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Sustainability of a common pool resource under an open access regime over time: the case of a coastal lagoon in Colombia

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Sustainability of a common pool resource under an open access regime over time: the case of a coastal lagoon in Colombia

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Abstract

The main goal of this research is to analyze the long-term sustainability of the Ciénaga Grande de Santa Marta (CGSM) based on some of the most relevant socioeconomic, ecological, and institutional changes that it has suffered between 1993 and 2018. The CGSM is an estuarine lagoon located on the Caribbean coast of Colombia, characterized by an open access regime. The CGSM is the coastal lagoon ecosystem that provides most of the fishery resources in the country, and about 30,000 people (3,500 active artisanal fishers and their families) depend economically on this ecosystem. Despite its importance, the CGSM has been affected by various anthropogenic activities for several years. Important factors affecting the ecosystem are the construction of a highway, between 1956 and 1960, along the northern part of the lagoon which closed its natural connection with the Caribbean Sea, the contamination of its waters, and the reduction of water flow from the rivers that provide freshwater to the lagoon and the overfishing. To analyze the long-term sustainability of this lagoon, we combine previously existing data on various socioeconomic, ecological, and institutional variables with our own primary data on some social and institutional aspects of fishery management in this lagoon. This has allowed us to examine the CGSM's sustainability over time.

Although the CGSM is one of the socio-ecological systems with more academic and technical studies in Colombia, there is a scarcity of research analyzing jointly, in the long term, the ecological state with the socio-economic contributions for the management of resources in this ecosystem. It is due mainly to the lack of historical data on social and institutional topics. Thus, this study not only contributes to the literature on collective action for managing common pool resources and social-ecological systems, but it also provides new information that complements the current scientific knowledge that exists about this important coastal ecosystem. The results show an incipient recovery of the lagoon system in ecological terms and a lag performance on economic and institutional. Likewise, we found the ability of the fishing community to respond to natural and human changes has varied through time.

Key words: Ciénaga Grande de Santa Marta, Colombia, sustainability over time, open access regime, collective action, Social–ecological system.

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1 INTRODUCTION

Long-term analyses of artisanal fisheries are necessary for designing appropriate policies for the sustainable management of a fishery that employs 50 of the world's 51 million fishers, and is responsible for over half of the annual marine catches around the world. The traditional data to analyze them are time series of catch and effort (Tesfamichael *et al*., 2014), from which catch per unit effort (CPUE) is calculated. However, to analyze the sustainability over time is fundamental to take into account ecological, biological, socioeconomic and institutional data.

Multidimensional data collection for small-scale fisheries is not usually readily available in official records. This could be the reason why there are few studies around the world that study the long-term performance in fisheries, considering all these dimensions of analysis to explore the sustainability of the fishery. To the best of our knowledge, there are several studies analyzing the fishery performance over time (i.e. Barausse *et al.*, 2011; Fortibuoni *et al.*, 2017; Tesfamichael *et al*, 2014;), but only Rivera *et al.* (2016) and Wilson *et al.* (2015), have evaluated the sustainability of fisheries over time including the social, economic and institutional aspects of fishery. For instance, Rivera *et al.* (2016) used apart from the landings and effort, a 10-year time series of market prices and annual revenue, to determine the long-term sustainability of the gooseneck barnacle fishery in Asturias. Likewise, Rivera *et al.* (2016) and Wilson *et al.* (2015) provided an over-time comparison of an artisanal coral reef fishery in the Dominican Republic. They analyzed socioeconomic (e.g. population, connectivity, dominant livelihoods, dependence of fishing) and institutional variables (e. g. association membership, fishers power in the value chain, rule effectiveness) in two time periods: between 1985 and 1995 and 2012- 2014.

In this context, to combine results of structured and standardized monitoring programs with detailed and disaggregated fishery statistics, represent an important source of information that can be used as proxies to evaluate long-term changes in small scale fisheries and communities (Fortibuoni *et al.*, 2017).

In Ciénaga Grande de Santa Marta (CGMS), an estuarine lagoon located on the Caribbean coast of Colombia, characterized by an open-access regime, a structured and standardized monitoring program of its fishery resources has been carried out since 1993. The CGSM is one of the socio-ecological systems with more academic and technical studies in Colombia, due to geomorphological and physicochemical changes that have occurred in the estuary since 1956, which have caused a strong social and environmental crisis. Despite to have an interesting biological and ecological data collection, there is a scarcity of research analyzing jointly, in the long term, the ecological state of this lagoon with the socio-economic contributions for the management of resources in this ecosystem. It is due mainly to the lack of historical data on social and institutional topics.

To overcome this gap, we combine previously existing data on various socioeconomic, ecological, and institutional variables with our own primary data on some social and institutional aspects of fishery management in this lagoon, using available data for the last 25 years. This has allowed us to examine the CGSM's sustainability over time. For this, we organized the data in three dimensions: socio-ecological, socioeconomic, and socio-political and institutional, with five, three and two variables or indicators respectively. So far, the results show an incipient recovery of the lagoon system, in terms of composition catch, the mangrove coverage, and water quality. In contrast, CPUE shows a decrease in time, which could mean that although there has been a recovery of mangroves and water quality, this has not been enough to achieve the sustainability of fishery resources. Despite this, the CGSM continue supporting the livelihoods of fishery communities in the region.

The paper is structured as follows: in the next section, we describe the materials and methods. It includes the study area and the data collection and data analysis. In Section 3, we present the main results of this research. Finally, in Section 4, we offer some conclusions.

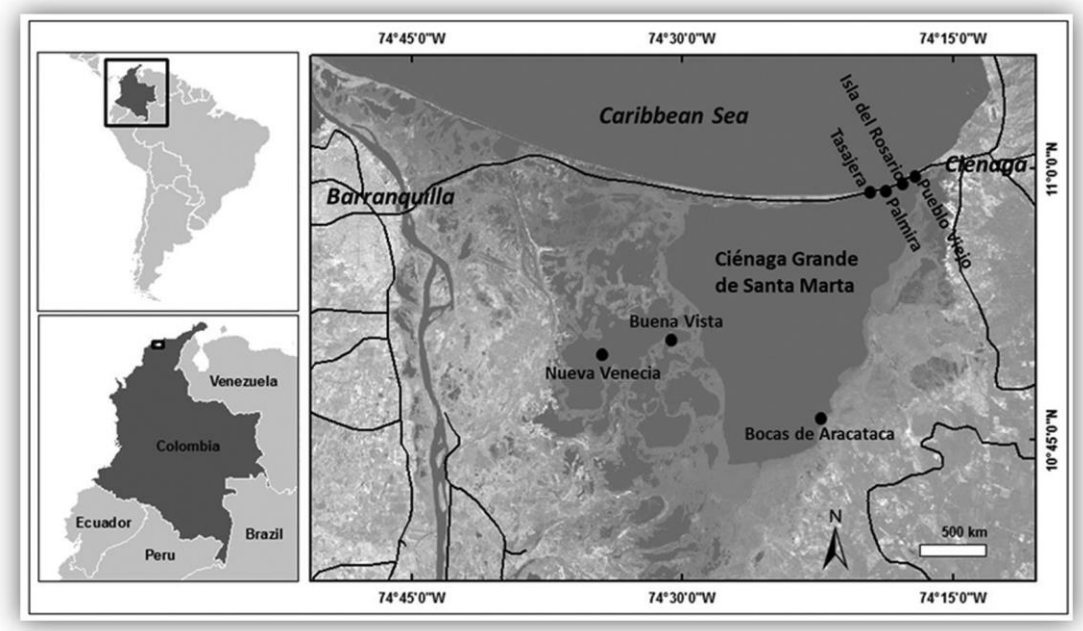
2 MATERIALS AND METHODS

2.1 Study area

The CGSM is located on the Caribbean Coast of Colombia. It comprises about 4.900 $Km^{2,}$ which include the largest and most diverse mangrove forests in Caribbean Colombia. In addition, it includes 1.300 Km^2 of wetlands and water bodies. This lagoon support the development of many species of molluscs, fish, crustaceans, reptiles and birds. It receives fresh water from the Magdalena River and the Sierra Nevada de Santa Marta´s rivers originating in the mountain system provide the fresh water necessary to maintain (Leal-Florez, 2007; Vilardy and González, 2011). It contributes to maintaining fishing productivity in this lagoon. This type of lagoon is important not only for the species that interact in it, but also, it has become the source of subsistence for the families settled around it (Tasajera, Palmira, Isla del Rosario y Pueblo Viejo (county seat) and on it (stilt villages: Nueva Venecia, Buenavista and Bocas de Aracataca), therefore its location is very strategic and important in ecological and socioeconomic terms. The CGSM is located in the center of a larger region known as the CGSM Ecoregion. The CGSM was declared a Fauna and Flora Sanctuary in 1977, it was also designated as a Ramsar site in 1998 and a Biosphere Reserve in 2000. The economic activity associated with this important lagoon is the fishing.

More than 5.000 people are dedicate to this activity. Fishing in the CGSM contributes a large percentage to Colombia's economy, since the species captured in this lagoon are sold both in the local area and in the interior of the country. The most captured species within the CGSM are the Corbinata (*Umbrina choroides*), Chivo (*Ariopsis sp*), Cachama (*Colossoma macropomum*), Mojarra Rayada (*Eugerres plumieri*), Sábalo (*Megalops atlanticus*), Bocachico (*Prochilodus magdalenae*), among others. For their extraction, fishers use different fishing gears such as fixed gillnets, shrimp nets, cast nets, etc.

Figure 1. Ciénaga Grande de Santa Martha and fishing communities



Source: reproduced from Torres-Guevara *et al*. (2016, p. 336).

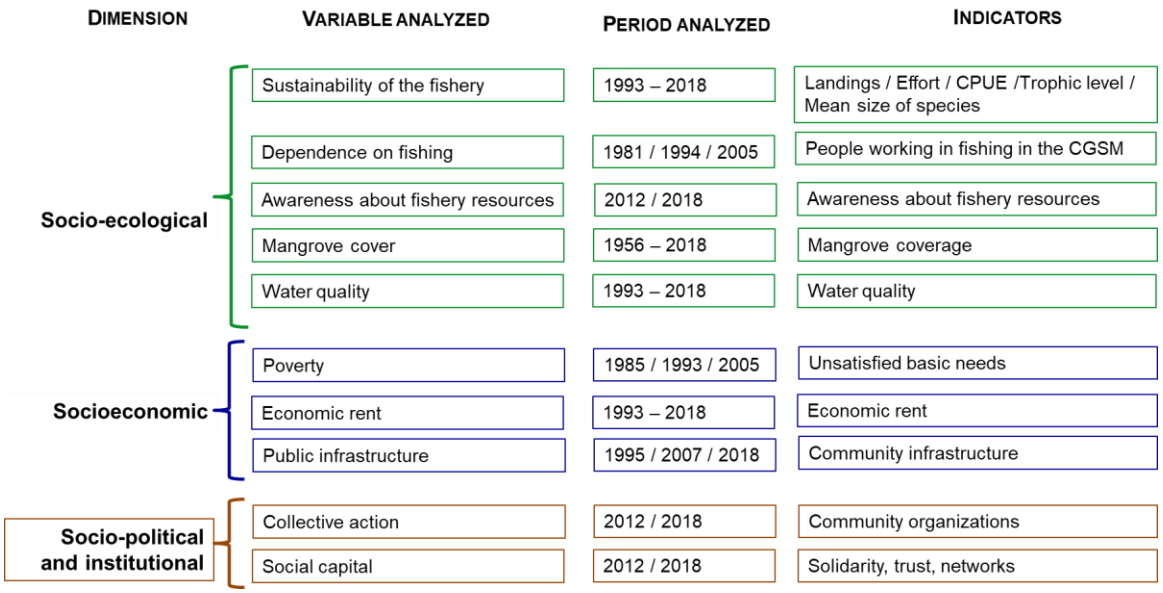
2.2 Data collection and data analysis

To analyze the CGSM´s long-term sustainability we conducted a longitudinal case study (Yin, 2014), which included both quantitative and qualitative analyses. Given the lack of data for some socioeconomic and institutional variables, it was not possible to compare specific ‘‘snapshots,’’ or periods of time. Instead, we used all the available data with which we felt sure we could analyze the long-term sustainability of this important ecosystem. It allowed us to closely examine the most relevant socioeconomic, ecological, and institutional changes that CGSM has suffered since 1993. Figure 2 shows for each dimension the indicators or variables analyzed and the years or period of time analyzed.

We used five indicators to analyze the changes in the CGSM's social-ecological conditions in the last 25 years: i) sustainability of the fishery, ii) dependence on fishing, iii) awareness about fishery resources, iv) changes in the mangrove coverage, and v) changes in the water quality. To evaluate the sustainability of the fishery, we analyzed a 23-year time-series of landings, effort, catch per unit effort (CPUE), trophic level (TL) and catch composition. The data about fishery resources was got from the Institute for Marine and Coastal Research (INVEMAR)'s Fisheries Information System (SIPEIN)[1] and, specifically for trophic levels from www.fishbase.org and www.sealifebase.ca. When a trophic level was not possible to find to any specie, we assigned the trophic level from a similar specie.

[1] This system collects and processes data of fishing information for the CGSM since 1993.

Figure 2. Dimensions, indicators and periods analyzed



The dependence on fishing of CGSM's fishers, was estimated as the ratio between the number of fishers and the total inhabitants living in the eleven municipalities that conform the Ecoregion CGSM. To build the indicator, we used data from various sources such as Colombian government official reports, academic literature upon the CGSM and statistics from the National Administrative Department of Statistics (DANE for its acronym in Spanish)[2]. The awareness about fishery resources of CGSM's fishers, was determined based on three sources. The first, were data collected in 2008 by Vilardy and González, (2011) through semi-structured interviews to 131 social actors linked to this socio-ecological system. The second source, were data collected by the first author through a survey conducted in February 2013, with 172 CGSM's fishers[3]. The third source, were some five workshops conducted on November 2018 by the third author in Tasajera, Pueblo Viejo, Nueva Venecia y Buenavista, with 84 fishers. These workshops were encouraged by the Autonomous Regional Corporation of Magdalena CORPAMAG[4], in order to promote the formulation of a macro project that allows the ecological associations, fishers and farmers of the CGSM recover their productive capacity.

To examine the trend of mangrove cover, we used the data on mangrove basal area collected by INVEMAR's since 1993 from five stations with different disturbance levels. Based on these data, we calculated the rate of mortality and the rate of recovery between 1993 and 2018. We supplemented these data with academic literature generated by previous studies upon the

[2] DANE is the government entity responsible for producing the official statistics in Colombia.

[3] Fishers surveyed were selected from SIPEIN (INVEMAR's Fisheries Information System). The questionnaire included 107 questions about sociodemographic aspects, environmental awareness, social capital, trust, reciprocity, collective action, and external aid received. For more details about the survey see (Luz Elba Torres-Guevara, Schlüter and Lopez, 2016)

[4] CORPAMAG is the government agency in charge of environmental management and control in the Department of Magdalena, Colombia

CGSM. Finally, to analyze the changes in water quality, we used data on annual weighted average salinity levels reported by INVEMAR since 1993 from 28 stations which are grouped in six zones that include strategic points such as mouths of rivers and streams, natural channels, the connection between the Caribbean Sea and the CGSM, the stilt villages and the main water body of the lagoon (INVEMAR, 2018b). We chose this parameter because salinity is the characteristic that best defines an estuary (Roldán and Ramírez, 2008) and its variations allow to analyze the deterioration or recovery of the water quality. To supplement these data, we also took into account the presence of heavy metals and chemical and microbiological contaminants. Given that the water quality is only one of the variables choose to analyze the CGSM sustainability through the time, we discuss the general trend from this variable based on the data reported by INVEMAR each year since 1999. In addition, we use academic literature that complemented our assessment.

To establish the socioeconomic conditions of CGSM's fishers, we used three indicators: poverty, economic rent and public infrastructure. The data about poverty was gathered from the DANE. To investigate the economic rent, we used data from SIPEIN database. Finally, to determine the community infrastructure, we built an indicator following Maldonado and Moreno (2014), which evaluate the presence of 10 public infrastructure items: health center, hospital, elementary school, high school, roads, piped drinking water, sewerage, public electricity, solid waste collection and disposal, and natural gas. We verified the presence of these items in each community and then assigned a point to each of them, if they existed. Thus, the lower the number of services to which the community had access, the lower the score.

Finally, the socio-political and institutional dimension was studied based on some variables associated to social capital. It includes: community organizations, networks and mutual support, collective action, solidarity and trust. The data for these variables were gathered from four sources: i) the survey conducted by the first author on February 2013 to 172 CGSM's fishers, ii) 75 informal interviews conducted in August 2011 by the first author to fishers, community leaders and key informants, iii) the workshops conducted on November 2018 by the third author with 84 fishers and iv) secondary data from CORPAMAG and the Chamber of Commerce of Santa Marta.

3 RESULTS AND DISCUSION

To analyze the long-term sustainability of the CGSM, we organized the data in three dimensions: socio-ecological, socioeconomic and socio-political and institutional. Now, we are going to present the findings for each dimension, based on the variables or indicators that we built using the available data in each of them.

3.1 Socio-ecological dimension

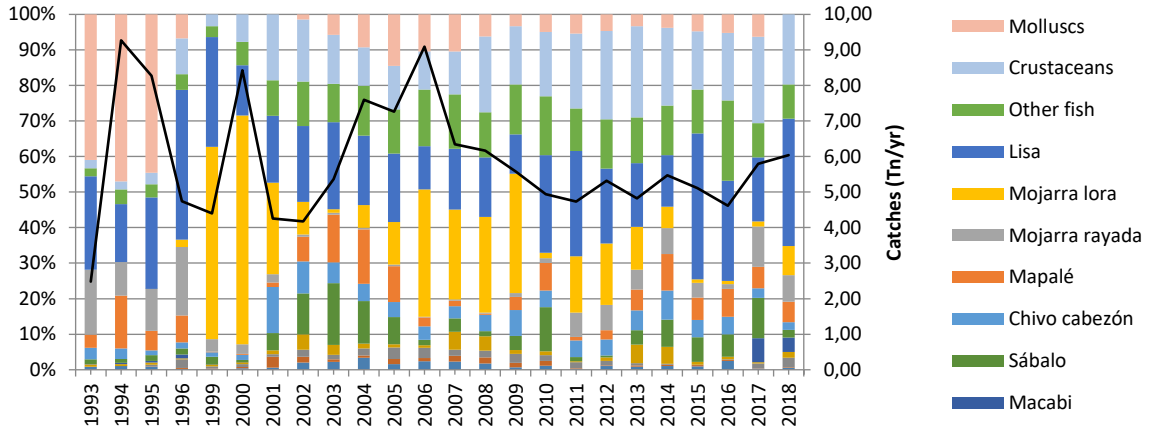
3.1.1 Sustainability of the fishery

More than 90 species are exploited in CGSM, from which 80 are finfish and represent on average more than 70% of the production. Two different performance are presented: one

between 1993 and 2006, where there are extreme variations in the catches (mean 6.28, SD 0.66); and another, between 2007 and 2018, where the catches seem to stabilize (mean 5.41, S.D 0.17) (Figure 3).

The dominant species landed have changed through the time: while in 1994 the Ostra (*Crassostrea rhizophorae*), the Mapale (*Cathorops mapale*), the Mojarra Rayada (*Eugerres plumieri*) and the Lisa (*Mugil incilis*) represented respectively 41.7%, 14.9%, 9.5% and 16.3% of landings; in 2015, the Jaiba Roja (*Callinectes bocourti*), the Jaiba Azul (*Callinectes sapidus*), the Camaron (*Farfantepeneus notialis - F. subtilis*), the Mojarra Peña (*Caquetaia kraussi*), the Mapale (*Cathorops mapale*), the Macabi (*Elops schmitti*), the Mojarra Rayada (*Eugerres plumieri*), and the Lisa (*Mugil incilis*), represented 12%, 6%, 4%, 3%, 6%, 4%, 8%, and 39% of landings respectively (Figure 3).

Figure 3. Catch composition in a 23-year time-series of CGSM fishery

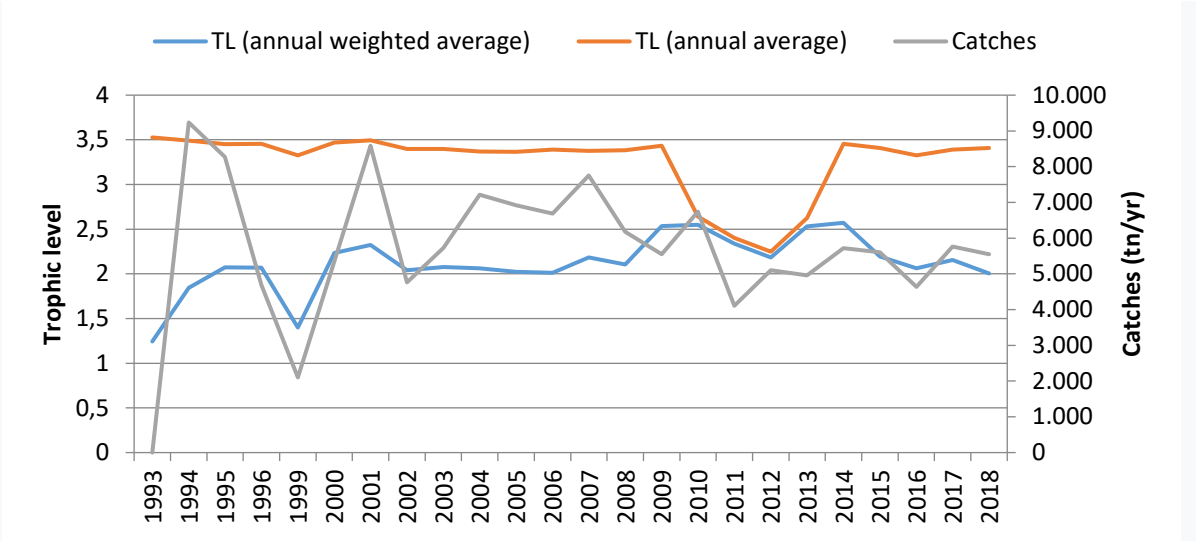


Data source: (INVEMAR, 2018b)

Even the number of species has changed: between 1993 and 1998 the 80% of the catches were represented by 4 species, after the opening of the channels, the 80% of the catches were represented by 8 species. The reduction in the representativeness of the mollusks on the total catch is underlined, in contrast to a greater representativeness of the crustaceans. Regarding the finfish, the Lisa is perhaps the only specie whose representativeness in the total catch remains in time, followed by the Mojarra Lora which appears after the opening of the channels.

To analyze if changes in the composition of landings reflect changes in the structure of underlying fish communities, we have calculated the mean trophic level of CGSM fishery, which is showed in Figure 4. The mean trophic level (Tl) of fish landed from CGSM has remained relatively constant from 1995 to 2018. Between 2011 and 2013 landings felt from 6.6 in 2011 to 4.1 ton in 2013 which coincided with a slight decrease in the mean trophic level. However, when we take into account the TL annual weighted average, we found that the trophic level is growing, with an estimator of slope of around 0.0237 TL each year. The increase in mean trophic level through time could be from an increase in the abundance of large fishes and a decrease in smaller pelagic species which feed at a lower trophic level.

Figure 4. Mean trophic level in a 23-year time-series of CGSM fishery

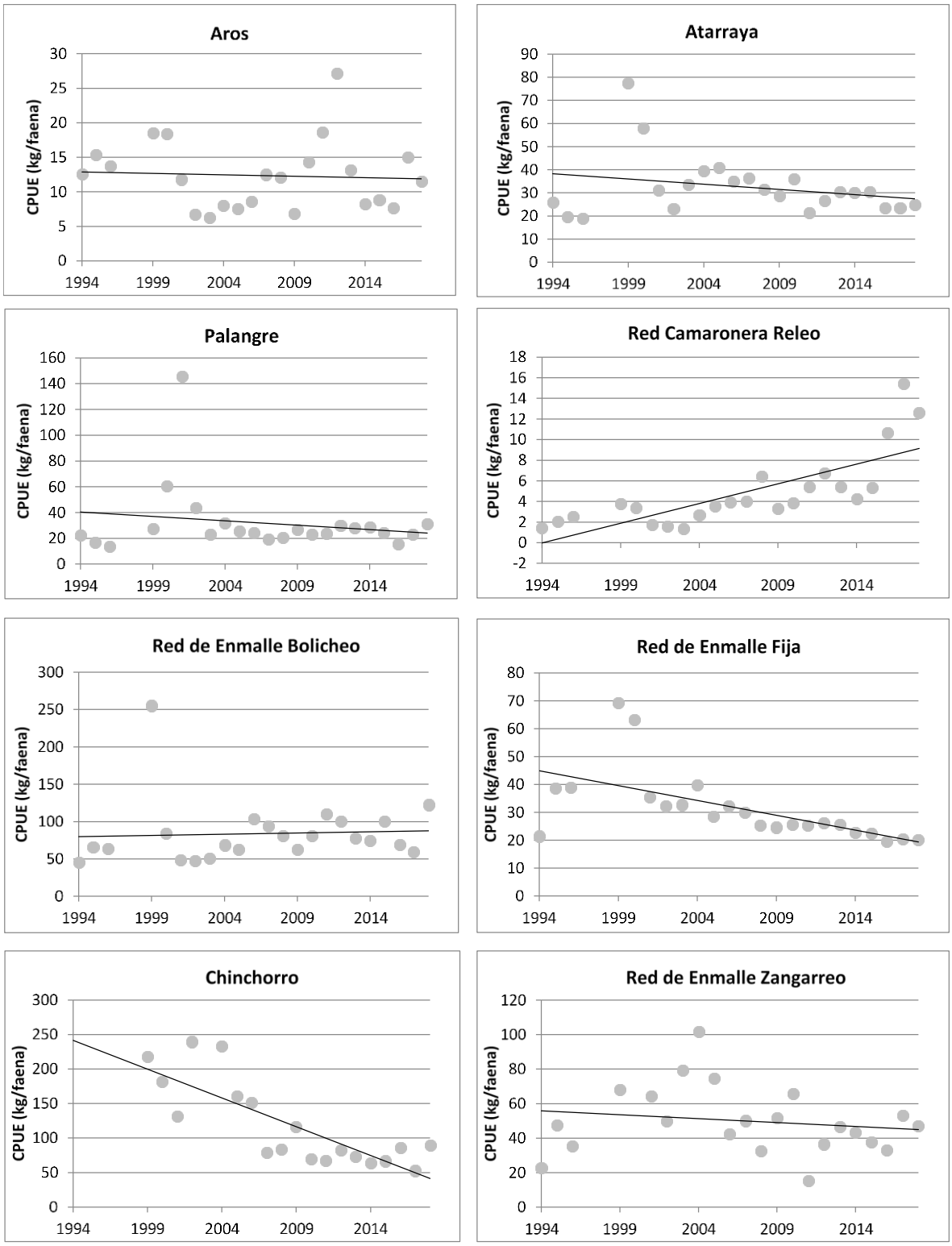


Data source: (INVEMAR, 2018b)

Even though the composition and TL seem to show an ecological recovery of the fishing communities, and a greater diversity in the catches, the CPUE -an indicator of fishing abundance- shows a different performance. Figure 5 shows that for the main CGSM's fishing gear, the CPUE trend is negative.

It is possible to see that before the opening of the channels, the most efficient gears were the gill nets, especially the bowling which reached maximum levels of 134.5 Kg faena $^{-1}$ on November 1993, when its target species, the Mojarra Rayada was abundant. After the opening of the channels and until 2006, the seine net was the fishing gear with the best CPEU.

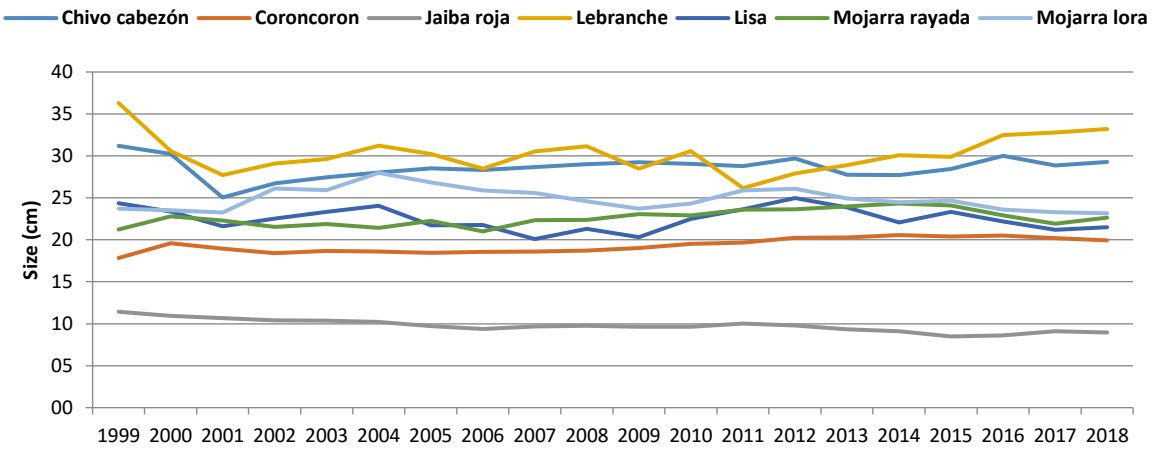
Figure 5. CPUE for fishing gears reported in a 23-year time-series of CGSM fishery



Data source: (INVEMAR, 2018b)

From the estimations of the average sizes of catches, the degree of pressure exerted by the fishing gears on the resource can be observed. Figure 6 shows the average catch sizes for species that represent over 50% of the catch. According to the Figure 6, relatively constant sizes are reported in the period studied, with the exception of the Jaiba Roja and the Mojarra Lora, that show a decrease in their average size of catches, although the latter has been catches on average above its mean maturity size. On the other hand, the Chivo Cabezon and the Lisa are catches on average below their mean maturity size, during the whole time of analysis.

Figure 6. Mean size for some species in a 23-year time-series of CGSM fishery



Data source: (INVEMAR, 2018b)

3.1.2 Dependence on fishing

According to the results of the 'indicator people working in fishing in the CGSM', we found that the dependence on fishing from inhabitants living in the Ecoregion CGSM is low and remained stable through the time (see Table 1). But, if we compare this result with the proportion of people from fishing villages that depend on fishing, we found that it is higher, especially in the stilt villages. For example, in 1993, Pueblo Viejo's county seat was a ratio of 0.0569 while Nueva Venecia was 0.8418. A reason that can explain the high dependence of stilt villages is that they live within CGSM and they do not have other economic alternatives.

Table 1. Indicator people working in fishing in the Ciénaga Grande de Santa Marta

Municipality / Village	1982	1993	2005
SITIO NUEVO			
Nueva Venecia*	0.4978	0.8418	-
Buenavista*	0.5355	0.3141	-
PUEBLO VIEJO			
Bocas de Aracataca*	0.2559	0.2326	-
Isla del Rosario	0.2124	-	-
Palmira	0.2828	-	-
Tasajera	0.2294	-	-
Pueblo Viejo**	0.2473	0.0569	-
Ecoregion CGSM	0.0097(1)	0.0117(2)	0.0094

*Stilt village ** County seat **(1)** Data for 1981 **; (2)** Data for 1994
Data source: (INDERENA, 1981; Andreis, 1999; DANE, 1999, 2012; Rueda and Defeo, 2003; Fadul-Otero, 2008)

Torres-Guevara *et al*. (2016) reported that 93% of fishers surveyed in 2013 were dedicated exclusively to fishing and the 88% depend only on the CGSM's fishing. Likewise, 66% stated they were fishers because in the region there is no more employment alternatives. These data confirm the high dependence of the fishers on this lagoon. This situation seemingly have not changed since then, because in the workshops carried out at the end of 2018, participants stated that most of people in the fishing villages are dedicate exclusively to the fishing, due to it is what they know to do. In addition, according to them, in these villages there is no other alternative employment, different from the commercialization of fish or shrimp, the arrangement of nets or the cleaning of canoes. One option for the CGSM's fishers that live near to the highway is go fishing in the sea. However, since the canoes and fishing gears are different from the ones they use in the lagoon, they have to rent them or work with a fisher that normally fishing in the sea.

3.2 Awareness about fishery resources

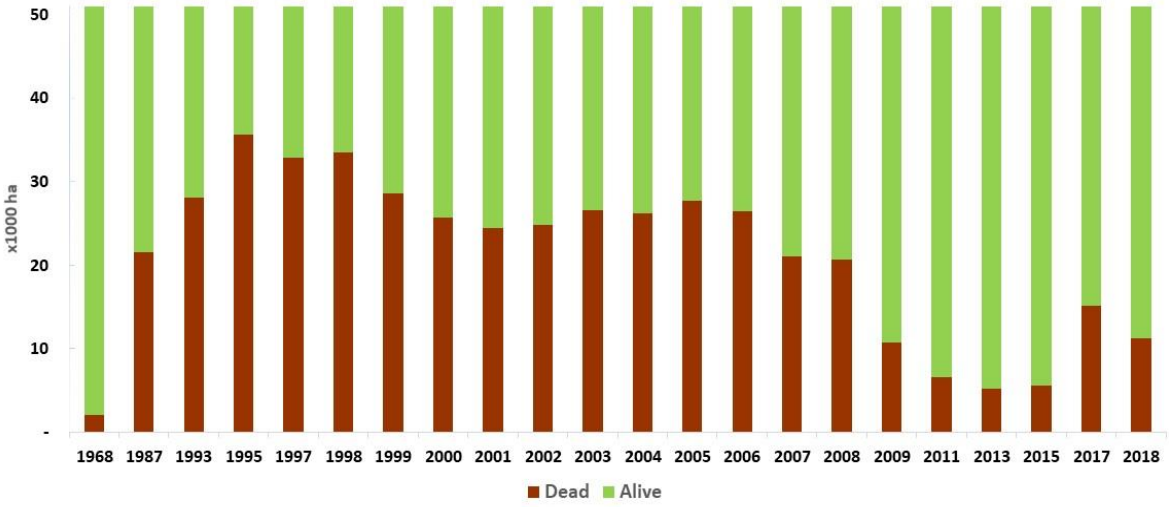
The perception that different actors have about the ecosystem services that supply the CGSM was evaluated in 2008 by Vilardy and González (2011). According to these authors, the people interviewed perceived that about half of the services (43.4%) generated by the ecosystems from the Ecoregion CGSM had reduced or disappeared, especially the provisioning of food. In relation to the fishing, they found that there was a tendency to the reduction.

Torres-Guevara *et al*., (2016), evaluated in 2013 fishers' perception about the availability of fishery resources in that moment and in the future. They found that 81% of fishers perceived that the resources were beginning to become scarce and 73% believed that in the future there will not enough fish if they continue fishing as they did in that moment. Likewise, they evaluated their perception about the changes that has suffered in the last years. They established that most of the CGSM's fishers surveyed (81%) considered that the lagoon had suffered negative changes in the last years due to multiples factors that included overfishing, the use of nets with small mesh sizes and some activities of the government such as the construction of the highway to connect Ciénaga and Barranquilla and the road parallel to the Magdalena River, which interrupted the flow of fresh water from the river to the lagoon. This fishers' perception about the fishery resources seems not to have changed. In fact, in the

workshops carried out at the end of 2018, we found that fishers have a similar opinion. In general terms, they perceive that fishery resources are less abundant that some years ago. Inclusive, around 50% of fishers mentioned that dredging operations are key because it allow not only the entrance of fresh water to the lagoon but also the entry of fish, which increase the fishery resources in the CGSM.

3.2.1 Mangrove coverage

Figure 7. Dead and live mangrove coverage in the region of Ciénaga Grande de Santa Marta from 1956 to 2018



Data source: (INVEMAR, 2008, 2018a, 2018b; Ibarra *et al.*, 2014)

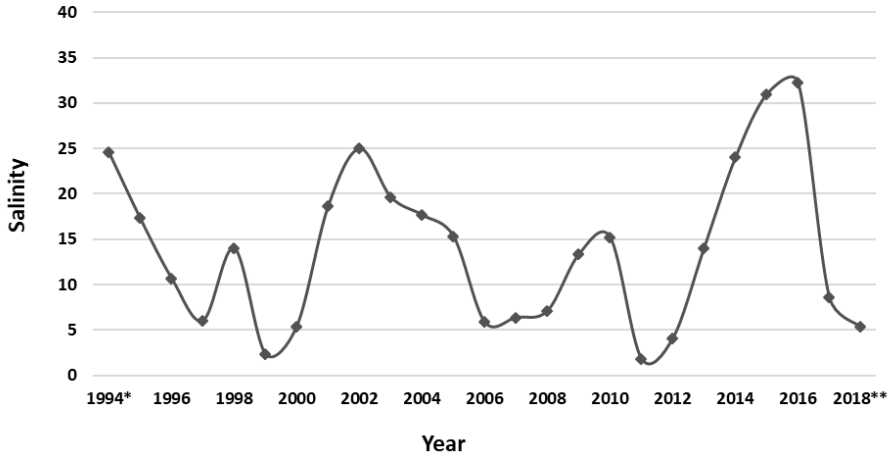
In the Ecoregion CGSM, the mangrove forest is a key resource because is the natural habitat for many species of birds, fish, crustaceans and mollusks. Therefore, its conservation is very important. Unfortunately, this ecosystem was one of the most affected by the strong changes produced in the hydrological regime of CGSM. According to the literature (INVEMAR, 2008, 2018a, 2018b; Ibarra *et al.*, 2014), two events in particular were responsible for these changes: i) the construction between 1956 and 1960 of the highway to connect Ciénaga and Barranquilla, which reduced from 2000 m wide to 80-100 m wide, the natural connection between the lagoon and the Caribbean sea, and ii) the construction in the 1970s of a road parallel to the Magdalena River (on the eastern side), without respect their connections. Due to this, there was an increasing in the salinization of soils and water, which caused a massive mortality of mangrove (González, 1989; Botero and Mancera-Pineda, 1996; INVEMAR, 2002). In fact, between 1956 and 1968 died 2094 ha of mangrove (a rate of 174 ha year^{-1}). However, in the next years, this rate increased until 1930 ha year^{-1} for the period 1993-1995. It meant a loss of 28.570 ha (44% of total mangrove coverage). From 1996, the mangrove started to recover as result of the restoration activities carried out by the government through the project PROCIENAGA[5]. From that moment, the mangrove forest have had a rate of recovery that have fluctuated between 122 ha year^{-1} in 2015 and 5771 ha year^{-1} in 2009. It is

[5] It was a megaproject carried out between 1992 and 2002 by the Colombian government, in order to work in the rehabilitation of CGSM.

important to highlight that given mangrove is very sensible to the changes in the water quality, it is key to maintain an adequate flow of water from the sea and the rivers that provide water to it.

3.2.2 Water quality

Figure 8. Annual weighted average of salinity in the region Ciénaga Grande de Santa Marta.



*Data for 4 months. **Data for 8 months.
Data source: (INVEMAR, 2018b)

The water quality in the CGSM has varied in the last 25 years due to natural and anthropic factors. Salinity is a variable that affect both fishery resources and mangrove forest, for that reason, the analysis is mainly based on it. Figure 8 shows the performance of this variable between 1994 and 2018. In general terms, can be observe that salinity has fluctuated widely through the time. According to INVEMAR (2018b), these changes are produced for multiples factors such as the reduction or increasing of the rainfalls due the "El Niño or La Niña" events and the entry of fresh water, nutrients, sediments and chemical and organic contaminants through the rivers and channels. In general terms, we found that water quality in the CGSM has fluctuated in the last 25 years. Thus, for example between 1999 and 2007, the CGSM´s water quality was low due to the presence of chemical and microbiological contaminants in some areas, and the entrance of an important quantity of nutrients and sediments, which produced changes in the physical, chemical and biological properties of water. For that reason, there were some episodes of massive fish mortalities. In the next seven years (2008-2014), the water quality was adequate, despite there was variations in the salinity and an important input of nutrients, sediments and chemical and organic contaminants to the system. Since then, the presence of high concentrations of nutrients and heavy metals in some areas of the system have reduced the water quality. Finally, it is important to state that in areas near to the stilt villages is common to found a very poor sanitary quality of the water.

3.3 Socio-economic dimension

3.3.1 Poverty

In Colombia, the indicator of unsatisfied basic needs[6], allows to determine the level of poverty of a municipality. It ranges from 1 to 100 and reflects the ratio of poor households in a community. The greater the proportion, the higher the poverty. In the case of fishing villages that depend of the CGSM's fishery resources, we found that despite it has improved from 1985 it continue been so high (see Table 2). These results reveals the difficult living conditions in which the fishers of these fishing communities, despite the Ecoregion CGSM is a Fauna and Flora Sanctuary, a Ramsar Site and Biosphere Reserve.

Table 2. Indicator of poverty in the region Ciénaga Grande de Santa Marta

Municipality / Village	Year		
	1985	1993	2005
SITIO NUEVO			
Buenavista*	85.6%	76.6 %	60.76%
NuevaVenecia*			
PUEBLO VIEJO			
Bocas de Aracataca*	87.0 %	71.2 %	68.32%
Isla del Rosario			
Palmira			
Tasajera			
Pueblo Viejo**			

*Stilt village ** County seat D

Data source: (DANE, 1999, 2012)

3.3.2 Public infrastructure

Community infrastructure is an indicator that allows to have an idea about the presence of the State in the region. In addition, it is largely associated with the level of poverty in which fishing communities live. In our case, we found that in the towns located on the highway that connects Ciénaga and Barranquilla (Palmira, Isla del Rosario, Tasajera and Pueblo Viejo), the infrastructure has improved considerably. In fact, as can be seen in Table 3, this has doubled between 1995 and 2018, which somehow indicates an improvement in the quality of life of its inhabitants, even though they still lack of services as basic as the provision of drinking water through the aqueduct and not from a container truck. In the stilt villages the situation is thoroughly different, despite the indicator show a slight improvement, except in Bocas de Aracataca that continue with the same infrastructure since 1995.

[6] In Colombia, a household is consider as poor if it is in, at least, in one of the next situations: i) the house is made with materials that are consider inadequate for human accommodation, ii) it has an inadequate access to sewage and clean water (it is obtained from a river or spring, rain water, or container truck), iii) there are a critical overcrowding (more than three persons per room), iv) there are more than three people per employed member and the head of household has a maximum of two years of approved primary education; and v) there is at least one school-aged child (between 6 and 12) relative of the head of household but he/she does not attend school(DANE, 2012). It is important to mention that when a household has two or more of these situations, the household members are considered to live in a state of misery (DANE, 2012).

Table 3. Indicator of public infrastructure in the region Ciénaga Grande de Santa Marta

Village	Year		
	1995	2007	2018
SITIO NUEVO			
Buenavista*	1.0	3.0	3.0
Nueva Venecia*	1.0	2.0	5.0
PUEBLO VIEJO			
Bocas de Aracataca*	1.0	3.0	1.0
Isla del Rosario	3.0	5.0	8.0
Palmira	3.0	5.0	7.0
Tasajera	3.0	6.0	8.0
Pueblo Viejo**	5.0	9.0	9.0

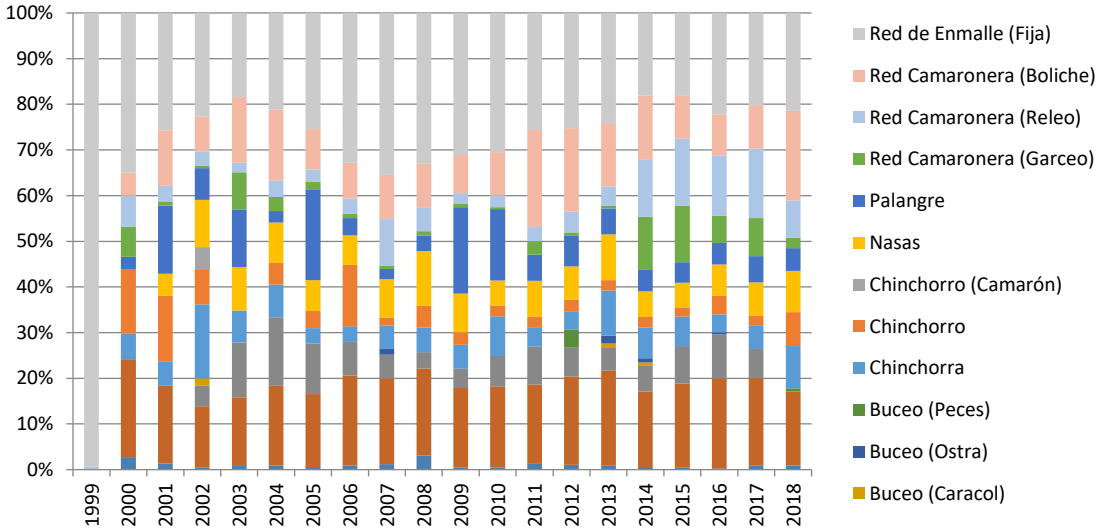
*Stilt village ** County seat
Data source: (Acosta-Monsalvo, 1995; PROCIENAGA, 1995; Barros-Acosta, 2005; DNP, 2007; Gómez-Melendez, 2016)

Finally, it is worth mentioning that currently in Bocas de Aracataca the only infrastructure available is an elementary school, but there is no teacher. In Buenavista and Nueva Venecia, there is a health center that operates only when there is some health brigades in the zone, intermittent electricity supply, and a primary school in Buenavista and a primary and secondary school in Nueva Venecia.

3.3.3 Economic rent

The profits of the CGSM fishery come from different gears. Figure 9 shows the distribution of profits by type of gear. As can be seen, the gears that most contribute to the economic rent are the gill net (fixed), the seine net and the shrimp net (Boliche), which represent on average 43% of the profits of the fishery.

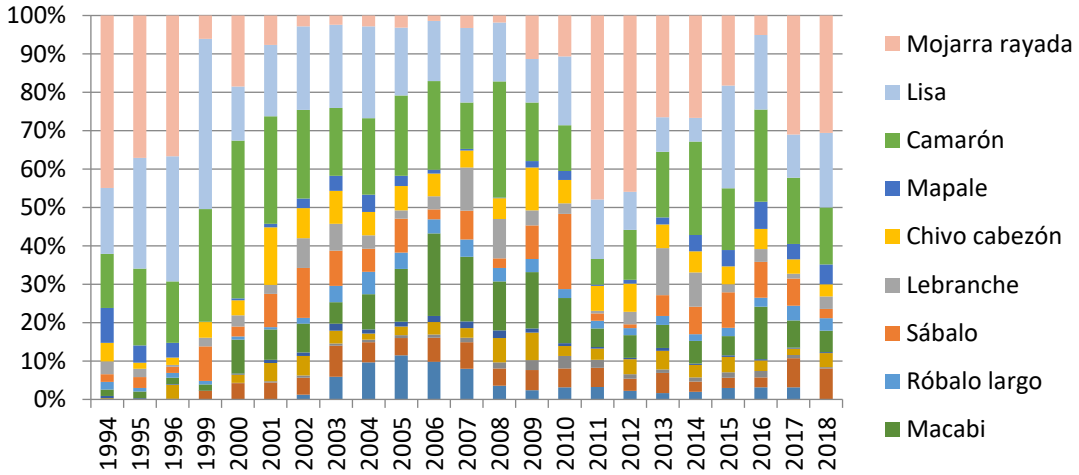
Figure 10. Composition of economic rent by type of fishing gear



Data source: (INVEMAR, 2018b)

According to the data, more than 80% of the profits comes from 14 species, being one of the most representative the Mojarra Rayada, the Lisa and the shrimp (Figure 11). The change in monetary values are associated with the change in the composition of the fishery resources. Before the re-opening of the channels, the composition of catches by species was dominated by estuarine such as Mojarra Rayada, Lisa, Mapalé, oyster and snail, which had the highest commercial prices; after the re-opening that composition changed. On the one hand, the decrease in catches in Mojarra Rayada and the disappearance of oyster and snail, and on the other hand, the domain of freshwater species, such as Mojarra Lora (which led to the introduction of the seine net), and the Mojarra Peña with low prices.

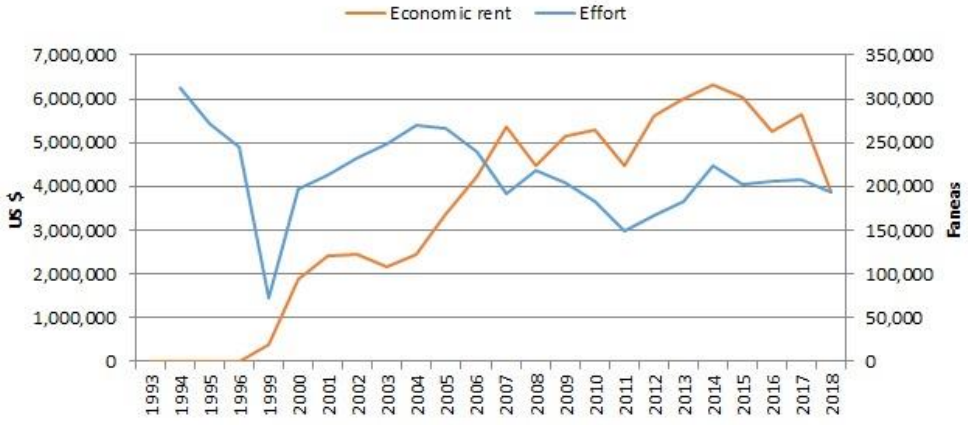
Figure 11. Composition of economic rent by type of species



Data source: (INVEMAR, 2018b)

Although a decrease in the prices of several species is reported after the channels were opened, Figure 12 shows that the economic rent has a growing trend over time. It is possible to identify two different periods: one in which the rent rises rapidly with an increasing effort, and another in which the rent continues to rise, but with a lower effort. In short, after 2006, there is a greater efficiency in the generation of economic rents.

Figure 12. Economic rent and effort



Data source: (INVEMAR, 2018b)

3.4 Socio-political and institutional dimension

To understand how people interact to create institutions (rules) that allow them to exploit or manage a natural resource in a sustainable way has become increasingly important. The existence of collective action, trust, solidarity, networks and community organizations are key factors to achieve this (Ostrom, 1990, 2010).

Despite the Ecoregion CGSM has been widely studied, the analysis of these social aspects are scarce. In the research about collective action in the CGSM, carried out by Torres-Guevara *et al*. (2016), they found that a key factor that has impeded the collective action for a sustainable fishing in CGSM has been the indiscriminate and strong violence inflicted by the illegal armed groups on CGSM's fishers since the 1960s. It has caused not only great fear among fishers but also has weakened the social capital, which is evidenced by the low participation in community activities (79% of fishers surveyed did not participate in any activity during 2011) and the distrust in local government, farmers, ranchers and traditional leaders (between 50% and 62% stated they did not trust at all). According to fishers that participated in the workshops, after the signing of the peace agreement on August 2016, they perceive that the violence has reduced. However, the common crime is still an issue that concerns them so much.

The expectations of CGSM's fishers about solidarity, network and mutual support, were evaluated in 2013 by Torres-Guevara *et al.* (2016) through the survey. To evaluated solidarity they asked fishers if they had a problem who help them. The answers more frequent were family (98%), buddies (57%), friends (45%), neighbors (45%), co-workers (37%) and fishers (22%). To evaluate networks and mutual support, they asked the fishers if a natural disaster occurred in the CGSM who they though would come together to solve the problem. 54% said that fishers, 23% the whole community, 11% the State, 11% all people that depend on it and 1% nobody. They also asked them what people normally did when there is a problem that affects the entire community. 52% told that they block the highway in order to pressure the local goverment and solve the problem, 29% answered they work together to solve the problem, 14% named a representative, 4% said each person tries to fix it on their own and the remaining 1% gave other options.

Regarding community organization Torres-Guevara *et al*. (2016) found in 2011 58 small community organizations grouped in a higher-level organization called: Association of Community Organizations of the Ciénaga Grande de Santa Marta (ASOCOCIENAGA). However, according to the fishers, the inappropriate management by the board of directors had undermined their trust in these associations. This situation seems has not changed and currently many of these organizations are inactive. Despite this the number of community organizations increase to 67. In addition, there is another organization that group: Permanent Assembly of Fishers' Organizations and fish farmers of Ciénaga Grande de Santa Marta (APOPESCA).

4 CONCLUSIONS

People have faced multiple shocks changing or increasing the fishing gears that they used to use. It allowed them to get over the reduction in their income, generated by the ecological crisis that has suffered the lagoon.

The Lisa is so far the most valuable fishing resource, given that is has demonstrated it is the most resilient species to the hydrological changes. It is so relevant to remain food security of these fishers' communities. Especially, for those who have demonstrated a high fishing dependence over time.

We found a growing economic rent in contrast to CPUE decreasing. It can be indicating that economic rent comes from higher prices, due to the scarcity of fishery resources. This would suggest that this rising trend in income may disappear in the coming years. This is because, although there is a recovery in the mangrove coverage, the water quality, and the trophic level, it has not been enough to recover the fishing resource and keep it sustainable over time.

This last result is very important because the increase in profits may be encouraging the increase in effort, which is counterproductive given that according to our analysis for the last 25 years, fishers have not managed to organize themselves to exploit the resource in a sustainable manner.

Finally, it is important to mention that apparently, the level of recovery of fishery resources is lagging behind that of mangrove and water. This would indicate that to achieve a total recovery of the resource it is necessary to invest more effort in awareness processes of the new generations of fishers

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5 REFERENCES

Acosta-Monsalvo, R. (1995) "Plan de Desarrollo del Municipio de Sitio Nuevo 1995-1997." Sitio Nuevo: Alcaldía de Sitio Nuevo, Magdalena, Colombia, p. 93.

Andreis, A. C. de (1999) "La mirada que mira la mirada:un caso de alianza en la Ciénaga Grande de Santa Marta." Barranquilla: Universidad del Norte, Centro de Investigaciones en Desarrollo Humano, p. 44.

Barausse, A. *et al.* (2011) "Long-term changes in community composition and life-history traits in a highly exploited basin (Northern Adriatic Sea): the role of environment and anthropogenic pressures.," *J. Fish Biol. 79*, 79, pp. 1453–1486.

Barros-Acosta, H. (2005) “Esquema de Ordenamiento Territorial del Municipio de Pueblo Viejo (2005-2017).” Pueblo Viejo: Alcaldia de Pueblo Viejo, Magdalena, Colombia.

Botero, L. and Mancera-Pineda, J. E. (1996) “Sintesis de los cambios de origen antropico ocurridos en los últimos 40 años en la Ciénaga de Santa Marta (Colombia),” *Rev. Acad. Colom. Cienc.*, XX(78), pp. 465–473.

DANE (1999) “Colombia Estadística 1993-1997.” Bogotá D.C.: Departamento Administrativo Nacional de Estadística (DANE), p. 1401.

DANE (2012) “Censo General 2005. Necesidades Básicas Insatisfechas – NBI, por total, cabecera y resto, según departamento y nacional a 30 Junio de 2012.” Bogotá D.C.: Departamento Administrativo Nacional de Estadística (DANE).

DNP (2007) “Base Sisben Aprobada DNP Nov/2007.” Bogotá D.C.: Departamento Nacional de Planeación (DNP).

Fadul-Otero, V. (2008) *Modelo dinámico del sistema sociobiológico Ciénaga Grande de Santa Marta*. Universidad de los Andes, Facultad de Ingeniería.

Fortibuoni, T. *et al.* (2017) “Analysis of Long-Term Changes in a Mediterranean Marine Ecosystem Based on Fishery Landings,” *Front. Mar. Sci.*, 4(33).

Gómez-Melendez, J. M. (2016) “Plan de Desarrollo Municipal 2016-2019. Municipio de Sitio Nuevo, Magdalena.” Sitio Nuevo: Alcaldía de Sitio Nuevo, Magdalena, Colombia, p. 166.

González, E. (1989) “Cambios ocurridos en la cobertura del manglar de la Ciénaga Grande de Santa Marta durante los años 1956 a 1987. Informe presentado a COLCIENCIAS-INVEMAR.” Santa Marta, p. 25.

Ibarra, K. P. *et al.* (2014) “Monitoreo de las condiciones ambientales y los cambios estructurales y funcionales de las comunidades vegetales y de los recursos pesqueros durante la rehabilitación de la Ciénaga Grande de Santa Marta. Informe Técnico 2014.” Santa Marta, Colombia: 140 p.+ anexos., p. 140 + anexos.

INDERENA (1981) “Ecoplan de la Ciénaga Grande de Santa MArta, Colombia.” Bogotá D.C.: Instituto Nacional de los Recursos Naturales Renovables y del Ambiente (INDERENA), p. 30.

INVEMAR (2002) “Monitoreo de las Condiciones Ambientales y los Cambios Estructurales y Funcionales de las Comunidades Vegetales y de los Recursos Pesqueros Durante la Rehabilitación de la Ciénaga Grande de Santa Marta. Informe Técnico Final 1999-2002. Volumen 1.” Santa Marta, Colombia: Instituto de Investigaciones Marinas y Costeras “José Benito Vives de Andréis” (INVEMAR), p. 323.

INVEMAR (2008) “Monitoreo de las condiciones ambientales y los cambios estructurales y funcionales de las comunidades vegetales y de los recursos pesqueros durante la rehabilitación de la Ciénaga Grande de Santa Marta. Informe técnico final 2008.” Santa Marta, Colombia: Instituto de Investigaciones Marinas y Costeras “José Benito Vives de Andréis” (INVEMAR), p. 129.

INVEMAR (2018a) “Monitoreo de las condiciones ambientales y los cambios estructurales y funcionales de las comunidades vegetales y de los recursos pesqueros durante la rehabilitación de la Ciénaga Grande de Santa Marta. Informe Técnico 2017, Volumen 16.” Santa Marta, Colombia: Instituto de Investigaciones Marinas y Costeras “José Benito Vives de Andréis” (INVEMAR).

INVEMAR (2018b) “Monitoreo de las condiciones ambientales y los cambios estructurales y funcionales de las comunidades vegetales y de los recursos pesqueros durante la rehabilitación de la Ciénaga Grande de Santa Marta. Informe Técnico Final 2018. Volumen 17.” Santa Marta, Colombia: Instituto de Investigaciones Marinas y Costeras “José Benito Vives de Andréis” (INVEMAR), p. 178 + anexos.

Leal-Florez, J. (2007) *Impacts of Non-Native Fishes on the Fish Community and the Fishery of the Ciénaga Grande de Santa Marta Estuary, Northern Colombia.* Bremen University, Bremen, Germany.

Maldonado, J R; Moreno-Sánchez, R. (2014) “Estimating the adaptive capacity of local communities at marine protected areas in Latin America: a practical approach,” *Ecology and Society*, 19(1), p. 16.

Ostrom, E. (1990) *Governing the Commons. The evolution of institutions for collective action*. Cambridge: Cambridge University Press.

Ostrom, E. (2010) “Analyzing Collective Action,” *Agricultural Economics*, 41(1), pp. 155–166.

PROCIENAGA (1995) “Plan de Manejo Ambiental de la Subregión Ciénaga Grande de Santa Marta 1995- 1998.” Santa Marta, Colombia: Proyecto de Rehabilitación de la Ciénaga Grande de Santa Marta (PROCIENAGA). CORPAMAG, INVEMAR, CORPES C.A., GTZ., p. 354.

Rivera, A. *et al.* (2016) “Assessing the sustainability and adaptive capacity of the gooseneck barnacle co-management system in Asturias, N. Spain,” *Ambio*, 45(2), pp. 230–240.

Roldán, G. and Ramírez, J. (2008) *Fundamentos de limnología neotropical, Editorial Universidad de Antioquia*. doi: 10.1167/iovs.15-17290.

Rueda, M. and Defeo, O. (2003) “Linking fishery management and conservation in a tropical estuarine lagoon: Biological and physical effects of an artisanal fishing gear,” *Estuarine, Coastal and Shelf Science*, 56(5–6), pp. 935–942.

Tesfamichael, D., Pitcher, T. J. and Pauly, D. (2014) “Assessing changes in fisheries using fishers’ knowledge to generate long time series of catch rates: a case study from the Red Sea,” *Ecology and Society*, 19(1).

Torres-Guevara, L. E., Schlüter, A. and Lopez, M. C. (2016) “Collective action in a tropical estuarine lagoon: adapting Ostrom’ s SES framework to Ciénaga Grande de Santa Marta, Colombia,” *International Journal of the Commons*, 10(1), pp. 334–362.

Torres-Guevara, L. E., Schlüter, A. and Lopez, M. C. (2016) “Collective action in a tropical estuarine lagoon: adapting Ostrom’s SES framework to Ciénaga Grande de Santa Marta, Colombia,” *International Journal of the Commons*, 10(1), pp. 334–362.

Vilardy Q., S. P. and González N., J. E. (2011) *Repensando la Ciénaga: Nuevas miradas y estrategias para la sostenibilidad en la Ciénaga Grande de Santa Marta.* Santa Marta, Colombia: Universidad del Magdalena y Universidad Autónoma de Madrid. Santa.

Wilson, M., Pavlowich, T. and Cox, M. (2015) “Studying common-pool resources over time: A longitudinal case study of the Buen Hombre fishery in the Dominican Republic,” *Ambio*. Springer Netherlands, 45(2), pp. 215–229.

Yin, R. K. (2014) *Case Study Research: Design and Methods*. 5th ed. Thousand Oaks, CA: Sage Publications.