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Research Article

Length-based indicators for the management of sport fishery in Yucatan, Mexico

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ABSTRACT. Sportfishing is an activity of increasing popularity that involves a large number of users and high levels of fishing effort. In Yucatan, most of the target species in sport fishing are the same as those of commercial fisheries. However, there is no record of fishing effort or catch volumes. Thus the impact of sport fishing on these populations is unknown. This study analyzes the catches made by users of sport fisheries of nine species (*Epinephelus morio*, *Haemulon plumieri*, *Seriola dumerili*, *Lutjanus synagris*, *Ocyurus chrysurus*, *Calamus bajonado*, *Sphyraena barracuda, S. guachancho* and *Mycteroperca bonaci*) through length-based indicators. Samples of species' sizes were obtained from the catches made during 10 fishing tournaments held in Yucatan's three-port towns (Sisal, Yucalpeten, and Telchac) between 2015 and 2016. The catch variables that were evaluated included: the number of mature individuals P_{mat}, optimal length P_{opt}, and the number of mega-spawners P_{mega}. Length measures were derived from 1,252 individuals. Only *H. plumieri*, *L. synagris*, and *S. guachancho* exhibited sustainable indicator values, while *E. morio* and *C. bajonado* demonstrated extremely low values. In most species, sport fishing affects a high proportion of juveniles. The results suggest that sportfishing contributes to the fishing pressure of a species and commercial fishing, due to the capture of juveniles of economically important fish. It is essential to establish a systematic monitoring method of such activities and increase the priority level of the evaluation and management of this fishery.

Keywords: recreational fishing; limited data; fishery evaluation; length-based indicator; Gulf of Mexico

INTRODUCTION

Recreational fishing is defined as that carried out on aquatic animals (mainly fish) whose capture is not the primary resource used to provide the basic nutritional needs of an individual and where the product is generally not sold or traded in domestic, black, or exported markets (FAO, 2008). When such an activity is performed to participate in tournaments, it is called sport fishing.

Examples of coastal sport fisheries worldwide indicate that this is an activity of increasing importance (Ihde *et al.*, 2011; Font & Lloret, 2014; Tunca *et al.*, 2016; Hyder *et al.*, 2018) involving a large number of users and consequently high levels of fishing effort (Cowx, 2002; Pitcher & Hollingworth, 2002), which approximates the fishing effort of commercial fishing (Coleman *et al.*, 2004; Cooke & Cowx, 2006). Therefore, in the absence of adequate control measures, sport-recreational fishing also has multiple biological effects on exploited species, ecological effects on the aquatic ecosystems in which it is carried out (McPhee *et al.*, 2002; Coleman *et al.*, 2004; Cooke & Cowx, 2004, 2006; Lewin *et al.*, 2006) and socioeconomic effects on the communities in which it is developed (Steinback *et al.*, 2004; Lloret *et al*., 2008).

Recreational fishing has ample development potential in the Gulf of Mexico. Approximately 23 million recreational fishing trips from the USA (31%) were carried out in the northern region of the Gulf in 2009 (NMFS, 2010). While in the southeast region of the Gulf of Yucatan, there is no statistical data regarding the activity or systematic studies of any kind. There is no official procedure to monitor the results of fishing tournaments, record biological data of fisheries, or ensure follow-up of rules established by the official

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standard NOM-017-PESC-1994 or by the National Fishing Chart (DOF, 2018). According to the latest official national data from CONAPESCA (2017), 55% of recreational fishing permits are issued in Pacific Mexican states, 21% are issued in the Gulf of Mexico-Caribbean coastal and inland water states, and 23% are obtained online from USA territories (*i.e.*, San Diego, California).

Leisure and sport fishing is the third most important recreational activity on the coast of Yucatan (García-de Fuentes *et al.*, 2011) and is practiced freely or during tournaments in marine and estuarine areas throughout the year, mainly from June to September. Various fishing techniques are practiced: bottom and middle water line or angling, jigging, trolling, and spearfishing in marine waters; flyfishing and line from shore. In the last decade, both the number of marinas and service providers associated with this activity has been increasing according to reports, mainly in tourist ports (Mexican Federation of Sport Fishing, *com. per.*). The number of stores for recreational fishing gear has increased six-fold in Merida's last six years, the State's capital city (there are currently 13 stores), while the number and coverage of docked yachts in Yucalpeten port have duplicated since 2005. By 2015, 1,233 docked yachts were seen in 7.88 marine ha. Currently, two harbors for recreational vessels are being constructed in Telchac, and this project is targeted to the demand of mainly foreign owners (Vidal-Hernández *et al.*, 2017). Likewise, the activity is perceived as a productive alternative with development potential for the coastal communities that face the overexploitation of traditional commercial fishing species (DOF, 2018).

Approximately 10 to 20 sport fishing tournaments are organized by local businesses, schools, and fishing gear stores in Yucatan for national citizens to reach up to 350 participants using small fishing boats. These events can last from one to three days. These tournaments typically have three competition categories to acquire a trophy: heaviest specimen, largest specimen, and highest total catch in weight. Some tournaments specify points for particular species in which groupers (*Epinephelus morio*, *Mycteroperca banaci*), snappers (*Lutjanus synagris*, *Ocyurus chrysurus*), crevalle jack (*Caranx hippos*), great barracuda (*Sphyraena barracuda*), great amberjack (*Seriola dumerili*), sierra (*Scomberomorus* spp.) and bonito (*Sarda* spp.) practically always compete (Vidal-Hernández *et al.*, 2017).

The lack of information to evaluate the impact of the continuous and increasing pressure of sport fishing on local stocks can be addressed from the perspective of the set of analysis methods called "for data-limited." The size-based indicators proposed by Froese (2004) are based on the relationship between fisheries management and the theory of life history of the species, applied to the sizes of the fish that constitute the catches (Cope & Punt, 2009). The indicators attempt to reflect the catches' sustainability characteristics by avoiding growth and recruitment overfishing (Cope & Punt, 2009). These are mainly based on the size of the fish that constitute the catches, which should be exclusively composed of mature individuals and individuals with sizes whereby the highest yield of a cohort is produced; while avoiding the capture of the largest individuals or mega-spawners (Froese, 2004; Cope & Punt, 2009). The indicators are presented in Table 1, according to Froese (2004) and Cope & Punt (2009).

Sportfishing in Yucatan has become intensive, and its popularity continues to increase. Also, information on the fishery's ecological and social aspects is scarce, which puts its sustainability at risk. This study aims to evaluate sport fishing catches in Yucatan using the length-based indicators of Froese (2004), as an initial approach to this fishery to obtain the necessary information to design adequate measures for use in sport fishery management.

MATERIALS AND METHODS

Study area

The study area is located in the marine sections of Sisal, Yucalpeten, and Telchac ports in the northwest Yucatan Peninsula (Fig. 1), which is part of the extended continental shelf north of the Yucatan Peninsula known as Campeche Bank. This area is characterized by a slightly steep slope (Piñeiro & Giménez, 2001).

The Campeche Bank has an area of approximately 129,499 km^2, bounded by the 200 m isobath and the coastline. The substrate is characterized by sediments consisting of variable proportions of limestone, mud, sand, and shells, in addition to some irregularities formed by cays and coral reefs (García, 1980). An element of marked influence in this region is the upwelling that occurs in the eastern portion of the platform's slope, which favors primary production (Piñeiro & Giménez, 2001).

The coastal zone of Yucatan integrates 16 fishing communities, and in just two decades, the number of fishers has tripled, and the number of small-scale fishing vessels has doubled (Fraga, 2004). In recent years, sport fishing in this region has become increasingly popular (CONAPESCA, 2017; Vidal-Hernández *et al.*, 2017; Poot-López *et al.*, 2018), especially to visitors from abroad that are attracted to recreational fishing in coastal communities of Yucatan (Aguilar-Cordero *et al.*, 2012).

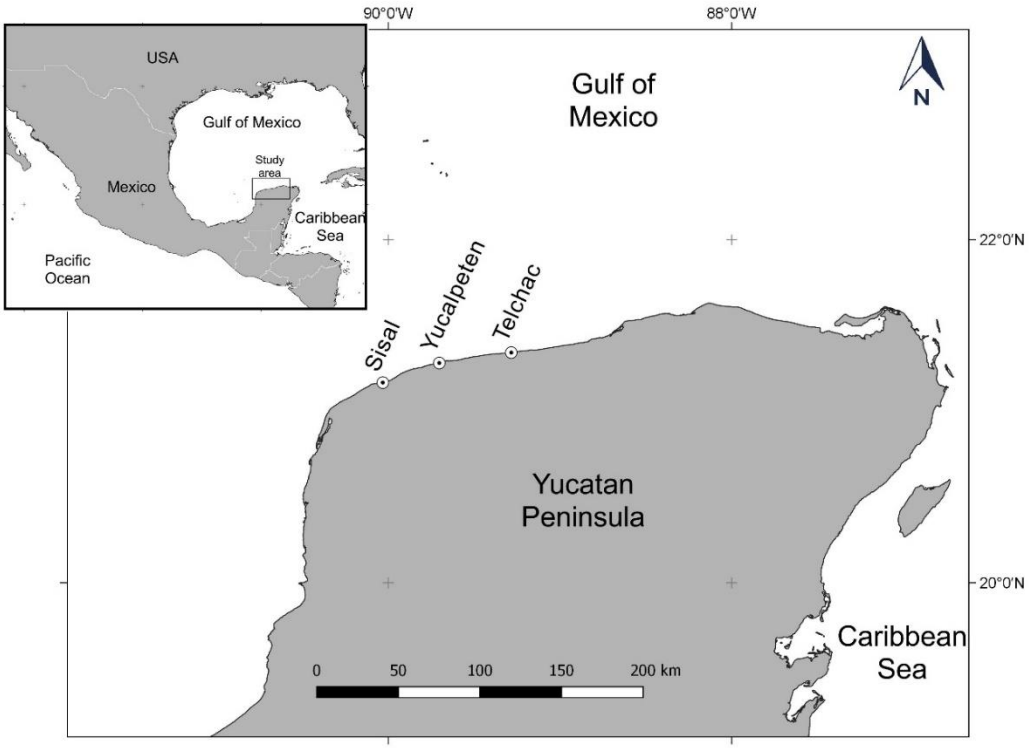

Figure 1. Study area. Location of the three ports in which the catches of sport fishing tournaments were sampled, on the northern coast of the Yucatan Peninsula, Mexico.

Data collection

Catch samples were collected from 10 (five in 2015 and five in 2016) tournaments in Sisal, Yucalpeten and Telchac ports along the northwest coast of the Yucatan Peninsula (Fig. 1) during two seasonal vacations (April and July) from 2015 to 2016 (periods in which the fishing tournaments take place). Since there are no official monitoring strategies for leisure or sport fishing activities, the only current non-official but an organized way to register landings is during tournaments.

Catch samples were obtained from fishing tournaments under a context of family-event competition; fishing was performed using hook and line and, less frequently, by trolling in sites with depths less than 20 m. Boats and engines were generally the same as those used by small-scale fleet fishers from the fishing port (boats less than 7.62 m in length and containing an outboard motor), most of which (90%) were rented from local fishers.

Samples were taken between 06:00 and 14:00 h. All catches made by participants that were judged during the tournaments were recorded, and most catches that did not enter into the contest were also recorded. However, approximately ten percent of the total catches made during the events were not recorded since they were released, consumed, or hidden for trade purposes. The total length (TL) of each individual was measured with a conventional ichthyometer with a ± 1 cm precision. Specimens were identified using fish guides of the Gulf of Mexico developed by Hoose & Moore (1977) and Fisher (1978).

Data analysis: length-based indicators

To evaluate sport fishing catches in Yucatan, the length-based indicators were applied (Froese, 2004; Cope & Punt, 2009) (Table 1), using the species' length-frequency distributions caught in the fishing tournaments.

Length frequency distributions were made for each of the species captured, encompassing all seasons and ports. A minimum sample criterion of at least 30 specimens per species ($n \geq 30$) to ensure a good representation of the size distribution of the catches was established and proceed with the estimation of the indicators. When the minimum sample criterion was met, we proceeded to calculate the indicators by species per location.

Nine species were included in the analysis: red grouper *Epinephelus morio*, white grunt *Haemulon plumieri*, greater amberjack *Seriola dumerili*, lane snapper *Lutjanus synagris*, yellowtail snapper *Ocyurus chrysurus*, jolthead porgy *Calamus bajonado*, great

Table 1. Length-based indicators (Froese, 2004; Cope & Punt, 2009) used to analyze the impact on nine species caught in sport fishery tournaments on the northern coast of the Yucatan Peninsula, Mexico. P_L = catch proportion of the length class L; L_m: length at first maturity; L_{max}: maximum length; L_{opt}: optimal length.

Indicator	Formula
Pmat. Proportion of sexually mature individuals from total catches measured as the percentage of mature specimens from the catch. The objective is to allow 100% of fish to spawn at least once before being caught to rebuild and maintain healthy breeding populations (*Pmat* = 1).	$P_{mat} = \sum_{L_m}^{L_{max}} P_L$
P_{opt}. The proportion of individuals of the size that maximizes the yield from total catches, measured as the percentage of individuals captured within ±10% of the optimum length. The objective is to capture 100% of the fish within ±10% of the optimum length (P_{opt} = 1).	$P_{opt} = \sum_{0.9L_{opt}}^{1.1L_{opt}} P_L$
Pmega. The proportion of individuals to ensure the conservation of sexually mature individuals of the largest sizes, mega-spawners. It is measured as a percentage of large fish in the catch: fish of a size larger than the optimum length plus 10%. Values of 30 to 40% of mega-spawners reflect a healthy age structure (P_{mega} = 0.3-0.4).	$P_{mega} = \sum_{1.1L_{opt}}^{L_{max}} P_L$
Pobj. Sum of the three previously defined indicators. Values between 1 and 2 represent selectivity patterns that follow the sustainability recommendations of Froese (2004).	$P_{obj} = P_{mat} + P_{opt} + P_{mega}$

barracuda *Sphyraena barracuda*, guachanche barracuda *Sphyraena guachancho* and black grouper *Mycteroperca bonaci*.

The estimated proportion of the catches in each length interval (*PL*) was calculated by fitting the logistic model to the accumulated length-frequency distributions, using the formula: $PL = 1 / [1+ exp (a - b \times L)]$, where a and b are parameters of the logistic model and L is the length interval for which the estimate is performed. The adjustment process was performed using the least-squares criterion and Newton's nonlinear numerical method (Neter *et al.*, 1996).

Estimates of the length at first maturity (L_m) and of the optimum length (L_{opt}) were required to calculate the length-based indicators (Table 1). A bibliographic search was done for estimates of L_m and $L\infty$. Parameters K and M of each species were used to calculate L_{opt} according to Beverton (1992) as $L_{opt} = L_\infty [3 / 3 + (M / K)]$; where L_∞ = asymptotic length, a parameter of the Von Bertalanffy growth model (cm); M = natural mortality rate (yr^{-1}); and K = growth coefficient of the Von Bertalanffy growth model (yr^{-1}).

When no parameter was identified, it was estimated through empirical relationships proposed by Froese & Binohlam (2000) and Then *et al.* (2015); L_∞ from L_{max}: $\log L_\infty = 0.044 + 0.9841 * \log (L_{max})$; L_m from L_∞: $\log L_m = 0.8979 * \log L_\infty - 0.0782$; L_{opt} from L_∞: $\log L_{opt} = 1.0421 * \log L_\infty - 0.2742$; and M from t_{max}: $M = 4.899\ t_{max}^{-0.916}$). For the parameters documented in fork length (FL), total length transformations (TL) were carried out through the form: $TL = a + b$ (FL), where parameters a and b were obtained from Fishbase (Froese & Pauly, 2019). Parameters derived from literature and parameters estimated by empirical relationships are shown in Table 2.

Additionally, the following indicators were calculated: $L_{max5\%} / L_\infty$ and $L_{95\%} / L_\infty$ where $L_{max5\%}$ = mean length of largest 5% and $L_{95\%} = 95^{th}$ percentile of the length distribution. The reference point in both cases is >0.8, which is related to the conservation of the largest individuals. Indicators were also calculated about the conservation of immature individuals: $L_{25\%} / L_m$, L_{mean} / L_m and L_c / L_m, where $L_{25\%} = 25^{th}$ percentile of the length distribution and L_{mean} = mean length. Values >0.3 are expected in the first indicator, while values >1 are expected in the last two. Likewise, the L_{mean}/L_{opt} ratio was calculated where $L_{mean}/L_{opt} \approx 1$ would be expected; meaning that L_{mean} of the catch is predicted to be equal to the L_{opt}, which has been proposed as a measure to reduce the impact of fishing by allowing fish to grow before being caught (Froese *et al.*, 2016; Fitzgerald *et al.*, 2018).

RESULTS

The total length (TL) was obtained from 1,252 fish belonging to 22 fish species. Nine species (1,056 individuals) were analyzed according to the minimum data criterion to proceed with the calculation of the indicators (Table 3); 57% of measurements were made

Table 2. Parameters for the estimation of length-based indicators from nine species caught in sport fishing tournaments in the northern coast of the Yucatan Peninsula, Mexico. L_m: maturity length (cm); L_∞: asymptotic length (cm) and k: growth coefficient (yr^{-1}), both of the Von Bertalanffy growth model; M: natural mortality rate (yr^{-1}). *Standard or fork lengths transformed to the total length.

Species	Location	Reference	L_m	L_∞	k	M
Epinephelus morio	Campeche Bank	Brulé *et al.* (1999)	50.9			
	Cuba	Rodríguez (1994) in DOF (2014)		82.7	0.21	
	Campeche Bank	Burgos & Defeo (2004)				0.24
Haemulon plumieri	Cuba	García-Cagide (1987) in Fishbase (2019)	18.4*			
	Yucatan	Domínguez-Viveros & Ávila-Martínez (1996)		41.7		
Seriola dumerili	Carolina-Florida	Harris *et al.* (2007)	74.7*	142.8*	0.28	
	Adriatic Sea	Kožul *et al.* (2001)				0.3
Lutjanus synagris	Cuba	Rodríguez-Pino (1962) in Fishbase	20.2			
	Yucatan	Torres-Lara & Salas-Márquez (1990)			0.28	0.36
		Froese & Binohlan (2000)		41		
Ocyurus chrysurus	Southeast United States	Muller *et al.* (2003)	20.9			0.2
	Yucatan	Mexicano-Cíntora (1999)		59.05*	0.22	
Calamus bajonado	Florida	Burton *et al.* (2017)		73.7	0.14	0.32
		Froese & Binohlan (2000)	39.7			
Sphyraena barracuda	Caribbean Sea	Bent-Hooker (2006)	66.7	153.3	0.12	
		Then *et al.* (2015)				0.21
Sphyraena guachancho		Froese & Binohlan (2000)	51.2	97.8		
Mycteroperca bonaci	Florida	Crabtree & Bullock (1998)		130.6	0.19	
		Fishbase (2019)	67.7			
		Then *et al.* (2015)				0.38

Table 3. The number of individuals measured from analyzed and non-analyzed fish species of samples taken during sport fishing tournaments along the northern coast of the Yucatan Peninsula, Mexico.

Species analyzed	Common name	Total	2015	2016
Epinephelus morio	Red grouper	369	104	265
Haemulon plumieri	White grunt	249	146	103
Seriola dumerili	Greater amberjack	104	75	29
Lutjanus synagris	Lane snapper	82	82	0
Ocyurus chrysurus	Yellowtail snapper	78	48	30
Calamus bajonado	Jolthead porgy	57	36	21
Sphyraena barracuda	Great barracuda	51	23	28
Sphyraena guachancho	Guachanche barracuda	35	0	35
Mycteroperca bonaci	Black grouper	31	10	21
Species not analyzed				
Epinephelus spp.	Grouper	49		
Caranx spp.	Jack	23		
Calamus calamus	Saucereye porgy	23		
Lutjanus spp.	Snapper	23		
Caranx hippos	Crevalle jack	22		
Cynoscion nebulosus	Spotted weakfish	20		
Caranx latus	Horse-eye jack	7		
Scomberomorus maculatus	Atlantic Spanish mackerel	7		
Epinephelus adscensionis	Rock hind	6		
Balistes spp.	Triggerfish	5		
Gerres cinereus	Yellowfin mojarra	4		
Cynoscion spp.	Weakfish	4		
Sarda sarda	Atlantic bonito	*3*		

in Yucalpeten, 28% in Sisal, and 15% in Telchac. Of the analyzed species, *Epinephelus morio* and *Haemulon plumieri* represented 59% of the total number of individuals (35 and 24% respectively). Yucalpeten samplings were mostly integrated with *E. morio*, while Telchac and Sisal were mostly composed of *H. plumieri*.

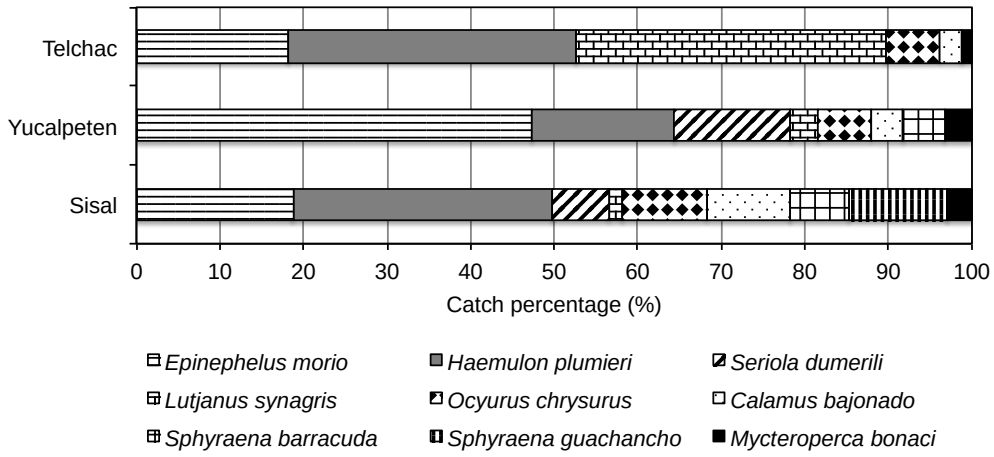

Figure 2. Catch percentage by port in sport fishing tournaments in the northern coast of the Yucatan Peninsula, Mexico.

Sphyraena barracuda or *Seriola dumerili* were not recorded in Telchac; on the other hand, Sisal was the only port where specimens of *Sphyraena guachancho* were recorded (Fig. 2).

Two categories of species could be differentiated according to their mean length L_{mean}. Those of relatively large L_{mean} between 59.3-85.6 cm TL, among which *S. barracuda*, *S. dumerili*, *S. guachancho*, and *Mycteroperca bonaci* were observed; and another group with a relatively small L_{mean} between 26.1-33 cm TL which included species *H. plumieri, Lutjanus synagris, Ocyurus chrysurus, E. morio,* and *Calamus bajonado*. Table 4 presents the values of the six calculated ratios for each species. Two species (*S. barracuda* and *S. guachancho*) obtained optimal values in the six indicators. On the other hand, for three species (*E. morio*, *C. bajonado*, and *M. bonaci*), only one indicator was above the reference point.

The results demonstrate that only *H. plumieri, L. synagris*, and *S. guachancho* present values of P_{mat} (>90%), which approximates the objective of 100%, indicating that fishing almost entirely affects adult individuals in these three species. *S. dumerili*, *O. chrysurus*, *S. barracuda*, and *M. bonaci* displayed mean values between 29 and 63% of P_{mat}, indicating that a significant proportion of the catches of these species are juveniles. However, the proportion of mature individuals in the catches of *C. bajonado* and *E. morio* were extremely low (<2%), suggesting that all catches from both species were juveniles (Fig. 3).

Concerning P_{opt}, the highest percentages also occurred in *S. guachancho* (61%), *H. plumieri* (48%) and *L. synagris* (39%), although these are relatively high values in comparison with the other species, these values are still far from the 100% objective of the catches within ±10% L_{opt}. Catches of the other species were far from optimal length; they were all observed to be between 0 to 14% of P_{opt} (Fig. 3).

With regards to P_{mega}, only *S. guachancho* presented a relatively high value of P_{mega} (21%), indicating a moderate capture of large individuals. In the rest of the species, P_{mega} values varied from 0 to 7%, indicating that sportfishing does not affect individuals of greater size, which is considered mega-spawners (Fig. 3).

The P_{obj} values showed that only three species, *H. plumieri*, *L. synagris*, and *S. guachancho* had values higher than 1, indicating that sportfishing catches of these species constitute a range of sizes that meet the sustainability requirements of the indicators. On the other hand, values of P_{obj} in *C. bajonado* and *E. morio* were extremely low; the remaining four species obtained intermediate values of P_{obj} (Fig. 3). Figure 4 provides a comparative summary of the four indicators.

DISCUSSION

There is increasing evidence that sport fishing can lead to a decrease in the fish population, contributing to the fisheries' decline and affecting ecosystems when fish mortality is high and selective exploitation is intense (Cooke & Cowx, 2004; Wolf-Christian *et al.*, 2006). Our results highlight that a large portion of fish catches by users of the sport fishery in Yucatan comprise a high proportion of juveniles. Only three (*Haemulon plumieri, Lutjanus synagris,* and *Sphyraena guachancho*) out of the nine analyzed species presented indicator values close to the objective (Froese, 2004); also important because information on sport fishery in the region is very scarce, in addition to overlapping with commercial fishing species.

Methods that can be used to evaluate fishery sustainability when only limited data exits provide

Table 4. Total lengths (cm) and length-based indicators of the species analyzed in sport fishing tournaments in the northern coast of the Yucatan Peninsula, Mexico. L_{min}: minimum length, L_{mean}: mean length, L_{max}: maximum length, L_{opt}: optimal length, L_m: first maturity length, L_∞: asymptotic length, (L_c): first capture length, $L_{max5\%}$: mean length of largest 5%, ($L_{max5\%}$), $L_{95\%}$: 95th percentile of the length distribution, $L_{25\%}$: 25th percentile of the length distribution. The green and red colors show the indicators that met the reference point and those that did not, respectively.

	L_{min}	L_{mean}	L_{max}	L_{opt}	L_m	L_∞	L_c	$L_{max5\%}$	$L_{95\%}$	$L_{25\%}$	$L_{max5\%}/L_\infty$	$L_{95\%}/L_\infty$	$L_{25\%}/L_m$	L_{mean}/L_m	L_c/L_m	L_{mean}/L_{opt}
Reference point											> 0.8	> 0.8	> 0.3	> 1	> 1	≈ 1
Species																
Epinephelus morio	20.0	30.4	67.0	59.9	50.9	82.7	29.1	49.8	38.1	25.8	0.60	0.46	0.51	0.60	0.57	0.51
Haemulon plumieri	16.9	26.1	35.5	26.0	18.4	41.7	25.9	37.3	31.5	23.7	0.89	0.76	1.29	1.42	1.41	1.00
Seriola dumerili	39.3	73.9	138.3	105.2	74.7	142.8	69.7	133.1	102.2	57.6	0.93	0.72	0.77	0.99	0.93	0.70
Lutjanus synagris	18.0	27.6	39.2	28.6	20.2	41.0	27.1	36.3	32.6	25.1	0.89	0.79	1.24	1.37	1.34	0.97
Ocyurus chrysurus	19.0	28.8	57.0	45.3	20.9	59.1	27.7	48.0	36.7	24.3	0.81	0.62	1.16	1.38	1.32	0.64
Calamus bajonado	23.0	33.0	60.0	41.8	39.7	73.7	30.9	56.3	41.0	27.1	0.76	0.56	0.68	0.83	0.78	0.79
Sphyraena barracuda	36.0	85.6	150.0	96.8	66.7	153.3	85.2	140.7	137.1	65.7	0.92	0.89	0.98	1.28	1.28	0.88
Sphyraena guachancho	54.0	71.3	95.0	63.1	51.2	97.8	69.2	94.5	82.6	64.1	0.97	0.84	1.25	1.39	1.35	1.13
Mycteroperca bonaci	28.0	59.3	100.0	78.2	67.7	130.6	58.8	99.3	93.8	45.7	0.76	0.72	0.68	0.88	0.87	0.76

suitable tools that can guide management actions focused on maintaining sustainable yields over time (Apel *et al.*, 2013). Although it is clear that the length-frequency distributions obtained from the sportfishing catches do not necessarily reflect the size structure of the entire population vulnerable to fishing, it does represent the size structure that is being pressured by sport fishing, which was the objective of this work. It is necessary to point out that most retained individuals (close to 90% of those caught, competing or not) were included in the analysis; thus, there was no bias due to competing sizes. In this sense, if any size structure were biased towards larger sizes, as could be expected from sport fishing competing catches, the indicators' values would tend to move further away from the optimum, especially P_{mega}. However, due to the mode in which sport fishing is carried out in Yucatan, it is highly probable a high overlap in size range captured by sport fishing and small-scale fishing.

Although precise detection of patterns in the indicators requires medium and long-term time scales (>5 years), when there is a piece of lack information, the use of length-based indicators, such as those applied in this study, can provide valuable information which could be contributory to the first management measures of the fishery. Also, the limitation to make final recommendations must be recognized, as it is probable that changes in size structures and the magnitude of catches will occur over time, therefore the values of the proportions of the indicators will vary in the same way. There are not recent registers that sport fishing activities in the State have changed (L. Vidal, *com. pers.*). Despite this limitation, the information provided in this article represents a starting point in understanding the effect of sport fishing on fish populations in Yucatan. Moreover, from this, suggest continuous monitoring of the size structure of sport fishing, not only with the participation of fisheries administration and academic research institutions but also of fishers, sport-fishermen, tournament organizers and the general public, incorporating these actions within a framework of citizen science, such as suggested by Pita *et al.* (2020).

The study results allowed species to be categorized into three groups according to the indicators' values. The first group was composed of the species *H. plumieri*, *L. synagris*, and *S. guachancho*, with values of $P_{obj} > 1$ indicating that members of this group can be considered as being sustainably fished. A second group with intermediate values of P_{obj} (0.38-0.71) was composed of the species *Mycteroperca bonaci*, *Ocyurus chrysurus*, *Sphyraena barracuda*, and *Seriola dumerili*; and the third group was composed of *Calamus bajonado* and *Epinephelus morio* and exhibited extreme-

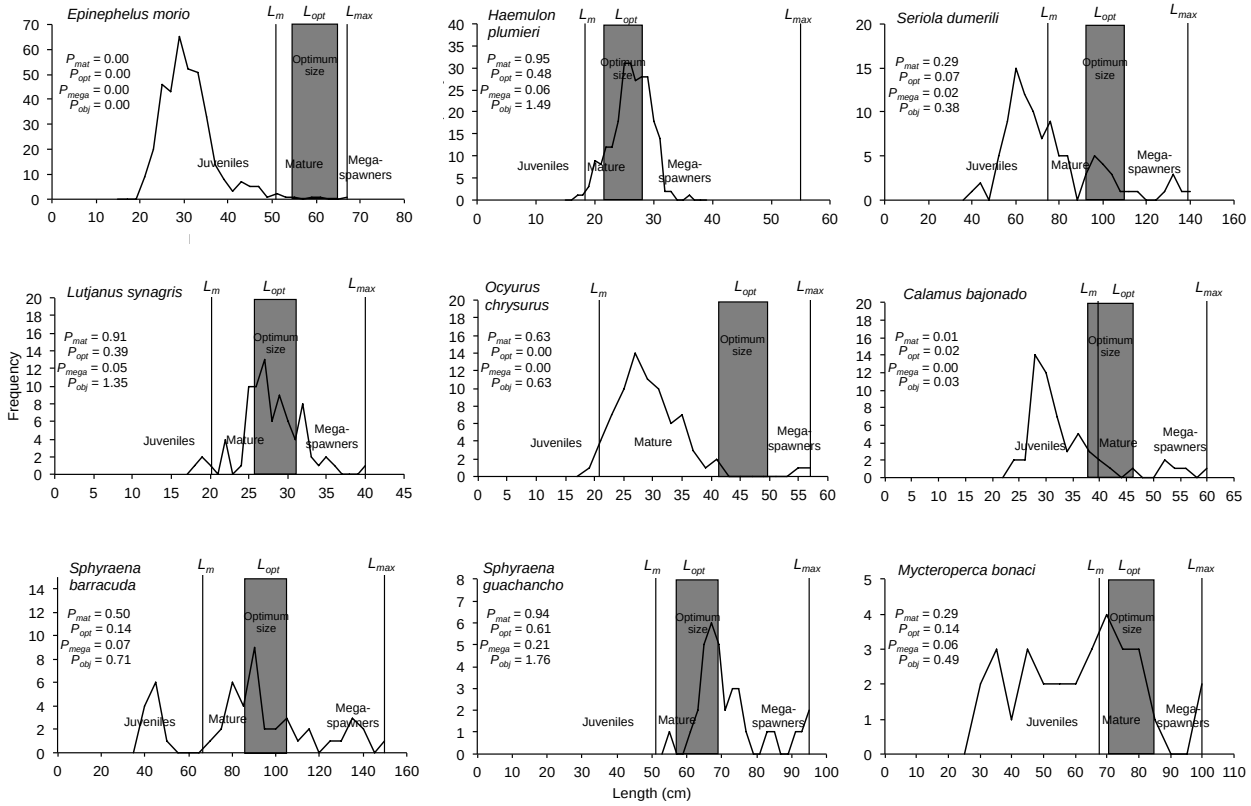

Figure 3. Length - frequency distributions of the species analyzed of the sportfishing tournaments on the northern coast of the Yucatan peninsula, Mexico. L_m: length at first maturity; L_{opt}: optimal length; L_{max}: maximum length.

ly low P_{obj} values (0.00-0.03). It shows that it is crucial to consider these differences in sport fishing management actions, such as in the issuance of fishing permits or encouraging or discouraging sport fishing of certain species.

Guachanche barracuda *S. guachancho* exhibits high values in all indicators. Unlike *H. plumieri* and *L. synagris,* this species is not associated with the red grouper - black grouper fishery, which is the largest fish fishery of the Yucatan Peninsula (DOF, 2014). Thus, *S. guachancho* has the potential to be considered as an exclusive species of sport fishing.

Lane snapper *L. synagris* is another species that exhibited higher values of P_{obj}; almost all of the individual catches had reached their maturity, and approximately 40% were of optimal length. However, *O. chrysurus* displayed a P_{mat} value of 63%, and P_{opt} and P_{mega} (Fig. 4) values close to zero. Values close to zero agree with the results of Poot-López *et al.* (2018), who found a greater proportion of immature specimens in *O. chrysurus* rather than *L. synagris*, in which the first catch size (L_{50}) was similar to its maturity size (L_m). Even though results in both species represented 15% of total analyzed specimens (Fig. 2), Poot-López *et al.* (2018) demonstrated that catch composition varies monthly, with *L. synagris* being a key component of catches from January to April, and *O. chrysurus* from September to December.

Except for *S. barracuda,* a species allocated to the second and third groups, with non-optimal indicator values, found among the 33 species associated with the red grouper - black grouper fishery located in the south of the Gulf of Mexico, that is currently considered in deterioration (Monroy-García *et al.*, 2014; DOF, 2018). Red grouper *E. morio* is considered as being overexploited (Burgos & Defeo, 2004; Giménez-Hurtado *et al.*, 2005). In this regard, our study suggests an inadequate selectivity pattern of sport fishery catches of *M. bonaci*, *O. chrysurus*, *S. dumerili*, and especially *C. bajonado* and *E. morio.*

The response to fishing pressure may be different in the dioecious species than in the protogynous hermaphroditic, such as *M. bonaci* and *E. morio* (Crabtree & Bullock, 1998; Brulé *et al.*, 1999), where the pattern of sex change plays a fundamental role (Alonzo & Mangel, 2005). In the case of length-based

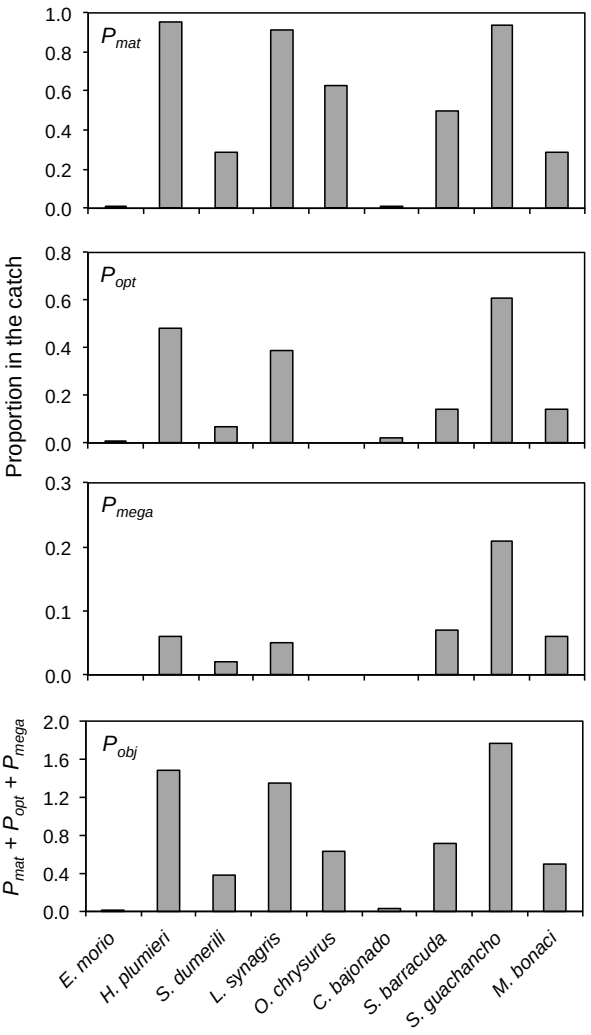

Figure 4. Length-based indicators (P_{mat}, P_{opt}, P_{mega}, and P_{obj}) calculated for the nine analyzed species of the sportfishing tournaments on the northern coast of the Yucatan Peninsula, Mexico.

indicators, it is important to consider the sex and the transition size. In *E. morio,* the size at which females change sex occurs in a range of 41.0-85.4 cm FL, with a mean of 59.7 cm FL (Brule *et al.*, 1999). In this type of species, P_{mega} would be more important than P_{mat}. It is necessary to understand the endogenous or exogenous signals that induce sex change to comprehend how fishing impacts these populations (Alonzo & Mangel, 2005). It is also important to recognize that the age and length of the first maturity in stocks that have been subject to overfishing may change in response to the high fishing mortality to which the stocks are subjected (Harris *et al.*, 2001). It should be taken into account to continue evaluating or updating the estimated size of the main species at first maturity, which may be reflected in the estimation of length-based indicators.

The depth at which sport fishing occurs can explain the effect of sport fishing on the juveniles of most species. The large proportion of individuals with smaller sizes than L_m and L_{opt} does not necessarily mean the absence of larger specimens in the population since most of these species (*i.e.*, groupers) are distributed by size. Juveniles are found in shallow water while adults are found in deep water (Hernández & Seijo, 2003; López-Rocha & Arreguín-Sánchez, 2008, 2013), suggesting that sportfishing zones are not far from the coast. The coast of Yucatan has an extensive continental platform. Hence vast distances must be traveled to reach relatively large depths. Although recreational and sport fishing is increasing, fishers do not travel far from the coast for this activity.

A particular case is the greater amberjack (*S. dumerili)*, which is one of the most important leisure fishing species in the Gulf of Mexico, it is overexploited on the north of the Gulf of Mexico, and within recreational fishing activities, private boats have been identified as the sector with the highest number of catches (Diaz *et al.*, 2005). There are no regulations for fishing of this species in Yucatan; furthermore, it is classified as an associated catch in the fisheries of red grouper - black grouper, red snapper, Atlantic Spanish mackerel, common snook and horse-eye jack from the south of the Gulf of Mexico (DOF, 2018). Of the evaluated species in this study, *S. dumerili* was the third most common catch, constituting 10% of total measurements. Also, of the evaluated catches, it was one of the species with the lowest indicator values, *S. dumerili* is one of the most vulnerable species to sport fishery.

Ihde *et al.* (2011) indicate that leisure fishing in the USA continues to grow in importance and they warn that there is a lack of successful performance-based strategies designed for commercial fishing, these authors suggest management objectives based on size and initiatives based on key stakeholders. On the coast of Yucatan, there is no record of catches or mortality estimates from leisure or sport fishing. This study, in conjunction with the study by Poot-López *et al.* (2018), demonstrates that more than 40 species are caught by leisure and sport fishing on the north coast of the Yucatan Peninsula.

While it is recognized that a more extended study period is desirable, to observe possible trends in the selectivity patterns, our results can now guide some measures such as: 1) excluding certain species from sport fishing such as: *C. bajonado* and *E. morio*, 2) promote the capture of *H. plumieri* and *L. synagris* as target species for sport fishing, with *S. guachancho* being a sport fishing exclusive species; while discouraging sport fishing of *M. bonaci*, *O. chrysurus*, *S.*

barracuda and *S. dumerili*, 3) implementation of a monitoring system in sport fishing tournaments, 4) use of methods for limited data that will enable the generation of knowledge and, thus, allow records to be generated by monitoring programs, in addition to supporting the design of specific regulatory measures for species that are often captured recreationally and 5) encourage recreational and sport fishers to fish at greater depths, as well as strive to eliminate the prize category of highest total catch weight in the local tournaments, since it is for this reason mainly that fishers retain any species of small sizes. It is essential to increase the priority level of the evaluation and management of sport fishing.

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