Artisanal Fishery and Catch Structure of the Smalleye Smooth-hound Shark, *Mustelus higmani* (Springer & Low 1963), from the Northeastern Region of Venezuela

RAFAEL TAVARES[1,4], LEONARDO SANCHEZ[2,4], and ELEA MEDINA[3,4]
[1]*Instituto Nacional de Investigaciones Agrícolas (INIA), Isla de Margarita, Estado Nueva Esparta, Venezuela*
[2]*Universidad del Zulia, Maracaibo, Estado Zulia, Venezuela*
[3]*Universidad Central de Venezuela, Caracas, Distrito Capital, Venezuela*
[14]*Centro para la Investigación de Tiburones, Caracas, Distrito Capital, Venezuela*

ABSTRACT

We analyzed the elasmobranch composition and catch structure of *Mustelus higmani* caught by the artisanal fishery in the northeastern region of Venezuela. A total of 38 species of elasmobranchs were recorded, being the most taken *M. higmani* (40.8%), *Rhizoprionodon porosus* (12.6%), *R. lalandei* (9.4%), and *Carcharhinus limbatus* (8.0%). *M. higmani* catches were composed by 36.2% of males and 63.8% of females. Males measured between 32 and 59 cm TL and females measured between 35 and 75 cm TL. Differences in length composition between sexes were highly significant (Kolmogorov-Smirnov test; $p < 0.000$). Mean length at maturity ($TL_{50\%}$) estimated from binomial maturity data fitted to a logistic model were 52.5 cm TL in males and 59.9 cm TL in females. Females with near term embryos and with yolked eggs in the ovary indicate an annual reproductive cycle. The brood size was 2 - -9 and birth length estimate was 25 cm TL. On the basis of the length at maturity estimates, an important proportion of immature *M. higmani* were caught by the fishery. A needed manage measure must be the revision and modification of the fishing gear characteristics.

KEY WORDS: Caribbean, biology, elasmobranchs, *Mustelus*, Triakidae

Pesquería Artesanal y Estructura de las Capturas del Tiburón Viuda Amarilla, *Mustelus higmani* (Springer & Low 1963), en la Región Nororiental de Venezuela

En el presente estudio se analizó la composición de elasmobranquios y las capturas de la especie *Mustelus higmani* procedente de la pesquería artesanal llevada a cabo en la región nororiental de Venezuela. Se registraron un total de 38 especies de elasmobranquios, siendo las mas frecuentemente capturadas *M. higmani* (40,8%), *Rhizoprionodon porosus* (12,6%), *R. lalandei* (9,4%), and *Carcharhinus limbatus* (8,0%). Las capturas de *M. higmani* estuvieron constituidas por 36,2% de machos y 63,8% de hembras. La talla de los machos varió entre 32 y 59 cm LT y la de las hembras entre 35 y 75 cm LT. La composición de tallas fue significativamente diferente entre sexos (Kolmogorov-Smirnov test; $p < 0.000$). Las estimaciones en la talla promedio de madurez ($LT_{50\%}$) fueron 52,5 cm LT para los machos y 59,9 cm LT para las hembras. Se encontró que *M. higmani* posee un ciclo reproductivo anual, una vez que las hembras grávidas contenían simultáneamente embriones en el útero y óvulos vitelogénicos en los ovarios. El número de embriones registrado por camada fue 2-9 y la talla de nacimiento estimada fue 25 cm LT. Basados en las estimaciones de las tallas de madurez sexual, se observa que una proporción importante de individuos inmaduros de *M. higmani* son seleccionados en la pesquería. Como medida de manejo se recomienda la revisión y modificación de las características del arte de pesca empleado.

PALABRAS CLAVES: Caribe, biología, elasmobranquios, *Mustelus*, Triakidae

La Pêcherie Artisanale et la Structure de Prise du Requin Smooth-hound Smalleye, *Mustelus higmani* (Springer & Low, 1963), de la Région du Nord-Est du Venzuela

Nous avons analysé la composition des captures élasmobranches et la structure de *Mustelus higmani* capturés par la pêcherie artisanale dans la région nord-est du Venezuela. Un total de 38 espèces d'élasmobranches ont été enregistrées, soit *M. higmani* étant le plus capturé (40,8%), *Rhizoprionodon porosus* (12,6%), *R. lalandei* (9,4%), et *Carcharhinus limbatus* (8,0%). Les captures de *M. Higmani* étaient composées de 36,2% de mâles et 63,8% des femelles. Les mâle mesuraient entre 32 et 59 cm TL et les femelles mesuraient entre 35 et 75 cm TL. Les différences dans la composition en longueur entre les sexes sont très significatives (test de Kolmogorov-Smirnov, $p < 0,000$). Les longueurs moyennes à la maturité (TL-50%) estimée à partir des données de maturité du binôme montée sur un modèle logistique TL étaientt de 52,5 cm TL chez les mâles et 59,9 cm TL chez les femelles. Les femelles ayant des embryons à court terme et avec des œufs vitellins dans l'ovaire indiquent un cycle annuel de reproduction. La taille des couvées a été de 2-9 et l'estimation de la taille de naissance était de 25 cm TL. Sur la base des estimations de la longueur à la maturité, une proportion importante de *M. higmani* immatures ont été capturés par la pêcherie. Une mesure de gestion nécessaire doit être la révision et la modification des caractéristiques des engins de pêche.

MOTS CLÉS: Caraïbes, biologie, élasmobranches, Mustelus, Triakidae

INTRODUCTION

Sharks and rays (Subclass Elasmobranchii) are a group of fishes characterized by slow growth, low fecundity and late maturity. These biological attributes result in low intrinsic rates of increase and low resilience to fishing mortality (Hoenig and Gruber 1990, Stevens *et al*. 2000). Over the last two decades, a dramatic decline in abundance has been documented for several elasmobranch populations worldwide (for details see Musick and Bonfil 2005). Therefore, concerns over the impact of fishing on this

resource are currently being raised an international level.

Venezuela is the second fishing nation operating in the Caribbean Sea and western central Atlantic with the highest catches of elasmobranchs (Vannuccini 1999). Artisanal fishery contributes about 90% to the total shark production of the nation and in some regions this resource has a significant cultural and economic importance (Tavares 2008). The shark landings from the northeastern region of Venezuela (comprising the estates of Sucre and Nueva Esparta) fluctuated around 3000 tn between 1990 and 2006. Preliminary analysis of the catch composition indicated that the group of hound sharks (Genus *Mustelus*) was the most commonly caught (51%) by the artisanal fishing conducted in this region (Tavares 2008). In spite of the importance of the hound sharks as a fishery resource, the state of their populations in the Venezuelan Caribbean is unknown.

The smalleye smooth-hound shark, *Mustelus higmani*, is distributed from Venezuela to southern Brazil and it's a typical bottom species inhabiting along the South American Atlantic continental shelf (Compagno 2002). *Mustelus higmani* is a poorly studied shark species occurring in the western Atlantic and consequently biological and fishery data is lacking throughout its distribution range. In the present study, we analyzed the elasmobranch catch composition by species and examined the sex proportion, size at maturity and length structure of *M. higmani* caught by the artisanal fishery in the northeastern region of Venezuela.

MATERIALS AND METHODS

The data analyzed in this paper were obtained at the main landing ports of the artisanal fishery in the Margarita Island by the Fishery Research Program of the Instituto Nacional de Investigaciones Agrícolas (INIA) during the period 2007 - 2008. In 2007, information were collected by poorly-trained biologists for elasmobranchs, hence the data base for this year had to be reexamined in order to remove bias related to taxonomic identification of the species. For 2008, elasmobranch data are very precise because it was strictly collected by well-trained biologists. The artisanal fishing activities constitute a multi-specific fishery that operates on the basis of the seasonal abundance of the distinct marine resources presented in the region. The small-scale fishing vessels are mainly wooden motorized boats (5 - 10 m long) and a variety of fishing gears (gillnets, longline, traps and coastal seines) can be used by the fleet. Nevertheless, sharks are mostly caught by the drift and bottom gillnet fishery. The fishing ground, along the eastern continental shelf and including Margarita, Coche, Cubagua and Los Hermanos islands, is delimited approximately by 10°30´-11°40´ N and 62°00´- 65°10´ W (Figure 1).

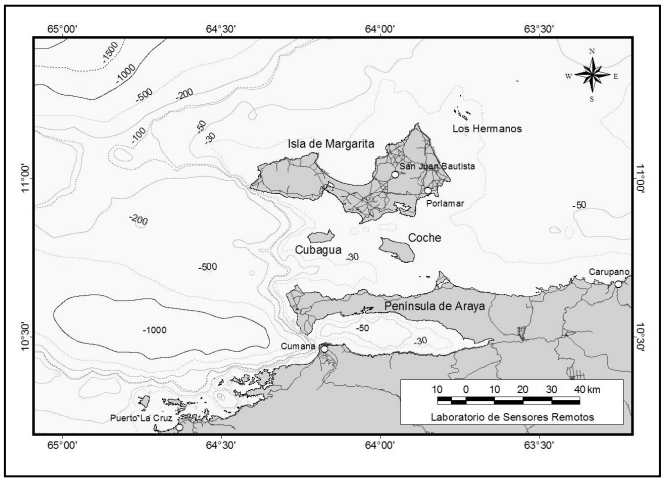

Figure 1. Map of the study area showing the geographic location of Margarita Island, northeastern region of

Shark catches were examined in order to estimate species contribution by numbers (n%). When possible, individuals of *M. higmani* were sexed, measured (total length, TL), weighed and examined for maturity condition. Total lengths of either gutted and behead sharks (i.e. carcasses) were reconstructed by creating the following conversion equations:

$$TL = [a + b(D_{12}L)] + \varepsilon$$

$$TL = [a + b(PL)] + \varepsilon$$

where, TL is the is the length from the anterior tip of the snout to the posterior tip of the upper lobe of the caudal fin, $D_{12}L$ is the length from the origin of the first dorsal fin to the origin of the second dorsal fin, PL is the length from the origin of the pectoral fin to the posterior tip of the upper lobe of the caudal fin, a and b are regression parameters, and ε is the error expression. The distribution of measurement errors was also analyzed in order to evaluate the accuracy between the biometric variables. Additionally, a one-way analysis of variance (ANOVA I; a = 0.05) was applied in order to compare mean error-square (e^2) between models.

Length structure of *M. higmani* catches was described through a length-frequency histogram. Then, differences between length composition by sex were tested by using a two-sample Kolmogorov-Smirnov test (a = 0.05). Males were considered adults when they had calcified claspers, and adult females when they had developing ova or pregnancy stage. To evaluate the size at maturity, a logistic model was fitted to binomial maturity data using least squares non-linear regression. The logistic function is:

$$PM = 1/\left(1 + e^{(a+bTL)}\right)$$

where, PM is the proportion of mature sharks, TL is the total length, a and b are regression parameters. The length at which 50% of the individuals were mature ($TL_{50\%}$), was

then obtained by substituting PM = 0.5 in above equation. Additionally, embryos were quantified and measured (TL) with the purpose to estimate female fecundity and birth length.

RESULTS

Elasmobranch landings were composed by 34 species distributed into 18 families. Seven species of sharks accounted for 83.0% (n = 3,314) of landings, the most important being the smalleye smooth-hound, *M. higmani* (40.8%), the Caribbean sharpnose shark, *Rhizoprionodon porosus* (12.6%), the Brazilian sharpnose shark, *R. lalandei* (9.4%), the blacktip shark, *Carcharhinus limbatus* (8.0%), the dusky smooth-hound, *M. canis* (7.2%), the Atlantic sharpnose shark, *R. terraenovae* (3.0%) and the narrowfin smooth-hound, *M. norrisi* (2.0%). Regression analysis between length variables ($D_{12}L$ vs. TL and PL vs. TL) of *M. higmani* and derived error distributions are shown in Figure 2. Comparison between mean error-square (e^2) was highly significant (ANOVA; $F = 13.03$, $p < 0.001$). Therefore, taking into account the higher r-square (r^2) value and lower mean error-square (e^2) value, the model PL vs. TL was most accurate to estimate TL. This is because the PL measurement produces minor error variability, when compared with the $D_{12}L$ measurement (Figure 2).

Mustelus higmani catches comprised 36.2% of males and 63.8% of females; a significant difference between observed and expected sex ratios ($c^2 = 7.59$; $p < 0.05$). Males measured between 32 and 59 cm TL (mean: 49.5 cm TL), and females measured between 35 and 75 cm TL (mean: 52.4 cm TL). However, catches were primarily composed by individuals measuring between 44 and 56 cm TL, in both sexes (Figure 3). Difference in length composition between sexes was highly significant (K-S; $p < 0.000$). For male *M. higmani*, the smallest mature individual measured 44.0 cm TL, and $TL_{50\%}$ estimate was 52.5 cm; for females the smallest mature was 52.0 cm TL and $TL_{50\%}$ value was 59.9 cm (Figure 4). The occurrence of pregnant females with near term embryos and with yolked eggs in the ovary indicates an annual reproductive cycle. The brood size recorded per pregnant female oscillated between 2 and 9. On the basis of largest embryos, the birth length was estimated to be about 25 cm TL. Considering the mean length at maturity estimated in the present study, an important proportion of immature *M. higmani* were caught by the artisanal fishery.

DISCUSSION

For the study area, elasmobranch landings were composed by 34 species, representing about 35% of the elasmobranch fauna described for Venezuelan waters. Results revealed that hound sharks (*Mustelus*) constitute an important group caught by the artisanal fishery. For the northeastern region of Venezuela, the evolution of inter-annual landings and abundance data suggest the presence of overfishing signs for hound shark populations. Landing

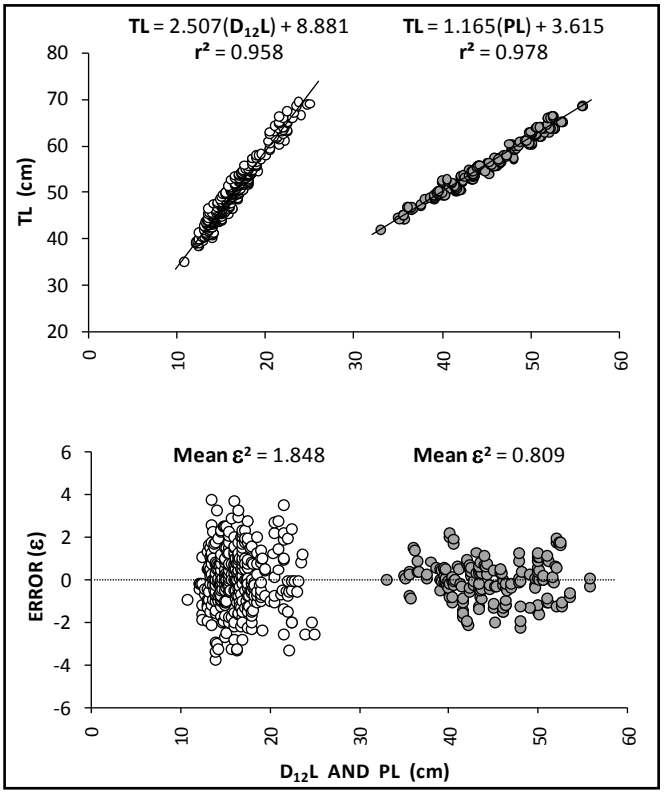

Figure 2. Regression analysis and measurement error distribution of the length variables (TL, $D_{12}L$ and PL) select-

time series for *Mustelus* sharks showed a continuous increasing tendency during the period 1990 - 2004, after which captures abruptly declined to recent years (Tavares, 2008). The analysis of the Venezuelan seine fishery indicated that the abundance of the *Muslelus* group declined of about 75% from 1970 to 2003 (source: Instituto Nacional de Investigaciones Agricolas). In the Los Roques Archipelago, Venezuelan Caribbean, the local populations of *M. canis* and *M. norrisi* were significantly depleted by the artisanal gillnet fishery in the 1980s (Tavares 2005).

The analysis of the catch composition indicated that *M. higmani* was the elasmobranch species most frequently caught (40.8%) in the study area. The percentage value obtained for this species agrees with that previously reported by Tagliafico *et al*. (2005). However, the contribution values presented for the other main species differ from those estimated in our study. This discrepancy resulted from several problems of the study conducted by the above mentioned authors, such as species misidentification and inadequate sampling methods that produced a biased species contribution. According to Shing (2006), the species *M. higmani*, *R. porosus*, and *R. lalandei* are also usually captured by the artisanal fishery conducted around Trinidad and Tobago. This Caribbean island state is situated (10° N-61° W) on the continental shelf of Venezuela, at approximately 250 km east of Margarita island. Therefore, the commonest occurrence of *M. higmani* on

both study regions could indicate that a single stock exist along the northeastern continental shelf of South America

In landing ports, shark catches composed by gutted and beheaded individuals make difficult identification of the distinct species. Nonetheless, *M higmani* carcasses can be easily recognized from other species (including *M. canis* and *M. norrisi*) due its typical morphology and color. This feature made possible to reconstruct the original total lengths (TL) from other length measures ($D_{12}L$ and PL). The differences registered between catch numbers and length composition by sex suggest the presence of sexual segregation on *M. higmani*. This finding was also mentioned in the review book of Compagno (2002), who wrote that catches of this species are commonly made of considerable numbers of one sex individuals. Male *M. higmani* reach sexual maturity with lengths (44.0 - 52.5 cm TL) slightly smaller than females (52.0 - 59.9 cm TL). These lengths at maturity estimates, as well the birth length (25 cm TL) and brood size (2 - 9) observed in this study are similar with the only available information (Compagno, 2002). Results demonstrated the species *M. higmani* has an annual reproductive cycle, biological characteristic involved in highly productive shark populations. An annual reproductive cycle has also been documented for other species of hound sharks; *M. schmitti* in the Patagonia, Argentina (Chiaramonte and Pettovello, 2000), *M. canis* in the northwest Atlantic Ocean (Conrath and Musick, 2001), *M. henlei* in the northern Gulf of California (Perez-Jimenez and Sosa-Nishizaki, 2008).

The information presented in this study is a modest contribution for the fishery and biological knowledge of the smalleye smooth-hound, *M. higmani*. Major efforts must be done with the purpose of complete the biological data required for stock evaluation. Owing the large numbers of immature *M. higmani* taken by the artisanal fishery in the study region, we recommend as manage measure, the revision and modification of the fishing gear characteristics (i.e. gillnets used by the artisanal fleet). Other needed measure will be the identification and delimitation of nursery areas, once these marine zones inhabited by juveniles have to be protected or closed for shark fishing.

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