was tagged, S2 in 16.3% and S3 1n 4.6% of the days. Female sharks were continuously present within the study site for periods ranging from 1 to 3 days, with a mean of 1, while the male stayed from 1 to 21 days, with a mean of 8.

The movement pattern of the tracked sharks seemed to be very restricted, with few receivers presenting a high detection density and most of the detections from each shark being recorded in few receivers from the array (Fig. 4a). Although detection density was higher in the receivers to the south of Jaboatão River, 99.9% of them were from S1 (male). Close to 62% of the detections from S1 were recorded in two of the stations located to the south of Jaboatão River, with only 0.1% being recorded to the north of it. In the case of S2 (female), 97.5% of the detections were recorded in two receivers and all of them came from receivers located to the north of Jaboatão River. S3 (female) movements weren’t as restricted as the other two having 48% of detection concentrated in two receivers that were 10 km apart (Fig. 4b).

All three sharks had most of their detection at night (χ^2= 48, df= 1, p< 0.01, for S1; χ^2= 14.73, df= 1, p < 0.01, for S2; χ^2= 22.34, df= 1, p < 0.01, for S3; χ^2= 36.44, df= 1, p < 0.01 for all sharks together). S1, however, was detected at all hours of the day with a peak between 2:00 and 4:00 and a lower detection rate between 9:00 and 14:00. About 94% of the detections from S2 were recorded in hours with no light, after sunset and before sunrise (18:00- 4:00). In the case of S3, 61% of the detections also occurred at night (Fig. 5). The peak shown by this last shark at 10:00 and 11:00, however, was only observed in the day the shark was tagged and at the receiver closest to the release point. After this post release period S3 was never detected during the day again.

S1 exhibited an apparent seasonal migration pattern, being present in the monitored area only during summer months (Figure 6). From January to April, S1 was constantly detected, with a high daily detection density in receivers to the south of the Jaboatão River. From May to September, no detection of S1 was recorded. From October to January 2011, S1 begun to be detected again, but with a slightly different pattern, being more detected by receivers to the north of Jaboatão River, but with a much lower density. In the case of S2, although it was present in the monitoring area throughout the months, 92.9% of its detections happened in September and October. S3 was only present in the monitoring area in the first and second months following its tagging and its presence hasn't been recorded since then. All three sharks were absent from the monitored area during December.

Minimum linear distances travelled by all sharks were estimated at 17.4 km for S1, 5.1 km for S2 and 14.4 km for S3. All three sharks had a considerably low percentage of detections at receivers located closest to the site of capture (Fig. 7). S1 had significantly more detections in adjacent sites then in its primary site of release (χ^2= 2121.50, df= 1, p< 0.01) and most of its detections (61.7%) were concentrated in two adjacent receivers, located 0.8 to 2.9 km from the release site. Although detections of S1 were relatively few at its primary site, the shark was recaptured only 0.55 km from the tagging site, after 469 days at liberty. S2 detections were also significantly higher in adjacent receivers (χ^2= 360, df= 1, p< 0.01), particularly in a receiver located only 1.3 km of its tagging site. No detections of S2 were recorded in areas over 3 km from the primary site. Although S3 didn't have any detection at the receiver closest to the capture site (primary site), this shark was released in an area 10.7 km to the north of its primary site to test its attachment to the site of capture, and most of its detections

(44.3%) were recorded by receivers located 0.8-1.9 km from the release site, with only one detection in a receiver near (1.7 km) the primary site.

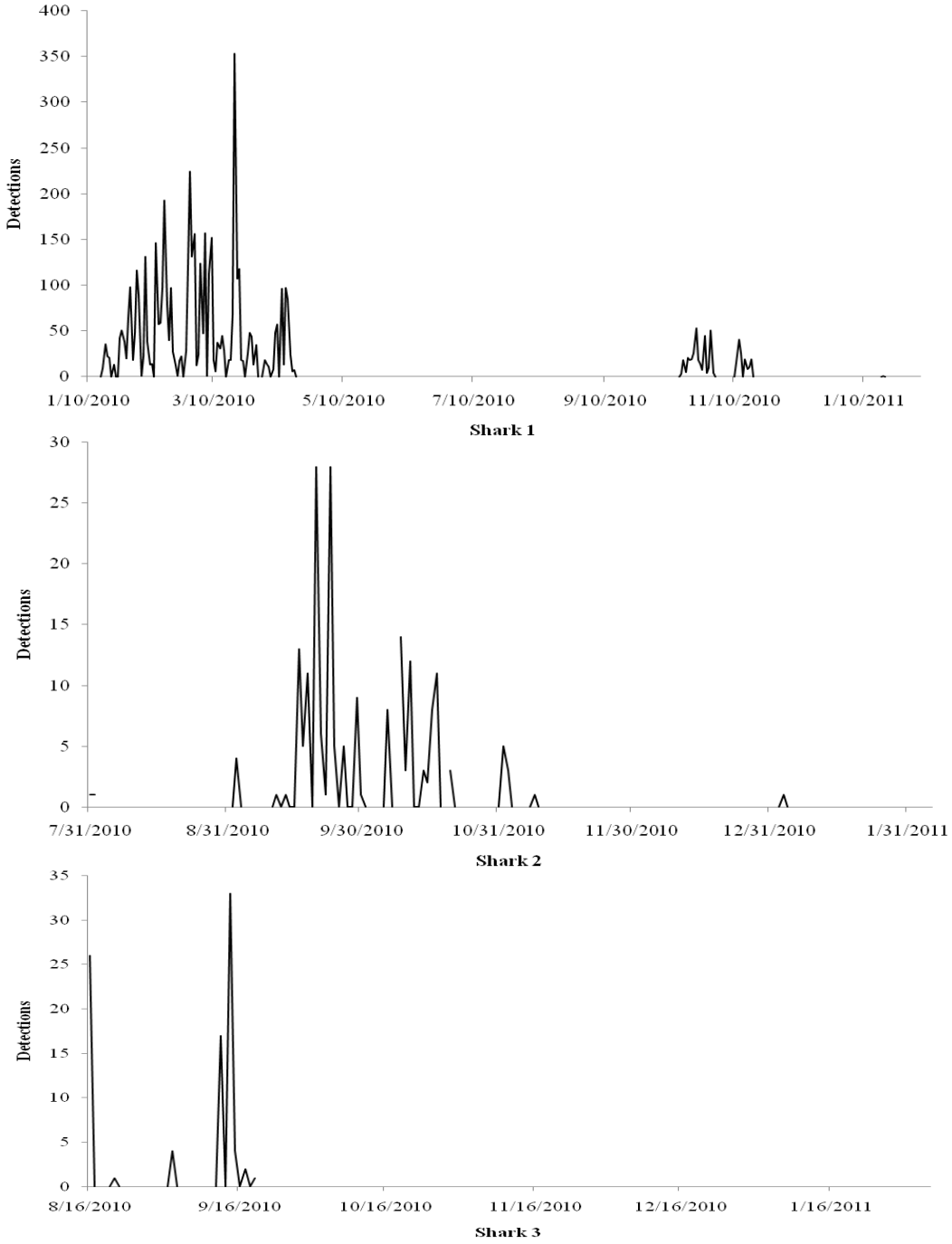

Figure 3. Daily number of detection for each shark at every receiver inside the array.

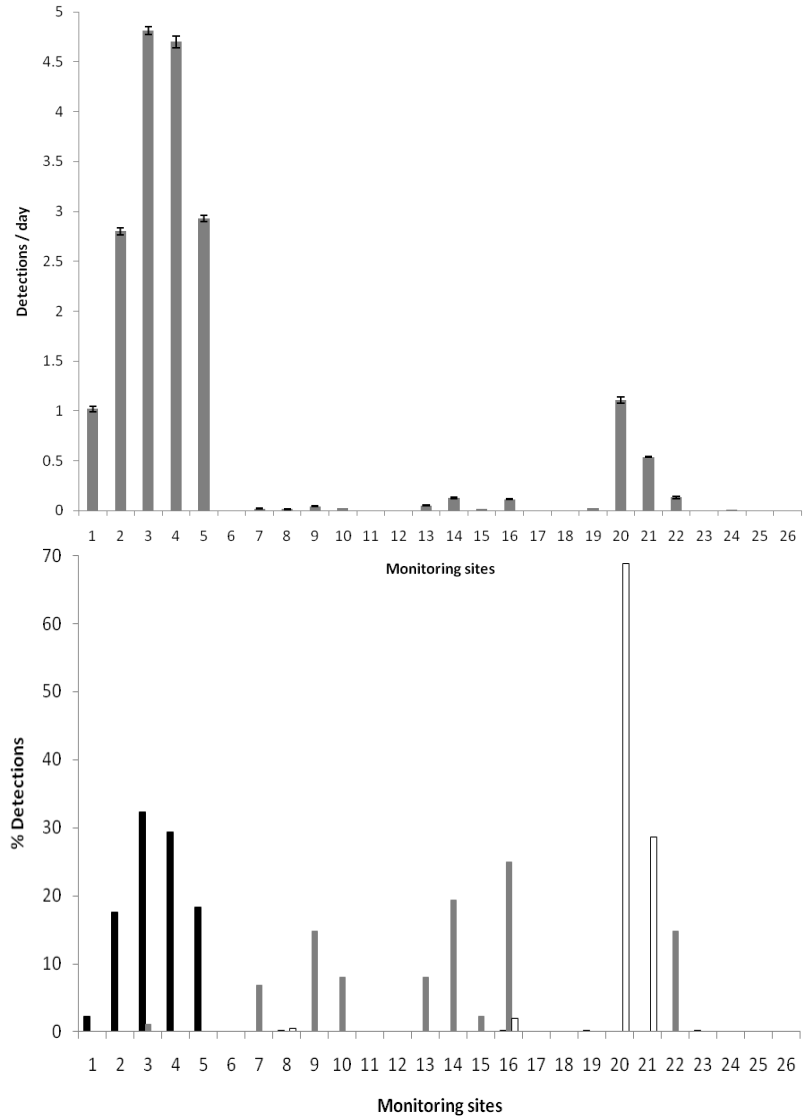

Figure 4. **a.** Mean density of detection per day (± SE) of all sharks on all receivers; **b.** Percentage of detection at all receivers for each shark. Solid bars are detections of S1, open bars are detections from S2 and grey bars are detection from S3.

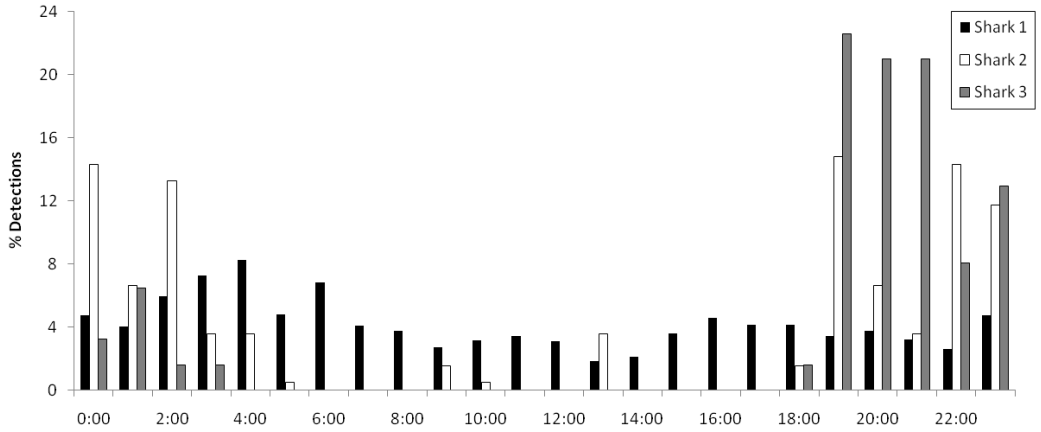

Figure 5. Percentage of detection of each shark at each hour of the day for all receivers in the array.

Daily home range sizes could only be estimated for S1. Both home range estimators (MCP and kernel) reflected a small home range, especially for the first period of detections. Daily home range sizes (95% fixed kernel) ranged from 0.02 to 3.00 km^2. Mean daily home range sizes varied between months from 0.26 km^2, in March, to 0.77 km^2, in November.

Monthly MCP home range estimates for sharks S1 and S3 ranged between 0.26 and 16.23 km^2. MCP estimates for S1 were noticeably larger in October, than from January to April (Fig. 8). S3 monthly MCP was estimated only for August and September, ranging from 1.32 to 7.46 km^2.

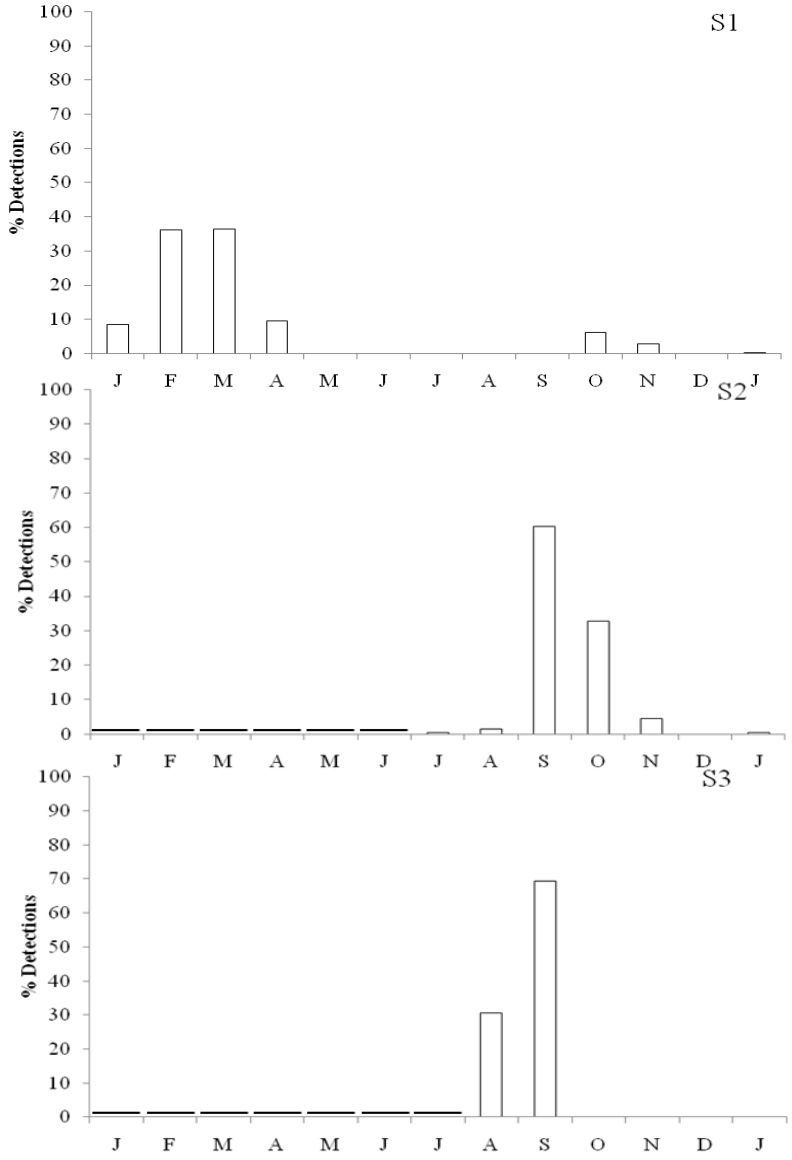

Figure 6. Percentage of all detection records plotted by month for the three nurse sharks tracked off Recife. *Dashed lines* represent the period when the sharks S2 and S3 weren't been monitored.

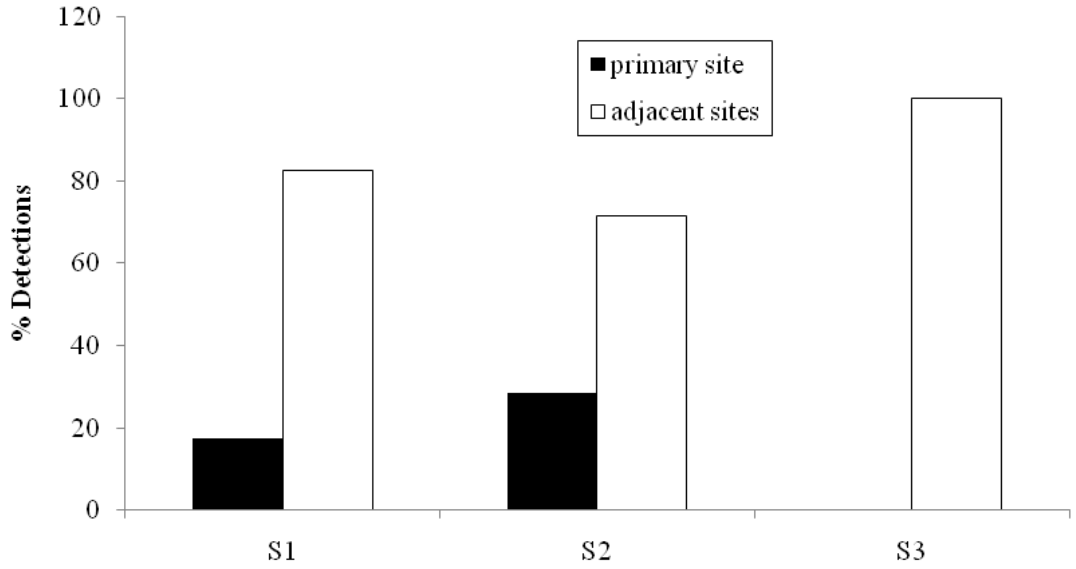

Figure 7. Relative proportion of detections recorded for individual sharks at their primary site (the receivers nearest their capture) to the proportion of detections at adjacent sites (all other receivers combined).

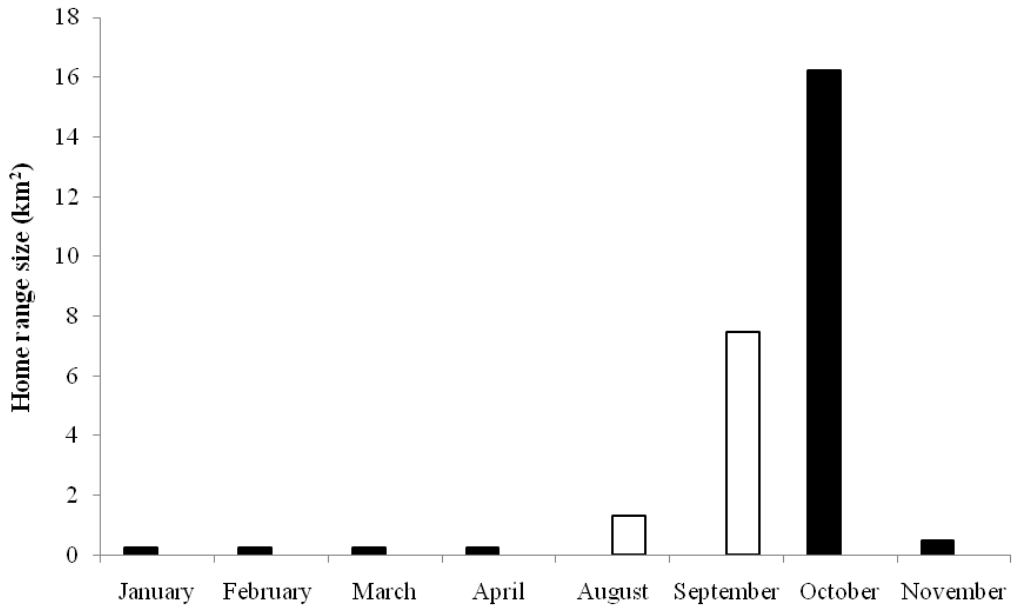

Figure 8. Monthly MCP home range estimates (km^2) for sharks S1 and S3.Solid bars are MCP sizes for S1 and open bars are MCP sizes for S3.

Discussion

The length frequency distribution of both males and females indicates that the majority of tagged sharks were juveniles according to size at maturation proposed by Castro (2000), although the two largest sharks tagged during this study were bigger than the maximum size proposed for the species by the same author.

Tag and recapture data support the occurrence of site fidelity in *G. cirratum*. Although the recapture rate found in the present study was rather lower than the ones found for nurse sharks in Florida (over 20%; Carrier, 1985; Carrier & Luer, 1990), it was similar to the rate found for this species at Everglades National Park (Wiley & Simpfendorfer, 2007), which is higher than most recapture rates obtained for other shark species (Kohler & Turner, 1998). Not only the recapture rate was substantial but sharks were recaptured in close proximity or within a small distance from the capture site, which could be an indication of fidelity to those sites, as suggested by Carrier & Luer (1990).

Although the monitoring was made through a non-overlapping array of acoustic receivers that covered only part of the coastal habitat off Recife, the acoustic monitoring of *G. cirratum* revealed that sharks remained in the monitored area for variable periods of time, being present for continuous periods from 1 to 8 days in average. Although two of the sharks used the area over a long period of time, up to four consecutive months for one of them, they were continually moving in and out of the monitored area.

There have been very few studies with the acoustic monitoring of nurse sharks to compare the results with the present ones. Chapman et al. (2005) demonstrated that nurse sharks at an oceanic atoll off Belize uses a wide range of habitats but that individual sharks showed site fidelity to some specific areas where there was a high number of detections. Sharks off Recife have also demonstrated site fidelity to specific areas where few receivers recorded almost all detections from a specific shark. Although all three sharks weren't frequently recorded at the receiver closest to the primary area of capture, all sharks have shown site fidelity to some areas. This pattern could be perceived for all three monitored sharks as they've shown more than 50% of detections in only one or two receivers each with small range of movements. This pattern of site fidelity have also been documented for many other tropical shark species (Gruber et al., 1988; Morrissey & Gruber, 1993; Chapman et al., 2005; Heupel et al., 2004; Heupel et al., 2006; Garla et al., 2006; Papastamatiou et al., 2010)

Although all sharks were mostly detected during nighttime, the frequency distribution of detections by hours of the day was significantly different between sexes. The male specimen (S1) was present at all hours of the day showing a higher degree of residency to the area south of Jaboatão River, while the other two sharks, both females, were detected almost only at night. The higher frequency of detection during nighttime is a very common pattern that has been described for many reef and coastal sharks species and is often related to wider nocturnal movements (Klimley & Nelson, 1984; Mckibben & Nelson, 1986; Gruber et al., 1988; Holland et al., 1993, Ackerman et al., 2000; Sundstrom et al., 2001; Heupel et al., 2004; Garla et al., 2006).

Another important difference in the movement patterns between sharks was that both females were almost never recorded at receivers to the south of Jaboatão River, even though one of them was caught close to one of the receivers located there. Furthermore, they were mostly detected at receivers located inside a deeper channel that runs parallel to the coast close to the beach and the exposed arenite reefs (Hazin et al., 2008). The more nocturnal detections for these sharks, therefore, could be related to a wider movement dispersion related to foraging activity at night, as suggested for other shark species (Tricas et al, 1981; Mckibben & Nelson, 1986). Since the longline is deployed at night, sharks are probably being caught during their feeding hours, when they are relatively distant from the core of their home range, what would then explain the lack of site fidelity to the primary tagging site and the high number of detection only during night time. This could also explain the absence of the two tagged sharks that were never detected after tagging. However, it is also possible that those sharks have died due to the trauma associated with the surgery or to an eventual capture by local fishers, since this species is commonly reported as incidental *by-catch* on artisanal fisheries (Carrier & Pratt, 1998; Compagno, 2001, Rosa et al., 2005, Santander-Neto et al., 2010).

The pattern of absence of detections exhibited by the male was already reported for nurse sharks off Recife trough the analysis of the catch rates from the Shark Monitoring Program off Recife from 2008-2010, where a pattern of lower catches during rainy months was observed for males, differently from a year-round presence for females (Ferreira, unpublished data). Occasional long distance movements have been recorded for nurse sharks at Florida coast (Carrier & Luer, 1990), the Everglades National Park (Wiley & Simpfendorfer, 2007) and Glover's reef atoll (Chapman et al.,

2005). The presence of S1 only during summer months (January-April 2010 and October 2010-January 2011) and its absence from the area during winter months (May to September), with its return by September 2010 to the same area where most of the detections had been recorded in January 2010, indicate a high degree of fidelity to this area and a pattern of faithful return to this site, reinforcing the results from the tag-recapture data.

Home range estimates for S1and S3 were small during all months of monitoring. Although further studies on daily activity patterns with a greater sample size of nurse sharks are still necessary, the results of the present study suggest that the nurse sharks is a semi-resident species in the coastal waters of Recife and although the activity space is usually small, there are some indication of occasional wider movements at night, as well as a possible seasonal migration, as indicated by the tagged male.

Most studies on shark movements and home range utilizing passive acoustic telemetry monitoring are carried out inside estuaries, around oceanic islands or atolls (Heupel et al., 2004; Chapman et al., 2005; Garla et al., 2006; Heupel et al., 2006; Wetherbee et al., 2007; Heupel et al., 2008; Papastamatiou et al., 2010). The present study, however, was conducted in a tropical coastal habitat with a non-overlapping array of receivers and therefore the absence of a shark inside the monitored area should be taken with caution. Nonetheless, the initial results from tag-recapture data and the acoustic monitoring of nurse sharks off Recife indicates that this methodology can be extremely useful to provide essential information on the movement patterns and residency of nurse sharks in the coastal waters off Recife, an aspect that is of great significance for the adoption of management actions needed to ensure the species conservation.

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4. Considerações Finais

Os resultados apresentados em ambos os capítulos indicam que o tubarão lixa é uma espécie residente da região costeira de Recife e que a população é representada principalmente por indivíduos imaturos. A existência de um possível padrão de migração sazonal verificada principalmente para os machos, tanto com os dados de captura como com os dados acústicos, é uma importante informação para a maior compreensão da ecologia da espécie. A preferência dos machos por meses com salinidades mais altas é uma possível explicação da existência desse padrão, porém, apenas com estudos sobre a biologia reprodutiva e alimentar da espécie na costa brasileira, monitoramento acústico por um maior período de tempo e monitoramento por satélite será possível realizar afirmações sobre migrações sazonais e explicar o sentido ecológico das mesmas.

A pequena quantidade de indivíduos maduros e a maior número de registros durante a noite sugerem que esta não é uma área de reprodução para a espécie. Por outro lado, os resultados do presente trabalho indicam um padrão de movimentação relativamente pequeno sugerindo que a falta de espécimes maduros, e também de neonatos, pode ser um efeito da seletividade do equipamento de pesca. Estudos futuros sobre a utilização do habitat pela espécie e o emprego de diferentes artes de pesca e/ou ampliação da área de estudo poderão solucionar as dúvidas que restam na caracterização da população de tubarões lixa nessa região.

Na Lista Vermelha da IUCN, a espécie *Ginglymostoma cirratum* está avaliada como deficiente em dados. No Brasil, o tubarão lixa é uma espécie classificada como ameaçada, sendo protegida por lei. Portanto, informações sobre a ecologia do tubarão lixa são essenciais para formulação de ações para o manejo e conservação da espécie, ao nível local, uma vez que os resultados obtidos no litoral de Recife indicam que a população é caracterizada por indivíduos imaturos, residentes, com pequena área de dispersão, mas que apresentam comportamento migratório diferente para cada sexo, com os machos possivelmente realizando migrações sazonais.

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