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What fishers' local ecological knowledge can reveal about the changes in exploited fish catches

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ABSTRACT

This study focuses on a small-scale fishing community which primarily exploits fish in Tijucas Bay (Santa Catarina State, Brazil). The region is near a marine protected area and is also exploited by the industrial fishing fleet and shrimp fishers, however there is a lack of baseline and monitoring data about fisheries. We aimed to understand aspects of the historical dynamics of catches exploited by small-scale fishers and investigate their causes, through local ecological knowledge. We focused on four main target species: ***Genidens barbus***, *Micropogonias furnieri*, *Macrodon ancylodon* and *Mugil liza*, which are the most important species targeted by fishing communities in the study area. We used face-to-face individual interviews with 34 fishers to identify changes in the current and past catches based on fishkners' perceptions. The current catches were smaller than the best previous catches for all species, suggesting a decline in catches. The perceived causes for the decline in catches were the industrial fishing, the shrimp trawling bycatch, and the overall increase in fishing effort. Fishers' owledge has proved to be an important complementary tool in the monitoring of catches. Management actions are needed to overcome this trend in declining local fish catches and to ensure the livelihoods of small-scale fishers.

1. Introduction

The small-scale fisheries are the major supplier of seafood to coastal and inland communities of developing countries (Pauly, 2006). For those people, fish is the major animal protein source and essential to food security (Dey et al., 2005). The advent of large-scale commercial fishing, combined with small- and medium-scale fishing, and other activities related to urban and industrial expansion, has contributed to the decline in marine resources (Jackson, 2010; Stewart et al., 2010). Globally there is a depletion trend in stocks, caused by overfishing (Pauly and Zeller, 2016).

Fishers have a comprehensive knowledge of the exploited species and can provide valuable information in data-less management scenarios (Ramires et al., 2007). Fishers' knowledge can also help fill gaps in knowledge of fish stocks (Patterson, 2010). In the assessment of fish stocks, the perception of fishers may also prove more accurate than methods traditionally used such as catch sizes and visual census (Daw et al., 2011). Fishers' knowledge is also useful in revealing important information about the resources that often has not been identified by researchers (Neis et al., 1999). Integration of fishers' knowledge in the fish stocks assessments is still challenging (Johannes et al., 2000; O'Donnell et al., 2010a; Daw et al., 2011). The difficulty in accepting the use of the knowledge of fishers in assessing fish stocks is due to the need for time series data and rigid statistical testing approaches that are often not applicable to this kind of knowledge (Johannes and Neis, 2007). Therefore, for proper implementation of local ecological knowledge, it is necessary to develop a broad understanding of the fishing community, including their beliefs and their socio-economic context (Aswani, 2010). Additionally, a better understanding of the psychological aspects of memory and perception of fishers is required (Daw, 2010). Local ecological knowledge of fishers should be probed with the same analytical rigor to that given to other sources of information. Methods to quantify and fix biases of local knowledge are required, despide of been frequently influenced by the context of the region (O'Donnell et al., 2010b). However, the low accuracy or even the bias can also affect the perception of scientists (Daw et al., 2011). The existence of this bias does not discredit local knowledge, but it emphasizes the need for a cautious analysis (O'Donnell et al., 2010b; Patterson, 2010). Interviews using quantitative methodological approaches can contribute to the available data for understanding the decline of fish species over time (Lima et al., 2016), provide information about the history of changes in the local ecosystems (Patterson,

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2010), and overcome the lack of data in landings for small-scale fisheries (Damasio et al., 2015).

Most Brazilian target species are overexploited (Isaac et al., 2006). In the Southeast and South coastal regions, where most of the Brazilian large-scale fishing is concentrated, there are no identified resources able to sustain new fisheries (Brasil, 2006). However, contrary to what scholars suggest (Sumaila et al., 2010; Anticamara et al., 2011), the Brazilian government continues subsidizing the development of the fishing sector instead of investing in appropriate fishery management (Abdallah and Sumaila 2007).

Santa Catarina State, one of the largest domestic fish producers, has a large and diversified fleet (Sunye, 2006). The region contributes about half of Brazil's commercial fishing yields (MPA, 2011) and large-scale fishing accounts for 92% of the total landed volume in Santa Catarina (Vasconcellos et al., 2007). In the 1990s, the collapse of the sardine *Sardinella brasiliensis* fishery led purse seine vessels to target other pelagic resources, such as Atlantic thread herring *Opisthonema oglinum*, Atlantic bumper *Chloroscombrus chrysurus*, mackerel Scombridae, and mullet *Mugil liza*, as well as demersal resources, such as croaker *Micropogonias furnieri* and catfish *Genidens* spp. (Occhialini and Schwingel, 2003). The redirection of fishing efforts to new targets without regulation also led to overexploitation (Haimovici et al., 2006), raising conflicts with small-scale fisheries that traditionally exploited these species (Sunye, 2006). This is the case in Tijucas Bay, located in the central coastal region of Santa Catarina, with a conglomeration of villages and households highly dependent on fish for food and income (Martins et al., 2014; Sousa et al., 2016).

Our focus relied on four species: the white catfish, *Genidens barbus*; whitemouth croaker, *Micropogonias furnieri*; king weakfish, *Macrodon ancylodon;* and mullet, *Mugil liza*, which are the most important species targeted by fishing communities included in the study region. The species are targeted for small-scale and commercial fisheries along south and southeast Brazilian coast, specially gillnet fishing, trawlers, purse seines and also beach seines but just for the mullets (Herbst and Hanazaki, 2014; Queirolo et al., 2016; Haimovici et al., 2016; Arana et al., 2016; Lemos et al., 2016). Given the vast knowledge of small-scale fishers on the exploited resources, this study aimed to understand aspects of the historical dynamics of catches exploited by small-scale fishing in Tijucas Bay and investigate their causes using local ecological knowledge.

2. Material and methods

2.1. Study area

Tijucas Bay is located on the central coast of Santa Catarina State in southern Brazil and includes the estuary of the Tijucas River (Fig. 1). The bay comprises a mosaic of coastal and marine ecosystems and is in the buffer zone of a marine protected area (MPA), the Marine Biological Reserve of Arvoredo (IUCN Category Ib, Dudley, 2008). Eight fishing communities surround the bay, three of which were investigated: Barra do Rio, in the municipality of Tijucas; Canto dos Ganchos, in the municipality of Governador Celso Ramos; and Santa Luzia, in the municipality of Porto Belo. These communities were selected as are the ones with most involvement with fish, in terms of catches volume and livelihoods dependence (UNIVALI, 2008; Medeiros, 2009; Sousa et al., 2016). The small-scale fishing activity is mainly practiced within the bay with gillnets and small size boats and no technological equipments such as GPS (Global Position System) or sonars (Martins et al., 2014).

2.2. Data collection and analysis

Data collection occurred between June 2010 and September 2011, after preliminary visits for familiarization with the study area and to meet local leaders to present the project and to obtain formal consent for the research. We initially interviewed fishers presented by the leaders and then interviewed fishers they suggested, following the snowball methodology (Bernard, 2006).

We interviewed 34 fishers (24 from Barra do Rio, six from Santa Luzia and four from Canto dos Ganchos), representing 85% of fishers in the three communities. Not all fishers were experts in fishing for all species, and therefore only responded for those species they had experience with. Of this total, 32 fishers answered the survey about *G. barbus*, 31 about *M. furnieri*, 22 about *M. ancylodon* and 26 about *M. liza*. Fishers were asked about their best historical catch (the so-called "*best catch*") represented by the highest amount captured (in kg) in a day of fishing in a given year for a given target species. We also asked about the best daily catch (so-called "*current catch*"), or the highest amount captured (in kg) in a day of fishing for a given target species in the year they were interviewed. We are assuming that the gears used in the past were similar to those currently used, since the fishers could not give this information with accuracy. We then asked if they considered that the catches were increasing or decreasing over the years, followed by an open-question of the perceived causes for these variations, with all the given causes registered. Fishers were twice interviewed, since the surveys were timed to coincide with the seasonal availability of each target species: November to March for *Genidens barbus* and *Micropogonias furnieri,* and from June to September for *Macrodon ancylodon* and *Mugil liza*.

The variable *best catch* was modelled using Generalized Additive Models—GAMs (Wood, 2006) (Table 1). GAMs were selected over linear and generalized linear models due to their ability to deal with non-linear relationship between response and explanatory variables (Davies et al., 2014). In order to assess the changes perceived, we create a variable based on the adjusted differences (so-called "*catch differences*") of the *best catch* minus the *current catch* in using GAMs.

The variables *best year*, *age*, and *target* (*M. furnieri, M. liza*, *G. barbus*, and *M. ancylodon*) were used for modelling *best catch* and *catch differences* (Table 2). We did not considered community as an explanatory variable since all communities are in close proximities to each other, the respondents had similar characteristics in terms of fisheries, socio-economic dynamics, and fishing grounds. Models were fitted using Poisson distribution family because *best catch* are discrete count data. Because the overdispersion we used negative binomial distribution family in the absolute values of *catch differences*. The nine candidate models were ranked by AIC values calculated for all candidate models (Zuur et al., 2009). The causes for variations in the catches of each species were analyzed by Principal Component Analysis (PCA) to identify key factors influencing the catch of each species. Analysis was performed using *mgcv* (Wood, 2011), *MuMIn* (Bartoń, 2016) and *devtools* (Wickham and Chang, 2016) packages for the R Program (R Core Team, 2017).

3. Results

The total *best catch* was mainly explained by *year* and *age* including the smooth interactions by *target* as variables (Table 2). Also, the fitted model showed a peak in 1990–2000 years followed by a reduction in *catch differences* (Fig. 2G). When the perceived *best catch* was recent (after 2000), *catch differences* (*best catch* minus *current catch*) are reduced. Fishers also experienced variation in *catch differences* according to *target* (Fig. 2H) which influenced the confidence interval variation in the model for *catch differences.*

General models showed differences for *target* and we modelled separetely against the same explanatory variables. For all species, *best catch* and *catch differences* are influenced by *age* (Table 2). The *year* influenced *best catch* for *M. furnieri* and *G. barbus, except for M. liza* and *M. ancylodon* in which *age* alone explained the sources of variation (Table 2). Fishers' *age* influenced fluctuations in best catch with increasing trend for *G. barbus*, *M. ancylodon*, and decreasing trends for *M. liza*. Older fishers experienced higher daily catches for *M. furnieri* (Fig. 2B), and *M. Liza* (Fig. 2F). For *M. Liza,* only one young fisher