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Measuring Triple Bottom Line Performance in a Fishery Attempting to Recover from Collapse

The Case of the Colombian Queen Conch Fishery

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Contents

1. Introduction **1**

2. Fishery Overview **2**

2.1 The QC Fishery: An Iconic Caribbean Fishery 2

2.2 Description of the Colombian QC Fishery 3

2.2.1 Growth and Exploitation (1970-1992 Period) 3

2.2.2 Conservation (1992-2004 Period) 5

2.2.3 Collapse (2004-2017 Period) 7

2.2.4 Rebuilding and Current Outlook (2017-Present) 9

3. Methodology **11**

4. Results **13**

4.1 Output Indicators 13

4.1.1 Ecology 15

4.1.2 Economics 15

4.1.3 Community 16

4.2 Input Components (Wealth Enabling Factors) 18

4.2.1 Macro Factors 18

4.2.2 Property Rights and Responsibility 19

4.2.3 Co-Management 19

4.2.4 Management 20

4.2.5 Post-Harvest 20

5. Discussion: Rebuilding Challenges **20**

5.1 Management and Conservation of the Resource 20

5.2 QC Products and Market Issues 23

5.3 Regional Coordination to Combat IUU Fishing 24

5. Conclusions **24**

References **26**

Appendices **32**

Measuring Triple Bottomline Performance in a Fishery Attempting to Recover from Collapse: The Case of the Colombian Queen Conch Fishery

Jorge Marco and Diego Valderrama*

Abstract

The rebuilding of collapsed fisheries is a major challenge for fisheries science and management, requiring multi-faceted evaluations to assess the current and potential performance of recovering fisheries. Single-dimensional analyses such as stock abundance assessments are only partially effective in determining the best course of action for fisheries in this condition. This study relied on the Fishery Performance Indicators (FPIs) – a rapid assessment tool for measuring economic, social and ecological outcomes from fishery management systems – to analyze performance and rebuilding challenges for the Colombian queen conch (*Lobatus gigas*) fishery. The ecological and economic indicators clearly revealed an underperforming fishery, even when compared to other fisheries in developing countries. Performance improved in the community (social) indicators, reflecting the socioeconomic and cultural importance of the fishery, even when operating at subsistence levels. Results also showed that rebuilding is constrained not only by ecological factors but also for managerial and economic reasons. In particular, bioeconomic modeling is strongly recommended for the fishery in order to add useful economic advice to the policy-making process, which has been traditionally guided by biological considerations such as maximization of sustainable yield.

Keywords: development; fisheries management; fisheries performance indicators; pillars of sustainability; triple bottom line

JEL Codes: Q01, Q22, Q56

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1. Introduction

The collapse of a fishery is often defined by profound changes in the fishery system (García *et al*., 2018) and substantial socioeconomic impacts in the fishing community (Wakeford *et al*., 2007; Munro, 2010). In many commercial fisheries around the world, overfishing has been the major factor driving collapse (Pauly *et al*., 2002; Baum *et al*., 2003; Myers and Worm, 2003), and therefore most administrative responses to recover stock abundance have been related to reducing fishing pressure (Khan and Chuenpagdee, 2014). Although a growing body of empirical evidence shows that collapsed fisheries can bounce back once fishing pressure is reduced or removed (Worm *et al*., 2009; Cardinale, 2011; Costello *et al*., 2016; Hilborn and Costello, 2017), recovery times for fish populations and habitats are often slow (from one to several decades) and unpredictable (Hutchings, 2000; Pedersen *et al*., 2017; Duarte *et al.*, 2020; Hilborn *et al.*, 2020) given the complexity of fishery systems (Mahon *et al*., 2008) and the uncertainty surrounding the factors affecting the recovery process (Neubauer *et al*., 2013). Depletion of fish stocks could be associated with other drivers also playing a major role, e.g., weak legal and policy governance frameworks, incomplete or inaccurate ecosystem data, partial scientific understanding of fish dynamics, mismanagement, environmental change, or sociocultural shifts. Analyzing potential for rebuilding thus requires a holistic and interdisciplinary approach (Khan and Chuenpagdee, 2014). However, lack of information and data usually prevents multi-dimensional evaluation (Chu *et al*., 2017).

This study used the Fishery Performance Indicators (FPIs) as a methodological tool to examine the performance of the Colombian queen conch (QC) fishery, which recently underwent a major collapse in landings. Introduced by Anderson *et al.* (2015), the FPIs are a broadly applicable and flexible tool for assessing performance in individual fisheries (artisanal or industrial, small-scale or large-scale, data-poor or data-rich) and for establishing linkages between enabling conditions, management strategies, and the outcomes of sustainability-based indicators. The FPIs were developed to address the critical need for a more holistic way of assessing the performance of fishery management systems in addition to traditional, biologically-based analysis, given the lack of standardized, reliable data to evaluate fisheries performance. The rationale behind the FPIs is the Triple Bottom Line (TBL) perspective (Asche *et al*., 2018) that defines successful fisheries as those which are ecologically sustainable and capable of generating sustainable positive net income and wealth. Rather than imposing a single notion of sustainability, the FPIs provide a broad range of metrics, organized into a framework that provides indicators of environmental and socioeconomic outcomes as well as factors that may enable such outcomes (Anderson *et al*., 2015). This framework is envisioned primarily to support analyses linking sustainable livelihoods and ecosystem health with specific inputs (Agrawal, 2002; Ostrom, 2009; Cinner *et al*., 2012).

A major advantage of the FPIs is their ability to establish meaningful comparisons across fishery management systems and make inferences about how to improve fishery performance (Anderson *et al*., 2016). The FPIs are also well suited to make comparisons over time in individual fisheries by evaluating the impact of investments and changes in management regimes (Chu *et al*., 2017).

The main objective of this paper is to examine the performance of the Colombian QC fishery in year 2018 through the FPI instrument in order to identify the most significant challenges fishery managers will face as rebuilding takes place during the next few years. Results from the FPI evaluation can also provide a baseline to make comparisons over time and evaluate whether or not fishery recovery is successful.

The remainder of this article is organized as follows: Section 2 briefly describes the QC fishery. Section 3 provides details on the FPI methodology used to evaluate fishery performance and potential for rebuilding. Results are summarized in Section 4, with the most significant challenges presented in section 5. Conclusions are presented in the final section.

2. Fishery Overview

2.1 The QC Fishery: An Iconic Caribbean Fishery

The species (*Lobatus gigas*, formerly known as *Strombus gigas*) is a large marine gastropod mollusk, the most commercially important one among true conchs (family *Strombidae*). It is distributed across the Caribbean Sea, the coastal waters of northern South America and south Florida, and Bermuda at the northernmost edge of its range. Along with spiny lobster (*Panulirus argus*), the QC fishery is one of the most economically important capture fisheries in the Wider Caribbean: the overall value of total QC exports was estimated at more than USD 74 million in 2017 (Prada *et al*., 2017).

The QC fishery has been a source of social and cultural identity throughout the Caribbean region since pre-Columbian times. Traditionally, conch shells have been utilized for religious ceremonies, trade and ornamentation, while pearls have been used in jewelry. On many islands, QC meat has become an important part of the local diet and cuisine, finding its way into several popular dishes. QC fishing (“conching”) is also a popular recreational activity in many Caribbean communities. With approximately 20,000 QC fishers and around 6,000 registered boats (Prada *et al*., 2017), an important number of households in the region are connected either directly or indirectly with the fishery and are therefore strongly interested in conserving the resource.

2.2 Description of the Colombian QC Fishery

At present, the Colombian QC fishery is a small-scale, data-poor and artisanal fishery. The current conditions of the QC fishery are better understood by recognizing four different historical periods in the development of the fishery, as suggested by Bomhauer-Beins *et al.* (2019).

2.2.1 Growth and Exploitation (1970-1992 Period)

While catches of QC have been recorded throughout the Wider Caribbean since the mid-1800s, the commercial fishery in Colombia began in the early 1970s in the San Bernardo and Rosario archipelagos, two groups of coastal coral islands located southwest of the city of Cartagena (Mora, 1994). Following the local extinction of stocks due to overfishing in 1977, the fishery shifted to the oceanic archipelago of San Andres, Providence and Santa Catalina (henceforth denoted as ASPC), located farther to the north. Areas with current and historic populations of QC in Colombia are depicted in Fig. 1.

In these early stages, the QC resource essentially supported an artisanal fishery devoted to domestic markets. Estimated annual landings[1] during this period ranged from 2 to 12 metric tons (mt) (Fig. 2). Artisanal fishing methods have remained relatively unchanged since then. Typically, QC is harvested by free diving, with the fishing unit consisting of one small fiberglass or wooden canoe (7-10 meters long), powered by outboard engines (30-70hp) and carrying on average 3-4 fishers (the captain, who usually fishes, and 2-3 more fishers). A common measure of effort is a day trip, which lasts approximately eight hours. Fishers easily collect conchs by hand because individual animals move slowly (around 10 meters/hour), form large aggregations and have no defense mechanisms (Prada *et al*., 2017). Most conch fishing occurs on wide shallow banks of sand, seagrass, algae and reef habitat suitable for the species, where individuals are collected in bags and taken to the surface. Effort is dedicated to conch fishing, but reef fish and spiny lobster can be harvested as well.

[1]The estimation of total landings in the QC fishery is controversial due primarily to two reasons: (i) in many cases, it is unclear whether reported landings refer to the entire conch or to the meat content only; and (ii) as different levels of meat processing can be undertaken at sea or on board, landings estimates may include meat processed at different grades.

Higher prices coupled with the opening of new marketing channels increased national and international demand for QC products (meat, shells and pearls). A kg of cleaned meat can be purchased in international markets for around USD 5-12, while shells are usually worth between USD 1-10. In contrast, a pearl can fetch several thousand dollars (USD 500-10,000). In order to meet the growing demand, an industrial fishery concentrated around the northern (more distant) banks of Serrana, Serranilla and Roncador developed in the mid-1980s. This fishery relied mostly on labor and capital from mainland Colombian firms, predominantly from the city of Cartagena (see Fig. 1). The intensity of effort was obviously greater in the industrial fishery, as mother boats transported small canoes to the fishing grounds, larger crews (7-10 fishers) were involved, and trips lasted longer, from 7 to 30 days. The fishery also had the ability to partially process and freeze conch meats at sea. As most harvesting was at a depth greater than 10 meters, fishers used both scuba and hookah gear. Both artisanal and industrial fisheries have traditionally generated low levels of bycatch.

The industrial fishery experienced substantial development through the 1980s and early 1990s. Landings peaked at 813 mt in 1988 (Fig. 2), of which 496 mt were exported to the United States, generating USD 2.78 million in export revenue (NMFS, 2019a). The average catch per unit of effort (CPUE) for the commercial QC fishery (including both artisanal and industrial fisheries) during the 1985-1992 period was 43.5kg/day/fisher (Prada *et al*., 2009).

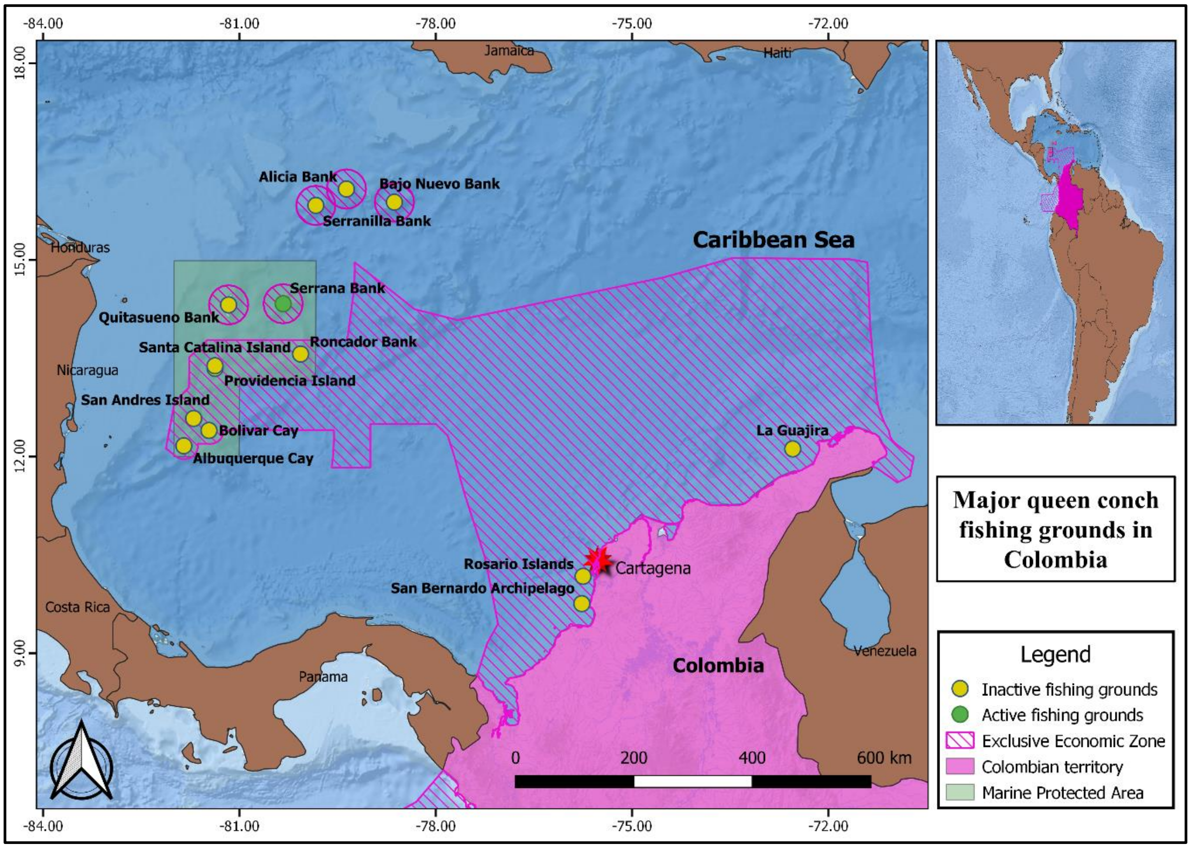

Figure 1. Major QC fishing grounds in Colombia. Map developed by the authors using the software QGIS v3.6.2.

2.2.2 Conservation (1992-2004 Period)

As is typically the case in open-access fisheries, the economic expansion of the QC fishery undermined ecosystem stability and the survival of the remaining stock. García (1991) estimated QC natural mortality (M) and fishing mortality (F) at 1.397 $year^{-1}$ and 3.866 $year^{-1}$, respectively[2]. In turn, Gallo Nieto *et al*. (1996) estimated mortality of the stock at 0.73 (M) and 1.39 (F), respectively. Following the Gulland (1971) method, these estimates were useful in determining the overfished status of stocks. Furthermore, surveys of the major industrial fishing grounds for the period 1989-1999 revealed a decline in QC densities from 769 to 22 individuals/ha at Serranilla Bank, from 669 to 34 individuals/ha at Roncador Bank, and from 921 to 318 individuals/ha at Serrana Bank. QC reproduction is apparently negligible at densities below 50 individuals/ha due to a pronounced Allee effect (Stoner and Ray-Culp, 2000). At densities of 100 individuals/ha or higher, not only is the success of QC reproduction

[2] These mortality rates correspond to the rate of exponential decline in population dynamic models for fishing stocks.

ensured but the quality of habitat for new juveniles is also increased (Stoner, 1989; Stoner *et al*., 1995).

Overfishing became a major concern in the late 1980s, leading to the permanent closure of Quitasueño Bank due to serial depletion of stocks. As a result, the species was included in the Convention on International Trade in Endangered Species (CITES) Appendix II in 1992. These two events ushered the fishery into a conservation period characterized by resource scarcity and reduction in fishing pressure, which extended through 2004 (see Fig. 2). The average catch per unit effort (CPUE) for the commercial QC fishery (including both artisanal and industrial fisheries) within this period was 31.7kg/day/fisher (Prada *et al*., 2009).

During this period, managers implemented a number of measures aimed at stock recovery and ecosystem health that have remained relatively unchanged since then (see Table 1). Measures include (i) total allowable catch (TAC); (ii) seasonal and area closures; (iii) size restrictions in terms of shell lip and minimum capture weight, among others; (iv) technology restrictions, i.e., prohibition of scuba and hookah gear; and (v) fishing licenses. These policies were further bolstered by the declaration of the Seaflower Marine Protected Area (MPA) in 2005 (Taylor *et al.* 2013; see Fig. 1). In fact, QC was selected as one of the key bio-indicators to measure the effectiveness of the MPA (Prada *et al*., 2009).

At the end of this period (2000-2004), QC exports amounted to USD 3.2 million, with 5,858 pearls, 565 mt of conch meat, and 4,002 shells accounting for 63%, 36%, and 1% of the export value (Prada *et al.* 2009; CITES, 2019). Conch meat is the major commodity by weight but the pearl trade is more valuable (Appeldoorn, 2013).

Unfortunately, ineffective coordination in conjunction with the lack of a truly comprehensive fishery management plan caused the resource to remain overexploited. As a result, there was an increase in illegal, unreported and unregulated (IUU) fishing, as well as growing disputes between fishery communities and decision-makers. In 2004, the estimated number of illegal fishermen was around 400, twice as many as the number of legally registered fishermen (Prada *et al.*, 2009). There were also disagreements within fishery communities, as artisanal fishermen felt they had little participation in planning and decision-making processes. Differing views on fishery management goals, mandatory reductions in fishing effort, and increasing costs eventually triggered irreconcilable conflicts between the artisanal fishery (led by the local community, called *raizales*) and the industrial fishery (led by non-resident firms). A "race to fish" between the artisanal and industrial fleets ensued.

2.2.3 Collapse (2004-2017 Period)

The fishery collapsed in 2004 as a result of overfishing, IUU fishing[3], illegal trade, and conflicts between industrial and artisanal fishers. Consequently, the fishery was closed from 2005 to 2007, and again from 2011 to 2013[4] (Fig. 2).

The second closure brought about three important changes in the management system:

(i) the Providence, Santa Catalina, Albuquerque and Bolivar Banks were closed indefinitely because local stocks had been depleted;

(ii) it was ruled that the northern banks (Roncador, Serrana, Serranilla, Bajo Nuevo and Alicia) would support fishing activity upon scientific recommendation. Thenceforth, an annual quota would be determined through a control rule based on the harvesting of 8% of the estimated exploitable biomass (Medley, 2008; Smikle, 2010). The maximum catch would be allowed if adult densities exceeded 100 individuals/ha – which would ensure a Maximum Sustainable Yield – and it would be reduced progressively from 8% to 4% if adult densities fell between 50 and 100 individuals/ha. Fishing activity would not be allowed if adult densities dropped below 50 individuals/ha (Minimum Stock Threshold), as reproduction of the stock would otherwise be compromised;

(iii) industrial fishing was banished because the remaining QC stocks were deemed incapable of supporting this level of fishing pressure. The industrial fishing fleet was mostly sold out and registered with flags from countries such as Honduras.

These measures led to the most abrupt changes since commercial exploitation began in the 1980s. Since 2013, the QC resource once again supports an artisanal, subsistence fishery. In contrast to earlier years, however, fishing is only allowed at the Serrana Bank. Stocks seem to have recovered to some degree at Bajo Nuevo and Alicia Banks but IUU fishing is still taking place.

From an economic perspective, the fishery morphed from a largely export-oriented fishery (the fourth largest in the southwestern Caribbean) to a fishery largely devoted to domestic markets, with approximately 80 percent of the harvest being marketed in hotels,

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[3] In Figure 2, we use the annual TAC limits published by the government authority (the Ministry of Agriculture and Rural Development) for the 2004-2019 period. To the best of our knowledge, TACs have been fulfilled for all these years; however, actual landings may have been up to twice the annual TACs due to IUU fishing (AUNAP, personal communication, 26 October 2018).

[4] In November 2012, the International Court of Justice (ICJ) issued a ruling on a dispute between Colombia and Nicaragua regarding territories and maritime jurisdictions. In consequence, Colombia lost access to an important fishing area (called *Luna Verde*) in the ASPC.

restaurants and establishments on San Andres Island (E. Castro, personal communication, November 8, 2018). From a social perspective, overfishing has had verifiable negative effects on artisanal fishers and local communities. Because meat prices are lower in the domestic market[5], revenues from the fishery have declined. In addition, fishing costs have increased because fishers must traverse longer distances to reach Serrana Bank (fuel costs and ice represent 43% and 28% of the operating costs[6], respectively). Moreover, conch fishing has become a riskier activity as fishermen explore deeper locations (>10 m) without autonomous (hookah and scuba) gear in order to increase harvests. Also, the overall decline in production and exports has dramatically reduced the number of direct and indirect jobs associated with the fishery, diminishing benefits to local communities.

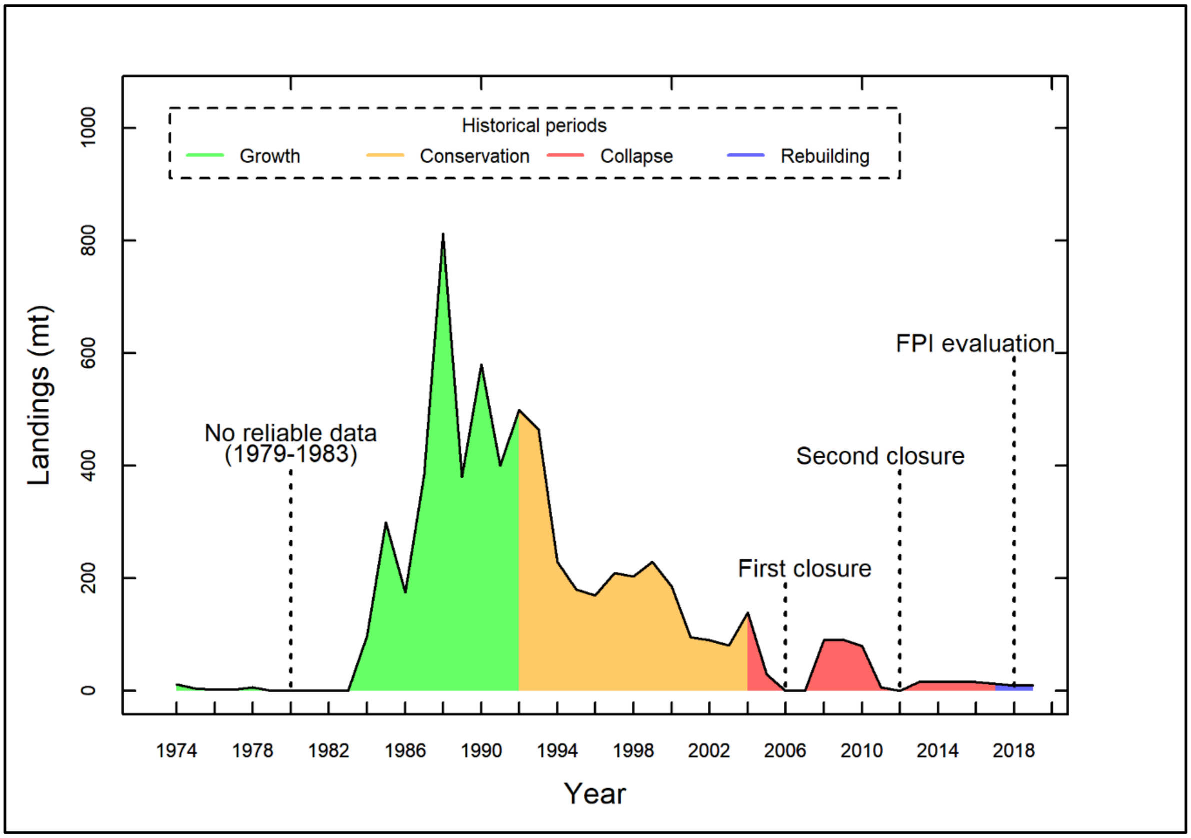

Figure 2. Estimated landings (in metric tons) from the Colombian QC fishery. Sources: Ospina *et al.* (1996) for the 1974-1984 period; Prada *et al.* (2009) for the 1985-2003 period; annual TAC limits published by the government authority (the Ministry of Agriculture and Rural Development) for the 2004-2019 period. No reliable data are available for the period 1979-1983 (Ospina *et al.*, 1996).

[5] A kg of conch meat is purchased at around USD 3-5. It is sold in restaurants at around USD 5-9.
[6] Rodríguez and Lázaro, personal communication, November 21, 2018.

2.2.4 Rebuilding and Current Outlook (2017-Present)

QC fishing remains an artisanal occupation in the ASPC, with around 90 fishermen and 15 boats officially involved (Prada *et al*., 2017). The artisanal fishing community in the ASPC (including those fishermen involved in QC fishing) consists of approximately 1,800 fishers, 74% of whom are based in San Andres and 26% in Providence (PDD, 2016). Unfortunately, there have been no major studies to determine the benefits and dependency of local communities on the QC fishery. Hence, identifying who might be informally involved in conch fishing is a difficult task. The age structure of QC fishermen is skewed towards older groups: 70% of fishermen are 41-61 years old, while only 10% are 21-40 years old. The best alternative jobs are farming and tourism. Although experienced fishermen prefer to engage exclusively in fishing, younger fishermen alternate jobs. At present, a typical trip involving 4-6 fishermen lasts 7-15 days, which is longer than the historical norm. The number of cooperatives and associations is high (11 in San Andres and 3 in Providence) compared to other regions in Colombia; it is estimated that 50% of artisanal fishermen are currently affiliated with one or more of these associations (PDD, 2016). The annual TAC is divided among cooperatives. Usually, the revenue from a QC fishing trip is divided between the captain and the fishermen, with the former receiving a higher share. Fishermen also pay a fee to use the boat. Female participation in the post-harvest sector is substantial (FAO, 2016), although no official data are maintained.

The current management system for conch fishing in Colombia is aimed at enhancing reproduction and stock recruitment through a series of regulations restricting catches. Table 1 summarizes its major features.

Table 1. Management System for the Colombian QC Fishery, 2018.

Management System	Colombian QC Fishery
Access	Regulated open-access. Cooperatives must hold permits and register boats and participating fishermen.
Season Length	Throughout the year except during the reproductive season (June 1-October 31)
Area of Operation	Permitted in areas where density of adults exceeds 50 individuals/ha (preferably 100 individuals/ha). Serrana Bank is the only bank open to fishing.
Catch Quota	The annual, fishery-wide TAC is 10 mt of cleaned meat.
Minimum Size	Minimum meat weight for adults (lip greater than 7 mm and shell length greater than 24 cm) is 225g before cleaning or 100g cleaned.
Fishing Techniques	Conchs collected manually by free diving. Autonomous diving gear is prohibited.
Protected Areas	The Seaflower MPA encloses 7 out of the 10 major fishing banks in the ASPC (see Fig. 1), restricting fishing activities.
Exports	International trade regulated by CITES and the FAO Code of Conduct for Responsible Fisheries. However, no exports are currently taking place.
Governance	Decentralized. ASPC fisheries are managed under a special regime in Colombia. Several responsibilities (administration, monitoring, research, etc.) have been transferred from the national (AUNAP[7]) to the regional authority (JUNDEPESCA[8]). Landings are also reported through the SAP[9]. CORALINA[10] is the agency with a mandate for environmental issues.

The fishery has entered into a rebuilding period characterized by the development of two strategic plans (Regional and National) aimed at reversing the overfished status of the stock. We briefly discuss the two plans below.

Under the auspices of the FAO, a ten-year Regional Fisheries Management and Conservation Plan was released in 2017 (Prada *et al*., 2017). While not binding, the plan recommends that the signatory countries (e.g., Colombia) implement 14 management measures recognized as fundamental to guarantee the sustainability of the fishery. In particular, the Regional Plan encourages signatory countries to (i) strengthen cooperation and

[7] Spanish acronym for National Authority for Aquaculture and Fisheries.
[8] Spanish acronym for Departmental Board for Fisheries and Aquaculture.
[9] Spanish acronym for Secretary of Agriculture and Fisheries.
[10] Spanish acronym for Corporation for Sustainable Development in the ASPC.

coordination efforts among all Caribbean countries to combat IUU fishing, (ii) explore the potential of innovative strategies such as spatial management and co-management, and (iii) improve data collection (i.e., catch and effort) and traceability of QC products throughout the value chain.

Colombia is including most of the Regional Plan recommendations in its own ten-year National Plan to be released in 2020, which is aimed at promoting the recovery, conservation, and sustainability of QC stocks. The National Plan establishes several lines of action in addition to those recommended in the Regional Plan. For the ASPC, a management system based on limited-access – and potentially individual fishing quotas (IFQs) as well – is proposed in order to eliminate the open-access problem of rent dissipation (Clark and Munro, 1980). Special management schemes could be implemented in banks with low QC densities. Exhaustive and periodic stock assessment surveys would be carried out in La Guajira peninsula and the Rosario and San Bernardo archipelagos (see Fig. 1) to determine whether exploitation can be allowed in these banks in the near future. At present, unregulated fishing activity is taking place in all these banks, highlighting the need for a management framework based on well-defined and enforceable rules.

Although recommended reforms to the current management system for the Colombian QC fishery have not yet been implemented, the proposed measures in both the Regional and National plans could potentially usher the QC fishery into a new period of restoration and growth. Within this context, our FPI evaluation provides a timely benchmark reflecting performance of the fishery prior to the implementation of any potential reforms.

3. Methodology

The FPIs evaluate performance of a fishery through 122 metrics divided into two main categories: output indicators and input components. Outputs are those metrics that reflect whether the fishery is delivering economically viable and socio-ecologically sustainable results (based on TBL outcomes), shedding light on the segment(s) of the fishery supply chain where benefits tend to accumulate. Input components are conditions that contribute to the process of generating socioeconomic prosperity in the fishery without degradation of the resource base. Output indicators and input components are broken into key dimensions reflected in specific metrics (see Appendix A). Because metrics rely on data that should be available for each fishery, FPIs normally do not require primary data collection. Although individual metrics may be imprecise, the multi-dimensional evaluation eventually leads to an accurate impression of what works and what does not work in the fishery. The FPIs are therefore sufficiently robust to be applied in both data-poor and data-rich environments. Detailed information about the methodology is provided in Anderson *et al.* (2015) and Asche *et al*. (2018).

The FPIs are designed to capture experts' assessments of fishery performance. Given the complexity of fishery systems, it is convenient to elicit the opinion of several experts when evaluating a fishery. We describe below the field work and the six-step process used in the assessment of the QC fishery.

Steps 1 and 2. Several in-person interviews were conducted from October 2018 through January 2019. In the first round of evaluation, two experts from AUNAP (based in Bogotá, Colombia's capital) and one from National University (Colombia's top public university) were interviewed. A second round of evaluation included two experts from CORALINA and one from AUNAP, all of whom were based in San Andres Island. The latter interviews were conducted during the 71st Conference of the Gulf and Caribbean Fisheries Institute (GCFI) held in San Andres in November 2018. In addition, we held informal conversations with four QC fishermen. Ten fishery experts were interviewed in total. Excepting fishermen, experts were asked to assign scores for those metrics in their specific area of expertise, which enhanced the quality of scores because experts focused on the metrics with which they were most familiar. Throughout the assessment, experts were asked to provide explanations and the degree of uncertainty regarding the chosen scores.

Step 3. All metrics were scored from 1 to 5 (or NA if the metric did not apply, e.g., a metric related to individual transferable quotas applied to a fishery with no harvest rights). For the output metrics, a score of 5 is indicative of excellent performance, while 1 denotes very poor performance. Overall performance in any given dimension is assessed by estimating the average score across all metrics contained within that dimension. As a benchmark, a score (or average score) of 3.5 or higher is indicative of good performance. In addition, each quantitative score (1-5) is assigned a quality rating of "A", "B" or "C" indicating the degree of confidence the expert places on her/his assessment; an "A" (high) quality rating is assigned if the expert is highly confident that the score is correct, while a "C" (poor) quality rating is assigned when the fishery expert is not very confident of her/his score. Following the two evaluation rounds, all scores and explanations were verified by the authors of the paper through an exhaustive consultation of publicly available information sources such as official statistics and reports, data proxies, unpublished reports, etc.

Step 4. If an output metric or dimension received a score or average score below 3.5, it is considered to have "room for improvement" in the coming years. Moreover, the researcher can also identify data collection needs by examining the metrics assigned "B" or "C" quality ratings in the evaluation. Finally, functional relationships between input components and output indicators can be inspected once the evaluation has concluded.

Step 5. Analysis of the results leads to an improved understanding of the ecological, economic and social performance of the fishery, which can yield useful insights to enhance effectiveness of fishery management systems.

Step 6. The evaluation can be repeated on a periodic basis (*i.e.*, 5 years) as fishery conditions change and additional information becomes available.

This six-step process provides policy-makers and fishery experts with a framework for iterative learning towards sustainably managed fisheries. In the specific context of the Colombian QC fishery, this methodology may be used by policy-makers and stakeholders to identify priority areas of action for the rebuilding of the fishery. Findings from the analysis can complement and be contrasted with the objectives and management strategies outlined in both Regional and National Plans.

4. Results

The performance of the QC fishery and its management system is first examined through the output indicator results, followed by a discussion of the input component (enabling factors) results.

4.1 Output Indicators

Fig. 3 displays the average output indicator scores[11] for the Colombian QC fishery with dimensions arranged by sector (see Fig. 1 in Anderson *et al.* 2015): *Stock Performance* (Ecologically Sustainable Fisheries), *Harvest Sector Performance* (Harvest Performance, Harvest Asset Performance, Risks, Owners, Permit Holders & Captains, and Crew) and *Post-harvest Sector Performance* (Market Performance, Post-Harvest Industry Performance, Post-Harvest Asset Performance, Processing Owners & Managers, and Processing Workers). The fishery received acceptable scores (above 3.5) for Owners of Processing Capital and Captains/Boat Owners, with benchmark scores (score of 3.5) for Risks and Crew. All other indicators suggested room for substantial improvement in the fishery.

[11] Overall, quality ratings indicated that experts were confident of their assessments, as 46 output scores were assigned a quality rating of "A", 21 scores were assigned a "B" rating and only 1 score was assigned a "C" rating.

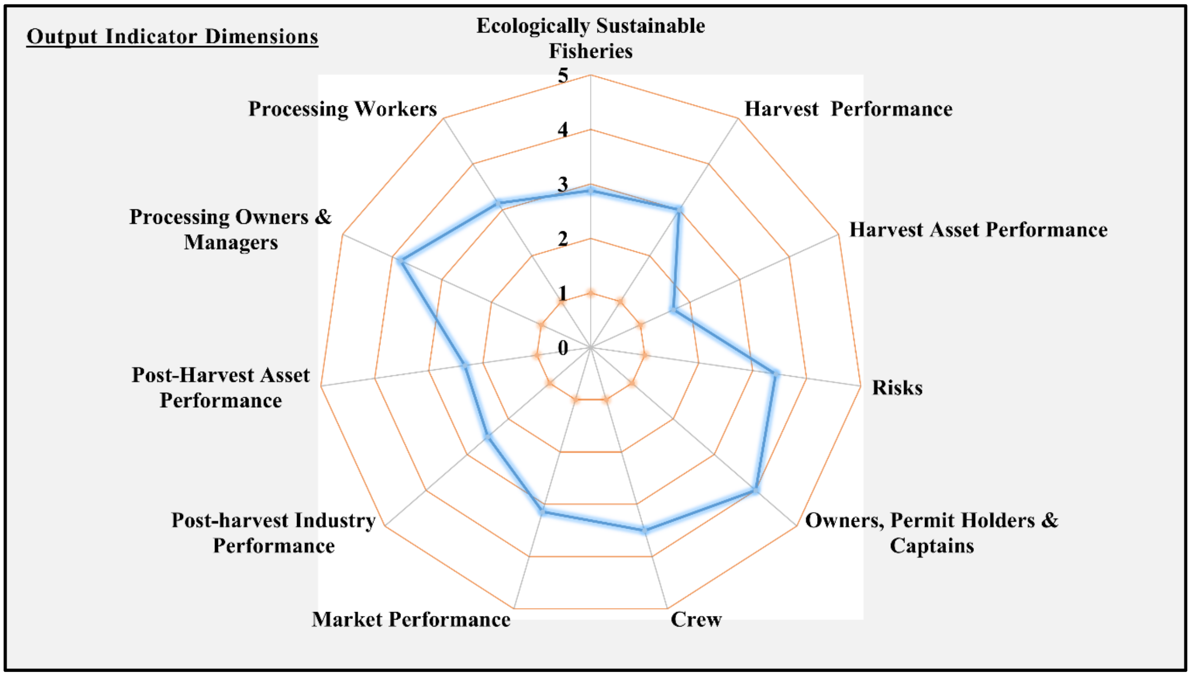

Figure 3. Average output scores for the Colombian QC fishery. Scores below 3.5 denote dimensions with poor performance.

According to the Fishery Sector partitioning, compared to the 61 global case studies (including 20 and 41 fisheries from developed and developing countries, respectively) reported in the seminal Anderson et *al.* (2015) article, the QC fishery ranked 44th in *Stock Performance*, 48th in *Harvest Sector Performance* and 49th in *Post-harvest Sector Performance*. When compared to the 41 fisheries from developing countries, the QC fishery ranked 24th in *Stock Performance*, 30th in *Harvest Sector Performance* and 28th in *Post-harvest Sector Performance* (see Table 2). These rankings indicate a relatively poor performance of the QC fishery sectors in both the global and developing country contexts analyzed by Anderson *et al.* (2015), as the QC fishery was consistently ranked within the third or fourth quartiles of the dataset. These results are not surprising given the gross mismanagement of the resource throughout the years.

While the grouping of dimensions presented in Fig. 3 reflects the structure of the supply chain, the same set of 68 output metrics used to characterize the fishery sectors can also be categorized as direct measures of sustainability outcomes (see Table A-1 in Appendix A). Next, we discuss the results of the evaluation in terms of the TBL partitioning.

4.1.1 Ecology

The fishery earned a low score (2.88) in the Ecologically Sustainable Fisheries dimension because the majority of fishing grounds are overfished. Management measures are aimed primarily at promoting stock recovery and ecosystem conservation; however, little improvement has been observed thus far. Low densities and IUU fishing are impairing QC reproduction and reducing the habitat quality for new juveniles as well. Moreover, there is increasing concern among experts about the effects of climate change on QC reproduction and habitat.

According to the *Ecology* indicator, the fishery ranked 44th (third quartile) among the 61 global case studies. The fishery ranked 25th (third quartile again) when compared to the 41 fisheries from developing countries (see Table 2).

4.1.2 Economics

The fishery achieved the lowest score (1.7) in Harvest Asset Performance. This is because of its regulated open-access nature, meaning that very little value accrues to the boat or the permit. Poor performance in this dimension is also due to the small harvests resulting from overfishing and limited access to the formal finance sector, which forces many fishers to rely on local moneylenders for capital financing needs. Harvest Performance received a score of 3 because fishing activity is severely constrained. Nowadays, fishers need to explore farther and deeper fishing grounds in search of large agglomerations of QC stocks, resulting in increased fishing costs and in turn increased captures per trip, because fishermen need large harvests to ensure profitability in each trip. This situation has indirectly contributed to overfishing and the rapid fulfillment of the TAC (fishermen currently need less than half of the available fishing days to fulfill the TAC). Managers have informally adopted a conservation rule based on exploitation at constant rates (Medley, 2008) as the basis to estimate annual TACs. However, this rule does not take into consideration any economic factors such as increased fishing costs, meaning that management goals are formulated without any regard to the economic aspects of fishing.

The Post-Harvest Sector received a score of 3 because it operates well below its capacity. In 2008, the fishery was the fourth-largest exporter in the southwestern Caribbean (Prada *et al*., 2009). Through 2011, 90% of QC products were exported to markets as diverse as the U.S. (meat and pearls), Switzerland (pearls), Japan (pearls), and Vietnam (shells). Although the fishery has the ability to compete in international markets, only one processing plant currently operates in the ASPC. However, this plant does not process any QC product because the entire catch is allocated to the domestic market. This is the case even though demand for QC products has increased in international markets, with U.S. conch imports increasing from USD 5.7 million in 2014 to USD 24 million in 2018 (NMFS, 2019b). The Post-Harvest Sector also performs poorly due to the high interest rates prevailing in the region.

The fishery reached the benchmark score of 3.5 in the Risk dimension due the low annual volatility (based on revenue, landings and price) as TACs and management measures have remained more or less constant during the last 10 years. Because all catch is devoted to domestic markets, variation in prices can be explained by location and volatility in fuel prices.

According to the *Economics* indicator, the fishery ranked 57th (bottom quartile) among the 61 global case studies. The fishery ranked 36th (also bottom quartile) when compared to the 41 fisheries from developing countries (see Table 2).

4.1.3 Community

The QC fishery is viewed as an important economic activity that provides employment and income to remote coastal communities, contributing to food security and poverty alleviation. Historically, the local community has been strongly involved in the artisanal fishery; in addition, the species is highly prized in domestic markets.

The highest scores (3.5, 3.8 and 4.0) were assigned to the Crew, Processing Owners and Managers, and Owners, Permit Holders and Captains dimensions respectively (Fig. 3). Despite the numerous harvesting restrictions, the fishery is profitable for the captains. Their earnings are 4-5 times the regional average if a pearl is found during the fishing trip; otherwise they amount to 3-4 times the regional average, allowing them to provide higher education for their children, among other benefits. The fishery is prized by the local community and captains are held in high esteem, even though captains are not necessarily leaders in their community. Although the fishery is less profitable for the crew, it still compares favorably to alternative occupations because it provides a perception of economic security. Their earnings are 3-4 times the regional average if a pearl is found during the fishing trip; otherwise they earn 2-3 times the regional average. In general, the crew is highly specialized in QC fishing and held in fairly high esteem by the local community.

According to the *Community* indicator, the fishery ranked 30th (second quartile) among the 61 global case studies. The fishery ranked 18th (second quartile) when compared to the 41 fisheries from developing countries (Table 2).

Table 2. Scores and Rankings of the QC Fishery Relative to the 61 Case Studies Reported in Anderson *et al*. (2015), Arranged by TBL and Fishery Sector Partitioning.[a]

Item	Triple Bottom Line			Fishery Sector		
	Ecology	*Economics*	*Community*	*Stock*	*Harvest*	*Post-harvest*
Scores	2.88	2.57	3.79	2.88	3.10	3.00
Ranking - Global (62 fisheries)	44th (III)	57th (IV)	30th (II)	44th (III)	48th (IV)	49th (IV)
Ranking - Developing countries (42 fisheries)	25th (III)	36th (IV)	18th (II)	24th (III)	30th (III)	28th (III)

[a] The second row (Global) compares the QC fishery to the 61 case studies (62 fisheries in total). The third row (Developing countries) compares the QC fishery to the subset of 41 fisheries from developing countries (42 fisheries in total). Roman numerals in parentheses indicate the quartile associated with the ranking.

Table 2 and Fig. 4 in Anderson *et al.* (2015) suggest the following generalizations about fishery management systems:

(i) Open-access fisheries (e.g., the Colombian QC fishery) rank near the bottom when sorted by the *Ecology* indicator, primarily because of overfishing.

(ii) The *Ecology* indicator is an unsatisfactory proxy for the other two pillars (*Economics* and *Community*) of the TBL perspective. Asche *et al*. (2018) found that better ecological performance minimally improves economic benefits in fisheries under open-access regimes and slightly improves economic benefits in fisheries under limited-access regimes, suggesting that each bottom-line indicator should be monitored separately. In contrast, Colombian QC fishery management has been based mostly on ecological information. While the *Ecology* indicator was assigned a low score (2.88), the *Economics* indicator earned an even lower score (2.57), with the *Community* indicator receiving the highest score (3.79). In addition to the TBL perspective, we argue that the analysis of the structure of the supply chain (see Fig. 4 and Table 2) may also help identify rebuilding challenges in collapsed fisheries, especially when they are performing poorly in the economic metrics.

(iii) Even when the resource is depleted, the fishery enterprise is very important for local communities. In Anderson *et al.* (2015), the *Community* indicator scores were on average higher than the *Ecology* and *Economics* indicator scores for the 61 global case studies: 3.76 for *Community,* 3.43 for *Ecology* and 3.35 for *Economics*. When analyzing the 41 fisheries from developing countries, average scores were 3.72 for *Community*, 3.06 for *Ecology* and 3.12 for *Economics*. In both cases, the *Community* indicator clearly outperformed the other two pillars. This contrast is even greater in the case of the Colombian QC fishery: 3.79 for *Community*, 2.88 for *Ecology* and 2.57 for *Economics* (Table 2).

The identification of these trends will provide useful insights when examining the rebuilding challenges faced by the Colombian QC fishery.

4.2 Input Components (Wealth Enabling Factors)

Fig. 4 displays the summary of scores[12] for the input dimensions (see also Table A-2 in Appendix A). Relatively high scores were achieved for the *Macro Factors* Environmental Risk and National Economy. A moderate score (3.3) was recorded for Collective Action, while all other dimensions were assigned low scores (below 3).

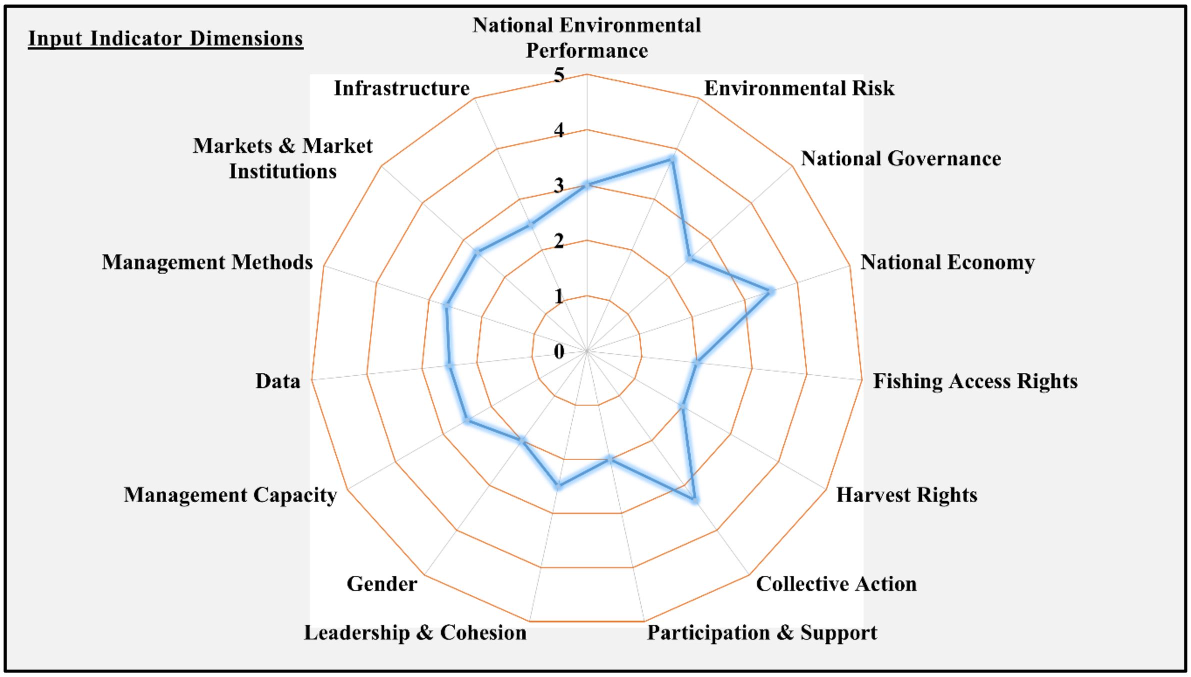

Figure 4. Average input scores for the Colombian QC fishery.

4.2.1 Macro Factors

A relatively high score (3.8) was assigned to Environmental Risk because there is no concrete evidence yet on adverse impacts from environmental factors. However, scientists expect QC populations to be affected by increasing sea temperatures and acidification in the near future (e.g., Stoner *et al.*, 1992; Barilé *et al.*, 1994; Aranda and Manzano, 2017).

[12] The experts were also confident in the output scores: 44 input scores were assigned a quality rating of "A", 9 were assigned a "B" and 1 score was assigned a "C".

Moreover, other environmental factors such as pollution by microplastics may already be inducing habitat degradation.

The Environmental Performance Index (Wendling *et al.*, 2018) revealed that environmental performance in the Colombian Caribbean is relatively low compared to other countries in the southwestern Caribbean; a score of 3 was assigned accordingly. National Governance, as reported by the World Bank's Worldwide Governance Indicators (Kaufmann *et al*., 2010), was also found to be deficient (score of 2.5). The worst performing dimensions were Government Effectiveness and Control of Corruption. In contrast, National Economy reached the benchmark score of 3.5 as estimated from the Index of Economic Freedom (Miller *et al*., 2019) and the Gross Domestic Product per Capita statistics. In both cases, 2018 was the reference year.

4.2.2 Property Rights and Responsibility

The two dimensions in this component (Fishing Access Rights and Harvest Rights) were assigned a score of 2. Fishing Access Rights performed poorly because the fishery is nominally managed under regulated open-access, although in practice there exist informal factors that restrict access to the fishing grounds. IUU fishing from neighboring countries is a paramount concern in the region[13]. Harvest Rights are impaired by the high political uncertainty surrounding the fishery: given the collapse of the stock, fishermen know that the fishery can be closed at any time. This negatively affects the Security and Durability Indices.

4.2.3 Co-Management

Co-management remains at a pre-implementation phase in the fishery and therefore more work is needed to improve bottom-up-driven management interventions. Several reasons explain the poor performance of the fishery (score of 2.5) in this component. On the one hand, the fishing community is not empowered to participate actively in fishery management; as a result, incentives for voluntary compliance are diminished and enforcement costs increase. There is evidence that fishermen who are more involved in the crafting of regulations are more likely to comply with management plans (Pomeroy and Berkes 1997). On the other hand, even though the number of cooperatives and associations in the region is relatively high compared to other areas of the country, managers lack adequate resources to get these organizations involved in the decision-making process. An additional challenge lies in the fact that some local leaders who do not belong to the QC

[13] In 2019, QC illegal fishing was estimated at 9.8 mt, which represents the entire annual TAC for the Colombian QC fishery (AUNAP, personal communication, November 28, 2019).

fishing community may have unrelated economic interests, which reduces the ability of QC fishers to provide a strong, shared vision for fishery management. Gender received a low score (2) because there is little involvement of women in the harvest sector; female participation tends to be greater in the post-harvest sector.

4.2.4 Management

National and regional authorities have made substantial investments to improve management of the resource; however, the enormous size of the region creates equally enormous monitoring challenges (patrolling in particular). As explained previously, Caribbean countries recently committed their most significant effort to coordinate regional management plans (Prada *et al*., 2017). At the national level, regulations restricting QC meat consumption during the reproductive season continue to be flouted. In recent years, incentives for voluntary compliance have decreased while enforcement costs have increased. Moreover, policies and management are strongly influenced by ecological data, when it is becoming increasingly clear that the fishery requires new types of data and analysis to guide more comprehensive assessments. For all these reasons, the Management component achieved a low score (2.6).

4.2.5 Post-Harvest

The dimensions in this component (Markets and Market Institutions, and Infrastructure) received a score of 2.7 and 2.5, respectively. Local QC markets lack readily available and accurate price and quantity information. Experts were uncertain about the proportion of harvest traded in transparent markets with competitive pricing. The fishery also lacks access to technologies that may enable improvements in product quality or product development. Roads are inefficient by international standards. Extension services to assist the fishing community have been established but their outreach capability is still limited.

5. Discussion: Rebuilding Challenges

In assessing rebuilding challenges for the Colombian QC fishery, the following key issues have been identified, with varying relevance over the near-, mid- and long-term future.

5.1 Management and Conservation of the Resource

An interesting result emerging from the FPI evaluation is the contrast between the low scores achieved in the *Ecology* and *Economics* indicators (2.88 and 2.57, respectively) and the good performance (3.79) in the *Community* indicator. This is explained by the fact that the species is a source of social and cultural identity, with many families traditionally involved in the artisanal fishery. Although the fishing community has a strong interest in the conservation of the resource, they have relatively little influence on decision-making and management. In the near term, the fishery will need to develop more coherent programs with clear guidelines to facilitate community participation. This does not necessarily imply co-management but at least engagement among principal actors and local leaders. The accurate identification of local stakeholders will be crucial because local leaders are not always members of the QC fishing community. Given that the management system is highly decentralized (see Table 1), better coordination amongst fishery managers will be essential. In this direction, adaptive management based on periodic data collection and analysis for fish stock assessment would facilitate coordination (Kaplan and McCay, 2004) and offers a cost-effective way to recover from collapse. In recent studies, Duarte *et al.* (2020) and Hilborn *et al.* (2020) found that scientifically assessed stocks have better chances of recovery than unassessed stocks, due to improved fisheries management and regulatory status.

A major concern relates to property rights. As explained above, reforms leading to a restriction of access to the fishery or a privatization of user rights (as in IFQs) would enhance performance of the fishery almost immediately. Given the importance of the QC fishery to the local community, as reflected in the *Community* indicator, the implementation of Territorial Use Rights (TURFs) over a sedentary species such as the QC may create economic incentives to allocate resources efficiently in order to generate wealth (Cancino *et al.*, 2007; Branch, 2009; Nowlis and Van Benthem, 2012). For example, the banishment of scuba and hookah gear for QC harvesting is a sensible conservation measure under the current regime of regulated open access. However, under a rights-based management system such as a TURF, eschewing scuba and hookah gear in favor of less efficient harvesting methods such as freediving may be unnecessary as incentives for overfishing are lessened by the strengthened property rights. TURFs may also encourage conservation of QC stocks, as fishermen would be more involved in management. Within the QC fishery context, TURFs could be co-managed by the existing cooperatives in the ASPC. One must be mindful, however, that TURFs might introduce new management challenges, such as the coordination required to control outsiders and the improved flow of information demanded by spatially based management, especially in light of the high level of IUU fishing reported in the Caribbean.

An additional factor possibly constraining the economic performance of the fishery is related to Medley’s rule of exploitation at constant rates. Given that past quotas were set at excessive levels, fishery managers informally adopted a conservation rule based on the annual removal of 8% of the exploitable biomass (Medley 2008). However, this rule does not take into account economic factors such as increases in fishing costs associated with declining densities and trips to distant banks. Consequently, fishing incomes have declined substantially in recent years, threatening the economic viability of the fishery.

Given these considerations, the fishery would benefit greatly from the development of a bioeconomic model aimed at identifying optimal management strategies and potential sources of efficiency gains in the harvesting of the resource. A useful precedent is the age-structured model for U.S. Atlantic sea scallop fisheries developed by Valderrama and Anderson (V&A) (2007), which demonstrated the economic and environmental advantages associated with rotational management of sea scallop beds as opposed to low, constant exploitation rates. The findings from the V&A study, along with the empirical evidence provided by survey areas in the Great South Channel of Georges Bank – where a high number of recruits were observed following the closure of areas to fishing for a number of years (Dawicki, 2008) – elevated the role of rotational harvesting in scallop management plans (NOAA Fisheries, 2019). Similar to the QC resource, the Atlantic sea scallop fishery was characterized by "boom and bust" periods until the resource was officially declared overfished in 1997. However, introduction of rotational harvesting and other management innovations, coupled with favorable environmental conditions, led to a strong recovery of the fishery in the early 2000s.

QC also appears to be a good candidate for rotational fishing because the species moves slowly, exhibits low natural mortality, and is relatively long-lived. The bioeconomic model could be used as a decision-making tool allowing managers to determine rent-maximizing exploitation rates while simultaneously ensuring the environmental sustainability of the resource. Following closure periods that are sufficiently long to rebuild QC biomass, extraction at exploitation rates higher than those recommended by Medley's conservation rule (Medley, 2008) could contribute to increased incomes for fishers, especially in the more distant fishing grounds. The key insight to communicate to fishery communities would be that gains derived from closures could potentially outweigh the initial loss of revenue. This may require, in turn, the ability to rotate openings and closures across banks or alternate target species (i.e., alternate QC with spiny lobster[14] during the closure periods). Development of the bioeconomic model would fulfill one of the major recommendations of the 2017 Regional Fisheries Management Plan (Prada *et al.*, 2017), i.e.,

[14] A high percentage of the effort and labor participating in the spiny lobster (SP) fishery is non-resident because resident labor in the ASPC is insufficient to fulfill the annual TAC.

"to explore the potential of innovative strategies such as spatial management and co-management".

The model could also be used to conduct a comparison of the resource's economic potential under optimal management with the rents achieved by focusing on local consumption and exclusion of the industrial, export-oriented fleet (the status quo scenario). The model could also estimate fishing costs and benefits associated with efficient harvesting methods such as scuba diving and compare them to the status quo (freediving harvesting) under current regulations. These analyses would provide valuable information on the economic value associated with a potential transition towards rights-based management, and on how these economic gains would compare to the required investment on monitoring and enforcement to reduce IUU fishing.

Complementary interventions (e.g., active restoration of fish habitats after having reduced or removed the fishing pressure) may also contribute to approaching the reference abundance ranges (100 individuals/ha for the QC fishery) that support sustainable catches; such approaches may be effective on a similar timescale as fish stock recovery; for example, recovery occurred in less than a decade for oyster reefs and other non-coral invertebrate populations (Duarte *et al.*, 2020).

5.2 QC Products and Market Issues

Resource scarcity and the decision to shun international markets are not the only factors limiting the economic potential of the fishery. Resource under-utilization is another issue. It is estimated that somewhere between 60 and 85% of the conch biomass is wasted in Colombia. Because no value is added to the shells, fishermen typically throw them back into the sea. In contrast, neighboring countries are already extracting value from QC by-products: for example, the meat tissue is used as bait for other fisheries, the operculum is sought after in jewelry manufacturing, and shells are employed as garden fertilizers (Lawrence and Phillips, 2013). Thus, production of value-added conch-derived items should be pursued as a strategy to enhance economic sustainability.

Although the interest in mariculture is not new in the region (Brownell and Stevely, 1981), its potential to complement the traditional QC capture fishery needs to be further investigated. In particular, production of pearls through mariculture holds great promise because pearls are more valuable than meat (Appeldoorn, 2013). Mariculture could also mitigate the illegal trade and smuggling associated with pearls found in the wild[15]. In addition, mariculture could become a key supplier to the meat trade, even more so if the species is added to CITES Appendix I.

5.3 Regional Coordination to Combat IUU Fishing

Combating IUU fishing in the Wider Caribbean presents a broad range of challenges (Prada *et al*., 2017). For example, (i) many aspects of the fishery such as the pearl trade or meat conversion factors remain unregulated; (ii) in some countries, illegal trade is linked to drug trafficking and therefore illegal fishing is not the highest priority during enforcement patrolling; (iii) national regulations often have low or inappropriate fines for non-compliance; (iv) real-time satellite-based enforcement is rarely available to fishery managers; and (v) QC closure periods are uncoordinated across Caribbean countries.

Addressing the above-mentioned challenges will require enhanced coordination and cooperation among Caribbean countries. For instance, a harmonized regional closed season may contribute to increasing QC recruitment and conservation, and coordinated patrolling may help decrease enforcement costs in those countries lacking sufficient resources for effective enforcement within their jurisdictions.

6. Conclusions

This study used the FPI methodology, the most comprehensive global tool currently available to gauge the health of fishery systems, to examine the environmental, economic and social performance of the Colombian QC fishery. Despite its great socio-cultural significance for Caribbean communities, the fishery underwent substantial overfishing during the 1980s and 1990s and eventually collapsed in 2004, and has been operating as a subsistence fishery since 2013. Although the FPI evaluation unsurprisingly revealed substantial underperformance in most environmental and economic metrics, the fishery managed to achieve relatively high scores in the social indicator due to the socioeconomic importance of the resource for fishing communities with relatively few economic alternatives.

The QC fishery has the potential to become another success story such as those mentioned in Duarte *et al.* (2020) and Hilborn *et al.* (2020). However, the FPI evaluation revealed room for improvement in order to achieve success. Besides improving coordination

[15] Pearls occur at a frequency of 0.1% in the ASPC; that is, a pearl is found in only 1 out of 1,025 collected individuals (Ortegón-Guasca, 2006). Moreover, there is just a 1 in 10 chance that this pearl would meet high-quality requirements in the international market.

and enforcement of regulations, the stock assessment should be expanded to include mid- and long-term economic and marketing objectives. It is understandable that management has thus far been focused on stock recovery, but it is also clear that economic insights will be essential to satisfy the TBL perspective of environmental, economic and social sustainability. In this regard, bioeconomic modeling of the fishery is recommended to assess the potential of rotational harvesting of fishing grounds instead of the current model of constant exploitation rates. Useful to this purpose is the example of the Atlantic sea scallop fishery in the Northeastern U.S., which endured overfishing through the 1990s but commanded a strong recovery in the 2000s, driven partially by the implementation of rotational management. Bioeconomic modeling could also provide much-needed insights on the potential economic gains associated with higher-value markets (i.e., export markets) or the cost savings that could result from a transition to rights-based management schemes. Depending on the level of scientific knowledge of the resource, bioeconomic modeling could even provide guidance on the management strategies most conducive to the production of high-quality pearls from the fishery.

There is a great deal of interest among local and regional stakeholders to achieve recovery of this iconic Caribbean fishery. Our analysis with the FPIs is timely because it provides a snapshot of the Colombian fishery at a very critical moment in its historical timeline, when multiple attempts are being made to recover from a recent collapse of the stock. This snapshot can be used as a benchmark to evaluate progress in the fishery in the medium and long term, regardless of the nature of reforms introduced to the management system.

References

Agrawal, A. (2002). Common Resources and Institutional Sustainability. In National Research Council (Ed.). The Drama of the Commons. Washington, DC: The National Academies Press.

Anderson, J. L., Anderson, C. M., Chu, J., Meredith, J., Asche, F., Sylvia, G., et al. (2015). The fishery performance indicators: A management tool for triple bottom line outcomes. *PLoS ONE, 10*(5), e0122809. doi:10.1371/journal.pone.0122809.

Anderson, J. L., Anderson, C. M., Garlock, T., and DeAlessi, M. (2016). The Fishery Performance Indicators for California and Indonesia Fisheries Management Systems, University of Florida, Institute for Sustainable Food Systems Research Report, Gainesville, FL.

Appeldoorn, R. S., and Baker, N. (2013). A Literature Review of the Queen Conch (*Strombus Gigas*). Department of Marine Sciences, University of Puerto Rico, 80.

Aranda, D. A., and Manzano, N. B. (2017). Effects of near-future-predicted ocean temperatures on early development and calcification of the queen conch *Strombus gigas*. *Aquaculture International, 25,* 1869–1881.

Asche, F., Garlock, T. M., Anderson, J. L., Bush, S. R., Smith, M. D., Anderson, C. M., et al. (2018). Three pillars of sustainability in fisheries. *Proceedings of the National Academy of Sciences*, *115*(44), 11221–11225; doi: 10.1073/pnas.1807677115.

Barilé, P. J., Stoner, A. W. and Young, C. M. (1994). Phototaxis and vertical migration of the queen conch (*Strombus gigas* linne) veliger larvae. *Journal of Experimental Marine Biology and Ecology, 183,* 147–162.

Baum, J. K., Myers, R. A., Kehler, D. G., Worm, B., Harley, S. J., and Doherty, P. A. (2003). Collapse and conservation of shark populations in the Northwest Atlantic. *Science, 299*, 389–392.

Bomhauer-Beins, L., de Guttry, C., and Ratter, B. M. W. (2019). When culture materializes: Societal dynamics in R\resilience of social-ecological systems in the case of conch management on Abaco. *The Bahamas Sustainability, 11,* 1080.

Branch, T. A. (2009). How do individual transferable quotas affect marine ecosystems*? Fish and Fisheries*, *10*, 39–57.

Brownell, W. N. and Stevely, J. M. (1981). The biology, fisheries, and management of the Queen Conch, *Strombus gigas*. *Marine Fisheries Review, 43*(7), 1–12.

Cancino, J., Uchida, H., and Wilen. J. E. (2007). TURFs and ITQs: Coordinated vs. decentralized decision making. *Marine Resource Economics*, *22*, 391–406.

Cardinale, M. (2011). Fishery reform: Many stocks secured. *Nature*, *476*, 281.

Chu, J., Garlock, T. M., Sayon, P., Asche, F., and Anderson, J. L. (2017). Impact evaluation of a fisheries development project, *Marine Policy*, *85*, 141-149, ISSN 0308-597X, https://doi.org/10.1016/j.marpol.2017.08.024.

Cinner, J. E., McClanahan, T. R., MacNeil, M. A., Graham, N. A., Daw, T. M., Mukminin, A., Feary, D. A., Rabearisoa, A. L., Wamukota, A., and Jiddawi, N. (2012). Co-management of coral reef social-ecological systems. *Proceedings of the National Academy of Sciences*, *109*, 5219–5222.

CITES. (2019). Convention on International Trade in Endangered Species of Wild Fauna and Flora Trade Database. Data taken from: https://trade.cites.org/

Clark, C. W., and Munro, G. R. (1980). Fisheries and the processing sector: Some implications for management policy. *The Bell Journal of Economics*, *11*(2), 603–616.

Costello, C., Ovando, D., Clavelle, T., Strauss, C. K., Hilborn, R., Melnychuk, M. C. Branch, T. A., et al. (2016). Global fishery prospects under contrasting management regimes. *Proceedings of the National Academy of Sciences*, *113*(18), 5125–5129; doi: 10.1073/pnas.1520420113.

Dawicki, S. (2008). NOAA Atlantic sea scallop survey shows strongest recruitment on Georges Bank in seven years. Research Communication SS08.16, Northeast Fisheries Science Center, National Marine Fisheries Service. Woods Hole, MA. Available at https://www.nefsc.noaa.gov/press_release/2008/SciSpot/SS0816/index.html

Duarte, C. M., Agusti, S., Barbier, E., et al. (2020). Rebuilding marine life. *Nature*, *580*, 39–51. https://doi.org/10.1038/s41586-020-2146-7.

FAO. (2016). [In Spanish]. El rol de la mujer en la pesca y la acuicultura en Chile, Colombia, Paraguay y Perú. Oficina Regional para América Latina y Caribe, 38.

Gallo Nieto, J., et al. (1996). [In Spanish] Evaluación de la pesquería del caracol pala (Strombus gigas) y la langosta espinosa (Panulirus spp.) en el Departamento Archipiélago de San Andrés, Providencia y Santa Catalina (Caribe colombiano). Mem. de Resúmenes del X Sem. Nal. Cienc. y Tecnol. del Mar, CCO / COLCIENCIAS. Santafé de Bogotá (Colombia), Oct. 28-31.

García, M. I. (1991). [In Spanish] Biología y dinámica poblacional del caracol pala Strombus gigas L., 1758 (Mollusca, Mesogastropoda) en las diferentes áreas del Archipiélago de San Andrés y Providencia: Tesis, Univ. del Valle, Fac. de Ciencias, Cali. 183.

García, S. M., Ye, Y., Rice, J., and Charles, A., eds. (2018). Rebuilding of marine fisheries. Part 1: Global review. FAO Fisheries and Aquaculture (Technical Paper No. 630/1). Rome, FAO. 294.

Gulland, J. A. (1971). The Fish Resources of the Ocean. Fishing News (Books), West Byfleet, 255.

Hilborn, R., and Costello, C. (2017). The potential for blue growth in marine fish yield, profit and abundance of fish in the ocean. Marine Policy. http://dx.doi.org/10.1016/j.marpol.2017.02.003.

Hilborn, R., et al. (2020). Effective fisheries management instrumental in improving fish stock status. *Proceedings of the National Academy of Sciences, 117*(4), 2218–2224; https://doi.org/ 10.1073/pnas.1909726116.

Kaplan, I. M., and McCay, B. J. (2004). Cooperative research, co-management and the social dimension of fisheries science and management. *Marine Policy, 28*, 257–258.

Hutchings, J. A. (2000) Collapse and recovery of marine fishes. *Nature, 406*, 882–885. doi:10.1038/35022565.

Kaufmann, D., Kraay, A., and Mastruzzi, M. (2010). The Worldwide Governance Indicators: Methodology and Analytical Issues. Policy Research (Working Paper no. WPS 5430). World Bank. https://openknowledge.worldbank.org/handle/10986/3913 License: CC BY 3.0 IGO.

Khan, A., and Chuenpagdee, R. (2014). An interactive governance and fish chain approach to fisheries rebuilding: A case study of the Northern Gulf cod in eastern Canada. *Ambio, 43*(5), 600–613. doi:10.1007/s13280-013-0446-y.

Lawrence, D., and Phillips, L. D. (2013). New approaches to the conservation and sustainable development of Strombus Gigas and related species. Strombus Gigas Alliance, San Pedro Town, Ambergris Caye, Belize. (31 pp).

Mahon, R., McConney, P., and Rathindra N. R. (2008). Governing fisheries as complex adaptive systems. *Marine Policy, 32*(1), 104–112, ISSN 0308-597X, https://doi.org/10.1016/ j.marpol.2007.04.011.

Medley, P. (2008). Monitoring and managing queen conch fisheries: A manual. FAO Fisheries Technical paper 514. FAO, Rome. 2008.

Miller, T., Kim, A. B., and Roberts, J. M. (2019). 2019 Index of Economic Freedom, 25th Anniversary Edition. Washington: The Heritage Foundation, http://www.heritage.org/index.

Mora, O. (1994). [In Spanish] Análisis de pesquería de caracol pala (Strombus gigas L.) en Colombia. pp 137–144 (in) Appeldoorn, R. S., and Rodriguez, R. (eds.) Queen conch biology, fisheries, and mariculture. Fundación Cientifica Los Roques, Caracas, Venezuela.

Munro, G. R. (2010). From drain to gain in capture fisheries rents. A synthesis study. FAO Fisheries Technical Paper, *538*, 49.

Myers, R.A., and Worm, B. (2003). Rapid worldwide depletion of large predatory fish communities. *Nature*, *423*, 280–283.

NOAA Fisheries. (2019). Atlantic Sea Scallop Fishery. Available at https://www.greateratlantic. fisheries.noaa.gov/sustainable/species/scallop/

NMFS. (2019a). Annual Trade Data by Product, Country/Association. National Marine Fisheries Service, Fisheries Statistics and Economic Division. Data taken from: https://www.st.nmfs.noaa.gov/pls/webpls/trade_prdct_cntry_ind.results?qtype=IMP&qyearfrom=1975&qyearto=2019&qprod_name=CONCH&qcountry=3010&qsort=COUNTRY&qoutput=TABLE.

NMFS. 2019b. Commercial Fisheries Statistics. National Marine Fisheries Service, Fisheries Statistics and Economic Division. Data taken from: https://www.st.nmfs.noaa.gov/commercial-fisheriesforeign-trade/applications/annual-trade-balance-for-product.

Neubauer, P., et al. (2013). Resilience and recovery of overexploited marine populations. *Science*, *340*,(6130), 347–349, doi: 10.1126/science.1230441.

Nowlis, J., and Van Benthem, A. A. (2012). Do property rights lead to sustainable catch increases? *Marine Resource Economics*, *27*, 89–105.

Ortegón-Guasca, O. A. (2006). [In Spanish] Perla del caracol pala Strombus gigas (Linnaeus, 1758): Apariciones y primer ensayo de su formación, Caribe colombiano. Trabajo de grado para optar al título de Biólogo Marino. Universidad de Bogotá Jorge Tadeo Lozano, 179.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science, 325*, 419–22.

Ospina, J. F., Chiquillo, E., and Gallo, J. (1996). [In Spanish] Evaluación de captura y esfuerzo del caracol pala Strombus gigas (Linnaeus, 1758) en el Departamento Archipiélago de San Andrés, Providencia y Santa Catalina (Caribe Colombiano). Boletín Científico No 4/125–139, Santa Fe de Bogotá.

Pauly, D., Christensen, V., Guénette, S., et al. (2002). Towards sustainability in world fisheries. *Nature, 418*, 689–695.

PDD. (2016). [In Spanish]. Plan de Desarrollo Departamental 2016-2019: "Los que soñamos somos más". Gobernación ASPC, 596.

Pedersen, E. J., et al. (2017). Signatures of the collapse and incipient recovery of an overexploited marine ecosystem. *Royal Society Open Science. 4*(7), 170215. http://dx.doi.org/ 10.1098/ rsos.170215.

Pomeroy, R. S., and Berkes, F. (1997). Two to tango: The role of government in fisheries co-management. Marine Policy, 21, 465–480.

Prada, M. C., Castro, E., Taylor, E., Puentes, V., Appeldoorn, R. S., and Daves, N. (2009). Non Detriment findings for the Queen Conch in Colombia. NOAA Fisheries-Blue Dream Ltd (Eds.). San Andres Island, Colombia, 51.

Prada, M. C., Appeldoorn, R. S., Van Eijs, S., and Pérez, M. M. (2017). Regional Queen Conch Fisheries Management and Conservation Plan. FAO Fisheries and Aquaculture Technical Paper No. 610. Rome, FAO. 70.

Smikle, S. G. (2010). Pedro Bank queen conch fishery, assessment and TAC recommendation. Unpublished report of the Fisheries Division of Jamaica, Ministry of Agriculture.

Stoner, A. W. (1989). Winter mass migration of juvenile queen conch Strombus gigas and their influence on the benthic environment. *Marine Ecology Progress Series, 56,* 99–104.

Stoner, A. W., Sandt, V. J., and Boidron-Metarion, I. F. (1992). Seasonality in reproductive activity and larvae abundance of queen conch *Strombus gigas*. Fish BNOOA 90, 161–170.

Stoner, A. W., Ray, M., and Waite, J. M. (1995). Effects of a large herbivorous gastropod on macrofauna communities in tropical seagrass meadows. *Marine Ecology Progress Series, 121*, 125–137.

Stoner, A. W., and Ray-Culp, M. (2000). Evidence for Allee effects in an overharvested marine gastropod: Density dependent mating and egg production. *Marine Ecology Progress Series*, *202*, 297–302.

Taylor, E., Baine, M., Killmer, A., and Howard, M. (2013). Seaflower marine protected area: Governance for sustainable development. *Marine Policy*, *41*, 57–64.

Valderrama, D., and Anderson, J. (2007). Improving utilization of the Atlantic sea scallop resource: An analysis of rotational management of fishing grounds. *Land Economics, 83*(1), 86–103. http://www.jstor.org/stable/27647749.Wakeford, R.C., Agnew, D.J. and Mees, C.C. 2007. Review of institutional arrangements and evaluation of factors associated with successful stock recovery plans. CEC 6th Framework Programme No. 022717 UNCOVER. MRAG Report, March 2007. 58pp.

Wendling, Z. A., Emerson, J. W., Esty, D. C., Levy, M. A., de Sherbinin, A., et al. (2018). 2018 Environmental Performance Index. New Haven, CT: Yale Center for Environmental Law & Policy. https://epi.yale.edu/, doi: http://10.13140/RG2.2.34995.12328.

Worm, B., Hilborn, R., Baum, J. K., Branch, T. A., Collie, J. S., Costello, C., Fogarty, M. J., Fulton, E. A., et al. (2009). Rebuilding global fisheries. *Science*, *325*, 578–585.

Appendices

Appendix A

A.1 Output Indicators

The 68 output metrics, grouped within three indicators and 14 dimensions, identify and measure whether the fishery is delivering ecologically sustainable and socioeconomically viable results. The Triple Bottom Line (TBL) partitioning is represented as follows. The *Ecology* indicator groups a single dimension (Environmental Performance) and primarily captures disturbances in the marine ecosystem caused by the fishing activity. Fishing pressure, regulatory mortality, or poor handling, among others, may compromise the fishery's ability to generate sustainable outcomes. The *Economics* indicator groups six dimensions (Harvest, Harvest Assets, Risk, Trade, Product Form and Post-Harvest Assets) and measures whether the fishery is effectively generating economic benefits; it can also identify whether economic gains accumulate within the harvest sector through vessel profits and the value of permits or within the post-harvest sector in the form of processing capital. The *Community* indicator groups seven dimensions (Managerial Returns, Labor Returns, Health and Sanitation, Community Services, Local Ownership, Local Labor and Career) and captures the extent to which the fishery contributes to livelihoods, employment, income and other social benefits (i.e., access to health care and education) within its community (Anderson *et al*., 2015). In addition to the TBL partitioning, dimensions and metrics can also be arranged by fishery sector: *Stock Performance*, *Harvest Sector Performance* and *Post-harvest Sector Performance* (see Fig. 1 in Anderson *et al.* 2015 and Table A-1 in Appendix A).

A.2 Input Components

The 54 input metrics, grouped within five components and 15 dimensions, capture exogenous enabling conditions that may affect the output scores and management success in the fishery. The *Macro Factors* component groups four dimensions (General Environment Performance, Exogenous Environmental Factors, Governance and Economic Conditions) and reflects the institutional state of the country or region under evaluation. The *Property Rights and Responsibility* component groups two dimensions (Fishing Access Rights and Harvest Rights) aiming to measure the strength of property rights in the fishery. The *Co-management* component groups four dimensions (Collective Action, Participation, Community and Gender) and examines the role that local stakeholders play in determining the management of the fishery. The *Management* component groups three dimensions (Management inputs, Data, and Management Methods) and evaluates the fishery information system and its integration within the decision-making process. Finally, the *Post-Harvest* component comprises two dimensions (Market and Market Institutions, and Infrastructure) which evaluate whether the economic and physical infrastructure of the region enables the generation of sustainable livelihoods (Anderson *et al.* 2015).

Table A-1. Outputs Scores for the Colombian QC Fishery for 2018.

Dimension	Indicator	Measure	2018
Environmental Performance	Ecology	Proportion of Harvest with a 3rd Party Certification	1
	Ecology	Percentage of Stocks Overfished	1
	Ecology	Degree of Overfishing	2
	Ecology	Stock Declining	3
	Ecology	Regulatory Mortality	4
	Ecology	Selectivity	5
	Ecology	Illegal, Unregulated or Unreported Landings	3
	Ecology	Status of Critical Habitat	4
Harvest Performance	Economics	Landings Level	3
	Economics	Excess Capacity	1
	Economics	Season Length	3
	Community	Harvest Safety	5
Harvest Asset Performance	Economics	Ratio of Asset Value to Gross Earnings	1
	Economics	Total Revenue versus Historic High	1
	Economics	Asset (Permit, Quota) Value versus Historic High	1
	Economics	Borrowing Rate Relative to Risk-free Rate	2
	Economics	Source of Capital	2
	Economics	Functionality of Harvest Capital	3
Risk	Economics	Annual Total Revenue Volatility	4
	Economics	Annual Landings Volatility	5
	Economics	Intra-annual Landings Volatility	1
	Economics	Annual Price Volatility	5
	Economics	Intra-annual Price Volatility	2
	Economics	Spatial Price Volatility	4
	Community	Contestability & Legal Challenges	3
Owners, Permit Holders & Captains	Community	Earnings Compared to National Average Earnings	4
	Community	Fishery Wages Compared to Non-fishery Wages	4
	Community	Education Access	4
	Community	Access to Health Care	3
	Community	Social Standing of Boat Owners and Permit Holders	4
	Community	Proportion of Nonresident Employment	5

(continued on next page)

Table A-1 *(Continued)*

Dimension	Indicator	Measure	2018
Crew	Community	Earnings Compared to National Average Earnings	4
	Community	Fishery Wages Compared to Non-fishery Wages	3
	Community	Education Access	3
	Community	Access to Health Care	3
	Community	Social Standing of Crew	3
	Community	Proportion of Nonresident Employment	5
	Community	Crew Experience	5
	Community	Age Structure of Harvesters	2
Market Performance	Economics	Ex-vessel Price versus Historic High	3
	Economics	Final Market Use	4
	Economics	International Trade	1
	Economics	Final Market Wealth	2
	Economics	Wholesale Price Relative to Similar Products	3
	Economics	Capacity of Firms to Export to the US & EU	5
	Economics	Ex-vessel to Wholesale Marketing Margins	4
Post-harvest Industry Performance	Economics	Processing Yield	1
	Economics	Shrink	3
	Economics	Capacity Utilization Rate	3
	Economics	Product Improvement	1
	Community	Sanitation	4
	Community	Regional Support Businesses	3
Post-Harvest Asset Performance	Economics	Borrowing Rate Relative to Risk-free Rate	2
	Economics	Source of Capital	3
	Economics	Age of Facilities	2
Processing Owners & Managers	Community	Earnings Compared to National Average Earnings	5
	Community	Manager Wages Compared to Non-fishery Wages	4
	Community	Education Access	4
	Community	Access to Health Care	3
	Community	Social Standing of Processing Managers	4
	Community	Nonresident Ownership of Processing Capacity	3
Processing Workers	Community	Earnings Compared to National Average Earnings	3
	Community	Worker Wages Compared to Non-fishery Wages	3
	Community	Social Standing of Processing Workers	2
	Community	Education Access	3
	Community	Access to Health Care	2
	Community	Proportion of Nonresident Employment	5
	Community	Worker Experience	4

Table A-2. Inputs Scores for the Colombian QC Fishery for 2018.

Component	Dimension	Measure	2018
Macro Factors	General Environmental Performance	Environmental Performance Index (EPI)	3
	Exogenous Environmental Factors	Disease and Pathogens	4
		Natural Disasters and Catastrophes	4
		Pollution Shocks and Accidents	4
		Level of Chronic Pollution (Stock effects)	3
		Level of Chronic Pollution (Consumption effects)	4
	Governance	Governance Quality	3
		Governance Responsiveness	2
	Economic Condition	Index of Economic Freedom	4
		Gross Domestic Product (GDP) Per Capita	3
Property Rights & Responsibility	Fishing Access	Proportion of Harvest Managed Under Limited Access	4
		Transferability Index	1
		Security Index	2
		Durability Index	2
		Flexibility Index	1
		Exclusivity Index	2
	Harvest Rights	Proportion of Harvest Managed	4
		Transferability Index	1
		Security Index	2
		Durability Index	2
		Flexibility Index	1
		Exclusivity Index	2
Co-Management	Collective Action	Proportion of Harvesters in Industry Organizations	4
		Harvester Organization Influence on Fishery Management	3
		Harvester Organization Influence on Business & Marketing	3
	Participation	Days in Stakeholder Meetings	2
		Industry Financial Support for Management	2
	Community	Leadership	2
		Social Cohesion	3
	Gender	Business Management Influence	2
		Resource Management Influence	2
		Labor Participation in Harvest Sector	1
		Labor Participation in Post-Harvest Sector	3
Management	Management Inputs	Management Expenditure to Value of Harvest	2
		Enforcement Capability	3
		Management Jurisdiction	3
		Level of Subsidies	2

(continued on next page)

Table A-2. *(continued)*.

Component	**Dimension**	**Measure**	**2018**
Management	Data	Data Availability	2
		Data Analysis	3
	Management Methods	MPAs and Sanctuaries	4
		Spatial Management	3
		Fishing Mortality Limits	1
Post-harvest	Markets & Market Institutions	Landings Pricing System	3
		Availability of Ex-vessel Price & Quantity Information	2
		Number of Buyers	3
		Degree of Vertical Integration	2
		Level of Tariffs	4
		Level of Non-tariff Barriers	2
	Infrastructure	International Shipping Service	2
		Road Quality Index	2
		Technology Adoption	2
		Extension Service	3
		Reliability of Utilities/Electricity	2
		Access to Ice & Refrigeration	4