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Understanding Artisanal Fishers' Behaviors: The Case of Ciénaga Grande de Santa Marta, Colombia

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Abstract: We investigate the ecological impact caused by fishing grounds and the fishing gear/methods used by fishers in Ciénaga Grande de Santa Marta (CGSM), an estuarine lagoon located on the Caribbean coast of Colombia. To do so, we build individual and composite ecological sustainable indicators based on the opinions of a group of experienced fishers and a group of scientists. Additionally, we use those indicators to examine the influence of socioeconomic and perceptional factors on fishers' fishing behaviors and how those behaviors may be affecting CGSM fishery resources. Our results suggest that fishers and scientists differ in their opinions about the impact of fishing on CGSM. Additionally, we found that having a higher level of education, sharing household expenses with other family members and spending more hours fishing lead to ecologically-sustainable fishing behavior, while the perception that the government is responsible for CGSM conservation leads to ecologically unsustainable fishing behavior.

Keywords: artisanal fishing; fishers' behavior; ecological sustainability; local ecological knowledge; Colombia

1. Introduction

Artisanal fisheries are relevant for poverty alleviation and food security, mostly in developing countries [1,2]. However, despite their ecological, economic and social importance, such fisheries are being threatened by several external factors, such as pollution and increasing demands, as well as by internal factors, such as the use of destructive fishing gear and practices [3,4]. As a result of these disturbances, both ecosystems and fishing communities have been seriously affected, and their future livelihoods are in peril.

A sustainable fishery requires taking into account conservation and environmental aspects, along with the social, economic and institutional dimensions of the fishery activity [5]. Any management approach should include the fundamental components of sustainability: ecology, society, economics and institutions [6–8]. Additionally, it is critically important to understand fishers' behaviors and how those behaviors are influenced and may influence all components of sustainability [9–13].

There is an extensive literature examining the socioeconomic conditions influencing the long-term sustainability of artisanal fisheries. Some studies have found that fishers who are more educated or wealthier are more likely to use less destructive gear [14]; whereas those with female heads of households or suffering food insecurity use more destructive gear [3,14]. Some studies have determined that fishing strategies, including fishing ground selection and effort, depend on wealth and experience, as well as distance to the market, seasonal dynamics, traditions, profits and information [15–19]. Perceptions regarding the resource have a mixed influence over behavior, and they are dependent on socioeconomic status [12].

The use of the traditional ecological fishers' knowledge as a complement to scientific research is becoming increasingly common [20–23] because it allows for better communication between scientists and resource users [24,25]. However, more importantly, it acknowledges that fishers have an immense ecological knowledge of aspects such as habitats, species, migration and stock structure [26] and that scientists could learn from this. The inclusion of fishers' knowledge may provide important information to scholars and policy makers about ways to manage natural resources in a sustainable manner that could improve the development and implementation of policies [26].

Our research was conducted in Ciénaga Grande de Santa Marta (CGSM), an estuarine lagoon of immense ecological and social importance located on the Caribbean coast of Colombia. We used survey data and developed individual and composite fishing impact indicators for each fisher participating in the survey. To build these indicators, we used a database with information about fishers' fishing behaviors between 2006 and 2010. In particular, we used data on fishing grounds visited, as well as fishing gear and methods used. This information was combined with two evaluations of the ecological impact caused by fishing in these grounds and by using these types of gear and methods. One evaluation was made by a group of experienced CGSM fishers and another one by a group of scientists either working in scientific research on CGSM's fishery or involved in its management. We then investigated the influence of socioeconomic and perceptional factors on fishers' fishing decisions and how these decisions affect the fishery resources by looking at two different points of view: the indicators built with the assessment by the group of experienced CGSM fishers and the indicators based on the scientists' assessment.

The CGSM social-ecological system has been widely studied [27,28]. However, to our knowledge, there are no studies that have specifically examined the behavior of CGSM's fishers. Furthermore, among the studies on fishers' local knowledge, we have seen no study analyzing fishers' impacts on the fishery's ecological sustainability comparing experienced fishers' and scientists' knowledge. The results from this study show that the sustainability of fishing practices is understood in different ways by experienced fishers and by scientists. These different understandings suggest that some additional work is needed to reach some common understanding of how the fishing activity is affecting not only the ecological sustainability of CGSM, but its sustainability as a whole.

2. Study Site and Overview of the Fishing Practices

CGSM is an estuarine lagoon situated in the center of a larger region (about 4900 km^2) known as Eco-region Ciénaga Grande de Santa Marta (Eco-region CGSM) and separated from the Caribbean Sea by a 212-km^2 sand bar called Salamanca Island (see Figure 1). CGSM is one of the most important coastal lagoons of Colombia due to its large size (450 km^2) [29] and its ecological and social value. In fact, it was declared as a Fauna and Flora Sanctuary in 1977, it was also designated as a Ramsar site in 1998 and a Biosphere reserve in 2000 [27,30–32]. There are about 25,000 people living in seven small communities near the lagoon, and most of them rely on the fishery for subsistence. Three of these communities are stilt villages: Bocas de Aracataca, Buenavista and Nueva Venecia; and four are located on the highway connecting Ciénaga and Barranquilla: Isla del Rosario, Palmira, Tasajera and Pueblo Viejo (urban area).

The living conditions in the area are very difficult. According to data from the National Administrative Department of Statistics (DANE)—the public entity responsible for producing the official statistics in Colombia [33]—73% of households in the stilt villages have unsatisfied basic needs, and 50% of its inhabitants live in conditions of misery. In the villages located on the main road, 58% of households have unsatisfied basic needs, and 28% live in conditions of misery.

In addition, these communities have been and continue to be victims of the armed conflict that Colombia has experienced since the 1960s. Additionally, other anthropogenic activities, such as the construction of roads and water channels, have reduced the fishery resources and deteriorated the quality of life [27,28,34]. Torres-Guevara *et al.* [35] found that the strong violence inflicted on the population since the 1960s by illegal armed groups and the economic development in the Colombian Caribbean Region are key factors explaining the lack of collective action among fishers to manage the fishery.

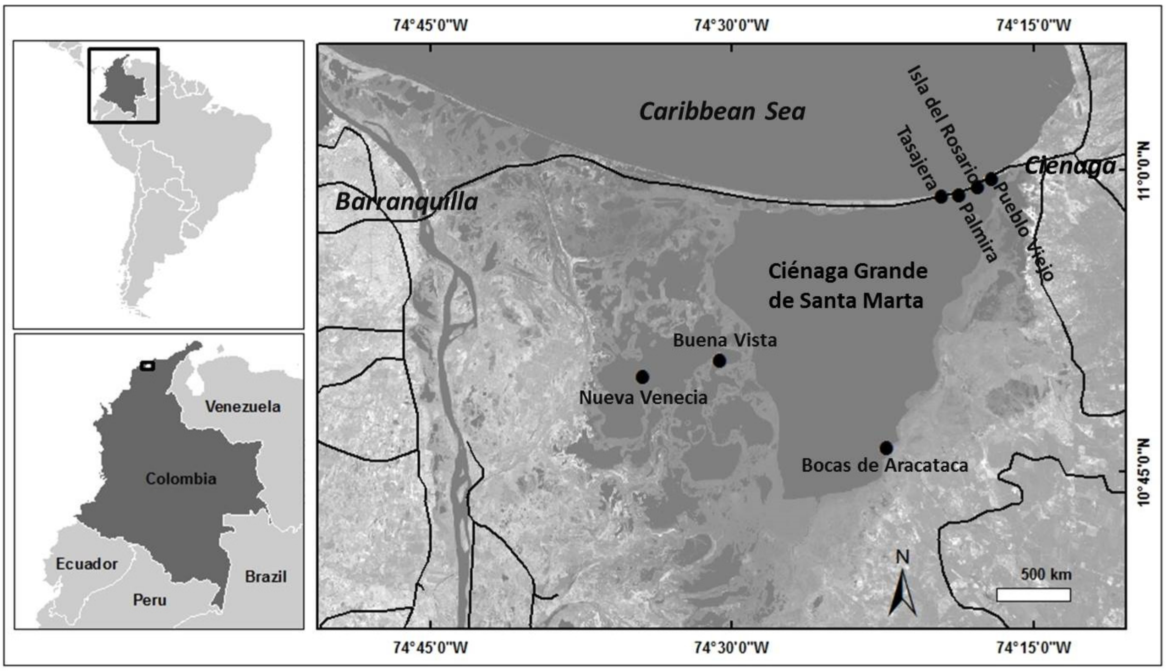

Figure 1. Tasajera and Ciénaga Grande de Santa Marta, Colombia. Source: map produced by Dr. Guiying Li, Center for Global Change and Earth Observations, Michigan State University.

CGSM is characterized by a *de facto* open-access regime where property rights have not been allocated. Thus, fishers from other communities also fish in CGSM, imposing additional pressure on its resources. According to Blanco *et al.* [36], CGSM is one of the largest fisheries in Colombia with 3500 active fishers in the lagoon every day. Fishing is a year-round activity done only by men. The main products extracted from the lagoon are five fish species, two crab species and shrimp, although it is reported that 109 species are commercially exploited in the lagoon [37–39]. Fishers use one or several types of fishing gear/methods during their daily work, depending on the species targeted and the period of the year. CGSM has well-defined dry (March to June) and wet (September to December) seasons separated by two transition periods [40]. The most common gear used are cast nets, fixed gill nets (trammels), encircling gill nets (*boliche*), long lines, seine nets, crab traps and shrimp nets [36,37,39].

3. Methods

3.1. Survey

In February 2013 the first author conducted, with the support of two survey takers, a survey of 172 CGSM fishers selected from the Institute for Marine and Coastal Research (INVEMAR)'s Fisheries Information System (SIPEIN). This system collects and processes data of fishing information for CGSM, and contains information from 1014 fishers who landed fish at Tasajera's fish market between 1999 and 2010. Some of these fishers had fewer observations in SIPEIN over that period of time because

INVEMAR collects data on fishers selected unsystematically, five days per week, and in five fish landing sites where fishers sell their fishing products.

We defined three criteria to select the fishers to invite to participate in the survey. These criteria were: (1) those with a minimum of five observations in 2009 and five in 2010; (2) individuals who also had observations for at least three other years between 1999 and 2008; and (3) those with at least 15 observations in total between 1999 and 2008. These inclusion criteria enabled us to select active fishers and to guarantee that each selected fisher had sufficient data to evaluate his behavior. In total, 245 fishers met these criteria; however, once in the field, it was only possible to contact and survey 172 of them.

The questionnaire included 107 questions about individual and household sociodemographic aspects, perceptions of the fishery resources and their management, social capital, trust, reciprocity and external aid received. The questions were developed based on common-pool resources literature (e.g., see [41–44]), fishers' behavior literature [3,15,18], the World Values Survey and our previous fieldwork carried out in this community. For this particular study, we were interested in the data that allowed us to identify socioeconomic and perceptional factors that might be influencing fishers' fishing behaviors. The data are presented in the results section.

3.2. Evaluation of the Ecological Impact of Fishing in CGSM

The evaluation process consisted of four stages. In the first stage, we prepared a list of all fishing grounds and gear (with their respective methods) registered in the SIPEIN database. In total, we identified 116 fishing grounds where fishers fish. We found seven different types of gear used: five types of nets, long lines and crab traps. One of the nets, the gill net, is used with two methods—encircling and fixed—thus, we established eight different fishing methods. For the nets, we identified 36 different mesh sizes.

In Stage 2, we defined six fishing zones within CGSM according to their ecological characteristics and importance, namely protected areas, natural nursery areas, mouths of rivers and streams, mangrove roots and other vegetation, mouth of La Barra (also called La Barra Bridge) and water far away from the mangrove. Then, we classified all 116 fishing grounds identified in Stage 1 into one of these six zones.

We then chose three criteria normally used to evaluate the ecological impact of fishing gear/methods on the ecosystem [37,45,46], namely, impact on the habitat, efficiency and selectivity of fishing gear, and target species impact. To reduce the number of fishing nets evaluated, we defined two groups of mesh sizes for each method: ecologically unsustainable (nets with the smaller mesh size) and ecologically sustainable (nets with the larger mesh size) based on fishing literature [34,37,47–49] and scientists' knowledge. For the shrimp nets, we defined only one group since shrimp inside CGSM are juveniles, and therefore, it is unsustainable to catch them [48]. Additionally, for each type of fishing gear, we jointly evaluated two aspects: fishing method and the dimensions of the fishing gear. For the latter, we evaluated the mesh size of the nets, the caliber of the hooks for the long lines and the size of the entrance gap for the crab traps.

Due to the diversity of fishing resources in CGSM, we considered only the main fishing resources extracted [50,51] for the evaluation. Thus, in the third stage, we selected five types of fish and three invertebrates. We did not evaluate the impact of the fishing on each species, instead, we asked fishers and scientists who participated in the evaluation to consider all of the species jointly. Finally, we used the information gleaned in the preceding three stages to create two questionnaires to collect experienced fishers' and scientists' opinions on the ecological impact of fishing on CGSM's main fishery resources and their habitat. These questionnaires included questions for each of the fishing zones, as well as questions regarding the different types of fishing gear and methods identified earlier.

To collect the data, the first author conducted workshops and interviews in Tasajera and Santa Marta in March, 2013, with 25 experienced CGSM fishers and 25 scientists selected using convenience and snowball sampling. The latter were identified with the help of INVEMAR's researchers working in the region. Regarding fishers, we selected native fishers with more than 20 years of fishing experience who were familiar with the different fishing gear/methods we identified in the SIPEIN database. It is important to mention that some of the fishers who participated in this evaluation had also participated in the survey that we conducted in February 2013 with CGSM fishers. In selecting scientists, we invited resource management, conservation practitioners and scientific researchers of different disciplines (e.g., fishery engineers, marine biologists, economists, biologists). The selected scientists are widely recognized by their peers as experts due to their experience working in CGSM or special knowledge in a particular area of study (e.g., population dynamics, ecology and distribution of the species, fishing gear and practices).

Fishers and scientists were graded on a scale from 1–5, where 1 meant low impact and 5 meant high impact: (1) ecological impact of fishing in each fishing ground (graded by fishers) or zone identified previously (graded by scientists); and (2) ecological impact of the fishing gear/methods on CGSM's main fishery resources.

3.3. Construction of Individual and Composite Indicators to Evaluate the Ecological Impact of Fishing in CGSM

Based on the results of the evaluation described in the previous section, we first built individual indicators for fishing grounds and fishing gear/methods and then compiled these into composite indicators (see Figure 2).

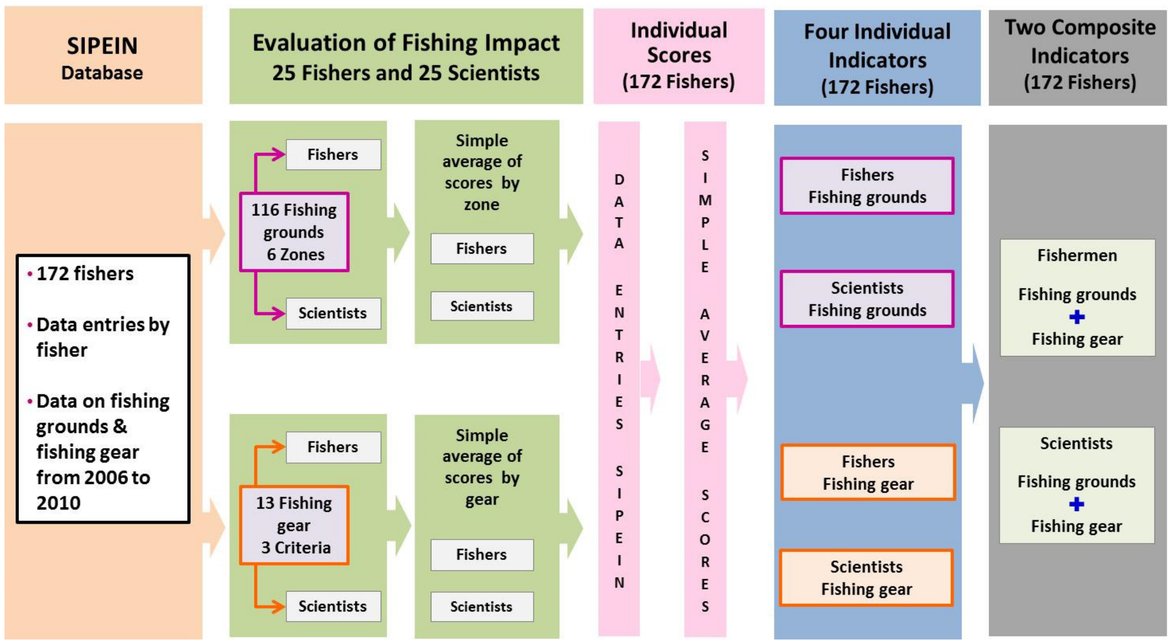

Figure 2. Methodology to build individual and composite indicators to evaluate the ecological impact of fishing in Ciénaga Grande de Santa Marta (CGSM). SIPEIN: INVEMAR's Fisheries Information System.

To build the individual indicators based on scientists' opinions, we first calculated a simple average of the scores the scientists provided for each of the six fishing zones. Then, we repeated the same procedure for each of the thirteen fishing gear/method evaluated. We repeated the same process to build the individual indicators based on experienced fishers' opinions, using their scores. We then merged these scores with the information from SIPEIN for each of the 172 fishers in our survey and calculated four individual indicators for each of them: two for fishing grounds—one based on scientists' scores and the other based on experienced fishers' scores—and two for fishing gear/methods—one based on experienced fishers' scores and the other based on scientists' scores.

To build the composite indicators**,** we first assigned a weight to each individual indicator (fishing ground and fishing gear/method) using the equal weighing method [52]. We used this method because we did not have information to determine which of the components—fishing grounds or fishing gear/method—was more important. Then, we aggregated them using the linear aggregation method, which consists of adding the weighted individual indicators, and according to OECD and JRC [52], it is the most appropriate when individual indicators have the same measurement unit. We thereby obtained two composite indicators for each fisher, one based on experienced fishers' opinions and the other based on scientists' opinions.

4. Results

4.1. Experienced Fishers' and Scientists' Views on the Fishing Grounds and Fishing Gear/Methods

We found that experienced fishers had a much more nuanced understanding of the area than scientists. Therefore, they were able to evaluate the 116 fishing grounds, while scientists were only able to evaluate the six larger fishing zones into which these 116 grounds were clustered. Figure 3 provides the first insight into the differences and similarities between the understandings of experienced fishers and scientists regarding the ecological impact caused by the different fishing grounds and fishing gear/methods commonly used by fishers.

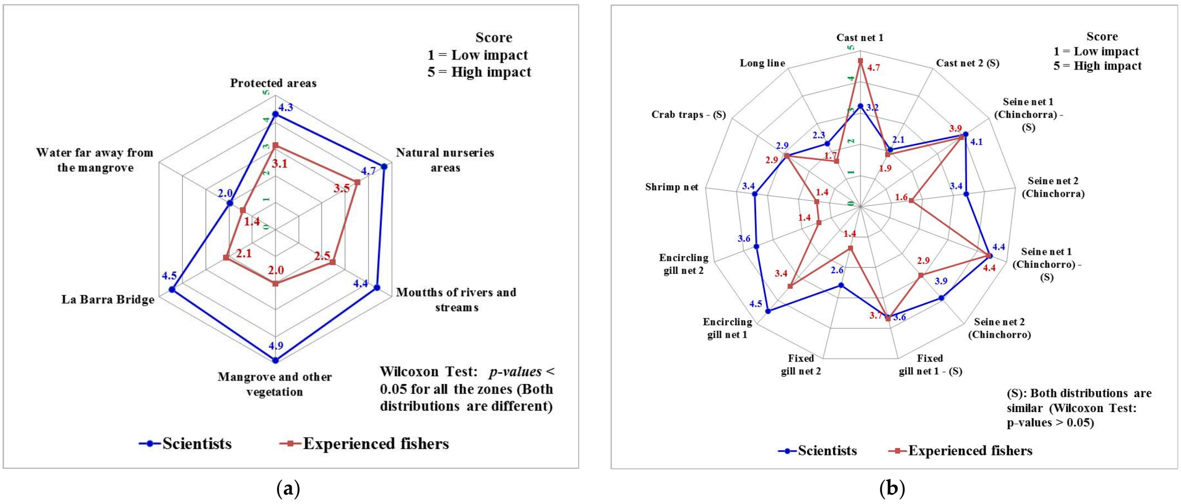

Figure 3. Radar graphs of average scores given by experienced fishers and scientists who evaluated the fishing impact on CGSM of fishing zones and fishing gear/methods. Specifications of fishing gear/methods: Cast Net 1, 0.25″–2.25″; Cast Net 2, 2.50″–3.00″; Seine Net 1 (*Chinchorra*), 1.50″–2.50″; Seine Net 2 (*Chinchorra*), 2.75″–3.50″; Seine Net 1 (*Chinchorro*), 0.75″–1.00″; Seine Net 2 (*Chinchorro*), 1.01″–2.00″; Fixed Gill Net 1, 1.25″–2.50″; Fixed Gill Net 2, 2.75″–4.00″; Encircling Gill Net 1 (*Boliche*), 1.25″–2.50″; Encircling Gill Net 2 (*Boliche*), 2.75″–4.00″; shrimp net, 0.50″–1.00″; crab traps with an entrance gap of 23 cm; long lines with hook calibers, 10–12. (**a**) Average scores for fishing grounds by zones; (**b**) Average scores for fishing gear/methods by sizes. Source: from [53].

In all cases illustrated in Figure 3a, experienced fishers' scores are lower. This shows that experienced fishers believe fishers have less impact on the ecological sustainability of CGSM than the scientists believe. There is a similarity in the patterns of both assessments, which may mean that both groups agree that it is more unsustainable to fish in the natural nursery areas than in the water far away from the mangrove, but clearly the assessments of the impact of fishing in the various areas are very different.

Figure 3b shows the assessments by fishers and scientists of fishing gear and methods. Some of the scores are very similar, while others show substantial differences. It is noteworthy that in the case of *Cast Net 1*, experienced fishers' scores are higher than scientists' scores. This result is explained by the fact that scientists consider that this gear causes lower impacts than other types of gear for several reasons: first, the fishing power of the cast net is relatively low; second, the gear does not harm the fish, so it can be returned to the water; and third, the size of catch depends largely on the skills, knowledge and working capacity of the fishers, since the operation of this gear requires a great deal of effort.

Table 1 shows statistically-significant evidence at the 1% level that fishers and scientists differ in their opinions about all fishing zones and about eight of thirteen fishing types of gear evaluated.

Table 1. Results of the Wilcoxon matched-pairs signed-rank test (2-tailed) for fishing grounds and fishing gear/methods scores (*p*-values).

#	Description	*p*-Value	
	Fishing Grounds by Zones		
1	Protected areas of National Natural Parks	0.0000	***
2	Natural nursery areas	0.0000	***
3	Mouths of rivers and streams	0.0000	***
4	Mangrove roots and other vegetation	0.0000	***
5	Mouth of La Barra (La Barra Bridge)	0.0000	***
6	Water far away from the mangrove	0.0000	***
	Fishing Gear/Methods		
1	Cast net 0.25″–2.25″	0.0000	***
2	Cast net 2.50″–3.00″	0.3820	
3	Seine net (*Chinchorra*) 1.50″–2.50″	0.2984	
4	Seine net (*Chinchorra*) 2.75″–3.50″	0.0000	***
5	Seine net (*Chinchorro*) 0.75″–1.00″	0.3998	
6	Seine net (*Chinchorro*) 1.01″–2.00″	0.0002	***
7	Fixed gill net 1.25″–2.50″	0.8232	
8	Fixed gill net 2.75″–4.00″	0.0000	***
9	Encircling gill net (*Boliche*) 1.5″–2.50″	0.0000	***
10	Encircling gill net (*Boliche*) 2.75″–4.00″	0.0000	***
11	Shrimp net 0.50″–1.00″	0.0000	***
12	Crab traps, entrance gap 23 cm	0.9380	
13	Long line, hooks calibers 10–12	0.0000	***

*** 99% significance.

As mentioned earlier, we developed individual indicators based on the experienced fishers' and scientists' scores, aiming to get two measures of ecological sustainability—one in terms of fishing grounds/zones and another in terms of fishing gear/methods. When we compared these indicators, we found that the indicators for the fishing grounds built on the experienced fishers' points of view ranged from 1.09 to 1.80, while the indicators built on scientists' opinions ranged between 1.96 and 3.73. Regarding the fishing gear/methods, we found the indicators based on experienced fishers' opinions fell between 1.40 and 4.68, while those based on scientists' opinions ranged from 2.28 to 4.46. Since the indicators were built with the scores described earlier, it is not surprising that the scientists' indicator values are higher than the experienced fishers' values. In addition, we noticed that the range of indicators is broader, and the values are higher for the fishing gear/methods than for the fishing grounds for both groups.

4.2. Socioeconomic and Perceptional Variables Affecting Fishers' Fishing Behaviors

Based on our knowledge of the community and the literature on socioeconomic factors and perceptions that are determinant in explaining *fishers' fishing behaviors* [3,12,54–56], we identified different variables that may help to explain the fishing behaviors of CGSM fishers. The variables are years of schooling (number in years), whether a fisher has to financially support others living outside his household (dummy variable), whether he shares household expenses with others in his household (dummy variable), average daily hours fishing (in hours), whether he is paying off a loan (dummy variable), whether he has job alternatives (dummy variable), his perception of CGSM's fishery resources (dummy variable) and his perception of who should conserve the lagoon (dummy variable).

Table 2 provides an overview of the variables identified and the expected impact each variable may have on the ecological sustainability of CGSM. Thus, a positive sign indicates that we expect that fishers with higher levels of education, who share household expenses, have alternative livelihood options, spend more time fishing in the CGSM and perceive that fishery resources are becoming scarce impact the CGSM's fishery less. In contrast, a negative sign indicate that we expect that fishers who have to financially support others living outside their household, pay off a loan and believe the conservation of the lagoon is not their responsibility exert a negative impact on the ecological sustainability of the lagoon. We examined the correlations among the different variables, and we found that correlation coefficients were low (<0.24), so no variables were removed from the analysis.

Table 2. Summary of variables used as explanatory variables to model fishers' behaviors and the expected impact they have on ecological sustainability.

Variable Name	Variable Type	Variable Definition	Mean/Prop	Expected Impact on CGSM Ecological Sustainability
		Socioeconomic Variables		
Years of schooling	Discrete	Number of years of formal education	3.76	+
Fisher has to financially support others living outside his household	Dichotomous	Fisher has to financially support others living outside his household 0 = fisher does not financially support others living outside his household 1 = fisher financially supports others living outside his household	0.31	-
Fisher shares in paying for household expenses	Dichotomous	Other family members help fisher with household expenses 0 = fisher does not share in paying for household expenses 1 = fisher shares in paying for household expenses	0.43	+
Fisher has job alternatives	Dichotomous	Fisher has job alternatives 0 = fisher does not have job alternatives 1 = fisher has job alternatives	0.34	+
Average daily hours fishing	Continuous	Average daily work time (including time to sell)	12.66	+
Fisher is paying off a loan	Dichotomous	Fisher is paying off a loan 0 = fisher is not paying off a loan 1 = fisher is paying off a loan	0.34	-
		Perception Variables		
Fishery resources have always been scarce or they are beginning to become scarce	Dichotomous	Perception about CGSM fishery resources 0 = fishers perceive there are many resources for all 1 = fishers perceive resources have always been scarce or they are beginning to become scarce	0.85	+
Government should help in the conservation of CGSM	Dichotomous	Perception about who should help in the conservation of the lagoon 0 = fishers believe they should help to conserve the CGSM 1 = fishers believe the government and other users of CGSM (different from the fishers) should help with the conservation of the lagoon	0.45	-

Total fishermen who participated in the study: 172.

We found that fishers in our study received on average only 3.76 years of formal education (SD = 3.9), and 28% of households consist of two or more nuclear families, with an average size of ten people. We further found that 31% financially support others living outside their households. In addition, 43% of the fishers stated that they share household expenses with other family members.

Another important variable in our analysis is the need to pay off a loan, and 34% of the fishers mentioned that they had one. In general, these loans are obtained outside the formal banking system (since no banks or cooperatives exist in the area), and most importantly, the interest rates paid in these informal systems are higher (20% *effective monthly)* than Colombia's official rates. Additionally, 66% of the fishers in our study do not have any alternatives to fishing to guarantee their livelihoods, and they fish on average 5.8 days per week (SD = 0.8) and 12.66 h per day (SD = 2.9). These last four variables are proxies for economic dependence on natural resources, and we expect them to have a negative impact on the ecological sustainability of CGSM.

Perceptions of environmental resources can also influence not only the way fishers use and manage those resources, but also the way they value them [12]. In this study, we evaluated two aspects that allowed us to understand fishers' perceptions of the fishery resources in CGSM. Most fishers (81.4%) believe that fishery resources are becoming scarce, whereas 15.1% think there are still many resources, and 3.5% think they always have been scarce. From the literature on common pool resources, we expect that some scarcity perception may lead to ecological sustainability. Regarding the entity that should be responsible for the conservation of CGSM, 55.2% affirm that fishers should help to conserve the lagoon, whereas 40.1% consider that it is the government's responsibility to do that, and 4.7% believe it is the responsibility of other CGSM's users. Not accepting that fishers have a responsibility in the management of CGSM may lead to unsustainable behavior.

4.3. Factors Influencing Fishers' Fishing Behaviors

To predict the factors influencing fishers' fishing behaviors in CGSM, we developed six OLS models using individual and composite indicators created for the 172 fishers as dependent variables. The independent variables are described in Section 4.2 and in Table 2, above. Table 3 displays the results of each of the OLS models. Models 1, 3 and 5 are based on indicators built using the experienced fishers' scores, and Models 2, 4 and 6 are based on the scientists' scores. Models 1 and 2 examine the socioeconomic and perceptional variables influencing fishers' fishing behaviors regarding fishing grounds; Models 3 and 4 examine these variables in relation to the commonly-used fishing gear/methods. In Models 5 and 6, we investigate fishers' fishing behaviors by using the composite indicators built on the experienced fishers' and scientists' opinions as dependent variables, respectively. We first present model results on the factors leading CGSM's fishers to behave in an ecologically-sustainable manner and, then, the factors explaining ecologically unsustainable behavior.

4.3.1. Factors Influencing an Ecologically-Sustainable Fishing Behavior

According to our analyses (see Table 3), three factors seem to lead to ecologically-sustainable fishing behavior among CGSM's fishers, namely spending more hours fishing in the lagoon (significant in all models), higher levels of education (significant in four of six models) and sharing household expenses with other family members (significant in five of six models). We have partial evidence that job alternatives (significant in three of six models) also may lead to sustainable fishing behavior.

The variable explaining fishers' sustainable behavior across all models is spending more hours fishing per day. In Models 1, 2, 3, 5 and 6, this variable is highly significant at the 1% level, and in Model 4, it is significant at the 10% level. This suggests that those fishing for more hours per day exhibit a behavior more ecologically sustainable than those who spend fewer hours.

Table 3. Determinants of fishers' fishing behaviors (OLS). Dependent variable: individual indicators and indices (impact: 1 = low, 5 = high).

Indicators	**Individual Indicators**								**Composite Indicators**			
	Fishing Grounds				**Fishing Gear**				**Fishing Grounds and Fishing Gear**			
Evaluator	**Experienced Fishers**		**Scientists**		**Experienced Fishers**		**Scientists**		**Experienced Fishers**		**Scientists**	
Model	**1**		**2**		**3**		**4**		**5**		**6**	
Socioeconomic Variables												
Years of schooling	–0.0025 (0.0018)		–0.0226 (0.0063)	***	–0.0701 (0.0165)	***	–0.0048 (0.0062)		–0.0363 (0.0086)	***	–0.0137 (0.0045)	***
Fisher has to financially support others living outside his household (dummy)	0.0093 (0.0178)		0.0401 (0.0646)		0.3014 (0.1573)	*	0.0414 (0.0553)		0.1553 (0.0832)	*	0.0407 (0.0403)	
Fisher shares in paying for household expenses (dummy)	–0.0106 (0.0185)		–0.1177 (0.0649)	*	–0.3521 (0.1501)	**	–0.1406 (0.0597)	**	–0.1814 (0.0803)	**	–0.1292 (0.0435)	***
Fisher has job alternatives (dummy)	–0.0349 (0.0173)	**	–0.0845 (0.0601)		–0.1327 (0.1390)		–0.0980 (0.0508)	**	–0.0838 (0.0745)		–0.0912 (0.0406)	**
Average daily hours fishing	–0.0106 (0.0032)	***	–0.0545 (0.0110)	***	–0.1080 (0.0269)	***	–0.0185 (0.0103)	*	–0.0593 (0.0142)	***	–0.0365 (0.0080)	***
Fisher is paying off a loan (dummy)	0.0315 (0.0204)		0.0624 (0.0651)		0.2413 (0.1513)		0.0630 (0.0591)		0.1364 (0.0819)	*	0.0627 (0.0481)	
Perception Variables												
Fishery resources have always been scarce or they are beginning to become scarce (dummy)	0.0289 (0.0178)		0.1414 (0.0590)	**	–0.0382 (0.1855)		0.0063 (0.0549)		–0.0047 (0.0957)		0.0739 (0.0508)	
Government should help in the conservation of CGSM (dummy)	0.0398 (0.0175)	**	0.1648 (0.0578)	***	0.2899 (0.1410)	**	0.1391 (0.0535)	***	0.1649 (0.0758)	**	0.1520 (0.0416)	***
Constant	1.3717 (0.0466)	***	2.8927 (0.1536)	***	3.7881 (0.3779)	***	3.7307 (0.1546)	***	2.5799 (0.1986)	***	3.3117 (0.1203)	***
R^2	0.1541		0.2619		0.2163		0.1241		0.2200		0.2820	

*** = 99% significance; ** = 95% significance; * = 90% significance. Robust standard errors are in parentheses.

From Models 2, 3, 5 and 6 in Table 3, we find that education level is statistically significant at the 1% level, indicating that fishers with more years of education tend to use fishing gear/methods and fishing grounds with less impact on CGSM. However, the influence of this factor in fishers' fishing behaviors varies depending on the indicator analyzed—fishing grounds, fishing gear/methods or both—and the evaluator. Thus, when fishers' fishing behaviors are evaluated using the indicators built on experienced fishers' scores, we find that education does not influence their behaviors regarding the fishing grounds they visit (Model 1), but it does influence the fishing gear/methods they use (Model 3). In contrast, when we use the indicators built on the scientists' scores, education is an important determinant of fishers' fishing behaviors with respect to the fishing grounds visited (Model 2), but not in regard to the fishing gear/methods used (Model 4). When we use the composite indicators (Models 5 and 6), education is an important determinant of fishers' fishing behaviors.

Sharing in paying for household expenses is an important determinant of sustainable fishing behavior among CGSM's fishers. As shown in Table 3, this variable is significant at the 10% level in Model 2, at the 5% level in Models 3, 4 and 5 and at the 1% level in Model 6. This means that fishers sharing their household expenses with other family members are impacting the CGSM's fishery less than those not sharing household expenses.

Having job alternatives is another factor that influences fishers to behave in an ecologically-sustainable way. Table 3 shows that this variable is significant at the 5% level in Models 1, 4 and 6, indicating that fishers who have alternative sources of income, not dependent on the CGSM fishery, might cause lower impacts on this ecosystem. However, the influence of this factor on fishers' fishing behaviors also varies depending on the aspect analyzed and the evaluator.

4.3.2. Factors Influencing Ecologically Unsustainable Fishing Behavior

Based on our results, fishers who believe that the government should be responsible for the CGSM's conservation behave in an ecologically unsustainable way. The variable *government should help conserve CGSM* is significant at the 1% or 5% level in all models. These results suggest that regardless of the aspect evaluated (fishing grounds, fishing gear/methods or both) or the evaluator (experienced fishers or scientists), fishers who believe that the conservation of CGSM is the responsibility of the government or of other users (45% of fishers surveyed) are exerting a significantly negative impact on the lagoon.

The other three variables included in our models—*a fisher has to financially support others living outside his household* (significant in two of six models), *a fisher is paying off a loan* (significant in one of six models) and the belief that *fishery resources always have been scarce or are beginning to become scarce* (significant in one of six models)—do not explain fishers' fishing behaviors in most of the models. Therefore, we do not have strong evidence to conclude that these variables are negatively affecting the fishers' fishing behaviors.

5. Discussion

As described earlier, we find that experienced fishers and scientists have particularly different perceptions about the ecological impact of fishing on CGSM. Our findings suggest that fishers and scientists differ in their opinions about the fishing impact in all fishing zones and in eight out of thirteen types of fishing gear evaluated. The results can be explained by the fact that the lagoon provides the main livelihood for most fishers. This might lead them not to see their behaviors as detrimental to the environment, since they rely on it for their subsistence. If resources in CGSM are depleted, this group will be the most affected, so they believe their fishing behaviors are not damaging the fishery, at least not as much. Scientists, on the other hand, have some bias favoring CGSM conservation, and this might have led to relatively high scores. These discrepancies need to be resolved before any management plan can be successfully implemented in CGSM to reduce the impact on the fishery resources and improve their stewardship [26].

The results from the regression analyses show that more time spent fishing leads to ecologically-sustainable behavior. This result seems counterintuitive. However, studies have shown that the relationship between time spent fishing, fishing gear/method and sustainability is not straightforward [57,58]. In the context of CGSM, time spent fishing depends on many factors, such as the target species, the distance fishers have to go to get to a fishing ground, the period of the year and, undoubtedly, the fishing gear and methods used. Some of these factors may lead to unsustainable fishing behavior, while others lead to more sustainable fishing behavior. Due to data constraints, we did not control for the target species or for the period of the year when the data were collected. We were interested in having an assessment on the sustainability of fishing gear and methods, as well as in fishing grounds. Additionally, if we disregard the disinvestment effect of different gear [59], then an important reason for a fisher to employ unsustainable gear is that they often provide a higher catch per unit effort. If a fisher has a preference for spending less time fishing, a reasonable assumption, and is satisfied when reaching a sufficient amount of fish, then we would conclude that fishers using less sustainable gear are spending less time fishing.

Regarding education, our findings show that higher levels of education seem to have a positive influence on fishers' decisions. Nevertheless, this result varies depending of the indicator used and the evaluator. Our results are consistent with Cassels *et al.*'s [54] findings in North Sulawesi (Indonesia) and with Silva's [14] study with artisanal fishers in Marine Protective Areas in Tanzania, showing that there is a relationship between lower levels of education and the use of destructive fishing gear. This result suggests that the government and other organizations could improve the ecological sustainability of CGSM by raising the education level of the fishers. The result aligns with different efforts around the world to promote not only education, but also environmental education to encourage behavioral changes and conservation outcomes.

We found that sharing household expenses with other household members seems to promote sustainable fishing behavior among CGSM's fishers. A similar result is found with the variable *having job alternatives*. A possible explanation of these results is that these fishers depend less on the fishery resources, since others in their households are helping to sustain the family. In contrast, the lack of income opportunities can create a high dependence on the fishery resources, which in turn may compromise resource sustainability [60]. Nevertheless, when fishers' fishing behaviors are evaluated using the indicator built on experienced fishers' scores for fishing grounds, this variable does not appear to influence their behaviors**.** This result is supported by fishers' statements gathered from our conversations, explaining, for example, that if there are more people at home sharing the household's expenses, they will be able to rest on Sundays, reducing the fishing pressure for that day.

A potential explanation of why some fishers who believe that conservation of the CGSM is not their responsibility behave in an ecologically-unsustainable way is that they blame the government for the deterioration of the lagoon. The main reason for this situation is that between 1956 and 1960, the government built a highway that closed off the natural connection between the Caribbean Sea and the CGSM, producing a drastic change in its hydrological balance. Construction of this highway and other dirt roads and altering of the course of rivers for irrigation purposes, reducing the flow of fresh water to the lagoon, have caused several negative changes in the ecosystem and its population [27,28,32,34,35,61].

Finally, we provide some disclaimers related to the methodological approach we chose to examine the ecological impact of fishing in CGSM, which could lead to some potential biases in this study. The first potential bias concerns the group of fishers sampled in this study. The SIPEIN database provides unique data about real fishing behavior of fishers over time. However, there are many inconsistencies in the observations per fisher, reflected in missing data. This led us to reject a random sample from this database and instead to select fishers whose record shows more than a minimum number of observations over various years. This may lead, on the one hand, to some selection bias of the fishers who participated in the survey. On the other hand, sampling fishers with most entries might lead to the analysis of the most active fishers in CGSM and, therefore, the most relevant to assess sustainability.

6. Conclusions and Implications for CGSM Management

The literature on fishers' local ecological knowledge shows the importance of taking into account fishers' knowledge for the development of any fishery management plan [22,62–65], because it adds valuable information to supplement scientific knowledge. In this study, we analyzed the socioeconomic and perceptional factors that lead CGSM's fishers to exhibit fishing behaviors that are ecologically sustainable or unsustainable by looking at their fishing behaviors from two different points of view—a group of experienced CGSM fishers and a group of scientists. This allowed us to determine socioeconomic factors that make CGSM's fishers behave in an environmentally-sustainable or unsustainable manner with respect to the fishing grounds they visit and the fishing gear or methods they use.

We found that scientists and experienced fishers have different understandings of the impact fishing gear used and fishing grounds visited may have on the ecological sustainability of CGSM. Experienced fishers reported lower scores than scientists, and that result may be explained by the fact that fishers do not have means to make a livelihood other than from extracting resources from CGSM; thus, they cannot accept that they may be hurting the fishery; whereas the scientists are influenced by the fact that they want to conserve CGSM. It will be useful to develop the mental models of each group as a way to study more explicitly the difference between them. This difference is something that needs to be reconciled before any management plan can be developed and implemented in the area. With increased common understanding in the assessment of the situation, it becomes more likely that a legitimate and ultimately successful management regime can be developed.

We found that socioeconomic factors and fishers' perceptions about the responsibility for conservation of CGSM may influence their fishing behaviors when it is measured with the indicators we calculated. In summary, having more education, sharing household expenses with other family members and spending more hours fishing lead to behavior that reduces the impact on the lagoon and is more ecologically sustainable. At the same time, the perception that the government should be responsible for CGSM's conservation may lead fishers to behave in an ecologically unsustainable way.

It is important to stress that our analysis includes factors affecting fishers' fishing behaviors that have not been analyzed in previous studies, namely a fisher has to financially support others living outside his household and a fisher shares in paying for household expenses. We found weak evidence that the first variable influences fishers' behaviors, but the second variable showed a strong relationship to fishers' ecologically-sustainable behavior.

In this study, we look at some factors affecting the ecological sustainability of CGSM; however, we are aware that to achieve a sustainable use of CGSM's fishery resources, it is not enough to achieve its ecological sustainability: other factors of sustainability, such as social, economic and institutional sustainability [6], should be taken into consideration, and we acknowledge that CGSM had faced difficulties that have affected its social, economic and institutional sustainability over time. We hope that our analysis of the differences in perceptions of fishers and scientists in the assessment of the sustainability of fishing practices and behaviors contributes to an improved understanding of one set of sustainability factors that can inform improved policy development and management planning.

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