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# Advances in the study of Mexican fisheries with the social-ecological system (SES) perspective and its inclusion in fishery management policy

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ABSTRACT

This study describes the progress of the use of the SES perspective and/or the consideration of users' participation in the scientific literature that study Mexican fisheries, and their inclusion in the fishery management policy. Since 2001, there have been 57 published investigations on 19 fisheries, mostly from the north Pacific (n = 39), focussed mainly on the governance of SES of benthic fisheries, and from the southern Gulf of Mexico and the Caribbean Sea (n = 14), where co-management and the spiny lobster fishery are the most studied. From 21 fisheries having a fishery management plan (FMP), only seven have an international sustainability standard, while another seven fisheries having a sustainability standard have no FMP. In addition, only nine fisheries, with literature that addresses the SES perspective and/or considers the user's participation (out of a total of 19), have a FMP and only four of those fisheries have a sustainability standard. This reflects a mismatch between the interests of the academic, fishery, and government sectors. The SES perspective has been stable in the academic research since 2012, and has been implemented for some fisheries through participatory management processes of international fishery standards; however, this perspective needs to be fully included in Mexican fishery management instruments (e.g., FMPs) and its implementation could be a primary goal for Mexican fishery policy.

## 1. Introduction

The sustainability of fisheries depends to some extent on the ability of the fishery management system to adjust fishing pressure to appropriate levels, however, there is no unique scientific standard to judge fisheries' sustainability, because sustainability must have a social-ecological perspective (Hilborn et al., 2015) and include ecosystem, social and economic indicators. Holistic approaches have been adopted for sustainable fishery policies (Pitcher et al., 2009), and academic efforts have used integral approaches which recognise that managed fisheries involve the life history of marine species as well as that of human beings (Espinoza-Tenorio et al., 2011b). Ostrom (2009) framework for analysing the sustainability of social-ecological systems (SES) is one of those approaches because fisheries are complex systems (FAO, 2015) which include social (governance system and users) and ecological (resource units and resource system) subsystems in mutual interaction. Thus, the study of the whole SES or one of the subsystems is required to advance toward sustainable fishery management approaches (FAO, 2015).

The ecosystem approach to fisheries (EAF) recommended for coastal fisheries of Latin America (Seijo et al., 2011; FAO, 2015), fully incorporates the SES perspective because it takes into account the knowledge and uncertainties of biotic, abiotic, and human components of ecosystems and their interactions (Garcia et al., 2003). FAO (2015) establishes that the EAF and co-management, as a kind of governance, are ideal to move towards fisheries' sustainability, and that is not possible to develop an EAF without the users' participation because humans and their cultural diversity are integral components of the ecosystems.

In this regard, co-management is the collaborative and participatory process of regulatory decision-making among user groups, government agencies, and research institutions. In co-management, the responsibility for management is decentralised and delegated to user-organisations (Jentoft, 1989). Governance is the process involving all governing actors that can be more or less organised and are typically interactive (Chuenpagdee and Jentoft, 2009), including political and administrative consensus, social organisation, and social participation (Díaz de León et al., 2004). Hence, the governance plays a strategic role for the achievement of the sustainability of complex fishery SES (FAO, 2015).

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Historically, fisheries science has relied on the study of fish resource, which has led policies to consider only individual species or groups of species in the management units (FMU). The objective of this type of management is to achieve biological sustainability, leaving aside the objectives related to economic efficiency and social equity (Berkes, 2003), which sometimes ultimately results in biological unsustainability of the fishery. The fishery policy of Mexico is an example of this management regime because the National Fishing Chart (DOF, 2018) judges the fisheries' sustainability based only on the population status of the FMUs, excluding the status of the social subsystems.

Fisheries management in Mexico is governed by the General Law of Sustainable Aquaculture and Fisheries (LGPAS, by its Spanish acronym). Although there is no definition of fishery sustainability in LGPAS, the National Commission of Aquaculture and Fishing of Mexico (CONAPESCA, by its Spanish acronym) established that the fishing system needs a holistic vision taking into account biological, ecosystem, socioeconomic, and legal-administrative aspects (CONAPESCA, 2010). However, although this management perspective has been considered by CONAPESCA, its implementation has been only partial in relation to the challenges faced by Mexican fisheries (Espinoza-Tenorio et al., 2015).

In addition, Mexican fisheries management is a big challenge because small-scale fisheries account for about 97% of the Mexican marine fleet (Fernández et al., 2011), and the conventional fishery management science traditionally used, lacks the methods to deal with the complexities of small-scale fisheries, which needs a different management regime beyond command-and-control measures, empowering fishers to self-organise and self-manage so they can learn and adapt (Berkes, 2003). Among the complexities of small-scale fisheries, Salas et al. (2011) established that the Latin American coastal fisheries are characterized by lacking solid governance structures, having incomplete knowledge, inadequate incentives and subsidies that stimulate overcapacity in certain periods, great uncertainty associated with stock fluctuations due to natural causes, the growing demand for limited fishery resources, and lack of alternatives for coastal development.

The objective of this research is to assess the progress of the use of the SES perspective and/or consider user participation in the scientific literature that study Mexican fisheries. The research also addresses the incorporation of both elements in fisheries management plans (FMP), and the implementation of the participatory process in fisheries management through international standards.

## 2. Material and methods

Through a search in Scopus and Google Scholar databases, the scientific literature specialised in Mexican fisheries that use the SES perspective and/or consider user participation was identified. Studies with the SES perspective included those that use a transdisciplinary framework (SES approach and EAF) and those that use the SES concept (e.g., establish that fisheries are SES), but not a framework. Studies that consider users' participation included those that assess governance and those that recognise the existence of co-management. Literature that addressed only biological or ecological aspects, such as conventional stock assessments and literature that focussed on the ecosystem trophic mass balance, were excluded from the analysis. This is because the objective of this research is to assess the progress in the study of Mexican fisheries with the SES perspective and/or the consideration of users' participation.

The literature was grouped by year and by the four fishing coastal regions established by the CONAPESCA. The subjects of study addressed by the selected literature were classified into four categories: SES, EAF, governance, and co-management. The four fishing coastal regions are: Region 1, North-Pacific (NP), including the states of Baja California, Baja California Sur, Sonora, Sinaloa and Nayarit; Region 2, South-Central Pacific (SCP), including the states of Jalisco, Colima, Michoacán, Guerrero, Oaxaca and Chiapas; Region 3, Western Gulf of Mexico (WGM), including the states of Tamaulipas and Veracruz; and Region 4, southern Gulf of Mexico and the Caribbean Sea (SGM-CS), including the states of Tabasco, Campeche, Yucatan and Quintana Roo) (CONAPESCA, 2010). An additional category covering all regions was added because some studies were conducted at a national level.

Fisheries included small-scale fisheries, medium to large-scale fisheries, or both. The small-scale fisheries (SSF) are characterised by fishing boats smaller than 10.5 m long, with or without an outboard motor, limited autonomy (maximum three fishing days), and with or without an ice-based storage system (DOF, 2007). On the other hand, the medium to large-scale fisheries (LSF) are characterised by fishing boats larger than 10.5 m, stationary motor, ample autonomy (more than five fishing days), large storage capacity, and the use of mechanic devices to set and recover the fishing gear (DOF, 2018).

A revision of the Mexican fisheries management plans (FMPs) was conducted in order to identify whether the SES perspective addressed in the literature has been incorporated within the strategic goals, the target objective, and through the concept of sustainability. The elaboration of the FMPs is coordinated by researchers from INAPESCA (National Aquaculture and Fisheries Institute) and sanctioned (officially approved) by CONAPESCA before publication. Every FMP included small-scale or medium to large-scale fisheries or both. The FMPs were described by year and coast (Pacific and Atlantic) because some include two regions. The region will be noted when an FMP includes a single region.

Finally, the Mexican fisheries with international sustainability standards were identified by year and region, and they were considered as examples of the implementation of management participatory process (e.g., co-management). The sustainability standards are the Marine Stewardship Council (MSC) and the Seafood Watch Program of Monterey Bay Aquarium (MBA); though they are different organisations fulfilling different roles (e.g., MSC emphasises a more collaborative processes among users). The MSC is used to assess if a fishery is well-managed and sustainable (www.msc.org) and MBA assesses the relative sustainability of wild-capture fisheries (Fisheries Standard Version F3.2). Both standards include as a key criterion for fishery management stakeholder inclusion. In addition, we identified those fisheries with a Fishery Improvement Project (FIP, 2018), which are "multi-stakeholder initiatives that aim to improve a fishery towards sustainability and MSC certification" (www.msc.org).

## 3. Results

Of the 57 studies on Mexican fisheries with SES perspective or that consider user's participation or both, Region 1 (NP) has 68.4%, Region 4 (SGM-MC) 24.6%, Region 2 (SCP) 1.8%, and Region 3 (WGM) 1.8%; the remaining 3.5% comprises the global region (Appendix A). The studies included assessments of multispecific and monospecific fisheries, but the latter has been carried out only in Region 1 (NP) and 4 (SGM-MC). In Region 1, most of the studies focussed on the pen-shells (*Atrina tuberculosa* and *Pinna rugosa*), abalone (*Haliotis* ssp.), and red lobster (*Panulirus interruptus*) fisheries, and in Region 4, most of the studies were conducted on the spiny lobster (*Panulirus argus*) fishery.

### 3.1. Annual frequency of the literature, FMPs and sustainability standards

The publication of the literature with SES perspective and/or that consider user's participation (n = 57) began in 2001, however, 84% has been published since 2009; and the period of publication of the FMPs (n = 21) was 2012–2015, with 62% published in 2014 and 28% in 2012. The first Mexican fishery recognised with a sustainability standard was the red rock lobster fishery in 2004; later, in the period 2012–2018, another 13 fisheries have been certified, with the highest frequency in 2017 (n = 6) and 2014 (n = 3) (Fig. 1).

### 3.2. Subjects of study in the literature

In Region 1 (NP), 25 of the 39 studies explicitly consider fisheries as SES or assessed governance, although only 17 of them address both. The SES were analysed together with co-management in three studies and with EAF in two studies. The co-management and EAF are addressed in ten and eight studies, respectively. The only study in Region 2 (SCP) addresses the EAF and co-management, and the study of Region 3 (WGM) addresses co-management. Of the 14 studies of Region 4 (SGM-MC), eight deal with co-management, six consider fisheries as SES, five assessed governance, and two addressed EAF (Table 1).

### 3.3. Inclusion of the SES perspective and user's participation in Mexican fishery policy

In Mexico, there are 21 FMP, of which nine belong to the Mexican Pacific (Region 1 and 2) and 12 to the Gulf of Mexico and the Caribbean Sea (Regions 3 and 4). Ten FMPs are for SSF, five for each coast; four FMPs are for LSF, one from the Pacific and three from the Atlantic; and seven FMPs are for fisheries with both SSF and LSF, three from the Pacific and four from the Atlantic (Table 2), although some of those fisheries include mainly LSF, such as seaweed and yellowfin tuna in the Pacific.

A concept of sustainability was found in 15 FMPs published in 2014 and 2015, three from the Pacific (brown and blue crabs, jumbo squid, and yellowfin tuna) and all from the Atlantic. These FMPs indicate that the sustainability of the fishery should be socially acceptable, economically and politically viable, environmentally friendly, and in a context of equity for present and future generations. Although, none of the FMPs explicitly considers the fisheries as SES nor uses the EAF, in the concept of sustainability is implicit the SES perspective. However, in the glossary of six FMPs from the Atlantic (octopus, pink shrimp, red grouper, sea cucumber, seabob shrimp, and spiny lobster), sustainability is established based only on the ecological perspective, just as the existence of equilibrium between the species and its environment. The FMP for small pelagic fishes (Pacific) is the only one that recognises the existence of co-management, and the FMP for spiny lobster (from the Atlantic) mentions the assessment of governance through the MSC certification process.

In addition, the 15 FMPs mentioned above, have a strategic goal and a target objective, which integrate SES attributes. All these plans have the same strategic goal that states that fisheries should have a balanced social environment (stable or improved social environment and improved social benefit are other examples mentioned). In the target objective, the expectation of co-management in eight of these FMPs is inferred; and in only two FMPs (for the mullets and, brown and white shrimp fisheries), is it explicitly mentioned. It is also expected the adaptive management in five FMPs; the use of environmental and social indicators in four FMPs; and biological, ecological, social, and economic development, and a fishing sector with self-management capacity in one FMP each one (Table 3).

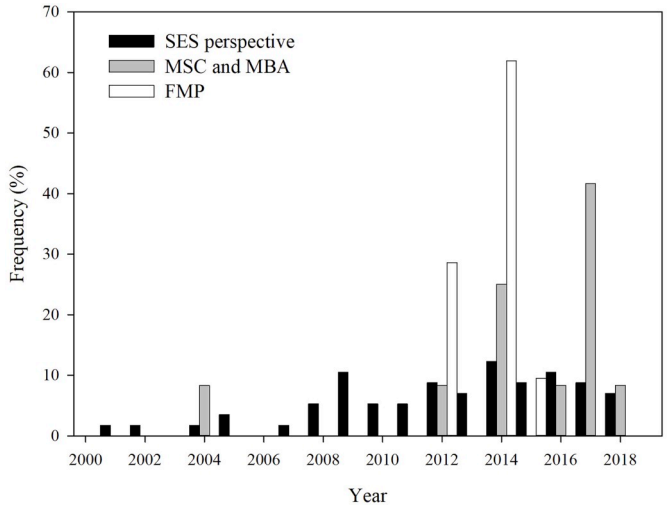


**Fig. 1.** Annual frequency (period 2001–2018) of the publication of literature with SES perspective and/or that consider user's participation (n = 57), fishery management plans (n = 21) and international sustainability standards (MSC and MBA) (n = 12) for Mexican fisheries.

**Table 1**
Subjects of study related to the social-ecological system perspective and the consideration of user's participation addressed by the 57 studies by fishery regions. Regions: North-Pacific (NP); South-Central Pacific (SCP); Western Gulf of Mexico (WGM); southern Gulf of Mexico and the Caribbean Sea (SGM-CS); and in the four regions (FR).

| Study issues | Regions | | | | |
|---|---|---|---|---|---|
| | NP | SCP | WGM | SGM-CS | FR |
| Ecosystem approach to fisheries | 8 | 1 | | 2 | 1 |
| Social-ecological systems | 25 | | | 6 | 1 |
| Governance | 25 | | | 5 | 1 |
| Co-management | 10 | 1 | 1 | 8 | 2 |
| Total of studies by region | 39 | 1 | 1 | 14 | 2 |

### 3.4. International standards, FMPs, and literature with SES perspective

There are 14 Mexican fisheries with sustainability standards of MSC or MBA or both; 79% of these fisheries are from the Pacific and the rest from the Atlantic. The red rock lobster (Region 1) fishery is the only one that has MSC and MBA certifications; the fisheries for small pelagic fishes and yellowfin tuna (Pacific) have MSC certification, and the fisheries for abalone and seaweeds (Region 1) and brown shrimp (Atlantic) have MBA certification. The fisheries for blue, brown and white shrimps, brown and blue crabs, jumbo squid, the yellowtail amberjack (all from Region 1), blue swimming crab, and the Caribbean spiny lobster (from Region 4) have MBA recognition and FIP. Most of the 14 fisheries with a sustainability standard, and the five fisheries with FIP are concentrated in Region 1 (NP) and Region 4 (SGM-CS) (Fig. 2, Table 2), which correlates with higher efforts in the use of the SES perspective and/or the consideration of user's participation in the study of Mexican fisheries.

Five fisheries from the Pacific with FMP also have a sustainability standard (three with MBA and two with MSC), and the red rock lobster fishery has MSC and MBA, but no FMP. In the Atlantic, only two fisheries with FMP have a sustainability standard (MBA), the brown shrimp and the Caribbean spiny lobster fisheries. One fishery from the Pacific and another from the Atlantic with FMP also have FIP. In addition, three and nine fisheries from the Pacific and Atlantic, respectively, have FMP and no sustainability standards or FIP. Finally, the fisheries for the barred sand bass, the clam from Baja California, the ocean whitefish, white snook (all from Region 1), and the red and black groupers (Region 4) have an FIP. There are only four fisheries having literature that addressed the SES perspective, FMP, and a sustainability standard—two from the Pacific, the brown and blue crab, and jumbo squid fisheries, and two from the Atlantic, the brown shrimp, and Caribbean spiny lobster fisheries (Fig. 2, Table 2). Finally, the literature with SES perspective or that consider the user's participation or both has been conducted for ten SSF and for nine fisheries with both SSF and LSF.

## 4. Discussion

The production of literature with the SES perspective or that consider the user's participation or both for Mexican fisheries has stabilised since 2012. Most of the Mexican FMPs have included aspects of the SES perspective, and several fisheries have sustainability standards; however, there is a mismatch in the fishing resources selected in the

**Table 2**
Mexican Pacific and Atlantic fisheries for species or group of species by type of fishery, small-scale fishery (SSF) and medium to large-scale fisheries (LSF), having literature with the SES perspective and/or that consider the user's participation, fishery management plan (FMP) and sustainability standard (MSC and MBA) or fishery improvement project (FIP).

| Fisheries | Type of fishery | Literature | FMP | Standard |
|---|---|---|---|---|
| Pacific | | | | |
| Abalone (*Haliotis*) | SSF | ✓ | | MBA |
| Barred sand bass (*Paralabrax nebulifer*) | SSF | | | FIP |
| Blue shrimp (*Litopenaeus stylirostris*) | SSF, LSF | ✓ | | MBA, FIP |
| Black murex snail (*Hexaples nigritus*) | SSF | ✓ | | |
| Brown and blue crab (*Callinectes*) | SSF | ✓ | ✓ | MBA, FIP |
| Brown shrimp (*Farfantepenaeus californiensis*) | SSF, LSF | ✓ | | MBA, FIP |
| Clam (*Panopea globosa*) from Sonora | SSF | | ✓ | |
| Clam (*Panopea* spp) from Baja California | SSF | | ✓ | FIP |
| Gulf corvina (*Cynoscion othonopterus*) | SSF | ✓ | ✓ | |
| Jumbo squid (*Dosidicus gigas*) | SSF, LSF | ✓ | ✓ | MBA, FIP |
| Ocean whitefish (*Caulolatilus princeps*) | SSF | | | FIP |
| Pen shell (*Atrina tuberculosa*, *Pinna rugosa*) | SSF | ✓ | | |
| Red rock lobster (*Panulirus interruptus*) | SSF | ✓ | | MSC, MBA |
| Red sea urchins (*Strongylocentrotus*) | SSF | ✓ | ✓ | |
| Scallops (*Spondylus calcifer*) | SSF | ✓ | | |
| Seaweeds (*Chlorophyta*) | SSF, LSF | | ✓ | MBA |
| Small pelagic (*Sardinops*, *Engraulis*, *Scomber*) | LSF | | ✓ | MSC |
| Yellowfin tuna (*Thunnus albacares*) | SSF, LSF | | ✓ | MSC |
| Yellowtail amberjack (*Seriola lalandi*) | SSF | ✓ | | MBA, FIP |
| Whiteleg shrimp (*Litopenaeus vannamei*) | SSF, LSF | | | MBA, FIP |
| White snook (*Centropomus viridis*) | SSF | | | FIP |
| Atlantic | | | | |
| Blue swimming crab (*Callinectes sapidus*) | SSF | | | MBA, FIP |
| Brown* and white shrimp (*Farfantepenaeus aztecus*, *Litopenaeus setiferus*) | SSF, LSF | ✓ | ✓ | MBA* |
| Caribbean spiny lobster (*Panulirus argus*) | SSF, LSF | ✓ | ✓ | MBA, FIP |
| Conch (*Turbinella*, *Busycon*, *Pleuroploca*, *Lobatus*, *Strombus*) | SSF | | ✓ | |
| Elasmobranchs | SSF, LSF | ✓ | | |
| Mullets (*Mugil cephalus*, *Mugil curema*) | SSF | | ✓ | |
| Octopus (*Octopus maya*, *Octopus vulgaris*) | SSF, LSF | ✓ | ✓ | |
| Pink shrimp (*Farfantepenaeus duorarum*) | LSF | | ✓ | |
| Red and black grouper (*Ephinephelus*, *Mycteroperca*) | SSF, LSF | ✓ | ✓ | FIP |
| Red and rock shrimps (*Farfantepenaeus*, *Sicyonia*) | LSF | | ✓ | |
| Red snapper (*Lutjanus campechanus*) | SSF, LSF | ✓ | | |
| Sea cucumber (*Isostichopus*, *Holuthuria*) | SSF | ✓ | ✓ | |
| Seabob shrimp (*Xiphopenaeus kroyeri*) | SSF | | ✓ | |
| Snook (*Centropomus undecimalis*) | SSF | | ✓ | |
| Yellowfin tuna (*Thunnus albacares*) | LSF | | ✓ | |

production of literature, the elaboration of FMPs and the implementation of management participative processes through sustainability standards.

The highest concentration of literature with the SES perspective and/or that consider user's participation is found in the Mexican North Pacific, followed at a lesser degree by the southern Gulf of Mexico and the Caribbean Sea. Historically, the North Pacific is the most important in terms of marine resources (OCDE, 2007; SAGARPA, 2017), and has research capacities to support integral approaches (Espinoza-Tenorio et al., 2011a). For this reason, the generation of data on marine SES is concentrated in this region (Palacios-Abrantes et al., 2019).

**Table 3**
Social-ecological system (SES) perspective attributes in the strategic goals and target objective of fishery management plans (PMP) by littoral in Mexico (Pacific and Atlantic).

| Attributes related to SES perspective | Pacific | Atlantic |
|---|---|---|
| Balanced social environment | 3 | 12 |
| Co-management | 3 | 7 |
| Adaptive management | 1 | 4 |
| Environmental and social indicators | | 4 |
| Biological, ecological, social and economic development | | 1 |
| Fishing with self-management capacity | | 1 |

In addition, fishers organisations of the North Pacific have been collaborating with academic institutions and Civil Society Organisations (CSOs) to conduct investigations (Ponce Díaz et al., 2009; McCay et al., 2014). Also, CSOs have significantly influenced key attributes of multi-scale governance, mainly in the Gulf of California, such as institutional scale representation, cooperative management, and collective action (Espinosa-Romero et al., 2014). At the beginning of the 2000s, the consolidation of the CSOs in the northwest of Mexico took place and that is when some fishery certifications (e.g., MSC) processes started being supported by these organisations (Cisneros-Montemayor and Cisneros-Mata, 2018).

In the north Pacific and the Caribbean Sea, there are some fisheries (e.g., pen-shell, abalone, and spiny lobster fisheries) which attract the attention of academics who use the SES perspective. However, more interdisciplinary research efforts are required to increase the understanding of social-ecological fishery systems from other fishery regions and other relevant fishery resources, such as mono-specific fisheries (e.g., Mayan octopus in the southern Gulf of Mexico) or multi-specific fisheries (e.g., teleost and elasmobranch fisheries) that are relevant to regional fishery systems. In this regard, Palacios-Abrantes et al. (2019) suggest that resources to support more marine research and/or enhance collaboration in knowledge exchange between institutions are needed to generate data on marine SES for the central-south Pacific and western Gulf of Mexico regions. Nevertheless, in the present study, advances are perceived with respect to the scenario described by Espinoza-Tenorio and Espejel (2012) in which no interdisciplinary research was identified, along with a lack of research on fishery policy and little research on the type of organisations involved in fishery management.

The research with the SES perspective is a methodological improvement for assessing the sustainability potential of fisheries as proposed by Berkes (2003), and it is useful to improve policies and strategies for resource management (Berkes and Folke, 1998). However, even though the production of literature on fisheries with the SES perspective in Mexico is stable, it seems that the disconnection between academic production and the provision of decision-relevant information to policy makers as described by Leenhardt et al. (2015) is happening, which hinders the implementation of management approaches based on that research. In fact, a holistic management approach has rarely been implemented in Mexico, for example, to diminish the conflict between conservation measures and fisheries (Espinoza-Tenorio et al., 2010).

The FMPs are instruments of Mexican fishery policy, however, they are few (n = 21) compared to around 61 fisheries included in the National Fishing Chart (DOF, 2012; DOF, 2018). FMPs are enhanced for resources with high economic profitability and/or in which the decrease of their populations has generated serious impacts on the fishery system (e.g., sea cucumber fishery). In the target objective and strategic goals of the FMPs, SES aspects are included, with the balanced social environment as the most frequently mentioned (n = 15), which is closely related

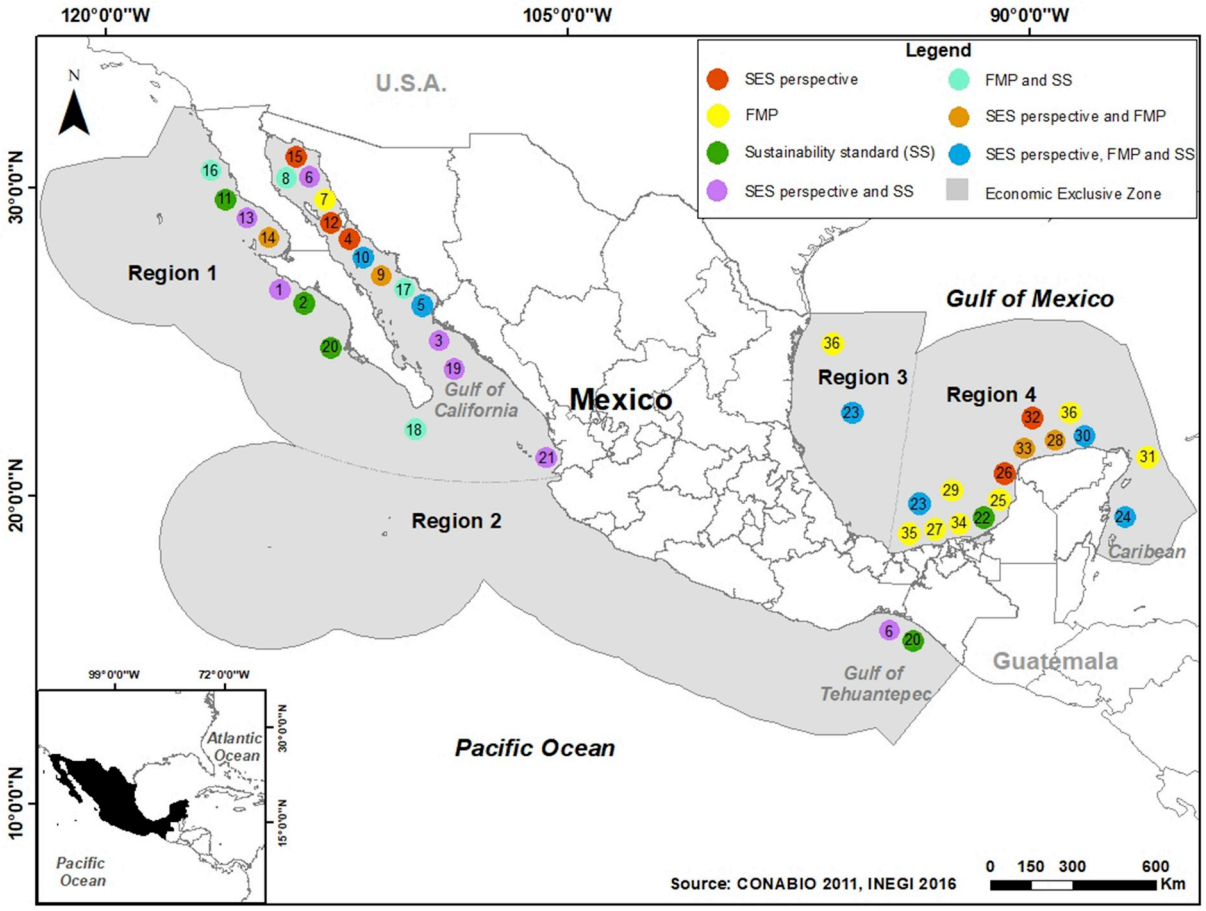


**Fig. 2.** Mexican fisheries by species or group of species by region having literature with the SES perspective (also include those that consider the user's participation), fishery management plan (FMP), sustainability standard (SS) or a combination of them. Different colors are used to identify the fisheries with an element or a combination of elements. Number in circles correspond to the fisheries of 1: Abalone (*Haliotis*); 2: Barred sand bass (*Paralabrax nebulifer*); 3: Blue shrimp (*Litopenaeus stylirostris*); 4: Black murex snail (*Hexaples nigritus*); 5: Brown and blue crab (*Callinectes*); 6: Brown shrimp (*Farfantepenaeus californiensis*); 7: Clam (*Panopea globosa*); 8: Clam (*Panopea*); 9: Gulf corvina (*Cynoscion othonopterus*); 10: Jumbo squid (*Dosidicus gigas*); 11: Ocean whitefish (*Caulolatilus princeps*); 12: Pen shell (*Atrina tuberculosa, Pinna rugosa*); 13: Red rock lobster (*Panulirus interruptus*); 14: Red sea urchins (*Strongylocentrotus*); 15: Scallops (*Spondylus calcifer*); 16: Seaweeds (*Chlorophyta*); 17: Small pelagic (*Sardinops, Engraulis, Scomber*); 18: Yellowfin tuna (*Thunnus albacares*); 19: Yellowtail amberjack (*Seriola lalandi*); 20: Whiteleg shrimp (*Litopenaeus vannamei*); 21: White snook (*Centropomus viridis*); 22: Blue swimming crab (*Callinectes sapidus*); 23: Brown and white shrimp (*Farfantepenaeus aztecus, Litopenaeus setiferus*); 24: Caribbean spiny lobster (*Panulirus argus*); 25: Conch (*Turbinella, Busycon, Pleuroploca, Lobatus, Strombus*); 26: Elasmobranchs; 27: Mullets (*Mugil cephalus, Mugil curema*); 28: Octopus (*Octopus maya, Octopus vulgaris*); 29: Pink shrimp (*Farfantepenaeus duorarum*); 30: Red and black grouper (*Ephinephelus, Mycteroperca*); 31: Red and rock shrimps (*Farfantepenaeus, Sicyonia*); 32: Red snapper (*Lutjanus campechanus*); 33: Sea cucumber (*Isostichopus, Holuthuria*); 34: Seabob shrimp (*Xiphopenaeus kroyeri*); 35: Snook (*Centropomus undecimalis*); 36: Yellowfin tuna (*Thunnus albacares*). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

to the fishers' welfare (e.g., capacitation, alternative employment, infrastructure). Co-management is explicitly mentioned only in two FMPs (for the mullets and brown, and white shrimp fisheries) and its expectation in eight FMPs is inferred through the active participation of all actors in the management process of the fishery. The co-management could be included in all FMPs, and its implementation could be a primary goal for fishery policy because according to Cinner et al. (2012), co-management can help to the sustainability of fisheries, even in the social-ecological contexts most susceptible to failure such as small-scale coastal fisheries.

The FMPs lack the assessment of fisheries governance, which is essential to sustainable fisheries management, especially in SSF (Espinosa-Romero et al., 2014). Hilborn (2007) and Hilborn et al. (2005) established that the key to sustainability of a fishery is good governance through the establishment of appropriate institutions, including a reward system, so that the individual welfare of users, managers, and scientists is maximised by actions that contribute to a socially desirable outcomes. Thus, a major effort is required in Mexico to assess governance and incorporate good governance as a key element in the FMPs.

The process of international sustainability standards is helping to incorporate SES elements into fishery management in Mexico. For example, MSC certification is an emerging mechanism for encouraging sustainable fishing, and has had a positive impact on fisher's cooperatives and gained international recognition for the Mexican fishery policy; although, benefits of MSC certification (e.g., empowerment) could not be repeated in many fisheries, like in the Mexican red rock lobster, if they do not have co-management, community-based objectives, and strong organisation (Pérez-Ramírez et al., 2012a). In fact, few Mexican fisheries are likely to seek MSC certification because the challenges of implementation may be especially difficult to achieve for SSF (Pérez-Ramírez et al., 2012b). This is probably true for Latin America and other developing countries worldwide, where the factors for the low participation in certification initiatives are the lack of information about the fisheries, lack of fishing property rights, market characteristics, costs generated by the process of certification, and lack of local market interests to pay for certified products (Pérez-Ramírez and Lluch-Cota, 2010). However, regardless of the certification process that some fisheries achieve, Mexican fishery policy could incorporate the SES

perspective in its fishery management instruments (e.g., FMPs), to move toward sustainable fishery management approaches.

It is concluded that in the last decade there was a stable production of literature with the SES perspective, that has been partially included in the Mexican fishery policy through the FMPs and implemented through a participative process through international sustainability standards. However, there is a mismatch between the interest of the academic, fishery and government sectors, and there are still many fisheries that need to be included in this trend of the use of the SES perspective to improve their assessment and management. However, the use of this perspective is not enough to guarantee the sustainable management of the fisheries, because it is necessary to adjust the interactions between the components of the SES to maintain its operation.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2019.105065.

## References

Berkes, F., 2003. Alternatives to conventional management: lessons from small-scale fisheries. Environ. Times 31, 5–20.

Berkes, F., Folke, C., 1998. Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge University Press, Nueva York, USA.

Chuenpagdee, R., Jentoft, S., 2009. Governability assessment for fisheries and coastal systems: a reality check. Hum. Ecol. 37, 109–120. https://doi.org/10.1007/s10745-008-9212-3.

Cinner, J.E., McClanahan, T.R., MacNeil, M.A., Graham, N.A.J., Daw, T.M., Mukminin, A., Feary, D.A., Rabearisoa, A.L., Wamukota, A., Jiddawi, N., Campbell, S.J., Baird, A.H., Januchowski-Hartley, F.A., Hamed, S., Lahari, R., Morove, T., Kuange, J., 2012. Comanagement of coral reef social-ecological systems. Proc. Natl. Acad. Sci. 109, 5219–5222. https://doi.org/10.1073/pnas.1121215109.

Cisneros-Montemayor, A.M., Cisneros-Mata, M.A., 2018. A medio siglo de manejo pesquero en el noroeste de México, el futuro de la pesca como sistema socioecológico. Relac. Estud. Hist. y Soc. 153, 99–127. https://doi.org/10.24901/rehs.v39i153.392.

CONAPESCA, 2010. Políticas de ordenamiento para la Pesca y Acuacultura Sustentables, en el marco de Programa Rector de Pesca y Acuacultura. SAGARPA, México, D. F.

Díaz-de-León, A., Fernández, J.I., Álvarez-Torres, P., Ramírez-Flores, O., López-Lemus, L. G., 2004. The sustainability of the Gulf of Mexico's fishing grounds. English translation. In: Caso, M., Pisanty, I., Ezcurra, E. (Eds.), Instituto Nacional de Ecología. In: Withers, K., Nipper, M. (Eds.), vol. 2007. Harte Research Institute for Gulf of Mexico Studies, Texas A&M University-Corpus Christi, TX, USA, pp. 457–467.

DOF, 2018. Carta Nacional Pesquera, SAGARPA. Diario Oficial de la Federación. SAGARPA.

DOF, 2012. Carta Nacional Pesquera. Diario Oficial de la Federación. SAGARPA.

DOF, 2007. Ley General de Pesca y Acuacultura Sustentables. Nueva Ley publicada en el Diario Oficial de la Federación el 24 de julio de 2007. Última reforma publicada DOF 19-01-2018. Diario Oficial de la Federación, México.

Espinosa-Romero, M.J., Rodriguez, L.F., Hudson, A., Villanueva-aznar, C., Torre, J., 2014. The changing role of NGOs in Mexican small-scale fisheries: from environmental conservation to multi-scale governance. Mar. Policy 50, 290–299. https://doi.org/10.1016/j.marpol.2014.07.005.

Espinoza-Tenorio, A., Espejel, I., 2012. Investigación sobre el manejo holístico de la pesca en México: prioridades gubernamentales para el siglo XXI. Cienc. Pesq. 20, 91–96.

Espinoza-Tenorio, A., Espejel, I., Wolff, M., 2015. From adoption to implementation? An academic perspective on Sustainable Fisheries Management in a developing country. Mar. Policy 62, 252–260. https://doi.org/10.1016/j.marpol.2015.09.001.

Espinoza-Tenorio, A., Espejel, I., Wolff, M., 2011. Capacity building to achieve sustainable fisheries management in Mexico. Ocean Coast Manag. 54, 731–741. https://doi.org/10.1016/j.ocecoaman.2011.07.001.

Espinoza-Tenorio, A., Espejel, I., Wolff, M., Zepeda-Domínguez, J.A., 2011. Contextual factors influencing sustainable fisheries in Mexico. Mar. Policy 35, 343–350. https://doi.org/10.1016/j.marpol.2010.10.014.

Espinoza-Tenorio, A., Montaño-Moctezuma, G., Espejel, I., 2010. Ecosystem-based analysis of a marine protected area where fisheries and protected species coexist. Environ. Manag. 45, 739–750. https://doi.org/10.1007/s00267-010-9451-0.

FAO, 2015. Enfoque ecosistémico pesquero. Conceptos fundamentales y su aplicación en pesqueríasde pequeña escala de América Latina, por Omar Defeo. FAO Documento Técnico de Pesca y Acuicultura No. 592. Roma, Italia.

Fernández, J.I., Álvarez-Torres, P., Arreguín-Sánchez, F., López-Lemus, L.G., Ponce, G., Díaz-de-León, A., Arcos-Huitrón, E., del Monte-Luna, P., 2011. Coastal fisheries of Mexico. In: Coastal Fisheries of Latin America and the Caribbean. FAO Fisheries and Aquaculture Technical Paper. No. 544. FAO, Rome, pp. 231–284.

FIP, 2018. Proyectos de mejora pesquera [WWW Document]. https://fisheryprogress.org. accessed 10.1.18.

Garcia, S.M., Zerbi, A., Aliaume, C., Do Chi, T., Lasserre, G., 2003. The ecosystem approach to fisheries. Issues, terminology, principles, institutional foundations, implementation and outlook. FAO, Rome. https://doi.org/10.1111/j.1467-2979.2010.00358.x. FAO fisheries technical paper. No. 443.

Hilborn, R., 2007. Moving to sustainability by learning from successful fisheries. AMBIO A J. Hum. Environ. 36, 296–303. https://doi.org/10.1579/0044-7447(2007)36[296:MTSBLF]2.0.CO;2.

Hilborn, R., Fulton, E.A., Green, B.S., Hartmann, K., Tracey, S.R., Watson, R.A., 2015. When is a fishery sustainable? Can. J. Fish. Aquat. Sci. 72, 1433–1441. https://doi.org/10.1139/cjfas-2015-0062.

Hilborn, R., Orensanz, J.M., Parma, A.M., 2005. Institutions, incentives and the future of fisheries. Philos. Trans. R. Soc. Biol. Sci. 360, 47–57. https://doi.org/10.1098/rstb.2004.1569.

Jentoft, S., 1989. Fisheries co-management: delegating government responsibility to fishermen's organizations. Mar. Policy 13, 137–154.

Leenhardt, P., Teneva, L., Kininmonth, S., Darling, E., Cooley, S., Claudet, J., 2015. Challenges, insights and perspectives associated with using social-ecological science for marine conservation. Ocean Coast Manag. 115, 49–60. https://doi.org/10.1016/j.ocecoaman.2015.04.018.

McCay, B.J., Micheli, F., Ponce-Díaz, G., Murray, G., Shester, G., Ramirez-Sanchez, S., Weisman, W., 2014. Cooperatives, concessions, and co-management on the Pacific coast of Mexico. Mar. Policy 44, 49–59. https://doi.org/10.1016/j.marpol.2013.08.001.

OCDE, 2007. Política Agropecuaria y Pesquera en México: Logros Recientes, Continuación de las Reformas. Organización para la Cooperación y el Desarrollo Económicos.

Ostrom, E., 2009. A general framework for analyzing sustainability of social-ecological systems. Science 325, 419–422. https://doi.org/10.1126/science.1172133.

Palacios-Abrantes, J., Cisneros-Montemayor, A.M., Cisneros-Mata, M.A., Rodríguez, L., Arreguín-Sánchez, F., Aguilar, V., Domínguez-Sánchez, S., Fulton, S., López-Sagástegui, R., Reyes-Bonilla, H., Rivera-Campos, R., Salas, S., Simoes, N., Cheung, W.W.L., 2019. A metadata approach to evaluate the state of ocean knowledge: strengths, limitations, and application to Mexico. PLoS One 14. https://doi.org/10.1371/journal.pone.0216723 e0216723.

Pérez-Ramírez, M., Lluch-Cota, S., 2010. Fisheries certification in Latin America: recent issues and perspectives. Interciencia 35, 855–861.

Pérez-Ramírez, M., Phillips, B., Lluch-Belda, D., Lluch-Cota, S., 2012. Perspectives for implementing fisheries certification in developing countries. Mar. Policy 36, 297–302. https://doi.org/10.1016/j.marpol.2011.06.013.

Pérez-Ramírez, M., Ponce-Díaz, G., Lluch-Cota, S., 2012. The role of MSC certification in the empowerment of fishing cooperatives in Mexico: the case of red rock lobster co-managed fishery. Ocean Coast Manag. 63, 24–29. https://doi.org/10.1016/j.ocecoaman.2012.03.009.

Pitcher, T.J., Kalikoski, D., Short, K., Varkey, D., Pramod, G., 2009. An evaluation of progress in implementing ecosystem-based management of fisheries in 33 countries. Mar. Policy 33, 223–232. https://doi.org/10.1016/j.marpol.2008.06.002.

Ponce Díaz, G., Weisman, W., Mccay, B., 2009. Co-responsibility and participation in fisheries management in Mexico: lessons from Baja California Sur. Pesca y Conserv. 1, 1–9.

SAGARPA, 2017. Anuario Estadístico de Acuacultura y Pesca 2017 de la Comisión Nacional de Acuacultura y Pesca. SAGARPA, CONAPESCA.

Salas, S., Chuenpagdee, R., Charles, A., Seijo, J.C., 2011. Coastal fisheries of Latin America and the Caribbean region: isseues and trends. In: Coastal Fisheries of Latin America and the Caribbean. FAO Fisheries and Aquaculture Technical Paper. No. 544. FAO, Rome, pp. 1–12.

Seijo, J., Charles, A., Chuenpagdee, R., Salas, S., 2011. Toward sustainability for coastal fisheries of Latin America and the Caribbean: effective governance and healthy ecosystems. In: Coastal Fisheries of Latin America and the Caribbean. FAO Fisheries and Aquaculture Technical Paper. No. 544. FAO, Rome, pp. 403–421.