Population Analysis of The Snapper *Lutjanus Griseus*, Based on The Artisanal Fisheries of The Tamiahua Coast, Veracruz

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ABSTRACT

Artisanal fishery in the Gulf of Mexico is mainly undertaken for subsistence and is, thus, of great socioeconomic importance, with Lutjanidae one of the most important families caught in the region. However, there is scarce fisheries knowledge in the Gulf of Mexico and, in light of pressure from the fishing community, research into the population dynamics of these species is of vital importance for the management or conservation of coastal resources. This study aims to contribute information for the analysis of the population of Lutjanus griseus (Linnaeus, 1758), a common species on the Tamiahua coast, in the state of Veracruz. Samples and biometric data (weight, sex, total length and maturity) were recorded by the fishing community on this coast. The monthly population structure was constructed using fish size. Data from 987 individuals, the size of which oscillated from 15 to 80 cm, were registered over the course of a year. The sex ratio was 1:1, while the maximum calculated age was 10 years. Von Bertalanffy and Gompertz growth models reported a maximum age and growth of $L\infty=182.46$ $K= 0.05$ and $t^o = -1.71$. The best fit was achieved by means of the Gompertz model, as based on the Akaike criteria and the biological interpretation of the parameters. Reported data and the models used in this study suggest that the minimum catch size should be 40 cm and that the fishery should either cease activities in the months of the reproductive peak or that quotas should be among the fishing cooperatives on the coast of Tamiahua.

Key words: Growth, age, *Lejanas griseus*, population, sex.

INTRODUCTION

Snapper distribution generally coincides with the presence of coral reefs, with its distribution limit found in the northern West Atlantic, and on the coasts of Massachusetts, North and South Carolina, Florida, the Gulf of Mexico, the Caribbean and southeast Brazil (Fischer, 1978).

Some studies have taken a joint approach to biological aspects, such as sexual maturity, sex ratio (Claro *et al.*, 2001; García-Cagide *et al.*, 2001; Chiappa-Carrara *et al*., 2004), and age structure (Amezcua *et al.*, 2006), to determine the age, growth and mortality of *Lutjanus peru* and *L. guttatus*. Dynamic population studies reveal catch size recommendations oscillating between 30 and 40 cm (Rojas, 2001; Rojas, 2004; García-Contreras *et al.*, 2009; Manjarres *et al*., 2010).

While studies undertaken in the Gulf of Mexico on the snapper are scarce, research conducted by Burton (2001, 2002), Mikulas (2008) and Wells *et al.* (2008) determined age, growth parameters and mortality rates in order to propose management guidelines. Among studies conducted on snapper fishing in Verzcruz, Jiménez-Badillo *et al.,* (2006), Jiménez-Badillo and Castro-Gaspar (2007) and Gutiérrez, (2012) are highlighted.

Research has also been undertaken on decreasing snapper production levels, given that this family was found to be at its maximum sustainable yield (Arreguín-Sánchez and Arcos Huitron, 2011), while Cullis *et al*. (2012) performed a fishery analysis in order to implement a per trip catch quota program.

L. griseus is a little-studied species despite the ecological importance of the snapper to the stability of coastal ecosystems (Pérez-España, 2003). According to the National Fisheries Charter, the current situation shows that, in the last 5 years, the average annual snapper catch for the Gulf of Mexico was 4,257 t, of which Veracruz contributed 417 t (CNP, 2010). This resource, which comprises scaled fish species (60% of the total fishery production), has been considerably decreasing.

MATERIALS AND METHODS

From March 2012 to May 2013, 987 *Lutjanus griseus* organisms were caught for this study using longline and hooks in the fishing area off the Tamiahua coast, found in the central eastern area of the Gulf of Mexico between 21° 50’ 05” latitude North and 97° 50’ 0” longitude West and 21º 10’ 0” latitude North and 97º 40’ 0” longitude West.

Biometric data was taken for total length (TL) and weight (gutted weight - GW), while the sex ratio and sexual maturity were determined.

The per-month size composition for the population sampled was obtained by means of a frequency histogram. Average male and female sizes were compared by means of a Student’s t-test, while the median sizes caught each month were compared via a Kruskal-Wallis non-parametric ANOVA test.

Finally, the population size was ascertained, in accordance with Sparre and Venema (1997), using the statistical programs Statistica Version 7 (2004) and SPSS Statistics (2005) Version 19. The ratio/relationship/relation between length (TL) and weight (GW) was determined by means of a potential model, $PE= a*LT^b$, where “a” and “b” are the regression constants generated by the logarithmic transformation of TL and GW and the fit is made via the method of least squares (Ricker, 1975).

The gonads were extracted from each organism and, based on their coloration and morphology, the sex and sexual maturity was determined in accordance with the Nikolsky classification (1963), as adapted for tropical fisheries.

Two deterministic models were compared for the growth calculation, with the aim of establishing the best fit to the length-age data and obtaining the most reliable growth parameters (Braccini *et al*., 2007). The Von Bertalanffy model (1938) was applied, as it is the most commonly used to describe fish growth:

$$L_t = L_\infty\left(1 - e^{-k(t-t_0)}\right)$$

In this model, *Lt* is the length of the individual at age *t*, $L\infty$ is the asymptotic length, *k* is the parameter for growth rate, and t_0 is the theoretical age at zero length. The Gompertz model was also applied (1825).

$Lt = L\infty e\text{-}e\ (-k\ (t\text{-}to))$

In order to fit the models, the least squares criterion was used, while the Akaike information criterion, described in the following formula (Bolker, 2008), was applied in order to select the best fit:

$AIC = -2 \ln L(\theta) + 2k$

where L (ɵ) is the verisimilitude and k is the number of estimated parameters in the model.

Parameters from the Von Bertalanffy equation (Sparre & Venema 1997) were used to estimate natural mortality:

$\log M = -0.0066 - 0.279 \log (L\infty) + 0.6543 \log (K) + 0.4634 \log (T)$

The Beverton and Holt equation (1956), in which L is the average size of fish of length L and above and L´ is the size at which all fish of this size and larger are caught, was used to obtain the rate of mortality due to fishing:

$z = K^* (L\infty - L) / (L - L')$

RESULTS

The *L. griseus* population mainly comprised individuals 30 to 50 cm in size, with an average size of 39.52 cm, a maximum size of 134.0 cm and a minimum size of 15.0 cm. (Fig. 1).

The non-parametric Kruskal-Wallis (H) test detected significant differences among the median sizes for the different months sampled (H=107.63; $P < 0.05$).

The individuals caught in the month of September presented sizes smaller than 30.0 cm, with fish caught from October to July increasing in size. Lengths of 40.0 cm and above were found from November to May 2013 (Table 1).

In terms of the relationship between total weight and total length for males and females, a positive and significant relationship was found, with a correlation coefficient of $r^2 = 0.93$ and a $P < 0.0001$. The value for Coefficient B was 3.1, which indicates that the growth presented by *L. griseus* is isometric. The maximum weight registered for *L. griseus* corresponded to a 42 kg individual with a size of 134.0 cm, which, according to the model, corresponds to a weight of 41.480 kg (Fig. 2).

With regard to the average size, the females were larger than the males (38.56 cm and 36.52 cm respectively); however, these differences were not statistically significant (t=0.61 $P < 0.54$).

The sex ratio for the population studied was 1:1.2. The females matured at a length of 22.0 cm and the males at 25.0 cm.

In accordance with Nikolsky (1963), 22.68% of the total population was found to be in Phase III and 28.71% in Phase IV.

Natural mortality was M=0.34 from the value of K=0.10 upwards, corresponding to a low mortality rate, which is due to the fact that there are few predators and that the temperature of tropical waters is not a harmful factor for the species. Mortality per catch was F=0.52.

DISCUSSION

Although large *L. griseus* individuals (20 to 90 cm) on the Tamiahua coast are displaced beyond the reef and smaller individuals remain within its protection, even juvenile individuals are displaced to estuarine environments (Nagelkerken, 2009).

With regard to estimations of the size-weight relation in *L. griseus,* studies carried out in the Caribbean (Claro *et al*., 2001) have produced highly significant values, as Burton has also described (2001, 2002), for *L. analis* and *L. griseus* on the east coast of Florida. In the *Alacranes* reef (Yucatán), the values for the correlation were also high (r^2= 0.98) for *L. griseus* (González-Gándara *et al*., 2003), a little higher than the result reported in the present study (r^2= 0.93), which is probably due to the fact that the present research found an atypical value of 134.0 cm, the largest size reported for this species. Those studies which recommend catch sizes report values lower than 30.0 cm and individuals that are mainly sexually immature. This same situation presents on the Colombian coast of the Caribbean (Manjarrés, 2010; Rojas and Puentes, 2004), where a catch size of 48.0 cm has been reported due to the fact that fishery there focuses on undersized organisms.

It was found that *L. griseus* fishing is concentrated on organisms smaller than 40.0 cm (average 39.52 cm), which could negatively affect the population dynamic, leading, for example, to early sexual maturity and the redirection of physiological effort to reproduction at the expense of growth, which would reduce the recruitment of large individuals. Therefore, the selectivity of fishing gear should be calibrated for sizes larger than 25.0 or 30.0 cm (Wells *et al*., 2008). Generally, in the snapper populations of the Gulf of Mexico, individuals reach sexual maturity at sizes that fluctuate around 23.0 cm (84%) (Brulé *et al*., 2004). Moreover, Domier *et al.* (1996) report that sexually mature males measuring 18.0 cm can be found on the east coast of Florida at the beginning of March, while females measuring 19.0 cm and in an advanced state of sexual maturity (between stages 4 and 5, according to Nikolsky, 1963) can be found in the region up to mid-June. Spawning presents in the months of July and August and culminates in September. Rojas and Puentes (2004) also observe that *L. arginteventris* individuals in a more advanced state of maturity present throughout the months of May, June, August, November and December. This coincides with that reported by Grimes (1987) for *L. griseus,* while the insular species spawn in spring and fall. The sex ratio reported in the present study is similar to that found on the Florida and Caribbean coasts, where the population is 1:1.06 and 1:1.13 male-female, respectively. Rojas and Puentes (2004) reported a 1:1.2 female-male sex ratio, which is the same result found in the present study.

The minimum size to reach sexual maturity concurs with that reported by Claro and Linderman (2008), who affirm that females mature at 22.0 cm and males at 23.0 cm, up to a maximum size of 26 cm at an age of 1 to 2 years. Similarly, for *L. jocu*, Brulé *et al*., (2009) (Bloch and Schneider, 1801) stipulate that the minimum catch size, as a fishing regulation measure, should depend on the size at which individuals sexually mature, which differs in terms of the type of reproduction and the spawning phase for each species. Necessarily, this would involve a different minimum catch size for each species, which, in turn, protects juveniles. Similarly, Gutiérrez (2012) mentioned that the first catch size for the species *Ocyurus chrysurus* (Bloch) (Perciformes: Lutjanidae) caught with number 3 and 4 hooks, was 36.0-38.0 cm, while this was

26.0-28.0 cm, 44.0-46.0 cm and 40.0-42.0 cm with number 10, 6 and 14 hooks, respectively, concluding that juveniles should be protected by artisanal fishing.

This study also determined the growth parameters, obtaining $L\infty$= 182.41 cm K= 0.05 $t0$= -1.71, where the estimated length is greater than that reported by studies conducted in Florida, which reported values of $L\infty$= 89.0 cm K= 0.10 $t0$= -0.3 (Manooch, 1987), or that reported by Burton (2002), namely - $L\infty$= 71.6 cm K =0.11 $t0$= -1.33. Lower values, of $L\infty$= 77.22 cm, K= 0.11 and t0= -3.73, have even been reported on the coast of Brazil (Padovani and Rezende, 2004). With a maximum length of 134 cm found via artisanal fishing, it can be deduced that the species *L. griseus* undergoes rapid growth at a young age, which subsequently slows as individuals reach great lengths (Braccini *et al*. 2007). Moreover, studies focusing on the biological aspects of snappers agree that they are long-lived species. The growth values for *L. griseus* registered on the Caribbean coasts are lower, with values such as $L\infty$= 54.8 cm K =0.23 $t0$= -1.06, which contrasts with the values registered on the coasts of Florida and Tamiahua, where the organisms reach greater lengths. The differences found between the populations in Florida and Tamiahua and the Caribbean may be due to a greater availability of food in the two former areas or to the fact that the populations in the Caribbean are over-exploited.

The K values indicate that *L. griseus* is a species susceptible to rapid over-exploitation and show that adult individuals probably constitute a part of recruitment along with juveniles.

Mortality is an indispensable parameter for understanding population dynamics given that it can be used to obtain species exploitation rates for use in their management (Pauly, 1980).

A fishing mortality of Z= 0.52 was obtained for *L. griseus*, while natural mortality was an estimated M=0.34, coinciding with the natural mortality obtained for the species *L. analis* (Cuvier, 1828) and *L. synagris* (Linneus, 1758), with values of M=0.35, M=0.37 and M= 0.33, respectively (Manjarrés *et al.*, 2004).

Manooch (1987) identified a fishing mortality of *Z*=0.60 for *L. griseus*, considering that these values indicate both that the snapper species slowly reach their maximum size and that they present low natural mortality rates. Given that the mortality data reported here partially coincides with that reported by the authors mentioned above, the natural mortality of *L. griseus* can be considered “acceptable”.

With regard to fishing mortality in *L. analis*, Burton (2002) affirmed that estimations are higher (Z=0.49) than they were 20 years ago, referring to the fact that catches are aimed at breeding individuals, which suggests that this resource is overexploited and coincides with the statistics reported here. Similarly, the same study also reported a value of M=0.38 for *L. griseus*, although fishing mortality was found to be high (Z=0.94), indicating that this resource is exploited at intense levels. Moreover, the recruitment of individuals to the exploited population occurs between the ages of 4 and 5 years old. The estimated mortality rates in the study fall within that reported for snapper species and denote, in the case of fishing mortality, that the resource is found to be in a state of moderate exploitation. This, thus, would favor the recovery of the population, due to the fact that there has been a moderate increase in artisanal fishing catches and that these increases may reach a high level of production.

Among the 24 main fisheries of the Gulf of Mexico (CNP, 2010), *Lutjanidae* fishing comprises more than 50% of the fishing effort and requires immediate attention and regulation (Vázquez-Hurtado *et al*., 2010).

Based on the foregoing, fisheries analysis is an important tool for ascertaining the state of fish populations in order to regulate fisheries and provide complete biological-fishery information on which the sustainable management of fishing resources can be based. In this sense, the study of the size structure of *L. griseus* caught on the Tamiahua coast via artisanal fishing has revealed it to be predominated by individuals measuring 30- 50 cm. This finding is similar to the data obtained for *L. griseus* in Florida, whose intervals included sizes of 30-57 cm (Burton, 2001), suggesting that the population of this species is abundant in relation to the sizes reported here.

Aside from the economic interest in these snapper species, they are also an important ecological component at a community level as they are apex predators that consume shrimps, crabs, fish and cephalopods in the reefs of the Gulf of Mexico (Pérez-España, 2003). Moreover, the community of Antón Lizardo makes up 86% of the catch of the fisheries in reef zones (such as the Veracruz reef system) (Jiménez and Castro, 2007), with the *Lutjanidae* family contributing 16.33% of the economic value of the marine fishery of Tamiahua (Arguelles *et al.*, 2010). Both of the foregoing are evidence that the high commercial value of this species could provoke a collapse in its fishery, leading to the fishing of smaller-sized individuals and reducing the number of catches. In the south east of the Gulf of Mexico, snappers represent 54% of the catches made by the coastal fleet, while at the same time being the principal contributor to maintaining the ecological balance of the complex communities of hard-bottom tropical fish. A decrease in the population level could drastically affect the structure of the community of benthic organisms, as well as the trophic dynamic of coral ecosystems (Brulé *et al*., 2009). Under these conditions, the species *L. griseus* represents an important resource in the catches made by the fishing fleet on the Tamiahua coast, which could rapidly generate a level of over-exploitation. Arreguín-Sánchez and Arcos (2011) state that snapper species are at their maximum sustainable yield, which could generate the exploitation of this resource. Even bad practice during catches could cause a deterioration in the reefs, thus damaging coastal marine diversity.

Although the official fisheries statistics lack precise information at a species level, fisheries production statistics for *L. griseus* showed that this family is fundamental to artisanal fishing, which has notably maintained moderate increases in terms of both the catch and the fishing effort. As mentioned above, with two cooperatives with a different level of fishing effort responsible for the catches, consequently, said catches increase unequally. Some authors suggest the application of generalized linear models for detecting which variables can be mainly used to down detail the fishing effort (Parrága and Correa, 2010). The aforementioned authors standardize the fishing effort corresponding to *L. synagris* catches with the objective of avoiding excessive increases in both monthly and annual production, which would involve species management.

Snappers present two migrations, during which, throughout the transition from winter to summer (March-April), a notable decrease in growth occurs, but which is short in duration, given that, from April to May, individuals again begin to increase in size, reaching maximum growth intensity by the end of the summer (September-October). These conclusions, made by Claro *et al.*, (2001), concur with that which is reported here for April to June, as with November and December, where sizes above 40 cm are registered, while, from September to October, sizes were lower, which could be due to the fact that the population presents individuals recruited from the most recent reproductive season.

Studies on spawning aggregations for snapper species in reefs in the Atlantic Ocean are reported for the months of May and July (Domeier *et al*., 1996; Lindeman *et al*., 2006; Burton *et al*., 2005; Graham *et al*., 2008, cited in Claro *et al*., 2009) in the context of an increased fishing effort. This finding is apparently occurring with *L. griseus* on the Tamiahua coast, due to the fact that, in May, the fishing effort increases in terms of the catch, possibly a month prior to the spawning aggregation.

The application of regulatory measures for the species *L. griseus* is necessary, due to a moderate catch increase (CNP, 2012) and the fishing effort reported here.

Currently, the *ad hoc* creation of legislation for the protection of a species involves the participation of various agencies and a relatively long development process (DOF, 2009). This process includes reviewing the different pieces of legislation in force which have shared benefits or, in this case, which apply to 55 species in common, in order to generate specific legislation per species.

In this sense, this suggests the generation of specific legislation for *Lutjanidae*, which includes information related to the reproductive period – the first catch size, the age at which mature size is achieved, and the recommended hook type – as a possible closure period with which the species could be exploited adequately. Similarly, the information obtained could be included in Official Mexican Standard NOM-65-PESC-2007, which regulates the exploitation of grouper species and associated species on the coasts of the Gulf of Mexico and the Caribbean Sea. This indicates that all species listed in the NOM present abundancies and specific biological characteristics that converge in their distribution in some zones of the Gulf of Mexico and the Caribbean Sea. For this reason, it is necessary to ascertain the biological characteristics of each species in order to generate regulatory measures for its sustainable exploitation (DOF, 2009), such as a reduction in the catching of juveniles in the population, namely the fishing of commercial sizes of 40 cm, which would be younger than the age of first or second maturation.

One management measure explored by Stewart (2008), depending on the natural mortality rates, focused on mitigating the effects in order to reduce catch numbers. This was achieved through the creation of apertures in fishing nets for certain sized (< 30 cm) individuals and a balance in traps in shallow waters in which the fish are more likely to survive, as well as the establishment of legal criteria for deep waters.

Similarly, Brandt and Jackson (2013) establish a form of managing *L. campechanus* that determines that individuals must be caught at sizes of 40 cm, considering that these sizes produce 3.2 metric tons. For this, they propose the use of traps with nets in a pyramid shape, which protect the reefs and slightly reduce the fishing effort. Given that this study found a similar pattern for *L. griseus* in terms of size and spacing in reef zones, this management approach can be considered for the species.

The structure of the *L. griseus* population off the Tamiahua coast seems to indicate that it is especially vulnerable to fishing between the months of May and September, for which reason the species should be protected by legislation during these months. It can be concluded that the *Lutjanus griseus* population on the Tamiahua coast principally comprises individuals between 30.0 and 50.0 cm in size.

For the first time, a size of 134.0 and a weight of 42.0 kg cm have been registered for *L. griseus* in the Gulf of Mexico. The sex ratio was 1:1.2, male to female, while the size at first maturity in females was 22.0 cm and 25.0 cm for males.

Age is estimated as up to 10 rings, while the growth parameters were L∞=182,46 K= 0.05 and to = -1.71, with the Gompertz model providing the best description of *L. griseus* growth.

The estimated natural mortality value was M=0.34 and F=0.52 per catch. The *L. griseus* individuals caught range from 2 to 6 years old and are still biologically reproductive, which presents a risk for the population. The production of the fishery presented slight catch increases in 2013. The monthly catch volumes demonstrated significant differences, depending on the month featured in this research.

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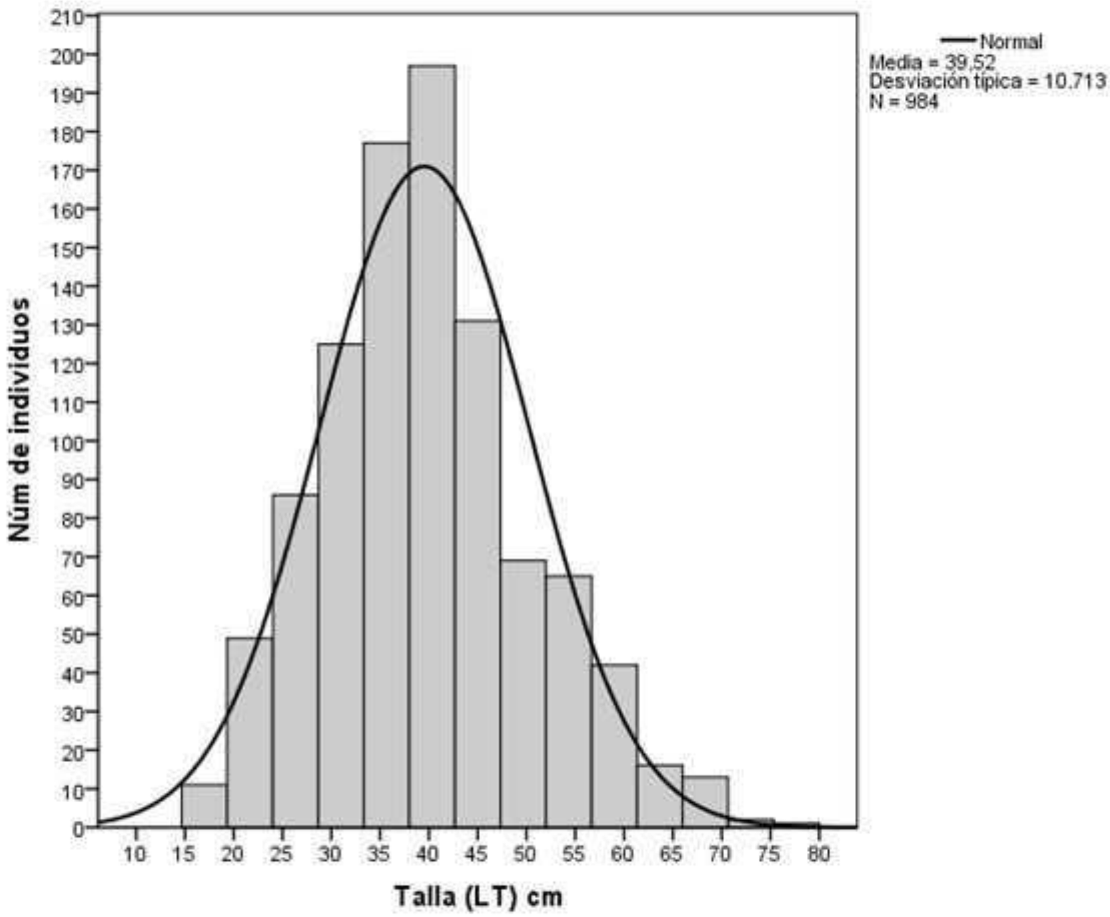

Fig. 1 Histogram of size for the *Lutjanus griseus* population of the Tamiahua coast, Veracruz, Mexico

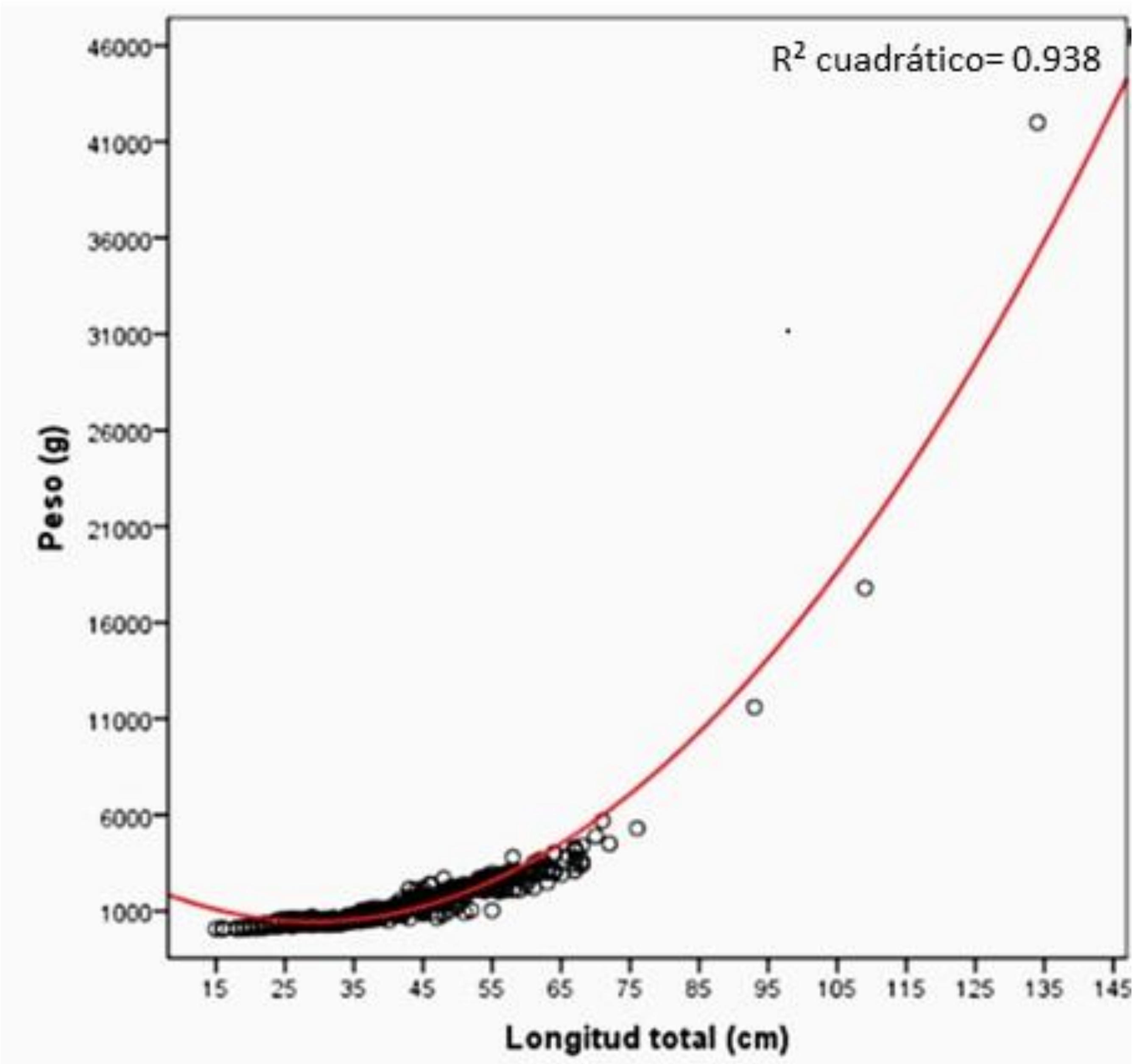

Fig. 2 Total Length and weight relation (n=987) for *Lutjanus griseus* individuals of the Tamiahua coast, Veracruz, Mexico

Table 1. Kruskal Wallis test, monthly differences (average size) for *Lutjanus griseus* organisms caught in the Laguna de Tamiahua coast, Veracruz, Mexico

Year	Months	Size	E.E.
2012	March	41.26	1.30
2012	April	36.63	1.43
2012	May	45.45	1.28
2012	June	46.65	3.81
2012	July	38.89	.88
2012	August	37.09	1.53
2012	September	33.52	1.43
2012	October	35.01	1.21
2012	November	40.52	.80
2012	December	40.71	1.00
2013	February	38.62	2.49
2013	March	40.24	1.68
2013	April	41.28	.72