Ocean and Coastal Management 154 (2018) 20–25

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Implementation of a multiple indicator system for fisheries with limited information in a context of co-management, case study: Spiny lobster fishery in the Galapagos Marine Reserve

Jorge Ramírez-González[a,*], Gonzalo Banda-Cruz[b], Jerson Moreno[b], Dan Ovando[c], Harry Reyes[d], Patricia Rosero[d], Isabel Timpe[d]

[a] WWF Ecuador, Piqueros y 18 de febrero S/N, Puerto Ayora, Galápagos, Ecuador
[b] Conservation International Ecuador, ZIP CODE/170515, Casilla Postal 17171388, Ecuador
[c] Bren School of Environmental Science and Management Santa Barbara, University of California Santa Barbara, Santa Barbara, 93106-5131, CA, USA
[d] Dirección del Parque Nacional Galápagos, Av. Charles Darwin s/n, ZIP CODE 200102, Puerto Ayora, Galápagos, Ecuador

1. Introduction

Little or limited information in fisheries is a frequent barrier to solve in order to achieve sustainable management of fisheries resources. A considerable number of fisheries in the world have this data-limited characteristic (Vasconcellos and Cochrane, 2005; Costello et al., 2012), particularly small-scale fisheries (Smith et al., 2009). There are already several approaches, methodologies and applications to avoid the limited information barrier in fisheries (Carruthers et al., 2014; Dowling et al., 2014; Newman et al., 2014); but there are scarce cases and discussions of designing management systems for fisheries with limited information that have become public politicies (Dowling et al., 2015).

McDonald et al. (2014) have been among the few authors who have documented the process of implementing a fisheries management system with limited information, from the design to the application in public policy. They propose an Adaptive system of multiple indicators and reference points (ASMIPR) with a focus on fishermen's participation. This system is a nine-step cycle: 1) Definition of objectives; 2) Identification of target species; 3) Identification of indicators; 4) Identification of reference points; 5) Definition of management rules for the fishery; 6) Collection and analysis of information; 7) Calculation of performance indicators and reference points; 8) Interpretation of results and; 9) Adjustment of fishery management measures. The authors describe this system using the shellfish and lobster fishery in Belize as a case study.

The spiny lobster fishery in the Galapagos Marine Reserve (GMR), according to a definition by Dowling et al. (2015) is a "limited information" fishery one. That is to say, it has data on effort and capture, but the analysis of its populations presents much uncertainty (Szuwalsky et al., 2016), but there are other sources information, such as maturity, fecundity and mortality (Hearn, 2004; Hearn and Murillo, 2008; Hearn and Toral-Granda, 2007) to know the lobster status in GMR.

Within the GMR only artisanal fishing is allowed by local fishermen and since 1998, the GMR has officially used co-management as its fisheries governance system (Castrejón, 2011). The fishery was overexploited until 2012, when it began to recover; finally, in 2014 it was declared healthy (Reyes et al., 2012; Dirección del Parque Nacional Galápagos, 2015). During this period, authorities and users agreed to initiate the design and implementation of an ASMIPR to ensure the recovery of the fishery capable.

This article compares the proposal of ASMIPR implementation by McDonald et al. (2014) with the implementation experience in the spiny lobster fishery in the GMR since both application contexts are very similar: Both the Belize case study from McDonald et al. (2014), and the GMR example profiled here, are small-scale fisheries targeting similar species with similar socio-economic situations and with the active participation of fishermen in management decision-making. The aim of this paper is to analyze challenges, similarities and differences between these two case studies, providing a reference for the implementation of ASMIPR in other fisheries with limited data.

2. Implementation of ASMIPR in the spiny lobster fishery in the GMR

This section describes the implementation of ASMIPR in the spiny lobster fishery in the GMR using the nine-step cycle proposed by McDonald et al. (2014). Besides, a section was added to analyze the implementation of ASMIPR within the particular context of co-management in the GMR.

2.1. Definition of objectives

The objectives of ASMIPR responded to the justification of its

* Corresponding author.
E-mail addresses: jorge.ramirez@wwf.org.ec (J. Ramírez-González), gonzalo.bandacruz@gmail.com (G. Banda-Cruz), j.Moreno@conservation.org (J. Moreno), dovando@bren.ucsb.edu (D. Ovando), hreyes@galapagos.gob.ec (H. Reyes), pattyrosero@gmail.com (P. Rosero), mitimpe@hotmail.com (I. Timpe).

https://doi.org/10.1016/j.ocecoaman.2017.12.027
Received 12 April 2017; Received in revised form 13 December 2017; Accepted 25 December 2017

implementation on the spiny lobster fishery in GMR. There was the necessity to achieve the objectives of the Galapagos National Park Directorate (GNPD) management plan for GMR fisheries. The general objective of this plan is: "To ensure the sustainable development of the fisheries and the fishing sector in the GMR"; and the particular objectives for the spiny lobster fishery are:

Biological: To recover the abundance of lobster populations, ensuring a healthy population structure.
Economic: To improve the economic profitability of the lobster fishery in a long-term.
Social: To contribute to the improvement of the life quality of fishermen and their families.
Governance: to strengthen the participation of the artisanal fishing sector and the capacity of the GNPD, and other relevant institutions in the co-management of lobster resource.

Another justification was to improve the spiny lobster fishery management, knowing its stock status. In 2012, 2013 there was an unexpected increase in catches of this resource in the Galapagos and the total allowed catch was fulfilled before the closure of fishery. During these years, the lobster fishery was declared as in recovery (Reyes and Ramírez, 2013; Dirección del Parque Nacional Galápagos, 2014). However, there was a need for the GNPD, fishermen and other stakeholders, to know the actual status of the spiny lobster populations and to seek an alternative management for the fishery that would not be based only on total allowed catch and fishing season.

Therefore, the ASMIPR had the following objectives: 1) to meet both general and particular objectives for the lobster fishery in the GMR established in the FC; 2) to know the actual status of lobster populations and; 3) to adapt the management system for this fishery.

2.2. Identification of target species

The spiny lobster fishery is one of the most important in the GMR, often being the most important local fishery in terms of catches and economic income (Reyes et al., 2012; Dirección del Parque Nacional Galápagos, 2014; Dirección del Parque Nacional Galápagos, 2015; Dirección del Parque Nacional Galápagos, 2016). After the collapse of the sea cucumber fishery in Galapagos in 2005, lobster became the main fishery in Galapagos due to the income it generated (Castrejón, 2011). In 2012, 2013, there was an upsurge in the commercial interest and catches of pelagic fish (yellowfin tuna *Thunnus albacares* and swordfish *Xiphias gladius*), placing this newer finfish fishery in competition for first-place in terms of economic importance with the spiny lobster fishery (Ramirez and Reyes, 2015). Currently, the spiny lobster fishery remains one of the most important in Galapagos.

The identification of the target species was very simple because, prior to the creation of the GMR, the spiny lobster fishery had been differentiated from the rest by having its own characteristics such as: fishing zones, fishing season, fishing method, etc. The two fished spiny lobster species in the Galapagos are: red lobster (*Panulirus penicillatus*) and green lobster (*Panulirus gracilis*).

2.3. Identification of indicators and reference points

The indicators and reference points for spiny lobster in the GMR were identified simultaneously, for this reason they are described in the same section and not separately as indicated by McDonald et al. (2014).

Due to the high uncertainty regarding the red and green lobster population status in the Galapagos, rather than choosing a single indicator, a system of multiple indicators and reference points capable of determining if the resource is in healthy, recovery or critical (overexploited) status was selected. Since both spiny lobster species have different biological parameters and the red lobster has more known biological information (growth, mortality, sexual maturity, fecundity) than the green lobster, the indicators and reference points are differentiated for each species. There are three indicators described for the red lobster and one indicator for the green lobster, as explained below.

Table 1
Indicators, reference points, population status and indicator performance methodologies for red and green spiny lobster in GMR. ∗Applies only for red spiny lobster.

Indicator	Reference points	Population status	Indicator performance methodology
CPUE	Positive trend in last five years	Healthy	Standardized CPUE
	Does not apply		
	Negative trend in last five years	Critical	
Mortality (F/M)*	< 1	Healthy	Catch Curve
	≤ 1.5 and ≥1	Recovering	
	> 1.5	Critical	
Spawning potential Ratio*	> 40%	Healthy	Length Based Spawning Potential Ratio
	≥20% and ≤40%	Recovering	
	<20%	Critical	

In order to calculate the performance of each indicator, methodologies for fisheries with limited information were proposed (Table 1). Debevec et al. (2014) detail the methodologies for identifying and calculating indicators and reference points for mortality and spawning potential ratio of the red lobster. The reference points and performance methodologies of CPUE for red and green lobster are detailed in the Fisheries Technical Commission (2014).

It is important to mention that at the beginning the catch was included as an indicator while the maximum sustainable yield (MSY) and the maximum economic yield (MEY) were considered as reference points. However, there was much uncertainty in the performance calculations of this indicator. For example, applying surplus production models, the MSP fluctuated between 123 Ton. (Fox model) and 106 ton (Schaefer model) on the red lobster (internal data GNPD); and using robust models the MSP reached up to 181 tons for this same species (Dirección del Parque Nacional Galápagos, 2015). So, direct calculation of MSY and associated reference points was deemed unfeasible in that moment. Therefore, experts of the Fisheries Technical Commission recommended to focus on CPUE and two length-based assessment methods, as indicators of fishery health.

2.4. Definition of management rules for the fishery

Another argument to support the decision to use multiple indicators is that, it reduces uncertainty and increases confidence relative to use only one indicator (McDonald et al., 2014).

The Fishing Technical Commission of the Participative Management Board (PMB) developed a first proposal of management rules and it consisted on decision recommendations for each status of the resource (healthy, recovering and critical) for each indicator (CPUE, fishing mortality, and spawning potential ratio). Each decision recommendation had a logic regarding the indicator; for example, if the spawning potential ratio is in critical condition, one recommendation is not to capture large-sized females to protect the so-called mega breeders, which means, those females capable of producing many more eggs than smaller, recently matured females.

Subsequently, this proposal was socialized with the fishermen of Galapagos for their feedback. There was no consensus among fishermen on two decision rules (mortality and critical spawning potential ratio), the disagreements were enlisted, and it was agreed that the recommendation for these decisions would be made when the case would be presented. The final matrix of ASMIPR decision rules for spiny lobster in the GMR is shown on Table 2.