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Research Article

Somatic condition and average catch size of the Mexican barred snapper *Hoplopagrus guentherii* in the northwestern Gulf of California

Marcial Trinidad Villalejo-Fuerte[1], Leonardo Andrés Abitia-Cárdenas[1] Nurenskaya Vélez-Arellano[2], Arturo Tripp-Quezada[1] & Julio César Martínez-Ayala[1]
[1]Instituto Politécnico Nacional, Centro Interdisciplinario de Ciencias Marinas
La Paz, Baja California Sur, México
[2]Laboratorio de Ecología de Pesquerías y Cuerpo Académico Manejo de Recursos Pesqueros
Facultad de Ciencias del Mar, Universidad Autónoma de Sinaloa, Mazatlán, México
Corresponding author: Nurenskaya Vélez-Arellano (nurens@hotmail.com)

ABSTRACT. The present study aimed to understand the population dynamics of the Mexican barred snapper *Hoplopagrus guentherii* in Santa Rosalía, Gulf of California. This species is among the most economically important resources of artisanal fisheries. The size structure ranged from 28 cm (female) to 69 cm (male) total length. The weight-length relationship expressed with the equation $W = a \times Lt^b$ for all specimens and by sex indicated isometric growth. There was a greater number of females than males. The gonadosomatic index showed two maturity peaks in April and June and two spawning periods in May and July. The hepatosomatic index decreased during spawning, reflecting the energy translocation, but the general condition of *H. guentherii* did not vary significantly during the year. The size at first capture was estimated to be 42.5 cm in total length, constituting basic information for the fisheries management of the species.

Keywords: *Hoplopagrus guentherii*; population dynamics; morphophysiological indices; management

INTRODUCTION

Snapper species are large predatory fish that inhabit coral reefs, mangroves, and seagrass ecosystems. They function as energy transporters and ecological controls of crustaceans, mollusks, and other low-level trophic consumers. They are commonly associated with live-bottom and deep reef areas (Bermúdez-Almada & García-Laguna 1985, Franks & Vanderkooy 2000, Manzanilla-Verde et al. 2023). Snappers significantly contribute to commercial and recreational landings in tropical and subtropical regions (Amezcua et al. 2006, Piddocke et al. 2015). They are caught using nets and handlines and sold fresh (Allen 1985). Due to its economic importance, some species are estimated to be overfished or at risk of overfishing (Amezcua et al. 2006, Murugan et al. 2014, Manzanilla-Verde et al. 2023). However, the lack of information regarding its biological growth and the socioecological vulnerability of the resource makes the attempts to implement a management plan difficult (Amezcua et al. 2006, Piñón et al. 2008 Manzanilla-Verde et al. 2023).

The Mexican barred snapper *Holopagrus guentherii* Gill, 1862, is one of the ten most economically important reef species in the Gulf of California. It is part of the multispecies snapper fishery (DOF 2023). It is endemic to the eastern Pacific and is distributed from southern Baja California and the northern Gulf of California to Ecuador, including the Galapagos, Malpelo, and Cocos islands (Allen 1985). This species inhabits rocky and coral reefs, which can be found down to 100 m depth. Juveniles can enter the lagoons on rocky shores (Allen & Robertson 1994). It is caught using handlines and gillnets.

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Information on the biology of *H. guentherii* is scarce, and the International Union for the Conservation of Nature (IUCN) catalogs it as Least Concern (CMS 2015). Besides a minimum catch size (Amezcua 2007, DOF 2023), no other conservation measures exist. It has been classified generally as a carnivorous, nocturnal predator that is predominantly benthic and consumes fishes, mollusks, crustaceans, and echinoderms (Thomson et al. 1979, Bermúdez-Almada & García-Laguna 1985, Abitia-Cárdenas et al. 1990, Allen & Robertson 1994). No information has been published in the past three decades regarding population dynamics, individual growth, reproductive biology, or details on the feeding strategy of this species.

Analyses of the fish population size structure, weight-length relationships, and sexual proportions describe the state of populations, allowing the estimation of weight based on length or of weight according to age (Le Kren 1951, Ricker 1968, Beyer 1991, Pauly 1993, Petrakis & Stergiou 1995, González-Gándara et al. 2003), and also weight-length relationships allow annual comparisons of morphological indices among fish populations in different regions or evaluations of interannual variations of the same population (Ozaydın & Taskavak 2006).

Considering the mentioned above, the present study describes the size structure, weight-length relationship in general and by sex, sexual proportion, variation of the gonadosomatic and hepatosomatic indices over an annual cycle, and average catch size of *H. guentherii* to contribute to its fishery management.

MATERIALS AND METHODS

Samples of *H. guentherii* were obtained monthly from January to December 2022 at the port of Santa Rosalía, Baja California Sur (27°19′45.14″N, 112°15′13.40″W) (Fig. 1). Specimens were caught by the artisanal fishing fleet that operates outboard motorboats between 1 and 15 nm from the coast. Fishermen use fishing lines with Norway number 6 hooks, and monofilament gillnets with a 15 cm mesh size. Nets were placed at 5 to 30 m depth for 10 to 12 h. Specimens were sampled randomly and processed in the field immediately after landing.

Total length (TL) was measured with a 1 mm precision ichthyometer; total weight (TW), gonadal weight (GW), and liver weight (LW) were measured with a digital scale with ± 0.01 g precision. Sex was identified by visual examination, considering three categories: males, females, and undifferentiated; the latter corresponded to fish whose sex could not be identified visually according to the criteria by Nikolsky (1963).

Fishery samples' size and weight structure were calculated in general and by sex. The weight-length relationship was also calculated in general and by sex, using the equation $W = a \times Lt^b$. The sexual proportion was analyzed in general, by size, and by weight with a χ^2 analysis.

The monthly variation of the gonadosomatic index (GSI) was used to infer the population's maturation and spawning periods. The interpretation of this index was based on the following criteria: a sustained increase in the index was interpreted as gamete development, the highest point of the curve as an indicator of population maturity, a sustained decrease as evidence of gamete expulsion, and low values as post-spawning and inactivity (Villalejo-Fuerte & Ceballos-Vázquez 1996).

$$\mathrm{GSI} = \frac{\text{Gonadal wet weight(g)}}{\text{Eviscerated fish wet weight (g)}} \times 100$$

The metabolic activity of the liver was estimated with the hepatosomatic index (HSI). The interpretation of liver relative weight variability assumed the existence of annual oscillations due to the accumulation and use of biochemical reserve substances in the liver (Hile 1936, Le Kren 1951, Hismayasari et al. 2015).

$$\mathrm{HSI} = \frac{\text{Liver wet weight (g)}}{\text{Eviscerated fish wet weight (g)}} \times 100$$

The general condition of the population was estimated with Fulton's condition factor (CF), which is an indicator of the species' feeding or reproductive condition (Fulton 1904). Criteria by Hile (1936) and Le Kren (1951) were used to interpret this index, assuming higher levels of the CF occur when the population has an optimal physiological condition and low values are due to the use of reserves stored in somatic tissues.

$$\mathrm{CF} = \frac{\text{Eviscerated wet weight (g)}}{\text{Total length}^3\text{ (cm)}} \times 100$$

Finally, monthly means were compared to analyze the annual variation of the indices using Kruskal-Wallis tests and Dunn's multiple comparisons tests (Zar 2009).

The average catch size (Lc) is obtained at 50% of the cumulative relative frequency of individuals captured (Sparre & Venema 1997). To estimate Lc, the total lengths of specimens were grouped in 2 mm intervals, obtaining the absolute and relative frequencies by size class and the cumulative relative frequencies; the latter were graphed as observed data, and the resulting curve was fit to the logistic model (Sparre & Venema 1997). The mathematical model used was the following:

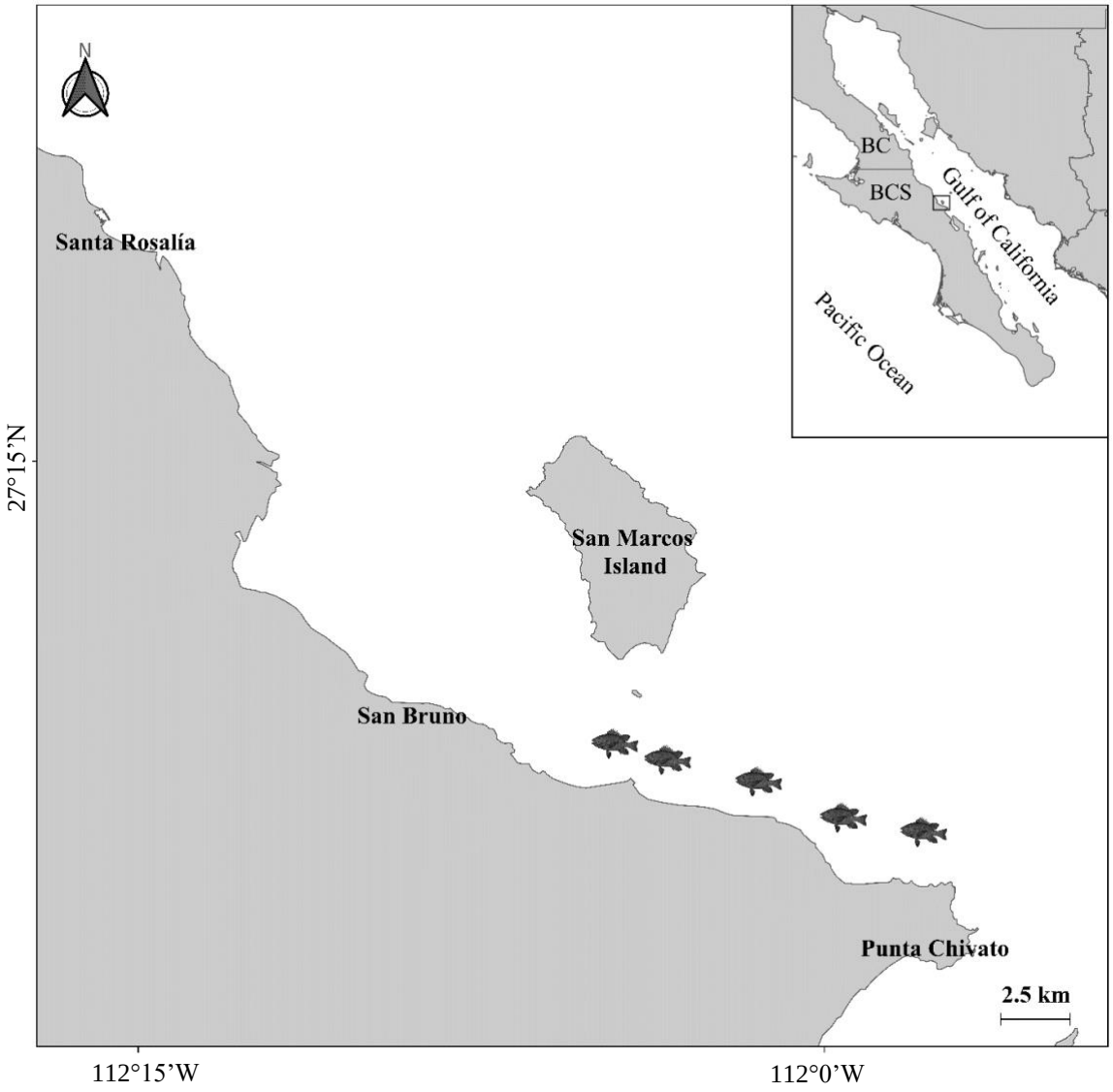

Figure 1. Location of the study area. Fishing areas are shown with images of snappers in the northwestern Gulf of California. BC: Baja California, BCS: Baja California Sur.

$$Lc = \frac{1}{1 + e^{(a-(b\times TL))}}$$

where Lc is the estimated frequency of organisms caught with respect to TL, and *a* and *b* are constants obtained with an iterative method using the program R.

The average catch size of the *H. guentherii* wild population was obtained by finding the inflection point corresponding to 50% of the Lc curve (Lc_{50}% = absolute a/b value).

RESULTS

Two hundred eighty-two Mexican barred snappers *H. guentherii* were sampled in Santa Rosalía, Gulf of California. TL ranged from 28 cm (female caught in August) to 69 cm (male caught in April). The mean TL was 44.2 cm, and the standard deviation was 7.5 cm; TW ranged from 0.441 to 6.745 kg, with a mean of 1.868 kg and a standard deviation of 1.078 kg (Fig. 2, Table 1).

The weight-length relationship, expressed with the equation $W = a \times Lt^b$ for all sampled specimens and by sex, indicated isometric growth with a high correlation coefficient (Fig. 3, Table 2), n = 282.

In addition to a high correlation of the weight-length relationship for each sex, obtained with the equation $W = a \times Lt^b$, the Student's t confidence intervals showed that the slope did not differ significantly from positive

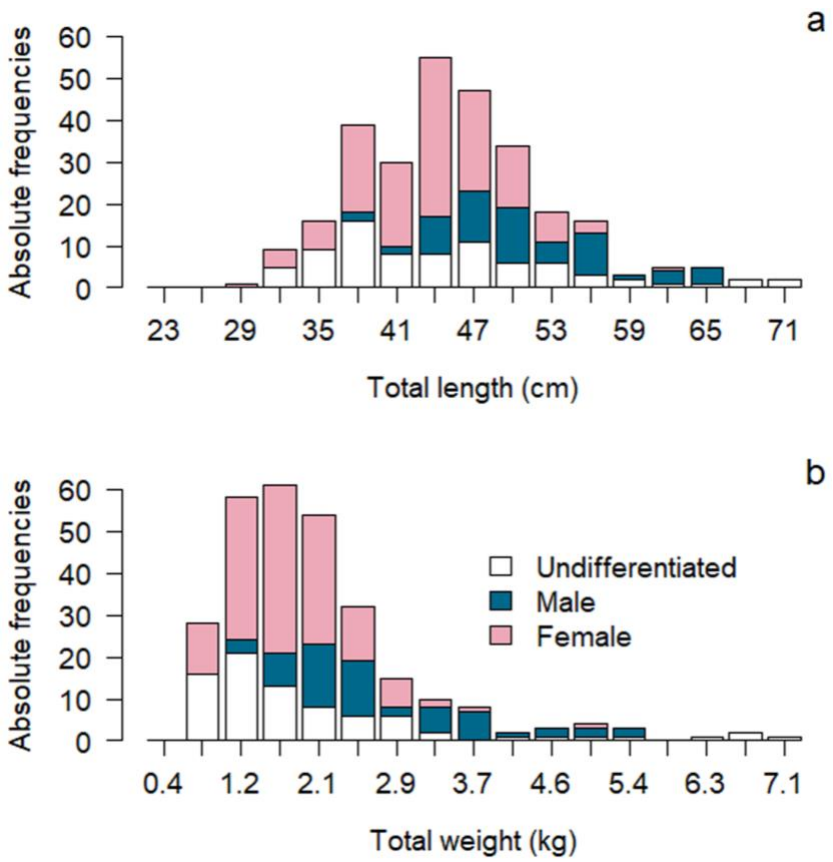

Figure 2. General size and weight structure of the Mexican barred snapper *Hoplopagrus guentherii* landings from January to December 2022 in the northwestern Gulf of California. a) Total length, and b) total weight.

Table 1. The mean of total length (TL), total weight (TW), and sexual proportion in general and by month of the Mexican barred snapper *Hoplopagrus guentherii* from January to December 2022, with standard deviations (SD), n = 282. *Indicates significant differences. F: females, M: males, UND: undifferentiated.

Month	n	Descriptive statistics				Sexual proportion			χ^2
		TL (cm)	SD (cm)	TW (kg)	SD	F	M	UND	
Jan	21	38.62	4.28	1.1453	0.3668	17	0	4	17*
Feb	15	45.83	5.40	1.8017	0.6151	3	0	12	3
Mar	31	48.96	7.80	2.4567	1.1494	13	17	1	0.5
Apr	22	49.20	10.2	3.3202	1.9264	12	9	1	0.7
May	12	43.50	9.26	1.8275	1.3129	6	1	5	3.6
Jun	12	46.25	6.22	2.0842	0.8536	7	3	2	1.6
Jul	23	44.59	6.29	1.9398	0.8295	12	11	0	0.0
Aug	38	38.69	4.86	1.2086	0.4606	16	3	19	8.9*
Sep	14	44.97	4.95	1.8596	0.5385	7	5	2	0.3
Oct	31	44.48	8.64	1.9657	1.2066	12	10	9	0.2
Nov	13	41.87	5.88	1.5209	0.6963	10	1	2	7.4*
Dec	50	43.43	3.92	1.6461	0.4174	38	10	2	16.3*
Total	282					152	68	62	38.7*

isometric growth for both sexes together and by sex. Therefore, we infer this species' shape does not change during its growth (Table 2). Males presented significantly greater sizes and weights than females and undifferentiated organisms (Table 3).

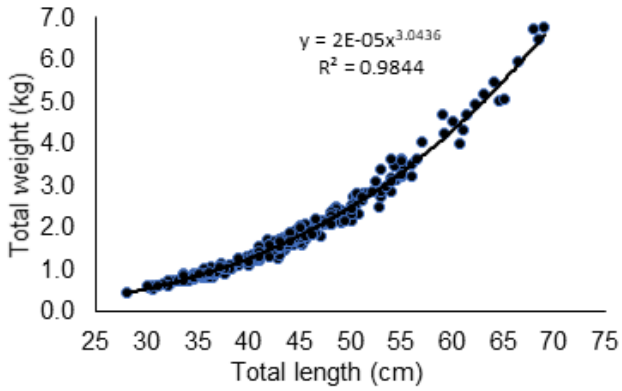

Figure 3. Length-weight relationship for all sampled Mexican barred snapper *Hoplopagrus guentherii* specimens from the northwestern Gulf of California fishery (n = 282).

The visual examination of gonads after dissection showed that ovaries were cylindrical, ranging from pink to red. Testicles were white and triangular-shaped, whereas undifferentiated specimens presented very thin, thread-shaped, transparent to white gonads. The sexual proportion by month showed that no males were recorded in January and February, and no undifferentiated individuals were recorded in July (Table 1).

GSI variations showed a sustained increase in March (March 23), with two peaks that differed significantly from the other months, in April (April 26) and June (June 13), as well as a noticeable decrease in May and July. Values were low during the remaining months (Fig. 4a). This suggests that the first spawning period could occur in May, only 30 days after the highest GSI peak.

The HSI showed a sustained increase during the first four months of the year, a significant decrease in May compared with April, and a maximum in June, which differed significantly from the remaining months, except July. During July and August, sustained decreases and values were low during the remaining months (Fig. 4b). The CF showed little variability during the study period; there was only a significant decrease in February compared with the remaining months (Fig. 4c).

The average catch size of the 282 specimens sampled from the commercial fleet was 42.5 cm TL (Fig. 5).

DISCUSSION

The coefficient of correlation of the weight-length relationship (r = 0.992) indicated a high correlation between relative growth and Mexican barred snapper weight and TL. The slope of the curve (b = 3.0) suggested isometric relative growth, according to the criteria by Crozier & Selig (1914). Espino-Barr et al. (2008) reported similar weight-length relationship values to those found in this study for 108 *H. guentherii* specimens (a = 0.043, b = 2.982, and coefficient of determination R^2 = 0.972), which led them to conclude that the Mexican barred snapper presents isometric growth. We deduce that morphological correlations in *H. guentherii* are adequate to use indices to describe the annual variation in the physiological condition (Le Kren 1951) and to apply growth models structured by age (Bertalanffy 1934, Sparre & Venema 1997, Salgado-Ugarte & Saito-Quezada 2020).

The size and weight analysis by sex showed that males were significantly larger and heavier than females. These differences could be explained by the differential growth of the two sexes; however, this was not part of the present study. There is currently no published information on the sexual differentiation of *H. guentherii*; however, the results of this study indicated that it is a gonochoric species.

The sexual proportion analysis showed significant differences in the proportion of males and females for the entire sample. In the months when there were significant differences in sexual proportion, there was a greater number of females, which indicates that artisanal fishermen are catching more females. This difference in sexual proportion could be explained by the migration of males to deeper areas, probably to feed, which makes them less vulnerable to the fishermen's fishing gear. Stark (1971), cited by Santamaría-Miranda et al. (2003), pointed out that gray snapper *Lutjanus griseus* males in Florida were more abundant in reef areas far from the coast, whereas females preferred coastal areas.

The GSI is a reliable estimator of gonadal development in different fish species (Le Kren 1951, Teixeira et al. 2010, Hismayasari et al. 2015, Sharma & Ram 2020). Although the GSI has not been histologically validated for *H. guentherii*, the observed trend suggests that gonadal development begins in February. The GSI curve and sampling dates indicated that 63 days passed from the beginning gonadal development until the first maturation peak. This process involves the proliferation of reproductive cells by mitosis and the later incorporation of vitellus during the growth and maturation of oocytes; this produced an increase in the gonad weight of *H. guentherii*, resulting in increased GSI values, which reached a maximum in April and were interpreted as the maximum maturity stage of the population.

Considering that high GSI values were found in males and females, there may be high synchronization

Table 2. Length-weight relationship and growth type of the Mexican barred snapper *Hoplopagrus guentherii* Student's *t*-test ($P = 0.05$). SE(b): standard error (b), CI: confidence interval.

Sex	n	*a*	*b*	SE(b)	R^2	CI	Growth
Males	68	0.0175	3.03	0.0583	0.98	2.75-3.00	Isometric
Females	152	0.0148	3.08	0.0527	0.99	2.92-3.15	Isometric
Total	282	0.0166	3.04	0.0293	0.99	3.01-3.14	Isometric

Table 3. Length and weight values by sex of the Mexican barred snapper *Hoplopagrus guentherii* (n = 282). Different letters indicate significant differences. F: females, M: males, UND: undifferentiated, SD: standard deviation, CI: confidence interval, $P = 0.05$.

Sex	n	Total length (cm)					Total weight (kg)				
		Mean	SD	CI	Min	Max	Mean	SD	CI	Min	Max
M	68	50.9[a]	7.37	49.1-52.6	36	69	2.801[a]	1.28	2.48-3.11	0.98	6.74
F	152	42.9[b]	6.23	41.9-43.9	28	68	1.672[b]	0.85	1.53-1.81	0.44	6.70
UND	62	40.2[c]	6.04	38.6-41.7	30	53	1.321[c]	0.59	1.16-1.47	0.53	2.85
Total	282	44.25	7.55	43.3-45.1	28	69	1.867	1.07	1.74-1.99	0.44	6.74

in the gonadal maturation of both sexes. A similar result was reported for the spotted rose snapper *Lutjanus guttatus* off the Michoacan coast, Mexico (Sarabia-Méndez et al. 2010), and for the golden snapper *L. inermis* (Lucano-Ramírez et al. 2012). According to the GSI decrease and sampling dates, the first spawning period occurred in May, only 30 days after the highest GSI peak.

It is also probable that this species forms aggregations during the reproductive period, which favors a 1:1 sexual proportion, as happened in this study. A similar behavior has been observed in other Gulf of California snapper species. Vega et al. (2016) reported aggregations of 500 to 700 Pacific red snapper *Lutjanus peru* and 50 to 100 *L. guttatus* spawning individuals in Coiba National Park, Panama. In the Atlantic Ocean, aggregations of 40 to 100 cubera snapper (*L. cyanopterus*), lane snapper (*L. synagris*), and dog snapper (*L. jocu*) specimens have been documented on the Cuban continental shelf.

Little has been published on *H. guentherii* behavior, and no studies have been undertaken to describe spawning areas, aggregation size, or behavior of this species during reproductive events. However, local fishermen state that they have seen aggregations of 300 to 500 individuals "laying" (an expression they use to refer to a group of spawning fish) in spring and summer. Fishermen also report that this species is caught regularly at Tortuga Island, located 40 km from the study area towards the central Gulf of California.

It is common to find very short periods of gonadal recovery in species with short spawning periods that form aggregations for reproduction. It was the case for the Mexican barred snapper, which reached a second GSI peak in 23 days; this was considered a second "maturity" peak, with a later second "spawning" peak between June and July. Other snapper species also have more than one spawning period per year. Cruz-Romero et al. (1991) reported that in the Mexican Pacific, *L. peru*, *L. guttatus*, and *L. argentiventris* presented two spawning periods in July and November during the first four months of the year. *H. guentherii* probably presents partial spawning, like *L. argentiventris*, which presents asynchronous gonadal development (Piñón et al. 2008). Although the presence of oocytes at advanced maturation stages after the first spawning period in *H. guentherii* should be verified with histological studies, it would explain the short gonadal recovery time. The size and age at maturity of *H. guentherii* are unknown, although small females (28 cm) and small males (36 to 37 cm TL) were identified. Still, the size of gonadal maturity should be determined through histological studies.

Gamete development in the gonads, as well as spawning, requires a high amount of energy that is occasionally provided by reserves stored in organs such as the liver, where lipids used to synthesize vitellogenin accumulate; this is a precursor substance of vitellus, which is stored in the oocytes during vitellogenesis (Saborido-Rey 2008).

In *H. guentherii*, the GSI and the HSI showed sustained growth during the first months of the year. This fact suggests that reserves produced by the liver were not used during the first stages of gonadal development, whereas in May, there was a significant decrease in HSI and GSI. These trends in the indices

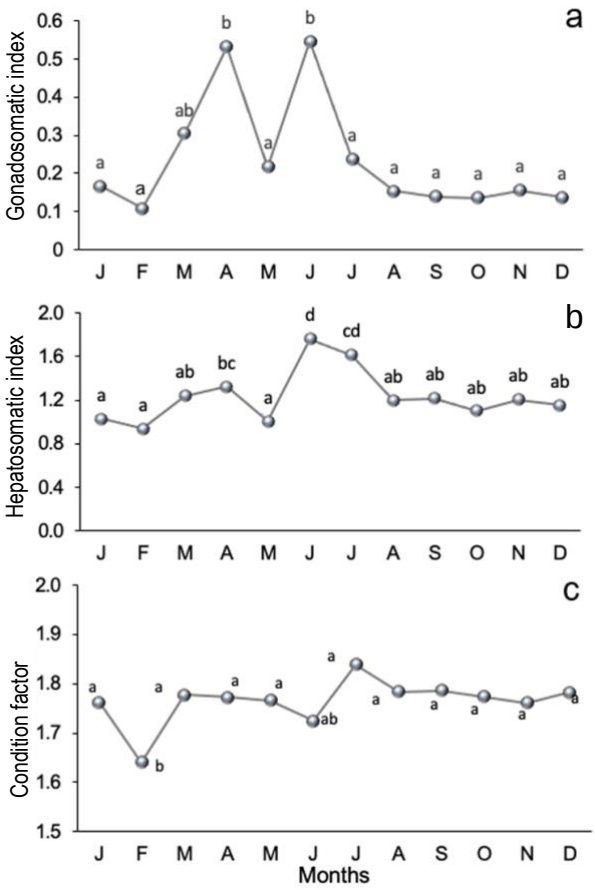

Figure 4. Annual variation of the a) gonadosomatic index, b) hepatosomatic index, and c) condition factor for *Hoplopagrus guentherii* in Santa Rosalía, Gulf of California, Mexico. Different letters denote significant differences with $P < 0.05$.

could be caused by the mobilization and use of liver reserves during spawning that month. Gonadal recovery in June indicated a second maturity period in *H. guentherii*; later, a second spawning period in July coincided with a decrease in HSI, highlighting the importance of liver reserves and their influence in the gonadal developmental process in the Mexican barred snapper and the possible relationship between maturity and spawning periods.

The CF showed little variability during the study period. There was only a significant decrease in February compared with the remaining months. Le Kren (1951) and Cushing (1975) reported that factors such as age, sex, gonadal cycles, and feeding rates could affect condition values in fish, producing changes correlated with the CF. The little variability in *H. guentherii* CF could be explained by the abundance of food in the study area. Abitia-Cárdenas et al. (1990) reported that this species has a wide diet spectrum, which allows it to acquire the necessary energy to maintain an optimal condition year-round. A finding that supports this is that during dissections, abundant brilliant red fat that had accumulated in the viscera of the specimens was observed in practically all specimens and during all months of the study period. We strongly recommend undertaking trophic ecology studies to examine the correlation between maturation and spawning periods, as well as variations in the body condition of this species.

Trippel & Neil (2004) introduced the term "stock reproductive potential", which represents the annual variation in a population's capacity to produce viable eggs and larvae. Alonso-Fernández & Saborido-Rey (2012) emphasized the importance of integrating basic reproductive biology into stock evaluations, such as the age and size of reproductive fish, maturation, and physiological condition of the populations.

The maximum length reported for the Mexican barred snapper *H. guentherii* is 92 cm TL (Allen 1985); the maximum TL recorded in this study was 69 cm TL, and the average catch size was 42.5 cm TL. As suggested by Amezcua (2007), the minimum catch size proposed in the study area would be 40 cm TL, whereas the DOF (2023) established a minimum legal catch size for Mexico at 45 cm TL. The difference between the suggested local and legal country catching size implies that a fraction of the actual catches of Mexican barred snapper in Santa Rosalía are below the official minimum catch size, which could be due to the simplification of the size structure due to the fishery data and the lack of other management measures.

It should also be considered that the smallest specimen recorded in this study was a 28 cm female, and two 36 and 37 cm TL males were recorded. Males larger than 41 cm TL were more frequent in the catches, which suggests that the minimum catch size proposed by Amezcua (2007) could be adequate. On the other hand, 26% of specimens caught in the study were below the legal minimum catch size (DOF 2023). The catch percentage below the legal size permitted would probably not affect the population abundance significantly, as the fishery for this species in Santa Rosalía targets specimens whose sex can be identified visually. Therefore, individuals have probably already been recruited to reproduce at those sizes.

Given that the scientific basis for recommended minimum legal catch sizes (Amezcua 2007, DOF 2023) has not been provided, we recommend undertaking as reference a histological study of reproduction in males and females to determine the average size at reproduction, in addition to the proposed minimum size as a function of the catch curve. With this information, it

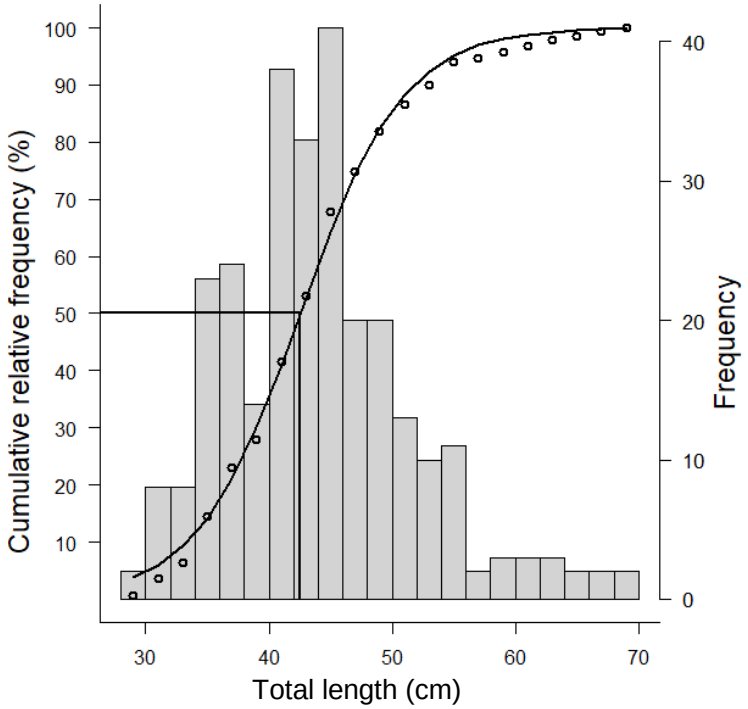

Figure 5. Average catch size of the Mexican barred snapper *Hoplopagrus guentherii* from the northwestern Gulf of California fishery. The bars correspond to the size composition of the *H. guentherii* catches. The points are the observed frequencies corresponding to this size structure. The solid line is the frequencies estimated by the mathematical model used. The estimated mean capture size of the wild population was 42.5 cm.

would be possible to propose a minimum legal catch size to reflect the population of this area better.

The present study on the *H. guentherii* fishery carried out during an annual cycle shows that results of population dynamics (size structure of the population, the weight-length ratio, the sex ratio, the inference about its reproductive season through the variation of the GSI, the variations of the HSI as well as the average catch size) are an important contribution to the establishment of a baseline in the management of the fishery in the local area.

CONCLUSIONS

Our results suggest that the reproductive processes of *H. guentherii* occur in spring-summer and affect the general condition of the organisms, particularly the liver condition. At the population level, *H. guentherii* presented two annual reproductive cycles: two maturity peaks and two spawning periods. Although we do not know how often each female spawns during each period, we can infer that the GSI presented strong synchronicity in maturation, and the two spawning periods are short in the study area.

The *H. guentherii* fishery is becoming relevant in the Gulf of California. This species has great potential for sports fishing, given its large size, fishing fighting prowess, and the taste of its meat.

Credit author contribution

M.T. Villalejo-Fuerte: resources-provision of study materials, conceptualization, investigation, formal analysis, writing-original draft; L. Andrés Abitia-Cárdenas: resources-provision of study materials, writing-review & editing; N. Vélez-Arellano: investigation, formal analysis, methodology, writing-review & editing; A. Tripp-Quezada: writing-review & editing; J.C. Martínez-Ayala: writing-review & editing.

Conflict of interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

ACKNOWLEDGMENTS

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REFERENCES

Abitia-Cárdenas, L.A., Rodríguez-Romero, J. & Galván-Magaña, F. 1990. Observaciones tróficas de tres especies de peces de importancia comercial de Bahía Concepción, Baja California Sur, México. Investigaciones Marinas CICIMAR, 5: 55-61.

Allen, G.R. 1985. FAO species catalogue. Vol. 6. Snappers of the world. An annotated and illustrated catalogue of lutjanid species known to date. FAO Fisheries Synopsis, 125: 208.

Allen, G.R. & Robertson, D.R. 1994 Fishes of the tropical eastern Pacific. University of Hawaii Press, Honolulu.

Alonso-Fernández, A. & Saborido-Rey, F. 2012. Relationship between energy allocation and reproductive strategy in *Trisopterus luscus*. Journal of Experimental Marine Biology and Ecology, 416-417: 8-16. doi: 10.1016/j.jembe.2012.02.001

Amezcua, F. 2007. Tallas mínimas de captura. SAGARPA, CONAPESCA. [http://www.gob.mx/cms/uploads/attachment/file/104543/Cartel_8_Tallas_Minimas_Captura_II_2007.pdf]. Reviewed: March 28, 2024.

Amezcua, F., Soto-Avila, C. & Green-Ruiz, Y. 2006. Age, growth, and mortality of the spotted rose snapper *Lutjanus guttatus* from the southeastern Gulf of California. Fisheries Research, 77: 293-300. doi: 10.1016/j.fishres.2005.10.012

Bermúdez-Almada, B.R. & García-Laguna, G. 1985. Hábitos alimenticios en los peces de las zonas rocosas de la Bahía La Paz, B.C.S. Tesis Licenciatura, Universidad Nacional Autónoma de México, Ciudad de México.

Bertalanffy, L. 1934. Untersuchungen über die Gesetzlichkeiten des Wachstums. 1. Algemeine Grundlagen der Theorie. Roux'Arch. Entwicklungsmech. Organization, 131: 613-653. doi: 10.1007/ BF00650112

Beyer, J.E. 1991. On length-weight relationships. Part II: Computing mean weights from length statistics. Fishbyte, 9: 50-54.

Crozier, W.J. & Selig, H. 1914. Correlations of weight, length, and other body measurements in the weakfish, *Cynoscion regalis*. U.S. Burma. Fishery Bulletin, 33: 141-147.

Convention on the Conservation of Migratory Species of Wild Animals (CMS). 2015. Appendices I and II of the Convention on the Conservation of Migratory Species of Wild Animals. [http://www.cms.int/en/species]. Reviewed: August 12, 2024.

Cruz-Romero, M., Espino-Bar, E., Mimbela-López, J., García-Boa, A., et al. 1991. Biología reproductiva de tres especies de *Lutjanus* en las costas de Colima, México. Informe final de CONACyT: PO2PCCPR 892739.

Cushing, D.H. 1975. Marine ecology and fisheries. Cambridge University, Cambridge. [https://www.cambridge.org/gb/universitypress/subjects/life-sciences/natural-resource-management-agriculture-horticulture-and/marine-ecology-and-fisheries]. Reviewed: March 28, 2024.

Diario Oficial de la Federación (DOF). 2023. Carta Nacional Pesquera 21 de julio. [https://www.gob.mx/imipas/acciones-y-programas/carta-nacional-pesquera-51204]. Reviewed: March 28, 2024.

Espino-Barr, E., González-Vega, A., Santana-Hernández H. & González-Vega, H. 2008. Manual de biología pesquera. Universidad Autónoma de Nayarit, Nayarit. [https://www.inapesca.gob.mx/portal/Publicaciones/Manuales/2008-Espino-Barr-etal-Manual-de-BIOLOGIA-PESQUERA.pdf]. Reviewed: March 28, 2024.

Franks, J.S. & Vanderkooy, K.E. 2000. Feeding habits of juvenile lane snapper *Lutjanus synagris* from Mississippi coastal waters, with comments on the diet of gray snapper *Lutjanus griseus*. Gulf and Caribbean Research, 12: 11-17. doi: 10.18785/gcr.1201.02

Fulton, T.W. 1904. The rate of growth of fishes. Twenty-second annual report. Part III. Fisheries Board of Scotland, Edinburgh, pp. 141-241.

González-Gándara, C., Pérez-Díaz, E., Santos-Rodríguez, L. & Arias-González, J.E. 2003. Length-weight relationships of coral reef fishes from the Alacran Reef, Yucatan, Mexico. Naga, WorldFish Center Quarterly, 26: 14-16.

Hile, R. 1936. Age and growth of the Cisco *Leucichthys artedi* (Le Sueur) in the lakes of the northeastern highlands, Wisconsin. Bulletin U.S. Bureau of Fisheries, 48: I-3-I7.

Hismayasari, I.B., Marhendra, A.P.W., Rahayu, S. & Supriyadi, D.S. 2015. Gonadosomatic index (GSI), hepatosomatic index (HSI), and proportion of oocytes stadia as an indicator of rainbowfish *Melanotaenia boesemani* spawning season. International Journal of Farming and Allied Sciences, 2: 359-362.

Le Kren, 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: 201-219.

Lucano-Ramírez, G., Ruiz-Ramírez, S., González-Sansón, G. & Ceballos-Vázquez, B.P. 2012. Biología reproductiva del pargo *Lutjanus inermis* (Perciformes: Lutjanidae), en el Pacífico central mexicano. Revista de Biología Tropical, 60: 393-403.

Manzanilla-Verde, B., Villegas-Sánchez, C.A., Cabanillas-Terán, N., Castro-Pérez, J.M., et al. 2023. Insight into the trophic niche and prey contribution in the diet of *Lutjanus griseus* (Linnaeus, 1758) captured by artisanal fishing fleet in the central and southwest Gulf of Mexico. Regional Studies in Marine Science, 63: 1-9. doi: 10.1016/j.rsma.2023.103005

Murugan, A., Vinod, K., Saravanan, K.R., Anbalagan, T., et al. 2014. Diversity, occurrence and socio-economic aspects of snappers and job fish (Family: Lutjanidae) fisheries from Gulf of Mannar region, south-east coast of India. Indian Journal of Geo-Marine Sciences, 43: 618-633.

Nikolsky, G.V. 1963. The ecology of fishes. Academic Press, New York.

Ozaydın, O. & Taskavak, E. 2006. Length-weight relationships for 47 fish species from Izmir Bay (eastern Aegean Sea, Turkey). Acta Adriatica, 47: 211-216.

Pauly, D. 1993. Fishbyte section editorial. The ICLARM Quarterly, 16: 26.

Petrakis, G. & Stergiou, K.I. 1995. Weight-length relationships for 33 fish species in Greek waters. Fisheries Research, 21: 465-469. doi: 10.1016/0165-7836(94)00294-7

Piddocke, T.P., Butler, G.L., Butcher, P.A., Purcell, S.W., et al. 2015. Age validation in the Lutjanidae: a review. Fisheries Research, 167: 48-63. doi: 10.1016/j.fishres.2015.01.016

Piñón, A., Amezcua, F. & Duncan, N. 2008. Reproductive cycle of female yellow snapper *Lutjanus argenti-ventris* (Pisces, Actinopterygii, Lutjanidae) in the SW Gulf of California: gonadic stages, spawning seasonality and length at sexual. Journal of Applied Ichthyology, 25: 18-25. doi. 10.1111/j.1439-0426. 2008.01178x

Ricker, W.E. 1968. Methods for assessment of fish production in fresh waters. Blackwell Scientific Publications, Oxford.

Saborido-Rey, F. 2008. Ecología de la reproducción y potencial reproductivo en las poblaciones de peces marinos. Universidad de Vigo, Vigo.

Salgado-Ugarte, I.H. & Saito-Quezada, V.M. 2020. Métodos cuantitativos computarizados para biología pesquera. UNAM, Ciudad de México.

Santamaría-Miranda, A., Elorduy-Garay, J.F., Villalejo-Fuerte, M. & Rojas-Herrera, A.A. 2003. Desarrollo gonadal y ciclo reproductivo de *Lutjanus peru* (Pisces: Lutjanidae) en Guerrero, México. Revista de Biología Tropical, 51: 489-502.

Sarabia-Méndez, M., Gallardo-Cabello, M., Espino-Barr, E. & Anislado-Tolentino, V. 2010. Characteristics of population dynamics of *Lutjanus guttatus* (Pisces: Lutjanidae) in Bufadero Bay, Michoacan, Mexico. Hidrobiology, 20: 147-157.

Sharma, L. & Ram, R.N. 2020. The relationship of gonadosomatic index and hepatosomatic index in two different age groups of common carp. International Journal of Current Microbiology and Applied Sciences, 9: 727-732. doi: 10.20546/ijcmas.2020.903-087

Sparre, P. & Venema, S.C. 1997. Introduction to tropical fish stock assessment. Part 2. Ejercicios. FAO Fisheries Technical Paper, 306: 339-429.

Stark, W.A. 1971. Biology of gray snapper, *Lutjanus griseus* (Linnaeus) in the Florida Keys. Studies in Oceanography, 10: 11-150.

Teixeira, S.F., Duarte, I.F. & Ferreira, B.P. 2010. Reproduction of the fish *Lutjanus analis* (mutton snapper; Perciformes: Lutjanidae) from northeastern Brazil. Revista de Biología Tropical, 58: 791-800. doi: 10.15517/rbt.v58i2.5246

Thomson, D.A., Findley, L.T. & Kerstitch, A.N. 1979. Reef fishes of the Sea of Cortez. The rocky-shore fishes of the Gulf of California. University of Texas Press, Austin.

Trippel, E. & Neil, S.R.E. 2004. Maternal and seasonal differences in egg sizes and spawning activity of northwest Atlantic haddock (*Melanogrammus aeglefinus*) in relation to body size and condition. Canadian Journal of Fisheries and Aquatic Sciences, 61: 2097-2110. doi: 10.1139/f04-125

Vega, A.J., Maté, J.L. & Robles, Y.A. 2016. Proceedings of the 68th Gulf and Caribbean Fisheries Institute, November 9-13, 2015, Panama City, pp. 112-117.

Villalejo-Fuerte, M. & Ceballos-Vázquez, B.P. 1996. Variación de los índices de condición general, gonádico y de rendimiento muscular en *Argopecten*

circularis (Bivalvia: Pectinidae). Revista de Biología Tropical, 44: 591-594.

Zar, J.H. 2009. Biostatistical analysis. Prentice-Hall, New Jersey.

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