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Detecting a need for improved management in a data-limited crab fishery

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ABSTRACT

A majority of fisheries worldwide lack effective management because of poor quality data and limited resources. Data-limited stock assessments are increasingly used where model-based, data-rich approaches are not possible. However, their widespread use is constrained by several important limitations, especially the inability to estimate biomass or maximum sustainable yield (MSY)-based reference points. Here we applied several data-limited stock assessments and utilized expert opinion to identify early warning signs of depletion in the rapidly growing Southern California (CA) rock crab fishery, a small scale yet economically valuable fishery being managed with relatively limited information. We chose our specific assessment methods with the aid of a decision support tool (FishPath) designed to help identify context-appropriate options for assessing and managing fisheries. Results of five assessments indicated that serial depletion, regional overfishing, and effort creep may be occurring in the rock crab fishery. Expert opinion regarding changes in fishery operations and fishing effort provided vital insights for interpreting assessment results. We illustrate a general path for enhancing understanding of fishery impacts in a data-limited fishery, and sound rationale for proactive management to address warning signs of overfishing in the southern CA rock crab fishery.

1. Introduction

Conventional stock assessments estimate maximum sustainable yield (MSY)-based reference points for management by fitting a population model to a time series of fishery-dependent and -independent data (Carruthers et al., 2016; Dowling et al., 2016). Fisheries managed using conventional stock assessments are, with a few exceptions, large-scale, data-rich, and relatively well-managed (Hilborn and Ovando, 2014). Such characteristics describe about 10% of global fisheries, while 90% of the world's fisheries are small-scale, and lack the data and resources needed to perform conventional stock assessments (Costello et al., 2012; Worm and Branch, 2012; Carruthers et al., 2014; FAO, 2016). Poor management of these data-limited fisheries threatens hundreds of millions of people who rely on sustainable fisheries for protein intake and employment (FAO, 2016).

Relatively simple quantitative and sometimes qualitative assessments can help in data-limited situations by elucidating trends in catch, effort, or proxy indicators of stock status, without quantifying traditional biomass-based reference points (Kruse et al., 2005; Dowling et al., 2015; Quinn et al., 2016). Simulations indicate that data-limited assessments can lead to better management results than conventional, data-rich methods when paired with context-specific monitoring and decision rule protocols (Geromont and Butterworth, 2015; Carruthers et al., 2016). However, data-limited methods can also lead to poor management outcomes, especially when based on inadequate data or relying on an inappropriate type of assessment (e.g., Carruthers et al., 2014; Free et al., 2017). Applying multiple data-limited assessments that use a variety of data streams may be more suitable than selecting a single assessment type that may not be appropriate, or the results of which demonstrate even moderate uncertainty (Carruthers et al., 2014; Berkson and Thorson, 2015). For example, Carruthers et al. (2014) demonstrated poor performance of assessments that used catch data only, but stressed the high value of adding information about historical fishing effort or depletion levels to improve assessment performance.

The use of several independent yet complementary methods may improve the ability to make informed decisions under certain circumstances. For example, Lindegren et al. (2012) suggested that multiple methods be used to diagnose early warning signs of ecological regime shifts because ecosystems are unique, the performance of individual diagnostic tools are context-dependent, and a suite of results provides the most robust information. Using multiple data-limited assessments is realistic for many fisheries because these methods are often designed to be easily understood and implemented in diverse socioeconomic and governance settings, usually require few resources, and are emerging as

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pre-packaged, management-focused computer applications (Dowling et al., 2016). Consideration of multiple assessment outputs and the patterns they suggest may serve as a means to direct management guidance in a proactive manner (Prince et al., 2011).

Selecting the appropriate assessments from the wide variety of available data-limited methods is often a challenging and subjective process (Dowling et al., 2016). Navigating the universe of options can be daunting without a thorough understanding of the available methods, including input requirements and associated caveats and assumptions. FishPath (Dowling et al., 2016) – a newly developed decision support platform designed to facilitate the selection of appropriate assessment and management approaches for data-limited fisheries – can help users identify those methods that may be most applicable to their fishery. FishPath is a repository of information that catalogues data requirements and assumptions of more than 50 assessment methods to help users identify an appropriate assessment methodology for use. The tool does not prescribe a specific way to monitor, assess, or manage a fishery, nor does it perform assessments. Rather, it serves as an organizational framework to streamline the process of selecting appropriate methods. We used FishPath to identify a select set of data-limited assessment approaches for the rapidly growing Southern California (CA) multispecies rock crab fishery in the United States (US). We applied these methods to aid stakeholders and managers in understanding the impacts of fishing on the resource and to begin the process of developing management guidance.

Our primary objective was to explore whether data-limited rock crab stocks in southern CA are threatened with overfishing. Studies of crab and other fisheries have focused on detecting overfishing, but the methods developed to date have largely been data-rich or model-based (Myers and Quinn, 2002; Orensanz et al., 2005). Here, we systematically selected an array of data-limited assessments, applied them to data streams already collected by the state, and identified early warning signs of overfishing in the previously unassessed multispecies CA rock crab fishery. The process identified here and the results of this work provide managers and stakeholders with a foundation for being proactive in the face of uncertainty without a need for technical and resource intensive assessment approaches. We do not suggest that data-limited assessment should immediately translate into regulatory action, rather that our process stimulates informed decision making regarding how to monitor, assess, and manage a fishery. The guiding principles of fishery management law at US state and federal levels call for such approaches, dictating that management be based on the best available scientific information, and that action should not be significantly delayed by lack of information or high levels of uncertainty (CDFW, 2001; MSFCMA, 2007). We encourage similar processes be undertaken for small-scale data-limited fisheries worldwide.

2. Methods

2.1. Study system: Southern CA rock crab

The Southern CA rock crab fishery targets male and female red (*Metacarcinus* or *Cancer productus*), yellow (*Metacarcinus* (formerly *C.*) *anthonyi*), and brown (*Romaleon antennarium* (formerly *C. antennarius*)) rock crab. The fishery primarily operates within the Santa Barbara Channel (SBC) coastal marine ecosystem, which covers an area of several thousand square kilometers and includes coastal stretches of mainland CA and the Northern Channel Islands (Fig. 1). Small-scale, state-managed fisheries such as rock crab often operate without harvest control rules that adjust catch or effort in response to assessment outputs (Larinto, 2013). The CA Department of Fish and Wildlife (CDFW) oversees all aspects of management for CA rock crab including permitting, enforcement, and recommendations for decision makers. CDFW manages rock crab by restricting the number of available southern CA permits and enforcing a statewide size limit of 108 mm. However, rock crab growth rates and maximum sizes vary with species, sex, and location, so the size limit is of unknown efficacy for each individual species and there is no other catch or effort restriction for permit holders (Carroll and Winn, 1989; Culver et al., 2010). Mating and molting cycles, recruitment, and life history traits of rock crab are also poorly understood, especially as they vary across the steep gradient of marine productivity in the SBC (Wilson et al., 2012).

The CA rock crab fishery is subject to data collection protocols, but not at levels sufficient to generate information that can inform estimates of biomass or MSY. Consequently, the fishery has never been assessed, rapid fishery growth in recent years has created the potential for overfishing, and the fishery is managed via a single size limit despite being multispecies and spatially structured (Parker, 2003; Culver et al., 2010). Many crab fisheries worldwide, both data-poor and data-rich, have suffered from overcapacity and serial depletion when managed under size, season, and sex-based methods, despite comprising a multibillion dollar annual global industry (Orensanz et al., 1998; Fina, 2005; Salomon et al., 2007; FAO, 2016). Notoriously large uncertainties surround model-based estimates of biomass or MSY for many crab fisheries – even with robust data – because of difficulties in aging individuals, variable incremental growth patterns, strong spatial population structure, and pervasive environmental influences on model parameters, including estimates of recruitment and natural mortality rates (Orensanz and Jamieson, 1998; Zheng, 2005; Punt et al., 2013; Szuwalski et al., 2015). Our application of data-limited assessments to detect signs of overfishing without estimating MSY aims to provide a suitable foundation for management that maybe beneficial to CA rock crab and other data limited crab fisheries worldwide.

The only long-term data for the CA rock crab fishery are commercial landing receipts that collect total landings by 10 sq. nm “blocks”. Landings receipts do not provide effort data and did not distinguish between species until 1995, and the majority of catch for all three species was still recorded as a single category called “unspecified rock crab” until 2010 (Parker, 2003; CDFW, 2015). Rules adopted in 2004 capped the number of southern rock crab trap permits and provided no mechanism for entry of new participants. Rule changes in 2010 then allowed transfer (sale) of permits at a rate of five per year. Signs of a related increase in fishing intensity included a near doubling of landings from 2010 to 2014, with over 2000 metric tons (MT) of rock crab sold for $6.845 million USD in 2014–15 (CDFW, 2015). The fishery then closed in November of 2015 due to a domoic acid outbreak. The closure lasted two months along the mainland SBC coast and five months for most of the Channel Islands, which affected fishing effort to an unquantified degree (CDFW, 2016). Some fishers in interviews reported seeing smaller and fewer crab in their traps than in past decades, and unpublished data showed that catch rates and crab sizes were lower in fished areas than in adjacent Santa Monica Bay, where commercial crabbing had been disallowed for decades (Parker, 2003, personal communication). We compiled all existing information on the rock crab fishery (Table S1) by interviewing fishers, scientists, and managers, reviewing available literature, and organizing landing receipt data from 1970 to 2015 (CDFW, 2015). We focused on the period of 1970–2015 to avoid the confounding impact of the fishery closure, but we also obtained a summary of total landings in 2016 and preliminary total landings in 2017 (CDFW, 2017). We used four types of data in our analyses: total landings, spatial distribution of catch, and species composition of catch (from landing receipts) as well as expert opinion regarding market demand and fishery operational characteristics.

2.2. Data-limited assessment of CA rock crab

We identified and performed five data-limited assessments to explore early warning signs of overfishing in the CA rock crab fishery after considering over 40 published methods (Dowling et al., 2016).These five methods (and > 40 others) are catalogued in FishPath with their associated data requirements, limitations and assumptions. FishPath is designed to help stakeholders and managers identify potential