

Research Article

**Population structure and reproductive aspects of puffer fish
Sphoeroides annulatus (Jenyns, 1842) (Osteichthyes: Tetraodontidae),
landed in Teacapán, Sinaloa, Mexico**

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ABSTRACT. The puffer fish *Sphoeroides annulatus* is an important target species for the artisanal fishing fleets of NW Mexico. To obtain information on population structure of the local stock, we determined the total length and total weight (TL and TW) ranges, sex ratio and reproductive stages of 745 specimens of this species, landed from May 2010 to April 2011 in Teacapán, Sinaloa, NW Mexico. TL ranged from 15 to 40 cm and TW from 100 to 1600 g. There were no differences between mean TL (27.41 ± 4.14 cm) and TW (534.5 ± 226.0 g) of males and females respectively. Sex ratio was not significantly different ($\chi^2 = 0.03$, $P > 0.05$) from 1F:1M. The length-weight relationship for both sexes was $TW = 0.044TL^{2.815}$, $R^2 = 0.895$. The value of the slope b was significantly lower than 3 ($P < 0.05$), and indicated negative allometric growth. The distribution of maturity stages indicated one main reproductive period from June to September and one less intense, from November to December for females, and in December for males. Size at first maturity ($L_{50\%}$) of females was 26.52 cm and that of males was 27.41 cm.

Keywords: puffer fish, *Sphoeroides annulatus*, size distribution, weight distribution, sexual maturity, reproduction, northeastern Pacific.

Estructura poblacional y aspectos reproductivos del botete diana *Sphoeroides annulatus* (Jenyns, 1842) (Osteichthyes: Tetraodontidae), capturado en Teacapán, Sinaloa, México

RESUMEN. El botete diana *Sphoeroides annulatus* es un importante recurso pesquero para las flotas pesqueras artesanales del NW de México. Para obtener información sobre la estructura poblacional del stock local, se determinó el rango de longitud total y peso total (TL y TW), proporción sexual y estadios reproductivos de 745 especímenes, desembarcados entre mayo 2010 y abril 2011, en Teacapán, Sinaloa, noroeste de México. No hubo diferencias entre LT promedio ($27,41 \pm 4,14$ cm) y TW promedio ($534,5 \pm 226,0$ g) entre machos y hembras. La proporción entre sexos no resultó significativamente diferente de 1H:1M ($\chi^2 = 0,03$; $P > 0,05$). El modelo de la relación longitud-peso fue $TW = 0,044 LT^{2,815}$; $R^2 = 0,895$ para ambos sexos. El valor del parámetro b fue significativamente menor que 3, indicando que el tipo de crecimiento es alométrico ($b \neq 3$, $P < 0,05$). La distribución de los estadios de madurez indica un periodo reproductivo principal de junio a septiembre y otro menos intenso de noviembre a diciembre en hembras y en diciembre para machos. La talla de primera madurez ($L_{50\%}$) fue de 26,52 cm en hembras y 27,41 cm en machos.

Palabras clave: botete diana, *Sphoeroides annulatus*, distribución de tamaño, peso, madurez, biología reproductiva, Pacífico nororiental.

INTRODUCTION

The puffer fish *Spherooides annulatus* (Jenyns, 1842) is a common species in marine and coastal waters of the eastern Pacific from southern California to Peru, including the Gulf of California (Bussing, 1995; Amezcua-Linares, 1996), which has become a target species for the artisanal fishing fleets of the Mexican NW, for its high market price due to the quality of its meat (Chávez-Sánchez *et al.*, 2008; Aguilera & Duncan, 2009).

According to Arreguín-Sánchez & Arcos-Huitrón (2011), this resource has been fully exploited during four of the five years for which data on landing volumes are available for the Gulf of California. Since this information concerns the 1979-1988 period, and because of the increased fishing effort devoted to this species, it is conceivable that captures have reached or possibly exceeded sustainable levels.

However, in spite of its increasing commercial interest, information on this species is scant. Particularly, studies on its reproductive biology in coastal Sinaloa waters are scarce and partially contradictory, possibly because of geographic or interannual differences of climatic and oceanographic conditions. According to Castellanos-Rodríguez *et al.* (1982) and Komar (2001), *S. annulatus* has a short reproductive season lasting two and three months, from April-May to June, whereas Sánchez-Cárdenas *et al.* (2007, 2011) described two annual reproductive periods. The first was longer and more important; it lasted from April to August with intense spawning from June to August, while the second lasted between October and November.

Total length (TL) of landed organisms ranged from 19.5 to 44.0 cm, and TL at first maturity (TL₅₀ = length at which 50% of the organisms are sexually mature: Rodríguez-Gutiérrez, 1992), were 28.2 and 28.6 cm for females and males, respectively (Sánchez-Cárdenas *et al.*, 2007, 2011).

Most of these results were obtained using the landings of the Mazatlán artisanal fishing fleet. In this work we analyze the information on size distribution, biometric relationships and sexual maturity obtained from landings of the Teacapán fishing fleet between 2010 and 2011.

MATERIALS AND METHODS

Information was obtained approximately every second week, between May 2010 and April 2011, at Playa Sur (Southern Beach), which is located immediately to the south of the town of Teacapán and it is the main

landing site of the local artisanal fishing fleet (Fig. 1). Sample size depended on the size of the catches, and was at least 20% of all puffer fish landed. Total length and weight (TL and TW) were determined to the nearest 1 mm and 1 g with a measuring board and a digital scale, respectively. Sex and maturity stages were determined using the morphochromatic maturity scale by Sánchez-Cárdenas *et al.* (2007), which recognizes five stages (resting, early developing, late developing, ripe and spawned) for females, and four (resting, developing, ripe and spent) for males.

The normality of size and weight distribution was verified with Kolmogorov-Smirnov tests, and the data were used to calculate length-weight relationships separately for each sex and for the total sample, adjusting the data to the model:

$$TW = a TL^b \text{ (Pauly, 1983)}$$

The frequencies of the maturity stages of each sex were determined monthly (Salgado-Ugarte *et al.*, 2005), and the size at first maturity was calculated as in Gunderson *et al.* (1980), using the logistic model:

$$P_x = 1 / (1 + e^{a + bTL}) e^{a + bx}$$

In this model, P_x is the proportion of organisms at size x with clear signs of gonadic activity (stages III, IV and V: advanced development, mature and spawned for females, respectively) and stages II, III and IV (in development, mature and ejaculate), in the case of males.

The mean TL and TW values of each sex were compared using Mann-Whitney tests, because the data were not normal (Kolmogorov-Smirnov test). The allometry of TW-TL relationships were determined by Student's t tests, and χ^2 tests served to determine whether monthly and yearly sex ratios were different from the theoretical 1:1 value. All tests were performed with $\alpha = 0.05$ (Zar, 1996).

RESULTS

Data were obtained for a total of 745 organisms (375 males and 370 females, 50.3 and 49.5%, respectively). TL ranged from 15 to 40 cm; 56.2% of the females and 63% of the males were within the range 26 to 32 cm. The respective mean values were 27.5 ± 3.8 cm for males and 27.3 ± 4.5 cm for females, with no significant difference between sexes (Mann-Whitney, $P = 0.966$). The global mean value for both sexes was 27.41 ± 4.14 . The size distribution was bimodal, and the modal values were 20 and 28 cm (Fig. 2).

TW ranged from 100 to 1600 g, with 61.69% of the catches between 300 and 700 g. The mean values were 528.5 ± 209.3 g for males and 531.3 ± 249.7 g

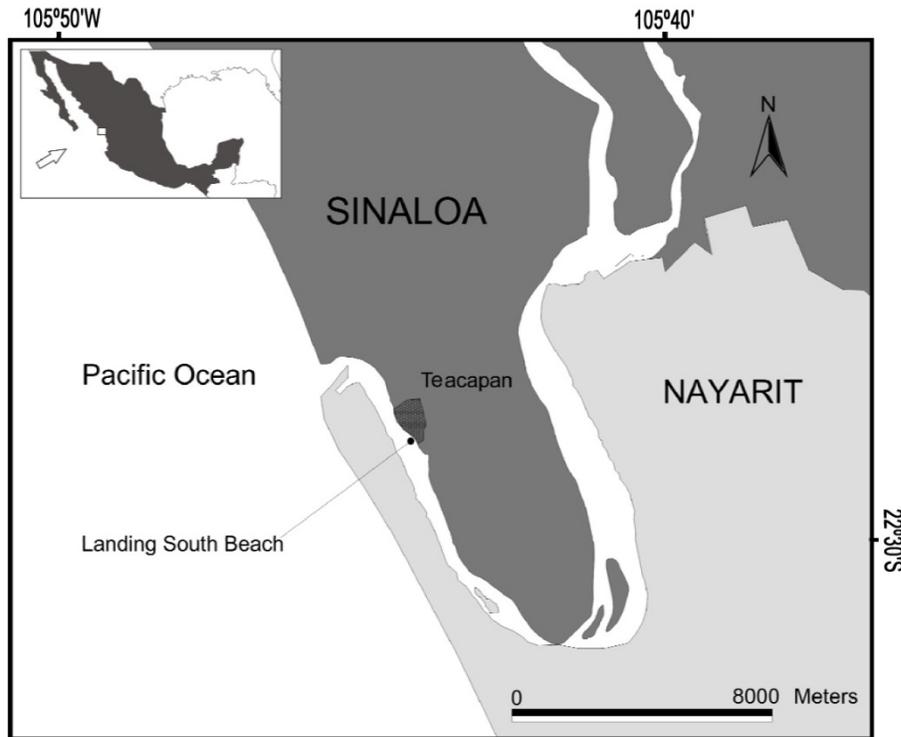


Figure 1. Study area in Teacapán, Sinaloa, Mexico.

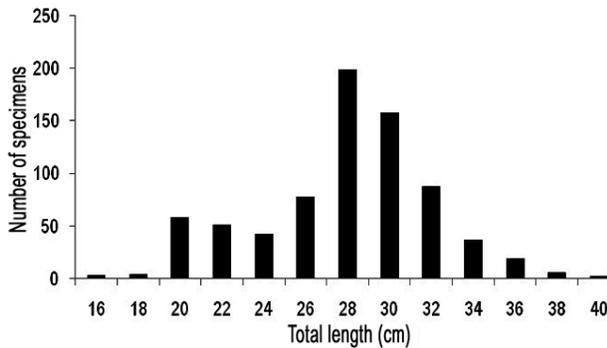


Figure 2. Frequency of total length of *Sphoeroides annulatus* caught in Teacapán, Sinaloa, Mexico.

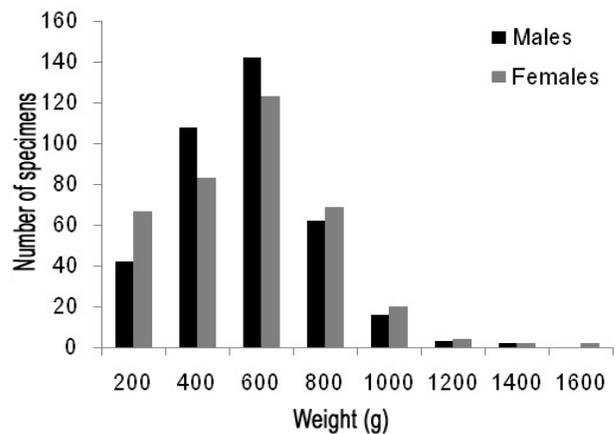


Figure 3. Frequency distribution of total weight by sex of *Sphoeroides annulatus*, in Teacapán, Sinaloa, Mexico.

for females and the means were not significantly different (Mann-Whitney, $P = 0.896$). Considering both sexes, mean TW was 534.5 ± 226.0 g and the only modal value was 600 g (Fig. 3).

The relationships between TW and TL for males and females were described by the equations:

$$TW = 0.036 TL^{2.87}, R^2 = 0.921 \text{ (females)}$$

$$TW = 0.058 TL^{2.73}, R^2 = 0.860 \text{ (males)}$$

The values of both slopes were significantly lower than 3 ($P < 0.05$), indicating negative allometric growth for both sexes. The equation calculated using all data was:

$TW = 0.044 TL^{2.815}$, $R^2 = 0.895$ and the slope was again significantly lower than 3 ($P < 0.05$) (Fig. 4).

The F: M ratios calculated for each sampling date were not significantly different from the expected 1:1 value. The annual F: M ratio was 0.987 F: 1 M.

Between >75 and >90% of the females were in maturity stages III to V from June through August. Stage V was dominant (87.5%) in August and it was present until December, but with lower percentages

(20 to 30%). Stages III to IV appeared again in March 2011, and increased in April to 40% (Fig. 5a).

Stage III males (mature) were found from May to August, with high values in May (87.1%) and June (64.8%). They appeared again in October and November, were absent from December through February, but reappeared in March and April 2011. Stage IV (spent) occurred between May and September, with the highest percentage (57.1%) in August 2010, immediately after the period of highest frequency of stage III (Fig. 5b).

According to the logistic model, the length and sexual maturity data obtained indicated that 50% of the females are sexually mature at the 26.52 cm and males at 27.41 cm (Fig. 6).

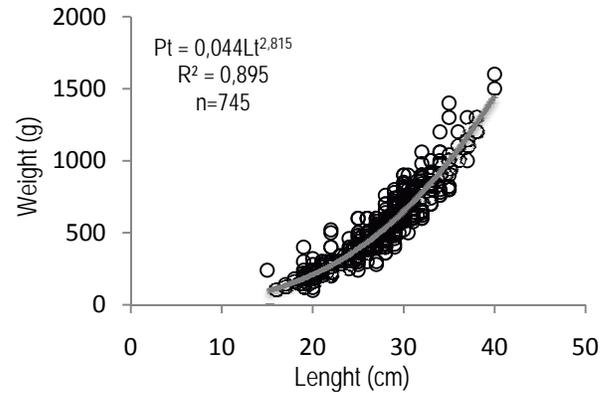


Figure 4. Length-weight relationship of the general sample *Spherooides annulatus*, in Teacapán, Sinaloa, Mexico.

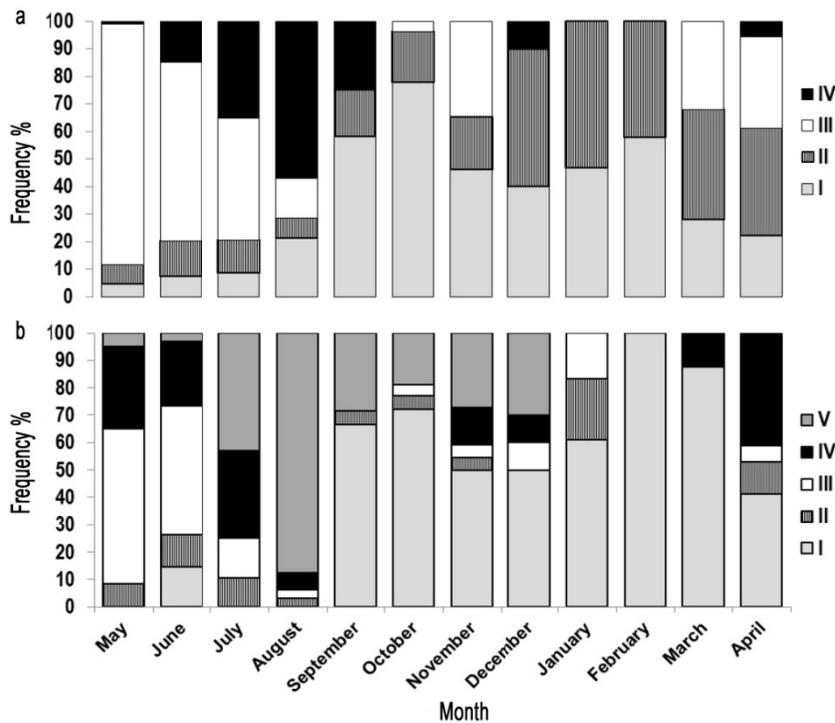


Figure 5. Relative frequency distribution of occurrence of later stage in *Spherooides annulatus* in Teacapán, Sinaloa, Mexico. a) males, b) females.

DISCUSSION

The size range found in Teacapán is not different from that reported by Castellanos-Rodríguez *et al.* (1982), Sánchez-Cárdenas (2005) and Morán-Angulo (2009), but only the first of these authors found a bimodal distribution for TL, with modal values of 18.5 and 30.5 cm, which are similar to those reported here.

This discrepancy in the type of size distribution is possibly due to the origin of the catches, since Sánchez-Cárdenas (2005) and Morán-Angulo (2009)

obtained their samples in Mazatlán whereas those of Castellanos-Rodríguez *et al.* (1982) originated from different sources (bycatch from the offshore shrimp fishery, and coastal fleets of Mazatlán and Teacapán). According to Sánchez-Cárdenas *et al.* (2007), the lack of specimens smaller than 20 cm in the Mazatlán landings could be due to the low number of young specimens in marine waters, such as those of Mazatlán Bay, than in estuarine environments. This seems confirmed by the presence in Teacapán of organisms <20 cm TL, since this fleet operates largely at the mouth of this estuarine system.

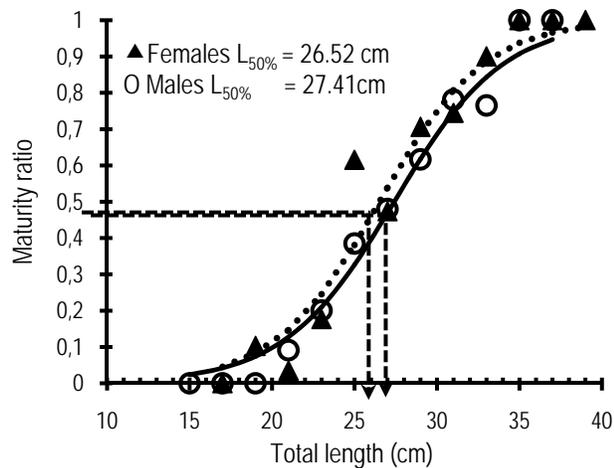


Figure 6. Size at first maturity of females and males of puffer fish *Sphoeroides annulatus* adjusted to a logistic model in Teacapán, Sinaloa, Mexico.

There are also discrepancies concerning the type of growth: while we found negative allometric growth for both sexes, Sánchez-Cárdenas (2005) determined negative allometric growth for females but not for males, and Morán-Angulo (2009) found isometric growth for both sexes. As for size ranges, these differences could be explained by the different origin of the samples, or by differences in the sexual maturity cycle, since these could modify the value of the indicator of isometric-allometric growth. The overall 0.99H: 1M proportion found in this study is in agreement with Sánchez-Cárdenas (2005) for the whole annual cycle, but differs from the information obtained at the peak of the spawning season (June) in Mazatlán, where males were dominant over females (1M: 0.48H), which could be due to an harem behavior, not observed in this work, but similar to that reported for other Tetraodontid species (Kobayashi, 1986; Gladstone & Westoby, 1988).

The main spawning period found in this work was from June to August, followed by a minor peak in winter. Although the separation between first and second peak (December instead of October-November) was between one and two months longer than that observed by Sánchez-Cárdenas (2005) and Sánchez-Cárdenas *et al.* (2007), this partial agreement indicates that there are no differences in the reproductive behavior of this species in the two sampling areas. In both, the most intense reproductive activity coincides with the whole summer season, whereas the indications of Castellanos-Rodríguez *et al.* (1982) and Komar (2001) suggest a far shorter reproductive season, with peak activity limited to May and June.

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