Revista da Gestão Costeira Integrada 11(4):389-395 (2011)
Journal of Integrated Coastal Zone Management 11(4):389-395 (2011)

ASSOCIAÇÃO PORTUGUESA DOS RECURSOS HÍDRICOS
UNIVALI
http://www.aprh.pt/rgci/pdf/rgci-236_Oliveira.pdf
DOI:10.5894/rgci236
GESTÃO COSTEIRA INTEGRADA
Journal of Integrated Coastal Zone Management

Population Structure and Growth of Young Lemon Shark, Negaprion brevirostris (Poey, 1868), at the Atol das Rocas Biological Reserve, Brazil *

Estrutura Populacional e Crescimento de Jovens de Tubarão-limão, Negaprion brevirostris (Poey, 1868), na Reserva Biológica do Atol das Rocas, Brasil

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ABSTRACT

We conducted expeditions (N=16) to the Rocas Atoll Biological Reserve aiming study the lemon shark (Negaprion brevirostris) population. Young lemon sharks (N=239) were captured, without mortality, using drift gill nets. The frequency of occurrence was higher for males (N=127) than females (N=112) 1.0♂:0.9♀. Upon capture, sharks were sexed, measured (fork length, total length, and interdorsal length), and released alive. A subset of 73 young lemon sharks received an identification tag before being released. Recaptured females and males showed an increase in total length of 12.7 cm/ year and 12.4 cm/ year, respectively.

Keywords: lemon shark, Negaprion brevirostris, juveniles, population structure, growth, Atol das Rocas.

RESUMO

Foram realizadas 16 expedições à Reserva Biológica do Atol das Rocas para o estudo populacional dos tubarões-limão (Negaprion brevirostris) juvenis. Um total de 239 indivíduos foram capturados utilizando-se rede de arrasto. A proporção sexual entre os tubarões capturados foi 1.0♂:0.9♀, com 127 machos e 112 fêmeas. Quando capturados, os tubarões eram sexados, mensurados (comprimentos furcal, total e interdorsal) e libertados com vida. Um subgrupo de 73 espécimes foram marcados e libertados. Machos e fêmeas recapturados demonstraram um aumento no comprimento de 12.7 cm/ano e 12.4 cm/ano, respectivamente.

Palavras-chave: *tubarão-limão, Negaprion brevirostris, juvenis, estrutura populacional, crescimento, Atol das Rocas.*

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* *Submission: September 30, 2010; Evaluation: November 7, 2010; Reception of revised manuscript: July 25, 2011; Accepted: August 9, 2011; Available on-line: December 6, 2011*

1. INTRODUCTION

Elasmobranches (sharks and rays) are among the top predators in the marine environment. They therefore have a very important function in population control of fish as well as invertebrates at lower trophic levels (Ellis *et al.*, 1996; Camhi *et a*l., 1998). An adequate understanding of the intra and inter-specific relations involved in this balance requires further knowledge on biology, distribution, migration, behavior and population dynamics (McKibben & Nelson, 1986). A number of factors must be considered in the study of the population ecology, such as: the year-to-year fluctuations in population size, level of relative abundance, sex ratio and the life stages of the community in question (Morrissey & Gruber, 1993).

In studies on the population ecology of sharks, two methods of data collection are commonly used: the visual observation (visual census), using natural marks for the characterization of each unit, as carried out by Castro (2000) and Castro & Rosa (2005) in Atol das Rocas; or the capture, tagging, release and recapture method observed by Kato & Carvalho (1967) for sharks of the Pacific ocean, and Stevens (1976) and Casey & Kohler (1992) in the North Atlantic.

The lemon shark, *Negaprion brevirostris* (Poey, 1868), is distributed in the Western Atlantic Ocean, ranging from New Jersey (U.S.A.) to the southern part of the state of Bahia (Brazil) (Compagno, 1984). Within Brazil, its distribution ranges from the state of Pará to Rio de Janeiro, as well as the Atol das Rocas and Fernando de Noronha Archipelago (Soto, 2001).

Unique in the South Atlantic, the Rocas Atoll represents a singular ecosystem for the development of population studies, mainly for being a Marine Biological Reserve, in which the exploitation of its natural resources is forbidden.

Like other species of elasmobranch, the lemon shark presents a K-strategist life cycle, characterized by slow growth, high longevity, delayed sexual maturity and low fecundity (Hoenig & Gruber, 1990). Therefore, the lemon shark has been included on the list of animals threatened with extinction, issued by the Brazilian Ministry of the Environment through Normative Instruction N° 5, on May 21st, 2004 (MMA, 2004) and also exhibits life-history characteristics that make it vulnerable to overfishing (Gruber *et al.,* 2001). Freitas *et. al.* (2009) showed the comparatively lower population size and survival at Rocas than in Bimini Bahamas, and suggested that young lemon sharks are more fragile in this nursery.

The population study and to point out conservation are measures are of great importance for the management in marine protected area (MPA) as well as coastal environments.

The aim of the present study is to provide further information concerning the population size and growth increment rates in length of young lemon sharks in the Rocas Atoll Biological Reserve.

2. MATERIAL AND METHODS

2.1 Study Area

The Atol das Rocas (Fig. 1) is located 144 nautical miles (≈ 260 km) off Natal-RN in northeastern Brazil (Oliveira-Filho & Ugadim, 1976). The atoll has an elliptical shape, with an internal area of 7.2 km^2 (Kikuchi & Leão, 1994). Atol das Rocas has two islands, Farol Island and Cemitério Island. At low tide, both islands become connected and a group of isolated pools is formed. At high tide, the water in these pools is renewed, forming a Central Lagoon, with depths ranging from 0.3 to 2.0 m (Rosa & Moura, 1997) (Fig.1).

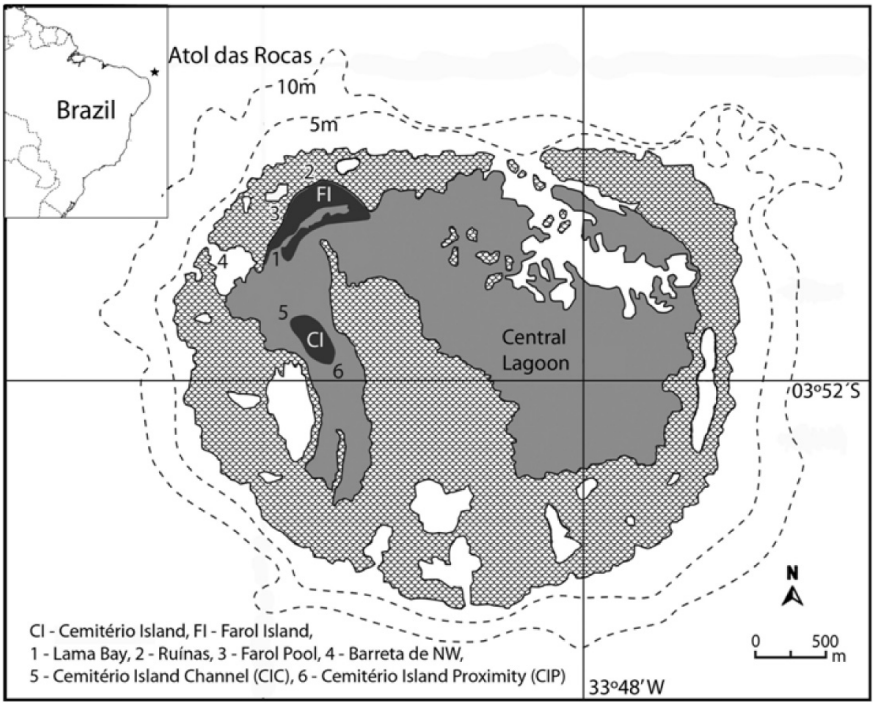

Figura 1. Localização do Atol das Rocas e indicação dos locais de captura e observações de indivíduos de tubarão limão

Figure 1. Location of the Rocas Atoll Biological Reserve and indication of capture and observation sites of lemon sharks (Adapted from Castro e Rosa, 2005).

2.2 Data Collection

In August, November and December 2000, and February and April 2001, 166 juvenile lemon sharks were captured alive with monofilament polyamide gillnet, with a mesh diameter of 15 mm and 100 mm between knots. During the first phase of study, the specimens captured received no identify tags. The second phase occurred in September and October 2001, and March, April, June, July, August and September 2002, in which 73 specimens was captured and tagged to determinate movements, habitat selection, the juvenile population and other important aspects of the life cycle in the atoll.

Data on the local environmental, such as water superficial temperature (C) and depth (cm) was collected throughout the tagging process. The tagging was performed in such a way as to cause the minimum stress possible, using numbered plastic color tags. The tags ('Rotatag', Allflex brand, rectangular shape, 4.0 x 1.5 cm) were attached with an applicator to the end of first dorsal fin, as this region has a low rate of rejection, good scarring and contains no nerve endings. In both collection phases, lemon sharks were captured at the following locations: Lama Bay, Ruínas, Piscinas do Farol, the Central Lagoon, Barreta de NW, Cemitério Island Channel (CIC) and proximities (CIP). The total length (TL), fork length (FL) and interdorsal length (ID) were measured, sex was determined and the presence of scars or other marks was observed. The sharks were released after the data collection. From the biometric data of recaptured lemon sharks, growth increment rates were determined.

2.3 Data Analysis

The Schnabel method was used to determine the estimated population size, following Sutherland (1996). This analysis is similar to Petersen's and is more appropriate for situations in which an animal was captured more than once. Population size was estimated by the following formulas:

$$A = \Sigma n_i M_i^2$$
$$B = \Sigma m_i M_i$$
$$C = \Sigma m_i^2 / n_i$$

where:

n_i= number of animals in the i^{th} sample; m_i= number of animals in the i^{th} sample that were tagged; M_i= number of animals previously tagged in the i^{th} sample given by:

$$M_i = \Sigma$$

The population size (N) is equal to:

$$N = A/B$$

The 95% limits of confidence for the estimate are determined by:

$$A/ [B \pm t \sqrt{(AC - B^2)/(S - 2)}]$$

where:

t = Student's t test, with S-2 degrees of freedom and 5% significance level; and **S=** number of samples. To test the reliability of the model, the expected values of m and u were used, as calculate by the following formulas:

$$Exp\ (m_i) = M_i n_i / N$$
$$Exp\ (u_i) = n_i - Exp\ (m_i)$$

where:

$u_i = n_i - m_i$: number of untagged animals in the i^{th} sample.

To determine whether the method is adequate for application to the proposed data, the reliability test for the G calculation was used, where the value of G was compared to the listed values of, with S-2 degrees of freedom.

$$G = 2\Sigma O_i \log_e (O_i/E_i)$$

where:

O_i= observed values in i, including both values of m_i and u_i.
E_i= expected values in i, including both values of m_i and u_i.

3. RESULTS

Two hundred and thirty nine lemon sharks were captured alive, with no mortalities. The lowest values for average estimated TL were observed in specimens captured between March and April – mean 65.8 cm and 65.9 cm, respectively. The average estimated TL increased throughout the year, reaching a maximum of 95.0 cm in November and decreasing in December (81.0 cm) (Fig. 2).

Most lemon sharks of both sexes were captured in Lama Bay (Fig. 3) at a depth of 48.0 cm and average water temperature of 27.0º C (Table I).

Tabela 1. Profundidade e temperatura média da água de captura de tubarões limão, no Atol das Rocas.
Table 1. *Mean capture depth and water temperature of lemon sharks at time capture in Rocas Atoll.*

Local	Temperature (°C)			Depth (cm)		
	Max	Min	Mean	Max	Min	Mean
Lama Bay	27,5°	26,5°	27,0°	60	20	48
NW Barreta	28,5°	28,0°	28,2°	40	25	32,5
Lagoon	27,5°	27,0°	27,2°	55	45	50
Ruínas	28,0°	26,0°	27,0°	55	45	50

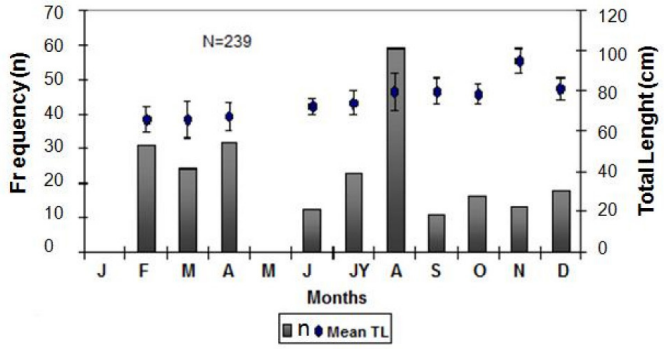

Figura 2. Comprimento total médio dos tubarões limão capturados, nos diferentes meses.
Figure 2. *Mean total length of captured lemon sharks by month.*

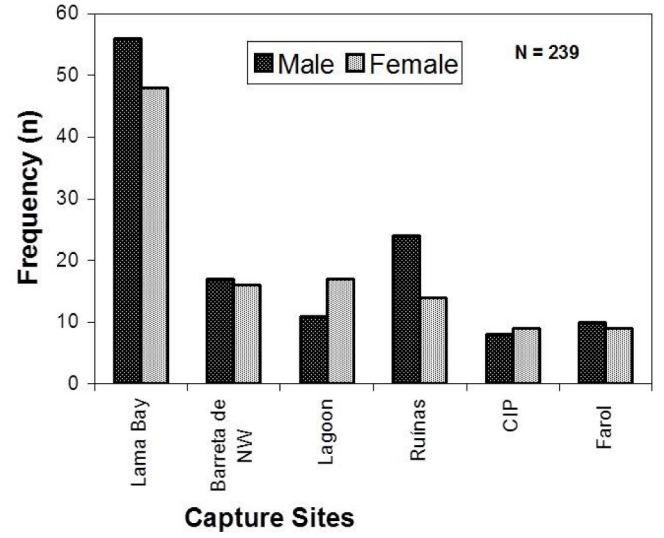

Figura 3. Freqüência absoluta, por sexo, de tubarão limão, em diferentes locais de captura.
Figure 3. *Absolute frequency of lemon sharks by sex, at different sites.*

Throughout all length classes and capture sites, the gender ratio of the specimens captured was almost *1.0♂:0.9♀* (127 males and 112 females). The highest catch index for females was observed in the class ranging from 60.0 to 70.0 cm TL. For males, the highest catch rate occurred in the class ranging from 70.0 to 80.0 cm TL (Fig .4).

Among the total of 73 captured and tagged sharks, 17 were recaptured once and 3 were recapture more than once. Only 4 recaptures (23.4%) occurred in different places where the tagging was performed. (Table II).

Lama Bay was the site where the highest capture and recapture rates occurred, corresponding to 52.9% of tagged specimens, 58.8% of sharks recaptured for the first time and 66.6% recaptured a second time.

According to the capture and tagging data, the estimated size of the juvenile lemon shark population in the Rocas Atoll Biological Reserve for the period studied indicate that the method used was not adequate in estimating population size.

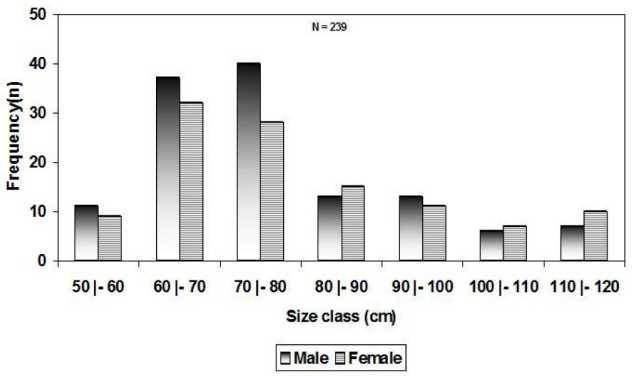

Figura 4. Freqüência absoluta de tubarões limão, por sexo, em diferentes classes de comprimento.
Figure 4. *Absolute frequency of lemon shark by sex in different size class.*

4. DISCUSSION

Gruber *et al* (1988) captured and tagged 333 young lemon sharks between 1981 and 1987 in the Bimini Atoll, Bahamas, with a 35.8% recapture rate over the 7 years. The recapture rate in the present study was 23.3% in just one year. This percentage was larger than that found by Kato & Carvalho (1967) for *Carcharhinus limbatus* off the Mexican Coast, which was 12% of 155 sharks tagged in one year. At the Revillagigedo Islands in the Pacific Ocean, the same author found a slightly larger recapture rate of 14% for *Carcharhinus albimarginatus,* with 138 sharks tagged also in one year.

A high degree of reliability was verified at sites where the sharks were captured and tagged. This seems to be related to tidal rhythms and current directions, as the juvenile lemon sharks swim toward Lama Bay always from inner portion of the atoll (eastern side) at the high tide. Also was observed the current on Barreta de NW is strong in the ocean-atoll direction during the high tide, being the inverse on low tide, coinciding, with the entrance and exit of lemon sharks.

The presence of groups of juvenile lemon sharks swimming with the current in the proximities of Farol Island toward in NW Barreta at low tide, suggests the shark uses the tidal currents of the atoll for locomotion, entering with the high tide front and exiting with the low tide movement. A similar fact also was observed by researchers in other regions (Medved & Marshall, 19**8**3; Stevens, 1984).

Some young lemon sharks were observed swimming in circles in groups, at times with more than 15 specimens. Gruber *et al.*, (1988) made the same observation in Bimini, where were groups ranged from 4 to 7 specimens. McKibben & Nelson (1986) suggest that the formation of juvenile groups of *Carcharhinus amblyrhynchos* or other species of shark has the function of protection, defending themselves from predation by larger sharks from other species.

There appears to be segregation by TL in the formation of juvenile groups, which present considerable homogeneity regarding size.

The segregation of spatial distribution among juvenile individuals is widely cited in the literature for both teleosts

Tabela 2. Principais características dos tubarões marcados e recapturados, no Atol das Rocas.
Table 2. *Main characteristics of tagged and recaptured sharks in Rocas Atoll.*

MARKING				1st RECAPTURE				2nd RECAPTURE				3rd RECAPTURE			
TL (cm)	Mark	Sex	Local Month	TL (cm)	Mark	Sex	Local Month	TL (cm)	Mark	Sex	Local Month	TL (Cm)	Mark	Sex	Local Month
75.0	099	♀	Br 09/99	77.0	099	♀	BL 10/99								
77.0	068	♂	BL 10/99	77.0	068	♂	BL 10/99								
71.0	094	♀	BL 03/00	79.0	094	♀	BL 08/00	79.0	094	♀	Lg 08/00				
67.0	073	♂	BL 03/00	72.0	073	♂	BL 06/00								
67.5	074	♂	BL 03/00	68.0	074	♂	B 03/00								
67.0	086	♀	R 03/00	69.0	086	♀	R 04/00								
66.0	057	♂	R 03/00	67.0	057	♂	R 04/00								
58.0	058	♂	R 03/00	60.5	058	♂	R 04/00								
59.0	059	♂	R 03/00	62.0	059	♂	R 04/00	68.0	059	♂	BL 08/00	68.0	059	♂	Lg08/00
67.0	089	♀	BL 04/00	71.0	089	♀	BL 07/00								
85.0	066	♂	BL 04/00	88.0	066	♂	BL 08/00	92.0	066	♂	BL 08/00				
65.0	054	♂	R 04/00	66.0	054	♂	R 04/00								
71.0	085	♀	R 04/00	77.0	085	♀	Lg 08/00								
113.0	037	♂	BL 08/00	113.0	037	♂	BL 08/00								
112.0	083	♀	BL 08/00	112.0	083	♀	BL 08/00								
98.0	038	♂	BL 08/00	98.0	038	♂	BL 08/00								
68.0	060	♂	R 08/00	68.0	060	♂	BL 08/00								

BL = Lama Bay; R = Ruínas; B = NW Barreta; Lg = Central Lagoon.

as well as elasmobranches (Luckhurst & Luckhurst, 1978; Branstetter, 1990; Wetherbee *et al.*, 1990; Castro, 1993; Hixon & Beets, 1993; Morrissey & Gruber, 1993; Simpfendorfer & Milward, 1993; Jones & McCormick, 2002).

Small, young fish seek out protected areas to escape from predation, which are commonly called nurseries. Under conditions of strong pressure from predation, the availability of these environments can influence species abundance (Nagelkerken *et al*, 2000; Jones & Mccormick, 2002). Furthermore, protected environments appear to be related to assisting in the capture of prey (Morrissey & Gruber 1993).

Lama Bay seems to be a primary and secondary nursery area for most of the specimens captured with a TL close to size-at-birth (60.0 to 65.0 cm). Juvenile lemon sharks around 120.0 TL were observed throughout the year, and adults over 250.0 TL were observed in December and February. Similar results were observed by Castro (1993) and Simpfendorfer & Milward (1993), who state that several species from the Carcharhinidae and Sphyrnidae families use the same area to give birth to pups, which remain loyal to the area until reaching adult age.

The annual growth increments observed for juvenile lemon sharks in the Atol das Rocas Biological Reserve was 12.7 cm per year for males and 12.4 cm per year for females. Morrissey & Gruber (1993) found smaller values for juvenile lemon sharks in the Bahamas, reporting growth increments between 6.4 and 9.9 cm per year, regardless of gender.

Such difference may be related to temperature. The atoll is located in a region close to equator (03°52` S) and is hotter than the Bahamas, which is located at 25º N. on metabolic processes includes the growth and reproduction of sharks (Gruber *et al*, 2001; Cortés, 2003).

Other species of large sharks from this family also show differences in growth rates between sexes, such as *Carcharhinus obscurus* (Simpfendorfer, 2000).

The concomitant presence of juvenile sharks, neonates and adults with bite marks at the same time of year (December, February and March) indicates the birth of lemon sharks occurs at the beginning of the year, with copulation occurring at the same time and gestation period of 10 to 12 months in the Atol das Rocas. For the Western North Atlantic, Compagno (1984) suggests the copulation

and parturition period occurs at the end of the spring and in summer, with the peak between the two seasons, resulting in one gestation period of approximately 11 months, which is similar to the results obtained in the present work.

CONCLUSION

The results show that the Rocas is an important nursery area for Negaprion brevirostris. The annual growth greater than that observed in Bimini in the Bahamas, and is influenced by the difference in water temperature also occurs as a result of greater availability of food that the young individuals have the Atol das Rocas. Besides being the only atoll in the South Atlantic Ocean and is a biological reserve, taking no fishing pressure or environmental degradation. Unlike the observations made in Bimini, developers have been dredging e removing mangroves in and around the North Sound nursery area since 1999. Though the resort's development is still in its early stages, there is already evidence that Bimini is being subjected to intolerable environmental degradation (Gruber *et al*, 2002; Jennings *et al*, 2006). The results of the study in Bimini, suggest that the ongoing development of the Bimini Bay Resort will affect the lemon shark population and that scaling down the development while it is still possible will prevent the collapse of the population (Bekker, 2007).

ACKNOWLEDGEMENTS

We are grateful to thank the IBAMA/ICMBio and CNPq for the financial support. Alessandra Fischer for helping in the data collection, and Mariana Coxey for edit the figure.

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