

## “What can archaeological otoliths of bonefish (*Albula vulpes*) tell us?”

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### ABSTRACT

Studies of zooarchaeological remains have focused on the reconstruction of economic and social aspects of marine resource exploitation, and recently on the reconstruction of former abundance of marine populations. The analysis of fish otoliths could contribute to document shifts in life history parameters of exploited populations. However, few studies take advantage of the growth bands recorded in archaeological otoliths to describe these parameters. In this study we use archaeological otoliths to estimate age and length distributions of the bonefish (*Albula vulpes*) in the late pre-Hispanic times. Bonefish were exploited by the Valencioids Amerindians in Dos Mosquises island at Los Roques Archipelago National Park (Venezuela) in the years 1300-1500 A.D. The age composition of the pre-Hispanic catches was estimated from sectioned sagittae, and otolith weight was used to reconstruct the total length of the pre-Hispanic bonefish. The comparison between the size and age distributions of the archaeological and the modern otolith samples from Dos Mosquises island, suggest that Amerindians exploited relatively younger and smaller bonefish in the pre-Hispanic times. The use of archaeological otoliths to estimate age and lengths distributions of fish in the past may play an important role in the study of the dynamics of exploited fish populations.

KEY WORDS: pre-Hispanic fishery, Los Roques Archipelago National Park, zooarchaeology, age estimation.

## “¿Que nos pueden decir los otolitos arqueológicos del pez ratón, *Albula vulpes*?”

El estudio de los restos zooarqueológicos ha estado orientado hacia la reconstrucción de los aspectos socioeconómicos de la explotación de los recursos pesqueros, y recientemente hacia la reconstrucción de la abundancia de las poblaciones marinas en tiempos pasados. El análisis de otolitos de peces provenientes de fuentes arqueológicas podría contribuir a documentar cambios en parámetros de la historia de vida de las poblaciones explotadas. En este trabajo se examina el uso de los otolitos arqueológicos para estimar la composición de edades y tallas de las capturas del pez ratón, *Albula vulpes*, en la época pre-Hispánica. Esta especie era explotada por los Amerindios Valencioides en la isla de Dos Mosquises Sur en el Parque Nacional Archipiélago de Los Roques (Venezuela) alrededor de los años 1300-1500 A.D. La distribución de edad fue estimada a partir del conteo de los anillos de crecimiento en cortes de los otolitos, y la longitud total de los ejemplares arqueológicos fue reconstruida utilizando el peso del otolito. La comparación entre las distribuciones de edad y talla de las muestras arqueológicas y las muestras modernas del pez ratón provenientes de la isla de Dos Mosquises, sugiere que los Amerindios explotaban individuos menos longevos y de menores tallas en los tiempos pre-Hispánicos.

PALABRAS CLAVES: Pesquería pre-Hispánica, Parque Nacional Archipiélago de Los Roques, zooarqueología, estimación de edad.

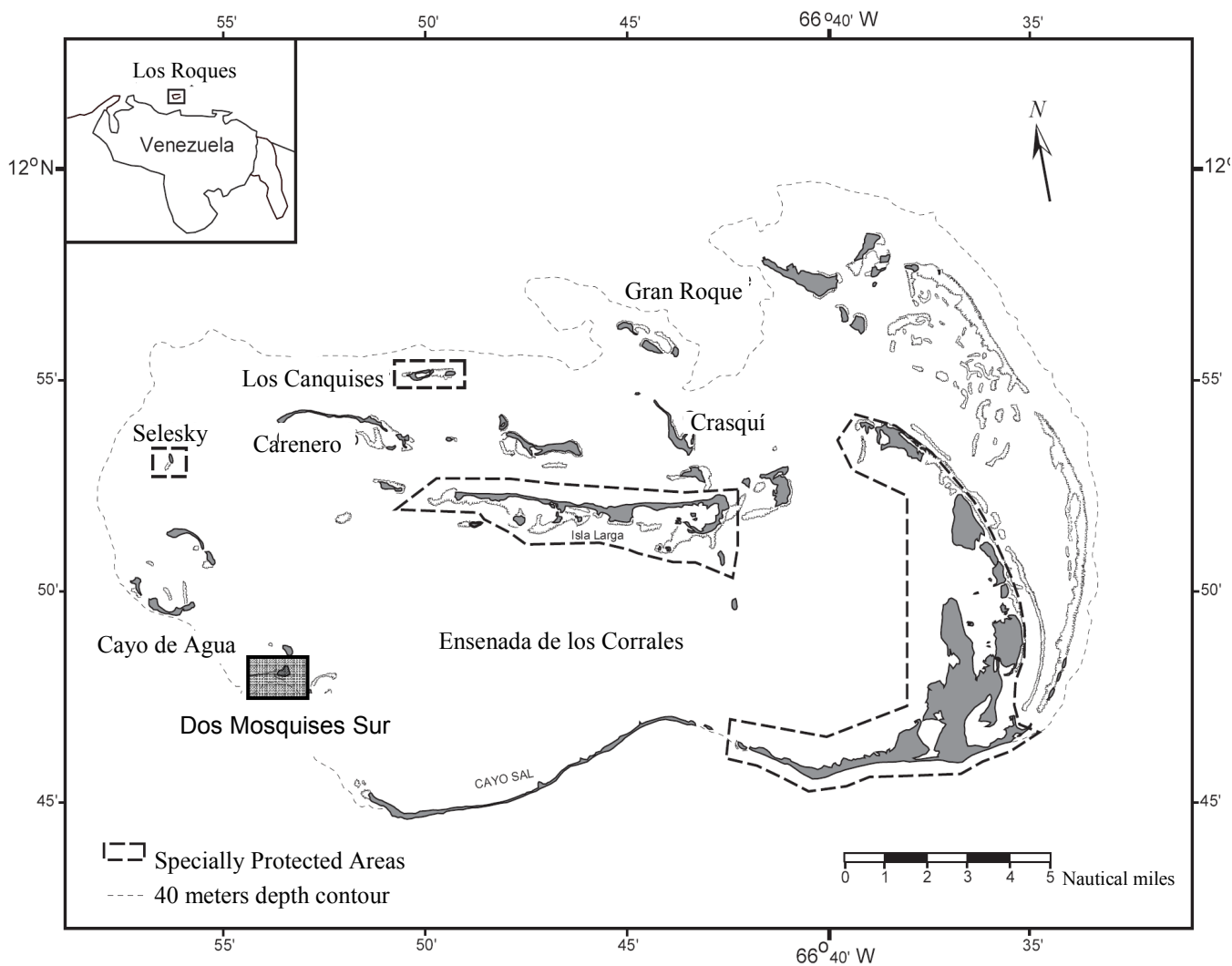
### INTRODUCTION

Studies of archaeological fish remains have mainly focused on the reconstruction of economic and social aspects of marine resource exploitation, and more recently on the reconstruction of former abundances of marine animal populations. Though the analysis of growth bands recorded in archaeological fish otoliths have been used to establish the season of capture and estimate fish size (Wheeler and Jones 1989), few studies have taken advantage of this growth bands to reconstruct the age and growth of fish populations in the past.

The abundance of fish remains recovered from archaeological sites in Dos Mosquises Sur Island (DMS) at Los Roques Archipelago National Park (LRA; Fig. 1), suggest that bonefish (*Albula vulpes*) were exploited by the

Valencioid Amerindians that occupied this island in the late pre-Hispanic times (i.e. between A.D. 1200 and 1500; Antczak and Antczak 2006). Even though conch (*Strombus gigas*) was by far the most exploited species at that time (Antczak and Antczak 2006), grunts (Haemulidae) and bonefish were probably two of the most important fish resources for the Amerindians in DMS (Antczak 1999).

Although there are no official statistics reporting bonefish landings in modern times, some of the oldest fishermen from LRA acknowledged that since the 1950s, bonefish were heavily exploited by the artisanal fishers who arrived to LRA from other regions of Venezuela. Bonefish were then captured in shallow waters using seine nets, and used as bait in longlines to fish for sharks and rays. After the use of seine nets was banned in LRA in the late 1980s,



**Figure 1.** Map of Los Roques Archipelago National Park showing the location of the study site, Dos Mosques Sur island.

bonefish were only caught occasionally, given that this species is not considered a meat fish in LRA and has no commercial value in the local market. In the last decade, however, this species has become the basis of a profitable recreational catch-and-release fishery in LRA (Posada et al. 2007).

In this study we combine the approaches of zooarchaeology and fisheries biology to reconstruct the age and size composition of bonefish exploited by the Valencioids Amerindians in DMS. This offers a unique opportunity to examine if the size and age distributions of bonefish have changed in more than 500 years in Los Roques Archipelago, from the times of the pre-Hispanic exploitation to the present.

## MATERIALS AND METHODS

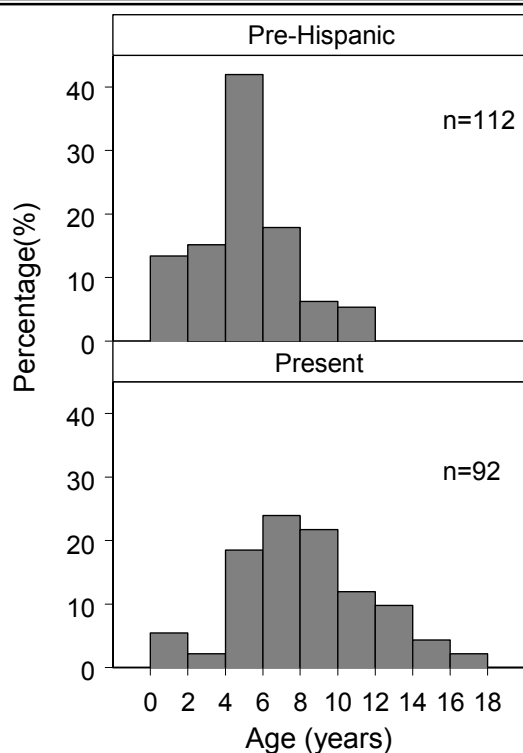
### Study Area

The present study was carried out in Los Roques Ar-

chipelago National Park (LRA), an insular reef platform located 155 Km to the north off the central coast of Venezuela ( $11^{\circ}44'45''$  to  $11^{\circ}58'36''$  N and  $66^{\circ}33'30''$  to  $66^{\circ}57'27''$  W). This archipelago is made up of 42 islands and 200 sand banks, and encompasses an area of 1250km<sup>2</sup> (Fig. 1).

### Archaeological otolith sample

The archaeological bonefish otoliths (sagittae) used for this study were recovered during systematic archaeological excavations carried out on Dos Mosques Sur Island (Fig. 1) as part of the *Archaeology of the Islands of Venezuela* research project, conducted by A. Antczak and M. Antczak. Dos Mosques Sur Island (DMS) was interpreted to be a multifunctional campsite occupied in the late pre-Hispanic times (i.e. between A.D. 1200 and 1500) by Valencioid Amerindians from the north central Venezuelan mainland (Antczak and Antczak, 2006).



**Figure 2.** Age distributions of pre-Hispanic and present-day bonefish (*Albula vulpes*) at Dos Mosquises Sur island, Los Roques Archipelago National Park.

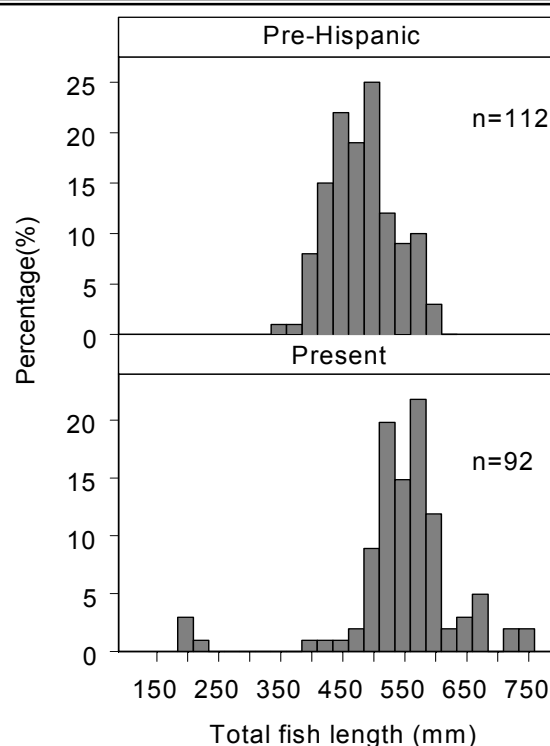
Otoliths and other fish remains recovered from DMS were dated by cultural artifacts (ceramics) in same context and by the stratigraphic position of this context. Bonefish sagittae were identified using a reference collection composed of modern specimens that were collected within less than one kilometer from the study site (see Antczak 1999 for methodology details). For this study, 125 left saggitae from archaeological sites at DMS were used to estimate the age distribution of the pre-Hispanic bonefish catches.

#### Present-day otolith samples

Present-day bonefish sagittae were obtained from 102 specimens collected with a beach seine (2 cm mesh opening) in shallow waters (< 2 meters) surrounding DMS (Fig.1). All individuals were measured (fork length, FL, mm), weighted (total weight, TW, g), and sex was recorded. Samplings were carried between 2003 and 2006.

#### Otolith preparation and age estimation

The left sagittae from the modern and archaeological samples were weighed to the nearest 0.0001 g (OW) using an electronic balance. Otoliths were then sectioned transversely, examined under a dissecting microscope with 40X magnification, and read for annuli by two independent readers.



**Figure 3.** Size distribution of pre-Hispanic and present-day bonefish (*Albula vulpes*) at Dos Mosquises Sur island, Los Roques Archipelago National Park. Observed total fish lengths are plotted for the present-day sample and reconstructed total fish length for the pre-Hispanic sample.

#### Age and size distributions

Fish length at capture is registered for all modern otoliths, but is unknown for the archaeological otoliths. Thus, conversion of the pre-Hispanic otolith measurements (i.e. weight, length, width) into fish lengths was required to be able to reconstruct the length of the fish at capture in the case of the archaeological sample. The highest correlation with the modern fish lengths was for otolith weight (OW, g), therefore the relationship between OW and total fish length (TL, mm) for the modern specimens was examined using various generalized linear models, to determine the best fit based on the coefficient of determination ( $r^2$ ).

Age distributions estimated from annuli counts were generated for the pre-Hispanic and modern otolith samples. Observed fish lengths were plotted for the modern bonefish, while the reconstructed fish lengths were plotted for the pre-Hispanic bonefish. The age and size distributions for the modern and pre-Hispanic samples were compared by a Kolmogorov-Smirnov two sample test.

## RESULTS AND DISCUSSION

### Reconstruction of pre-Hispanic fish length at capture

The reconstruction of pre-Hispanic fish lengths was carried out using the relationship between total fish length

(TL<sub>m</sub>, mm) and otolith weight (OW<sub>m</sub>, g) for the modern otoliths. This relationship was best described by the linear model ( $r^2=0.7027$ ):

$$TL_m = 307.047 + 419.325 * OW_m \quad (1)$$

The use of equation (1) to convert the pre-Hispanic otolith weight OW<sub>p</sub> into the fish length (TL<sub>p</sub>) was justified since: 1) the pre-Hispanic otoliths used in this study did not seem eroded and conserved the typical shape of the modern bonefish otoliths; and 2) the parameters of the age-OW regression did not differ for both the pre-Hispanic and modern sample ( $p<0.0001$ ). Therefore, we assume that the original weight of the archaeological otoliths was not altered by taphonomic factors, and that the relationship between the age of the fish and its otolith weight has not changed significantly over time.

#### Comparison of age and size distributions

The age distributions of pre-Hispanic and modern bonefish at DMS were different ( $p<0.001$ ). In the pre-Hispanic sample, bonefish in the younger age groups (0-4 years) were relatively over-represented (mean=4.643 ± 0.233 SE), whereas, in the modern sample, bonefish showed a clear shift towards older fish (mean=7.793 ± 0.374 SE; Fig. 2). Furthermore, the maximum observed longevity for the pre-Hispanic sample was 12 years, while modern bonefish reached a maximum of 17 years (Fig. 2). The distribution of sizes for the modern and pre-Hispanic sample were also different ( $p<0.001$ ). Modern bonefish ranged from 188 mm to 742 mm, while the reconstructed total fish length for the pre-Hispanic catches ranged from 334 to 609 mm (Fig. 3).

The size and age distributions of the pre-Hispanic sample, which presumably reflect those of the pre-Hispanic bonefish catches, suggests that the Amerindians at Dos Mosquises island exploited younger and smaller bonefish. The compressions of the age and size distributions of the pre-Hispanic catches, compared to those of the modern sample, could be attributable to either: environmental changes, changes in the marine food web, effects of intense fishing pressure or over-exploitation, gear or cultural selectivity.

The analysis of fish remains from archaeological sources have inherent biases, which may limit their interpretation. However the use of archaeological otoliths to estimate the age and lengths distributions of fishes in the past may play an important role in the study of the dynamics of exploited fish populations. Further work may extend the analysis to other species to test whether this results hold for other fishes exploited by the Amerindians in the late pre-Hispanic times at Los Roques Archipelago.

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