Adaptive Capacity of Fishing Communities at Marine Protected Areas: A Case Study from the Colombian Pacific

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Abstract Departing from a theoretical methodology, we estimate empirically an index of adaptive capacity (IAC) of a fishing community to the establishment of marine protected areas (MPAs). We carried out household surveys, designed to obtain information for indicators and sub-indicators, and calculated the IAC. Moreover, we performed a sensitivity analysis to check for robustness of the results. Our findings show that, despite being located between two MPAs, the fishing community of Bazán in the Colombian Pacific is highly vulnerable and that the socioeconomic dimension of the IAC constitutes the most binding dimension for building adaptive capacity. Bazán is characterized by extreme poverty, high dependence on resources, and lack of basic public infrastructure. Notwithstanding, social capital and local awareness about ecological conditions may act as enhancers of adaptive capacity. The establishment of MPAs should consider the development of strategies to confer adaptive capacity to local communities highly dependent on resource extraction.

Keywords Resilience · Coastal–marine resources · Community involvement · Colombian Pacific

INTRODUCTION

During the last two decades local, national, and global economic benefits of marine protected areas (MPA) have been estimated and discussed among academics (Dixon 1993; Arin and Kramer 2002; Bhat 2003) and recognized by policy makers and donors (Lutchman et al. 2005; Alban et al. 2006;

Janishevski et al. 2008; Wales 2008). Those benefits have reinforced the relevance of the establishment of MPA as the most direct strategy for avoiding the deterioration of valuable ecosystems and for guaranteeing the flow of environmental services they provide (Coad et al. 2009).

Establishing MPA also generates costs at different scales (Balmford et al. 2004; McCrea-Strub et al. 2011), including opportunity costs that local users assume by facing restrictions on using resources (Lutchman et al. 2005; Smith et al. 2010). However, often the distribution of benefits and costs of creating reserves are not estimated by MPA managers, and the local opportunity costs are not internalized by societies who value MPAs' services (San-chirico et al. 2002; Christie 2005). Additionally, the design, implementation, and management of MPA have usually been supported only on ecological issues, ignoring the role of local users, and disregarding the relevance of understanding fishing community's livelihoods for guaranteeing MPA governance and effectiveness improvement (Christie 2005; Charles and Wilson 2009; Cinner et al. 2010).

MPAs characterized by poor enforcement of rules, limited financing, the presence of local communities highly dependent on resources for food and income generation, and poor local users' participation on MPA decision making, translate into tensions between locals and authorities, lack of governance, and continued exploitation of resources (Marshall and Marshall 2007; Charles and Wilson 2009; Bush et al. 2012). Several authors have shown that a step in the search for effectiveness of MPA is to understand not only the ecological issues related with a MPA but also their human dimensions (social, economic, and institutional considerations) (Mascia 2003; Christie 2005; Charles and Wilson 2009) and, particularly, to determine whether fishing communities are able to face, overcome and take advantage of the establishment of

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MPAs that restrict access to—and use of—resources (Adger et al. 2005; Pomeroy et al. 2007).

Several approaches have been proposed for addressing human dimensions of MPAs and for understanding resource-dependent communities' livelihoods (Pomeroy et al. 2007; Charles and Wilson 2009; Cinner et al. 2010, 2011). Recently, the concept of adaptive capacity (AC) has gained wide recognition in the framework of climate change as it determines to what extent they are able to face climate-related disturbances, rather than merely characterize socioeconomic conditions of communities (Smit and Pilifosova 2001; McClanahan et al. 2008). Adaptive capacity is generally defined as the potential of a society to cope with perturbations and take advantage of new opportunities (McCarthy et al. 2001). Changes and perturbations may be—in addition to climate-change impacts—natural disasters, or human-induced disturbances to the social–ecological system, as tourism developments, infrastructure projects and conservation interventions such as the establishment of MPAs, that restrict access to—and use of—resources to local users.

Therefore, the AC can be used for determining integrally the ability of resource-dependent communities to face the establishment of MPAs that restrict the access to—and use of—resources they depend on. An estimation of AC will allow understanding fishing communities' livelihoods, and identifying where interventions must be performed in order to increase the ability of local communities to overcome and reduce the effects of restrictions on the use of resources (Maldonado and Moreno-Sánchez 2013).

Several authors have proposed methodologies for operationalizing the concept of adaptive capacity (Yohe and Tol 2002; Brooks et al. 2005; Cinner et al. 2011; Orencio and Fujii 2012), but few have proposed methodological approaches to measure either the impact of MPAs on local communities or the capacity of local users to cope with that type of disturbance (Marshall and Marshall 2007; McClanahan et al. 2008; Mascia et al. 2010; Maldonado and Moreno-Sánchez 2013).

This paper constitutes an application and validation of the methodological approach proposed by Maldonado and Moreno-Sánchez (2013) for estimating the adaptive capacity of fishing communities to the implementation of MPAs. We, specifically, estimate the IAC for a fishing community located in between two MPAs in the Colombian pacific.

MATERIALS AND METHODS

Study Area

The IAC is estimated for a fishing community (Bazán), located on the Colombian Pacific coast at the influence zone of two national parks characterized by being MPAs and

Fig. 1 Study region, showing the two national parks (Gorgona and Sanquianga) and the community surveyed (Bazán) in Colombia

Fig. 2 A typical house in Bazán

belonging to the category of parks that exhibit the strictest protection scheme in the country. Specifically, Bazán is situated within the jurisdiction of the Sanquianga National Park (SNP) and constitutes the nearest point from the continent to the Gorgona National Park (GNP) (Fig. 1).

Bazán can only be accessed by sea; it is an Afro-descendant Colombian community with about 245 residential houses (Fig. 2), whose main economic activities are the extraction of marine and coastal resources. In particular, local users collect shells (*Anadara tuberculosa*) from SNP mangroves and different species of fish (e.g., *Lutjanus* spp., *Notarius troschelii*, *Cynoscion phoxocephalus*, *Paralichthys* spp., *Centropomus armatus*, *Mustelus* spp.) around GNP.

Methodological Approach

The methodology proposed is based on Maldonado and Moreno-Sánchez (2013) who propose an operational

Fig. 3 Dimensions, indicators (labeled with three-letter acronyms), and sub-indicators (with *bullets*). *Source* Maldonado and Moreno-Sánchez (2013)

approach that allows, comprehensively, estimating, at local scale, an index of adaptive capacity (IAC) to the establishment of MPAs, organizing, adding and scaling down determinants, and indicators of adaptive capacity proposed previously in the literature. With this measurement it is not intended to test the establishment of a MPA or its efficiency. It is attempted to test the adaptive capacity of local communities, dependent on resources, to either the creation or the existence of a MPA. In that sense, this approach does not involve measurements of biological indicators.

The [Electronic Supplementary Material](#) presents a summary of this methodology, including the rationale for the use of dimensions and indicators. According to this proposal, the index of adaptive capacity (IAC) is made up of three complementary and analytical dimensions: socio-economic (SN), institutional (IN), and socio-ecological (SE), as shown in Fig. 3.

The socioeconomic dimension (SN) reflects “social and economic features of households and communities that shape their relationship with natural environment and confers them the ability to face disturbances.” SN comprises three indicators: poverty level (POV), community public infrastructure (INF), and occupational characteristics (OCC).

Poverty level (POV) is approximated through the combination of three sub-indicators: *basic needs satisfaction* (POV1), *poverty perception* (POV2), and *material style of life* (POV3). The indicator community public infrastructure

(INF) infers on provision of public goods by the state. Finally, the indicator that captures occupational characteristics (OCC) combines two complementary occupational attributes of households: occupational diversity (OCDI) and occupational mobility (OCMO).

Institutional dimension (IN), within the IAC, attempts to reflect “formal and informal rules and norms that govern relationships among individuals and between them and external institutions, for controlling access to—and use of—resources and natural capital they depend on” (Maldonado and Moreno-Sánchez 2013). It comprises indicators that allow capturing, at community level, structural social capital (SSC), cognitive social capital (CSC), and legitimacy of institutions—perception about MPAs (PAP).

Structural social capital (SSC) reveals “relatively objective and externally observable social structures, such as networks, associations, and institutions, and the rules and procedures they embody” (Uphoff 2000; Grootaert and Van Bastelaer 2002); it is constituted by five sub-indicators: community organization (SSC1), organizational density (SSC2), expectations about networks and mutual support at two levels (SSC3 and SSC4), and collective action (SSC5). Cognitive social capital (CSC) incorporates “subjective and intangible elements such as norms of behavior, shared values, reciprocity, and trust” (Grootaert and Van Bastelaer 2002) and is made up of three sub-indicators which attempt to capture solidarity (CSC1), cooperation (CSC2), and trust

(CSC3) among community members. Third, legitimacy, measured through PAP reflects households' perceptions about effects of the existence of MPAs on both household and community wellbeing.

Finally, the *socio-ecological dimension* (SE) captures “both the relationships between communities and the surrounding natural environment, and the ability to anticipate perturbations that affect natural capital they depend on” (Maldonado and Moreno-Sánchez 2013). SE is estimated through the combination of three indicators: resource-use dependence (*RUD*); awareness about ecological processes (*AEP*); and ability to anticipate disturbances (*AAD*).

Resource-use dependence (*RUD*) describes the extent to which local communities are dependent on the natural environment. It also reflects the flexibility of local users to adapt when perturbations affect the access to—and use of—natural capital (Cinner et al. 2009), and emulates risk spreading. Awareness about ecological processes (*AEP*) is incorporated in order to approximate the capacity to both learn and use acquired knowledge (scientific or traditional), as drivers of adaptive capacity (Armitage et al. 2007; Berkes 2007; Cinner et al. 2009). Literature suggests that awareness about ecological processes eases management interventions aimed to detain deterioration paths (Olsson and Folke 2001; Becker and Ghimire 2003; Aswani and Hamilton 2004; Ostrom 2005). It is important to note that this indicator is intended to capture the perception of respondents in the community, and not to test these perceptions against scientific knowledge. Lastly, ability to anticipate disturbances (*AAD*) measures the ability of a community to confront an unexpected perturbation affecting their livelihoods.

Within each dimension, indicators and sub-indicators are standardized to a 0–100 range and aggregated linearly, equally weighted. For analytical and comparative purposes, we suggest a colored scale, where green is associated to indicators within the range 66–100, yellow to indicators exhibiting values between 33 and 65, and red is used for indicators displaying values between 0 and 32; those colors reflect, respectively, high, moderate, and low ability of indicators to confer adaptive capacity to communities.

Sample and Data Collection

Following the proposed methodology, in October 2010 we applied face-to-face surveys to 110 household heads selected through a randomized stratified sampling, reaching a confidence level of 95 %. The sample was designed from cartography of the locality sketched with the assistance of local guides; all dwellings were accounted and mapped, differentiating residential ones.

The questionnaire was pre-tested within the same community 1 month before the final survey, by applying 12

surveys and eight semi-structured surveys. Previously, we carried out a focus group with members of Community Council and fishing associations to present the objectives and methods of the research. In Colombia, activities to be carried out with Afro-Colombian communities need prior informed consent and approval by local authorities. Experienced interviewers, who received training on specific issues related to this study, carried out pre-testing and definitive surveys. Local guides supported interviewers, introducing them to respondents and explaining the objective of the study to households.

Surveys comprised eight sections: household composition, housing, material style of life, social capital, understanding of the natural environment, ability to anticipate changes, food security, and perceptions about protected areas. Data was recorded and indicators estimated using the statistical software STATA 11®. Questionnaire is available from authors upon request.

RESULTS

Bazán households are made up, on average, of 6.15 members, mostly households formed by 4–9 persons (74 %). Fifty percent of members are children and 6 % are over 60 years. Seventy-five percent of people over 18 years are literate, but for people over 40 years only 62 % are literate; 93 % of children (5–15 years) currently attend school. Eighty-nine percent of respondents receive health coverage, mainly from the government-subsidized health program. Regarding household heads, 21 % were women, 88 % were at least 30 years, and 27 % were illiterate.

IAC Dimensions

Socioeconomic Component

Socioeconomic dimension is made up of three indicators: poverty level (*POV*), community public infrastructure (*INF*) and occupational characteristics (*OCC*).

In turn, *POV* is constructed through the combination of three sub-indicators: *Basic needs satisfaction* (*POV1*), *Poverty perception* (*POV2*), and *Material style of life* (*POV3*).

The sub-indicator for poverty level *POV1* estimated for the community of Bazán is extremely low; 9.1 % of households fulfill basic needs, compared with 72.2 % country-wide; this sub-indicator results from extremely limited access to sewerage and drinkable water (99 % of households collect rainwater for consumption; Fig. 4), and housing overcrowding. When approaching poverty by *POV2*, we obtained a value of 29.7 in a scale 0–100. *POV3* is estimated using principal component analysis (PCA) of selected assets ownership. Following Cinner et al. (2010), we asked about

Fig. 4 Members of Bazán community collecting water from a communal well

possession of 18 assets, including productive and non-productive assets (e.g., fishing gear, outboard engines, boats and households appliances). By applying PCA we condensed the 18 items to 7 components: (i) fishing nets, (ii) shrimp nets, (iii) longlines, (iv) handlines, (v) boats and engines, (vi) household appliances, and (vii) other assets. Scores for each component at each household are constructed from the PCA weights. The scores are standardized on a 0–100 scale, and the final value of the sub-indicator is calculated as the average of each component for the sample. The calculation of the POV3 sub-indicator resulted in a value of 27.5 ± 22.8 , which can be considered low, reflecting limited possession of productive and non-productive assets. The high value for the standard deviation shows a large inequality in asset possession in this community.

The three sub-indicators generate a *Poverty* indicator estimate of 22.1 ± 14.9 , reflecting a community characterized by acute poverty (Table 1).

To approximate access to public physical capital (*INF*), we included an indicator for presence/absence of public infrastructure in the community. From selected items (health center, elementary school, high school, hospital, roads, piped drinking water, sewerage, public electricity, solid waste collection, adequate solid waste disposal, natural gas), only the first three are present, implying a score for the community of 30 points for this indicator.

Socioeconomic dimension completes with the estimation of occupational characteristics indicator (*OCC*), which

Table 1 Results for the socioeconomic dimension, its indicators and sub-indicators

Indicators	Sub-indicators	Values
Poverty level (POV)		22.1
	Basic needs satisfaction—POV1	9.1
	Poverty perception—POV2	29.7
	Material style of life—POV3	27.5
Public infrastructure (INF)		30.0
Occupational characteristics (OCC)		61.5
	Occupational diversity—OCDI	87.7
	Occupational mobility—OCMO	35.3
Socioeconomic dimension		37.9

comprises two sub-indicators: occupational diversity (*OCDI*) and occupational mobility (*OCMO*). We found at least 25 different economic activities as income sources for economically active members of Bazán. On average, households have 2.1 economically active members who are, on average, engaged in 1.7 income-generating activities; the ratio between these two values yields an *OCDI* sub-indicator of 87.7 ± 21.4 . However, most of the economic activities reported are related to extraction of natural resources (69 %),

Table 2 Results for the institutional dimension, its indicators and sub-indicators

Indicators	Sub-indicators	Values
Structural social capital (SSC)		53.8
	Community organization—SSC1	71.9
	Organization density—SSC2	11.7
	Networks and mutual support A—SSC3	67.0
	Networks and mutual support B—SSC4	81.5
	Collective action—SSC5	36.7
Cognitive social capital (CSC)		55.3
	Solidarity—CSC1	61.1
	Cooperation—CSC2	71.4
	Trust—CSC3	33.3
Perception about existence of MPA (PAP)		51.7
	Perception about existence of MPA on household wellbeing	49.0
	Perception about existence of MPA on community wellbeing	54.3
Institutional dimension		53.6

described in the Dependence on resource use indicator below. OCDI is complemented with a sub-indicator that reflects *Occupational mobility* of the community. Out of 110 household heads, we found that 32 had changed their main economic activity during the last 5 years, 24 of them voluntarily. In addition, 68 out of 110 household's heads reported they wanted to change their main economic activity; therefore, the value for the sub-indicator is 35.3. This result shows moderate mobility of labor in Bazán as a result of few voluntary changes in occupation of economically active household heads; reported reasons for limited labor mobility included lack of financial resources, credit (96 %), lack of land (26 %), lack of training (57 %), lack of technical assistance (49 %), and lack of institutional support (29 %). *OCDI* and *OCMO* are averaged to obtain a value of 61.5 for the indicator occupational characteristics.

The aggregation of *POV*, *INF*, and *OCC* yields a value of $37.87 + 5.81$ (moderate to low) for the socioeconomic dimension of the IAC of the community of Bazán.

Institutional Component

The institutional dimension comprises three indicators: *Structural social capital* (SSC), *Cognitive social capital* (CSC), and *Perception about the existence of MPAs* (PAP).

The approach for measuring social capital attempts to capture different elements of structural (community organization SSC1, organization density SSC2, expectations about networks and mutual support SSC3 and SSC4—collective action SSC5) and cognitive social capital (solidarity CSC1, cooperation CSC2, and trust CSC3). For the community of Bazán, the SSC and the CSC indicators exhibit values of 53.8 and 55.3, respectively (Table 2).

Table 2 shows a trade-off between different components of social capital; for instance, sub-indicators such as SSC1, SSC3/SSC4, and CSC2, contribute to increase the value of SSC and CSC, while sub-indicators such as SSC2, SSC5, and CSC3 drive them to lower values. The final values for SSC (53.8) and CSC (55.3) indicators are moderate.

The perception about existence of MPAs for own-household (*PAP1*) and community (*PAP2*) wellbeing reached similar values: 49.0 and 54.3, respectively. Those values may demonstrate a perception of balance between benefits and costs because of the existence of the MPAs. The indicator PAP then averages 51.7 ± 21.0 .

Aggregating SSC, CSC, and PAP indicators we obtain a value for the Institutional dimension of the ICA of 53.57 ± 11.37 which given our scale of comparison is classified as moderate.

Socio-ecological Component

The socio-ecological sub-index is the result of three indicators: resource-use dependence (*RUD*), awareness on ecological processes (*AEP*), and ability to anticipate disturbances (*AAD*).

We found that 69 % of the economically active members from the surveyed households depend directly or indirectly, for income generation, on the extraction of natural resources, including shells harvesting (23 %), fishing (34 %), fish processing and trade (9.1 %), and boat-related activities (2.5 %) (Fig. 5). Therefore, *RUD* reaches a value of 31.0 (Table 3).

AEP is estimated applying PCA to three open-ended questions, asked to those household heads who perceive fish in the sea as diminishing during the last 10 years (99.1 %) (McClanahan et al. 2008; Cinner et al. 2010): (i) which is the main cause of sea-fish reduction? (ii) who has responsibility for this reduction? and (iii) how to increase sea-fish stocks? Open answers are grouped into categories for each question. The categories are scored using the PCA, standardized on a 0–100 scale, and averaged to provide a value for each question and a final value for the indicator.

Answers to the first question were grouped into five categories: overfishing, industrial fishing, inadequate fishing gear, lack of regulation enforcement and productive alternatives, and exogenous factors. This sub-indicator reaches a value of 74.9 ± 34.8 .

Fig. 5 Fishers preparing fishing nets

Table 3 Results for the socio-ecological dimension, its indicators and sub-indicators

Indicators	Sub-indicators	Values
Dependence on resource use (RUD)		31.0
Awareness about ecological processes (AEP)		69.3
	Causes of sea-fish reduction	74.9
	Responsibility for sea-fish decline	74.3
	Actions required to recover fish-stock	58.8
Ability to anticipate changes (AAD)		53.8
	Responses to solve food needs	53.9
	Responses to solve other needs	53.6
Socio-ecological dimension		51.4

The second question provided answers that were grouped into three categories: local fishermen, fishing activity (artisanal and industrial), and institutional environment. The sub-indicator value is 74.3 ± 36.6 .

Finally, answers about the actions reported as required to increase the amount of fish in the sea yielded five factors: fishing regulation, economic alternatives, changes in

the rights to access resources, control and surveillance, and others including local participation and education. The sub-indicator value is 58.8 ± 35.5 , lowest of the three variables used to estimate the *AEP* indicator.

Based on these results, *AEP* for community of Bazán reaches a value of 69.3 ± 21.7 .

To construct the indicator *AAD*, we used the household-head answers to a question based on a hypothetical scenario, in which community had to face a shock that would reduce fish catches by 75 %. Respondents chose among a list of options, grouped in categories: (i) continue fishing, do nothing or migrate from the community, (ii) move to other natural-resource extraction, (iii) move to agriculture, (iv) move to commercial, manufacturing, or service-related activities (including sustainable use of natural resources); each category received a score ranging from 0 to 100, and household's values were averaged for and among each question.

Findings show that the option most frequently selected for solving food needs is agriculture, while shifting to the services sector is majority preferred answer for solving other type of needs. However, 32 % of surveyed household-head answers reflect low ability to anticipate changes. The sub-indicator for addressing food and other needs obtained scores of 53.9 and 53.6, respectively. The aggregated indicator showed a score of 53.8 ± 38.8 (intermediate value).

The socio-ecological dimension reaches a value of 51.4 ± 14.7 (intermediate) on a 0–100 scale.

Fig. 6 Aggregated results for the estimation of the IAC

Table 4 Results from sensitivity analysis on weighting and functional form for estimating the dimensions and for estimating the IAC

Dimension	Functional form		
	Simple average	Min function	Product
For estimating dimensions			
Socioeconomic	37.87	22.1	4.08
Institutional	53.57	51.7	15.35
Socio-ecological	51.38	31.0	11.56
For estimating the IAC			
Min	37.87	22.10	4.08
Simple average	47.60	34.92	10.33
Socioeconomic emphasis	45.17	31.71	8.77
Institutional emphasis	49.09	39.10	11.59
Socio-ecological emphasis	48.55	33.94	10.64

Index of Adaptive Capacity

Figure 6 organizes findings from the three dimensions of the IAC and their indicators. Color bars show contribution of indicators (and dimensions) to the adaptive capacity of the community of Bazán (green = high; yellow = moderate; red = low). Figure 6 evidences that some indicators and sub-indicators constitute binding factors of the adaptive capacity for this community (red-colored), majority related to socioeconomic ones (poverty, public infrastructure). These findings are aggravated by the value obtained for RUD (within socio-ecological dimension), which also exhibits a low estimate, reflecting high resource dependence. Other values confer adaptive capacity (green-colored), as with occupational characteristics (socioeconomic) and awareness about ecological processes (socio-ecological) and to some extent (orange-colored) social capital, perception about protected areas and ability to anticipate disturbances.

Indicator aggregation within each dimension confirms socioeconomic conditions are the most important constraint on the adaptive capacity of communities, while socio-ecological and institutional components act as potential enhancers. Following the proposal of Maldonado and Moreno-Sánchez (2013) on aggregating dimensions using a Min Function, the IAC for Bazán is 37.9, estimated as the value of the dimension exhibiting the lowest estimate.

Sensitivity Analysis

Sensitivity analysis checks robustness of indexes' estimated values (Nardo et al. 2008). Thus, we tested different ways of estimating dimensions and the IAC. The most common sources of variance in index estimation are functional form (how indicators are aggregated to form a dimension) and weighting. Initially, we used simple average to aggregate the three indicators of each dimension:

$$D_i = (IND_1 + IND_2 + IND_3)/3.$$

The value for each dimension D_i is calculated as the average of three indicators, IND_i ($i = 1, 2, 3$). Alternatively, we aggregate indicators by multiplication:

$$D_i = SF * IND_1 * IND_2 * IND_3.$$

SF is a scaling factor (making values comparable). Another approach is weighting the most limiting indicator using a min function:

$$D_i = \min(IND_1, IND_2, IND_3).$$

Approach choice depends on information characteristics but, moreover, on researcher criteria. We tested the three approaches using our data (Table 4 upper panel) and although the absolute values of estimated dimensions varied, the ordering of importance was kept whatever the approach: institutional and socioeconomic dimensions

continued as enhancer and most binding, respectively, of community adaptive capacity.

The second source of debate is weighting, the way each dimension contributes to the index formation. Originally, we proposed loading all weight on the lowest dimension, to highlight the need of addressing the most binding characteristics. Alternatively, weighted average can aggregate dimensions. Here, we propose four alternative methods for weighting dimensions:

- a. Equal weighting: $IAC = a_1 * SN + a_2 * IN + a_3 * SE$, with $a_1 = a_2 = a_3$.
- b. Socioeconomic emphasis: $IAC = a_1 * SN + a_2 * IN + a_3 * SE$, with $a_1 > a_2 = a_3$.
- c. Institutional emphasis: $IAC = a_1 * SN + a_2 * IN + a_3 * SE$, with $a_2 > a_1 = a_3$.
- d. Socio-ecological emphasis: $IAC = a_1 * SN + a_2 * IN + a_3 * SE$, with $a_1 = a_2 < a_3$.

To test these, we used a weight of 1/3 for the three dimensions in case a; and for remaining cases, we weighted 1/2 the emphasized dimension and 1/4 the other two. Results are observed in the lower panel of Table 4. Although weights variations change absolute value, ordering of importance of dimensions was identical across cases: institutional dimension and socioeconomic characteristics remain the most enhancing and threatening (whatever the dimension weighting) attributes, respectively, of adaptive capacity.

In Table 4 we combine functional forms and weightings to have a set of possible values for dimensions and for the IAC. With respect to Bazán, results are robust to both functional form and weights and provide similar signals about policy recommendations.

DISCUSSION

This paper demonstrates estimation of Index of Adaptive Capacity, IAC, of a fishing community at the Colombian pacific coast to the establishment of MPAs that restrict use of—and access to—resources they depend on. We calculated the IAC for the community of Bazán, located between two natural national parks: Sanguiang and Gorgona.

Values of indicators and sub-indicators we obtained offer valuable information about different dimensions of the adaptive capacity of this fishing community, such as comprehension about ecological processes in which local users are immersed, up to institutional features (social capital and legitimacy of institutions), via estimation of several socioeconomic population characteristics (poverty, public infrastructure, occupational characteristics).

Generally, wide variation on estimated values exists, but some indicators and sub-indicators yield high values,

conferring adaptive capacity to the community (occupational characteristics and awareness about ecological processes), while it is concerning the extremely low value obtained for poverty indicator. Moreover, there is inequity in the possession of private physical capital, as cited in the literature (Smit and Pilifosova 2001) attenuating social resilience building.

Although this study was performed in the MPAs context, the IAC illustrates community ability to face restrictions associated to no-take reserves, and natural events in a climate-change scenario. Indicators and sub-indicators estimated allow policy makers to understand coastal-communities conditions and focus efforts for reducing their vulnerability, through strategies aimed to improve specific components of their AC.

Undoubtedly, poverty becomes the most binding factor of the AC of Bazán for facing external perturbations affecting livelihoods, including MPAs. The basic needs satisfaction sub-indicator (POV1) is extremely low, even compared with the same estimation for the municipality to which this community belongs. This sub-indicator reflects high deficiencies in public-services access, inadequate housing and high economic dependence within households. The perception of households about own wellbeing confirms this constraint. Similarly, the sub-indicator Material style of life reflects low levels of wealth in terms of possession of productive and non-productive assets.

As literature suggest, establishment of MPAs generates benefits to society at all scales; however, their existence also generates implementation, operative and opportunity costs, the latter being mainly assumed by local resource users. The equitable distribution of benefits and cost of conservation, as stated by the Convention of Biological Diversity (United Nations 1992), should guarantee that local users do not assume relative greater costs of conservation, but receive better opportunities to improve their quality of life. Payment for environmental services or conservation agreements among local resource users and conservation agencies constitute potential strategies for covering these opportunity costs and for offering institutional conditions conducive to development of successful and sustainable livelihoods. Capitals endowment, initiating with either public physical capital (basic infrastructure) or human capital, constitute a starting point to constructing community resilience (McClanahan et al. 2008).

Bazán is highly dependent on natural-resources utilization. It is well recognized that resource-users' income is highly seasonal due to natural cycles that affect resource availability throughout the year. Income instability worsens by the risk associated to uncontrollable natural events and volatility characteristic of some local fishing markets. Widely mentioned in the literature is the relevance of promoting diversification of the use of resources and alternative

(non-extractive) productive activities, as mechanisms to dissipate risks associated with resource dependence (Adger et al. 2005). Diversification also highlights an essential strategy for favoring movements (of socio-ecological systems) from undesirable states, characterized by poverty, vulnerability, and unsustainability, to desirable states (Walker et al. 2002; Armitage et al. 2007). Practices that promote economic diversification, while contributing to sustain ecosystem services, spread risk, as do financial markets through diversification of investment portfolios.

Findings also show that Bazán community is aware of their impact on coastal and marine resources. Socio-ecological dimension exhibits a high value partially due to the value estimated for the indicator “Awareness about ecological processes.” People in Bazán are concerned about industrial and artisanal fishing effects on fish stocks. Solutions they propose parallel existing regulations, but seek harmonization between sustainable local livelihoods and natural-resources conservation. Bazán recognizes the use of inadequate fishing techniques and proposes temporal and spatial closures, increasing surveillance and control on Bazán fishermen and on other fishing communities and industrial fishing sector. Positively, community households are aware of depleting fishing resources and recognize their affective role. Favorable too is a signal that solutions for stopping coastal and marine resources deterioration are non-conflicting with existent regulations. The awareness about socio-ecological processes that local users exhibit constitutes an initial step toward understating the local ecological knowledge (LEK) of this community. Convergence on LEK might improve our understanding about ability of communities to adapt.

With Social Capital, Bazán exhibits great potential for strengthening existing social structure, especially at informal levels: despite small size, more than 10 different community organizations exist; households exhibit high expectations about mutual support for solving problems that affect the community; most households offer responses that reflect cooperative behavior and other-regarding preferences. However, low community-organization participation and low meetings-assistance frequency on common problems, reduce social capital values. Additionally, we found a moderately low value for the variable measuring trust, which could be consistent with little participation in community organizations. Noteworthy, is that the question proposed for measuring trust is restrictive, as it measures childcare-related trust; as expected, most households trust only family members for own-kids care. We suggest improving trust estimation to incorporate complementary questions as proposed by Grootaert and Van Bastelaer (2002) or apply bespoke economic experimental games for measuring trust (Cox 2004; Walker and Ostrom 2009).

Nevertheless, answers to other questions related with social capital estimation indicate relative trust in local government, potentially positive in terms of the design of collaborative management strategies. As Pretty and Ward (2001) underline “trust lubricates collaboration.” Therefore, trust-building among stakeholders and authorities constitutes a fundamental step for achieving active participation in conservation processes affecting livelihoods.

Connection between social capital and resource management is well established in the literature (Ostrom 1990; Pretty and Ward 2001; Plummer and FitzGibbon 2006). The importance of approximating a measure of social capital within the framework of MPAs is supported by two elements: (i) social capital as an asset that favors livelihood strategies and allows households to automatically face natural or human-induced disturbances and, (ii) social capital as an input of conservation management strategies supported by active participation of local users. Community-based strategies for resource management require building and strengthening trust, capacity, and institutions at all scales (Berkes 2007), incorporating the role of social capital.

The relationship between AC and governance of MPAs is important; McClanahan et al. (2008) argue that communities exhibiting low AC are poorly prepared for facing and overcoming restrictions that strict MPAs impose. Therefore, communities exhibiting low AC could be unwilling to facilitate regulations on MPAs. McClanahan et al. also claim that if communities displaying low AC are located in zones that exhibit high environmental susceptibility, the first measures for conservation of strategic areas should be focused on alleviating poverty, investing in infrastructure, strengthening social capital, and developing income alternatives that allow locals to improve AC.

Finally, we observe that aggregation and functional form are issues that might affect absolute values; however, depending on the particular conditions of the communities, as it was the case for Bazán, relative values exhibit robustness to different functional forms and weights.

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