Fisheries Research 194 (2017) 155–163

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Age, growth parameters and fisheries indices for the lane snapper in the Abrolhos Bank, SW Atlantic

Alexandre Aschenbrenner[a,c,*], Matheus Oliveira Freitas[b,g], Gecely Rodrigues Alves Rocha[c], Rodrigo Leão de Moura[b,d], Ronaldo Bastos Francini-Filho[e], Carolina Minte-Vera[f], Beatrice Padovani Ferreira[a]

[a] Universidade Federal de Pernambuco, Departamento de Pós-graduação em Oceanografia, PE, Brazil
[b] Rede Abrolhos, Jardim Botânico St. 920, Rio de Janeiro, RJ, 22.460-000, Brazil
[c] Departamento de Ciências Biológicas, Universidade Estadual de Santa Cruz, Rodovia Ilhéus-Itabuna km 16, 45662-900, Ilhéus, BA, Brazil
[d] Universidade Federal do Rio de Janeiro, Instituto de Biologia and SAGE-COPPE, Avenida Carlos Chagas Filho 373, 21941-902, Rio de Janeiro, RJ, Brazil
[e] Departamento de Engenharia e Meio Ambiente, Universidade Federal da Paraíba, Rua da Mangueira, s/n, Centro, 58297-000, Rio Tinto, PB, Brazil
[f] Inter-American Tropical Tuna Commission, United States
[g] Universidade Federal do Paraná, Programa de Pós Graduação em Engenharia Ambiental, Centro Politécnico, 80210-170, Curitiba, Paraná, Brazil

ARTICLE INFO

Handled by Dr. B Arara

Keywords:
Lutjanus synagris
Otolith-based methods
Fishing indicators
Stock status
Abrolhos bank

ABSTRACT

Otolith-based methods combined with catch lengths were used to produce three simple fishing indicators for assessing stock status of the lane snapper *Lutjanus synagris* in the Abrolhos Bank, central Brazilian coast. Fish were obtained during landings between May 2005 and June 2007. Marginal Increment Analyses combined with edge analysis on sectioned otoliths (n = 303) confirmed annulus formation in an annual basis during June-October. Lane snapper were aged up to 18 years and the largest fish measured 56 cm total length. Growth was not significantly different between sexes, and the von Bertalanffy growth equation was derived as $Lt = 56[1-e^{(-0.22(t-0.0))}]$. Highest cohort yield was achieved between 33.5–41.4 cm (optimal length) at ages 4–6. Age at first maturity was 2.8 years, and generation length was 10 years. Instantaneous total mortality (Z) was 0.58 year^{-1} and natural mortality rate (M) ranged from 0.17–0.36 year^{-1}. Overall indicators point out for the need to implement fish management, as 30% of catch are composed of immature individuals and 7–12% by mega-spawners. A slot limit for the lane snapper in Abrolhos Bank is proposed, with restrictions for individuals < 24 and > 50 cm.

1. Introduction

Lutjanids (snappers) are important fisheries resources in tropical marine waters worldwide; they have been intensively exploited because of their superior meat quality and high commercial value (Allen, 1985; Polovina and Ralston, 1987). Snappers also play a major role as predators in reef ecosystems (Arreguín-Sánchez and Manickchand-Heileman 1998Claro et al., 2001). Worldwide, snapper stocks are overfished (Claro et al., 2009; Frédou et al., 2009a; 2009b), typical of patterns observed for unmanaged marine fisheries (Pauly et al., 2005; Pauly, 2009).

Twelve species of snappers occur off the tropical coast of Brazil (Moura and Lindeman, 2007). With the exception of *Lutjanus alexandrei*, all species are shared with the North and Central Atlantic (Moura and Lindeman, 2007). The lane snapper, *Lutjanus synagris* (Linnaeus, 1758), inhabits coastal reefs and adjacent habitats throughout the tropical and subtropical western Atlantic (Allen, 1985).

Snappers and groupers are historically among the main demersal fishery resource caught using hand line in Brazil (Freitas et al., 2011; Klippel et al., 2005a; Costa et al., 2003). In the last decades, the proportion of lane snapper in landings is reported to have increased after collapses of larger size congeners (Rezende et al., 2003). However, stock assessments indicated that the northeastern and eastern lane snapper stocks were overfished (Frédou et al., 2009a, 2009b; Klippel et al., 2005b). In addition, recent evaluations using IUCN criteria have classified this species as Near Threatened (NT), considering both its overfished status and lack of fisheries management (Lindeman et al., 2016).

Abrolhos is the largest and most biodiverse reef system in the South Atlantic, sustaining important small-scale coastal fisheries (Moura et al., 2013). Comprehensive biological information about the lane snapper and its fishery in Abrolhos are still lacking (but see Freitas

* Corresponding author at: Universidade Federal de Pernambuco, Departamento de Pós-graduação em Oceanografia, PE, Brazil.
E-mail address: brenner.ale@gmail.com (A. Aschenbrenner).

http://dx.doi.org/10.1016/j.fishres.2017.06.004
Received 22 September 2016; Received in revised form 31 May 2017; Accepted 3 June 2017
Available online 13 June 2017
0165-7836/

et al., 2011, 2014), and there are no published studies on age structure and growth. Previous stock assessments were done using proxies for age and growth parameters based on empirical relationships or data from the eastern stock (Klippel et al., 2005b). Age and growth studies are central to the estimation of mortality rates and productivity of exploited stocks (Beverton and Holt, 1957; Campana, 2001). Here we report the first age and growth study using direct methods, as well as the size structure of the catches of *L. synagris* in Abrolhos, eastern Brazil. Fisheries indicators are described for the species and a simple management strategy based on slot limits (minimal and maximum length of capture) is proposed.

2. Material and methods

2.1. Study area

This study was carried out in the Abrolhos Shelf (hereafter Abrolhos), which covers a large stretch (46000 km^2) of the central Brazilian coast. The cross-shelf profile of the region extends for about 200 km in its widest portion. It is a relatively shallow region, with depths rarely exceeding 50 m, and the shelf edge is at approximately 70 m depth (16° 40′, 19° 40′S − 39° 10′, 37° 20′W) (Fig. 1).

Nearly 300 species of fish and 20 species of reef-building corals have been recorded in Abrolhos (Moura and Francini-Filho, 2006), occurring across an extensive mosaic of mangrove forests, beaches and other benthic mega habitats. Rhodolith beds comprise the largest megahabitat (~21,000 km^2), followed by unconsolidated sediments (~20,000 km^2) and reefs (~9.000 km^2) (Moura et al., 2013).

Nearly 20,000 artisanal fishers work in Abrolhos, but there is little published information about the region's fisheries. Revisions of Eastern Brazil reef fisheries were performed in a broader area, thus Abrolhos' fish stocks and its fisheries remain poorly known (Klippel et al., 2005b). There are four marine protected areas (MPAs) in the region. The Extractive Reserves of Cassurubá (1006 km^2) and Corumbau (895 km^2) are multiple-use MPAs with incipient fisheries management, the National Marine Park of Abrolhos (913 km^2) is a no-take MPA with a nearshore paper-park portion and a well-implemented offshore area, and the largest Environmental Protected Area Ponta da Baleia/Abrolhos (3460 km^2) is a paper park with no management at all (Francini-Filho and Moura 2008; Francini-Filho et al., 2013).

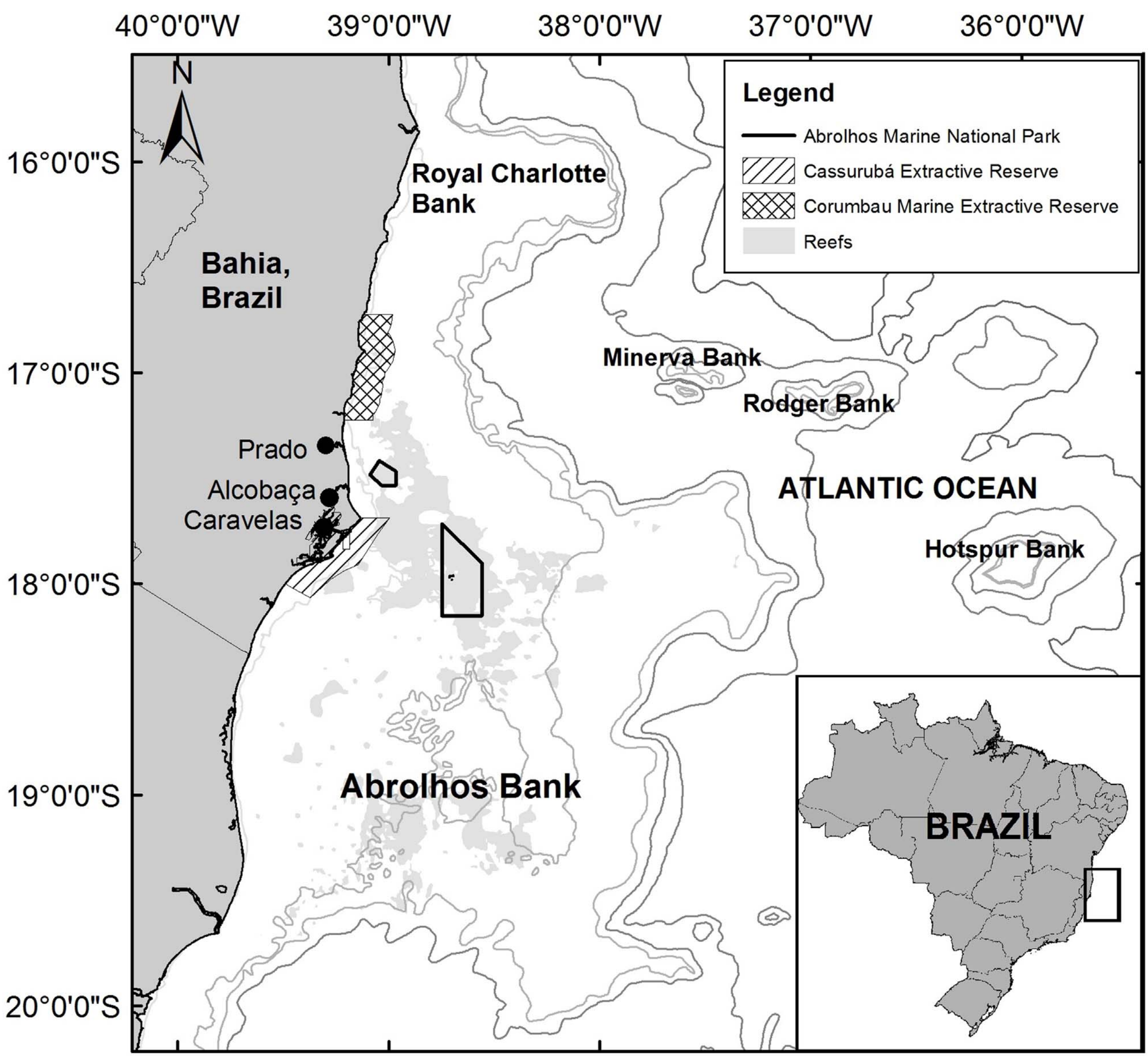

Fig. 1. Map of the Abrolhos Bank in central Brazilian coast and location of marine protected areas.

2.2. Sampling and data analyses

The data collection was part of a larger monitoring program encompassing all commercially important reef fishes at the four main coastal municipalities within the study region (Prado, Alcobaça, Caravelas and Nova Viçosa; Fig. 1). Sampling was performed between May 2005 and July 2007. Fish lengths were obtained for 929 individuals during landings of the artisanal fleet operating with hand line and gillnets. Sampling for lane snapper was conducted weekly on haphazardly selected landings, and at least 10% of the total catch from a given fishing trip were measured.

On a monthly basis, a subsample was selected for collection of biological material. For those specimens, measurement of total length (TL) to the nearest millimeter were taken, the sex was recorded as well as the body weight (W) to the nearest 0.1 g. Otolith collections were performed considering a broad range of sizes, with special attention to smaller and large individuals, as those are essential to a reliable inflection outcome in the growth curve parameter K.

Otoliths were either removed directly at the landing site, or fishes were bought and processed at the laboratory. In total, 306 *sagittae* otoliths were removed, washed in water, weighted to the nearest 0.0001 g and preserved in dry vials (Secor et al., 1991).

The relationship between total length (TL) and body weight (W) was estimated using the mathematical expression proposed by Le Cren (1951):

$$W = aTL^{b}, \quad (1)$$

where a and b are parameters. Additionaly, the logarithmic equivalent of weight-length relationship was performed in order to calculate 95% of confidence limit (CL) of the slope values b (Froese, 2006).

Prior to selection, weights of left and right otoliths were tested using a *paired t* test. As weights of left and right otoliths were not significantly different (t test $P > 0.05$), left otoliths were routinely chosen. Otoliths were embedded in transparent polyester resin and sectioned through their central region using a low-speed saw (Buehler-Isomet). Thin sections were hand polished using 400 − 1200 grip wet-dry sandpaper until annuli were clearly defined. Sections were then mounted on histological slides using Entelan and cover slips. Age was assigned according to annuli formation, defined as the area consisting of one opaque zone and one translucent zone (Ferreira and Russ, 1994). Otolith rings' counts (opaque bands) were performed using a stereomicroscope with reflected light on a black background. Under reflected light, the opaque marks had an intense milky white appearance, while the translucent marks had a darkened tone (Fig. 2). Otolith images were captured using the IMAGE Pro Plus V. 4.5 software (SPSS, 1999). Otolith readings were performed on ventral side along the same transect from the nucleus to the outer edge parallel to the *sulcus acusticus* as indicated by the dots in Fig. 2. Sections were observed and classified according to quality (adapted from Nowara et al., 2009): 1-unreadable (sections where age rings are extremely unclear or discontinuous, no pattern found); 2-poor (rings are unclear and not continuous for very long sections, or with large areas where rings are not distinguishable, leaving the count with a high degree of uncertainty); 3-regular (rings are visible around most of the section and fairly distinguishable, reader may be slightly unsure in some areas); 4-good (rings are overall clear, reader were confident with the age estimate) and; 5-excellent (rings are very clear and distinct, enabling an accurate and easily repeatable count).

All sectioned otoliths were read randomly five times by the first author, without knowledge of fish size and capture date (blind reading), in order to avoid bias in assigning ages (Burton, 2002). All readings were performed with at least fifteen days of interval between each other. Precision between readings was estimated using the Average Percent Error index (APE, Beamish and Fournier, 1981).

Marginal Increment Analyses (MIA) were used to validate the annual periodicity of ring deposition;

$$MIA = (R_t\text{-}R_n)/R_t \quad (2)$$

where R_t is the distance from otolith core section to the otolith edge (radius), R_n is the distance from the focus to the last opaque ring (Lai et al., 1996). Monthly mean marginal increments were calculated from otoliths with three to nine rings, and readability categories 3–5, in order to avoid biases related to crowding effect in older individuals and poor legibility of annuli (Piddocke et al., 2015). Means were plotted against month of capture, with minima indicating the month of annulus formation. As a convention, when the otolith edge is opaque, MIA is equal to 0 (Burton, 2002). Additionally, the percentage of otolith with translucent and opaque edges by month of capture was plotted against the MIA.

Growth parameters were estimated by fitting lengths at age to the von Bertalanffy growth equation:

$$L_t = L_\infty\ [1\text{-}e^{(-k(t-t0))}] \quad (3)$$

where L_t is the *TL* at age t, L_∞ the theoretical asymptotic length, K the body growth coefficient, and t_0 the theoretical age when fish length equals 0. Parameters were also estimated separately for males and females with the assumption of constant variance. The curves were compared using Kimura's likelihood Ratio Test (Haddon, 2001). The fish growth performance was estimated using Munro's growth performance (phi-prime) index (Pauly and Munro, 1984) as

$$\varphi' = log(k) + 2 \times log(L_\infty) \quad (4)$$

To compare the statistical significance of differences in φ' between our and other surveys, the Student's *t*-test analysis was performed using phi-prime index values (Sparre, 1987).

Highest cohort yield (HCY) (the higher average weight gain in a given year class and its respective lengths), were obtained by computing mean annual weight increment as the weight difference between successive ages. Mean weight for each age was obtained with the von Bertalanffy growth equation:

$$W_t = W_\infty\ [1\text{-}e^{(-k(t\ -t0))}]^{b} \quad (5)$$

where W_t is the Total Weight (*TW*) at age t, W_∞ the theoretical asymptotic weight, and b is the value of the slope provided by length-weight relationship.

Additionally, as the reproductive data compiled by Freitas et al.

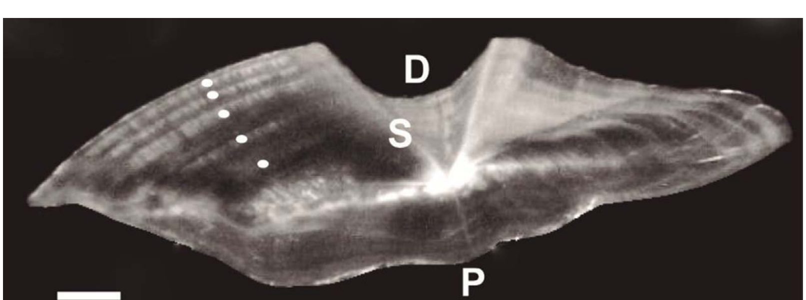

Fig. 2. Otolith section from nucleus to outer margin of a 5 year old lane snapper. Dots represent opaque bands, P = proximal face, S = Sulcus Acousticus, D = Dorsal margin, white bar represent scale bar = 1 cm. Note that opaque margin is being formed.

(2014) comes from the same individuals used herein, we also determined the age of maturation and generation length. The minimum age at which females and males became sexually mature (*Amin*) was recorded. The mean age at first maturity (A_{50}), of females or males were mature was estimated by fitting a logistic regression model using maximum likelihood (King, 1995). The logistic regression is given by:

$$P = 100/(1 + exp - r(A - A_{50})) \quad (6)$$

where *P* is the percentage of mature fish on age-class A, r is the width of the maturity. To predict the probability that an individual was mature based on its length, binary maturity observations (0 = immature, 1 = mature) and length (TL) were fitted to binary logistic models to construct maturity ogives (maturity-at-length probability plots) based on logistic regression (Villegas-Hernández et al., 2015). Generation length was estimated using the equation:

$$A_{50} + [Z(Longevity\text{-}A_{50})] \quad (7)$$

where *Z* is the total mortality rate and A_{50} mean age at first maturity (IUCN, 2014).

An age-length key was constructed and estimated ages (n = 303) were extrapolated for the total length sample (n = 929). Estimates of the instantaneous rate of total mortality (Z) were obtained using the age based catch-curve method of Beverton and Holt (1957) and Ricker (1975). The natural logarithm of the number of fish in each age class (N_t) was plotted against their corresponding age (t), and *Z* was estimated from the descending slope *b*. Estimates of the survival rate (S) were then calculated following Robson and Chapman, (1961) as:

$$S = e^{-Z} \quad (8)$$

A plausible range of values for natural mortality rate (M) was calculated using three methods: regression from longevity, *ad hoc* method based on longevity, and regression from the growth parameter *K*. The regression from the longevity method (Hewitt and Hoenig, 2005) was computed as follows:

$$ln(M) = 1.709–1.084 \times ln(tmax) \quad (9)$$

where *tmax* is the maximum age in the sample; and estimates of *M* are for lightly exploited stocks. The *ad hoc* method (Ault et al., 1998) is given by:

$$M = -ln(a)/tmax \quad (10)$$

where *a* is a small number corresponding to the fraction of recruits expected to survive to age *tmax*. We used *a* = 0.05 to be consistent with Ault et al. (1998). The regression from K (Jensen, 1996) was computed by:

$$M = 0.21 + 1.45k \quad (11)$$

where *K* is the growth parameter.

The *L. synagris* stock status in Abrolhos was assessed using three indicators proposed by Froese (2004), based on length distribution of catches: (I) percentage of mature specimens in the catch ($> L_{50}$) (calculated using Freitas et al., 2014 data); (II) percentage of fish caught at ± 10% optimum length (*Lopt*), obtained empirically using L_∞, M and K parameters, according to the expression by Beverton, (1992):

$$Lopt = \frac{3L\infty}{(3 + M/k)} \quad (12)$$

(III) percentage in the catch of fish of a size larger than optimum length plus 10% (> 1.1 *Lopt*), herein defined as mega-spawners as proposed by Froese (2004), representing large and old individuals in the catch that are much more fecund. Since *Lopt* is highly sensitive to M values, we tested the three different values of M for *Lopt*. Hence, Lopt values were considered plausible when they fall within the highest cohort yield range (HCY) (*i.e.* the higher average weight gain in a given year class and its respective lengths, Froese, 2004).

3. Results

Fish size (TL) ranged from 10.2 to 56 cm, with mean of 32.9 cm SE = 0.33 (n = 939). Otoliths subsample (for age determination, n = 306) fish size varied from 10.2 to 56 cm, with mean of 34.1 cm SE = 0.59, demonstrating that all size classes obtained in the catches were included in the age estimations.

Parameters of the length–weight relationship found for lane snapper were $W = 0.02TL^{2.89}$, $r^2 = 0.99$ and calculated standard error of slope (b) was ± 0.027. This result show that the 95% CL range was 2.85-2.90 indicating that the lane snapper tends to grow slightly faster in length than in weight (t-test, $P < 0.05$).

Otolith sections were largely readable and with good reproducibility between readings, with an APE of 4.8% (five readings). Also regarding readability, the 306 examined otoliths included 1% unreadable, 18% poor, 38% regular, 32% good, and 11% excellent specimens. Only unreadable otoliths (n = 3) were excluded from further analyses.

Otoliths' increments were found to be formed annually. Sections displayed wider age rings between ages 1–3, and continuously narrowed in subsequent ages. After ages 8–9 a crowding effect was observed (thin and tightly packed increments near the margins). Mean

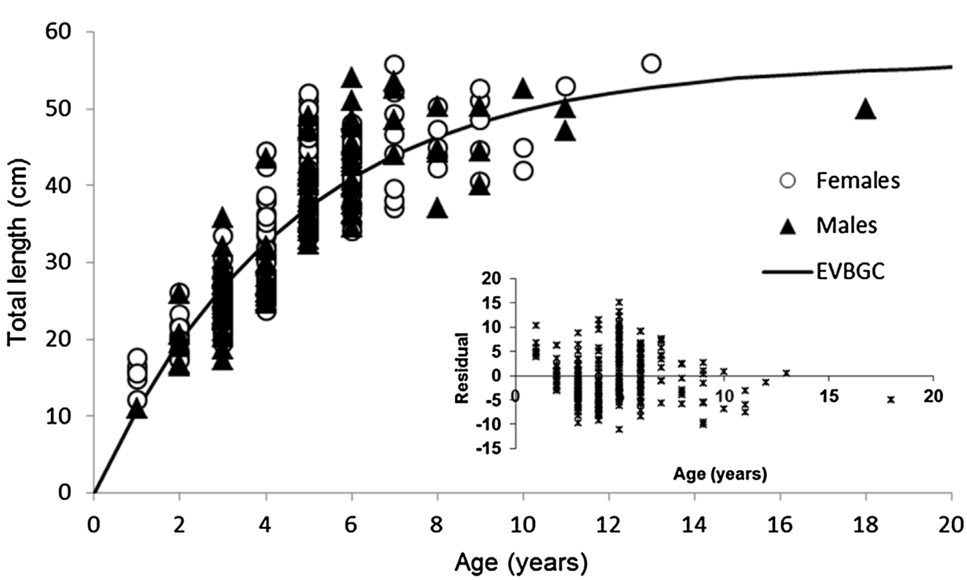

Fig. 4. von Bertalanffy growth curve (VBGC) fitted to length-at-age for Abrolhos' lane snapper sample (n = 303, r^2 = 0.86). Inside plot residual of size-at-age growth curve.

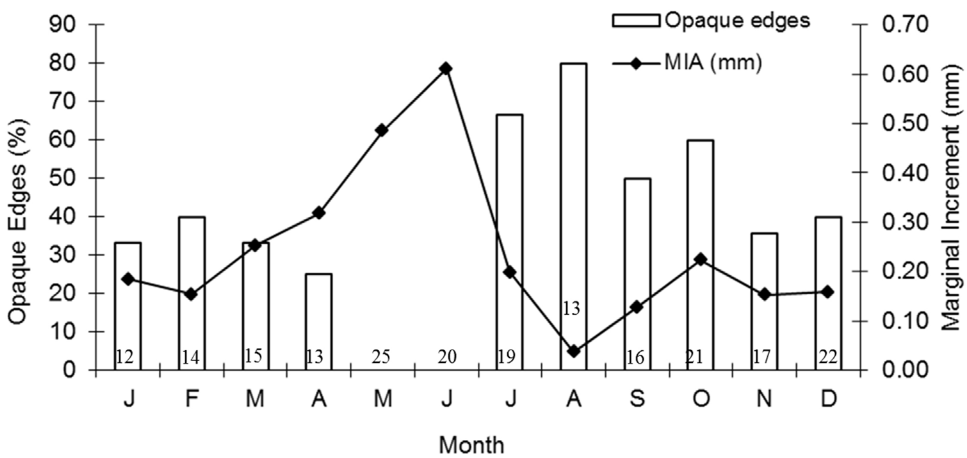

Fig. 3. Mean monthly marginal increments by ages (3–9) (line) and monthly frequency of opaque edges of sectioned otoliths (white bars) of *L. synagris* from the Abrolhos Bank (n = 207). Numbers above months (inside white bars) represent n of samples for each month.

MIA showed one annual minimum in August, and displayed a sinusoidal cycle with a one year frequency, validating the annual periodicity of otolith increments (Fig. 4). The highest monthly percentage of opaque edges (Fig. 3) was also recorded for August, providing further evidence that opaque bands formed yearly between the late austral winter and early spring.

Age-at-length data fitted to the von Bertalanffy (VB) model showed an initial rapid growth during the first years of life. A noticeable slow down occurred at approximately age 4, when fish reached an average 58% of the asymptotic length (Fig. 4). Length-specific growth coefficient (K) was 0.22 year $^{-1}$ ± 0.02 SE, L_∞ was 56.08 cm ± 2.72 SE, t_0 was 0.004 year ± 0.018 SE and r^2 = 0.84. Growth curves for each sex were not significantly different (Kimura's likelihood Ratio Test p = 0.66). The growth performance index (φ') was calculated as 2.84. The *t*-test result showed that there was no significant difference between the growth parameters of this and other studies in the Atlantic area (t = 0.012, P > 0.05) (Table 1).

Age-at-weight parameters for von Bertalanffy growth curve were W_∞ = 2200 g ± 587 SE, K = 0.23 year^{-1} ± 0.08 SE, t_0 = 0.04 year ± 0.002 SE, and r^2 = 0.77. Highest cohort yield (HCY) showed higher values for lengths (33.5-41.4 cm) comprising ages 4–6 (Fig. 5). After age 10 mean weight increment was less than 100 g per year.

The mean age at first maturity (A_{50}) for males and females was 2.8 years, while the age at which 100% of the population had spawned for the first time (A_{100}) was 4.7 years at the 95% Confidence interval (CI) (Fig. 6). Generation length estimated by IUCN proxy was 10 years for the studied population.

Predicted ages for total *L. synangris* catches in Abrolhos ranged from 0 to 18 years (mean = 4), with 3 years being the dominant class, comprising (n = 278), 30% of the total catch (n = 929). A noticeable gap was observed for ages 14–17, with no individuals recorded at these ages.

Individuals at age 3 were fully recruited to fisheries in Abrolhos. Estimates of total mortality (Z) and survival (S) derived from curve equation using fully recruited fish of range 3–13 years, the equations is y = −0.5761 x + 7.5943, were Z = 0.58 year^{-1} and S = 0.56 year^{-1}, with r^2 = 0.98, (n = 929). Estimates of natural mortality rates (M) for the three methods varied from 0.17 (Ault et al., 1998), 0.28 (Hewitt and Hoenig, 2005) and 0.36 year^{-1} (Jensen, 1996). Both Hewitt and Hoenig, Jensen methods generated plausible *Lopt* values (39.3 and 36.1 cm, respectively) that were within the HCY range (33.5-41.4 cm), while for Ault et al., 1998; Lopt value (44.5 cm) was outside the HCY range.

For both methods (Hewitt and Hoenig, Jensen) juveniles corresponded to 30% of the stock caught by fisheries. Considering Hewitt and Hoenig method, mature and Lopt range corresponded to 48% and 16% of the fish sampled, respectively, while mega-spawners represented 6% of the total catch (Fig. 7A). When using the Jensen method, mature range and Lopt range corresponded to 39% and 19%, respectively, while mega-spawners represented 12% of the total catch (Fig. 7B).

4. Discussion

Overall, mean and maximum size (32.9 and 56 cm TL, respectively) of the lane snappers caught in Abrolhos were higher than in other parts of Central Atlantic, where maximum size ranged from 20 to 31.8 cm FL (Cervigón and Fisher, 1979; Gómez et al., 1999, 2001; Luckhurst et al., 2000; Claro et al., 2001). Although, size differences may be influenced by ecological characteristics of each region, fishing gear and selectivity and/or exploitation levels may also cause important effects on body size (Claro et al., 2001; Frédou and Ferreira, 2005).

Table 1
Comparison of growth parameters (L_∞, K), growth performance index (phi-prime φ') and mortality rates for *L. synagris* from different areas. All rates are year^{-1}. TL = total length, FL = fork length. O = otoliths, S = scales, E = ELEFAN, W = Wetherall method and EM = Empirical Methods. N.A = not available, NE = northeast, CC = central coast and AB = Abrolhos bank.

Location	*Aging Method*	*L_∞ (mm)*	*K*	*Phi-Prime (φ')*	*Longevity*	*Z*	*M*	*Study*
Puerto Rico	E, W	490–516 (FL)	0.23	2.74–2.79	N.A	1.65	0.53	Acosta and Appeldoorn 1992
Northern Gulf of Mexico	O	469.5(TL)	0.194	2.63	17	0.375	0.228	Johnson et al., 1995
Florida	O	501 (TL)	0.134	2.53	10	0.678	0.272	Manooch and Mason, 1984
Trinidad	O	708–603 (TL)	0.22–0.2	3.04–2.86	7	N.A	0.47–0.42	Manickchand-Dass, 1987
Bermuda	O	331 (FL)	0.395	2.64	19	N.A	N.A	Luckhurst et al. (2000)
Cuba	O, S	516 (TL)	0.2	2.73	6	N.A	0.439	Claro and Reshetnikov (1981)
Jamaica	E, W	320–538 (FL)	0.25–0.076	2.41–2.34	14	N.A	N.A	Aiken (2001)
Cuba	O,S	380 (TL)	0.35	2.7	6	N.A	0.739	Rodriguez-Pino (1962)
Brazil NE	O	505 (TL)	0.23	2.77	7	N.A	N.A	Alegria and Menezes (1970)
Brazil CC	EM	592 (TL)	0.188	2.82	N.A	N.A	0.46	Klippel et al. (2005)
Brazil CC	O	312 (FL)	0.17	2.22	17	N.A	N.A	Leite Jr. et al. (2005)
Brazil AB	O	560 (TL)	0.22	2.84	18	0.58	0.28–0.36	This study

Fig. 5. von Bertalanffy growth curve (VBGC) fitted to weight-at-age (dashed line, $r^2 = 0.77$), and mean annual weight increment (g) (solid line) for the Abrolhos' *L. synagris* sample (n = 303).

Values of b recorded here indicate allometric growth, as confidence limits do not include 3, suggest that lane snapper specimens must increase in some other dimension, whether breadth or thickness, in greater proportion than they increase in length (Froese, 2006) and agree with b values range found for lane snapper in previous observations from other Atlantic areas (2.64–2.97; Froese and Pauly, 2016).

Validation of otolith increment formation is an essential issue in fish age determination. Although different methods may be used (e.g. tetracycline marking, mark-recapture, bomb radiocarbon and radiometry), the most commonly used method for lutjanids is MIA (Campana, 2001; Piddocke et al., 2015), as it is a reliable and yet relatively cheap and logistically simple technique (Campana, 2001). However, if not applied rigorously, MIA can be susceptible to bias and misinterpretation. Here, we tried to diminish bias in MIA by using age 0 and 1 individuals to beacon first annulus formation (rings were measured and served as a proxy of first annulus), as well as by including only clearly readable sections (categories 3–5). In addition, the edge packing effect observed for older specimens was avoided by selecting ages 3–9. However, separate validation for each age was not possible due sample size constrains. The edge analyses, in which age effects do not apply, displayed similar results, indicating that age effects were low or absent. In fact, performing MIA and edge analysis together is highly recommended (Piddocke et al., 2015). Therefore, we conclude that formation of annuli in Abrolhos' *L. synagris* population occurs annually in winter-spring, just before its spawning season (Freitas et al., 2014)

The growth parameters (L_∞, K) presented here agreed well with those from previous studies on *L. synagris* in other Atlantic Ocean localities (Table 1). The theoretical maximum length in the Abrolhos was slightly larger than records from the North Hemisphere (Acosta and Appleldoorn, 1992; Luckhurst et al., 2000; Aiken, 2001), except for Trinidad (Manickchand-Dass, 1987). Our estimate of the growth coefficient K was intermediate to those of other studies, with smaller values recorded in Florida (Manooch and Mason, 1984) and the highest in Bermuda (Luckhurst et al., 2000). Estimated longevities for Cuba, Trinidad, Florida and NE Brazil were remarkably lower (Alegria and Menezes, 1970; Claro and Reshetnikov, 1981; Manooch and Mason, 1984; Manickchand-Dass, 1987) than the 18 years longevity that we recorded in Abrolhos. The highest longevity for this species was recorded in Bermuda (Luckhurst et al., 2000). For this study, the growth performance index (φ') indicates a lower growth in the Northwestern Atlantic, and Caribbean Sea (except for Trinidad), when compared to the Abrolhos region. Although, higher growth (φ') was observed for Abrolhos, statistical test result showed that there is no significant difference between this study and previous studies' findings (Table 1).

Despite geographic variations in growth parameters, it is unclear whether these regional differences reflect fishing pressure or are associated to other factors that can control the size structure of local populations, such as water temperature, food availability and assimilative capabilities (Weatherley, 1976). Methodological differences, such as ring readings using different hard structures (otoliths, scales or urohyal bones), as well as length-frequency estimation methods, may limit comparisons between studies. Sampling from different types of fishing gears might also lead to different results for growth parameters (Campana, 2001).

The population of *L. synagris* in Abrolhos seem to attain maturity slightly later ($A_{50} = 2.8$ years) than some North Atlantic populations, such as recorded in Trinidad ($A_{50} = 1$-2 years) and in Cuba and Jamaica, where the lane snapper attains maturity in the first year of life (Thompson and Munro, 1983; Reshetnikov and Claro, 1975; Manickchand-Dass, 1987). However, geographic variability can be considerable, as a study in Jamaica reported similar higher age at maturity (A_{50} = 2–3 years) (Aiken, 2001).

Full recruitment of *L. synagris* to the Abrolhos' artisanal fishery was at age 3. Our estimate of total mortality ($Z = 0.58$ year^{-1}) was smaller than those for populations in Puerto Rico (Acosta and Appeldoorn, 1992) and Florida (Manooch and Mason, 1984) (Z = 1.65 and

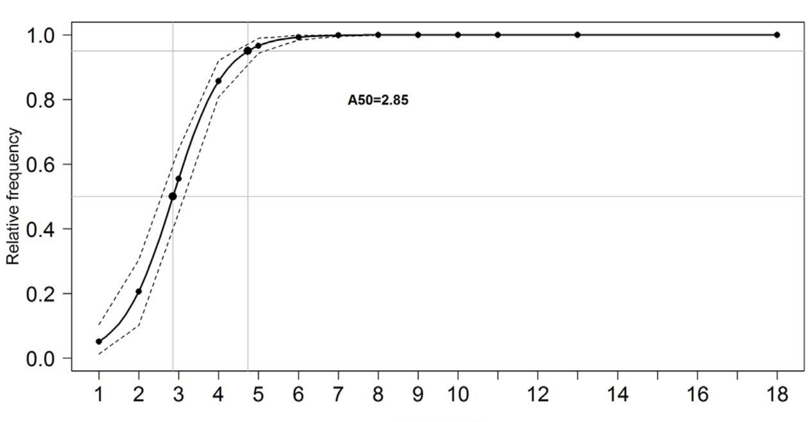

Fig. 6. Proportion of mature individuals at age for lane snappers *Lutjanus synagris* landed in the Abrolhos region between May 2005 and June 2007. Dashed lines indicate age at which 50% (A_{50}) and 95% (A_{100}) of individuals were mature (n = 296).

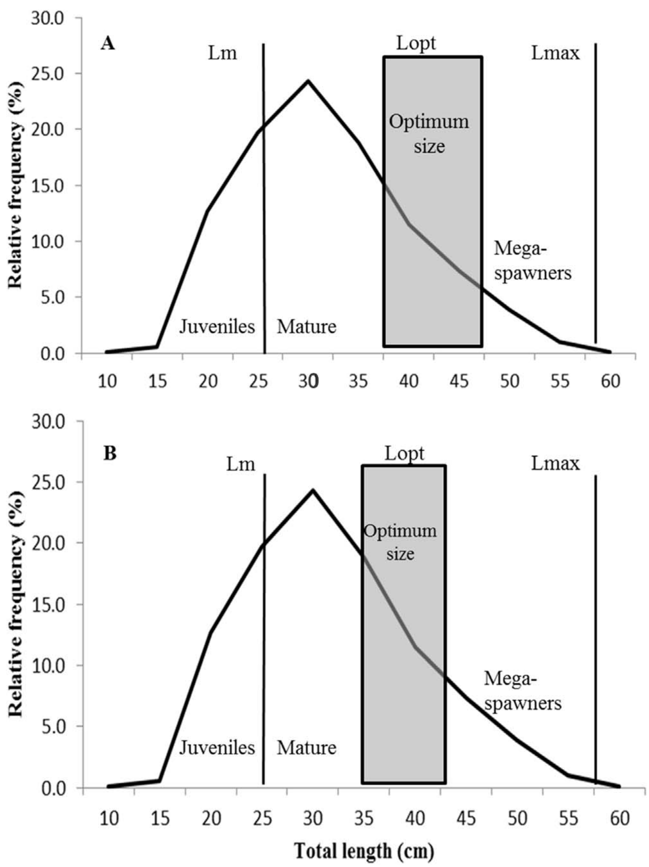

Fig. 7. Length–frequency of lane snappers *L. synagris* in landings between 2005 and 2007 in the Abrolhos region, and optimum length (*Lopt*) based on Hewitt and Hoenig (A) and Jensen (B) estimates for natural mortality (*M*). *Lm* indicates length at first maturity, *Lopt* indicates the length range where optimum yield could be obtained, and *Lmax* is the maximum recorded size.

0.67 $year^{-1}$, respectively), and larger than estimates for the Gulf of Mexico (Johnson et al., 1995) (Z = 0.37 $year^{-1}$) (Table 1). Because the Abrolhos' population is fully recruited at age 3, mean first maturity occurs earlier at 2.8 years, most landed individuals have already spawned once, which is a good indicator of stock replenishment. However, caution is needed, as the age of recruitment to the fishery is very similar to the age at first maturity, meaning that additional effort may rapidly affect population replenishment (Froese, 2004).

The three methods applied here to estimate natural mortality (M) produced relatively heterogeneous results, with M rates varying from 0.17 to 0.36 $year^{-1}$. Yet, as the Ault et al. (1998) methods generated Lopt values outside the range observed for HCY, we disregarded this result and consider that the plausible values of M vary from 0.28 to 0.36 for *L. synagris* in the study area.

Assessing stock status to subsidize management decisions depends on information availability. Ideally, traditional stock assessment models lies on large amounts of data such as total catch, relative abundance and effort (CPUE), biological (growth, natural mortality) and fishery selectivity data (King, 1995). Unfortunately, most fished stocks lack stock assessments and comprise the so-called data-poor fisheries (Cope and Punt, 2009), small-scale tropical fisheries in Brazil. Alternatively, simple metrics based on length compositions in the catches, such as the three indicators presented herein, can be reliably used to monitor population status relative to exploitation, avoiding growth and recruitment overfishing (Froese, 2004). Therefore, the metrics that we provide are useful reference points for future comparisons and decision making, and may also be used in more precise tock assessments when resources eventually become available.

Length distribution combined with biological parameters provided two potential scenarios for the *L. synagris* stock and its fishery in Abrolhos, assessed here by three simple indicators. According to Froese (2004), in order to maintain healthy spawning stocks, 100% of the fish catch should be from mature fish (Indicator I). However, for both scenarios examined here, only 70% of the catch corresponded to mature individuals. This means that roughly one third of the catch is comprised by juveniles that were not able to spawn at least once. Also, for both scenarios, 64%–58% of the Abrolhos' lane snapper landings encompass mature and optimum fish length (Indicator II). Ideally, the entire catch should satisfy these conditions (Froese, 2004). For the studied population, fish > 24 and < 44 cm TL should represent 100% of the catches. Finally, and also for the two scenarios, 6–12% of the lane snappers captured in Abrolhos comprise mega-spawners (Indicator III). According to Froese (2004), for regions where there is no upper size limit for captures, the catch reflects the age and size structure of the stock, with 30–40% of mega-spawners representing a desirable healthy age structure.

Conversely, in areas where upper size limit exists, a strategy with 0% mega-spawners in the catch is recommended (Froese, 2004). Therefore, Indicator III, suggests that the Abrolhos' *L. synagris* population displays an unhealthy age structure, already lacking mega-spawners, featuring low resilience against random events and fishing pressure (Craig, 1985; Longhurst, 2002; Froese, 2004). Currently, there is no upper size limit for capturing lane snappers in Abrolhos, and implementing this relatively simple measure shall promote stock recovery and improve the sustainability of its fishery.

The lane snapper is one of the main fish species targeted in the Abrolhos region, and fishing pressure towards its stocks is expected to increase due to the urban and industrial escalation in the region (Freitas et al., 2011; Moura et al., 2013). Our results, reveal that one third of the fish that are currently being caught has not achieved maturity, and landings lack mega-spawners. In addition, the indicators presented herein are aligned with the results from a stock assessment covering the broader eastern Brazilian coast (Klippel et al., 2005b), which categorized the lane snapper stock to be under a moderate overexploitation status. Therefore, we recommend that management of the Abrolhos' lane snapper fisheries is initiated soon, in order to avoid the decline of this important resource in a near future.

A 'slot limit' for *L. synagris* catches may help to protect immature and older larger individuals with the greatest reproductive potential (Coleman et al., 1999; Froese, 2004; Babcock et al., 2013), and would restrict fishing specimens < 24 cm TL (immature individuals that did not spawn at least once) and > 50 cm TL (mega-spawners with 10 or more years old). We acknowledge that slot limits are hard to implement in commercial fisheries, particularly those involving traditional communities that depend on catches below L_{50}, such as those on the Abrolhos Bank (Freitas et al., 2014), akin to most inshore fisheries along the tropical Brazilian coast. On the other hand, in spite of such management challenge, implementation of a slot limit may preventing a future population collapse, which would take at least 10 years (based on estimated generation length) for recovering with no fishing. The presence of two Extractive Reserves in the Abrolhos region, where fishers are more organized and legally count on Deliberative Councils and Management Plans, shall be the most obvious starting point to address such more complex management frameworks. Ultimately, successful implementation of fishing management depends on community agreement which would lead to adherence to rules (Motta et al., 2016; Moura et al., 2013; Busilacchi et al., 2012) under weak top-down enforcement, even if results are expected to materialize only in longer time frames. Nonetheless, considering that data results provided here were registered about 10 years ago and fisheries pressure are likely to increase over time, monitoring programs or at least an update is strongly recommended to assess current scenarios for lane snapper at the Abrolhos Bank.";

Acknowledgements

We thank Juliane Cebola, Guilherme Dutra, Danilo Araújo, Eduardo Camargo and Danieli Nobre for field support, Sergio Rezende for his help in the field, advice and criticism. We are grateful to the fishers from the Extractive Reserves of Corumbau and Cassurubá, and from the Colônias dos Pescadores of Prado, Alcobaça, Caravelas and Nova Viçosa for their continued support to our fieldwork. Conservation International provided logistic support and UESC and CEPENE/ICMBIO provided laboratory space and research facilities. Financial support was provided by Conservation International, Conservation Leadership Programme (Project F024801), FUNBIO (Pró-Arribada), CNPq/PELD Abrolhos (www.abrolhos.org) and CAPES (grant 8938/11-3 to MOF). We also acknowledge individual FAPESB (AA and MOF), CNPq (BPF, RBFF and RLM) and FAPERJ (RLM) grants.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.fishres.2017.06.004.

References

Acosta, A., Appeldoorn, R.S., 1992. Estimation of growth, mortality and yield per recruit for *Lutjanus synagris* (Linnaeus) in Puerto Rico. Bull. Mar. Sci. 50, 282–291.
Aiken, K.A., 2001. Aspects of reproduction, age and growth of the Lane Snapper, Lutjanus synagris (Linnaeus, 1785), in Jamaican coastal waters. Proceedings of the Gulf and Caribbean Fisheries Institute 52, 116–134.
Alegria, J., Menezes, F. de, 1970. Edad y crecimento del ariaco *Lutjanus synagris* en el Nordeste de Brasil. Arq. Cien. Mar. 10, 65–68.
Allen, G.R., 1985. Snappers of the World. An Annotated and Illustrated Catalogue of Lutjanid Species Known to Date. FAO, Roma (208 p.).
Arreguín-Sánchez, F., Manickchand-Heileman, S., 1998. The trophic role of lutjanid fish and impacts of their fisheries in two ecosystems in the Gulf of Mexico. J. Fish. Biol. 53 (Suppl. A), 143–153.
Ault, J.S., Bohnsack, J.A., Meester, G.A., 1998. A retrospective (1979–1996) multi-species assessment of coral reef fish stocks in the Florida Keys. Fish Bull. NOAA 96, 395–414.
Babcock, E.A., Coleman, R., Karnauskas, M., Gibson, J., 2013. Length-based indicators of fishery and ecosystem status: glover's Reef Marine Reserve. Belize. Fish Res. 147, 434–445.
Beamish, R.J., Fournier, D.A., 1981. A method for comparing the precision of a set of age determinations. Can. J. Fish Aquat. Sci. 38, 982–983.
Beverton, R.J.H., Holt, S.J., 1957. On the Dynamics of Exploited Fish Populations Fishery Investigations Series II. Ministry of Agriculture, Fisheries and Food, London, pp. 533p..
Beverton, R.J.H., 1992. Patterns of reproductive strategy parameters in some marine teleost fishes. J. Fish. Biol. 41, 137–160.
Burton, M.L., 2002. Age, growth and mortality of mutton snapper, Lutjanus analis, from the east coast of Florida, with a brief discussion of management implications. Fish. Res. 59, 31–41.
Busilacchi, S., Williams, A.J., Russ, G.R., Begg, G.A., 2012. Complexity of applying minimum legal sizes (MLS) of retention in an indigenous coral reef fishery. Fish. Manag. Ecol. 19, 233–244.
Campana, S.E., 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. J. Fish Biol. 59, 197–242.
Cervigón, F., Fisher, W., 1979. Infopesca. Catalogo de especies marinas de interés económico actual o potencial para América Latina. Parte 1. FAO/UNDP, Atlántico Centro y Sur Occidental. Rome (Sic/79.).
Claro, R., Reshetnikov, Y.S., 1981. Ecologia y ciclo de vida de la biajaiba, Lutjanus synagris (Linnaeus), en la plataforma Cubana. 1. Formacion marcas de crecimiento en sus estructuras. Inf. Cient. Tec. Inst. Oceanol. Acad. Cienc. Cuba Oceanol. 174, 1–28.
Claro, R., Lindeman, K.C., Parenti, L.R., 2001. Ecology of the Marine Fishes of Cuba. Smithsonian Institution Press, Washington and London (253p.).
Claro, R., de Mitcheson, Y. Sadovy, Lindeman, K.C., García-Cagide, A., 2009. Historical analysis of commercial Cuban fishing effort and the effects of management interventions on important reef fishes: 1960–2005. Fish. Res. 99 (1), 7–16.
Coleman, F.C., Koenig, C.C., Eklund, A.M., Grimes, C.B., 1999. Management and conservation of temperate reef fishes in the grouper-snapper complex of the southeastern United States. Am. Fish. Soc. Symp. 23, 242–244.
Cope, J.M., Punt, A.E., 2009. Length-Based reference points for data-limited situations: applications and restrictions. Mar. Coastal Fish. 1, 169–186. http://dx.doi.org/10.1577/C08-025.1.
Costa, P.A.S., Braga, A.C., Rocha, L.O.F., 2003. Reef fisheries in porto seguro, eastern brazilian coast. Fish. Res. 60, 577–583.
Craig, J.F., 1985. Aging in fish. Can. J. Zool. 63, 1–8.
Ferreira, B.P., Russ, G.R., 1994. Age validation and estimation of growth rate of the coral trout, Plectropomus leopardus, (Lacepede 1802), from Lizard Island, Northern Great Barrier Reef. Fish. Bull. 92, 46–57.
Frédou, T., Ferreira, B.P., 2005. Bathymetric trends of northeastern brazilian snappers. Braz. Arch. Biol. Technol. 48, 787–800.
Frédou, T., Ferreira, B.P., Letourneur, Y., 2009a. Assessing the stocks of the primary snappers caught in Northeastern Brazilian reef systems. 1: Traditional modelling approaches. Fish. Res. 99, 90–96.
Frédou, T., Ferreira, B.P., Letourneur, Y., 2009b. Assessing the stocks of the primary snappers caught in Northeastern Brazilian reef systems. 2 − A multi-fleet age-structured approach. Fish. Res. 99, 97–105.
Francini-Filho, R.B., Moura, R.L., 2008. Dynamics of fish assemblages on coral reefs subjected to different management regimes in the Abrolhos Bank, eastern Brazil. Aquat. Conserv. 18, 1166–1179.
Francini-Filho, R.B., Coni, E.O., Meirelles, P.M., Amado-Filho, G.M., Thompson, F.L., Pereira-Filho, G.H., Bastos, A.C., Abrantes, D.P., Ferreira, C.M., Gibran, F.Z., Güth, A.Z., 2013. Dynamics of coral reef benthic assemblages of the Abrolhos Bank, eastern Brazil: inferences on natural and anthropogenic drivers. PLoS One 8 (1), e54260. http://dx.doi.org/10.1371/journal.pone.0054260.
Freitas, M.O., Moura, R.L., Francini-Filho, R.B., Minte-Vera, C.V., 2011. Spawning patterns of commercially important reef fishes (Lutjanidae and Serranidae) in the tropical Western South Atlantic. Sci. Mar. 75, 135–146.
Freitas, M.O., Rocha, G.R.A., Chaves, P.T.C., Moura, R.L., 2014. Reproductive biology of the lane snapper *Lutjanus synagris*, and recommendations for its management on the Abrolhos Shelf. Brazil. J. Mar. Biol. Assoc. U.K. 94, 1711–1720.
FishBase. World Wide Web Electronic Publication R. Froese , D. Pauly , 2016; (Version 08. 2013). Available at: http://www.fishbase.org (Accessed 03 January 2016)
Froese, R., 2004. Keep it simple: three indicators to deal with overfishing. Fish Fish. 5, 86–91.
Froese, R., 2006. Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. J. Appl. Ichthyol. 22 (4), 241–253.
Gómez, G., Guzmán, R., Chacón, R., Márquez, M., 1999. Talla de madurez y fecundidad del pargo guanapo, Lutjanus synagris en el Golfo de Paria Edo. Sucre, Venezuela.D urante el período 1998. Acta Cien. Venez. 50, 375.
Gómez, G., Guzmán, R., Chacón, R., 2001. Parámetros reproductivos y poblacionales de Lutjanus synagris en el Golfo de Paria. Venezuela Zootecnia Trop. 19, 335–357.
Haddon, M., 2001. Modelling and Quantitative Methods in Fisheries. Chapman and Hall, London (406p.).
Hewitt, D.A., Hoenig, J.M., 2005. Comparison of two approaches for estimating natural mortality based on longevity. Fish. Bull. NOAA 103, 433–437.
IUCN Standards and Petitions Subcommittee, 2014. Guidelines for Using the IUCN Red List Categories and Criteria. V 11. Prepared by the Standards and Petitions Subcommitte (Downloaded from www.iucnredlist.org/documents/RedListGuidelines.pdf).
Jensen, A.L., 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Can. J. Fish. Aquat. Sci. 53, 820–822.
Johnson, A.G., Collins, L.A., Dahl, J., Baker Jr., M.S., 1995. Age, growth, and mortality of lane snapper from the northern Gulf of Mexico. Proc. Ann. Conf. Southeast Assoc. Fish. Wildl. Agen. 49, 178–186.
King, M., 1995. Fisheries Biology, Assessment and Management. Fishing News Books, Oxford (341pp.).
Klippel, S., Martins, A.S., Olavo, G., Costa, P.A.S., Peres, M.B., 2005a. Estimativas de desembarque da pesca de linha na costa central do Brasil (estados do Espírito Santo e Bahia) para um ano padrão (1997–2000). In: Costa, P.A.S., Martins, A.S., Olavo, G. (Eds.), Pesca e potenciais de exploração de recursos vivos na região central da Zona Econômica Exclusiva brasileira. Serie livros n.13. Rio de Janeiro Museu Nacional, pp. 71–82.
Klippel, S., Martins, A.S., Olavo, G., Costa, P.A.S., Peres, M.B., 2005b. Avaliação dos estoques de lutjanídeos da costa central do Brasil: análise de coortes e modelo preditivo de Thompson e Bell para comprimentos. In: Costa, P.A.S., Martins, A.S., Olavo, G. (Eds.), Pesca e potenciais de exploração de recursos vivos na região central da Zona Econômica Exclusiva brasileira. Serie livros n.13. Rio de Janeiro Museu Nacional, pp. 83–98.
Lai, H.L., Gallucci, V.F., Gunderson, D.R., Donnelly, R.F., 1996. Age determination in fisheries: methods and applications to stock assessment. In: Gallucci, V.F., Saila, S.B., Gustafson, D.J., Rothschild, B.J. (Eds.), Stock Assessment Quantitative Methods and Applications for Small-scale Fisheries. Lewis Publishers, Boca Raton, Florida, pp. 82–170 (527p.).
Le Cren, E.D., 1951. The length-weight relationships and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). J. Anim. Ecol. 20, 201–219. http://dx.doi.org/10.2307/1540.
Leite Jr., N.O., Martins, A.S., Araújo, J.N., 2005. Idade e crescimento de peixes recifais na região central da Zona Econômica Exclusiva entre Salvador-BA e o Cabo de São Tomé-RJ (13°S a 22°S). In: Costa, P.A.S., Martins, A.S., Olavo, G. (Eds.), Pesca e potenciais de exploração de recursos vivos na região central da zona econômica exclusiva brasileira. Série Livros − Documentos REVIZEE − Score Central. Museu Nacional do Rio de Janeiro, Rio de Janeiro, pp. 203–216 (248p.).
K. Lindeman , W. Anderson , K.E. Carpenter , R. Claro , J. Cowan , B. Padovani-Ferreira , L.A. Rocha , G. Sedberry , M. Zapp-Sluis . Lutjanus Synagris . The IUCN Red List of Threatened Species 2016: e.T194344A2317059 2016; http://dx.doi.org/10.2305/IUCN.UK.2016- 1. RLTS.T194344A2317059. en
Longhurst, A., 2002. Murphy's law revisited: longevity as a factor in recruitment to fish populations. Fish. Res. 56, 125–131.
Luckhurst, B.E., Dean, M.J., Reichert, M., 2000. Age, growth and reproduction of the lane snapper *Lutjanus synagris* (Pisces: lutjanidae) at Bermuda. Mar. Ecol. Prog. Ser. 203, 255–261.
Manickchand-Dass, S., 1987. Reproduction, age and growth of the lane snapper *Lutjanus synagris* (Linnaeus), in Trinidad, West Indies. Bull. Mar. Sci. 40 (1), 22–28.
Manooch, C.S., Mason, D.L., 1984. Age, growth and mortality of lane snapper from

southern Florida. NE Gulf. Sci. 7, 109–115.
Motta, F.S., Mendonça, J.T., Moro, P.S., 2016. Collaborative assessment of recreational fishing in a subtropical estuarine system: a case study with fishing guides from south-eastern Brazil. Fish. Manag. Ecol. http://dx.doi.org/10.1111/fme.12172.
Moura, R.L., Francini-Filho, R.B., 2006. Reef and shore fishes of the Abrolhos Region, Brazil. In: Dutra, G.F., Allen, D.R., Werner, T., McKenna, A.S. (Eds.), A Rapid Marine Biodiversity Assessment of the Abrolhos Bank, Bahia, Brazil. Conservation International, Washington, pp. 40–55.
Moura, R.L., Lindeman, K.C., 2007. A new species of snapper (Perciformes Lutjanidae) from Brazil, with comments on distribution of *Lutjanus griseus* and *L. apodus*. Zootaxa 1422, 31–43.
Moura, R.L., Secchin, N.A., Amado-Filho, G.M., Francini-Filho, R.B., Freitas, M.O., Minte-Vera, C.V., Teixeira, J.B., Thompson, F.L., Dutra, G.F., Sumida, P.Y.G., Guth, A.Z., Lopes, R.M., Bastos, A.C., 2013. Spatial patterns of benthic megahabitats and conservation planning in the Abrolhos Bank. Cont. Shelf. Res. 70, 109–117. http://dx.doi.org/10.1016/j.csr.2013.04.036.
G. Nowara , J. Verdouw , J. Hutchins . Otolith preparation and ageing of Patagonian toothfish, Dissostichus eleginoides, at the Australian Antarctic Division D.C. Welsford , G.B. Nowara , S.G. Candy , J.P. McKinlay , J. Verdouw , J. Hutchins , Evaluating Gear and Season Specific Age-length Keys to Improve the Precision of Stock Assessments for Patagonian Toothfish at Heard Island and McDonald Islands. Final Report. FRDC Project 2008/046 2009
Pauly, D., Munro, J.L., 1984. Once more on growth comparison in fish and invertebrates. Fishbyte Newsl. Network Trop. Fish. Scientists 2 (1), 21 21.
Pauly, D., Watson, R., Alder, J., 2005. Global trends in world fisheries: impacts on Marine ecosystems and food security. Philos. Trans. R. Soc. Lond. B 360, 5–12.
Pauly, D., 2009. Beyond duplicity and ignorance in global fisheries. Sci. Mar. 73 (2), 215–224.
Piddocke, T.P., Butler, G.L., Butcher, P.A., Purcell, S.W., Bucher, D.J., Christidis, L., 2015. Age validation in the Lutjanidae: a review. Fish. Res. 167, 48–63.
Polovina, J.J., Ralston, S., 1987. Tropical Snappers and Groupers: Biology and Fisheries Management Boulder. Westview Press, USA, pp. 659.
Rezende, S.M., Ferreira, B.P., Frédou, T., 2003. A pesca de lutjanídeos no nordeste do Brasil: histórico das pescarias, características das espécies e relevância para o manejo. Bol. Tec. Cient. CEPENE 11, 257–270.
Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191, 382.
Robson, D.S., Chapman, D.G., 1961. Catch curves and mortality rates. Trans. Am. Fish. Soc. 90, 181–189.
Rodriguez-Pino, Z., 1962. Estudios estadisticos y biologicos sobre la biajaiba (Lutjanus synagris). Notas Pesqueras Havana Cuba Nota 2, 1–16.
SPSS, Inc., 1999. SPSS Base 5.0 for Windows User's Guide. SPSS, Chicago.
Secor, D.H., Dean, J.M., Laban, E.H., 1991. Manual for Otolith Removal and Preparation for Microstructural Examination Columbia. Electric Power Research Institute and Belle W. Baruch Institute for Marine Biology and Coastal Research (85 p.).
Sparre, P., 1987. A method for the estimation of growth, mortality and gear selection/recruitment parameters from length frequency samples weighted by catch per effort. Pauly, D., Morgan, G.R. (Eds.), Length-based Methods in Fisheries Research. ICLARM Conference Proceedings, vol. 13, 75–102.
Thompson, R., Munro, J.L., 1983. The biology, ecology and bionomics of the snappers Lutjanidae. ICLARM Stud. Rev. 7, 94–109.
Weatherley, A.H., 1976. Factors affecting maximization of fish growth. J. Fish. Res. Board Can. 33, 1046–1058.
Villegas-Hernández, H., Munõz, M., Lloret, J., 2015. Reproductive traits of the pompano, Trachinotus ovatus (Linnaeus, 1758), in the north-western Mediterranean. J. Mar. Biol. Assoc. U.K. 96, 1053–1063. http://dx.doi.org/10.1017/s0025315415001265.