Preliminary Results from Tag-Recapture Procedures Applied to Lemon Sharks, *Negaprion brevirostris* (Poey 1868), at Los Roques Archipelago, Venezuela

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ABSTRACT

During the period 2005 - 2008, 13 field surveys were conducted within the Archipelago Los Roques in order to examine the population structure and growth of juvenile lemon sharks, *Negaprion brevirostris*. Tag-recapture procedures were concentrated in the Sebastopol Lagoon (SL), an area previously identified as a nursery ground for this species. During the study, a total of 102 juvenile *N. brevirostris* (40.4 - 95.0 cm PCL) were captured within the SL; of these, 96 individuals were successfully tagged and released. Length composition was significantly different between sexes (Kruskal-Wallis; $p < 0.001$). Neonates (mean size: 46.1 cm PCL) were observed during June and July months, indicating that the birth season corresponds to this period. Mean growth rates were 24.2 cm year^{-1} for males and 21.9 cm/year for females. These estimates indicated that in the study area, juvenile *N. brevirostris* grow more rapidly than do juveniles in other populations of the same species distributed in the western Atlantic.

KEY WORDS: Caribbean Sea, elasmobranchs, growth, nursery areas

Resultados Preliminares Obtenidos de la Aplicación del Método de Marcaje y Recaptura en Tiburones Limón, *Negaprion brevirostris* (Poey 1868), en el Archipiélago Los Roques, Venezuela

Durante el periodo 2005 - 2008, se realizaron 13 salidas de campo al Archipiélago Los Roques con el propósito de examinar la estructura de la población y el crecimiento de juveniles de tiburón limón, *Negaprion brevirostris*. Los trabajos de marcaje y recaptura se concentraron en la laguna de Sebastopol (LS), zona que había sido previamente identificada como área de criadero para esta especie. Durante el estudio se capturaron un total de 102 juveniles de *N. brevirostris* (40,4 - 95,0 cm LPC), siendo exitosamente marcados y liberados 96 individuos. La proporción de sexos fue similar para el grupo de individuos con tallas entre 40 y 60 cm LPC; sin embargo para el grupo de tallas mayores, las hembras dominaron las capturas (62,2%). La composición de tallas fue significativamente diferente entre sexos (Kruskal-Wallis; $p < 0.001$). Individuos recién nacidos (promedio: 46,1 cm LPC) fueron observados en junio y julio, indicando que la época de nacimiento corresponde a estos meses. Los promedios obtenidos para la tasa de crecimiento fueron 24,2 cm/ano en los machos y 21,9 cm/ano en las hembras. Estas estimaciones muestran que en el área de estudio, los juveniles de *N. brevirostris* presentan un crecimiento más rápido que en otras poblaciones juveniles de la misma especie, distribuidas en el Atlántico occidental.

PALABRAS CLAVES: Áreas de criadero, Caribe, crecimiento, elasmobranquios

Résultats Préliminaires des Procédures de Marquage de Recapture Appliquées aux Requins Citron, *Negaprion brevirostris* (Poey 1868), À Larchipel Los Roques, Venezuela

Au cours de la période 2005 - 2008, 13 enquêtes de terrain ont été menées au sein de l'archipel de Los Roques, afin d'examiner la structure de la population et la croissance de requins citrons juvéniles, *Negaprion brevirostris*. Les procédures de marquage de recapture ont été concentrées dans la Lagune de Sébastopol (SL), une zone précédemment identifiée comme une zone de reproduction pour cette espèce. Pendant l'étude, un total de 102 juvéniles *N. brevirostris* (40.4 - 95.0 cm PCL) ont été capturés dans le SL ; de ce nombre, 96 individus ont été marqués et relâchés avec succès. La composition en longueur a été significativement différente entre les sexes (Kruskal-Wallis, $p < 0,001$). Des nouveau-nés (taille moyenne: 46,1 cm PCL) ont été observés au cours des mois de juin et juillet mois, indiquant que la saison de naissance correspond à cette période. Les taux moyens de croissance ont été de 24,2 cm / an pour les mâles et 21,9 cm/an pour les femelles. Ces estimations ont révélé que, dans la zone d'étude, les juvéniles *N. brevirostris* croissent plus rapidement que ne le font les juvéniles dans d'autres populations de la même espèce distribuée dans l'Atlantique Ouest.

MOTS CLÉS: Mer des Caraïbes, élasmobranches, croissance, zones de reproduction, habitat

INTRODUCTION

Many shark populations around the world are depleted, and some species are considered to be threatened with extinction as a result of overfishing (Stevens *et al*. 2000, Cortés 2004). The capture of large numbers of juvenile sharks by commercial fisheries and the degradation of their essential habitats have significantly contributed to the reduction of shark populations (Camhi *et al*. 1998). The development of management and conservation strategies depends on information regarding the biological traits, population structure and habitat use of juvenile sharks. Protection of juvenile sharks will have positive implications for the recovery of adult populations which are usually depleted.

The lemon shark, *Negaprion brevirostris*, is a large, coastal, inshore tropical species of the continental and insular shelves; it also ventures into the open ocean, near or at the surface, for the purpose of migration. This species is distributed in the western Atlantic Ocean, from New Jersey to southern Brazil, including the Gulf of Mexico and Caribbean Sea (Compagno 1984). In waters of the Venezuelan Caribbean, *N. brevirostris* commonly occurs

around several oceanic islands characterized by the predominance of significant coral reef formations.

Tag-recapture techniques have been used to examine the distribution, growth, population size and survival rates of *N. brevirostris* in the western Atlantic region (Henningsen and Gruber 1985, Manire and Gruber 1991, Morrissey and Gruber 1993, Gruber *et al*. 2001, Tavares 2001, Barker *et al*. 2005, Freitas *et al*. 2006). Although the Los Roques Archipelago constitutes a common habitat for several species of sharks (Tavares 2005), information concerning the biology, distribution and abundance of *N. brevirostris* in this region is scarce or nonexistent. In order to contribute to the knowledge of shark biology, the present study used tag-recapture data to examine the population structure and growth of juvenile *N. brevirostris* in the Los Roques Archipelago.

MATERIALS AND METHODS

Los Roques Archipelago (LRA) National Park is a tropical insular shelf situated in the Caribbean Sea, 160 km directly north of the central coast of Venezuela (11º43'-11º58' N/66º35'- 6º57' W; Figure 1). It comprises more than 40 small and low islands that are arranged around a main central lagoon. The water temperature in the area ranges between 26 and 30ºC with the minimum values occurring in January - February and maximum values in June-October. The LRA is notable for its well conserved coral reef ecosystems and high marine diversity. Thirteen field surveys (each constituting 3 - 4 days of sampling) were conducted within the LRA between September 2005 and September 2008. Tag-recapture procedures were used in the Sebastopol Lagoon (SL), a nursery area for *N. brevirostris* (Tavares 2001). This semi-enclosed lagoon is located in the southeastern archipelago, within an Integral Protected Area (IPA; Figure 1) that is closed to sport and commercial fishing, transport boats and tourism activities. The SL is typically characterized by sandy and seagrass habitats and is almost completely bordered by mangroves.

Lemon sharks were captured with gillnets that were always set perpendicular to the shoreline, between 18:00 and 22:00 hours, and when possible between 3:00 and 6:00 hours. Captured sharks were measured (pre-caudal length, PCL; total length, TL), weighed, sexed, examined for the condition of the umbilical scar and identified by attachment of a conventional tag. The three types of external tags used, M-dart-tag (MT), plastic-dart-tag (PT) and roto-tag (RT) were provided by the Cooperative Shark Tagging Program/National Marine Fisheries Service of the USA. During the field surveys, measurements (PCL, TL and weight) were always recorded by the same researcher in order to minimize measurement errors. The project included educational activities for the fishing community of Los Roques Archipelago; the fishermen were trained in the collection of basic data (PCL, and the date and location of recapture) in case of future recaptures of tagged sharks.

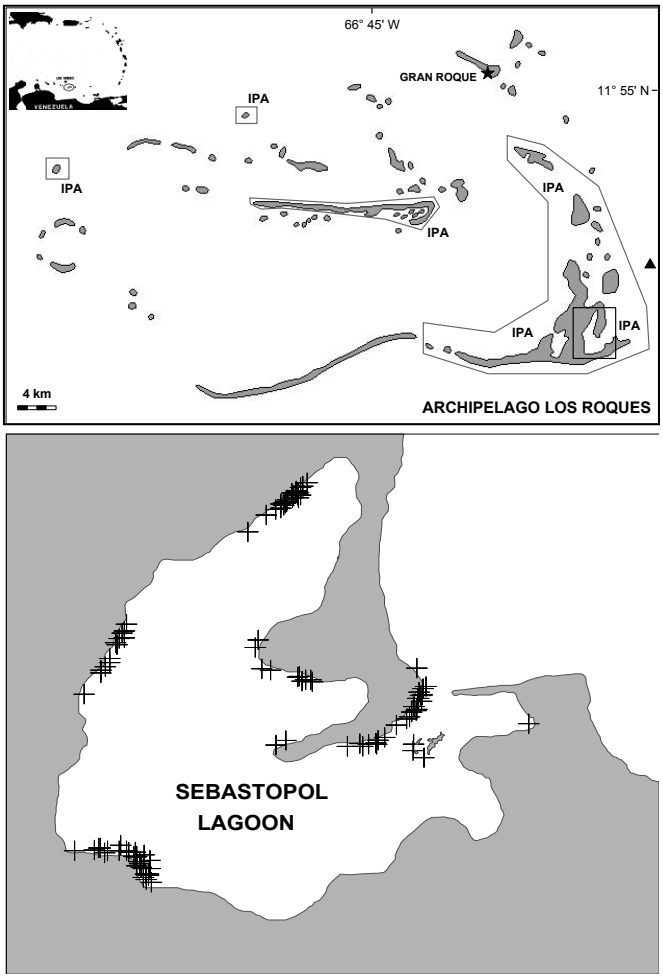

Figure 1. Map of the Archipelago Los Roques (LRA) National Park showing the location of the Sebastopol Lagoon (SL) and capture sites of juvenile *Negaprion brevirostris* (+). Also shown are the five Integral Protection Areas (IPA, established as a conservation measure) and the site of recapture of one individual by the local artisanal fishery (▲).

Based on captured lemon sharks, PCL and TL (in cm) can be estimated by using the following equations: $TL = 0.301 + |1.258 \cdot PCL|$ ($n = 99$; $r^2 = 0.997$) and $PCL = -0.048 + |0.793 \cdot TL|$ ($n = 99$; $r^2 = 0.997$). The juvenile population structure was described by constructing length frequency histograms by sex. Because the length data did not show a normal distribution (one-sample Kolmogorov-Smirnov; $p < 0.001$), comparison of length composition between sexes was analyzed by the Kruskal-Wallis test. The mean birth length was calculated on the basis of individuals identified as neonates (i.e. having an open or partially closed umbilical scar).

Growth rates of juvenile lemon sharks were calculated as centimeters per year (cm/year) on the basis of both single-recaptured and repeat-recaptured individuals. The rates of length increase of the repeat-recaptured individuals were estimated by using only data from the initial tagging

and latest recapture events. Subsequently, growth estimates were compared between sexes by *t*-test. A separate approach involving only the repeat-recaptured sharks examined the degree of variation in growth rate between recapture series and between individuals. All statistical analyses (significant if $p \leq 0.05$) were as given by Zar (1996). Comparisons of the juvenile growth rates between studies were based on the PCL.

RESULTS

During the study period, a total of 102 juvenile *N. brevirostris* were captured in the SL (Figure 1). The mortality of sharks due to the stress of capture and handling was 5.9%, but the deaths of the animals occurred only during the initial field surveys. Therefore, 96 lemon sharks were successfully tagged and released in the same capture sites. Other species of sharks were not captured within the SL. Marine fauna commonly caught during gillnet fishing activities were *Albula vulpes* (bonefish), *Gerres cinereus* (mojarra), *Haemulon plumieri* (gruntfish), *Lutjanus apodus* (snapper), *Caranx latus* (jackfish), *Dasyatis americana* (stingray), *Panulirus argus* (spiny lobster) and *Callinectes sapidus* (blue crab).

Captures comprised 64 females (size: 40.4 - 95.0 cm PCL) and 38 males (size: 41.4 - 85.5 cm PCL). Analysis indicated that the length composition of captured lemon sharks differed significantly between sexes (Kruskal-Wallis test; $p < 0.001$). The length frequency distribution showed that the dominance in numbers of the females was most marked among individuals of 70 - 95 cm PCL (Figure 2). Twenty-one neonates were captured during the months of June and July, indicating that at least part of the birth season lies within this period. The estimated mean birth length was 46.1 (± 2.2 sd) cm PCL.

During the study period, 18 individuals were recaptured once and other 3 individuals were recaptured twice. The recapture rate was therefore 25.0%. All recaptures occurred within the SL, except one that was registered by the local artisanal fishery in an area close to the eastern IPA (Figure 1). The period between release and recapture (DT) varied from 24 to 437 days. One single-recapture with a DT of only 3 days was excluded from the growth analysis. Data from the remaining 20 recaptures suggested mean growth rates of 24.2 (± 18.5 sd) cm/year for males and 21.9 (± 15.2 sd) cm/year for females (Table 1); the difference between sexes was not significant (*t*-test; df = 18, $p > 0.05$). For the analysis of individual growth variation, each of the individuals that were recaptured twice provided three rate estimates related to recapture series. These estimates were obtained from the data at tagging and at subsequent recapture events (R_1, R_2), and also from the difference between the data at first and second recapture (R_{1-2}). This analysis showed a clear difference in magnitude of growth rate between individuals, but a pattern of growth that was similar for the three individuals (Figure 3).

Table 1. Comparison of the growth rates for juvenile *Negaprion brevirostris* between studies and regions. Note: [a]sharks marked with M-dart-tags; [b]sharks marked with passive integrated transponder (PIT) micro-tags; [c]sharks marked with radio-transmitter-tags; [d]growth rates estimated from length-frequency analysis; [e]sharks marked with M-dart-tags, plastic-dart-tags and roto-tags.

Study	Region	Juvenile Growth Rate (cm/year PCL)		
		Males	Females	Overall
Henningsen & Gruber (1985)	Bahamas	---	---	8.3[a]
Manire & Gruber (1991)	Florida Keys	7.0[a]/16.7[b]	9.7[a]/17.8[b]	8.6[a]/17.1[b]
Morrissey & Gruber (1993)	Bahamas	---	---	6.7[c]
Barker *et al.* (2005)	Bahamas	---	---	6.2[b]
	Florida Keys	---	---	15.7[b]/20.0[d]
Freitas *et al.* (2006)	AR, Brazil	20.3[b]	18.8[b]	19.5[b]
Present Study	**LR, Venezuela**	**24.2**[e]	**21.9**[e]	**22.8**[e]

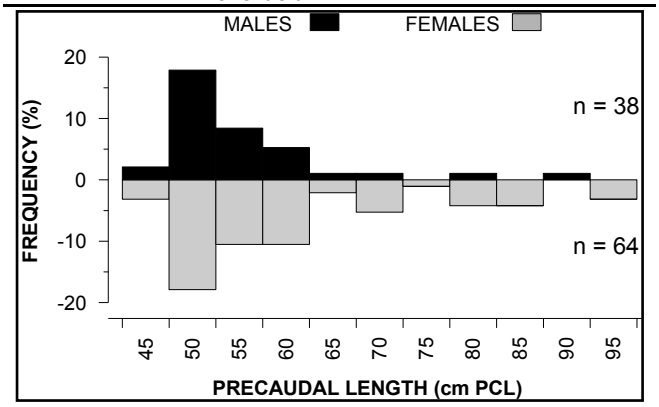

Figure 2. Length frequency distribution by sex of juvenile *Negaprion brevirostris* captured in the Sebastopol Lagoon, Los Roques Archipelago.

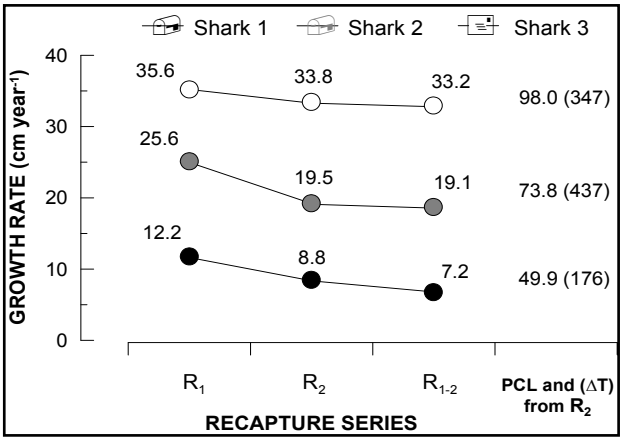

Figure 3. Growth rates of juvenile *Negaprion brevirostris* estimated from three repeat-recapture individuals. Note that each shark that was recaptured twice provided three rate estimates related to the recapture series (R_1, R_2, R_{1-2}). Also shown are the PCL (cm) and DT (days) for the second recapture (R_2).

DISCUSSION

The capture of neonate and juvenile lemon sharks, together with the absence of other shark species, confirmed that the SL constitutes a specific nursery area for *N. brevirostris*. However, nursery grounds of this species presumably extend to other similar areas along the eastern IPA. Since small lemon sharks are often observed in other internal lagoons and neighboring areas of the east IPA. Curiously, juvenile *N. brevirostris* are not observed or captured by the local fishery in internal zones of the western part of the archipelago. Analysis of the artisanal shark fishery has shown that adult individuals of this species (> 150 cm PCL) are caught near the main coral reefs bordering the LRA (Tavares 2005).

Analysis of the length data showed that juvenile *N. brevirostris* of both sexes remain within the SL until they reach a size of approximately 95 cm PCL. These larger juveniles then leave the SL, probably to explore other areas either within or outside the IPA. This change in habitats as ontogenetic progresses has been previously documented in other shark species. In the study area, the birth season of *N. brevirostris* includes the months of June and July. Seasonal variation in the birth periods among geographic regions is primarily conditioned by differences in water temperature. For example, births of *N. brevirostris* occur between February and April in the southwestern Atlantic and between April and July in the northwestern Atlantic (Barker *et al*. 2005, Freitas *et al*. 2006).

In the study area, the juvenile growth rates obtained for *N. brevirostris* were much higher than those reported for other regions of the western Atlantic (see Table 1). Moreover, the use of external tags in this study may even have resulted in underestimation of growth rates, since previous studies have demonstrated that external tags reduce juvenile growth (10 - 50%) in this species, when compared with internal PIT-tags (Manire and Gruber, 1991, Freitas *et al*. 2006). Although sample size was not large and juvenile growth showed great variability, the estimates presented here need not be considered unreliable, since other studies carried out in the LRA have also revealed a rapid juvenile growth for the blacktip shark, *Carcharhinus limbatus*, and the Caribbean reef shark, *C. perezi* (Tavares 2007, 2008). This rapid growth exhibited by juvenile lemon sharks in the SL may be attributable to the following factors:

i) High temperature of the seawater together with its comparatively slight seasonal variation;
ii) Abundance and availability of prey;
iii) Very low levels of competition and predation; and
iv) Absence of anthropogenic pressures.

Even though statistical analysis detected no significant differences in juvenile growth rates between sexes, males appear to grow at higher rates than females. The absence of statistical significance was due to the high variability observed in growth. If males do indeed grow more rapidly than females, then they will be the first to reach the maximum sizes observed within the SL, and hence may have swum further away. If this is the case, this would explain the predominance of females among the larger individuals recorded, between 70 and 95 cm PCL. The observed growth variation between individuals is probably indicative of differences in genetic traits rather than of sampling errors resultant from inaccuracies in length measurements; the degree of correspondence between growth rate series obtained from the repeat-recaptured sharks indicates a satisfactory precision of measurement. The data were insufficient to draw inferences about changes in juvenile growth according to ontogenetic development. Nonetheless, the growth rates of the three repeat-recapture individuals appeared to reduce with increasing length, and this finding is biologically acceptable. In the Bahamas, Barker *et al*. (2005) found no differences in juvenile growth rates for the lemon shark. These differences in juvenile growth patterns between nurseries could be also related to the above-mentioned factors of temperature, prey availability, competition and anthropogenic processes. Another important finding was the recapture registered outside the eastern edge of the IPA. It suggests that the habitat of juvenile *N. brevirostris* extends eastward of the IPA.

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