Appendix 2 - Measuring the components of social-ecological resilience index

Here, we explain how to estimate the variables in each component of the SERI: social resilience at the individual level (SRi), social resilience at the community level (SRc), and ecological resilience (ER). Component values are the average of their indicators, whereas the SERI is the average of the three components: SERI = (SRi + SRc + ER)/3. Components, indicators, and sub-indicators, and the score calculation are detailed below (See table A2.1).

Social resilience at the individual level (SRi)

This component includes aspects regarding social resilience at the individual level, considering the personal characteristics of individual fishers. SRi was measured through four indicators: flexibility (FLEi), ability to learn (AL), ability to organize (AO) and personal assets (ASi).

The FLEi indicator was based on four sub-indicators: flexibility to change, perception of MPA, resource use diversification, and gear diversification. Flexibility to change seeks to determine whether fishers would be open to changing their economic activity. Fishers who did not want to change their economic activity scored zero, whereas those that said they would be willing to change scored 1 point. The perception of the MPA reflects fishers' flexibility in a context of change and uncertainty of resource policies or conservation initiatives which affect the resilience of people in response to these changes (Suman et al. 1999, Marshall 2007). We used the fishers' acceptance of the planning or implementation of the MPA as a sub-indicator of the flexibility at the individual level. Fishers who agreed that a protected area was needed scored 1 point and those who disagreed were attributed 0. The resource use diversification sub-indicator was estimated from the number and types of natural resources exploited by an individual fisher. Fishers who exploited marine and terrestrial resources received 1 point; those who only exploited marine resources received 0.5 points, and those who only exploit fish received zero points (0 points). The gear diversification sub-indicator was measured by the ratio of the number of fishing gears used by a fisher and the variety of fishing gears represented in the sample, i.e., the number of fishing gears used by all the fishers interviewed.

The AL indicator refers to the years of schooling, fishing experience, and awareness of fishing impacts. The level of schooling, specifically, was calculated by the years of formal education achieved by a fisher and the relationship between the Brazilian average formal education and the average of all fishers in the sample. Fishers with a score below the average Brazilian schooling level did not receive points, those whose level was between the Brazilian and the sample average received 0.5 points and those who had a higher level than the sample average received 1 point. Fishing experience was measured by the ratio between fishing experience in years of an individual fisher and his age. Awareness of fishing impacts was estimated by a fisher's perception of the causes of stock reduction (e.g., overfishing, sea pollution, lack of governance, religion, predatory fishing and illegal fishing). Fishers who were unaware of the causes of stock reductions or quoted religion as a reason did not receive any points, those who quoted only one documented cause (e.g., overfishing, sea pollution, lack of governance, and illegal fishing) received 0.5 points, and those who quoted more than one documented cause received 1 point.

The ability to organize (AO) indicator covers aspects related to a fisher's ability to self-organize to prepare for changes to the socio-ecological system, either within the community or in their fishing activities. We understand that such an ability could include financial security, fishing investment, involvement in an association, and migration (but see below regarding how migration can be interpreted either way, depending on the situation). Financial security was assessed by the existence of alternative sources of income (e.g., savings or property), whereas fishing investment was measured by ownership of at least one boat. Fishers that had some sort of financial security or owned a boat scored 1 point in each of these sub-indicators, respectively. The association involvement sub-indicator is estimated by the involvement and frequency that a fisher participates in any community organization (e.g., fisher association, neighborhood organization). Fishers who were not involved with any organization did not score, those who were involved but rarely participated in meetings (maximum once a year) scored 0.5 points and those who showed a higher level of involvement (two or more meetings a year, which were generally held once a month) scored 1 point. Migration can be either understood to be a risk to societies, given its disruption to social and economic systems, or as an effective adaption strategy to environmental changes, given that it provides and alternative to people during harsh periods in their original place (Adger et al. 2015). Here, we used the second concept of migration to show a fisher's ability to deal with emerging risks in the communities, such as the loss of ecosystem services. Emigration may be the most effective way to allow people to diversify their income and build resilience when environmental changes threaten livelihoods (Adger 2000), and thus can function as an adaptive response to these changes. Considering that the communities examined here have similar socioeconomic and environmental characteristics, and there are overfishing concerns with some fish species, we expected equally emerging risks among fishers. Considering that the communities examined here have similar socioeconomic and environmental characteristics, and some of the target species may be overfished or overexploited, we expected equally emerging risks among fishers. Migration was estimated based on a fisher's relationship to the community they live in, by analyzing the number of years the outside fishers have been living in the community and the number of years they have been fishing there. Native fishers or fishers who migrated to the community in their childhood are not considered migrants and they did not receive points. However, if a fisher had migrated after they had turned 18 (adulthood in Brazil), and only then began to fish there, then they were considered to be a migrant and received 1 point.

Quantitative data on quality of life was used to estimate a fisher's' assets through the proxy "number of home appliances" (Cinner and Pollnac 2004). Our sub-indicator, assets at the individual level (ASi), measured an individual's material style of life based on the presence of household possessions from a list of 21 appliances, such as television, radio, gas stove, car, and refrigerator. After a normalization process was carried out to create a range between 0 and 1, we considered that those who had a greater number of appliances were more resilient.

Social resilience at the community level (SRc)

We selected three indicators to measure SRc: community flexibility (FLEc), social capital (SC) and community assets (ASc).

FLEc was measured based on economic diversification, which was established by the maximum number of economic activities for a specific reserve mentioned by interviewees and the manager of the reserve. The most resilient reserve was determined to be the one that had a greatest number of activities, whereas in the least resilient reserve the only economic activity carried out was fishing. We also carried out a normalization process to place the variable in a range between 0 (least resilient) and 1 (most resilient).

SC was estimated by fisher engagement, knowledge of management rules, collective action, social organizations and participation. Fisher engagement takes on different values depending on a fisher's level of engagement in environmental monitoring actions in the community. For example, a fisher who was engaged in any type of environmental monitoring (e.g., helping with government, university or non-governmental organization environmental projects) received 1 point and those who were not engaged did not score. Knowledge of management rules was based on a fisher's knowledge about local management rules in their communities: fishers who did not know the rules (0 points), fishers who knew one rule (0.5 points) and those who knew more than one rule (1 point). In turn, collective action was measured by demand for the reserve creation. Local demand (1 point) was considered more resilient in opposition to a top-down initiative (0 point), as local demand is assumed to promote community involvement in the management and promotion of SER (Gunderson, 2000). The social organizations sub-indicator was measured by the presence of social and fishery organizations in the MPA's region. Only reserves with social organizations were attributed 1 point and they were considered more resilient than the others. The fisher participation sub-indicator assessed the level of engagement that fishers have in social organization meetings and events (s/he acts only as a spectator, issues opinions, proposes ideas, etc.); essentially, it assessed whether a fisher participation is active or passive. The active fishers were attributed 1 point and the passive ones did not score. Fisher engagement, knowledge of management rules, and fisher participation sub-indicators were measured as the percentage of fishers who scored 0 or 1 in each reserve.

ASc was measured from fieldwork observations of the presence of 12 community-level aspects of infrastructure: schools, pharmacies, electrical services, banking access, sewage collection and treatment, access roads, food markets, phone services, post office service, police service, health centers, and hotels. The total number of infrastructure aspects by reserve was normalized to attribute a proportional score to each community which ranged from 0 to 1, whereby 1 was assigned to the reserve with most infrastructure.

Ecological resilience (ER)

Here, estimates of biological sensitivity (BS) and fish species exposure (FSE) were used as input indicators to determine the ER of the coastal ecosystem.

Four sub-indicators were used to estimate BS: climate exposure, coral bleaching risk, resilience of fish species and vulnerability of fish species. To measure climate exposure, we considered the differences in the average temperatures in the study area between 2011 (year of the sample) and the period 1985-2000, based on a dataset provided by the National Oceanic and Atmospheric Administration - NOAA (http://www.noaa.gov). According to the RCPs

(Representative Concentration Pathways) scenarios from the Intergovernmental Panel on Climate Change (IPCC), the RCP8.5 scenario is the worst for the climate. It ranges from 0.71 to 2.73 ° C in the 2090s compared to the 1990s (Bopp et al. 2013). Here, we considered an increase of up to 0.5ºC to be low (1 point), between 0.6 ºC and 2ºC to be medium (0.5 points) and over 2ºC to be high (0 points).

Coral bleaching risk was estimated by the presence of coral bleaching events in the study area, available from the Global Information System for Coral Reefs (http://www.reefbase.org). Based on the ReefBase categories of bleaching events (no bleaching, low bleaching, medium bleaching, and high bleaching), we attributed a score for coral bleaching risk: presence of one high bleaching event did not score, presence of low or medium bleaching events scored 0.5 points and absence of bleaching events scored 1 point.

Biological information on target fish can be extracted from scientific datasets available online. We used the indexes of fish species vulnerability (VUL) and resilience available in FishBase (httt://fishbase.org, Froese and Pauly 2017). The vulnerability index integrates the fish species characteristics related to their ecology and life history using fuzzy logic (Cheung et al. 2005). Similarly, the resilience index combines biological parameters of a species' life history with the intrinsic rate of population growth as the main determinant of resilience because it is the most complete parameter. Resilience is expressed on a scale that varies from very low, low, medium, and high and vulnerability is expressed by low, moderate, high, and very high. Following the FishBase classification, we created three categories for each indicator: low resilience – 0 points (including the very low and low categories), moderate resilience – 0.5 points (including the medium category), and high resilience - (including the high and very high categories); and low vulnerability – 1 point (including the low category), moderate vulnerability – 0.5 points (including the moderate category), and high vulnerability – 0 points (including the high and very high categories). Once we had those, we searched this information for all fish species caught by each fisher, as cited in the interviews, and used the mean as our sub-indicator value.

The economic demand sub-indicator follows the same estimates of scores and averages used in the VUL sub-indicator. For the threat level sub-indicator, we estimated the score by critically endangered or endangered (0 points), vulnerable (0.5 points) and near threatened, least concern or data deficient (1 point). We double-checked the status presented on FishBase with the status on the Brazilian Red List (Decree nº 445; Brazil's Red List 2014) (MMA 2014) and, whenever there was some divergence, we assumed the latter to be more accurate as it was more recent.

Table A2.1: Information used to calculate the Social-Ecological Resilience Index (SERI) of fishers, including components, indicators and sub-indicators. The specified data source is provided for each sub-indicator. RDSE Ponta do Tubarão = State Sustainable Development Reserve Ponta do Tubarão; RESEX Batoque = Extractive Reserve Batoque; RESEX Canto Verde = Extractive Reserve Prainha do Canto Verde.

Component / Indicator / Sub-indicador		**Information**	**Calculation/Scores**	**Data source**
Social Resilience at individual (SRi)				
Flexibility (FLEi)	Flexibility to change	Whether fishers were open to change or did not want to change their economic activity	Open to change = 1 Not open to change = 0	Survey question
	Resource Use Diversification	Number and types of natural resources used by fishers	Only fish = 0 Fish + other marine resource = 0.5 Fish + other resources = 1	Survey question
	Gear Diversification	Total number of fishing gear used by a fisher (FGF) Total number of fishing gear in the sample (FGS)	GD = FGF / FGS	Survey question
	Perception toward MPA	Fisher acceptance of the planning or implementation of MPAs	Agree = 1 Disagree = 0	Survey question
Ability to Learn (AL)	Years of schooling	Years of formal education achieved by a fisher (YS) Average of all fishers in the sample (µ Sample) Country average formal education (µ Brazil=5.8 ys)	LS < µ Country = 0 µ Country < LS < µ Sample = 0.5 LS > µ Sample = 1	Survey question mec.gov.br
	Fishing Experience	Fishers' age (FA) Fishing time in years (FT)	FE = FT / FA	Survey question

	Awareness of fisheries impacts	Fisher perception of the causes of stock declines (overfishing, sea pollution, lack of governance, religion, predatory fishing and illegal fishing)	Did not know about causes or quoted religion = 0 Quoted only one cause = 0.5 Quoted more than one cause = 1.0	Survey question
Ability to Organize (AO)	Financial Security	Whether the fisher has alternative sources of income (e.g., savings or property)	Yes = 1 No = 0	Survey question
	Fishing Investment	Whether the fisher owned a boat	Yes = 1 No = 0	Survey question
	Migration	Number of years the outside fisher had been living in the community Number of years the fisher had been fishing there	Native fishers and those who migrated to the community during their childhood = 0 Fisher had migrated after adulthood and only then he began to fish there = 1	Survey question
	Association Involvement	Fisher involvement (yes or no) Frequency of a fisher participation in a community organization (low = maximum of once a year, high = > twice year)	No involvement= 0 Low frequency = 0.5 High frequency = 1.0	Survey question
Assets (ASi)	Material style of life	Measured through the proxy "number of home appliances" by household.	Normalization process[a] was used to assign a proportional score to each fisher.	Survey question
Social Resilience at community (SRc)				
Flexibility (FLEc)	Economic diversification	The number of economic activities mentioned by interviewees and managers. The more resilient reserve was the one that had the greatest number of activities, whereas the only economic activity in the least resilient reserve was fishing.	Normalization process[a] was used to assign a proportional score to each community. RDSE Ponta do Tubarão = 5 RESEX Batoque = 4; RESEX Canto Verde = 6	Survey question

Social capital (SC)	Fisher engagement	Percentage of fishers engaged in environmental monitoring in the community	Engaged = 1 Not engaged = 0	Survey question
	Knowledge of management rules	Fisher knowledge of management rules inside or outside MPAs	Do not know the rules = 0 Know only one rule = 0.5 Know more than one rule = 1	Survey question
	Collective action	Demand for MPA creation: local demand (by community) or top-down initiative (by the government)	Local = 1 Top-down = 0	Manager's information
	Social organization	Presence of social and fisheries organizations in the MPA's region	Yes = 1 No = 0	mapaosc.ipea.gov.br
	Fisher participation	Percentage of participation of active fishers in the community organization	Active = 1 Passive = 0	Survey question
Assets (ASc)	Infrastructure	Measured through the presence of the community infrastructure, such as schools, pharmacies, electrical services, banking access, sewage collection and treatment, access roads, food markets, phone services, post office service, security service, health centers, and hotels	Normalization process[a] was used to assign a proportional score to each community. RDSE Ponta do Tubarão = 12; RESEX Batoque = 7; RESEX Canto Verde = 7.	Fieldwork observation
Ecological Resilience (ER)				
Biological sensitivity (BS)	Climate Exposure	Average SST in the year of the sample in the study area and average SST in the period between 1985-2000 in the study area	Low (increase up to 0.5ºC) = 1 Med (increase between 0.6/2ºC) = 0.5 High (increase over 2ºC) = 0	noaa.gov
	Coral Bleaching Risk	Frequency and intensity of coral bleaching	Presence of at least 1 high event = 0 Presence of low/medium event = 0.5 Absence of event = 1	reefbase.org

Fish Species Exposure (FSE)	Resilience of fish species	Resilience of fish species caught by fishers in the community	Low = 0 Med = 0.5 High = 1	fishbase.org
	Vulnerability of fish species	Vulnerability of fish species caught by fishers in the community	Low = 1 Med = 0.5 High = 0	fishbase.org
	Price category of fish species	Price Category of fish species caught by fishers in the community	Low = 1 Med = 0.5 High = 0	fishbase.org
	Threat Level of fish species	Threat Level of fish species caught by fishers in the community	Critical Endagerous / Endagerous = 0 Vulnerable = 0.5 Not threat / Least concern / Data deficient = 1	fishbase.org

[a]Normalization process means a standardization ranging from 0 (least resilient) to 1 (most resilient). To that end, we assigned the higher value of the variable with 1 point and we proportionally calculated the value for each fisher.

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