AQUATIC ECOLOGY

REVISTA DE Biología Tropical

https://doi.org/10.15517/rev.biol.trop..v73i1.60355

Lutjanus synagris (Acanthuriformes: Lutjanidae): reproductive biology and synchronization with lunar phases in the Gulf of Salamanca, Colombian Caribbean

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Received 07-VI-2024. Corrected 03-II-2025. Accepted 30-V-2025.

ABSTRACT

Introduction: *Lutjanus synagris* is one of the most common demersal fishes in the Colombian Caribbean and is of interest to artisanal fisheries, although in decline. The study of its reproductive patterns provides insight into its biology relevant to the general study of tropical fishes.
Objective: To assess the condition factor and gonadosomatic index, to determine the monthly incidence of mature fish, to estimate the mean length at sexual maturity (Lm), and to explore predictors affecting the condition factor and gonadosomatic index in the lane snapper *L. synagris*.
Methods: Extirpated gonads of males and females were classified according to their maturity status and related to fish length. The condition factor and gonadosomatic index were estimated according to standard formulae. Their dependency on variables related to climate, geographic space, and behavior were assessed using linear models.
Results: Condition factor was stable throughout the year, while the gonadosomatic index showed an increasing pattern from the first months of the year (dry season), reaching a peak in the second semester of the year. The incidence of mature fish was higher in about the same months as when the gonadosomatic index showed high values. An Lm of 26 cm total length was estimated for both sexes, 27 cm for males and 25 cm for females. Condition factor and gonadosomatic index were associated with several predictors, notably with moon phases.
Conclusion: A spatial and temporal signal for the reproductive patterns of *L. synagris* was found but decoupled from climate seasonality. The reproductive rhythm of *L. synagris* was related to moon phases as the main environmental cue.

Key words: biorhythms; condition factor; gonadosomatic index; tropical fishes.

RESUMEN

***Lutjanus synagris* (Acanthuriformes: Lutjanidae): biología reproductiva y sincronización con las fases lunares en el Golfo de Salamanca, Caribe colombiano**

Introducción: *Lutjanus synagris* es uno de los peces demersales más comunes en el Caribe colombiano y es de interés para la pesca artesanal, que está en declive. El estudio de sus patrones reproductivos ayuda en la comprensión de su biología, relevante para el estudio general de los peces tropicales.
Objetivo: Evaluar el factor de condición y el índice gonadosomático, determinar la incidencia mensual de peces maduros, estimar la longitud promedio de madurez sexual (Lm) y explorar predictores que afectan el factor de condición y el índice gonadosomático del pargo *L. synagris*.

Métodos: Las gónadas de machos y hembras extirpadas fueron clasificadas según su estado de madurez y asociadas a la longitud del pez. El factor de condición y el índice gonadosomático se calcularon con fórmulas estándar. Su dependencia de variables asociadas al clima, espacio geográfico y comportamiento fue evaluada mediante modelos lineales.
Resultados: El factor de condición fue estable en el año mientras que el índice gonadosomático mostró un patrón de incremento en los primeros meses (época seca) para alcanzar un máximo el segundo semestre del año. La incidencia de peces maduros fue mayor en los mismos meses en que el índice gonadosomático mostró valores altos. Un Lm de 26 cm longitud total fue estimado para ambos sexos, 27 cm para machos y 25 cm para hembras. El factor de condición y el índice gonadosomático se asociaron con varios predictores, notablemente, con las fases lunares.
Conclusiones: Se encontró una señal espacial y temporal en los patrones reproductivos de *L. synagris* pero desacoplada de la estacionalidad climática. El ritmo reproductivo de *L. synagris* está vinculado a las fases lunares como principal señal ambiental.

Palabras clave: biorritmos; factor de condición; índice gonadosomatico; peces tropicales.

INTRODUCTION

Condition factor, gonadosomatic index and maturation patterns are functional features of importance in the study of the biology of tropical marine fishes with relevance in conservation and management. Condition factor alludes to the physical health of individuals and hence of the population (Gubiani et al., 2020; Le Cren, 1951). It focuses on the question whether an individual weights what it should according to its measured length. An overall measure of condition factor is indicative of favorable or unfavorable environmental conditions for the population. In turn, the gonadosomatic index focuses on the reproductive cycle a fish goes through typically over a year. The main purpose of such an index is to identify the population time of spawning (Fontoura et al., 2009; Lowerre-Barbieri et al., 2011). The incidence of mature fish in time may shed light onto the same question, but more importantly, the study of the proportion of mature fish in representative length samples provides an estimation of one main life-history event in a fish, the mean length at sexual maturity (Lm), relevant for fishery management (Cope & Punt, 2009; Froese et al., 2008).

The lane snapper *Lutjanus synagris* Linnaeus (1758) is a fish species of commercial interest in the Caribbean coast of Colombia (García & Duarte, 2024; Ministerio de Agricultura y Desarrollo Rural, 2024), although in decline globally (García, 2010; García & Duarte, 2024), in our study area, the Golf of Salamanca (Martínez-Viloria et al., 2022; Salazar-Perez et al., 2020), and in other areas of the Colombian Caribbean (Martínez-Viloria, 2022; Ramírez et al., 2017). It is a notorious member of soft bottom fish assemblages (García et al., 1998; Manjarres et al., 2001) occurring throughout the extension of the coast from South to North in soft bottoms (García & Armenteras, 2015). Although Allen (1985) states that *L. synagris* main habitat is around coral reefs and vegetated sandy areas it turns out to be the most common fish in historical soft bottom trawls in the Colombian Caribbean (García, 2018; García & Armenteras, 2015).

Few studies have been conducted in Colombian Caribbean waters on reproductive aspects of *L. synagris*. Based on the gonadosomatic index different peaks in spawning activity have been suggested for this species. Arteaga et al. (2004) found two peaks in spawning, one from April to August with a maximum in May and a second peak in October in the Northern Colombian Caribbean Sea (Guajira Peninsula and Tayrona National Natural Park). Posada-Peláez et al. (2012) reports a peak in spawning from August to November in an area including the Eastern corner of the Gulf of Salamanca, the Tayrona National Natural Park, and some localities to the East but not reaching the Guajira

Peninsula. In both cases it is suggested that increased spawning is associated with the rainy season environmental and climatic conditions, that is, higher sea surface temperatures and lower sea surface salinity in contrast to the dry season (December to April) when an upwelling phenomenon takes place in the area conductive to lower sea surface temperature and higher salinity (Andrade & Barton, 2005).

Regarding condition factor no antecedent could be found in the primary literature focusing on Colombian populations of *L. synagris*. Estimations of Lm, on the other hand, are numerous and disparate (see García & Ramírez, 2016, their Table 1) for the Northern Colombian Caribbean coast including the Gulf of Salamanca with values ranging from 25.1 cm (Altamar et al., 2015) to 34.0 cm (Arteaga et al., 2004) total length for both sexes. Geographically the closest estimate of Lm is that of Posada-Peláez et al. (2012) whose study area partly overlap ours, with 28 cm total length for both sexes.

In this study, estimations of condition factor, gonadosomatic index and maturation patterns in time are given for *L. synagris* in the Gulf of Salamanca as well as an estimate of Lm. Via linear models the dependency of these indices on several climatic, environmental, and operative variables was explored.

MATERIALS AND METHODS

Fig. 1 shows the study area and the sampling stations. Sampling was conducted monthly from April 1997 to March 1998, excepting January and June. Stations were selected in three clusters according to oceanographic conditions in the Gulf of Salamanca which at the center shows an intrusion of oceanic water (García et al., 2013), plus some interspersed stations. Trawling operations at a station lasted an average 30 minutes at an average speed of 3.5 knots. On board *L. synagris* individuals were measured (standard length) and weighted. A representative sample of fishes were brought to the lab (in total 166 males and 123 females) and the stage of maturation was assessed by the appearance of gonads according to the scale of Holden & Raitt (1975). Afterwards the gonads of males and females were extirpated and weighted. Fishes classified in stage III, IV

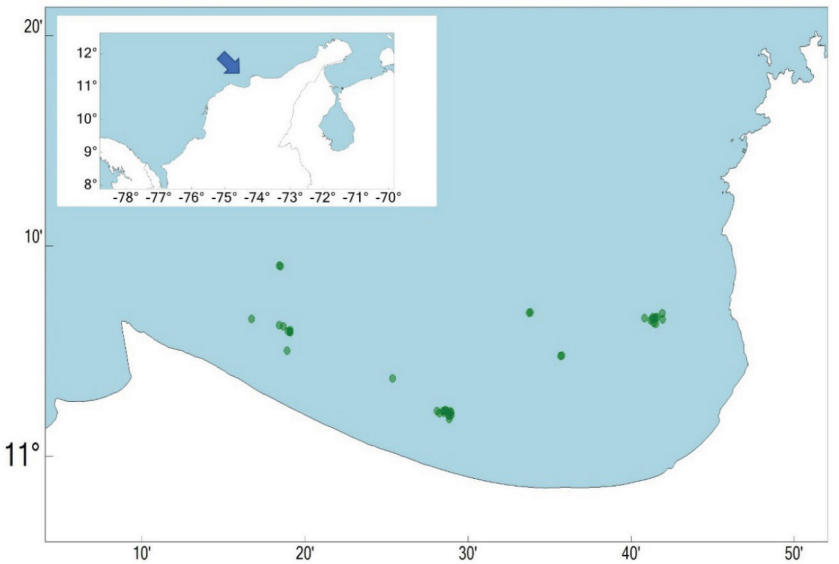

Fig. 1. Study area Gulf of Salamanca, Colombian Caribbean, and sampling stations. The arrow shows the position of the Gulf of Salamanca in the Colombian Caribbean coast.

and V (Holden & Raitt, 1975) of gonadal development were labeled as mature. At each station measurements of bottom salinity and temperature were made with the aid of a CTD probe.

Condition factor was found with the formula (Le Cren, 1951): CF = Wex / Wob, where Wex is the expected weight of an individual and Wob is the observed weight of the same individual. Expected weights were estimated from the length weight relationship derived by García et al. (1998) that originated from cruises in the study area in the period 1995 to 1998. The length weight relationship is based on 2015 individuals, size ranging from 8 cm to 33.5 cm (García et al., 1998). The formula for Wex is: $Wex = 0.0898 \times (SL / 10)^{2.63}$, where SL is standard length (cm). The gonadosomatic index was found with the formula: GDS = 100 × (Wgo / Wob), where Wgo is the weight of the gonad and Wob is the observed weight of the same individual.

Temporal trends of both indices and of the incidence in percentage of mature versus unmature fish were explored by means of boxplots and barplots. To estimate Lm for males, females and both sexes a logistic regression model was adjusted to the raw mature-immature data with individual lengths as the predictor variable. The Lm estimated and their bootstrap confidence intervals were transformed from standard length to total length (TL) with the formula $TL = 0.0 + 1.203 \times SL$, found in FishBase for *L. synagris* (Froese & Pauly, 2023).

The dependency of condition factor (CF) and gonadosomatic index (GDS) on variables related to climate (bottom salinity and temperature), space (latitude and longitude decimal transformed and depth), and fish behavior (time of the day when captured decimal transformed and moon phase of the day of capture) were explored. Latitude, longitude, depth, and time of the day correspond to the middle position and time of the research ship during a given tow. Correlations among the quantitative variables were found to be less than 0.5 (Pearson correlation test) in all cases. The linear model is CF / GDS ~ Latitude + Longitude + Depth + Time + Temperature + Salinity + Moon Phase. Regarding the results of the model, the dependency of CF and GDS on the moon phases was further explored with the model: CF / GSD ~ Moon Phase.

Multiple comparisons of means were conducted with the Tukey HSD test. Numerical analysis and graphics were done with R base (R Core Team, 2021) and R packages parzer (Chamberlain & Sagouis, 2021), car (Fox & Weisberg, 2019), ggplot2 (Wickham, 2016), cowplot (Wilke, 2020), Rmisc (Hope, 2022) and multcomp (Hothorn et al., 2008).

RESULTS

Fig. 2 and Fig. 3 show the monthly estimates of CF and GDS index, respectively. Except for March samples, no peak is noticeable in CF with ups and downs around one across the year and this is true for males, females and both sexes (Fig. 2A, Fig. 2B, Fig. 2C). The peak in March median is probably due to a small sample size (n = 8). CF medians grouped by season do not differ, but CF is more dispersed in the dry season (Fig. 2D). GDS index (Fig. 3) behaves in a richer fashion than CF. For males, females and both sexes there appear to be a building up of gonad material as the year progresses to May in the case of males and to September in the case of females, but with great dispersion (Fig. 3A, Fig. 3B). When plotted together the GDS index shows maximum values in March and April (Fig. 3C). Female gonads are noticeable heavier than male gonads as evidenced by the scale of the plots (Fig. 3). When grouped by season no difference in median GDS index is noticeable (Fig. 3D).

The incidence in percentage of mature individuals in the year is shown in Fig. 4. Mature males and females were found in all monthly samples. Proportionally mature females showed higher incidence than males (Fig. 4A, Fig. 4B). In general, the incidence of mature individuals is higher in the first months of the year with a decreasing trend from February to August (Fig. 4C). However, when grouped by season no difference in percentage incidence of mature fish is noticeable (Fig. 4D).

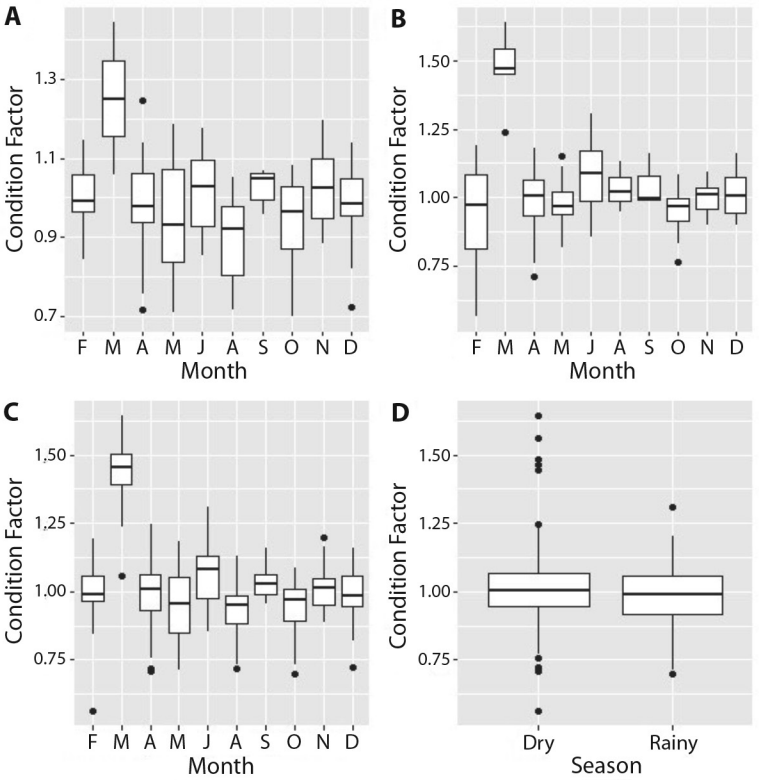

Fig. 2. Monthly series of condition factor of *Lutjanus synagris* in the Gulf of Salamanca, Colombian Caribbean from April 1997 to March 1998. **A.** Males. **B.** Females. **C.** Both. **D.** Seasonal comparison for both sexes.

The logistic model provides an estimate of Lm of 27 cm 26-28 CI (confidence interval) for males, 25 cm 24-26 CI for females and 26 cm 25-27 CI for both sexes (Fig. 5) which are within the same order of magnitude of other Lm estimates (see García & Ramirez, 2016, their Table 1) in the Northern Colombian Caribbean.

Results of the linear models adjusted to CF and GDS indices are shown in Table 1 and Table 2, respectively. An interesting finding is that moon phase has a significant effect in all instances ($p < 0.05$) affecting both indices and sexes (Table 1, Table 2). These results prompted the formulation of an additional linear model to closely explore the effect of moon phases, which is referred further below.

Predictors affected differentially CF and GDS indices of males and females. CF of males is affected positively by latitude while it is negatively affected by bottom temperature. CF of females is affected positively by longitude and negatively by time of the day when the

Table 1

Association between predictor variables and condition factor for *Lutjanus synagris* in the Gulf of Salamanca, Colombian Caribbean.

Variables/Sex	Males	Females	Both
Latitude	**< 0.05 +**	N.S.	**< 0.05 +**
Longitude	N.S.	**< 0.05 +**	N.S.
Depth	N.S.	N.S.	N.S.
Time	N.S.	**< 0.05 -**	N.S.
Temperature	**< 0.05 -**	N.S.	**< 0.05 -**
Salinity	N.S.	N.S.	**< 0.05 +**
Moon phase	**< 0.05**	**< 0.05**	**< 0.05**

The sign positive or negative indicates the direction of the association. Number in the table is the p-value of the test of hypothesis of no association. N.S., not significant.

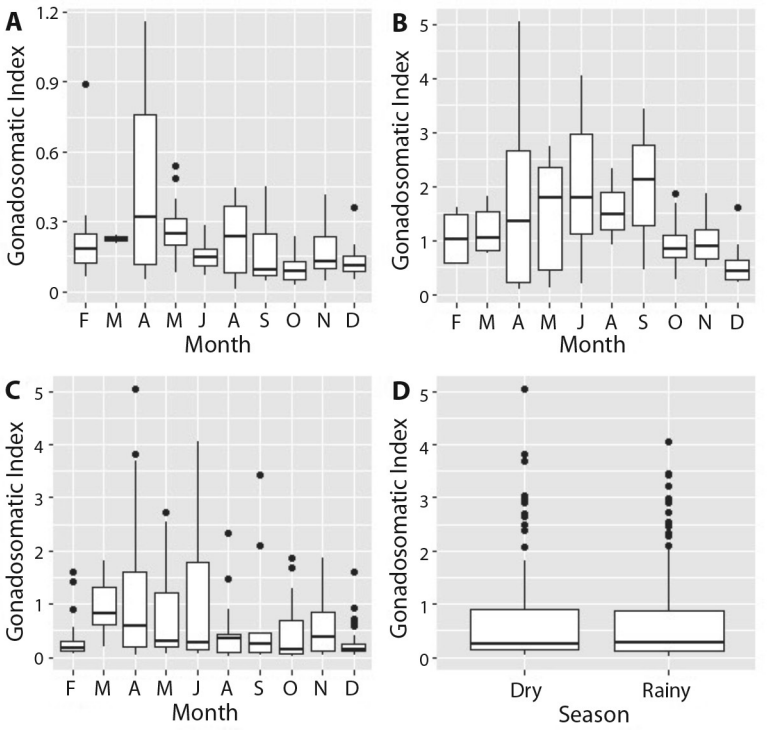

Fig. 3. Monthly series of gonadosomatic index of *Lutjanus synagris* in the Gulf of Salamanca, Colombian Caribbean from April 1997 to March 1998. **A.** Males. **B.** Females. **C.** Both. **D.** Seasonal comparison for both sexes.

Table 2
Association between predictor variables and gonadosomatic index for *Lutjanus synagris* in the Gulf of Salamanca, Colombian Caribbean.

Variable/Sex	Males	Females	Both
Latitude	N.S.	N.S.	N.S.
Longitude	**< 0.05 +**	N.S.	N.S.
Depth	N.S.	**< 0.05 +**	**< 0.05 +**
Time	N.S.	N.S.	N.S.
Temperature	N.S.	**< 0.05 +**	**< 0.05 +**
Salinity	**< 0.05 -**	**< 0.05 -**	**< 0.05 -**
Moom Phase	**< 0.05**	**< 0.05**	**< 0.05**

The sign positive or negative indicates the direction of the association. Number in the table is the p-value of the test of hypothesis of no association. N.S., not significant.

individual was captured (Table 1). GDS index of males, in turn, is affected positively by longitude and negatively by bottom salinity while for females GDS index was positively affected by depth and bottom temperature and negatively by bottom salinity (Table 2). When pooling males and females the response of CF and GDS index was contrasting. CF responded negatively to the bottom temperature and positively to bottom salinity while GDS index responded positively to bottom temperature and negatively to bottom salinity. CF was affected by latitude while GDS was not. GDS index was affected by depth while CF was not (Table 1, Table 2).

The linear model with moon phase as predictor confirmed the results of the full model. For males and females and when pooled CF and GDS indices were significantly affected by the moon phase ($p < 0.05$), except for CF in males. Table 3 shows the results of Tukey HSD multiple comparisons test. Noticeably, while for CF in females and both sexes the moon phase that is different from the others is waxing moon (Fig. 6), for GDS index the moon phase that is different from the others is waning moon (Table 3, Fig. 7).

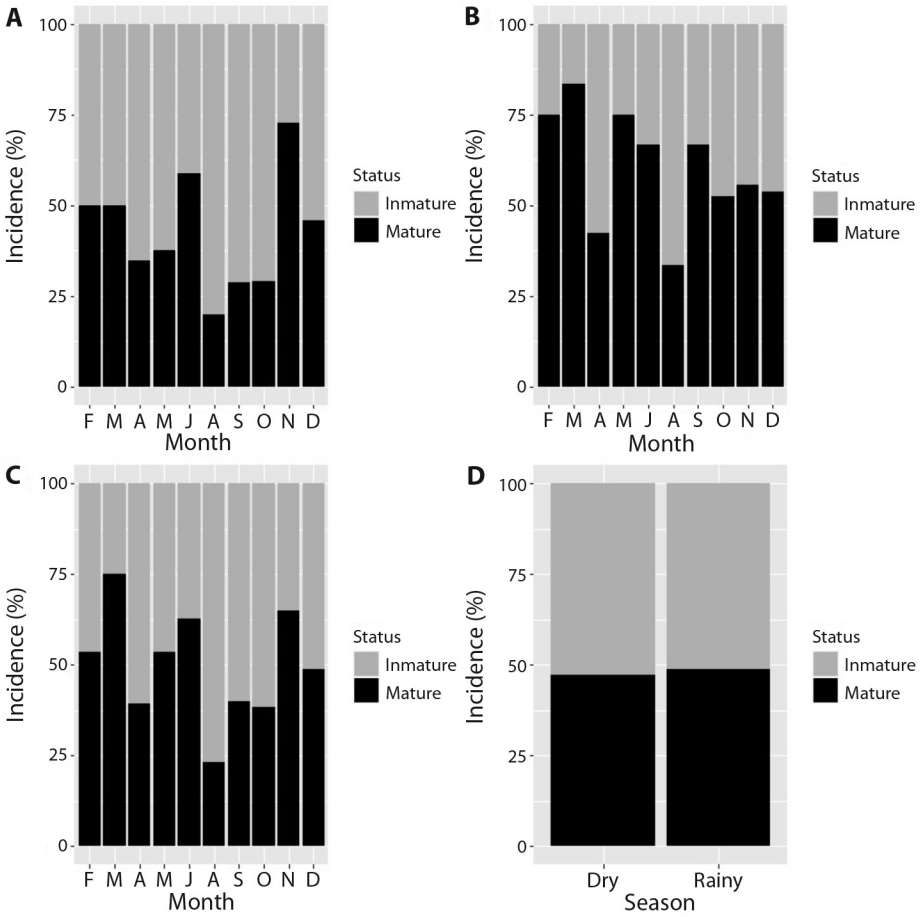

Fig. 4. Monthly percentage incidence series of mature individuals of *Lutjanus synagris* in the Gulf of Salamanca, Colombian Caribbean from April 1997 to March 1998. **A.** Males. **B.** Females. **C.** Both. **D.** Seasonal comparison for both sexes.

Table 3

Multiple comparisons of mean values of condition factor and gonadosomatic index of *Lutjanus synagris* by moon phase in the Gulf of Salamanca, Colombian Caribbean.

Group/Index	Condition Factor	Gonadosomatic Index
Males	$p > 0.05$ for all pairwise comparisons	Waning Moon ≠ New Moon, Full Moon
Females	Waxing Moon ≠ New Moon, Full Moon, Waning Moon	Waning Moon ≠ Full Moon
Both	Waxing Moon ≠ New Moon, Full Moon, Waning Moon	Waning Moon ≠ New Moon, Waxing Moon, Full Moon

Statistical significance was set at < 0.05. Tukey HSD test.

DISCUSSION

The first thing to notice is that the health condition of *L. synagris* was stable over the year and that no time period be it monthly or seasonal has bearing on health status at least in what the condition factor can tell us. Food offer in the year appears to be stable regardless of the seasonal upwelling. Upwelling phenomena have been traditionally associated with increased

Revista de Biología Tropical, ISSN: 2215-2075 Vol. 73: e60355, enero-diciembre 2025 (Publicado Jun. 10, 2025)

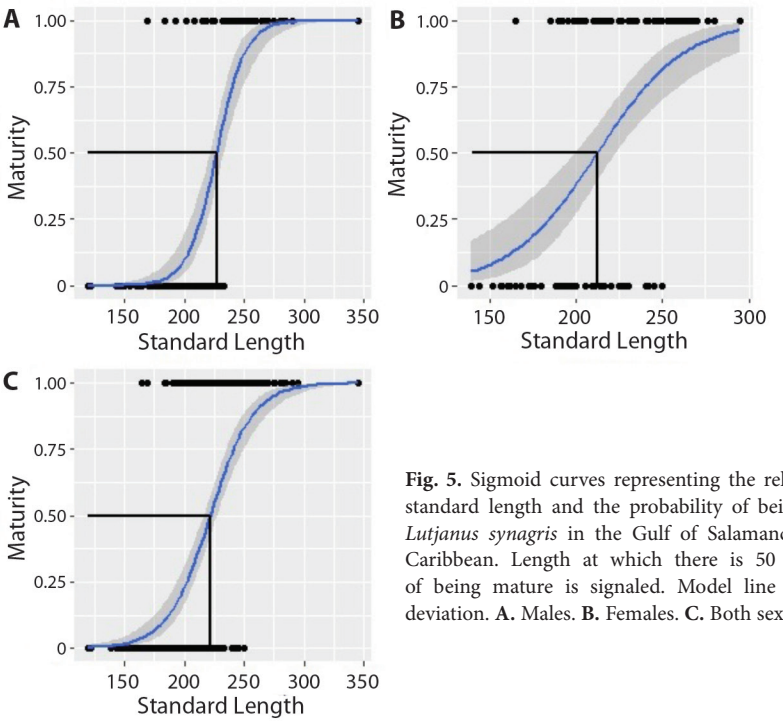

Fig. 5. Sigmoid curves representing the relation between standard length and the probability of being mature for *Lutjanus synagris* in the Gulf of Salamanca, Colombian Caribbean. Length at which there is 50 % probability of being mature is signaled. Model line plus standard deviation. **A.** Males. **B.** Females. **C.** Both sexes.

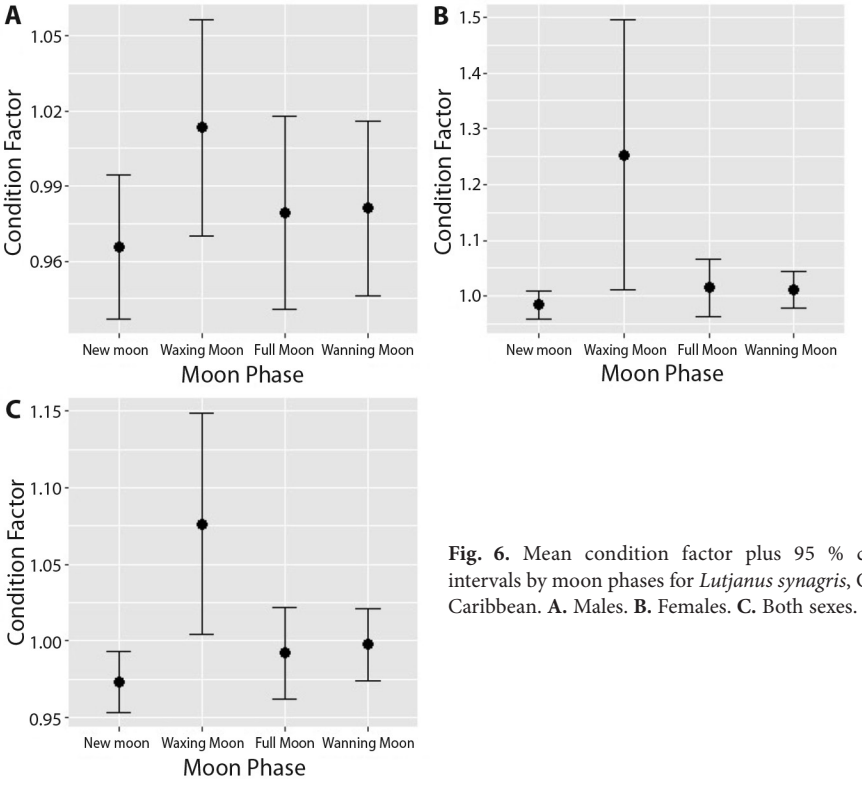

Fig. 6. Mean condition factor plus 95 % confidence intervals by moon phases for *Lutjanus synagris*, Colombian Caribbean. **A.** Males. **B.** Females. **C.** Both sexes.

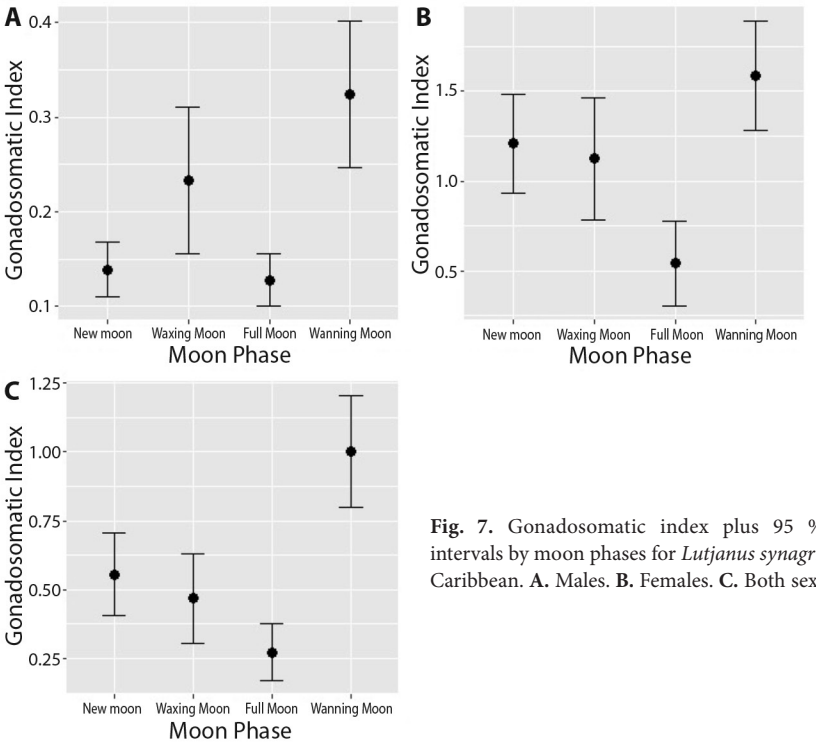

Fig. 7. Gonadosomatic index plus 95 % confidence intervals by moon phases for *Lutjanus synagris*, Colombian Caribbean. **A.** Males. **B.** Females. **C.** Both sexes.

primary productivity and via the food web to better food offer in the water column. However, for the Gulf of Salamanca it has been found that the effect of the upwelling is more reflected on temperature and salinity changes rather than on increased primary production (Ramírez, 1990). For instance, García et al. (2013) found that concentrations of chlorophyll did not differ in the dry (upwelling) and rainy seasons. On the other hand, seasonal change is not without consequences. Duarte & García (1999) found that the importance of crustaceans in the diet of *L. synagris* diminishes in favor of teleost in the dry season.

Males and females of *L. synagris* associated differentially to the predictors explored here in terms of CF. Males respond to the latitudinal gradient while females respond to the longitudinal gradient. Thus, the distribution of individuals in the geographic space is not homogeneous. Further research should be conducted focused on characterizing the environmental gradients offered to *L. synagris* in the Gulf of Salamanca to find a mechanistic explanation of these patterns.

The effect of movement of individuals during the day was detected only for females. The later the capture, the lower the CF. A hypothesis to be explored is whether this pattern is related to a feeding cycle with more incidence of empty stomachs at night. In turn, CF of males had a negative association with bottom temperature while for both sexes a positive association with bottom salinity emerges. These conditions, low temperature and high salinity are reminiscent of the conditions in the dry season (upwelling) thus this pattern enters in contradiction with the finding that no monthly or seasonal trend was found in the year. García et al. (2013) found three water masses in the Gulf of Salamanca with characteristic temperature and salinity and moving limits as the season change. One to the East under the influence of brackish water of the Ciénaga Grande de Santa Marta, one to

the center sector of the Gulf of Salamanca corresponding to a salty oceanic intrusion, and a third to the West under the influence of discharge of the Magdalena River. Thus, the Golf of Salamanca is not a homogeneous water body. The location of the stations may explain this pattern that is in line with the associations with latitude and longitude discussed earlier.

Unlike CF that showed no monthly tendency, the GDS index shows a tendency of increasing median values as the year progresses including and from the dry season (upwelling) and extending beyond. Median monthly values, however, showed substantial variability. On the other hand, the percentage incidence of mature individuals indicates predominance of mature fish approximately in the same months when high GDS index values were seen. Thus, with caveats, it appears that the main spawning activity of *L. synagris* occurred the first part of the year from February to a peak in September for females but continued the year round. These months partly overlap with the range given by Arteaga et al. (2004) and less so with the range given by Posada-Peláez et al. (2012). The main difference is that the range given here fully includes the dry season months. Given that bottom water temperatures and salinity are associated significantly with the GDS index, positively for temperature and negatively for salinity, and temperature increases, and salinity decreases as the year progresses thus it appears that spawning augmented activity is triggered by the gradients of these environmental variables until temperature and salinity reach a maximum and a minimum, respectively.

The same case as with CF, no seasonal difference in median GDS index was found. Considering these findings, the idea that the climate season per se correlates with the spawning cycle in *L. synagris* should be abandoned in favor of a scenario in which it is the gradient of increasing temperature and decreasing salinity that triggers augmented spawning activity.

The estimated length at first maturity, Lm, is well in the range of Lm values calculated for *L. synagris* in the Colombian Caribbean coast. However, these measures have been criticized because many of them come from sampling the fishery instead of sampling the population. García and Ramírez (2016) demonstrated that estimates of Lm significantly correlated to mean size of captured individuals that in turn depended on the selectivity patterns of the fishing gears. Thus, Lm estimates obtained from sampling the fishery do not necessarily reflect what is happening in the population and management measures based on Lm as indicator obtained that way may not be optimal. It would be interesting to conduct research on the current status of this trait in the Gulf of Salamanca for comparison.

The most interesting finding in this study is the significant association between moon phases and both CF and GDS indices values. Many marine species, including fishes, use moon phases as cue to synchronize relevant events in their life cycle (Andreatta & Tessmar-Raible, 2020; Tessmar-Raible et al., 2011) hence it might not be a surprise that *L. synagris* does so. However, to our knowledge in the Colombian Caribbean, apart from some mentions based on fishermen local knowledge (Altamar et al., 2010), the phenomenon of synchronization of biological activity with moon phases has not been documented, excepting Lopez and García (2001) in reference to postlarvae and juveniles of shrimps. In the context of fisheries Altamar et al. (2010) related CPUE with moon phases for the bigeye scad (*Selar crumenophthalmus*).

It is suggestive that while CF is significantly larger in the waxing moon, GDS index is significantly larger in the waning moon. Fishes appear to be preparing for the spawning events along the lunar cycle. This hypothesis should be tested with new research and field sampling designed to test it. At any rate it is clear that the lunar cycle superimposes on the yearly patterns for CF and GDS indices in *L. synagris* in the Gulf of Salamanca.

Shortcomings of the studies referenced here, including this, are the time period of observations that rarely extends more than one year and also that many are dependent on fishery landings instead of unbiased samples of the population. This renders the observations

to criticisms as just anecdotical. However, as reproduction is an event so central in the life history of species it can be viewed as a conservative set of traits. The challenge is to learn how reproduction characteristics that emerged in evolution are modulated by biological, climatic, environmental factors and impacted by human activities like fishing through clear cut questions and well-planned sampling.

Condition factor of the lane snaper *L. synagris* is stable throughout the year when followed at monthly time steps. The gonadosomatic index builds up the first months of the year to a maximum in September. The gradient of increasing temperature and decreasing salinity appears to trigger augmented spawning activity rather than a strict conformance with the dry and rainy seasons. Of the predictive variable tested the moon phases were the most determinant with the waxing moon significantly associated to the highest values of condition factor and the waning moon significantly associated to the highest values of the gonadosomatic index.

Ethical statement: The authors declare that they all agree with this publication and made significant contributions; that there is no conflict of interest of any kind; and that we followed all pertinent ethical and legal procedures and requirements. All financial sources are fully and clearly stated in the acknowledgments section. A signed document has been filed in the journal archives.

ACKNOWLEDGMENTS

This work was supported by COLCIENCIAS Grant No 2105-09-176-94 for the project Estudio ecológico pesquero de los recursos demersales del Golfo de Salamanca, Caribe colombiano. Estimación de la variabilidad de los componentes biológicos del Sistema. Comments by two anonymous reviewers helped to improve the manuscript.

REFERENCES

Allen, G. R. (1985). Snappers of the world. An annotated and illustrated catalogue of lutjanid species known to date. *FAO Fishery Synopsis*, *125*(6), 1–208.

Altamar, J., Manjarrés-Martínez, L., Duarte, L. O., Cuello F., & Escobar-Toledo, F. (2015). *Qué tamaños deberíamos pescar?* [Technical Report]. Autoridad Nacional de Acuacultura y Pesca (AUNAP), Universidad del Magdalena.

Altamar, J., Parraga, D., & Duarte, L. O. (2010). Influencia de la fase lunar en las tasas de captura de *Selar crumenophthalmus* (Carangidae) en el caribe de Colombia. Una aproximación por modelos lineales generalizados. *Acta Biológica Colombiana*, *15*(3), 121–130. https://doi.org/10.15446/abc

Andrade, C. A., & Barton, E. D. (2005). The Guajira upwelling system. *Continental Shelf Research*, *25*, 1003–1022. http://dx.doi.org/10.1016/j.csr.2004.12.012

Andreatta, G., & Tessmar-Raible, K. (2020). The still dark side of the moon: Molecular mechanisms of lunar-controlled rhythms and clocks. *Journal of Molecular Biology*, *432*, 3525–3546. https://doi.org/10.1016/j.jmb.2020.03.009

Arteaga, E., Criales-Hernandez, M. L., Rodriguez, D. J., Gomez-Canchong, P., & Manjarres, L. (2004). Dinámica reproductiva de los stocks de pargo rayado *Lutjanus synagris* (Linnaeus, 1758) en el área norte del Caribe Colombiano. In L. Manjarres (Ed.), *Pesquerías demersales del área norte del mar Caribe de Colombia y parámetros biológico-pesqueros y poblacionales del recurso pargo* (pp. 203–215). Universidad del Magdalena.

Chamberlain, S., & Sagouis, A. (2021). *parzer: Parse messy geographic coordinates. R package* (Version 0.4.1.) [Software]. CRAN. https://CRAN.R-project.org/package=parzer

Cope, J. M., & Punt, A. E. (2009). Length-based reference points for data-limited situations: Applications and restrictions. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science*, *1*, 169–186. https://doi.org/10.1577/C08-025.1

Duarte, L. O., & García, C. B. (1999). Diet of the lane snapper, *Lutjanus synagris* (Lutjanidae), in the Gulf of Salamanca, Colombia. *Caribbean Journal of Science*, *35*(1-2), 54–63.

Fontoura, N. F., Braun, A. S., & Milani, P. C. (2009). Estimating size at first maturity (L50) from gonadosomatic index (GSI) data. *Neotropical Ichthyology*, *7*(2), 217–222. http://dx.doi.org/10.1590/S1679-62252009000200013

Fox, J., & Weisberg, S. (2019). *An R Companion to Applied Regression* (3rd ed.). SAGE Publications.

Froese, R., & Pauly, D. (Eds.). (2023). *FishBase*. World Wide Web electronic publication. https://www.fishbase.org/

Froese, R., Stern-Pirlot, A., Winker, H., & Gascuel, D. (2008). Size matters: How single-species management can contribute to ecosystem-based fisheries management. *Fisheries Research*, *92*, 231–241. http://dx.doi.org/10.1016/j.fishres.2008.01.005

García, C. B. (2010). Conocimiento tradicional: Lo que los pescadores artesanales del Caribe colombiano tienen para decirnos. *Pan-American Journal of Aquatic Science*, *5*(1), 78–90.

García, C. B. (2018). Spatial richness patterns of soft bottom fish in the Colombian Caribbean shelf and slope. *Acta Biológica Colombiana*, *23*(1), 59–65. http://dx.doi.org/10.15446/abc.v23n1.66530

García, C. B., & Armenteras, D. (2015). *Atlas de la ictiofauna demersal de fondos blandos del Caribe Continental Colombiano: Aproximación a su biodiversidad.* Universidad Nacional de Colombia, Facultad de Ciencias.

García, C. B., & Duarte, L. O. (2024). A diagnosis of the artisanal fishery landings in the Colombian Caribbean coast by means of indicators. *Marine and Fishery Sciences*, *37*(2), 277–293. https://doi.org/10.47193/mafis.3722024010504

García, C. B., & Ramirez, J. (2016). Perceived length at first maturity in the lane snapper, *Lutjanus synagris* (Linnaeus, 1758) (Perciformes: Lutjanidae), along the Caribbean coast of Colombia. *Pan-American Journal of Aquatic Science*, *11*(1), 60–69.

García, C. B., Duarte, L. O., & Ramírez, G. (2013). Fisiografía y oceanografía del Golfo de Salamanca (mar Caribe, Colombia). In L. M. Melgarejo, C. B. García (Eds.), *Investigación en Ciencias del Mar: Aportes de la Universidad Nacional de Colombia* (pp. 111–140). Universidad Nacional de Colombia. Facultad de Ciencias. Red de Estudios del Mundo Marino, REMAR.

García, C. B., Duarte, L. O., & von Schieller, D. (1998). Demersal fish assemblages of the Gulf of Salamanca, Colombia (southern Caribbean Sea). *Marine Ecology Progress Series*, *174*, 13–25. https://doi.org/10.3354/meps174013

Gubiani, E. A., Ruaro, R., Ribeiro, V. R., & Gomez de Santa Fe, U. M. (2020). Relative condition factor: Le Cren's legacy for fisheries science. *Acta Limnologica Brasilera*, *32*, e3. https://doi.org/10.1590/S2179-975X13017

Holden, M. J., & Raitt, D. F. (1975). *Manual de ciencia pesquera. parte 2. Métodos para investigar los recursos y su aplicación*. Documento Técnico de Pesca Nº 115. FAO. https://openknowledge.fao.org/handle/20.500.14283/f0752s

Hope, R. M. (2022). *Rmisc: Ryan miscellaneous. R package* (Version 1.5.1.) [Software]. CRAN. https://CRAN.R-project.org/package=Rmisc

Hothorn, T., Bretz, F., & Westfall, P. (2008). Simultaneous inference in general parametric models. *Biometrika*, *50*(3), 346–363. https://doi.org/10.1002/bimj.200810425

Le Cren, E. D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology*, *20*(2), 201–219. http://dx.doi.org/10.2307/1540

Lopez, A. C., & García, C. B. (2001). Postlarvas y juveniles de camarones *Farfantepeneus* spp y *Xiphopenaeus kroyeri* en la Boca de la Barra (Ciénaga Grande de Santa Marta), Caribe Colombiano. *Boletín de Investigaciones Marinas y Costeras*, *30*, 177–198.

Lowerre-Barbieri, S. K., Ganias, K., Saborido-Rey, F., Murua, H., & Hunter, J. R. (2011). Reproductive timing in marine fishes: Variability, temporal scales, and methods. *Marine and Coastal Fisheries*, *3*, 71–91. http://dx.doi.org/10.1080/19425120.2011.556932

Manjarres, L., García, C. B., & Acero, A. (2001). Caracterización ecológica de las asociaciones de peces demersales del Caribe Colombiano norte con énfasis en los pargos (Lutjanidae). *Boletín de Investigaciones Marinas y Costeras*, *30*, 77–107.

Martínez-Viloria, H. M., Franke-Ante, R., Narváez-Barandica, J. P., & De La Hoz-Maestre, J. (2022). Estado de *Lutjanus synagris* en tres áreas protegidas del Caribe colombiano: Evaluación basada en datos limitados. *Boletín de Investigaciones Marinas y Costeras*, *51*(2), 83–106. https://doi.org/10.25268/bimc.invemar.2022.51.2.1104

Ministerio de Agricultura y Desarrollo Rural. (2024). *Series Históricas*. Servicio Estadístico Pesquero Colombiano (SEPEC). http://sepec.aunap.gov.co/Estadisticas/SeriesHistoricas

Posada-Peláez, C., Santafé-Muñoz, A., Grijalba-Bendeck, M., Bustos-Montes, D., González-Sarmiento, E., de la Hoz-Maestre, J., Castro-Martinez, L., Gómez-Cubillos, C., Guerrero-Berna, P., Olaya-Reyes, C., Palacio-Barros, C. M., & Restrepo-Gómez, D. (2012). Aspectos biológicos de las principales especies comerciales de la zona costera del departamento del Magdalena, Caribe colombiano. In M. Grijalba-Bendeck, D. Bustos-Montes, C. Posada-Peláez, & A. Santafé-Muñoz (Eds), *La pesca artesanal marítima del departamento del Magdalena (Colombia). Una visión desde cuatro componentes* (pp. 115–415). Fundación Universidad de Bogotá Jorge Tadeo Lozano, Ministerio de Agricultura y Desarrollo Rural.

R Core Team (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Ramírez, G. (1990). Evaluación de parámetros hidrográficos y su relación con la surgencia en las aguas costeras. In J. M. Díaz (Ed.), *Estudio ecológico integrado de la zona costera de Santa Marta y Parque Nacional Natural Tayrona* (pp. 19–54). INVEMAR.

Ramírez, J. G., Lleonart, J., Coll, M., Reyes, F., & Puentes, G. (2017). Improving stock assessment and management advice for data-poor small-scale fisheries through participatory monitoring. *Fisheries Research*, *190*, 71–83. http://dx.doi.org/10.1016/j.fishres.2017.01.015

Salazar-Perez, C., Choles-Rodriguez, E., & Manjarres-Martinez, L. (2020). Short-term changes in demersal fish assemblages exploited by an artisanal set gill net fishery in the Caribbean Sea (Colombia). *Ciencias Marinas*, *46*(1), 39–56. http://dx.doi.org/10.7773/cm.v46i1.3041

Tessmar-Raible, K., Raible, F., & Arboleda, E. (2011). Another place, another timer: Marine species and the rhythms of life. *BioEssays*, *33*, 165–172. https://doi.org/10.1002/bies.201000096

Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer.

Wilke, C. O. (2020). *cowplot: Streamlined Plot Theme and Plot Annotations for 'ggplot2'. R package* (Version 1.1.1.) [Software]. CRAN. https://CRAN.R-project.org/package=cowplot