# Age and Growth of *Mycteroperca bonaci* from Southern Gulf of Mexico

# Edad y Crecimiento de *Mycteroperca bonaci* del Sur del Golfo de México

# Age et Croissance de *Mycteroperca bonaci* dans le Sud du Golfe du Mexique

XIMENA RÉNAN[1]*, EMMANUEL SECA-CHABLÉ[2], and THIERRY BRULÉ[1]
*[1]CINVESTAV. Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Departamento de Recursos del Mar, Unidad Mérida. Antigua Carretera a Progreso K. 6. Ap. 73 Cordemex, Mérida Yucatán, México. C.P. 97310. *ximenarenan@me.com. [2]ITSSY. Instituto Tecnológico Superior del Sur del Estado de Yucatán, Carretera Muna-Felipe Carrillo Puerto, tramo Oxkutzcab- Akil, Km 41+400, Oxkutzcab, Yucatán, México. C.P. 97880.*

## ABSTRACT

*Mycteroperca bonaci* or black grouper is the second most important grouper species in southern Gulf of Mexico, supporting commercial and recreational fisheries. It is considered as near threatened specie by IUCN, its fishery as deteriorated and their population as decreasing thought out their distribution range. Even though it's economic importance, this study is the first to determine age and growth for the species in the Campeche Bank. During 1996 to 1999, 714 black groupers were captured using long line by the commercial fishing fleet. Otoliths were up through the gills-removed, alcohol cleaned and stored dry. Age determination was based on the assignation of annuli to the number of opaque zones from the otolith core to the otolith margin, in left sagittae thin sections. Individuals ranged in size from 25.6 to 160.0 cm ($L_F$) and in age from 2 to 27 years. Age-10 fish were the most numerous in the sample (*n* = 99), followed in frequency by age-9 and age-11 (n = 90 each one) and age-12 (n = 81), representing 50.4 % of total specimens. Young fish with age-2 (n = 2) and older fish with age-25 and age-27 (n = 1 each one) were poorly represented. The more frequent year-class was 1987 (n = 107). Edge-type analysis confirmed the formation of a single growth annulus per year, recording the smallest marginal increment values between February and March. The relationship between furcal length and age was described by the von Bertalanffy growth model as: $L(t) = 138.40 * (1 - e^{(-0.12 * (t - 0.068))})$.

KEY WORDS: Black grouper, *Mycteroperca bonaci*, age, growth

## INTRODUCTION

*Mycteroperca bonaci* or black grouper is a solitary reef species with a wide distribution range, from Bermuda and Massachusetts to southern Brazil, including southern Gulf of Mexico, Florida Keys, Bahamas, Cuba and throughout the Caribbean (Heemstra and Randall 1993). In Southern Gulf of Mexico, black grouper display a bathymetric distribution where adults inhabit offshore sandy-rocky bottoms with ridges and crevices whereas juveniles occupy inshore seagrass beds (Renán et al. 2003), feeding mainly in pelagic fishes (Brulé et al. 2005), and exhibiting a monandric protogynous hermaphroditism, with a reproductive period from December to March (Brulé et al. 2003).

Particularly at Campeche Bank, black groupers are captured throughout a tropical sequential multispecific fishery, which targets *Epinephelus morio* (red grouper), by two Mexican fishing fleets (one industrial, one artisanal) and one Cuban fleet (industrial) (Brulé et al. 2009). Campeche Bank CPUE data shows that there has been a 51% groupers landing decline since 1970s to 2011 (SAGARPA 2012). Even though in Mexico, there is no federal assessment per species in grouper fishery, scientific data accounts black grouper as the second most important species (Monroy et al. 2010), contributing with 40% (total weight) in 2003 (Brulé et al. 2003) to 32% in 2009 (Brulé et al. 2009) of the total grouper catch per weight.

Black grouper in the Campeche Bank are heavily fished: juveniles in nursery areas are captured by the artisanal fleet (Renán et al. 2006) whereas adults in their spawning and feeding aggregations are exploited by the industrial one (Tuz-Sulub 2008). Information on black grouper age and growth is basically for Florida populations (Manooch and Mason 1987, Crabtree and Bullock 1998), and in spite of its economic importance, there is no data on age and growth for the Campeche Bank black grouper population. Currently, the Campeche Bank grouper fishery only considers red grouper´s biology for management purposes: a month long fishery ban (15 February to 15 March) and a minimum size limit of 36.3 cm (total length), for all groupers in the Campeche Bank. Nevertheless, a long-term database of ages for all exploited species is critical to the proper management of the fishery (Lai et al. 1996). Therefore, information on Campeche Bank black grouper growth and age provided in this study, is imperative to attain an adequate fishery management.

## MATERIAL AND METHODS

From April 1996 to May 1999 black grouper were captured during 34 fishing trips by the industrial and artisanal fishing fleets with long line gear and hooks, in the Campeche Bank (20 - 23º N and 86 - 92º W) at depths between 2 to 35 m. Each individual was measured (fork length and standard length), weighed (total and gutted weight), and otoliths (sagittae) removed through the gill arch, cleaned with alcohol and stored dry in small paper bags.

In the laboratory, both otoliths were weighed with an analytical scale to the nearest 0.1 mg to obtain average weight per otolith. Only the left sagittae were used in the age determination. Each otolith per individual, was embedded in crystal resin and thin sectioned with an Isomet® 1000 Buehler® precision saw at 420 rpm with a 500 µm thickness. Four sections were taken for each otolith and attached to a slide with Ultrakitt® mounting medium. Each slide was examined with a stereomicroscope at magnifications of x 2.5, x 3.2 and x 4.0, under reflected light. To improve contrast, a drop of chamomile oil was placed below and over each section and observed against a black background. Age was annuli based on the number of opaque zones, from otolith core to margin, following the procedure by Brothers (1987), Campana and Jones (1992), Crabtree and Bullock (1998), and Wright et al. (2002). The first reader, selected the best otolith section (the clearer one), counted the number of annuli, and took digital photographs using a software-hardware working station consisting of a video camera attached to a stereomicroscope and connected to a computer. Using the digital photographs, the first reader obtained ages automatically with the Age & Shape® software. With the same pictures the second independent reader counted the number of annuli. Readings were compared (taken by the two readers and the Age & Shape), considering that at least two readings must agree to keep the sample otherwise it was eliminated.

The annuli count, edge type and capture date were used to calculate the annual age of a fish based on a calendar year proposed by Jearld (1983) according to the procedure by Lombardi-Carlson et al. (2006). Otoliths were advanced a year in age if their edge-type was translucent between the period of complete annulus formation (opaque zone formation) established in this study through the marginal increment analysis. In addition to annual or cohort age, biological age (fractional age) was determined for use in growth curves. A fractional period of a year was determined as the difference from peak spawning and capture date (black grouper peak spawning = February 15th; Brulé et al. 2003). If capture date was later in the year than the peak spawning date, the fractional period was added to annual age, if the capture date was before the peak spawning date, the fractional period was subtracted from annual age.

Marginal increment analysis was performed according to Lai et al. (1996) as measurement of the relative marginal increment (M.I.): M.I. = $(R - r_i) / r_i - r_{i-1})$, where R is the distance of the centrum- radii, $r_i$ and $r_{i-1}$ are the annulus-radii of the ultimate and penultimate annuli, respectively. Distance measurements of annulus radii were automatically extracted from the thin section digital photographs, with an image processing software.

Growth parameters were estimated by the least squares method (Sparre and Venema 1998). The von Bertalanffy growth curve $L_T = L_\infty(1-e^{(-K(t-t0))})$ was obtain, based on biological ages, using FISAT II program (Gayanilo et al. 2006). To compare black grouper estimated ages from different studies the *phi prime* $f = \ln K + 2*\ln L_\infty$ (Munro and Pauly *in* Sparre and Venema 1998) was calculated.

## RESULTS

A total of 928 black groupers were captured in the Campeche Bank between April 1996 and May 1999, with lengths that ranged from 25.6 cm to 160.0 cm (fork length, $L_F$. Figure 1A) and weights from 232 g to 35,200 g. (total weight, $W_T$. Figure 1B). From 928 black groupers, only 823 otoliths were examined, since 105 otoliths were either missing (n = 35) or broken (n = 70). Of the 823 otoliths, 109 (11.7%) were rejected because of disagreements among readers (n = 89) or because they were unreadable (n = 20).

Ages from 714 black grouper readable otoliths ranged from 2 years ($L_F$ = 33.8 cm) to 27 years ($L_F$ = 160 cm; Figure 2). Age-10 fish were the most numerous in the sample (n = 99), followed in frequency by age-9 (n = 90), age-11 (n = 90) and age-12 (n = 81), corresponding to 50.4% of total sampling. Young fish with age-2 and age-3 (n = 2 and n = 16, respectively) and older fish with age-21,

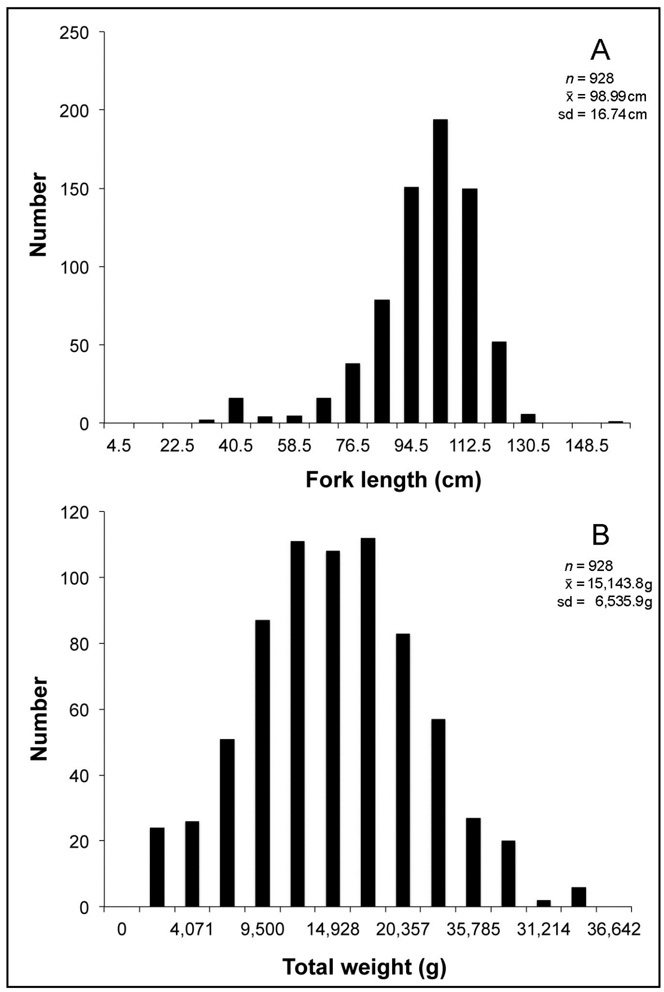


**Figure 1**. *Mycteroperca bonaci* fork length (**A**) and total weight (**B**) sampled from the Campeche Bank during 1996 to 1999. $\bar{x}$ = median numerical value; sd = standard deviation.

age-25 and age-27 (n = 2; n = 1; n = 1 respectively) were poorly represented (Figure 3). The more frequent year-class was 1987 (n = 107). Regression analyses between estimated age and fork length ($L_F$ = -8.90678 + 45.6049 *ln (age); $r^2$ = 92.70%), between fish total weight and age ($W_T$ = -22647.1 + 15974.5 *ln (age); $r^2$ = 74.70%) and between estimated age with otolith weight ($O_W$ = -0.143314 + 0.166687 *ln (age); $r^2$ = 69.80%), indicate a relatively strong relationship between variables and displayed statistically significant relationships at 99% confidence level ($p < 0.0001$).

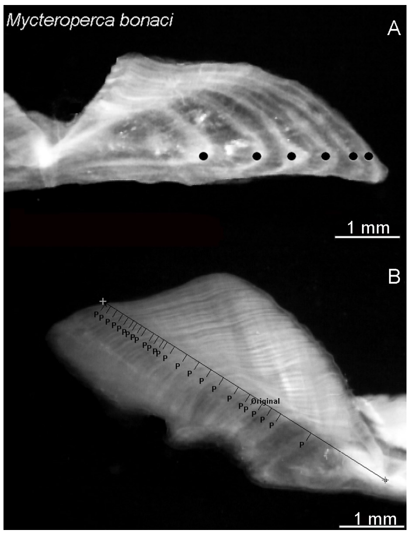


**Figure 2**. Sagittae thin sections of *Mycteroperca bonaci* captured in the Campeche Bank. 6-age (85 cm $L_F$) captured in September 1997 and (**B**) 25-age (128 cm $L_F$) captured in October 1997. Examples of annuli readings show directly observations by two readers (**A**) and automatically obtained age readings by Age and Shape software (**B**).

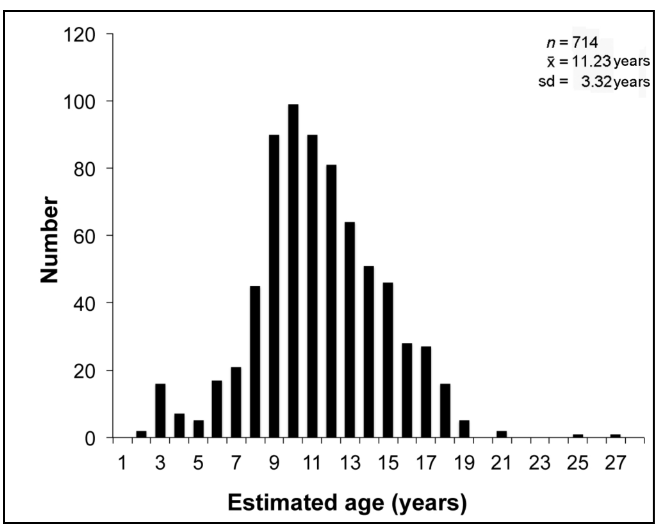


**Figure 3.** *Mycteroperca bonaci* estimated ages from readings of sagittae thin sections of individuals sampled from the Campeche Bank during 1996 to 1999.
$\overline{x}$ = median numerical value; sd = standard deviation.

Marginal increment analysis suggested that black grouper of the Campeche Bank form one annulus during November to February. Minimum percent marginal increments were registered during March (mean= 0.3638) and April (mean = 0.2823), without individuals with wide margins, suggesting that the annulus formation was completed (Figure 4).

The growth model parameters for black grouper from the Campeche Bank were L¥= 138.4 cm ($L_F$), K= 0.12 and $t_0$= 0.068 corresponding to the von Bertalanffy growth equation: $L(t) = 138.40 * (1 - e^{(-0.12*(t-0.068))})$ (Figure 5). The results for f (phi prime) for our study was: F = 7.76.

## DISCUSSION

*Mycteroperca bonaci* otoliths were easily manipulated, embedded in resin, thin sectioned and annuli clearly observed using only chamomile oil to clarify and improve contrast. As seen in other age studies (Crabtree and Bullock 1998), annuli from younger individuals were easier to read because there was a wider distance (translucent zones seen by reflected light) between each

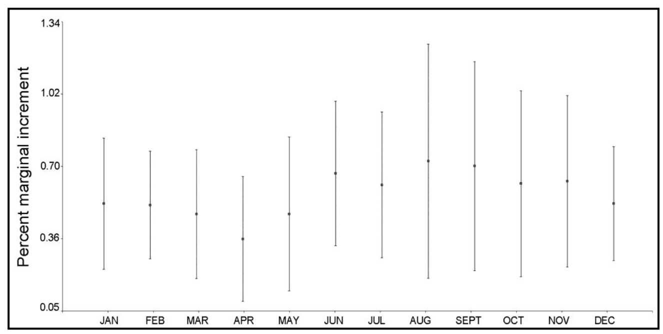


**Figure 4**. *Mycteroperca bonaci* percent marginal increments per month from individuals captured in the Campeche Bank during 1996 to 1999. Means are represented in dots whereas standard deviations in bars.

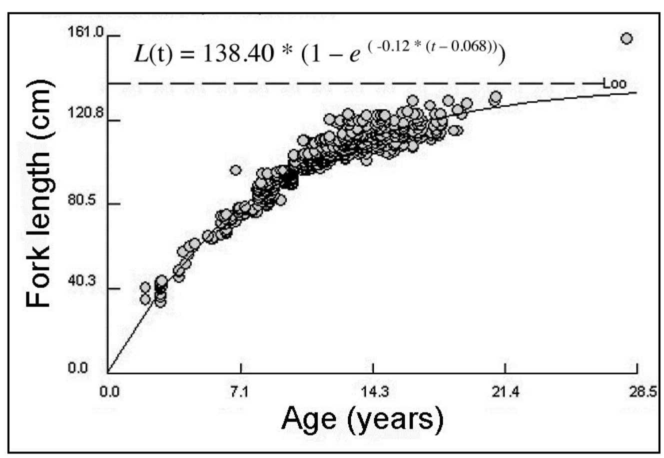


**Figure 5**. Von Bertalanffy growth curve for *Mycteroperca bonaci* from the Campeche Bank, based on estimated biological age and fork length of individuals captured during 1996 to 1999.

other. As more annuli are present in older individuals, these distances gradually diminish toward the otolith margin becoming less apparent and increasingly opaque.

During our study, 56 % of the individuals register ages between 9 and 12 (n = 401) years old with corresponding lengths of 84 to 102 cm ($L_F$). All of these individuals (100 %) displayed lengths above the established length at maturity (72.1 cm $L_F$) for black grouper from the Campeche Bank according to Brulé et al. (2003). All of these individuals were captured through the industrial fishing fleet that targets adults living in deeper and complex-bottom zones.

Black grouper from the Campeche Bank appear to form a single annulus, according to marginal increment analysis, during February and March, whereas black groupers from Florida waters deposit a single annulus between March and May (Manooch and Mason 1987) or between April and June (Crabtree and Bullock 1998). These differences might be attributable to methodological features, feeding variations, changes in calcium metabolism or differences in water temperature (Morales-Nin 1991) between northeastern and southern Gulf of Mexico.

Estimated ages for black grouper from the Campeche Bank displayed differences with black grouper from southeastern Florida waters. The eldest individual registered in our study was a 27-age black grouper at 160.0 cm ($L_F$), whereas Crabtree and Bullock (1998) and Manooch and Mason (1987) registered individuals with 33-age at 151.8 cm ($L_T$) and 14-age at 111 cm ($L_T$) for Florida waters respectively. Growth parameters from our study were different from the parameters obtained by Crabtree and Bullock (1998) and Manooch and Mason (1987). $L_{¥}$ for black grouper form the Campeche Bank ($L_{¥}$ = 138.4 cm $L_F$) was bigger than $L_{¥}$ of Florida populations ($L_{¥}$ = 135.2 cm $L_T$; $L_{¥}$ = 130.6 cm $L_T$). K from our study (K = 0.12) and the one established by Manooch and Mason (1987) (K = 0.115) were alike whereas our K was smaller than K established by Crabtree and Bullock (1998) (K = 0.169). Differences may be attributable to growth differences between populations, in feeding habits, in water temperature, etc. Nevertheless to evaluate the reliability of growth parameters f prime for growth curves were obtained for our study and for Florida black grouper populations. Campeche Bank black grouper F (F = 7.76), was very much alike to the f prime obtained from Crabtree and Bullock (1998) (F = 7.96) and for Manooch and Mason (1987) (F = 7.65) growth curves for black groupers from Florida waters. *Phi* prime displayed values show that there were no significant growth differences between growth curves from the Campeche Bank and Florida populations, considering f as the best index to evaluate overall growth performance since it has a minimum variance (Pauly *in* Sparre and Venema 1998).


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