

Mean size at sexual maturity of female *Cynoscion reticulatus* along the Pacific coast off Mexico

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ABSTRACT. Drums and croakers (Sciaenidae) are important to the species composition of coastal catches in the Gulf of California, Mexico. Among these species, the striped corvina (*Cynoscion reticulatus*) stands out because of its high fishery potential, high demand, and increased market value. The striped croaker has been under constant fishing pressure over the past 20 years. Still, there needs to be current biological information or reference points to allow the establishment of management measures for fisheries. The objective of the present study was to estimate the mean standard length at sexual maturity (SL_{50}) of females using various models and to suggest a minimum catch size (MCS) for *C. reticulatus* off the southern coast of Sinaloa. Monthly samplings of coastal fishery landings were done from December 2020 to December 2021 on the south coast of Sinaloa. The SL_{50} was evaluated based on 3 candidate models (Gompertz, Lysack, and White) through a binomial approach. Confidence intervals for SL_{50} were estimated using likelihood profiles and contours, and Akaike's information criterion (AIC) was used to select the best model. A total of 284 individuals were examined, of which 131 were used in calculations. White's model was the most adequate; however, based on AIC weights, all 3 models performed similarly, and SL_{50} (24.48 cm; C.I. 95% 12.9–70 36.0 cm) was estimated as their average. As a management measure, we propose a precautionary MCS of 36 cm SL for *C. reticulatus* off southern Sinaloa.

Key words: mean size at sexual maturity, minimum catch size, coastal fishery, drums and croakers, fisheries management.

INTRODUCTION

Many human settlements in the Gulf of California depend on coastal, artisanal, or small-scale fisheries, especially those of bony fishes, elasmobranchs, mollusks, and crustaceans (Lluch-Cota et al. 2007). Species belonging to the family Sciaenidae, known as “corvinas” in Spanish and “drums” or “croakers” in English (Chao et al. 1995, Froese and Pauly 2021), are becoming one of the most important families from a socio-economic and ecological viewpoint, especially those in the region that comprises the eastern Tropical Pacific Ocean (Robertson and Allen 2015).

On the coast of Sinaloa, 7 genera of drums and croakers (*Bardiella*, *Cheilotrema*, *Cynoscion*, *Menticirrhus*, *Micropogonias*, *Umbrina*, and *Roncador*) include 20 target

fish, which are targeted by several fishing fleets such as shrimp trawling boats (bycatch), gillnets, handlines, and longlines (targeted fishery) (DOF 2010). The shrimp trawl fishery affects around 33 species of drums and croakers in the Pacific coast of Mexico (López-Martínez et al. 2010, Palacios-Salgado 2011). Out of those, *Cynoscion reticulatus*, *Cynoscion xanthulus*, *Cynoscion phoxocephalus*, *Cynoscion parvipinnis*, *Larimus argenteus*, *Umbrina roncadorensis*, and *Micropogonias ectenes* stand out as common and important resources in local fisheries. These 7 species used to have a low market value; however, due to an increase in food demand at the local and national levels (Alfaro and Quintero 2014) and a decrease in the catch of species with higher commercial value, they now represent one of the main targets of coastal fisheries in Sinaloa. Notably, *C. reticulatus* has been a

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bycatch of the Pacific sierra fishery (*Scomberomorus sierra*); this species has the potential to become an important national fishery resource due to its wide distribution (from southern Baja California and Gulf of California, Mexico, to Colombia; Robertson and Allen 2015) and price.

Despite the economic potential and attention that *C. reticulatus* is currently receiving, this resource faces the same problem as most coastal resources: a severe lack of biological and fishery information for informed management and sustainable exploitation. Scientific information to evaluate exploitation, biological parameters of the population such as fish maturity and growth, are essential to develop strategies or management plans that contribute to the sustainable use of resources (Méndez-Espinoza et al. 2020). One of the most critical biological parameters to evaluate and manage fisheries is the mean size at sexual maturity (L_{50}), defined as the size at which 50% of individuals in a population are mature (Trippel and Harvey 1991, Trippel 1995, Fontoura et al. 2009, Jacob-Cervantes and Aguirre-Villaseñor 2014). This biological parameter is used to estimate the mature fraction of a fish stock (Cubillos and Alarcon 2010) and can help establish the minimum catch size (MCS) (Corgos and Freire 2006, Jacob-Cervantes and Aguirre-Villaseñor 2014).

Given that the striped corvina is a vital fishery resource in southern Sinaloa, and that there is a lack of biological information for its fishery management, we estimated the mean size at sexual maturity to inform the management authority (CONAPESCA) to establish a MCS for this resource caught off the coast of southern Sinaloa.

MATERIALS AND METHODS

Sampling

Approximately 30 individuals per month were obtained randomly from the commercial coastal fishery landings in the port of Mazatlán from December 2020 to December 2021. This fishery operates in the southern coast of Sinaloa, Mexico, from Barras de Piaxtla (22°45' N–106°02' W) to Chametla (23°36' N–106°54' W) (Fig. 1). Two fishing gears were used: (1) approximately 300-m long bottom gillnets with 3.0–3.5" mesh size and (2) 900-m long by 70-m deep bottom longlines with circular 12/0 hooks (Mustad 39960-D).

Collected individuals were transported to the Facultad de Ciencias del Mar of the Universidad Autónoma de Sinaloa. The total length (TL) and standard length (SL) of fresh individuals were recorded, sex was assigned by visual assessment of the gonads, and maturity was determined considering the 5 gonadal stages; the description was based on the morphochromatic scale for partial spawners (adapted from Holden and Raitt [1975]) (Table 1).

From the total number of organisms collected during sampling, only individuals with the following 3 conditions were used to estimate mean size at sexual maturity: (1) identified

as females, (2) sexual maturity stage could be determined, and (3) standard length was recorded.

Mean size at sexual maturity

Three *a priori* models that describe sigmoidal curves were selected to estimate the mean standard length at sexual maturity (SL_{50}). The sigmoidal models evaluated were:

$$\text{Gompertz (1825)} P_i = \exp^{-\exp^{-\beta_1(SL_i - SL_{50})}} \quad (1)$$

$$\text{Lysack (1980)} P_i = \frac{1}{1 + \exp^{-\beta_1(SL_i - SL_{50})}} \quad (2)$$

$$\text{White et al. (2002)} P_i = \frac{1}{1 + \exp\left[-\ln(19) \frac{SL_i - SL_{50}}{SL_{95} - SL_{50}}\right]} \quad (3)$$

SL_i is the standard length of class size i , SL_{50} is the standard length at which 50% of females are mature, β_1 is a rate of change, and SL_{95} is the length at which 95% of females are mature.

These models were adjusted to the SL-gonadal developmental stage data of females for each class, plus a logical adjustment value (immature female at 0 cm SL [at hatching]), and finally evaluated through a multimodel approach. The standard length was used because sometimes the caudal fin of individuals obtained from commercial fisheries can be damaged, and the TL cannot be recorded adequately.

Considering the observed proportion of sexually mature/immature females for each SL_i class, we assumed a binomial distribution to adjust the models (Haddon 2011). The mature or immature status was assigned according to descriptions

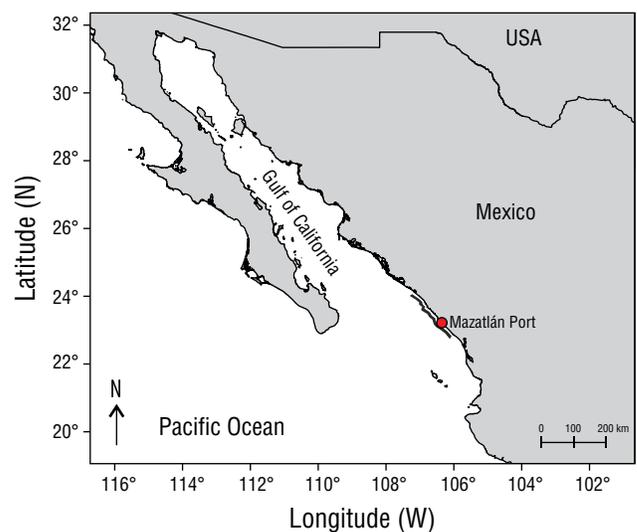


Figure 1. Map of northwestern Mexico. The shaded area near the port of Mazatlán shows the area of operation of the drum and croaker fishing fleet off the coast of southern Sinaloa.

Table 1. Macroscopic gonadal maturity scale for female partial spawners (adapted from Holden and Raitt 1975).

Stage	State	Description
I	Immature	Ovaries approximately 1/3 length of abdominal cavity, pinkish and translucent. Oocytes not visible to the naked eye.
II	Maturing or recovering	Ovaries approximately 1/2 length of abdominal cavity, pinkish and translucent. Not visible to the naked eye.
III	Mature	Ovaries approximately 2/3 length of abdominal cavity, pinkish-yellow with granular appearance. No transparent or translucent oocytes.
IV	Pre-spawn	Ovaries approximately 2/3 length of abdominal cavity, pinkish-yellow with superficial blood vessels. Transparent and visible mature oocytes.
V	Post-spawn	Ovaries approximately 1/2 length of abdominal cavity, flaccid. Opaque, dark, or translucent oocyte remains can be seen.

by Holden and Raitt (1975) as follows: females in stages III, IV, and V were considered “sexually mature,” and females in stages I and II were considered “sexually immature.” In addition, individuals were categorized based on whether they already had at least one reproductive event; females at the post-spawn stage were considered in the “mature” category, as they had previous reproductive activity.

Parameters (θ) were estimated by minimizing the negative likelihood logarithm ($-lnLl$), assuming a binomial distribution, using Newton's direct search algorithm (Neter et al. 1996).

Confidence intervals

Confidence intervals (CI) of the θ_i parameters of the candidate models were calculated using likelihood profiles: this method uses a χ^2 distribution with $n = 1$ degrees of freedom (d.f.) (Hilborn and Mangel 1997), where all values ≤ 3.84 are accepted within the CI of the individual parameter (Morales-Bojórquez and Nevárez-Martínez 2005). The χ^2 estimator was calculated as follows (Haddon 2001):

$$2[lnLL_{(\theta_{est})} - lnLL_{(\theta_i)}] < \chi^2_{d.f., 1-\alpha} \quad , \quad (4)$$

where $LL(\theta_{est})$ is the negative logarithmic probability of the most probable θ_i value, $LL(\theta_i)$ is the negative logarithmic probability based on the hypothesis of the θ_i value (profile or contour), and $\chi^2_{1-\alpha}$ is the value of the χ^2 distribution with a confidence level $1 - \alpha = 0.05$, and d.f. = 1 (profiles) or 2 (contours) (Haddon 2001).

Best model selection

After the CI calculation, we used several models to estimate the mean size at sexual maturity. The Akaike information criterion (AIC) was calculated for each of the evaluated models.

$$AIC = (-2lnLl) + (2k) \quad , \quad (5)$$

where $-lnLl$ is the likelihood value for each adjusted model and k is the number of parameters in the model.

Akaike differences were then calculated as follows: (Δ_{AIC}) $\Delta_{AIC} = AIC_i - AIC_{min}$. According to Burnham and Anderson (2002), models with $\Delta_i > 10$ have no statistical support, models with $4 < \Delta_i < 7$ have intermediate support, and models with $\Delta_i < 2$ have substantial support.

Finally, the data trend of each candidate model with $\Delta_i < 2$ was calculated, and an average model was obtained. We first evaluated the likelihood of each model by calculating the AIC weight (w_i) using the equation proposed by Burnham and Anderson (2002).

$$w_i = \frac{e^{-0.5\Delta_i}}{\sum_{i=1}^3 e^{-0.5\Delta_i}} \quad , \quad (6)$$

where Δ_i are Akaike differences (Δ_{AIC}) and w_i is the weight of evidence in favor of model i (Akaike 1983, Buckland et al. 1997, Burnham and Anderson 2002). Afterwards, the average SL_{50} (\overline{SL}_{50}) was calculated, which was the only parameter included in all candidate models. \overline{SL}_{50} was estimated by averaging the predicted response variable (SL_i) of each model using w_i as a weighting factor (Burnham and Anderson 2002). Finally, 95% confidence intervals were calculated based on the standard error of \overline{SL}_{50} (Katsanevakis and Maravelias 2008).

Finally, we undertook a detailed literature review (Table 2) to understand the variability in the mean size at sexual maturity in the genus *Cynoscion* in several areas of the American continent.

RESULTS

A total of 284 *C. reticulatus* ranging from 24.4 to 47.8 cm in SL (with a 28.4 to 49.4 cm TL) were sampled.

Of the 284 organisms, 6 were discarded as their sexual maturity stage could not be determined, which left 278 organisms (147 males and 131 females). Since only females were used in the analysis, the number of individuals was lower than the total ($N = 131$). Of these, 65% ($n = 85$) were considered

“sexually mature” (stage III [14 organisms], stage IV [16 organisms], and stage V [55 organisms]), and 35% ($n = 46$) were considered “sexually immature” (stage I [41 organisms] and stage II [5 organisms]). The SL and proportion of mature/immature organisms were grouped in 5-cm intervals (Fig. 2).

Average size at sexual maturity

The 3 models fit the data ($n = 131$) (Fig. 3). The parameters of each model have a particular meaning; these do not allow comparisons among them, except for the mean standard length at sexual maturity (SL_{50}), which ranged between 21.7 and 25.9 cm SL. The values estimated for each model are presented below:

$$\text{Gompertz: } P_i = \exp^{-\exp^{-0.09(SL_i - 21.7)}} \quad (7)$$

$$\text{Lysack: } P_i = \frac{1}{1 + \exp^{-0.12(SL_i - 25.9)}} \quad (8)$$

$$\text{White: } P_i = \frac{1}{1 + \exp\left[-\ln(19) \frac{(SL_i - 25.9)}{(50.1 - 25.9)}\right]} \quad (9)$$

Confidence intervals

The results of the estimate of likelihood profiles for Gompertz were $SL_{50} = [18.4, 24.6]$ $\beta = [0.064, 0.124]$ (Fig. S1a, b), those for Lysack were $SL_{50} = [22.8, 28.8]$ $\beta =$

$[0.640, 0.186]$ (Fig. S1c, d), and those for White were $SL_{50} = [21.6/29.0]$ $SL_{95} = [41.8/72.8]$ (Fig. S1e, f). Additionally, the Likelihood profile plots (Fig. S1) allowed us to observe that the likelihood value obtained from the model fit to the data did not denote the presence of local minima.

Best model selection

The lowest AIC value was obtained with the White model (Table 3). Therefore, according to the parsimony principle, this model was considered the most adequate to estimate SL_{50} in *C. reticulatus*. However, although it had the lowest AIC, the Gompertz and Lysack models also presented high statistical support ($\Delta_{AIC} < 1$).

Therefore, the 3 models exhibited sufficient statistical support to be integrated into the estimation of the average SL_{50} ($\overline{SL_{50}}$). Table 3 shows the Akaike weights were similar among the 3 models, that is, the weight of evidence in favor of each one. Thus, the average SL_{50} ($\overline{SL_{50}}$) was calculated and substituted in the model, resulting in the following proposed sigmoid model:

$$P_i = \frac{1}{1 + \exp\left[-\ln(19) \frac{(SL_i - 24.5)}{(50.1 - 24.5)}\right]} \quad (10)$$

Finally, once the parameter was estimated ($\overline{SL_{50}} = 24.5$ cm), the confidence interval was calculated (12.9 to 36.0 cm SL; Fig. 4).

Table 2. Estimates of size at maturity of fishes of the genus *Cynoscion* in several areas of the American continent.

Species	Area	Maximum size		Reference
		L_{50} (cm)	(TL cm)	
<i>Cynoscion squamipinnis</i>	Costa Rica	38	64	Campos et al. 1984
	Panama	40	64	Campos 1992
		31	64	Miranda and Sánchez 2018
<i>Cynoscion phoxocephalus</i>	Costa Rica	23.5	60	Campos et al. 1984
		40	60	Campos 1992
	Panama	30	60	Vega et al. 2008
		30	60	Miranda and Sánchez 2018
		35	130	Campos et al. 1984
<i>Cynoscion albus</i>	Costa Rica	65	130	Campos 1992
		75	130	Campos 1992
	Panama	75	130	Campos 1992
<i>Cynoscion jamaicensis</i>	Venezuela	25.1	50	Márcano et al. 2002
<i>Cynoscion othonopterus</i>	Upper Gulf of California	48	70	Mendivil-Mendoza 2018
<i>Cynoscion reticulatus</i>	Guatemala	33.08	90	Ortíz et al. 2021
<i>Cynoscion nebulosus</i>	Northwestern Gulf of Mexico	26–30	100	Brown-Peterson et al. 2002
<i>Cynoscion regalis</i>	Western Atlantic, United States	17	98	Lowerre-Barbieri et al. 1996

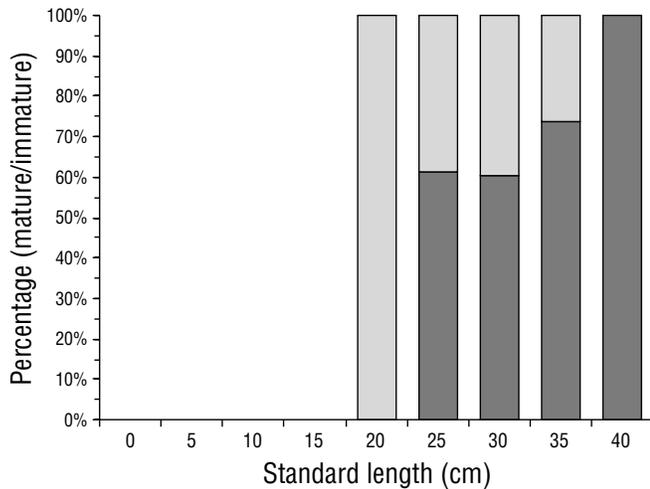


Figure 2. Proportion of mature/immature *Cynoscion reticulatus* caught off the southern coast of Sinaloa grouped in 5-cm standard length (SL) intervals. Light and dark bars represent the proportion of immature and mature fish, respectively.

DISCUSSION

The first step in properly managing a fishery resource is to understand the population dynamics. One of the most popular approaches to achieve this goal is the biological analysis of population parameters. According to Begg (2005), these parameters can characterize each population and are the consequence of the population’s life cycle. Among the most frequently used parameters are individual growth and mean size at sexual maturity (Winemiller and Rose 1992, McCann and Shuter 1997, Shuter et al. 1998, Espino-Barr et al. 2008) and, according to Hilborn and Walters (1992), the analysis of these 2 parameters (body size and growth) has been a major preoccupation of fishery scientists, as both are major components of biological production and are related to problems that cannot be ignored in fishery management, such as growth and recruitment overfishing.

Here, we estimated the mean size at sexual maturity (SL_{50}) of the striped corvina and established a baseline for future studies. As a reproductive strategy, size at maturity varies as a function of time, the environment, and fishery pressure (Gulland 1971, Csirke 1980, García-Alberto 2010). It can be reflected as changes to the size structure of a population, with a decrease in the number of large individuals and a modification in the ages at which maturity ogives are reached, among others. Therefore, interannual monitoring of size at maturity is essential, as it can indicate changes in the dynamics of a population.

Another benefit of estimating the SL_{50} is that it provides vital information for developing fishery management measures. For example, this parameter could be incorporated into modeling frameworks to analyze the state of the resource, estimate biomass, and establish catch quotas and MCS. The

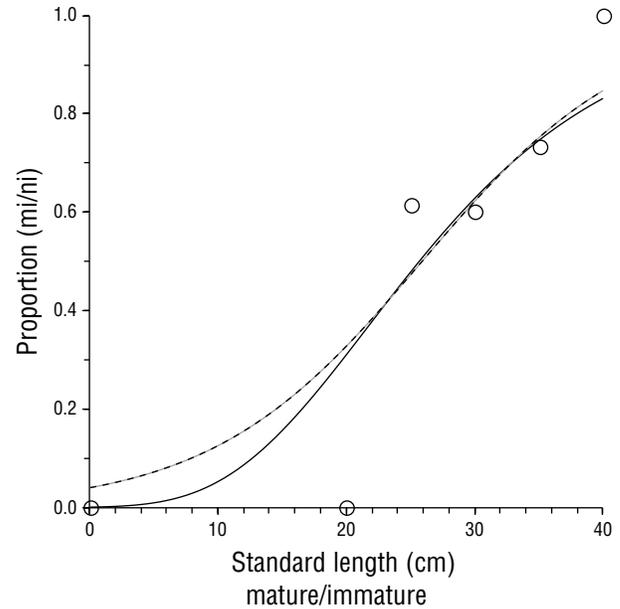


Figure 3. Dispersion diagrams of the proportion of mature/immature organisms by size class and fits of the Gompertz (black solid line), Lysack (grey solid line), and White (black dotted line) models for estimation of SL_{50} *Cynoscion reticulatus*.

MCS is defined as the minimum length an individual must reach before it can be captured. This length must be calculated with a biological basis related to the size at which the SL_{50} is reached and must include an additional period so that the individuals can contribute to a spawning event (Hutchings and Reynolds 2004, Aragón-Noriega 2015). This enables the recruitment of juveniles to the adult stock or to an area where the species is established or could be established (Fowler and Cohen 2013).

Minimum catch sizes are one of the instruments that can be used to regulate exploitation strategies in Mexico (DOF 2018). However, the procedure to establish these measures can be ambiguous, specifically when trying to establish the time or size after which SL_{50} is reached so individuals can contribute to spawning. Three possible strategies were considered to establish the MCS of *C. reticulatus* caught off southern Sinaloa based on the estimated SL_{50} , as follows:

- 1.- Use the estimate of weighted or average SL_{50} ($\overline{SL_{50}}$) as MCS, where MCS = 24.5 cm SL. Here, a precautionary approach would not be considered, and there would be the risk of keeping the resource in a state that is highly vulnerable to “growth overfishing” (overfishing of juveniles if there is any perturbation that leads to reproduction at smaller sizes).
- 2.- Use the upper estimate confidence interval of ($\overline{SL_{50}}$) as MCS to ensure that organisms have contributed at least once to spawning (MCS = 36.0 cm SL). This considers a precautionary approach by increasing the spawning potential.

3.- Estimate a third parameter (SL_i) for the equation through the inverse calculation of the average model equation, as follows:

$$SL_i = (50.1 - 24.5) \times \frac{-\ln \frac{1}{P-1}}{\ln(19)} + 24.5 \quad (11)$$

This new parameter could be $SL_{60}(P_{0.6})$, $SL_{70}(P_{0.7})$, or $SL_{75}(P_{0.75})$... $SL_{100}(P_1)$, as a function of the precautionary level wanted. For example, in this study at SL_{75} , the MCS would be 34.7 cm SL.

We consider strategy 2 (in this order) to be the most appropriate to manage the striped corvina fishery of the southern coast of Sinaloa, as basing the minimum catch size directly on the SL_{50} estimate (strategy 1) would be looking for half of the recruited population to the spawning stock; therefore, strategies 2 and 3 have the capacity to incorporate a precautionary approach. The most commonly used is strategy 2, in which the upper confidence interval of SL_{50} is used as MCS, which slightly increases the size to allow the incorporation of a greater percentage of organisms to the parental population but without increasing the size of the catch too much so that it remains profitable for the fishers; thus, it increases the likelihood of compliance with this regulation.

An important example of establishing and updating minimum catch sizes based on the upper confidence interval of L_{50} is the case of the Pacific thread herring, for which an MCS of 160 mm SL was established in 1983 in the Diario Oficial de la Federación (Official Gazette of the Federation; DOF 1983) and later updated in the official government policy NOM-003-PESC-1993 (DOF 1993). This size was updated to an MCS of 140 mm SL (NOM-003-SAG/PESC-2018; DOF 2019) based on the re-evaluation of L_{50} by Jacob-Cervantes and Aguirre-Villaseñor (2014) where the estimated L_{50} was 135 mm (130–139 mm) and, although official reports of the results of implementing this policy have not yet been published, it is clear that the bioecological balance of species changes over time, and we must adjust fishery management measures periodically to avoid misrepresenting resource behavior and overexploiting stocks.

On the other hand, it is pertinent to mention that in the case of the striped corvina, the previous management measure is suggested based solely on the estimation of SL_{50} due to the lack of other available information that could improve current management policy, despite the MCS being one of the basic and most common management measures used to avoid growth and recruitment overfishing. The main purpose of the MCS strategy is to allow fish to spawn at least once using length at maturity as a reference (Myers and Mertz 1998) and to catch fish at an optimum size for population growth (Froese et al. 2008). It would be better to base the management regulation on other elements, such as the size and age at first maturity, the weight increase curve, the critical age and size in the evolution of biomass per cohort, the analysis of the yield curve per recruit at different catch sizes, and even estimates of fecundity (Vazzoler 1979, Sparre and Venema 1992). In this ideal scenario, decision makers would be able to establish better regulation measures and increase the effectiveness of the management measures (e.g., MCS + ban). To date, this level of information is not available, so the next step would be to collect details of the selectivity of the fishing gear used to catch striped corvina and to evaluate the changes to meet the proposed MCS.

It should be noted that the individuals used in the analysis to estimate SL_{50} for *C. reticulatus* were fishery-dependent. This is a common approach in evaluating coastal resources, as a sampling of the catches has a low cost, easy access, and can lead to broad temporal coverage (Grazia-Pennino et al. 2016). However, the fishery is geared towards catching larger individuals; therefore, there may be a bias against smaller sizes, and young individuals could be underrepresented. This bias could lead to imprecise estimates of SL_{50} .

According to Birch (1999) and Trippel and Harvey (1991), size at maturity data should cover a broad size range to obtain a robust estimate. Our data included medium and large sizes; however, smaller individuals were not caught. Therefore, an in-depth literature review was undertaken to search for reports of size-based maturity stage of young individuals of this species. As this information could not be found, we chose to add a logical adjustment value, such as at size 0 cm SL (hatching), no female was sexually mature. This value was added with the intention to force the curve to reach 0 maturity at hatching

Table 3. Akaike values, Akaike differences of each model with respect to the model with the lowest AIC value (White's), and W_i for size at maturity models applied to obtain SL_{50} estimates for *Cynoscion reticulatus* females caught off the southern coast of Sinaloa.

Model	# Parameters	AIC	AIC differences (Δ_i)	W_i
Gompertz	2	21.336	0.040900884	0.32880439
Lysack	2	21.295	3.36549E-11	0.33559781
White	2	21.295	0	0.33559781

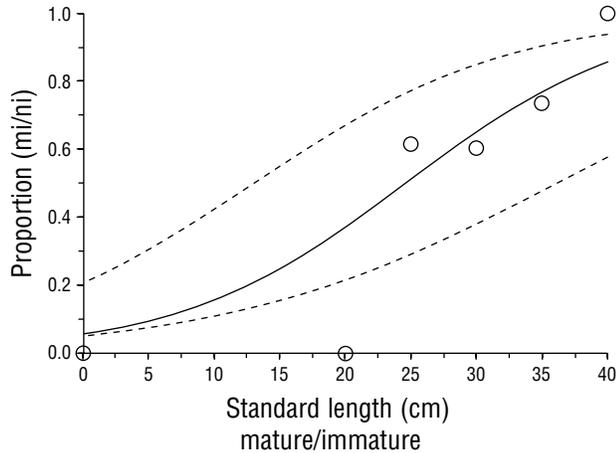


Figure 4. Dispersion diagram of the proportion of mature/immature organisms by size interval and curve described by White's model, including \overline{SL}_{50} (solid line), and lower and upper confidence intervals of the estimates.

length in order to be more realistic according to biological behavior. However, to prevent the added value from significantly changing the tendency of the curve, the White model (best model) was adjusted to both sets (original and the original plus our starting 0 hatching point). Finally, the residuals obtained were analyzed, and no differences were identified between them ($W = 39.5$, $P = 0.9634$); therefore, the addition of this value did not substantially change the trend of the data, but it did improve the behavior of the curve and the biological explanation.

Unfortunately, due to a lack of regional studies, no comparisons could be done between the estimates of SL_{50} and those obtained by other authors for the area or the country. The only study for this species in the area is that of Musso-Solari (2011), who identified a reproductive season from April to October, with peaks in May and October. The size range we found in the present study was 28.4 to 49.4 cm TL for males and 29.9 to 49.2 cm TL for females, compared to 24 to 71.5 cm TL for both sexes in Musso-Solari (2011). Hence, the author found a notably wider size range in the same study area (Southern coast of Sinaloa) but did not examine the stage of maturity. Therefore, future studies should focus on establishing periodic monitoring of reproductive status and population dynamics that can support resource management (catch quotas or MCS).

Lastly, in relation to the literature review of the mean size at sexual maturity in the genus *Cynoscion* genus in several areas of the American continent, we concluded that it is highly variable, and we did not find a latitudinal pattern or a relationship between maximum size and SL_{50} for each species. This highlights the importance of periodically estimating population parameters of the exploited resources.

In conclusion, as the striped corvina is increasing in commercial importance, there is still time to establish early fishery management measures to ensure its sustainable exploitation.

Therefore, in this work, we propose a relatively simple fishing regulation strategy that was estimated from information easily obtained from the landings of the fishery focused on avoiding growth overfishing, promoting population growth, and, finally, systematically collecting information so that it can be re-estimated periodically to allow for an adaptive fishery management approach. The next step is to obtain more information about the resource, such as sex ratio, spawning season, fecundity, relative growth, individual growth, mortality rates, and other variables; this will eventually allow for a full stock assessment to be performed to develop active management strategies (catch quotas).

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SUPPLEMENTARY MATERIAL

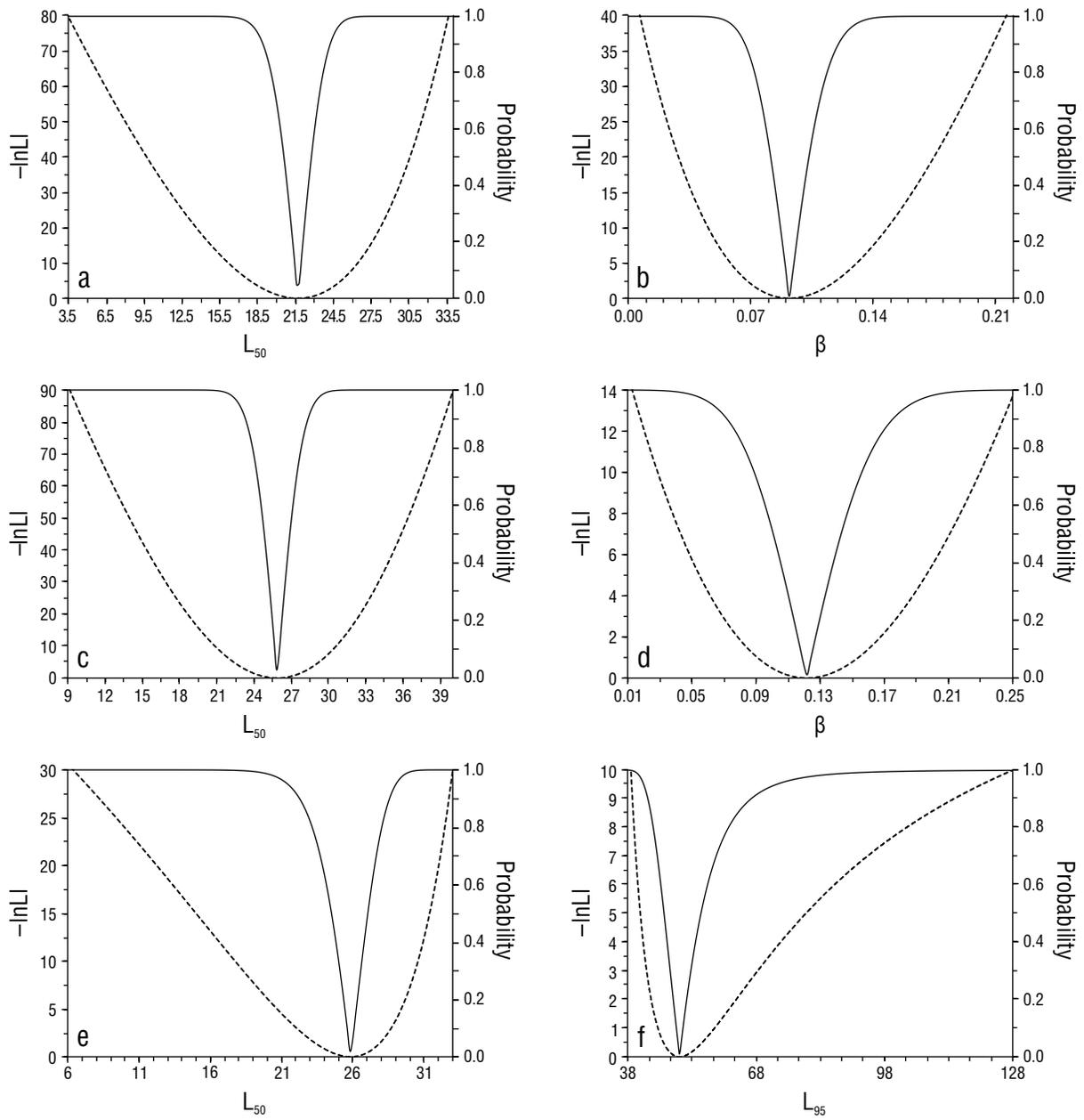


Figure S1. Likelihood profiles showing the 95% confidence interval for the mean standard length at maturity models (**a, b** = Gompertz; **c, d** = Lysack; **e, f** = White).