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Predicting vulnerability to management changes in data-limited, small-scale fisheries

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ABSTRACT

It is estimated that more than 200 million people worldwide depend on small-scale fisheries for their livelihood, driving the need for fisheries reform to develop effective, local-level governance systems to protect food security and lessen reliance on common resources. However, our ability to impose new management relies on the assessment of vulnerability and adaptive capacity, and the lack of social-ecological data often stifles decision making. Here we test the use of simple fisheries attributes from 33 fishing communities in an understudied, and chronically poor region of the Colombian Pacific, to generate indicators of relative fisheries adaptive capacity, as a proxy for vulnerability to planned management changes. We demonstrate the strengths of this approach using four variables (species assemblage, spatial dependence, gear dependence and compliance), and illustrate how potential threats to livelihoods can be identified early, and with limited data, allowing for management to adapt decision-making accordingly. We show that in the absence of detailed socio-economic information, relatively basic fisheries data recorded by community observers can be applied to decrease uncertainty by providing a rapid characterisation of community vulnerability to management decision-making, in a range of management intervention options.

1. Introduction

As coastal populations increase, and climate change drives biogeographical shifts of marine species [1], there is a potential for much greater conflict over natural resources, especially in traditional commons scenarios such as small-scale fisheries (SSF) [2]. The value of SSF has been increasingly recognised and studied over the past 30 years (see [3] for a review), contributing to poverty alleviation [4], food security [5–7], livelihoods [8], local economy [8] and human rights [9], and it is estimated that the livelihoods of more than 200 million people depend on them to some extent [10]. In developing countries fishing communities are notoriously marginalised, and isolation from infrastructure and access to alternative livelihoods only increases their reliance on a stochastic and generally low productivity fishing sector [11], while threatening the viability and health of coastal ecosystems [12].

The momentum and success of community based fishery management (CBFM) initiatives are providing a clearer understanding of the importance of accounting for links between the social and ecological dimensions of human vulnerability in fisheries management [13,14]. Vulnerability is used in a marine context to measure potential threats to livelihoods [15], resources or social-ecological systems from climate change [16], natural disasters [17] or anthropogenic disturbances [18]. It allows us to assess the extent to which communities are able to cope in the face of economic, socio-political or ecological changes [19]. Vulnerability to internal and external factors is rarely considered in policy development and management decision making [20], and systems developed to appraise fishery sustainability require a suite of ecological and socio-economic parameters [17,21]. Given the frequent lack of socio-economic data in isolated regions, there is an urgent need to develop empirical measures of vulnerability to identify potential threats, and generate information on which to base management decision-making in data limited fisheries, especially in resource-dependent communities, where fisheries livelihoods are threatened by

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internal and external disturbances.

In social contexts, the ability of a community or household to recover from livelihood disturbances, respond to changes, and take advantage of new opportunities, is termed adaptive capacity [22]. Adaptive capacity is commonly assessed according to the levels of natural, social, and financial capital found in each study community (e.g. [7,23]). In fisheries, and for the purpose of this study, we consider adaptive capacity to be the ability to: 1) respond to ecological or management changes affecting the availability or accessibility of fisheries products; and 2) to diversify fishing livelihood activities to exploit other resources available within the management framework.

In Colombia, fisheries represent 3% of gross domestic product, and its Pacific territory is responsible for around 80% of the total catch volume [24]. Across all fisheries, pelagic fish species (e.g. sardines, anchovy, tuna) represent the majority of landings followed by demersal fish species, shrimp, and lobster [25]. Small-scale fisheries land multiple species with a diverse array of mostly generalist gear types such as gill nets [24]. Despite a decrease in the volume of fisheries catch, the number of fishing vessels has notably increased in the last few years, suggesting that most fisheries exceeded their maximum sustainable yield and that resources are being overexploited [26].

Despite the economic growth of Colombia in the last few years, the Pacific coast has remained isolated from the rest of the country due to a lack of infrastructure development, and limited presence of government institutions. Indigenous and Afrodescendant inhabitants retain autonomy over their natural resources [27], which has limited impacts on coastal habitats compared to other parts of the region (Lopez-Angarita, unpubl. data), but it is one of the poorest regions of the country, exhibiting chronic poverty and malnutrition. A history of armed conflict in the region has exacerbated these symptoms, inducing fear and lack of trust in participatory processes, limiting socio-economic research activities and development initiatives [28]. Economic activities in these small, isolated communities, are limited to fishing and small-scale agriculture [27]. Fishing activities are predominantly artisanal and inshore, for subsistence and local commercialisation purposes [29], with very limited access to national and international markets. As such, low entry-cost, low income fisheries such as gleaning for mollusks, represent crucial food security for isolated communities [30], and can provide useful insight into the dynamics of poverty and resource reliance in fishing communities [31]. Given the geographical and political isolation of communities in this region of Colombia, formal management of SSF is limited, with very few regulations in place, and no monitoring of compliance. Inshore coastal fisheries in this region are in effect open access with some fishers being organized into member cooperatives. This project was part of initial efforts to increase capacity for community based fishery management.

As a way to protect resources from industrial fisheries, enhance fisheries sustainability, and protect artisanal fisheries livelihoods, there has been an increasing tendency in Latin America to create responsible fishing areas instigated and managed by the communities themselves where the primary input control is a ban on gill net fishing [27,32,33]. The first and only management effort of this kind on the Pacific coast of Colombia was established in 2008 as an exclusive artisanal fishing zone (Zona Exclusiva de Pesca Artesanal, ZEPA) extending out to 2.5 nautical miles from the coast of the Northern Chocó region [27]. A similar approach has been proposed for the Buenaventura municipality in Valle del Cauca region of Colombia, but success will be linked to communities' adaptive capacity and compliance, stemming from the intrinsic motivation to act collectively and adhere to regulations driven by social values [34–36].

In this study, we used 5086 individual species landings recorded from 2765 trips across 33 coastal communities in Valle Del Cauca, on Colombia's Pacific coast (Fig. 1) to predict relative vulnerability to management scenarios based on variables of spatial dependence, gear dependence, landed species assemblages and compliance.

2. Materials and methods

This study utilised information collected by community observers from 33 communities in the municipality of Buenaventura, Valle Del Cauca, on Colombia's Pacific coast (Fig. 1). Data were collected as part of the USAID Bioredd+ fisheries program between October 2012 - May 2014. Data collection did not adhere to a regular schedule, with the database reflecting many typical attributes and data limitations of SSF. Data recorded from fishers at landing sites were used to generate 4 key variables to estimate vulnerability to specific management measure of gill net bans within 2.5 miles of the coast:

2.1. Gear dependence

For this model we were interested in community vulnerability to the banning of gillnets as a planned management measure, so this variable was calculated as the proportion of gear type usage after the removal of gill nets. Gear usage was considered as the proportion of trips made per gear type, rather than catch weight by gear type, to avoid bias towards less targeted, higher yield gears. Gear dependence (*GD*) was calculated as the number of non-gill net trips (T_c) of a community, divided by the total of number of trips of a community (T_t), multiplied by 100. ($GD = (T_C/T_t) \times 100\%$).

2.2. Target species assemblage

Large and sporadic species assemblages limit the establishment of post capture processing and market chains, which depend on consistent and reliable sources of marketable fish. As such, landed species richness estimates were used as a proxy for relative target species assemblage size per community. The number of individuals of species recorded from each trip were used to generate Chao1 rarefaction estimates of landed species richness ± SE (see [37]) for each community, standardised by sampling effort using R package vegan [38] run in R statistics version 3.2.3. Species richness was then standardised as a score by dividing the diversity index of a community (D_c) by the maximum diversity index across all communities.

2.3. Spatial dependence

The extent to which community fishing effort is restricted within geographic space, by access to boats and propulsion methods of various levels (from paddle canoes to motorboats), was used as an indicator of financial and natural capital. It facilitated evaluation of the capacity that different communities have to access and exploit alternative fisheries resources at varying spatial scales. Boat type and method of propulsion were used as a proxy for spatial dependence (proportional to the maximum distance travelled in one fishing day). Potential travel distance weightings P_i are used to classify craft types from 1 to 8 (Table S2), with 1 representing a small distance coverage and 8 a large distance coverage. The community spatial dependence score (CSD) was calculated as:

$$CSD = \left(1 - \frac{1}{P_{max}\,\mathrm{T_t}} \sum_{i=1}^{N} \mathrm{T_{C_i} P_i}\right) \times 100\% \tag{1}$$

where T_{C_i} is the number of trips per craft type; T_t is the total number of trips per community, $P_i \in [1, P_{max}]$ is the weighted score for each craft, $N = 8$ is the number of craft-types and $P_{max} = 8$, the maximum score-value. Low summation values reflect very limited range (high spatial dependence), and high summation values indicate potential access to a relatively large geographic range (low spatial dependence).

2.4. Cumulative model

Variables 1–3 were combined into a novel cumulative model to