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Characteristics of population dynamics of *Lutjanus guttatus* (Pisces: Lutjanidae) in Bufadero Bay, Michoacán, Mexico

Características de la dinámica poblacional de *Lutjanus guttatus* (Pisces: Lutjanidae) en Bahía Bufadero, Michoacán, México

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ABSTRACT

Analysis of scales of *Lutjanus guttatus* (Steindachner, 1869) allowed the identification of three growth rings. Similar data were obtained with kernel density method. Values of the von Bertalanffy's growth equation are: L_∞ = 96.60 cm, W_∞ = 7,508 g, K = 0.22 years^{-1} and t_0 = –0.10 years. Maximum values of the condition factor occur during February and June and were preceded by two months of high values of the gastric repletion index. Maximum reproductive period was during April and August. Recruitment periods were from November to January and April to June. The recruitment length is 16 cm. The highest values of the hepatosomatic index are during December to June and showed an inversely proportional relation to the gonadosomatic index. First sexual maturity length is 30.63 cm and its longevity of 13.5 years. Forty one percent of *L. guttatus* individuals captured in Bufadero Bay are sexually immature, therefore we suggest a minimum capture size of 45 cm (age 2.5 years) and a closed season from August to September.

Key words: Life cycle parameters, von Bertalanffy's growth equation, longevity, recruitment, fishery.

RESUMEN

El análisis de las escamas de *Lutjanus guttatus* (Steindachner, 1869) permitió la identificación de tres anillos de crecimiento. Se observaron datos similares por medio del análisis de los estimadores de densidad por kernel. Los valores de la ecuación de crecimiento de von Bertalanffy calculados por el método no lineal simple son: L_∞ = 96.60 cm, W_∞ = 7,508 g, K = 0.22 años^{-1} y t_0 = –0.10 años. Los máximos valores del factor de condición ocurren durante febrero y junio y son precedidos en un lapso de dos meses por los mayores valores de los índices de repleción gástrica. Los períodos de máxima reproducción se presentaron durante abril y agosto. Los períodos de reclutamiento comprenden de noviembre a enero y de abril a junio. La talla de reclutamiento es de 16 cm. Los valores mayores del índice hepatosomático se presentaron durante diciembre y junio y mostraron una relación inversamente proporcional a los valores del índice gonadosomático. La talla de primera madurez sexual es de 30.63 cm y la longevidad de 13.5 años. El 41.10 % de la pesca comercial en Bahía Bufadero es de organismos

sexualmente inmaduros, por lo que se propone como talla mínima de captura una longitud de 45 cm (2.5 años de edad) y un período de veda de agosto a septiembre.

Palabras clave: Parámetros poblacionales, ecuación de von Bertalanffy, longevidad, reclutamiento, pesquería.

INTRODUCTION

Age determination is one of the most important objectives in the study of fish population dynamics, and from this information it is possible to get to know the population structure by age groups, longevity, recruitment age, sexual maturity and captures. Also, the determination of age allows studying the growth or the biomass increase of the population and the study of mortality or diminution of the biomass.

The method employed more frequently for age determination is growth rings identification in hard structures as: scales, otoliths, vertebrae and spines. The formation of these rings or marks happens periodically, fast growth rings in the period of higher food availability (generally in spring and summer) and slow growth rings in the periods with decrease of food availability (generally autumn and winter) (Gallardo-Cabello *et al*., 2007). These patterns of growth rings on scales may change because of the oscillation of physical and chemical parameters of oceanic currents, as happens in ENSO years. Fishes inhabiting tropical regions have less marked changes in food availability determined by seasonal periodicity than in cold regions; in these areas rainy and dry periods determine these oscillations in food quality and quantity, which will produce fast growth rings or slow growth rings in hard structures, respectively.

The diminution of growth rates of fishes happens when organisms reach sexual maturation (first to third year of age) and most of the energy goes to the formation of sexual products. It is in this period that the weight growth starts because of the storage of the fatty acids in the liver. These hepatic reserves decrease after spawning period (Espino-Barr *et al*., 2008).

Studies on age and growth of *L. guttatus* (Steindachner, 1869) have been carried out by Espino-Barr (1996), who found 14 age classes from scales and an equation $Ls = 63.0 [1 - e^{-0.1(t+0.1)}]$ and by Amezcua *et al*. (2006) who found 11 classes in the otoliths and its equation $Lt = 66.19[1 - e^{-0.13(t-0.23)}]$.

On this species there are important papers on reproduction analysis: Grimes (1987), Rojas (1997), Arellano *et al.* (2001), Rojas-Herrera (2001), Piñón (2003), Santamaría *et al.* (2003a) and Chiappa-Carrara *et al*. (2004). Studies on feeding and fat reserves indexes have been made by Sheaves (1995), Arellano *et al*. (2001) and Piñón (2003). Fishing assessment studies have been carried out by Rojo *et al*. (1999), Cruz-Romero *et al*. (2000), Santamaría *et al*. (2003b) and Chiappa-Carrara *et al.* (2004).

The spotted rose snapper, *Lutjanus guttatus* has a geographical distribution from the Gulf of California to Ecuador (Allen and Robertson, 1994; Fischer *et al*., 1995; Castro-Aguirre *et al*., 1999; Amezcua-Linares, 2008); it has a great commercial importance and is considered a first class species that reaches in the coasts of Jalisco, Colima, Michoacán, Oaxaca, and Guerrero, a price of $40.00 to $50.00 mexican pesos ($3.00 to $4.00 USD) on the beach and $80.00 to $100.00 mexican pesos ($6.00 to $8.00 USD) at the market (prices during 2008). Of the snapper group, *L. guttatus* is only overcome by *L. peru*, that reaches a higher commercial value (pers. com. Alejandro Trujillo, president of the Coop. Puerto Viejo). This study gives original information on age, growth, longevity, spawning periods, first sexual maturity length, recruitment periods and length, and condition factor, gastric repletion, gonadosomatic and hepatosomatic indexes of *L. guttatus* in Bufadero Bay, Michoacán, that will help design basic norms for the administration and regulation of fishing for this species, whose catches are not correctly registered.

MATERIALS AND METHODS

During 5 days in every other month from August 2005 to June 2006, samplings of 1,579 individuals from the commercial catch were taken in Bufadero Bay, Michoacán (18º04'24"N and 102º45'18" W). Of each individual total (Lt) and standard length (Ls), height (H), total (W) and eviscerated (We) weight were measured. Liver, gonad and stomach were weighed *in situ*, and preserved in 10% formaldehyde and 90% sea water and taken to the lab. Sex of 930 individuals was determined; the other 649 were immature. For age study scales were obtained from 984 individuals. The sample size was calculated with the formula described by Daniel (1991).

Around 10 scales were taken from the area under the left pectoral fin, below the lateral line (Ehrhardt, 1981; Holden & Raitt 1975, Ruiz-Durá *et al*., 1970) and stored in dry labeled envelopes. Following the method described by Holden and Raitt (1975), scales were washed to clean them of any tissue stuck to them. Later four scales were put in between two slides, sealing them with adhesive tape and labeled. Reading of the scales was carried out with the help of a transparency projector Kodak Ektagraphic with a 127 mm lens (that increases the size of the scale 13.4 times), and measured from the focus to the farthest border as its length, and as the width, between the longest lateral borders. Lines or rings of the scales were observed independently by two different people and the results compared.

Determination of the marginal increment was carried out according to Lai and Liu (1979) in order to determine the date in which the mark is formed and to validate its periodicity. In order to compare and validate the observations of growth rings on scales,

indirect methods were used: Petersen (1892), Bhattacharya (1967), and kernel density method (KDE), to determine the components of polymodal curves with monthly and annual periodicity (Salgado-Ugarte, 1992 y 2002).

The constants L_∞, K and t_0 of von Bertalanffy´s (1938) (vB) equation were obtained with Ford´s (1933), Walford´s (1946), Gulland´s method (1964), Beverton and Holt (1959) and two types of regression: simple non linear *vB* equation and weighted non linear *vB* equation to find the best fit (Salgado-Ugarte *et al*., 2005). Weight-length relationship was calculated with the function $W = a * L^b$ (Mendenhall, 1987; Zar, 1996). The weight for every age was obtained with the growth data in length and the weight-length function; and weight growth by substituting *Lt* and L_∞ for *W* and W_∞, in von Bertalanffy´s (1938) equation.

Monthly values of the condition factor (CF), equivalent to the "a" parameter of weight-length equation, were obtained for total and eviscerated weight (Safran, 1992), and compared with the confidence interval, to explain changes in the gonad and liver throughout the year. Gastric repletion state was classified according to Gallardo-Cabello and Gual-Frau (1984) as: GRI = number of full stomach/total number of stomach. The gonadosomatic index (GSI) was determined with the equation described by Rodríguez-Gutiérrez (1992): GSI = *W*g/*W**100, where *W*g is gonad weight and *W*t is the total weight of the individual. The hepatosomatic index (HSI) was calculated according to Rodríguez-Gutiérrez (1992) as HSI = WI/W *100, where WI is the liver weight and Wt is the total weight of the individual. Two condition factors were used: Clark's (1928, with eviscerated weight) and Fulton's (1902, with total weight). Gonadic maturity index was determined *in situ*, according to Nikolsky (1963). Size of first maturity was obtained by the logistic method (Salgado-Ugarte *et al*., 2005), which fits the sexual mature individuals' proportion in relation to total length (Lt). Age limit or longevity (95% of L_∞) was determined with Taylor´s equation (1958, 1960): $A_{0.95} = \ln(1 - 0.95)/K + t_0$.

RESULTS

The relation between total length (Lt) versus standard length (Ls) for *L. guttatus* (Fig. 1) presents a potential relation of isometric type $b = 1.00$ ($R^2 = 0.96$; $t_{(1579, 0.05)} = 0.007$), which means that the magnitude of growth is proportional between the Lt and Ls. Fig. 2 shows an isometric relation between Lt and height (H) with slope value of $b = 0.94$ ($R^2 = 0.88$; $t_{(1579, 0.05)} = 0.047$), which indicates that the length and the height of the organism maintain their same proportion as it increases in age. The relation between total weight (W) and Lt showed a slope of $b = 2.96$ ($R^2 = 0.96$; $t_{(1579, 0.05)} = 1.92$) (Fig. 3) which indicates an isometric growth with the organism maintaining a proportional weight to its length as it increases its age.

Table 1 shows maximum, minimum and average values of Lt, Ls, H and Wt, and in the Table 2 values of these measures related to length classes of *L. guttatus*.

The relation between length (SL) and width (SW) of the scale (Fig. 4) presents an isometric growth $b = 0.96$ ($R^2 = 0.97$, $t_{(983, 0.05)} = 0.728$) reason why the scales do not change their morphology conserving their form throughout the time. Table 3 shows the relation between length and width of the scales for different values of total length of *L. guttatus*. Likewise, the relation between Lt versus SL is isometric (Fig. 5): $b = 0.99$ ($R^2 = 0.96$, $t_{(983, 0.05)} = -8.489$), which verifies this type of structure to determine age and use of the growth equation of von Bertalanffy.

During the sampled months a maximum period of growth ring formation was observed in the scales: April (0.65 mm ± 0.30 Std. Dev.), which indicates that a growth ring is formed per year and scales are valid to determine age of *L. guttatus*.

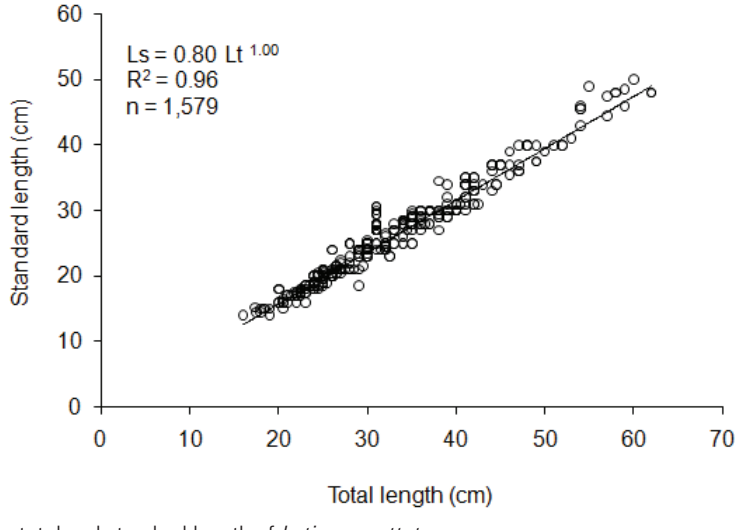

Figure 1. Relationship between total and standard length of *Lutjanus guttatus*.

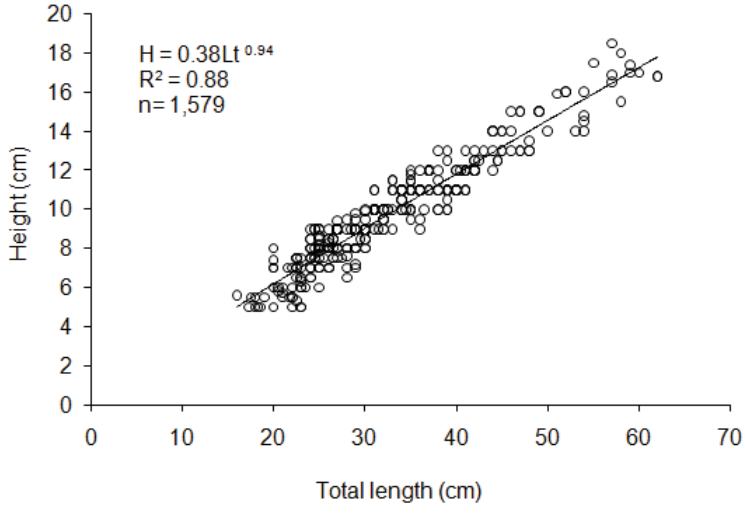

Figure 2. Relationship between total length and height of *L. guttatus*.

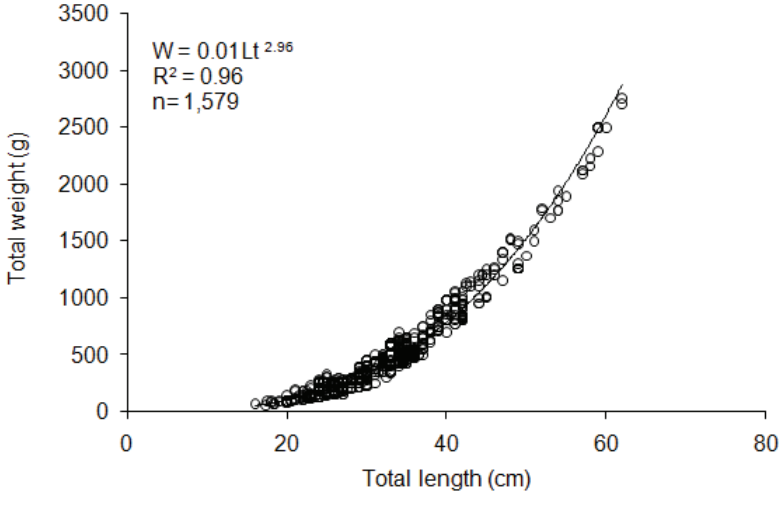

Figure 3. Relationship between total length and total weight of *L. guttatus*.

Analysis of growth rings in scales allowed the identification of 3 age groups. The percentage of scales that showed perfectly defined growth rings was 100 %.

Table 4 shows the values of von Bertalanffy's constants calculated by different methods, which are very similar among them. Nevertheless the nonlinear method provided the best correlation and the parameters are statistically better fitted to the observed data: L_∞ = 96.60 cm, K = 0.22 years^{-1} and to = –0.10 years with an adjustment of $p > 0{,}00$ (Chi^2 = 0.99, g.l. = 5 and α = 0.05).

Table 5 shows the average values of length and weight, as well as the instantaneous growth rate in length and weight for each age group. Fig. 6 shows observed and calculated values of the growth, with length and weight data of *L. guttatus*.

Table 6 summarizes values of the von Bertalanffys's constants for *L. guttatus* obtained by different authors in diverse areas from the Mexican Pacific, and Pauly's growth index (ϕ') (1979), which helps compare different growth curves. Values calculated in the present study are within the confidence intervals of this growth index (Table 7).

The months of highest increase in the condition factor for *L. guttatus* were February and June; for both Fulton's and Clark's indexes a lapse of two months are preceded by higher values of the gastric repletion index (Fig. 7).

The values obtained with KDE are shown in Table 8, for ages 1 to 3, and compared with the results obtained with scales readings.

The mean values for the indexes are: CF Fulton = 7.950 (± 0.235 s.d.), CF Clark = 6.040 (± 0.317 s.d.), GRI = 3.990 (± 0.198 s.d.), GSI = 4.760 (± 0.253 s.d.) and HIS = 5.430 (± 0.370 s.d.). The highest values the GSI appeared in April and August which correspond with the lower values of the HSI (Fig. 7).

Table 1. Values of total and standard length, height and weight of *L. guttatus*.

	Lt	Ls	H	W
average	32.42	25.64	9.85	487
maximum	62.00	50.00	19.50	2760
minimum	16.00	14.00	5.00	60
n	1579	1579	1579	1579
d.s	7.142	5.695	2.142	350.864

Table 2. Values of standard length, height and weight for total length classes of *L. guttatus*.

Lt (cm)	Ls (cm)	H (cm)	W (g)
9-11	8.00	3.02	9
11-13	9.60	3.56	16
13-15	11.20	4.09	25
15-17	12.80	4.61	37
17-19	14.40	5.12	52
19-21	16.00	5.63	71
21-23	17.60	6.14	94
23-25	19.20	6.64	122
25-27	20.80	7.13	154
27-29	22.40	7.62	192
29-31	24.00	8.11	236
31-33	25.60	8.60	285
33-35	27.20	9.08	341
35-37	28.80	9.56	404
37-39	30.40	10.04	474
39-41	32.00	10.51	552
41-43	33.60	10.98	638
43-45	35.20	11.45	732
45-47	36.80	11.92	835
47-49	38.40	12.39	947
49-51	40.00	12.85	1,069
51-53	41.60	13.31	1,201
53-55	43.20	13.77	1,342
55-57	44.80	14.23	1,495
57-59	46.40	14.68	1,659
59-61	48.00	15.14	1,834
61-63	49.60	15.59	2,021
63-65	51.20	16.05	2,220
65-67	52.80	16.50	2,431
67-69	54.40	16.95	2,656
69-71	56.00	17.39	2,894

Table 3. Values of the scale length and width for each total length of *L. guttatus*.

Lt	SL	SW
10	0.20	0.30
12	0.23	0.36
14	0.27	0.42
16	0.31	0.47
18	0.35	0.53
20	0.39	0.58
22	0.43	0.64
24	0.46	0.70
26	0.50	0.75
28	0.54	0.80
30	0.58	0.86
32	0.62	0.91
34	0.66	0.97
36	0.69	1.02
38	0.73	1.08
40	0.77	1.13
42	0.81	1.18
44	0.85	1.24
46	0.89	1.29
48	0.92	1.34
50	0.96	1.40
52	1.00	1.45
54	1.04	1.50
56	1.08	1.56
58	1.11	1.61
60	1.15	1.66
62	1.19	1.71
64	1.23	1.77
66	1.27	1.82
68	1.30	1.87
70	1.34	1.92

The period of massive spawning of *L. guttatus* occurs during August. Table 9 shows the spawning periods of this species in different localities from the Mexican Pacific by different authors. The first sexual maturity length of *L. guttatus* was 30.63 cm Lt. This length is defined as that at which 50% of all the individuals are sexually mature and its determination is particularly useful to separate the immature organisms of those sexually mature.

The longevity of *L. guttatus* determined in this paper is 13.5 years.

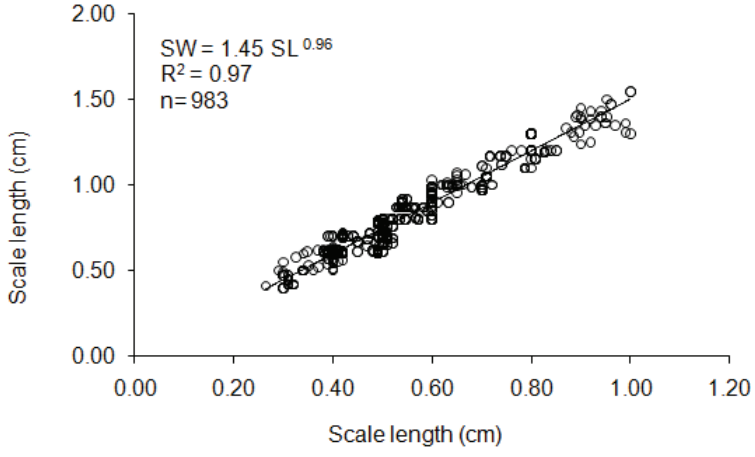

Figure 4. Relationship between scale length and width of *L. guttatus*.

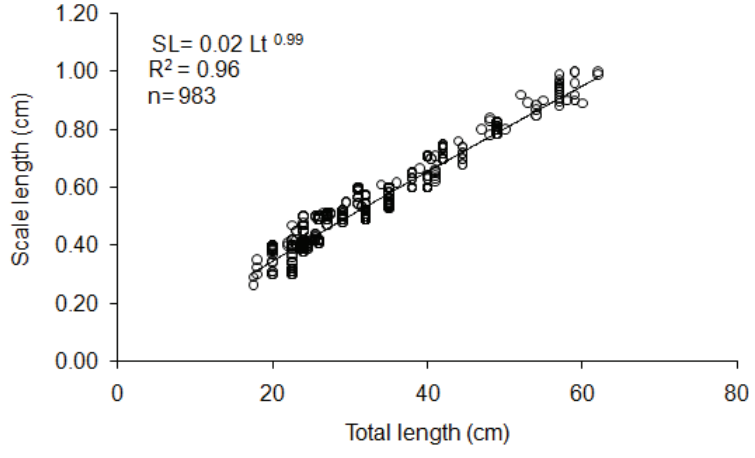

Figure 5. Relationship between fish total length and scale length of *L. guttatus*.

DISCUSSION

The scales of *L. guttatus* were obtained in the area protected by the left pectoral fin because it is the area that has less regenerated scales, however FAO (1982) mentions that the best scales to determine age are those obtained in the scapula (between the head and the dorsal fin). Scales turned out to be suitable structures to identify growth rings of *L. guttatus* which agrees with Espino-Barr (1996), and Sarabia (2005).

The amplitude of the growth rings on scales showed a progressive diminution as the organism aged. In this study the infinite length of *L. guttatus* was 96.60 cm Lt, the maximum length observed was 62 cm and the maximum reported by fishers was 75 cm. Amezcua-Linares (2008) reported a male of 80 cm for this locality and Espino-Barr *et al.* (2004) an organism of 87.31 cm in Jalisco. There are always big differences in sizes, depending on the sample, the latitude, the season of the year, the method to obtain the organisms, etc.

Values of longevity found in other areas by different authors are lower to those found in this paper, except for the reported in Oaxaca by Ramos-Cruz (2001). Differences with results obtained by other authors in the same area could be due to the use of standard length instead of total (as the case of Madrid-Vera, 1990), to the use of an indirect method (length frequencies) or the fishing aspects as effort, location and sampling strategy. However, values of the growth index for this species demonstrate its validity. The greater growth in length of *L. guttatus* happens during its first year of life with the intention to reduce natural mortality (Gallardo-Cabello *et al.*, 2007 and Espino-Barr *et al.*, 2008).

Recruitment age of *L. guttatus* is at one year, for this paper it was possible to obtain individuals of the 0 age group (less than one year) through the stomach analysis content of an individual of *L. guttatus* of 32 cm Lt, and a flounder *Cyclopsetta querna* of 32 cm Lt (sample from February 2006), who ate individuals of *L. guttatus* from 1.7 and 1.65 cm Lt, the scales of these organisms showed

Table 4. Growth parameters determined by different methods for *L. guttatus*.

	Ford-Walford	Gulland	Beverton & Holt	Simple non linear *vB* equation	Weighted non linear *vB* equation
a	9.863	9.863	4.507		
b	0.893	–0.107	–0.238		
R^2	0.974	0.351	0.988	0.999	0.999
Fitted R^2	0.968	0.189	0.986	0.999	0.998
L_∞	92.39	92.39	92.39	96.60	145.29
K	0.113	0.113	0.238	0.222	0.129
t_0			–0.082	–0.097	–0.129

Table 5. Estimated length and weight of each age by scales of *L. guttatus*.

Age (years)	Lt (cm)	Annual instant growth rate in length (cm)	*W* (g)	Annual instant growth rate in weight (g)
1	20.76		79	
2	35.74	14.98	396	316
3	47.76	12.02	933	538
4	57.40	9.65	1,609	675
5	65.14	7.74	2,339	731
6	71.36	6.21	3,063	724
7	76.34	4.99	3,741	678
8	80.34	4.00	4,351	611
9	83.55	3.21	4,886	535
10	86.13	2.58	5,346	460
11	88.20	2.07	5,735	389
12	89.86	1.66	6,060	325
13	91.19	1.33	6,330	270
14	92.26	1.07	6,552	222
15	93.11	0.86	6,734	182
16	93.80	0.69	6,883	148
17	94.36	0.55	7,003	121

the absence of growth rings, which means that they belonged to age group 0.

Mean lengths data obtained by scale readings are very similar to those obtained by KDE method, which validates both methods: direct and indirect, that is, that the growth rings formed on scales and the polymodal curve analyses give a good fit to determine the age in this species. Increase of the gastric repletion index values due to greater availability of food, are reflected in the index of the condition factor and in the hepatosomatic index after two months as a result of assimilation of nutrients through the processes of catabolism. On the other hand the gastric repletion index and condition factor diminish during spawning period, as a result of corporal wearing down of the fish (Santamaría *et al.*, 2003a; Gallardo-Cabello *et al.*, 2007; Espino-Barr *et al.*, 2008).

In this study, six maturity stages were identified, similar to those described by Rojas (1997) in the Gulf of Nicoya, Costa Rica and those reported by Piñón *et al.* (2009) for *Lutjanus argentiventris* in the Gulf of California. This species spawning period happens during August, which agrees with Arellano *et al.* (2001) observations in the coasts of Guerrero, nevertheless, other authors as Cruz-Romero *et al.* (1991) and Cruz-Romero & Espino-Barr (2006) found other spawning period months for *L. guttatus* in the coasts

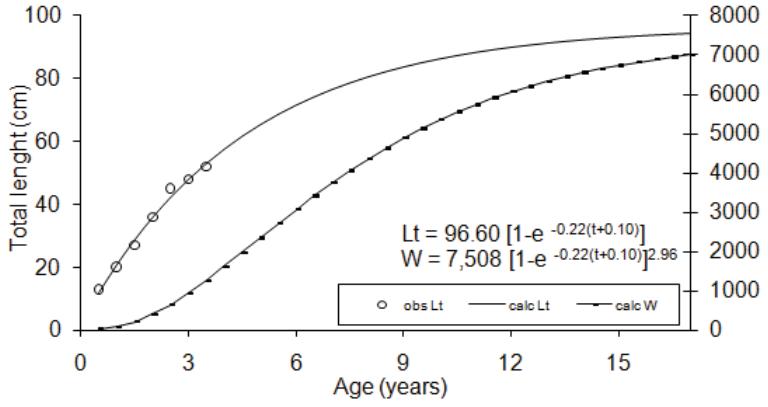

Figure 6. Growth curve in length and weight with von Bertalanffy's equation for *L. guttatus*.

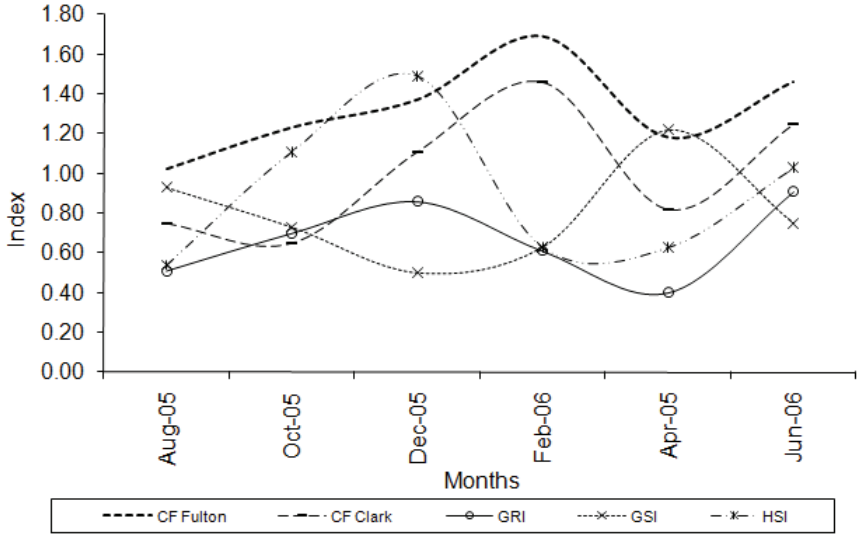

Figure 7. Condition factor (Fulton and Clark), gastric repletion index, gonadosomatic index and hepatosomatic index for different periods of time of *L. guttatus*.

of Jalisco and Colima. Organisms born during August appeared in the fishing grounds during April and June and those born in April recruited in the fishing area from November to January. They become recruited to the fishing gear over a year after. Recruitment length is 16 cm, and the period with greater recruitment of adult population happens during April and August.

L. guttatus reaches sexual maturity at a length of 30.63 cm Lt, value similar to that found by Cruz-Romero *et al.* (1991) of 29 cm Lt in Colima. On the other hand, Rojas (1997) reported a minimum maturity length of 31.5 cm Lt in the Gulf of Nicoya, Costa Rica. Similar values were reported by Rojo *et al.* (1999) and Santamaría *et al.* (2003a).

Of the 1,579 sampled organisms, 649 (41.10%) were sexually immature individuals. This is because the fishers prefer to capture organisms whose lengths approximately oscillate between 30 and 35 cm Lt and 400 g of weight, being these sizes the ones that pay higher price, because they fit in the plate and tourism prefers its consumption. Organisms of greater size have to be filleted and its commercial value descends. As a measure for protecting this species of overfishing, we suggest a closed season during August and September, to give a longer period of possibilities of spawning, and a first size of capture at 45 cm of length equivalent to 2.5 years of age, when most females have reproduced.

ACKNOWLEDGEMENTS

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Table 6. Growth parameters of *Lutjanus guttatus*, calculated by different authors in some areas of the Mexican Pacific.

Study area	Reference	Method	L_∞ (cm)	K (1/year)	t_0 (year)	ϕ'	Length
Golfo de California	Amezcua *et al.* (2006)	O	66.19	0.13	0.23	2.756	Lt
Colima	Cruz-Romero *et al.* (1991)	F	64.20	0.190	0.004	2.894	Lt
Colima	Espino-Barr *et al.* (1994)	S	80.00	0.260	0.018	3.819	Lt
Michoacán	Ruiz-Luna *et al.* (1985)	F	74.09	0.190	–1.130	3.018	Lt
Michoacán	Madrid-Vera (1990)	S	80.50	0.080	0.370	2.715	Ls
Michoacán	Present paper	S	96.60	0.220	– 0.100	3.312	Lt
Guerrero	Rojas-Herrera (2001)	O	68.44	0.138	–1.687	2.811	FL
Oaxaca	Ramos-Cruz (2001)	S	99.40	0.130	0.370	3.109	Lt

Note: O = otoliths, F = frequency analysis, S = scales.
Lt = total length, Ls = standard length, Fl = furcal length.

Table 7. Statistic values of the evaluation growth index of *L. guttatus*.

Statistic parameter	L. guttatus
n	5
Average	3.00
Std. Dev.	0.22
Std. Error	0.10
Inter. Conf. (superior)	3.31
Inter. Conf. (inferior)	2.72
Minimum	2.71
Maximum	3.31

Table 8. Relation between age and length obtained with scales and KDE.

Age (years)	Scales (cm)	KDE components (cm)
1	20.76	25.75
2	35.74	35.31
3	47.76	46.24

Table 9. Spawning period of *L. guttatus* in different states of the Mexican Pacific.

Spawning period	State on the Mexican Pacific	Reference
June-July and September-October	Jalisco	Cruz-Romero & Espino-Barr (2006)
March to April and July to November	Colima	Cruz-Romero *et al.* (1991)
May-June and November-January	Colima	Cruz-Romero & Espino-Barr (2006)
August	Michoacán	Present paper
April and August-December	Guerrero	Arellano *et al.* (2001)

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