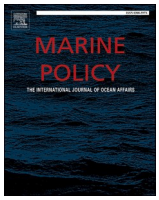
Marine Policy 161 (2024) 105999

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol



Stakeholders' perception on consumption, fishing, and conservation of Red grouper, *Epinephelus morio*, off the northern coast of the Yucatan Peninsula, Mexico

Fredy Hernández-Delgado [a], Alfonso Aguilar-Perera [a,*], Vinicius J. Giglio [c], Virginia Nóh-Quiñones [a], Jorge I. Euán-Ávila [b], Wilian de Jesús Aguilar-Cordero [a], Celia I. Sélem-Salas [a]

[a] Universidad Autónoma de Yucatán, Facultad de Medicina Veterinaria, Mérida, Yucatán, Mexico
[b] Centro de Investigaciones y Estudios Avanzados del IPN, Unidad Mérida, Km 6 Antigua carretera a Progreso C. P. 73, Cordemex, 97310 Mérida, Yucatán, Mexico
[c] Universidade Federal do Oeste do Pará – Ufopa, Campus Oriximiná, Brazil

ARTICLE INFO

Keywords:
Fish consumer
Grouper
Fishing regulations
Overexploitation
Perception
Yucatan

ABSTRACT

The fishery of Red grouper, Epinephelus morio, is one of the most commercially important in Yucatan, Mexico. However, catch trends declined from more than 14,000 t in 1970 to less than 6500 t in 2019. Consequently, the fishery authority (CONAPESCA) declared this fishery overexploited. Stakeholders may play a fundamental role regulating catch trends of Red grouper adopting responsible fishing and consumption. This work aimed to evaluate perceptions of stakeholders (fishers and fish consumers) on consumption, fishing status, and conservation of Red grouper in Yucatan using interviews and web-based questionnaires. Results revealed stakeholders regularly consume Red grouper, with fishing and consumption influenced by economic, social, and cultural factors. Stakeholders were aware of the fishery management in place, such as a seasonal, fishing ban and the minimum catch size, established by the federal government for Red grouper. Differences emerged regarding perception on fishery management between fishers and fish consumers. All stakeholders showed a willingness to follow regulations and responsible consumption during the ban, and proposed alternatives for protection through enhancing fishery regulatory measures, updating the ban and establishing spatial restrictions, such as zones for fishery protection (no-take zones). Understanding stakeholder perceptions is utmost because identifying this knowledge could provide a clearer scenario and more focused fishery management approaches for managers to promote the recovery of the Red grouper fishery. We recommend implementing a precautionary management scheme based on a combination of a management strategic evaluation and a renovated fishery strategy, along with other community-based approaches, for the Red grouper fishery in Yucatan

1. Introduction

Climate change, pollution, and overexploitation have transformed the marine ecosystems and impacted organisms, mainly those under commercial exploitation [1]. Among the most important collateral effects are the degradation of essential habitats, biodiversity reduction, and declining populations [2,3]. In many countries, management fishery regulations have not properly addressed impacts where overfishing plays a critical role affecting commercial fishes, such as groupers (Epinephelidae) [3–5]. Many grouper species are an important fishery resource worldwide [6]; however, about 20 species are at risk of extinction due to overexploitation [7–12]. In some regions of the world, initiatives for their conservation have been adopted [7–13] but an effective fishery management is lacking.

In Yucatan, Mexico, the fishery of Red grouper, *Epinephelus morio*, is among the most important [14,15]. However, the government fishery authority, known as the National Fisheries and Aquaculture Commission (CONAPESCA for its acronym in Spanish), declared this fishery overexploited [16,17]. Red grouper catches have declined from more than 14,000 t in 1970 to less than 6500 t in 2019, and this declining trend indicates a need to improve the fishery management regulations for the recovery of the fishery [18,19]. Current fishery management measures

* Corresponding author.
E-mail address: alfaguilar@gmail.com (A. Aguilar-Perera).

https://doi.org/10.1016/j.marpol.2023.105999
Received 26 December 2021; Received in revised form 10 August 2023; Accepted 22 December 2023

appear to be not enough [20]. Since the 1970 s, CONAPESCA has monitored catch volumes of Red grouper but catches have shown a declining trend [16–19]. As a measure to counterbalance this trend, in 2003 CONAPESCA implemented a one-month seasonal, fishing ban (February yearly) and established a minimum catch size (36.3 cm in total length) for Red grouper. In 2000 (with nine updates through years, with the most recent in 2023) CONAPESCA created the Carta Nacional Pesquera (CNP), or Fishery National Chart, which is an inventory and summary of fishery statistics with updated status. The CNP provides characteristics (e.g., catch volumes, fishing gear, regulatory instruments) and recommendations of recognized fisheries in Mexico, including that of Red grouper [17]. In 2014, CONAPESCA created a Fishery Management Plan (FMP) for Red grouper ratifying the minimum catch size, recommending a special hook, and establishing a new seasonal, fishing ban for two months (February 1 to March 31). Concurrently in 2014, CONAPESCA updated the NOM-065-SAG/PESC-2014, which is a regulatory instrument establishing terms and conditions for fishing grouper species in the southern Gulf of Mexico and Mexican Caribbean, and specifying the minimum size, hook types and the ban for Red grouper only [20]. Unfortunately, it was until 2017 that CONAPESCA enacted this latter fishing ban for the first time but the declining trends continue.

Besides CONAPESCA, two international, non-governmental organizations (NGOs), such as the Centro de Desarrollo y Pesca Sustentable (CeDePesca) and the Environmental Defense Fund (EDF), have organized workshops throughout years to fishers addressing various aspects of the Red grouper in Yucatan. However, little is known whether those efforts providing information to fishers have been effective for the recovery of the Red grouper population. The state government of Yucatan, through the Secretariat of Sustainable Aquaculture and Fishing (SEPASY), has provided for years a small economic support to fishers during the seasonal fishing ban to counterbalance their income.

In Yucatan, available scientific knowledge on Red grouper relies on aspects of its biology [21,22], population [23], distribution [24], and fishery management [15,25]. However, few studies have explored the current condition of its population [23,26] and none has evaluated the perception of stakeholders (i.e., fishers, consumers) in the fishery regarding the consumption, fishery status, and biological conservation. Worldwide, documenting the socio-ecological dimension of fisheries has relied on the fisher's traditional ecological knowledge [27–31]. However, fish consumer perceptions have rarely been surveyed and considered in fishery management. Documenting this latter perception could be vital to identify key components to implement a proper management and create sustainable fishery programs [29]. In this sense, fish consumers and fishers play a critical role in the conservation of commercial fishes since the former can select responsible options and avoid consumption of overexploited fish species [32-34] and the latter may catch fish species accordingly.

In this work, we addressed the perception of stakeholders (fishers and fish consumers) associated to the Red grouper fishery in Yucatan, Mexico, to respond the following questions: Do stakeholders know Red grouper is at risk of population collapse and its fishery overexploited? What do stakeholders suggest as viable strategies to properly be implemented for this fishery to avoid a population collapse? However, more importantly what do fish consumers know about this grouper? The aim of this work was to evaluate stakeholder perceptions related to consumption, fishing, and conservation of Red grouper, *E. morio*, off the northern coast of the Yucatan Peninsula, Mexico.

2. Materials and methods

2.1. Study area

Two small-scale, multispecies and multigear, fishing fleets (offshore and medium fleets) comprise the Red grouper fishery in Yucatan, which work in the Campeche Bank off the northern coast of the Yucatan Peninsula. These fleets use various types of vessels, but commonly they have mother vessels (up to 27 m long) which carry up to 14 small (1–3 m long) boats (called dinghies) operated by one fisher [26]. Besides Red grouper, the fleets catch associated fishes to the fishery, such as Black grouper (*Mycteroperca bonaci*), other grouper species, snappers (Lutjanidae) Jacks (Carangidae), and even sharks, using hand-held, fishing lines (longlines) with 50–100 hooks. Some vessels operate directly longlines of up to 2000 hooks. A non-standardized Catch-per-Unit-Effort (CPUE) has been unified for this fishery. Thus, scientists and managers have calculated CPUEs depending on data available from official fleets landings for analyzing catch trends [36]. Mayan fishers are key participants in the Red grouper fishery in the following fishing ports of Yucatan: Sisal, Celestun, Progreso, Telchac, Dzilam de Bravo, San Felipe, Río Lagartos, and El Cuyo [35,36] (Fig. 1).

2.2. Sampling design

From September to December 2020, we conducted in-person interviews with questionnaires to fishers and fish consumers in Progreso, Celestun, and Chicxulub. These latter ports have the highest economically active inhabitants in the coast [37] (Fig. 1). Due to the COVID-19 pandemic, we had to assemble on-line questionnaires through Google Forms to record information. Before applying questionnaires, we kindly requested voluntary consent to stakeholders for participating and informed them about the confidentiality of data use. We applied two types of mixed questionnaires: one for fishers and another for fish consumers. During prospective visits to coastal communities, we placed informative banners in strategic areas in restaurants, fish markets, and fishing ports and distributed information cards between people. Banners contained information illustrating the Red grouper characteristics and also invited fish consumers and fishers to respond the questionnaires in Google Forms using an URL and a QR code.

We applied a 26-items questionnaire to fishers and another with 23-items to fish consumers. Both questionnaires covered three topics: I) General data, II) Fishing and/or Consumption, and III) Biological conservation. Questionnaires were previously validated through a pilot study we applied online in May 2020. This pilot helped to identify problematic questions and opinions to improve questionnaires. To calculate a sample size for the number of fishers, we used the following formula for finite populations [38]:

$$n = \frac{Nz^2pq}{(N-1)d^2 + z^2pq}$$

where n is the estimated sample size, z = 1.96 Confidence interval 95%, p = 0.5 estimated proportion, q= 1-p, d= 0.1 (estimation error), and N = 10208, which is the number of active local fishers according to 2019 census of the Secretariat of Sustainable Fisheries and Aquaculture of Yucatan (SEPASY). Therefore, 95 fishers represented an appropriate sample size (confidence coefficient of 0.92). For the selection of fishers, we used a simple random sampling.

Regarding fish consumers, for ensuring a quality of sample size, rather than its quantity, we selected fish consumers using the "snowball", non-probabilistic technique [39], in which the most knowledgeable interviewee is tracked down by references from each other. For this, we considered the following selection criteria: adults between 15 and 65 years old, willing to complete the survey and consume fish at least once a week (preferably grouper) [40,41]. In addition, we recorded proposals from both fishers and fish consumers oriented on how to reach a responsible fishing and consumption of Red grouper in Yucatan.

2.3. Data analyses

Responses associated to fish consumption and responsible consumption, as well as fish species, social, demographic, and economic aspects, were collected from stakeholders through questionnaires. We

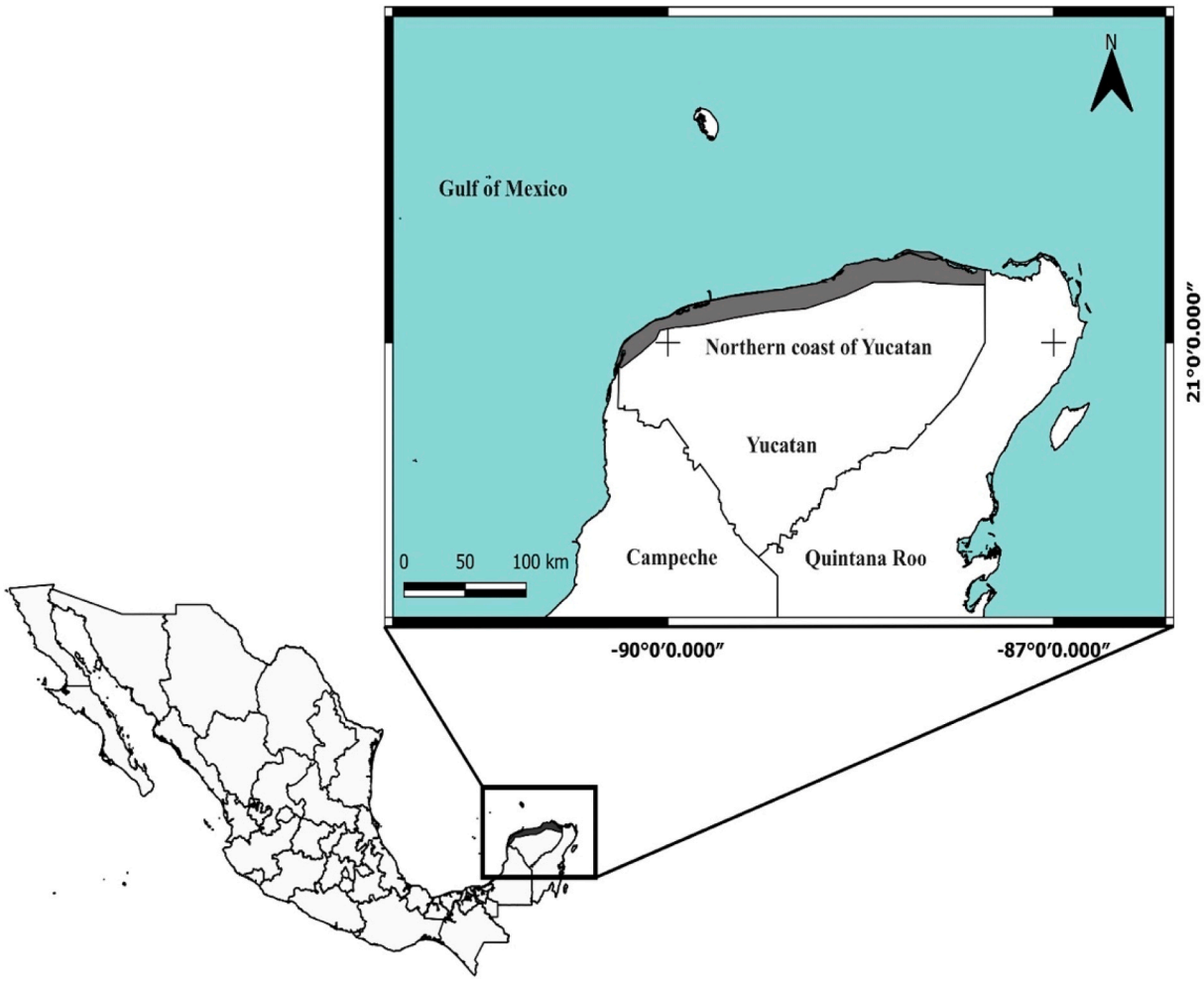


Fig. 1. The northern coast of the Yucatan Peninsula, Mexico, southern Gulf of Mexico, showing the geographic coverage (gray polygon), where participant stakeholders (fishers and consumers) reside.

compared perceptions from fish consumers and fishers using a logistic regression to adjust factors (e.g., age, years of experience consuming fish and fishing, and scholar level) with income as an independent variable and the answer (yes or no) as dependent variable. To verify differences between perceptions, we used a Mann-Whitney-Wilcoxon test because data did not meet assumptions for normality. For comparing differences between the proportions of each response category of stakeholders concerning qualitative variables of non-binary type, we used a Chi-Square test. Statistical analyses were conducted using R software [42] with a significance level of 5%.

3. Results

We applied questionnaires to 274 stakeholders, of which 123 were fishers (2 women and 121 men) and 151 fish consumers (74 women and 77 men) (Table 1). Average age of fishers and fish consumers were 36.7 ± 0.1(± standard error) and 36.8 ± 1.2 years, respectively. In scholar level, only 12.2% fishers finished bachelor's degree and 23.6% did not finish high school. However, most fish consumers were graduates, some with graduate studies. In general, the majority of stakeholders were from Celestún, Mérida, and Progreso, but people from other fishing towns were surveyed (Table 1).

Fishers showed an average experience of 18.7 ± 1.0 years and recognized at least five grouper species in the catch, captured fish due to economic needs, and had no other activities for wellbeing (Table 2). Less than half of fishers affirmed avoiding catching Red grouper during the

Table 1
Demographic characteristics of stakeholders, fishers (N = 123) and consumers (N = 151), associated to the Red grouper fishery off the northern coast of the Yucatan Peninsula, Mexico. Data are reflected as absolute frequencies (AF) and relative frequencies (RF).

		Fisher		Consumer	
		AF	RF (%)	AF	RF (%)
Sex	Female	2	1.63	74	49.01
	Male	121	98.37	77	50.99
Age	< 30 years	43	34.96	63	41.72
	31 to 45 years	49	39.84	41	27.15
	> 45 years	31	25.20	47	31.13
Scholar level	Primary	29	23.58	15	9.93
	High school	42	34.15	13	8.61
	High School/Technical	37	30.08	37	24.50
	Bachelor	15	12.20	56	37.09
	Master	0	0	17	11.26
	PhD	0	0	12	7.95
	No	0	0	1	0.66
Place of birth	Yucatan	113	91.87	123	81.46
	Other	10	8.13	28	18.52
Residence city	Celestun	55	44.72	51	33.77
	Merida	13	10.57	79	52.32
	Progress	8	6.50	16	10.60
	Other	47	38.21	5	3.31
Income (US$)	< 300	86	69.92	64	42.38
	300-600	27	21.95	48	31.79
	600-900	6	4.88	17	11.26
	> 900	4	3.25	22	14.57

Table 2
Comparison between stakeholders in relation to a given condition (variable) and knowledge regarding the Red grouper fishery (Mann-Whitney-Wilcoxon test, significant differences $p < 0.05$(*).

Variable	W	p
Experience	16,483.00	0.5
Age	17,258.50	0.5
Schooling	11,985.00	< 0.0001*
Income	14,037.00	< 0.0001*
Consumption (Kg)	23,972.00	< 0.0001*
Species	23,813.50	< 0.0001*
Price	11,986.50	0.0003*

seasonal fishing ban and a minority declared catching groupers of small size (less than 36 cm TL). Fish consumers were composed mostly by general public, while other fractions were restaurant owners, and a small part were persons from fisher cooperatives and supermarkets. The experience in fish consumption was 21.3 ± 1.3 years (Table 2). Fish consumers mostly purchase Red grouper either from fishers or restaurants. The grouper presentation bought was fresh and frozen fillets. The majority of fish consumers clearly recognized both Red grouper and Black grouper, and others did not recognize any grouper species, while others confused snappers (Lutjanidae) with groupers. On the other hand, fish consumers did not accurately identify the conservation category of grouper species *(E. itajara, E. morio* and *M. bonaci)* in Yucatan (Fig. 2).

Stakeholders assured to respect the seasonal, fishing ban and identified the minimum catch size (Fig. 3). Fish consumers declared consuming other fish during the ban to achieve a responsible consumption. Consumption on Red grouper is largely justified by its taste, access, quality, and tradition (Fig. 3), and is directed towards medium size individuals (36.3–50 cm). However, there was a difference between fishers and fish consumers because the former was not interested in consuming large groupers (> 50 cm) but small fish (< 36.3 cm), while the latter was interested in both fish sizes. Fishers recognized the Red grouper fishery as overexploited, while fish consumers were not convinced of any overexploitation and were not aware of the current

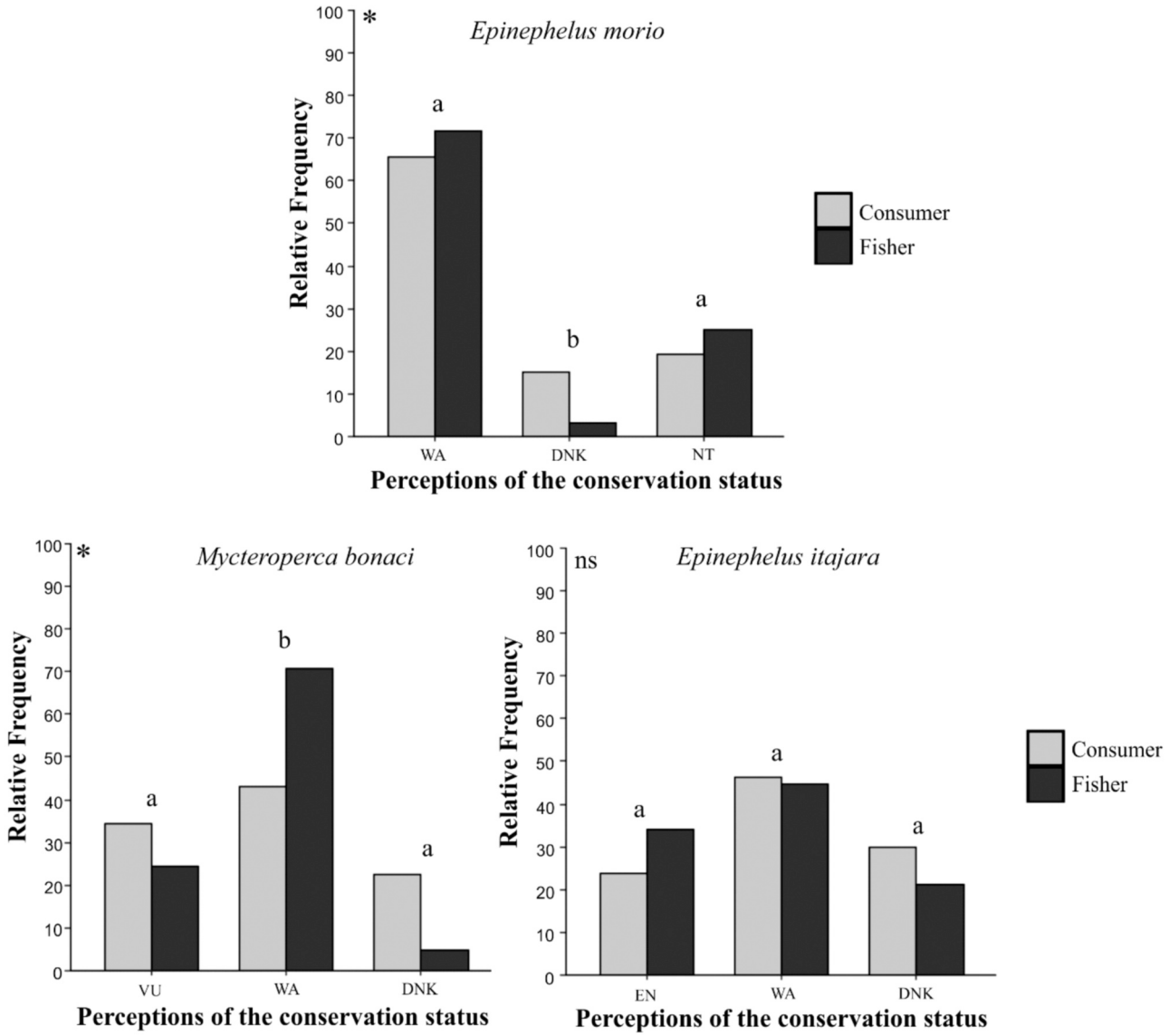


Fig. 2. Stakeholders' perception on the IUCN's conservation categories of groupers *Epinephelus morio* (top), *Mycteroperca bonaci* (down left), and *Epinephelus itajara* (down right) in the Gulf of Mexico. The following acronyms refer to the lack of knowledge of stakeholders about the conservation categories: DNK (Does Not Know) and WA (Wrong Answer) when the stakeholder thinks they know but the answer is incorrect. VU= IUCN's category of Vulnerable, NT = Near Threatened and EN Endangered. * denote Chi-Square Test showed p-value > 0.001 * and ns (Not significant). Homogeneous groups, as determined by the post hoc comparisons "Nominal peer independence" are linked by letters.

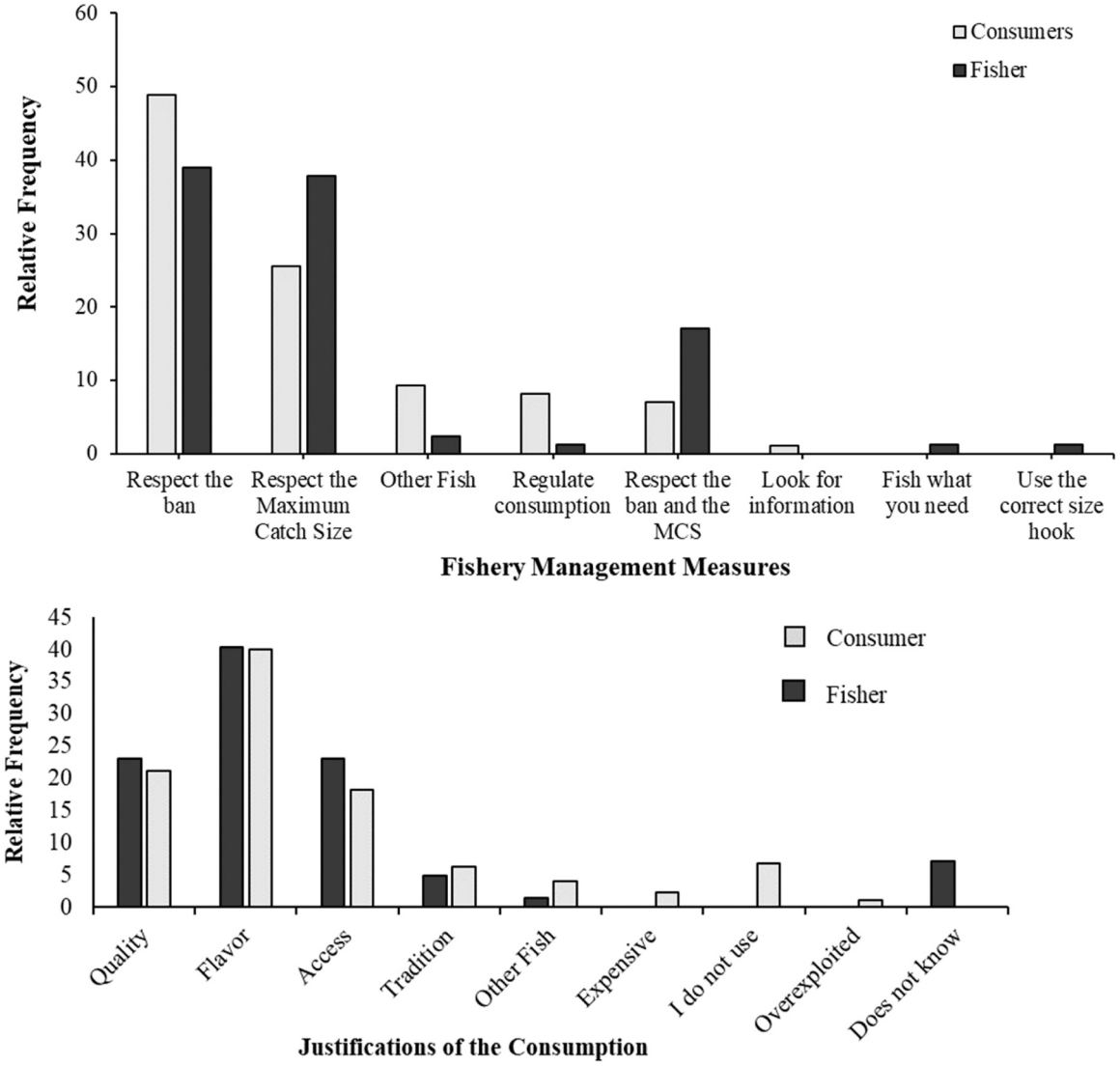


Fig. 3. Stakeholder perception of fishing management measures (upper graph) and justification of consumption (lower graph) for the Red grouper off the northern coast of the Yucatan Peninsula, Mexico.

fishery situation or considered the fishery under a good condition (Fig. 4).

Fishers confirmed consuming more grouper than fish consumers. In this variable, as well as in other variables (scholar level, income, number of grouper species known, price), significant differences were observed between both stakeholders (Table 2, Fig. 5). Some stakeholders were not completely aware of all fishery regulations imposed by CONAPESCA but recognized the fishing ban as the key regulatory measure. Among other fishery measures established by CONAPESCA, which some stakeholders were not able to easily recognize are the Fisheries Management Plan, The National Fisheries Chart (Carta Nacional Pesquera), and the NOM-065-SAG/PESC-2014. However, some fishers recognized the role CONAPESCA plays and the role SEPASY plays in the Red grouper fishery.

Some stakeholders showed evidences of not accurately knowing Red grouper's minimum catch size (36.3 cm TL) but all fishers recognized the seasonal fishing ban (February 1 to March 31). Half of the fish consumers ignored such period (Fig. 5). All stakeholders declared Red grouper is traditionally consumed in Yucatan. Fishers considered this grouper is not properly reported by CONAPESCA and mentioned they followed responsible fishing measures in comparison to consumption measures by fish consumers (Table 3). Stakeholder perception was influenced by the experience, income, and scholar level to a large extent, but not so much so by age.

4. Discussion

We recorded stakeholder perceptions on various aspects of the fishery of Red grouper in Yucatan, Mexico. Economic (i.e., revenue and price), social (scholar), and cultural (tradition, popular knowledge) factors affect their perception on consumption, fishing, and conservation. Our results revealed that groupers, particularly Red and Black, are important fish resources for fishers and fish consumers in Yucatan. However, stakeholders showed some complications recognizing the IUCN's conservation categories of these fishes. Worldwide, IUCN's scientists have assessed (the most recent in 2016) the population status of grouper species, where key threats included the excess fishing effort due to insufficient fishery management, a high pressure of international trade, a lack of compliance with national laws, and an inadequate surveillance in protected areas [13,18]. IUCN's categories at risk of extinction are Near Threatened, Vulnerable, Endangered, and Critically Endangered. Currently, Red grouper *Epinephelus morio* is under the IUCN's category of Vulnerable [11]. However, this latter scientific assessment has not been incorporated into any regulatory fishery instrument by the federal government in Mexico, and fishers and fish

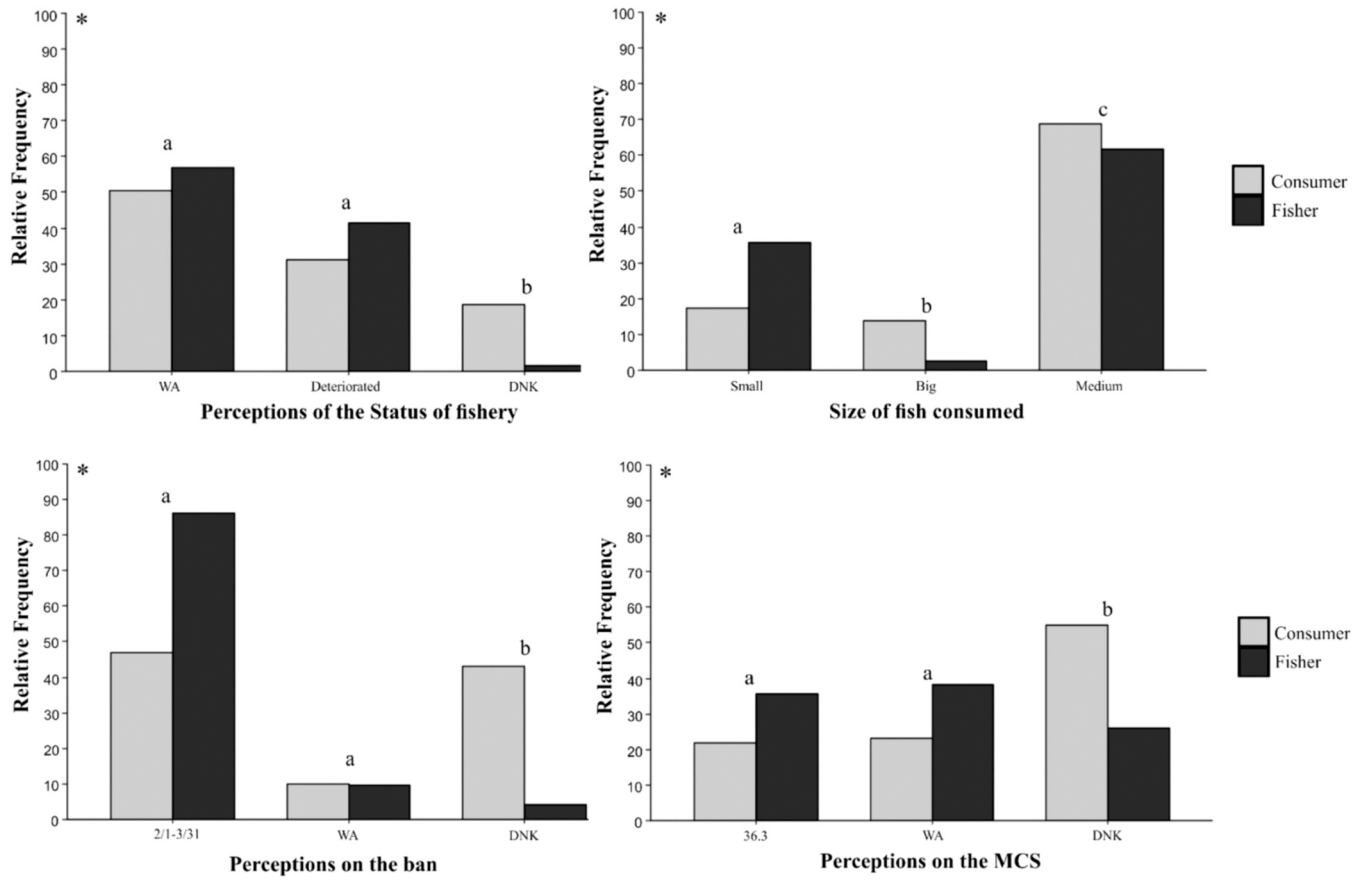


Fig. 4. Stakeholder perception on the fishery status (upper left), the grouper body size consumed (upper right), the fishery ban (lower left) and the minimum catch size (MCS, 36.3 cm TL) (lower right) of Red grouper off the northern coast of the Yucatan Peninsula. DNK = Does Not Know, WA =Wrong Answer. Results of Chi Square Test in both variables: p-value > 0.001 * . Homogeneous groups, as determined by the post hoc comparisons "Nominal peer independence", are linked by equal letters.

consumers are not aware of it widely.

In Yucatan, the Red grouper fishery includes various other associated fishes, such as the Black grouper, other grouper species and also snappers (Lutjanidae), jacks (Carangidae) and even sharks, but Red grouper chiefly receives more fishery management attention by CONAPESCA. This latter grouper is the main resource of the fishery in the international market [43–45]. In our work, fishers recognized grouper species better compared to those identified by fish consumers, and more valuable fish were recognized mostly by fishers. In comparison to other countries, like Brazil, fishers are capable of recognizing commercial fish depending on the commercial importance [46]. The high commercial value of groupers, and their meat quality [46,47], is appealing for fishers because of the market [48,49]. For instance, a fraction of fish consumers in Brazil justified consuming fish species at risk of extinction to be sporadic, such as the Atlantic Goliath grouper *E. itajara*, and fishers recognized the consumption of this latter grouper as illegal at international level. In fact, fishing Goliath has been forbidden in many countries because its populations have severely declined [34]. However, despite of this prohibition, there have been illegal captures. In Brazil, fish consumers are aware that some groupers they consume are at risk of extinction; however, these conditions groupers have appeared to be not enough reason to halt their consumption [35].

Stakeholders in Yucatan were aware of fishery regulations imposed by CONAPESCA. However, not all stakeholders recognized those regulations well, but fishers knew both the minimum catch size (36.3 cm TL) and the fishing ban (February 1 to March 31st), and partially knew the mandatory regulation of NOM-065-SAG/PESC-2014 [50]. Despite fishers are aware of these fishery instruments, the Red grouper fishery is declining and officially recognized by CONAPESCA as overfished. Specific reasons why this fishery is overfished are unknown, but it is possible the fishery instruments in place are not effective. However, the CNP provided suggestions for the Red grouper fishery, including a reduction of fishing effort, implement strategies established Fishery Management Plan, enhance data monitoring, and update the minimum catch size for Red grouper [17]. Possible causes of overexploitation are the lack of surveillance, reduction of environmental quality, and socio-economic conflicts [51]. Up to date, no rigorous measures have been adopted for the Red grouper fishery [43]. Besides, the fishery instruments currently in place are focused chiefly on Red grouper, while other groupers, such as Black, Nassau (*E. striatus*) and Goliath, are not considered to even have a minimum catch size or a specific seasonal fishing ban [43].

In Cuba, fishery management plans consider conflicts generated when applying new regulations, including the cultural patrimony from the community and advantages of small-scale fisheries in relation to sustainability and socioeconomics [52]. In Yucatan, stakeholders proposed measurements to protect the Red grouper such as the enhancement of regulatory measures to update the fishing ban and the establishment of locations with a permanent ban. These latter locations could be viable to be established as closed areas to fishing and managed as no-take zones. In Mexico, since 2012 a fishery instrument called 'zonas de refugio pesquero' (zones without fishing or fishery refuge zones) was created but these instruments have been established mainly inside natural protected areas (NPAs) (the term Marine Protected Area is not recognized in the environmental legislation in Mexico, but only Natural Protected Area) [18]. In general, in Mexico the implementation of NPAs without any public hearing has promoted local community conflicts affecting the performance of NPAs. In fact, it is necessary to

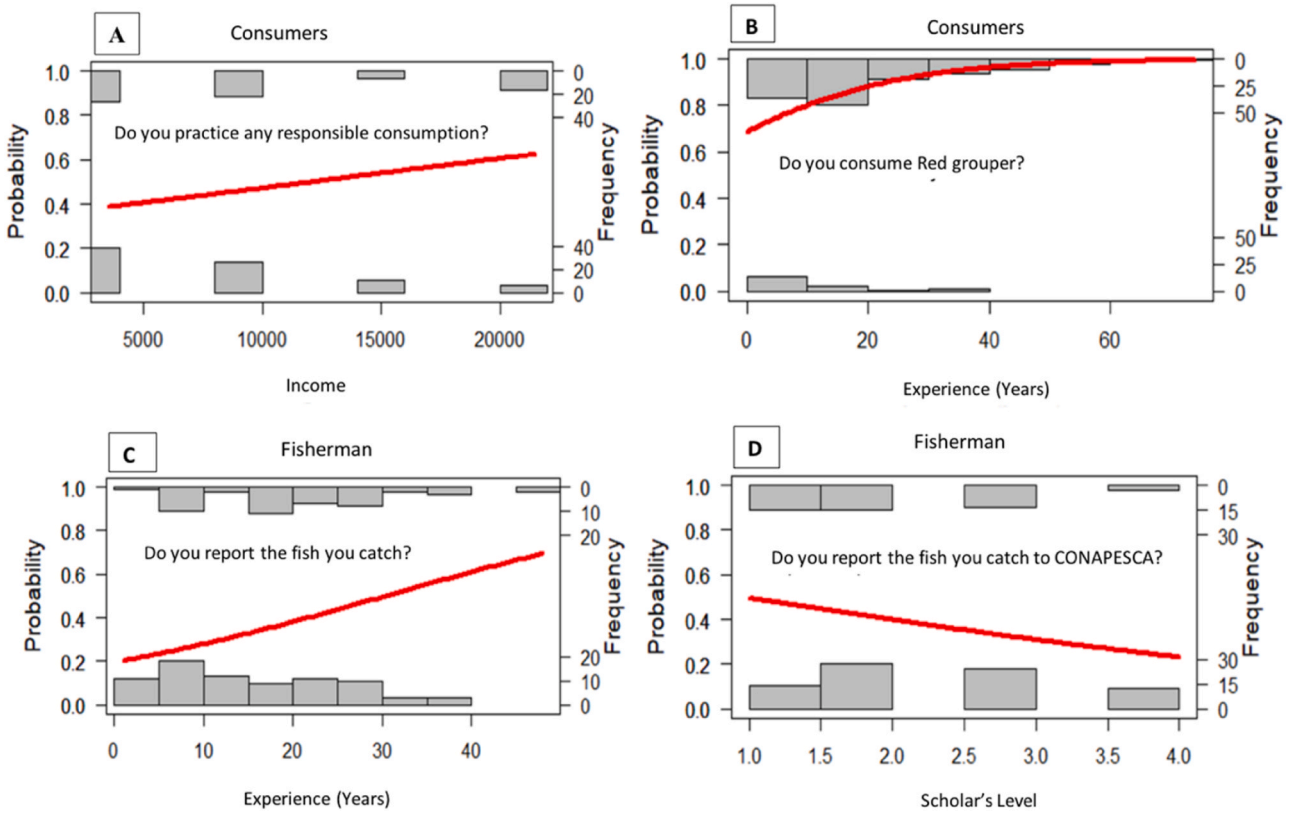


Fig. 5. Logistic regression curves adjusted on the probability stakeholder response, in a given situation, to the option of responsible consumption or fishing. A) Do you practice responsible consumption? depends of the income of the consumer household and increases the probability with income increase; B) Do you consume Red grouper? depends on the experience of the consumer and increases the probability with experience increased; C) Do you report groupers caught? depends of fishing experience and increases the probability with the increase in scholar level; D) Do you report grouper caught to CONAPESCA? depends of the fishing the experience and decreases the probability with the increase in the scholar level.

Table 3
Stakeholder responses on consumption, fishing, and conservation of Red grouper. Values reflect the proportion in percent to the total number of respondents for user. Results of the Chi-Square Test in both variables: p-value > 0.05 * and ns (Non-significant).

Questions about fishing, consumption and conservation (Only yes is considered)	Fisher	Consumer	Chi Square (p-value)
Do you consume grouper?	94%	86%	0.35 (0.55) **ns**
Do you consider Red grouper consumed or caught is reported to CONAPESCA?	37%	48%	1.42 (0.2) **ns**
Do you follow any responsible fishing and consumption measures for grouper?	68%	46%	4.27(0.03)*

validate the efficacy of those fishery refuge zones (no-take zones) as alternatives for the recovery of a given fishery in Mexico. In geographic areas outside Mexico, no-take zones managed partially by fishers have provided to be effective [53–55].

In our study, fishers suggested to sanction middlemen not following regulations and establish a fishing quota and a fixed price for Red grouper, which will benefit fishers. In other countries, such as Africa, rooted social complexity in fisher organizations permeates, which limits an adequate fisher response; however, fishers have understood the problematic situation and have suggested solutions to fight illegal fishing [29]. Among other stakeholder suggestions are increasing the popular science about the biology of Red grouper and its population condition and conservation, avoiding consuming Red grouper in restaurants during the seasonal, fishing ban and implementing workshops, including fishers and fish consumers, to augment the popular knowledge about the critical overfishing situation of Red grouper. Worldwide, social media is an important channel for augmenting popular knowledge of resources and reach public relevance when this information is effectively delivered [56]. In Indonesia, for instance, an active participation of stakeholders, including managers, promoted capacity building and offered a proper fishery management with collaboration in the grouper fishery of that region [57].

In our study, stakeholders suggested a mechanism in which fishers and middlemen be evaluated and have the opportunity to inform the government about the origin, measures, and species under commercialization (trackability). In some occasions, fishers use strategies to deter surveillance, such as misdeclaration of fish caught. In this current scenario, fish consumers are often cheated, and they consume other fish without knowing it. In this sense, it is necessary the government be capable to implement a regulatory program with sanctions and surveillance to avoid illegal fishing and mislabeling. In our work, fishers with high educational level perceived groupers they catch or consume are not reported properly to the CONAPESCA. In Brazil, scholarly fishers were in agreement with the management measures because they perceived these are important for their revenue. However, in our study as long as the scholar level in fishers increases, they are able to perceive the functioning of the fishery institutions better and probably fishers may lose trust in CONAPESCA. Economic factors play a key role in the fishing and consumption patterns [58–60]. Changes in people's behavior, or a lack of it, can be driven by financial limitations. In Yucatan, fish consumers on high economic position can afford what they consume because their capabilities to get informed. However, it is possible they could not worry if the grouper does not accomplish standards of good fishing practice.

The current situation the Red grouper fishery urgently calls for an

immediate implementation for a precautionary management scheme, chiefly using the risk-averse bioeconomic reference point preferably based on either the Maximum Economic Yield (MEY) or the Maximum Biological Production Yield [16]. These factors could provide a more economically reference point before the fishery reaches a point of no return. However, the fishery appears to have not only the commercial but also the recreational influence, with this latter having a lack of monitoring [43]. For the commercial fishery, it is necessary to implement an alternative stock assessment using not only ME but it is recommended to promote an approach based on using the development of the Management Strategic Evaluation (MSE) [61] and the process of Harvest Strategy (Limit Reference Point and Target Reference Point). The MSE involves defining a decision problem, specifying objectives, and simulating the managed system to help evaluate uncertainties, risks and trade-offs of management alternatives. This latter process involves the participation of stakeholders, scientists and managers to find solutions. The Harvest Strategy involves empirical indicators and control rules for managing exploitation of fisheries to target species [62,63], including a monitoring program, indicators to be calculated from the monitoring, and using indicators associated to reference points in management decisions by applying those decisions [62,63]. By applying the Harvest Strategy, it would be possible to know the consumption patterns between the human population. In general, the MSE and the Harvest Strategy can cover the scientific approach and collaborative approach, which may help to improve the grouper's fishery management and consequently help in the fishery recovery.

Since the factors considered in our study were not critical determinants of stakeholders' preferences, we highlight the need for a more comprehensive understanding of many other factors driving stakeholder perceptions in the Red grouper fishery in Yucatan. Therefore, we recommend the following actions: (1) to implement popular campaigns, coordinated and organized between the government, academia and NGOs, devoted to stakeholders (in particular fish consumers) for elucidating the biological characteristics of the Red grouper, but applying scientific follow-up surveys and interviews to identify the effectiveness of these campaigns in compliance with the recovery of the fishery (2) promote a more coordinated participation of policy makers, managers, and academia to filling the gap of knowledge in fish consumers on groupers selection complementing with interviews and focus groups to understand people preferences, (3) improve the mechanisms that fishery authorities use to communicate the management regulations to fishers and conduct follow-up surveys to understand the dynamics of fisher perceptions, and (4) incorporate stakeholder perceptions into the fishery management process (and in the amendments of the management plans).

In Yucatan, fishery managers of federal and state government are another group of stakeholders associated to the Red grouper fishery. While our work did not consider this group, we highlight the importance to identify their perception on the Red grouper fishery regarding how effective their outreach efforts to fishers have been in order to reach a consensus about possible solutions for the recovery of the fishery. We recommend the government adopting coordinated alternatives between academia and NGOS for the Red grouper fishery to reach a better level of fishery control by implementing a catch traceability scheme and a certification market for the fishery (e.g., Marine Stewardship Council, and Fairtrade, among others). On this latter, CeDePesca, and more recently EDF, have attempted to address ways to exchange ideas between fishers and managers to find proper solutions for the recovery of the Red fishery in Yucatan, but the federal government has had a slow response.

5. Conclusions

The fishery of Red grouper is very important to stakeholders (fishers and fish consumers) off the northern coast of the Yucatan Peninsula, Mexico. Stakeholder perceptions on the socio-economic, cultural, and biological conservation aspects of this fishery are key to improving its recovery. Most stakeholders knew little about the conservation categories of groupers and their vulnerability to fishing and overexploitation, but some knew about the fishery regulations imposed by the federal government (e.g., fishing ban, minimum catch size, NOM-065 SAG/PESC 2014). Difference in stakeholder's perception on fishing and conservation is probably associated to a lack of campaigns and the inclusion of fish consumers for the development of management plans, their implementation and monitoring of activities. Stakeholders are willing to participate in campaigns to provide protection to this fishery. By considering fish consumers participation in these campaigns is expected the fishery management will improve.

CRediT authorship contribution statement

Fredy Hernández-Delgado: Investigation, Methodology, Data Curation, Formal Analysis, Writing Original Draft, **Alfonso Aguilar-Perera:** Investigation, Conceptualization, Methodology, Formal Analysis, Supervision, Writing: Original Draft, Writing: Review & Editing' **Vinicius J. Giglio:** Methodology, Data Curation, Validation, Formal Analysis Writing: Review & Editing, **Virginia Nóh-Quiñones**: Formal Analysis, **Jorge I. Euán-Ávila**: Formal Analysis, Methodology, **Wilian de Jesús Aguilar-Cordero**: Methodology, Formal Analysis, **Celia I. Sélem-Salas**: Formal Analysis.

Data availability

The data that has been used is confidential.

Acknowledgments

We acknowledge stakeholders associated to the Red grouper fishery in Yucatan. We specially thank Mariano Canul Uicab, president of the cooperative "Pescadores del Golfo" and Carlos Jimenez, fisher from Celestun. We are grateful to Minerva Alonso from CeDePesca. IDEA Wild provided support with computer equipment. FHD thanks to Consejo Nacional de Ciencia y Tecnología (CONACYT, now CONAHCYT) for a MSc scholarship.

References

[1] T.P. Hughes, J.T. Kerry, M. Álvarez-Noriega, J.G. Álvarez-Romero, K.D. Anderson, A.H. Baird, et al., Global warming and recurrent mass bleaching of corals, Nature 543 (2017) 373–377, https://doi.org/10.1038/nature21707.

[2] F.C. Coleman, C.C. Koenig, K.M. Scanlon, S. Heppell, M.W. Miller, Benthic habitat modifications trough excavation by red grouper *Epinephelus morio*, in the Northeastern Gulf of Mexico, Open Fish. Sci. J. 3 (2010) 1–15, https://doi.org/10.2174/1874401X01003010001.

[3] P.J. Mumby, R.S. Steneck, A.J. Edwards, R. Ferrari, R. Coleman, A.R. Harborne, J. P. Gibson, Fishing down a Caribbean food web relaxes trophic cascades, Mar. Ecol. Prog. Ser. 445 (2012) 13–24, https://doi.org/10.3354/meps09450.

[4] W. Colglazier, Sustainable development agenda: 2030, Science 349 (6252) (2015) 1048–1050, https://doi.org/10.1126/science.aad2333.

[5] CBD, U. Strategic plan for biodiversity 2011–2020 and the Aichi targets. In Report of the Tenth Meeting of the Conference of the Parties to the Convention on Biological Diversity. 2010.

[6] A. Valdivia, Cox C.E., Bruno, J.F. Predatory fish depletion and recovery potential on Caribbean reefs. Sci. Adv. 3(3), e1601303.

[7] Y. Sadovy de Mitcheson, M.T. Craig, A.A. Bertoncini, K.E. Carpenter, W.W. Cheung, J.H. Choat, M. Liu, Fishing groupers towards extinction: a global assessment of threats and extinction risks in a billion-dollar fishery, Fish Fish 14 (2) (2013) 119–136, https://doi.org/10.1111/j.1467-2979.2011.00455.x.

[8] Y. Sadovy de Mitcheson, Aguilar-Perera A., Sosa-Cordero E. 2018. Epinephelus striatus. The IUCN Red List of Threatened Species e.T7862A46909843. https://dx.doi.org/10.2305/IUCN.UK.2018–2.RLTS.T7862A46909843.en.

[9] B. Padovani-Ferreira, Bertoncini A.A., Pollard D.A., Erisman B., Sosa-Cordero E., Rocha L.A., Aguilar-Perera A., Brule T. 2018. *Mycteroperca bonaci*. The IUCN Red List of Threatened Species. e.T132724A46916253. https://dx.doi.org/10.2305/IUCN.UK.2018–2.RLTS.T132724A46916253.en.

[10] A.A. Bertoncini, Aguilar-Perera A., Barreiros J., Craig M.T., Ferreira B. Koenig C. 2018. *Epinephelus itajara* (errata version published in 2019). The IUCN Red List of Threatened Species. e.T195409A145206345. https://dx.doi.org/10.2305/IUCN.UK.2018–2.RLTS.T195409A145206345.en.

[11] T. Brule, Bertoncini A.A., Ferreira B., Aguilar-Perera A., Sosa-Cordero, E 2018. Epinephelus morio. The IUCN Red List of Threatened Species. e.

T44681A46914636. https://dx.doi.org/10.2305/IUCN.UK.2018- 2.RLTS. T44681A46914636.en.
[12] Y. Sadovy de Mitcheson, C. Linardich, J.P. Barreiros, G.M. Ralph, A. Aguilar-Perera, P. Afonso, M.T. Craig, Valuable but vulnerable: over-fishing and under-management continue to threaten groupers so what now? Mar. Policy 116 (2020) 103909 https://doi.org/10.1016/j.marpol.2020.103909.
[13] B.E. Luckhurst, Development of a caribbean regional conservation strategy for reef fish spawning aggregations, Proc. Gulf Caribb. Fish. Inst. 54 (2003) 668–679.
[14] CONAPESCA. Anuario Estadístico de Acuacultura y Pesca, 2017. Comisión Nacional de Acuacultura y Pesca (CONAPESCA). Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA). 2017.
[15] S. Salas, Mexicano-Cíntora G., Cabrera M.A. ¿Hacia dónde van las pesquerías en Yucatán? Tendencias, retos y perspectivas. Centro de Investigación y Estudios Avanzados (CINVESTAV), Departamento de Recursos del Mar, Unidad Mérida. (2006) 109.
[16] R. Burgos, O. Defeo, Long-term population structure, mortality and modeling of a tropical multi-fleet fishery: the red grouper *Epinephelus morio* of the Campeche Bank, Gulf of Mexico, Fish. Res. 66 (2-3) (2004) 325–335, https://doi.org/10.1016/S0165-7836(03)00192-9.
[17] DOF. Carta Nacional Pesquera. Publicada en el Diario Oficial de la Federación el 26 de julio de 2022.
[18] SAGARPA. Ordenamiento pesquero de mero y especies asociadas de la península de Yucatán. Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. Delegación Federal en Yucatán. Subdelegación de Pesca. Departamento de Administración de Pesquerías. 2016.
[19] A. Hernández, Galindo G., Monroy C. Efectos de un programa de reducción de esfuerzo pesquero para embarcaciones mayores en el estado de Yucatán. CRIP-Yucalpetén INAPESCA. Opinión técnica. Documento interno; 2010: 33p.
[20] T. Brulé, J. Montero-Muñoz, N. Morales-López, A. Mena-Loria, Influence of circle hook size on catch rate and size of red grouper in shallow waters of the Southern Gulf of Mexico, North Am. J. Fish. Manag. 35 (6) (2015) 1196–1208, https://doi.org/10.1080/02755947.2015.1091409.
[21] T. Brulé, C. Déniel, T. Colás-Marrufo, X. Renán, Reproductive biology of gag in the southern Gulf of Mexico, J. Fish. Biol. 63 (6) (2003) 1505–1520, https://doi.org/10.1111/j.1095-8649.2003.00263.x.
[22] J.A. López Rocha, Arreguín Sánchez, F. Patrón, temporal de movimientos del mero *Epinephelus morio* en la plataforma continental norte de la península de Yucatán, México, Proc. Gulf Caribb. Fish. Inst. 60 (2008) 327–334.
[23] F. Arreguín-Sánchez, Contreras, M., Moreno, V., Burgos, R., Valdés, R.. Population dynamics and stock assessment of red grouper (Epinephelus morio) fishery on Campeche Bank, Mexico. In: Biology, fisheries and culture of tropical groupers and snappers: ICLARM Conference Proceedings. (1996) 202–217.
[24] M.O. Albañez-Lucero, F. Arreguin-Sánchez, Modelling the spatial distribution of red grouper (*Epinephelus morio*) at Campeche Bank, México, with respect substrate, Ecol. Model. 220 (20) (2009) 2744–2750, https://doi.org/10.1016/j.ecolmodel.2009.07.007.
[25] F. Arreguín-Sánchez, E. Arcos-Huitrón, La pesca en México: estado de la explotación y uso de los ecosistemas, Hidrobiológica 21 (3) (2011) 431–462.
[26] C. Monroy-García, Galindo-Cortes, G., Hernández-Flores A.. Mero *Epinephelus morio,* en la Península de Yucatán. Sustentabilidad y pesca responsable en México evaluación y manejo. SAGARPA, México. (2014) 245–276.
[27] S. Montiel S., Porter-Bolland L. Procesos locales en conservación: el gran desafío de la participación social. Tendencias, retos y perspectivas. Centro de Investigación y Estudios Avanzados (CINVESTAV), Departamento de Recursos del Mar, Unidad Mérida. (2019) 1–8.
[28] J.C. Young, A. Jordan, K.R. Searle, A. Butler, D.S. Chapman, P. Simmons, A. D. Watt, Does stakeholder involvement really benefit biodiversity conservation? Biol. Cons. 158 (2013) 359–370, https://doi.org/10.1016/j.biocon.2012.08.018.
[29] R.S. Bauge, Svanberg, K. 'Good' versus 'Bad' Fishermen. A case study on fishermen's perceptions of illegal fishing and the failure of co-management initiatives in Lake Babati Photo. Södertörn University. (2019) 1–36.
[30] C. Guidi, C.R.M. Baigún, L.G. Ginter, M. Soricetti, F.G. Rivas, S. Morawicki, F. Quezada, J.L. Bazzani, P.J. Solimano, Characteristics preferences, and perceptions of recreational fishers in northern Patagonia, Argentina, Reg. Stud. Mar. Sci. 45 (2021) 101828, https://doi.org/10.1016/j.rsma.2021.101828.
[31] A.B. Haque, M. Washim, N.G. D'Costa, A.R. Baroi, N. Hossain, R. Nanjiba, S. J. Hasan, N.A. Khan, Socio-ecological approach on the fishing and trade of rhino rays (Elasmobranchii: Rhinopristiformes) for their biological conservation in the Bay of Bengal, Bangladesh, Ocean Coast. Manag. 210 (2021) 105690, https://doi.org/10.1016/j.ocecoaman.2021.105690.
[32] J. Olson, J. Clay, P.M. da Silva, P.P, Putting the seafood in sustainable food systems (https://doi.org/), Mar. Policy 43 (2014) 104–111, https://doi.org/10.1016/j.marpol.2013.05.001.
[33] L. McClenachan, S. Dissanayake, X. Chen, Fair trade fish: consumer support for broader seafood sustainability, Fish Fish 17 (3) (2016) 825–838, https://doi.org/10.1111/faf.12148.
[34] V.J. Giglio, M.L.F. Ternes, O.J. Luiz, C. Zapelini, M.O. Freitas, Human consumption and popular knowledge on the conservation status of groupers and sharks caught by small-scale fisheries on Abrolhos Bank, SW Atlantic, Mar. Policy 89 (2018) 142–146, https://doi.org/10.1016/j.marpol.2017.12.020.
[35] POETCY. Programa de ordenamiento ecológico del Territorio Costero del Estado de Yucatán. Informe Final. Portal de la Secretaría de Ecología del Estado de Yucatán. 2007.
[36] DOF. ACUERDO por el que se da a conocer el Plan de Manejo Pesquero de Mero (Epinephelus morio) y especies asociadas en la Península de Yucatán. SAGARPA 25 noviembre 2014. 2014.
[37] INEGI, Estados Unidos Mexicanos. XIV Censo General de Población y Vivienda, 2010. Principales resultados por localidad de Yucatán. 2010.
[38] E.A. Marin-Monroy, R. Romero-Canyas, J.A. Fraire-Cervantes, D. Larson-Konar, R. Fujita, Compliance with rights-based fisheries management is associated with fishermen's perceptions of peer compliance and experience: a case study in the Upper Gulf of California, Ocean Coast. Manag. 189 (2020) 105155, https://doi.org/10.1016/j.ocecoaman.2020.105155.
[39] A. Davis, J.R. Wagner, Who knows? On the importance of identifying "experts" when researching local ecological knowledge, Hum. Ecol. 31 (3) (2003) 463–489, https://doi.org/10.1023/A:1025075923297.
[40] E. Babbie. Diseño de la investigación. Fundamentos de la investigación social. México: International Thomson Editores, (2000).
[41] K. Kelley, B. Clark, V. Brown, J. Sitzia, Good practice in the conduct and reporting of survey research, Int. J. Qual. Health Care 15 (3) (2003) 261–266, https://doi.org/10.1093/intqhc/mzg031.
[42] R Core Team, R: A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria, 2019.
[43] A. Aguilar-PereraA, Situación actual de conservación y manejo de meros y pargos en el sureste del golfo de México y mar Caribe, in: E. Rivera-Arriaga, I. Azuz-Adeath, O.D. Cervantes Rosas, A. Espinoza-Tenorio, R. Silva Casarín, A. Ortega-Rubio, A.V. Botello, B.E. Vega-Serratos (Eds.), Gobernanza y Manejo de las Costas y Mares Ante la Incertidumbre. Una Guía para tomadores de decisiones, Universidad Autónoma de Campeche, RICOMAR, 2020, pp. 855–878.
[44] C. Monroy, S. Salas, J. Bello-Pineda, Dynamics of fishing gear and spatial allocation of fishing effort in a multispecies fleet, North Am. J. Fish. Manag. 30 (5) (2010) 1187–1202, https://doi.org/10.1577/M09-101.1.
[45] G. Galindo-Cortes, L. Jiménez-Badillo, C. Meiners, Moving from stock assessment to fisheries management in Mexico: the finfish fisheries from the southern Gulf of Mexico and Caribbean Sea. Viability and sustainability of small-scale fisheries in Latin America and the Caribbean, Springer, Cham, 2019, pp. 243–263, https://doi.org/10.1007/978-3-319-76078-0_11.
[46] A. Begossi, S. Salyvonchyk, B. Glamuzina, S.P. De Souza, P.F.M. Lopes, R.H. G. Priolli, D.O. Do Prado, M. Ramires, M. Clauzet, C. Zapelini, D.T. Schneider, L. T. Silva, R.A.M. Silvano, Fishers and groupers (*Epinephelus marginatus* and *E. morio*) in the coast of Brazil: integrating information for conservation, J. Ethnobiol. Ethnomed. 15 (1) (2019) 1–26, https://doi.org/10.1186/s13002-019-0331-2.
[47] G. Hallwass, A. Schiavetti, R.A.M. Silvano, Fishers' knowledge indicates temporal changes in composition and abundance of fishing resources in Amazon protected areas, Anim. Cons. 23 (1) (2020) 36–47, https://doi.org/10.1111/acv.12504.
[48] R.A.M. Silvano, V. Nora, T.B. Andreoli, P.F.M. Lopes, A. Begossi, The 'ghost of past fishing': small-scale fisheries and conservation of threatened groupers in subtropical islands, Mar. Policy 75 (2017) 125–132, https://doi.org/10.1016/j.marpol.2016.10.002.
[49] B. Bentes, N.C.B. Mendes, A.G.C. de Macedo Klautau, C.S. Viana, J.G.R. Júnior, K. C. de Araújo Silva, C.E.R. de Andrade, L.J. Pereira Gomes, I.H.A. Cintra, Captura acidental da garoupa golias, *Epinephelus itajara* (Lichtenstein, 1822) e *Epinephelus* sp. (Bloch, 1793) na pesca industrial da costa Norte do Brasil: Uma espécie criticamente ameaçada (https://doi.org/), Biota Amaz. 9 (2019) 58–59, https://doi.org/10.18561/2179-5746/biotaamazonia.v9n1p58-59.
[50] DOF. 2015. Norma Oficial Mexicana NOM- 065-SAG/PESC-2014, Para regular el aprovechamiento de las especies de mero y especies asociadas, en aguas de jurisdicción federal del litoral del Golfo de México y Mar Caribe. SAGARPA. 3 de julio de 2015.
[51] S.M. Ortiz-Gallarza, Romero-Beltrán E., Romero-Leyva T.G., Osuna-Peralta Y.R., Ortiz-Ahumada J.C., Cruz-Borrego E., Aguirre-Villaseñor H., Chávez-Herrera D., Corro-Espinosa D., Madrid-Vera J. Panorama actual de las pesquerías ribereñas en ecosistemas costeros de Sinaloa, en: Mariño, U. U. y Alcalá, G. (Eds.), Pescadores en México y Cuba: Retos y oportunidades ante el cambio climático, Unas Letras Industria Editorial. México. 2020, pp. 57–106.
[52] L. López-Castañeda, Vázquez-Rodríguez J., Ramenzoni V.C., Rangel-Rivero A., González-Díaz S.P.,Vázquez-Sánchez V., Delgado-Pérez A., Yoskowitz D.W., Borroto-Escuela D. Conocimiento local y percepciones de cambios ambientales de pescadores artesanales residentes en Yaguajay, Sancti Spíritus, Cuba, In: Mariño, U. U., Alcalá, G. (Eds.), Pescadores en México y Cuba: Retos y oportunidades ante el cambio climático, Unas Letras Industria Editorial. México. 2020, pp. 119–140.
[53] A.B. Anderson, R.M. Bonaldo, D. Barneche, C.W. Hackradt, F.C. Felix-Hackradt, J. A. García-Charton, S.R. Floeter, Recovery of grouper assemblages indicates effectiveness of a marine protected area in Southern Brazil, Mar. Ecol. Prog. Ser. 514 (2014) 207–215, https://doi.org/10.3354/meps11032.
[54] R.J. Hamilton, M. Giningele, S. Aswani, J.L. Ecochard, Fishing in the dark-local knowledge, night spearfishing and spawning aggregations in the Western Solomon Islands, Biol. Cons. 145 (1) (2012) 246–257, https://doi.org/10.1016/j.biocon.2011.11.020.
[55] T.R. McClanahan, M.J. Marnane, J.E. Cinner, W.E. Kiene, A comparison of marine protected areas and alternative approaches to coral-reef management, Curr. Biol. 16 (14) (2006) 1408–1413, https://doi.org/10.1016/j.cub.2006.05.062.
[56] E. Britton, C. Domegan, P. McHugh, Accelerating sustainable ocean policy: The dynamics of multiple stakeholder priorities and actions for oceans and human health, Mar. Policy 124 (2021) 104333, https://doi.org/10.1016/j.marpol.2020.104333.
[57] H. Retnoningtyas, I. Yulianto, A. Soemodinoto, Y. Herdiana, T. Kartawijaya, M. Natsir, J.T. Haryanto, Stakeholder participation in management planning for grouper and snapper fisheries in West Nusa Tenggara Province, Indonesia, Mar. Policy 128 (2021) 104452, https://doi.org/10.1016/j.marpol.2021.104452.

[58] M.F. Pinto, J.S. Mourão, R.R.N. Alves, Animal source foods consumed in two fishing communities on the northeast coast of Brazil, Environ. Dev. Sustain. 19 (2) (2017) 679–692, https://doi.org/10.1007/s10668-016-9758-y.
[59] O.G. de Souza Junior, J.L.G. Nunes, R.A.M. Silvano, Biology, ecology and behavior of the acoupa weakfish *Cynoscion acoupa* (Lacepède, 1801) according to the local knowledge of fishermen in the northern coast of Brazil, Mar. Policy 115 (2020) 103870, https://doi.org/10.1016/j.marpol.2020.103870.
[60] J.L. Jacquet, D. Pauly, Trade secrets: renaming and mislabeling of seafood, Mar. Policy 32 (3) (2008) 309–318, https://doi.org/10.1016/j.marpol.2007.06.007.
[61] R.G. Feeney, D.V. Boelke, J.J. Deroba, S. Gaichas, B.J. Irwin, M. Lee, Integrating management strategy evaluation into fisheries management: advancing best practices for stakeholder inclusion based on an MSE for Northeast US Atlantic herring, Can. J. Fish. Aquat. Sci. 76 (7) (2019) 1103–1111.
[62] N.A. Dowling, C.M. Dichmont, M. Haddon, D.C. Smith, A.D.M. Smith, K. Sainsbury, Empirical harvest strategies for data-poor fisheries: a review of the literature, Fish. Res. 171 (2015) 141–153.
[63] S. Pascoe, T. Cannard, N.A. Dowling, C.M. Dichmont, S. Breen, T. Roberts, et al., Developing harvest strategies to achieve ecological, economic and social sustainability in multi-sector fisheries, Sustainability 11 (2019) 644.