Botto-Barrios, D., and L. M. Saavedra-Díaz. 2020. Assessment of Ostrom's social-ecological system framework for the comanagement of small-scale marine fisheries in Colombia: from local fishers' perspectives. *Ecology and Society* 25(1):12. https://doi.org/10.5751/ES-11299-250112

Research, part of a Special Feature on Managing local and global fisheries in the Anthropocene

Assessment of Ostrom's social-ecological system framework for the comanagement of small-scale marine fisheries in Colombia: from local fishers' perspectives

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ABSTRACT. Fishery resource management under extractive production models in the Anthropocene has contributed to the collapse of fish stocks, threatening the food and livelihood security of many people, especially fishers. Common-pool resource theory has established the relevance of the design principles of Elinor Ostrom, which favor collective actions for the management of these resources. With the help of small-scale fishers, we assessed the state of Ostrom's principles in the study system to determine the conditions required to implement fishery comanagement in the future. The communities of Taganga (Caribbean coast) and Tumaco (Pacific coast), Colombia, served as case studies because of their known dependence on fishing and because both communities are currently facing a social-ecological crisis within their top-down administrative frameworks. We performed six hearings, three in each community in 2009, 2012, and 2014, in which fishers brainstormed about the weaknesses that are closely related to Ostrom's social-ecological system framework. Additionally, 14 focus groups with 119 fishers (31 in Taganga in 2015; 88 in Tumaco in 2017) were conducted, one for each major fishing method used in each community. The obtained results made it possible to establish a community vision on the condition of the principles in each community, and the principles were prioritized by the fishers do determine which ones need immediate attention. The inhabitants of both Taganga and Tumaco expressed the urgent need to establish clear biophysical limits among resource users, to gain the participation of all actors involved, and to build nested enterprises. In particular, the community of Tumaco considered monitoring resources and regulations, establishing graduated sanctions, and recognizing basic rights to be priorities. Furthermore, future opportunities and conflicts related to fishery comanagement implementation were evident in both communities. Therefore, our results indicate that Taganga and Tumaco are not yet ready to implement fishery comanagement. Nevertheless, they have the knowledge and motivation to overcome the obstacles that prevent them from moving forward with managing their fishery resources and to face the tragedy of the commons.

Key Words: *Anthropocene; fishery comanagement; local ecological knowledge; small-scale fishing; social-ecological systems*

INTRODUCTION

Small-scale marine fishing is recognized globally as the main economic activity of coastal communities because it contributes to the food and livelihood security of the inhabitants of such communities (Food and Agriculture Organization 2012, Belhabib et al. 2015). However, a large proportion of the fish stocks that support this activity is overexploited (United Nations Environment Programme 2007, 2012, Food and Agriculture Organization 2012) as a consequence of human activities and their considerable planetary impacts (Jackson et al. 2001, Aswani et al. 2017, Redmore et al. 2018). Community-based approaches to the conservation and management of natural resources are considered appropriate to meet the challenges of this era (Ostrom 2009, Gadgil et al. 2002, Redmore et al. 2018). Consequently, efficient governance in coastal communities is key for sustainable fishery resources and for global fisheries (Anderson and Seijo 2010, Torres-Guevara et al. 2016).

In most Latin American countries, coastal and fishery management have been adopted based on a centralist approach, with state (top-down) controls imposed on fishery resources (Agüero and Claverí 2007, Salas et al. 2007). However, such top-down management regimes are rarely successful (Feeny et al. 1990, Ostrom 2005, Trimble and Berkes 2015). At present, there is a global trend toward the adaptive comanagement of the fisheries sector based on the theory of the commons and collective action, which states that it is possible that people may act collectively to manage common-pool resources in a sustainable manner (Ostrom 1990, Poteete et al. 2010). Given its great efficiency, the adaptive comanagement of fisheries has been proposed as a solution to overcome the current resource crisis (Pomeroy 2007, Evans et al. 2011, Cinner et al. 2012, Trimble and Berkes 2015).

Adaptive comanagement is a long-term collective action strategy that allows interested parties to share responsibilities within a specific natural resource system. Furthermore, such a strategy enables these parties to learn from their actions, ensuring sustainable local use of available resources (Ruitenbeek and Cartier 2001, Olsson et al. 2004, Armitage et al. 2007, Berkes 2009). Adaptive comanagement is based on the formulation of legal agreements that are politically negotiated between local residents (direct resource users) and different administrative levels. Through these agreements, residents are given the responsibility of making decisions regarding access to and use of natural resources in exchange for guaranteed benefits. Adaptive comanagement is appropriate for managing social-ecological systems (SESs), which require participatory approaches in terms of the interaction, deliberation, learning, and participation of stakeholders from the community and government (Schusler et al. 2003, Berkes 2010, Trimble and Berkes 2015).

Fishery comanagement has been implemented in the fisheries sector as an alternative management strategy (Wilson et al. 2003, Pomeroy and Rivera-Guieb 2006), and the strategy is considered a realistic solution to the problems faced by the world's fisheries (Gutiérrez et al. 2011). Fishery comanagement grants fishers

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greater responsibility and authority over fishery resource management and greater participation in the decision-making process. The strategy can be defined as an agreement in which both the fishery administrative body and fishers share responsibilities and authority over fishery management (Wilson et al. 2003, Pomeroy and Rivera-Guieb 2006). Furthermore, such a strategy is almost always based on shared beliefs regarding democracy, transparency, accountability, organization, participation, subsidiarity, association, ownership rights, distribution of power, and sustainability (Jentoft 2003).

In Latin America, fishery comanagement has been implemented in small-scale fishing. In Mexico, for example, institutional agreements have been developed regarding the conditions for access to resources, such as territorial use rights in fisheries (TURF) and provisions for marine tenure (Castilla and Defeo 2001, Costello and Kaffine 2008, McCay et al. 2014, Crona et al. 2017). Additionally, Costa Rica has three marine areas of responsible fishing that are officially recognized by the Instituto Costarricense de Pesca y Acuicultura (Costa Rican Institute for Fisheries and Aquaculture; Fargier et al. 2014, García Lozano and Heinen 2015). Furthermore, Panama has presented a draft of the new Fisheries, Aquaculture, and Related Activities General Law prepared by Panama's Aquatic Resources Authority (Autoridad de los Recursos Acuáticos de Panamá 2016). In line with these initiatives, Chile has made efforts to comanage benthic resources by implementing seasonal closures and management and exploitation areas in the central zone of the country (Castilla and Fernandez 1998, Castilla and Defeo 2001, Schumann 2007, Gelcich et al. 2010, 2019). During the last decade, fishery management bodies in Brazil have included guidelines and participatory frameworks in legislation that have fostered fisher engagement in decision-making processes under the framework of marine extractive reserves and sustainable use protected areas (Seixas et al. 2009, Silva et al. 2013, Trimble et al. 2014).

In Colombia, small-scale fishers have not been recognized as an important part of the fishery management process (Cuello and Duarte 2010, García 2010, Saavedra-Díaz et al. 2015*b*). The work of fishers is not recognized as employment because of the negation of fishing activity by policy makers (Berkes et al. 2001, Bené 2006). The fundamental rights (work and decent housing) of fishing communities are violated. Furthermore, small-scale marine fisheries do not contribute to the gross domestic product but to local economies, and this contribution is not evident because of a lack of traceability and marketing chains (Saavedra-Díaz et al. 2015*a,* 2016).

However, in the last decade, the engagment of small-scale Colombian fishing communities in comanagement has been acknowledged as being effective and as reducing the trend toward resource overexploitation (Saavedra-Díaz et al. 2016). Similarly, fishing communities consider comanagement a viable strategy for ensuring the sustainability of Colombian fishery resources and for demonstrating the need to establish joint regulations between the fishing authority and resource users (Saavedra-Díaz et al. 2014, 2015*a,b*). These communities have formal and informal regulations promoted by local stakeholders, although fishery comanagement has not yet been fully implemented (Saavedra-Díaz et al. 2015*b,* 2016, Jiménez-Torres and Saavedra-Díaz 2019). Along the Colombian Pacific coast, there is a tendency to implement control measures throughout a fishing area, such as the exclusive zone of artisanal fishing (ZEPA, as abbreviated in Spanish) in the North Chocoan Pacific (Navia et al. 2010, Ramírez-Luna 2013), an integrated regional management district comprising the Golfo de Tribugá-Cabo Corrientes (Decree 2372/10), the national district of integrated management comprising Cabo Manglares, Bajo Mira, and Frontera (Resolution 2299/17), and Uramba Bahía Málaga National Natural Park, an integrated management protected area in Valle del Cauca (Resolution 1501/10). Importantly, diagnostic reviews have also been performed regarding fishery management strategies that empower fishing communities along the Colombian Pacific coast (Zapata 2005, 2006, Beardon 2008, Navia et al. 2008) and the Caribbean coast (Corporación para el Desarrollo Sostenible del Urabá 2005, Fundación Ecosfera 2006, Mendoza et al. 2008, Santos-Martínez et al. 2013). In this regard, the efforts made during the last decade reflect the need to understand fishery management schemes in an integrated way, for example, by engaging all fishery-related stakeholders.

Authors such as Ostrom (1990), Berkes et al. (2001), Pomeroy et al. (2004), and Cox et al. (2010) describe the necessary conditions for managing common-pool resources. However, these conditions are not always sufficient. Some authors suggest that they are necessary conditions for the sustainable management of common-pool resources, depending on the general characteristics of the SES (Ostrom et al 2007, Baggio et al 2016). In the case of fisheries, these frameworks should be tailored to the particular context of each fishery (Armitage et al. 2009, Trimble and Berkes 2015) because the solutions that may be applicable in a given scenario may be useless in other contexts (Ostrom 1990, Basurto et al. 2013, Orensanz et al. 2013, Torres-Guevara et al. 2016). In 1990, Ostrom developed eight principles (i.e., clear boundaries, monitoring, collective choice, graduated sanctions, rule congruence, conflict resolution mechanisms, minimal recognition of rights, and nested enterprises; Table 1) that include suggested conditions for the sustainability of the commons and collective action; these principles were later validated by Cox et al. (2010) and Baggio et al. (2016). Because fishery comanagement is a collective action strategy, these principles have been used to assess fishery governance (Gelcich et al. 2006, 2019, Pomeroy 2007, Armitage et al. 2009, Fleischman et al. 2014, Galappaththi and Berkes 2015, Trimble and Berkes 2015).

The adaptive comanagement of fishery resources has shown positive results in Latin America and the Caribbean (Costello and Kaffine 2008, Gelcich et al. 2010, 2019, Silva et al. 2013, Fargier et al. 2014, McCay et al. 2014, García Lozano and Heinen 2015), and contemporary fishing communities in Colombia have shown the will to become involved in fishery management. Consequently, our research aims to evaluate the feasibility of implementing the participatory management of small-scale marine fisheries in the states of Magdalena and Nariño from the perspective of local fishers through the use of Ostrom's SES framework. The design of this research includes the examination of two case studies, Taganga (on the Caribbean coast) and Tumaco (on the Pacific coast), communities with which the researchers have maintained relationships for 10 years, to work on resource recovery and to improve the quality of life of fishers through participatory methodologies, taking a comprehensive approach to help secure the future of fishery resource management.

Table 1. List and definitions of Ostrom's design principles (Ostrom 1990, Cox et al. 2010). Principles were categorized (symbols) according to Ostrom (2009).

Principle (Ostrom 1990, Cox et al. 2010)	Definition (Cox et al. 2010)
P1A: Clearly defined user boundaries†	Clear boundaries between legitimate users and nonusers must be defined
P1B: Clearly defined resource boundaries‡	Clear boundaries are present that define a resource system and separate it from the larger biophysical environment
P2A: Congruence between rules and local conditions§	Appropriation and provision rules are congruent with local social and environmental conditions
P2B: Proportional equivalence between costs (provision rules) and benefits (appropriation rules)†	Benefits obtained by users from a common-pool resource, as determined by appropriation rules, are proportional to the amount of inputs required in the form of labor, material, or money, as determined by provision rules
P3: Collective-choice arrangements†	Most individuals affected by the operational rules can participate in modifying the operational rules
P4A: Monitoring of rule enforcement§	Monitors who are accountable to the users monitor the appropriation and provision levels of the users
P4B: Monitoring of resources‡	Monitors who are accountable to the users monitor the condition of the resource
P5: Graduated sanctions§	Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and the context of the offense) by other appropriators, officials accountable to the appropriators, or both
P6: Conflict-resolution mechanisms§	Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials
P7: Minimal recognition of rights to organize§	The rights of appropriators to devise their own institutions are not challenged by external governmental authorities
P8: Nested enterprises§	Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises

†User system, ‡Resource system., §Institutional system.

METHODS

Description of the case studies

Our study focused on small-scale marine fishers of the Taganga (Caribbean coast) and Tumaco (Pacific coast) communities (Fig. 1). The inhabitants are nationally and internationally known for their ancestral dependence on fishing. In Taganga, fieldwork was conducted over 3 mo (October–December 2015), whereas in Tumaco, fieldwork was conducted over 1 mo (March 2017).

In previous investigations, these communities have expressed an interest and willingness to participate in fishery management. They share similar fishery conditions and conflicts regarding the variety of methods and problems with the influence of external activities (e.g., tourism, port activities) and they have established informal regulations that they wish to formalize (Saavedra-Díaz 2012, Saavedra-Díaz et al. 2014, Jimenez-Torres and Saavedra-Díaz 2019). Similarly, these communities have identified weaknesses that prevent them from advancing in this process, and they claim that they are not ready to manage their fishery resources autonomously; these weaknesses are closely related to Ostrom's SES framework (Table 2; Saavedra-Díaz et al. 2014, Jimenez-Torres and Saavedra-Díaz 2016). Therefore, our research was motivated by the need expressed by these communities to advance fishery comanagement.

Taganga is a coastal village in the district of Santa Marta (departmental capital). It has approximately 4500 inhabitants (Botero and Zielinski 2010); of the total population, approximately 300 people are small-scale marine fishers who use and exploit the fishery resources found in the coastal environment, reefs, and open sea and who exert an influence on the natural protected area of Tayrona National Natural Park (Saavedra-Díaz 2012). Furthermore, local fishers use a wide variety of fishing gear that ranges from *chinchorros* (seine nets), their traditional form of fishing, to relatively modern gear such as gillnets, handlines, set longlines, traps, and harpoons (Torres 2009, Saavedra-Díaz 2012). Taganga is the main small-scale marine fishing port in the department of Magdalena and is characterized as one of the most organized and developed landing points in the department. The small-scale marine fishing fleet is varied and ranges from *cayucos* (dugout canoes) or canoes (both oar-propelled) to engine-powered boats with greater fishing autonomy, known as *pargueras* (Bustos-Montes et al. 2012). Most fishers sell all or most of their catches to local buyers (De la Hoz et al. 2015).

Fig. 1. Maps of the study area, showing the community of Taganga on the Caribbean coast and the community of Tumaco on the Colombian Pacific coast.

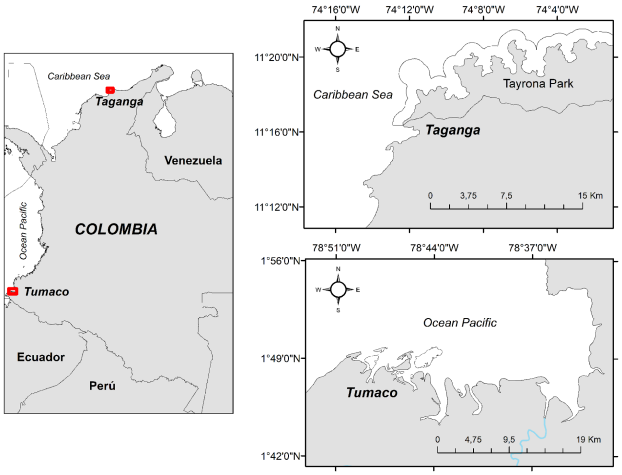


Table 2. Weaknesses identified by fishers in the case study communities based on the principles recommended by Ostrom (1990) to facilitate the comanagement of natural resources.

		Taganga			Tumaco		
Principle	Weakness	2009	2012	2014	2009	2012	2014
P1A: Clearly defined boundaries between users	Absence of a fishery census		X	X			X
	Territorial conflicts between tourism and fishing; fishing areas are damaged by tourism			X			
	Territorial conflicts with National Natural Parks	X	X	X			
	The local fishers are being displaced by external fishers	X	X	X			
	Decrease in the number of fishers			X			
	The maritime fishing territory for the community is not delimited				X		X
	Lack of regulation for foreign fishers				X	X	X
	Conflicts with industrial fishing				X		X
P3: Collective choice agreements	Low participation of fishers in decision making	X	X	X	X	X	X
	Lack of local leaders with credibility and recognition	X	X	X		X	X
	Low participation of young people in fishery			X			
	Fishers' attitudes				X		X
	Fishers' denial of guilt over depletion				X		X
P4A: Monitoring of resources	Overused resources				X	X	X
	Unregulated fish size				X		
	Inappropriate monitoring of fishery resources						X
P4B: Monitoring of rule enforcement	Inappropriate fishing methods				X		X
	Lack of regulations				X		
	Corruption					X	X
P5: Graduated sanctions	Low participation of fishers in monitoring of rule enforcement						X
	Corruption					X	X
P7: Minimal recognition of right to organize	Conflicts with fishery organization leaders				X		X
	Weak organization of fishers				X		X
	Low organization of fishers					X	X
P8: Nested enterprises	Lack of a union among fishers and lack of organization	X	X	X			
	Most fishers are not part of fishers' associations			X			
	Conflicts between fishers and institutions				X	X	X
	Lack of politicians with credibility and recognition					X	X
	Conflicts of interest between fishers			X			X
	Lack of a union among fishers					X	X
	Lack of governmental presence due to the insignificance of the fishers				X		

The community of Tumaco is located in the southwestern region of the department of Nariño, approximately 300 km from San Juan de Pasto (departmental capital). It has an estimated population of 160,034 inhabitants. The local residents are mainly Afro-descendants or indigenous peoples who have preserved the traditional forms of territorial ownership and government (Vélez et al. 2012, Desarrollo con Identidad Regional Entre España y Nariño 2015). In the Tumaco urban area, 1709 people collect shellfish, mostly women known as *piangüeras,* whereas 4428 fishers (CORPESCA 2009) use and exploit the fishery resources found in the coastal area, mangroves, seabed, and open sea (Saavedra-Díaz 2012). For the extraction of fishery resources, a wide range of fishing gear and methods is used, from manual shellfish collection to the use of more modern equipment such as gillnets, surrounding nets, handlines, set longlines, and harpoons. The small-scale marine fishing fleet is varied and includes small boats such as canoes as well as boats with greater autonomy (≥ 40 horsepower engines) that rove the Colombian Pacific coast (Saavedra-Díaz 2012). Tumaco is one of the major fishing ports in the Colombian Pacific. Most small-scale marine fishers in Tumaco sell their catches in the local market. However, a significant proportion of such catches is also exported to neighboring countries such as Ecuador (De La Hoz et al. 2012).

In Colombia, fishery management has been adopted from a centralist approach (top-down). Therefore, the fisheries are owned by the state, and environmental and agricultural authorities share the responsibility for fishery and aquaculture governance (OECD 2016). At present, the Ministerio de Agricultura y Desarrollo Rural (Ministry of Agriculture and Rural Development), through the Autoridad Nacional de Acuicultura y Pesca (AUNAP; National Authority for Aquaculture and Fisheries), is formally in charge of the small-scale marine fisheries sector in Colombia. However, other government bodies are also responsible for fishing activities and fishing areas. Consequently, the governance system of small-scale marine fisheries in the country has undergone a process of fragmentation. This element, together with the division of responsibilities among the different competent institutions in the country, has historically generated uncertainty and has led to a lack of shared criteria to guide sector policies (Saavedra-Díaz and Jentoft 2017).

In the two case study communities, artisanal fisheries are managed under the centralist approach described above. In the community of Taganga, there are two central-level institutions in charge of fisheries administration: an AUNAP office and the Dirección Territorial Caribe de Parques Nacionales Naturales de Colombia (PNN; National Natural Parks of Colombia), with the latter intervening because the community is in the natural buffer zone protected area (Tayrona National Natural Park). In this community, AUNAP and PNN set regulations based on spatial

Table 3. Characteristics of focus groups and participants in Taganga and Tumaco.

Focus group community	Fishing gear or method		Duration of discussion (h)	Participants (*N*)	Mean participant age (yr ± standard deviation)
	Local name	Technical name (Nédélec and Prado 1990)			
Taganga (total 31 participants)	*Chinchorro*	Seine nets	2.51	8	49.3 ± 11.0
	Línea	Handlines	1.59	5	46.2 ± 10.4
	Nasa	Traps	1.29	4	37 ± 15.5
	Pargueras	Handlines and set longlines	1.51	4	57.6 ± 2.6
	Palangre	Set longlines	1.56	5	35.6 ± 15.0
	Trasmallo	Gillnets	2.13	5	39.0 ± 7.2
Tumaco (total 88 participants)	*Boliche*	Surrounding nets	2.53	10	57.7 ± 7.21
	Cabo	Set longlines	2.43	19	45.6 ± 11.3
	Chinchorro	Seine nets	2.53	10	37.2 ± 15.0
	Espinel	Set longlines	2.50	8	35.8 ± 13.3
	Piangüeras	Collectors	2.33	12	51.8 ± 12.5
	Collectors of other beach species	Collectors	2.55	7	47 ± 8.2
	Trasmallo	Gillnets	2.28	12	39 ± 11.1
	Volantín	Handlines	2.43	10	24.2 ± 6.0

restrictions and zoning. In Tumaco, AUNAP is present and sets regulations based on temporal and spatial restrictions and restrictions and modifications of fishing gear, catch quotas, zoning, catch restrictions, and capture sizes. In both communities, regulations are established through mandatory administrative acts for fishers and the community in general. Similarly, the monitoring of compliance with regulations is supported by members of the Colombian National Navy, which is in charge of security in the marine area and the expedition of maritime traffic permits, including artisanal fishing.

Data sources

The local ecological knowledge (Berkes and Folke 2002, Charnley et al. 2007) possessed by the small-scale marine fishing communities of Taganga and Tumaco was used as a primary information source. To access this local knowledge, hearings were performed to start an informal discussion in which fishers brainstormed about the weaknesses that are closely related to Ostrom's SES framework and that affect small-scale marine fishing activity. Any fisher could identify a weakness or problem facing the community. These hearings were performed in 2009, 2012, and 2014 in both communities. The number of local community members participating in each hearing varied as follows: in Taganga, 22, 28, and 38 in 2009, 2012, and 2014, respectively; in Tumaco, 55, 20, and 105 in 2009, 2012, and 2014, respectively.

In addition to hearings, focus groups were conducted. This systematic qualitative method is used for data collection about processes (Bernard 2006). Six focus groups (Rabiee 2004) with 31 participants were conducted in Taganga during the period from October to December 2015. A focus group was arranged for each type of fishing gear currently used in the community (seine nets, gillnets, *pargueras,* set longlines, handlines, and traps; Table 3). Although we recognize diving as one of the fishing methods used in Taganga, fishers who use this method refused to participate in the research. In March 2017, eight focus groups with 88 participants were conducted in Tumaco. A focus group was established for each type of fishing gear or method currently used in that community (surrounding nets, set longlines, seine nets, set nets, *piangüeras,* collectors, gillnets, and handlines; Table 3). The selected fishers were referred by fishing leaders in each community, taking into account the fishing gear and crew.

In both communities, the traffic light metaphor was used; this metaphor made it possible to evaluate and visualize the fulfillment of goals and indicators according to the degree of progress. "Green" was assigned to the goals or indicators met, "yellow" to those that registered an advance, and "red" to those that were pending or with minimal advances (Ocho et al. 2012). Using the traffic light metaphor, the condition of Ostrom's eight design principles (Ostrom 1990, Cox et al. 2010) for successfully implementing comanagement was determined, and the eight principles were framed within Ostrom's (2009) categorization in the SES context (Table 1). This methodology allowed each fisher group to assign a traffic light color to each principle by consensus. Thus, the fishers assigned "red" to those principles that were absent in each community, which according to them needed immediate action, and "yellow" to those that they believed should be strengthened in the future. The "green" light was excluded, given that the processes of comanagement were in an incipient stage and the communities expressed weaknesses that did not allow them to advance in the implementation of systems for fishery resource comanagement (Saavedra-Díaz et al. 2014, Jimenez-Torres and Saavedra-Díaz 2016).

For each "red" principle, the fisher groups discussed and analyzed the reasons that motivated this categorization and proposed community and government solutions to strengthen the principle and to implement it in the community. In addition, the fishers identified possible conflicts that could arise when trying to advance such principles.

Data analysis

The qualitative information obtained from the hearings and focus groups was organized and coded using NVivo qualitative data analysis software (version 11, 2015, QSR International, Melbourne, Australia). This data analysis software is used to transform qualitative data into quantitative data. NVivo allows coders to identify and tag specific text segments and to associate them with a particular category or code. For the coding activities,

content analysis was used; this methodology requires the identification of themes that appear in transcriptions of speech (Hruschka et al. 2004). The coding process was performed by a coder, and three-letter combinations were used to assign each code. The coding process created three major categories, which corresponded to the reasons, solutions, and future conflicts from the analysis of the prioritized principles proposed by the fishers. In this manner, 73 codes were obtained. Here, we focus on those principles that obtained > 60% prioritization in each community.

With a view to presenting a vision of the current status of each of the eight principles in the communities by fishing gear, statistical descriptions were used (percentages). Finally, to build a community vision of the fishers and to explore the relationships between the eight principles and the reasons for prioritization, redundancy analyses (RDAs) were performed for each community. RDA is a method of extracting and summarizing the variance in a set of response variables that can be explained by a set of explanatory variables. RDA is a direct gradient analysis technique that summarizes the linear relationships between the components of response variables that are redundant with (i.e., explained by) a set of explanatory variables. RDA is an alternative to canonical correlation analysis (Buttigieg and Ramette 2014).

RESULTS

We analyzed whether the small-scale marine fishing activities carried out in the communities of Taganga and Tumaco met the suggested conditions for comanagement of common-pool resources proposed by Ostrom (1990; Table 1). In this section, we describe the weaknesses in each community that prevent them from advancing in the comanagement process. We also describe the status of the principles according to the prioritization exercise completed by all the fishers and include an analysis of the reasons for their prioritization. We then present statistical analyses supporting the community vision in each of the communities studied. Finally, we analyze the possible community and government solutions and conflicts to identify opportunities to increase compliance with the principles.

Weaknesses that prevent the communities of Tapanga and Tumaco from advancing in the comanagement process

In each community, the fishers identified the weaknesses that prevent them from advancing in the comanagement process according to Ostrom's principles (Table 2). Our analysis shows an increase in the number of weaknesses in both communities over a short period of time (5 yr). A significant number of weaknesses is identified by the fishers in Tumaco.

Prioritizing the principles of success for the small-scale marine fishing activities in Taganga and Tumaco

In both fishing communities, the urgent need to establish clear biophysical limits between resource users (P1A), collective choice arrangements (P3), and nested enterprises (P8) was noted. These principles were prioritized ("red" light) in both Taganga and Tumaco by 100% and 87.5% of participants, respectively. In particular, the community of Tumaco also prioritized work for monitoring resources (P4B) and rule enforcement (P4A), graduated sanctions (P5), and the minimal recognition of rights (P7; Table 4).

Table 4. Prioritization of the principles for success in Taganga and Tumaco calculated as the percentage of participants who believe that each principle should be prioritized ("red" light). Principles were categorized (symbols) according to Ostrom (2009).

Principle (Ostrom 1990. Cox et al. 2010)	Taganga	Tumaco
P1A: Clearly defined user boundaries†	100%	100%
P1B: Clearly defined resource boundaries‡	0.0%	37.5%
P2A: Congruence between rules and local conditions§	33.3%	25.0%
P2B: Proportional equivalence between costs (provision rules) and benefits (appropriation rules)†	0.0%	12.5%
P3: Collective-choice arrangements†	100%	87.5%
P4A: Monitoring of rule enforcement§	0.0%	87.5%
P4B: Monitoring of resources‡	0.0%	87.5%
P5: Graduated sanctions§	0.0%	75.0%
P6: Conflict-resolution mechanisms§	0.0%	37.5%
P7: Minimal recognition of right to organize§	50.0%	75.0%
P8: Nested enterprises§	100%	87.5%

†User system. ‡Resource system. §Institutional system.

The reasons for prioritizing the principles are documented based on the local ecological knowledge of the small-scale marine fishers in Taganga and Tumaco. In Table 5, we list the reasons for prioritizing the principles considered "red" by both communities (P1A, P3, and P8), particularly Tumaco (P4A, P4B, P5, and P7). Additionally, the percentage for each of the reasons prioritized by each community is included, together with the codes assigned to each reason used in the statistical analysis (RDA). Although the reasons for prioritizing each principle are community-specific, some are highlighted by both communities, including the lack of communication between government bodies and the community, the restricted engagement of fishers in decision-making processes, the inefficiency and corruption of the sector institutions, violations of fishers' rights, and ineffective monitoring of resources and compliance with laws and regulations.

Community vision of small-scale marine fishing activities in Taganga and Tumaco

To explore the relationships between the principles, fishing gear, and reasons for prioritization and to build a community vision on the status of the principles, RDAs were carried out for each community. Although the methodological design proposed one analysis per type of fishing gear, when the gear is excluded from the analyses, a greater percentage of total variance is explained in each analysis. This difference indicates that there is a community vision of the status of the principles in each of the communities under study, regardless of the fishing gear used by the participants.

The RDA of Taganga establishes relationships between the principles prioritized ("red" light) and the reasons for prioritization ($P < 0.0001$, from 500 permutations). The first three factors account for 97.4% of the total variance (Table 6). The x-axis (F1) represents 44.8% of the variance, showing a gradient between the principles: P1A, clearly defined user boundaries (negative scores); and P8, nested enterprises (positive scores). The y-axis (F2) accounts for 35.8% of the variance, showing a gradient

Table 5. Fishers' reasons for prioritizing Ostrom's design principles (Ostrom 1990, Cox et al. 2010) in two small-scale marine fishing communities in Colombia.

Prioritized principle	Code[†]	Reason for prioritization
P1A: Clearly defined user boundaries	npn	Fishing ban in Tayrona National Natural Park (75.0%[‡])
	ncg	Lack of communication between fishers and the government (12.5%[‡])
	ncp	No fisher census (12.5%[‡]) (46.6%[§])
	dpv	Violation of fisher rights (53.3%[§])
P3: Collective-choice arrangements	npa	Lack of fisher engagement in decision-making processes (62.5% [‡]) (46.6%[§])
	gss	Unsocialized government decisions (25.0%[‡])
	npa	Lack of participation of other stakeholders (12.5%[‡])
	ncg	Lack of communication between fishers and the government (20.0%[§])
	npa	Lack of participation of other stakeholders in the fisheries sector (20.0%[§])
	dpv	Violation of fisher rights (6.6%[§])
	ilp	Local institutions are not involved in the fisheries sector (6.6%[§])
P4A: Monitoring of rule enforcement	nmr	Lack of monitoring of compliance with rules (60.0%[§])
	pdn	Fisher does not know the regulations (20.0%[§])
	cor	Lack of operability and/or presence of corruption of the sector institutions (20.0%[§])
P4B Monitoring the resources	nmr	Lack of fishery resources monitoring (100%[§])
P5: Graduated sanctions	sin	Ineffective or nonexistent sanctions (77.7%[§])
		cor: lack of operability and/or corruption of the sector institutions (22.2%[§])
	cor	Lack of operability and/or presence of corruption of the sector institutions (22.2%[§])
P7: Minimal recognition of right to organize	ilp	Local institutions are not involved in the fisheries sector (33.3%[‡])
	dpv	Violation of fisher rights (33.3%[‡]) (30.0[§])
	anr	Stakeholders in the fisheries sector with no representation (33.3%[‡]) (40.0%[§])
	cor	Lack of operability and/or presence of corruption of the sector institutions (30.0%[§])
P8: Nested enterprises	ntc	Lack of community work (66.6%[‡]) (72.7%[§])
	nag	Lack of support for the fishers and the community (33.3%[‡]) (27.2%[§])

[†]Code used in the redundancy. [‡]Community of Taganga. [§]Community of Tumaco.

between the reasons: the lack of fisher participation (npp; negative scores) and the fishing ban in Tayrona National Natural Park (npn; positive scores).

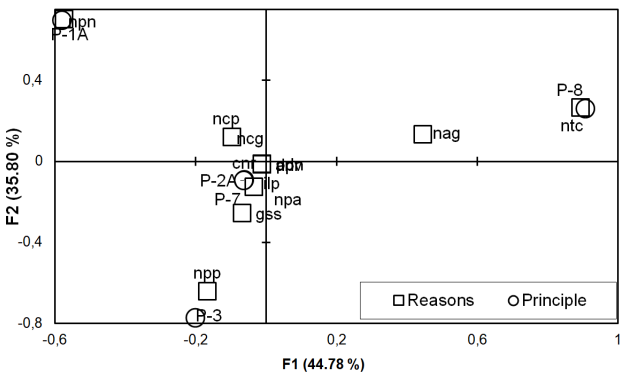
Table 6. Redundancy analysis results for the reasons for prioritizing the principles of success in Taganga.

Parameter	F1	F2	F3
Eigenvalue	0.243	0.194	0.091
Constrained inertia (%)	44.776	35.803	16.785
Cumulative %	44.776	80.579	97.363
Total inertia	27.026	21.610	10.131

The RDA plot of the reasons represented by the first two axes (Fig. 2) shows that from a community perspective, the principles that should be immediately strengthened are P1A (clearly defined user boundaries), P8 (nested enterprises), and P3 (collective choice arrangements). These principles are prioritized for all fishing gear types or methods.

The RDA for Tumaco (Fig. 3) establishes the relationships between the principles that have been prioritized ("red" light) and the reasons for their prioritization ($P < 0.0001$, from 500 permutations). The first three factors account for 55.0% of the total variance (Table 7). The x-axis (F1) represents 21.30% of the variance, showing a gradient between the principles from P1A, clearly defined user boundaries (positive scores), to P8, nested enterprises (negative scores). The y-axis (F2) accounts for 18.5% of the variance, showing a gradient between the lack of monitoring of fishery resources (nmr; negative scores) and the lack of fisher participation (npp; positive scores).

Fig. 2. Redundancy analysis biplot of the reasons for prioritizing each of the design principles, obtained through focus groups in Taganga. The x-axis (F1) accounts for 44.8% of the variance, and the y-axis (F2) accounts for 35.8%. See Tables 1 and 5 for definitions.



DISCUSSION

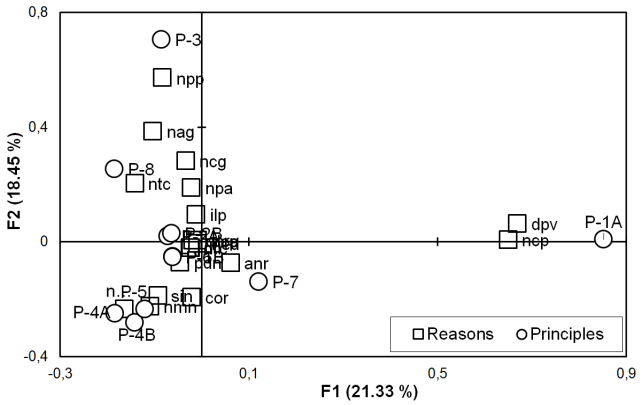
Fishery exploitation is considered the primary human disturbance in coastal ecosystems, and its open-access condition has contributed to the collapse of fish stocks (Pomeroy and Rivera-Guieb 2006, Jackson et al. 2001). Marine fishing is a complex and dynamic activity (Berkes et al. 2001) involving various actors. Each actor has an individual interest; thus, it becomes necessary to implement a governance system capable of

bringing together all interested parties (Bavinck et al. 2005). From this perspective, community-based conservation is a viable option for fishery resource management in the Anthropocene (Gutiérrez et al. 2011, Ban et al. 2017, Redmore et al. 2018).

Table 7. Redundancy analysis results for the reasons for prioritizing the principles of success in Tumaco.

Parameter	F1	F2	F3
Eigenvalue	0.099	0.086	0.070
Constrained inertia (%)	21.332	18.455	15.197
Cumulative %	21.332	39.787	54.984
Total inertia	10.829	9.369	7.715

Fig. 3. Redundancy analysis biplot of the reasons for prioritizing each of the design principles, obtained through focus groups in Tumaco. The x-axis (F1) accounts for 22.0% of the variance, and the y-axis (F2) accounts for 17.1%. See Tables 1 and 5 for definitions.



In Colombia, fishing has been managed from a centralist approach, and thus, key actors such as fishers are left out of the administration and decision-making processes (Cuello and Duarte 2010, García 2010, OECD 2016). Our study, conducted from the perspective of local fishers, shows that assessing the principles of success from this perspective may guide the transition from a top-down management model to a comanagement-based model in Colombia, as documented by Trimble and Berkes (2015) for another Latin American country. Previous studies conducted with different actors in the Colombian fisheries sector have noted that > 50.0% of such actors believe that a bottom-up management scheme is possible in the future and that joint work between communities and the fisheries administration is required (Saavedra-Díaz et al. 2015*a,* 2016).

The descriptive analyses (Tables 2 and 4) and RDAs (Figs. 2 and 3) are congruent and allowed a community analysis to be performed when the RDAs did not show significant differences among the different fishing gear types or methods. A significant percentage of fishers in this research believe that principles P1A (Taganga: 100%; Tumaco: 87.5%), P3 (Taganga: 100%; Tumaco: 87.5%), and P8 (Taganga: 100%; Tumaco: 87.5%) are critically important. Therefore, there is a critical situation with respect to principle P1A (clearly defined user boundaries) in both communities because of the multiple uses assigned to a single fishing ground (protected area, small-scale fishing, aquaculture, port activities, tourism, and diving), including illegal activities such as drug trafficking and the presence of foreign users and opportunists (Saavedra-Díaz 2012), and the lack of set institutional hierarchal levels for such arrangements. In line with our results, other studies carried out on fishery resources have also categorized clearly defined user boundaries as absent (Pinkerton and Weinstein 1995, Ernst et al. 2013, Fleischman et al. 2014, Trimble and Berkes 2015). To advance this principle, a community territory must first be defined based on political jurisdiction, and then the communities that share this territory for fishing grounds must be identified through political intervention (Saavedra-Díaz 2012, Trimble and Berkes 2015). Additionally, real resource users should be identified (legitimate fishers), and control on foreign users and opportunists should be imposed (Berkes 2015, Saavedra-Díaz et al. 2016). Considering that unclear territorial boundaries affect both governance and compliance with other principles (Fleischman et al. 2014), the open-access condition of fisheries only serves to worsen such blurred boundaries, fostering resource overexploitation and exacerbating the tragedy of the commons that surrounds these types of resources in developing countries (Ostrom and Hess 2000, Kosamu 2015, Baggio et al. 2016, Bresnihan 2019).

The basis for prioritizing P3 is the lack of collective choice arrangements, the weak organizational capacity of the community, and the lack of community work. In addition, although fisher organizations exist in Taganga and Tumaco, fishing issues are rarely addressed in meetings. Thus, fishers do not attend or are altogether excluded from such meetings (Fleischman et al. 2014, Trimble et al. 2014, Trimble and Berkes 2015). In light of these circumstances, in these communities, the design and implementation of participatory methodologies that respond not only to group or community approaches but also to individual approaches (Berkes 2009, Saavedra-Díaz 2012) are necessary. Moreover, it is essential to encourage the participation of legitimate fishers in the decision-making process (Saavedra-Díaz et al. 2016); users should at least be consulted about the establishment of policies and institutional changes even if they were not previously considered during the decision-making stage (Fleischman et al. 2014).

The absence of empowered community organizations, the lack of community work, and the establishment of institutional hierarchal levels for enforcing regulations and agreements, supervision, implementation, conflict resolution, and governance, according to that which is established by P8 (nested enterprises; Cox et al. 2010, Trimble and Berkes 2015, Baggio et al. 2016), substantiate this prioritization. Given the multiple uses of the fishing areas in both communities, this principle may be essential for establishing biophysical limits between resource users (P1A) and resource limits (P1B; Cox et al. 2010, Fleischman et al. 2014) Therefore, delegation of authority to the communities and the creation of committees at all levels where fishers can come together, such as in communities and local, regional, and national institutions, are essential. In this way, a network can be established for maintaining effective communication (Saavedra-Díaz 2012), fostering an equitable distribution of authority (Berkes 2009), and designing systems that decentralize power, such as polycentric systems (Carlsson 2000, Fleischman et al. 2014), horizontal

Table 8. Conflicts and solutions to advance the principles identified as priorities by the small-scale marine fishers of two communities in Colombia.

Principle	Conflicts	Solutions
P1A: Clearly defined user boundaries	None (87.7%‡) Disagreement between fishers and the fishing administration (25.0%†) (14.2%‡) Lack of communication between government and the community (25.0%†) Lack of fisher engagement (12.5%†) Unemployment (12.5%†) Proliferation of illegal activities (12.5%†)	*Community* Dialogue among the different community actors (50.0%†) (14.3%‡) Fisher shares his or her knowledge with the fishing administration (28.5%‡) Creation of community organizations (25.0%†) Promote the interest of local institutions in the fisheries sector (14.3%‡) Community participation (12.5%†) (28.5%‡) Community work (12.5%†) Does not know/Does not answer (14.3%‡) *Government* Fishing census (10.0%†) (63.62%‡) Subsidies or compensations for fishers (30.0%†) (9.0%‡) Administrative decisions on fisheries management (20.0%†) Involving fisher opinions (20.0%†) (9.0%‡) Government support for the fisher and the community (10.0%†) (18.2%‡) Government as a mediator in conflicts (10.0%†)
P3: Collective-choice arrangements	None (25.0%†) (71.4%‡) Lack of fisher engagement (37.5%†) Disagreement between fishers and the fishing administration (28.5%‡) Disagreement between fishers (25.0%†) Mistrust toward government agencies (12.5%†)	*Community* Community work (40.0%‡) Community participation (30.0%†) Dialogue between different community actors (20.0%‡) (10.0%†) Promoting the interest of local institutions in the fisheries sector (20.0%‡) Dialogue between government bodies (20.0%‡) Fisher shares his or her knowledge with the fishing administration (10.0%†) Creation of community organizations (10.0%†) Socializing decisions and fishing community agreements (10.0%†) *Government* Involving all fisheries sector stakeholders in the decision-making process (40.0%†) (83.3%‡) Socializing all government decisions (40.0%†) Establishing dialogue with the community (10.0%†) (16.6%‡) Government support for the fisher and the community (10.0%†)
P4A: Monitoring of rule enforcement	Disagreement between fishers and the fishing administration (42.8%‡) None (28.5%‡) Violation of regulations (14.2%‡)	*Community* Community participation (50.0%‡) Monitoring compliance with regulations (25.0%‡) Promoting the interest of local institutions in the fisheries sector (25.0%‡) *Government* Monitoring compliance with regulations (50.0%‡) Fighting corruption (25.0%‡) Government support for the fisher and the community (12.5%†) Subsidies or compensation for fishers (12.5%‡)
P4B: Monitoring of resources	Disagreement between fishers and the fishing administration (71.4%‡) None (28.5%‡) (25.0%*) Does not know/Does not answer (14.3%‡)	*Community* Monitoring the resources (50.0%‡) Community participation (50.0%‡) *Government* Monitoring the resources (38.4%‡) Training fishers (30.7%‡) Socializing all government decisions (15.4%‡) Subsidies or compensation for fishers (7.7%‡) Establishing dialogue with the community (7.7%‡)
P8: Nested enterprises	None (50.0%†) (33.3%‡) Corruption (33.3%‡) Disagreement among fishers (33.3%‡) Disagreement between fishers and the fishing administration (16.6%‡) Lack of fisher engagement (16.6%†)	*Community* Community work (42.8%†) (42.8%‡) Dialogue between different community actors† Dialogue among government bodies (28.5%†) (14.3%‡) Community participation (14.3%‡) Fisher shares his or her knowledge with the fishing administration (14.3%‡) Promoting the interest of local institutions in the fisheries sector (14.3%‡) Creation of community organizations (14.2%†) None (12.5%†) *Government* Government support for the fisher and the community (14.2%†) (50.0%‡) Dialogue with the communities (42.8%†) (12.5%‡) Engaging fisher opinions (25.0%‡) Agreement between fisheries sector institutions (14.2%†) Fishing census (12.5%‡) Does not know/Does not answer (28.5%†)

†Community of Taganga. ‡Community of Tumaco.

interactions (Fleischman et al. 2014), and policy networks (Carlsson 2000, McGinnis 2000).

With priorities > 80.0%, Tumaco, in particular, prioritizes principles P4A (monitoring rule enforcement, 87.5%) and P4B (monitoring resources, 87.5%). With similar significant percentages, Tumaco also prioritizes principles P5 (graduated sanctions, 75.0%) and P7 (minimal recognition of right to organize, 75.0%). These prioritizations are significant because they result from lacking or having insufficient monitoring processes carried out by the government or by fishers who fail to report violations of formal regulations or the use of inappropriate fishing gear. The fishers in Taganga do not prioritize these principles because they said that government bodies (e.g., Dirección General Marítima [General Maritime Directorate], AUNAP, and PNN) work in monitoring rule enforcement and resources, achieving results due to proximity to the capital city, whose economy depends on tourism and port activities (Aguilera Díaz and Alvis Arrieta 2000, Viloria-de-la-Hoz 2015).

However, the aforementioned situation in Taganga does not ensure full compliance with these principles. To strengthen and advance principles P4A, P4B, and P5, fishers and leaders recommend regulating the fisheries sector (Saavedra-Díaz et al. 2016), improving the fishing authority infrastructure, and coordinating national and local fishery policies. These efforts will encourage collaborative monitoring of compliance with regulations and of resources under governmental supervision (Fleischman et al. 2014, Berkes 2015, Saavedra-Díaz et al. 2016) and will help to avoid bribes and favor enforcement (Trimble and Berkes 2015, Saavedra-Díaz et al. 2016), thereby promoting the involvement of civil society and the international community interested in natural resource protection (Fleischman et al. 2014), and to encourage participatory research in which fishers and researchers work side by side (Saavedra-Díaz et al. 2016). The weaknesses identified in 2009, 2012, and 2014 (Table 2) coincide with the reasons expressed by the fishers in both communities when they prioritized the principles in 2017 (Table 4) and with the approaches made by other authors.

We acknowledge differences between both case studies, notably, the number of principles prioritized by a significant proportion of fishers in the community of Taganga is lower than that prioritized by fishers in Tumaco. However, this should not be understood as better preparation in the community of Taganga for the implementation of a system for fishery resource comanagement because previous studies of these communities reflect that, in general terms, Pacific communities are more aware of the need for regulations (Saavedra-Díaz et al. 2016). Furthermore, Tumaco, in particular, has made significant progress toward the comanagement of its resources through lobbying processes and the empowerment of marine fishers (Beardon 2008, Saavedra-Díaz et al. 2014, Jiménez-Torres 2016).

Understanding the common framework that describes and explains an SES also fosters an understanding of the processes that lead to resource improvement or deterioration (Ostrom 2009). The common framework for an SES connects and feeds back to the existing mutual relationships in the complex social system composed of the institutional system and the user system and to the ecological system composed of the resource system and resource units (Ostrom 2009, McGinnis and Ostrom 2014). This connection illustrates the link between the principles framed in each of these systems (Table 4), thus demonstrating the importance and need for complying with the principles to enable the successful implementation of comanagement in small-scale fisheries. However, the design principles of Ostrom (1990) can be wrongly interpreted as universal keys to success, or as a signal of disaster if absent, if the social and ecological contexts are not taken into account (Aswani et al. 2017).

When advancing the implementation of a participatory management strategy such as comanagement, the emergence of conflicts between the actors involved seems unavoidable. However, these conflicts may be regarded as a triggering factor or opportunity to move forward in the process (Pomeroy and Berkes 1997, Plummer and FitzGibbon 2004, Trimble and Berkes 2015) or as a challenge posed to such a process (Napier et al. 2005, Pomeroy 2007, Armitage et al. 2009). The cross-cutting conflicts identified by our study (conflicts of interest, lack of community work, and participation) are considered determinants of the failure of adaptive comanagement processes (Plummer et al. 2012, Trimble and Berkes 2015).

However, simply identifying the conflicts that arise in a comanagement process is insufficient; it is necessary to envision the steps to follow to advance the process effectively (Saavedra-Díaz et al. 2016). Therefore, we identify the conflicts that hinder the enforcement of the principles of success in these communities. Furthermore, from a local perspective, our research brings together the mechanisms (solutions) that make it possible to move forward and to face the conflicts that hinder compliance with the principles of success prioritized by each community (Table 8).

CONCLUSIONS

Ostrom's design principles (Ostrom 1990, Cox et al. 2010) have contributed to identifying and analyzing the weaknesses, reasons, solutions, and conflicts involved in the attempt to implement a comanagement strategy in the small-scale marine fishing activities of Taganga and Tumaco. In addition, such principles provide a prescriptive approach for implementing policies related to the intention to transition toward comanagement. At this critical juncture in the history of Colombia, with the post-peace agreement with the Fuerzas Armadas Revolucionarias de Colombia (FARC; Revolutionary Armed Forces of Colombia), and recognizing that other violent actors remain in the territory and have come to fill the power vacuum left by FARC, actions are urgently needed to strengthen these principles in rural communities to empower fishers and to allow them to respond adequately to the challenges posed both presently and in the future.

Although our analysis of the design principles of Ostrom's SES framework is a mere snapshot that needs to be replicated over time to include external factors (Trimble and Berkes 2015), our study provides evidence that the case study communities are not yet prepared to implement a management strategy such as comanagement. Despite this shortcoming, local actors show a willingness to move forward to overcome the barriers that prevent them from making progress, and these barriers are directly related to resource users and the government system. These results indicate a need to create institutional arrangements between interested parties at multiple levels and to reflect the importance of governance and how the lack thereof has contributed to the

overexploitation and poor state of small-scale marine fishing both worldwide (Coastal Resources Center 2006) and in Colombia (Saavedra-Díaz et al. 2015*a,* 2016). In addition, our study shows the usefulness of Ostrom's SES framework for evaluating the possibility of establishing comanagement in the SES of small-scale marine fisheries and as a tool for building robust governance structures for the participatory management of small-scale marine fisheries in the Anthropocene.

At this moment, this research is pertinent in both case study communities because the fishers in the "*En busca de herramientas de manejo pesquero participativo en Colombia*" ("In search of participatory fishing management tools in Colombia;" Unimagdalena-AUNAP 2014-2015) framework research project have proposed tools for comanaging fishery resources. Therefore, for both fishers and AUNAP, the assessment of the principles of Ostrom's SES framework presented here reveals that this framework is an instrument for implementing such tools because it shows the urgent need to work on aspects that are key for managing common-pool resources.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/11299

Acknowledgments:

This research was possible because of the participation and collaboration with Colombian marine fishers and local leaders from the communities of Taganga and Tumaco, with special thanks to the fishing leaders Luis Matos, Juan Asís Tejeda, Evert Ledesma, and Maria de Los Santos Valencia. We are thankful to Gloria De León, Jaime Gonzalez, Jesús Jiménez, and María De Los Ángeles González for their help with the fieldwork. This study was partially supported by the Departamento Administrativo de Ciencia, Tecnología e Innovación (COLCIENCIAS) [Administrative Department of Science, Technology and Innovation] under the program "Convocatoria para la formación de capital humano de alto nivel para el departamento del Magdalena-2014 (convocatoria 672 Cap. 1, Jóvenes Investigadores) [Call for the formation of high-level human capital for the department of Magdalena-2014 (Call 672 Chapter 1, Young Researchers)]", the Office of the Vice Rector for Research at the University of Magdalena, and the Fundación Para la Investigación, Conservación y Desarrollo Sostenible de los Socio-Ecosistemas.

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