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Improving stock assessment and management advice for data-poor small-scale fisheries through participatory monitoring

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ABSTRACT

Undetected but underlying biases in model parameterization strongly reduce the reliability and value of assessments of data-poor fisheries. We explore the effects of missing and misunderstood data on single-species stock assessments used to provide management advice. From 2006 to 2014, the Colombian government monitored landings of small-scale fisheries. During the same period, communities implemented a participatory monitoring program in the Central Guajira region. We found that the two data sources gave different results for the population status of the highest-valued fish, lane snapper (*Lutjanus synagris*), and the largest-landed species, white grunt (*Haemulon plumierii*). Recordings of landing points by the government monitoring program led to year-to-year underestimations and therefore misconceptions regarding population status and fishery trends. Overexploited and underexploited population statuses were seen to arise from the same fishing pressure as a result of the interplay between natural mortality and erroneous estimates of fishing mortality. The tested von Bertalanffy growth parameters affected the exploitation level, but not the population status, of the species. When data from the participatory monitoring program were incorporated, higher landings and a more severe overfishing trend emerged for both species. The management scenarios simulated using the best verified data available provided reasonable advice for recovering the lane snapper and white grunt populations. Furthermore, simulation of management measures sustained the employment and incomes of fishers. Our findings indicate that participatory monitoring should be incorporated into the assessment and management of data-poor resources.

1. Introduction

Most of the world's fish stocks are either lacking sufficient information or already depleted (Costello et al., 2012; Worm and Branch, 2012). This situation is critical because a large proportion of fisheries are located in developing regions, where increased demand for food and employment coincides with a weak control of fish stocks (Salas et al., 2007). Therefore, suitable integration and interpretation of available data on fisheries and stock status are key challenges. Both the quantity and quality of data on effort, landings and catch composition are important for assessing data-poor resources (Chen et al., 2003; Omori et al., 2016). Having fewer, but more reliable, fishery-dependent data could allow limited, but more robust, management advice to be provided for some species. Conversely, misconceptions of the real scope of available data may lead to misleading estimates of the historical and current pressures on fisheries.

The assessment of fisheries involves dealing with several sources of uncertainty (Scott et al., 2016). These uncertainties are usually interwoven with the underlying bias of the fishery model assumptions for evaluating target species in data-poor conditions (for instance, steady state; Rätz et al., 2010). Performing sensitivity tests and using the "Robin Hood" approach, which borrows data from the most reliable and related stocks, are recommended for improving model parameterization (Carruthers et al., 2014; Kokkalis et al., 2015). However, data-poor fisheries are challenged by unreported catches (Salas et al., 2007; Zeller and Pauly, 2007), leading to unpredictable estimates of trends in stock size and fishing effort (Omori et al., 2016). Consequently, misconceptions of the

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definition of fishing mortality result in highly risky results (Thorson and Prager, 2011), usually matched by a biased estimate of the life-history parameters of the studied targets from fishery-dependent data. This bias stresses the importance of "correctly" estimating natural mortality (Clark, 1999; Kenchington, 2013). Therefore, cumulative bias from multiple sources can magnify the uncertainty associated with the single-species stock assessment of data-poor fisheries (Smith et al., 2009).

The limitations of data-poor assessments appear to be sufficiently identified but poorly addressed. This occurs because stock assessment involves parameterizing a model, but the inputs cannot be verified in a data-poor context. Frequently, unverified information is the starting point for trying to improve the available data. For instance, the reconstruction of landings does not usually consider the impact of fishing effort 1) among fleets, 2) on landing points, or 3) on changes in fishing regime (Lindop et al., 2015; Wielgus et al., 2010; Zeller and Pauly, 2007). Thus, reconstruction of landings is based on several assumptions whose validation is often impossible (Chen et al., 2003).

To address these issues, we take as a case study the Amerindian Wayuu fishery located in La Guajira in the Colombian Caribbean. While it is recognized that fishery landings in the Central Guajira occur at many points along the 90-km stretch of coastline (Manjarrés, 2004), from 2006 to 2014, the government monitoring program (GOV) and subsequent management advice focused exclusively on urban areas (CCI, 2006; Puentes et al., 2014). During the same period, the Wayuu people conducted a participatory monitoring program (PAR) to record catches at most landing points, including urban and rural ones.

We explored the reliability of advice derived from single-species stock assessment for this data-poor fishery. To this end, we studied the performance of stock assessment associated with the official data provided by the GOV as a single entity and combined with the PAR data. We distinguish between fisheries with unverified data, also known as "data-random" fisheries, which can lead to misleading advice, and "data-poor" fisheries, in which the available data are optimized (Bentley, 2015).

The Wayuu fisheries are multi-species and multi-gear (Puentes et al., 2012). However, we selected the white grunt, *Haemulon plumierii,* the most important demersal species according to the landings, and the lane snapper, *Lutjanus synagris*, which fetches the highest market price among fish (CCI, 2006; Manjarrés, 2004), for this study. These two species are of great interest to Wayuu fishers, as the lane snapper covers income expectations and the white grunt meets social and food demands (J. Ramirez Pers. Comm.). We studied the effect of the GOV and PAR on the inputs of the length-based stock assessment models for both species (Lleonart and Salat, 1997; Rätz et al., 2010). Here, we paid special attention to the impact of the reported landings, von Bertalanffy growth parameters (*vBGP*), and natural mortality (M) (Abella et al., 1997; Gislason et al., 2010; Kenchington, 2013). Stock assessments of the lane snapper and white grunt were performed using population analysis based on the interaction among gear over a limited time series. Finally, we analyzed several management scenarios aimed at achieving a sustainable fishery for both species in parallel. The harvesting sizes, fleet deployment, catch volume, food security and incomes of local communities were taken into account in the development of the management simulations.

2. Methods

2.1. Study area

La Guajira is the northernmost region of South America (Fig. 1). Its central area has a wide and shallow continental shelf influenced by upwelling (Andrade and Barton, 2005; Sarmiento-Devia et al., 2013). These conditions promote high fishing activity (Manjarrés, 2004). Artisanal fisheries are dominant in the area, whereas trawl and larger long-line fleets are scarce (CCI, 2010; Zuñiga et al., 2004).

2.2. Data collection

The GOV database provided total landings by day from 2006 to 2011, but not the number of vessels. From November 2012 to July 2014, daily landings and the number of vessels were recorded. Throughout the study period, the catches of all vessels that arrived at five urban landing points in the Central Guajira were recorded (CCI, 2006). Data collection for the target species included the length frequency and macroscopic definition of maturity (CCI, 2006). For lane snapper, this information was only available in 2013. Little biological data for white grunt were collected because this species is not prioritized in the official fisheries advice (Barreto and Borda, 2008; Puentes et al., 2014).

A participatory monitoring program implemented by a local non-governmental organization (Fundación Ecosfera) and the Wayuu people was conducted during the same period. Through the participation of 19 communities, information from 85,347 daily trips (2006–2014) was recorded, based on over 18 rural and 3 urban landing points. The trained members of each community randomly collected landing data on four days a week. The total landings by species from the PAR were estimated using a daily raising factor – the number of sampled to unsampled active vessels. Additionally, the PAR collected length frequencies and maturity information for white grunt and lane snapper in 2010.

2.3. Data treatment

2.3.1. Landings reconstruction

Interpolation from reliable data was used to fill the gaps in landings for which the period and landing point were missing, following the methodology established by the Sea Around Us Project (Zeller and Pauly, 2007). Three landing points in urban areas, sampled at the same time by both the government and participatory monitoring programs, were used to determine the degree to which landings in urban areas were underestimated. The total landed catch and selectivity pattern by gear of both species were calculated separately for the GOV and the PAR. Because daily landings by each vessel were not available for the GOV from 2006 to October 2012, the catch per unit effort (*CPUE*) was annually calculated from total landings and active vessels by fleet. Additionally, by combining the available length frequencies and landings by fleet, we were able to estimate the average size of the fish caught per year.

2.3.2. Life-history parameters

The *vBGP* were estimated using a non-linear model fit to the modal progression data with the Bhattacharya method, the selected asymptotic length (L_∞) and the growth constant rate (k) according to the FISAT II routines (Gayanilo et al., 2005; Pinheiro et al., 2015). The *vBGP* of lane snapper were obtained from the encircling gillnets (n = 1271) of the GOV in 2013. Using data from the bottom gillnets (n = 541), long-lines (n = 1055) and encircling gillnets (n = 99) of the PAR, an additional set of *vBGP* were calculated. In the case of the white grunt, length frequencies were only available from the PAR study. Here, bottom gillnets (n = 977), long-lines (n = 181) and encircling gillnets (n = 15) provided the data to estimate the *vBGP*.

The *vBGP* calculated from fishery-dependent data on a population subjected to strong exploitation are probably biased (Then et al., 2015). We therefore explored several growth parameters for lane snapper derived from the literature (Acosta and Appeldoorn, 1992; Barreto and Borda, 2008; Frédou et al., 2009; Gómez et al., 2001; Johnson et al., 1995; Leite et al., 2005; Luckhurst et al., 2000;