

# Vulnerabilities of northern Peruvian small-scale fishing communities revealed by the COVID-19 pandemic

Adriana Gonzalez-Pestana<sup>a,b</sup>, Daniela C.S. Thorne<sup>a</sup>, Joanna Alfaro-Shigueto<sup>a,b,\*</sup>, Jeffrey C. Mangel<sup>a,c</sup>

<sup>a</sup> ProDelphinus, Jose Galvez 780E, Lima 15074, Peru

<sup>b</sup> Carrera de Biología Marina, Facultad de Ciencias Veterinarias y Biológicas, Universidad Científica del Sur, Panamericana Sur, Km 19, Lima, Peru

<sup>c</sup> Centre for Ecology and Conservation, School of Biosciences, University of Exeter, Cornwall Campus, Penryn, Cornwall TR10 9FE, United Kingdom

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## ABSTRACT

During periods of abrupt change, understanding sources of resilience for adaptability in small-scale fisheries (SSF) is important for enhancing their sustainability. This study aimed to understand the vulnerability of five diverse SSF communities in northern Peru amid COVID-19, by analyzing key sensitivity indicators that influence their response to the immediate impacts caused by the lockdown and their short-term adaptive capacity. We established a baseline for each fishing community, through socio-economic, fishery-related, and commercialization characteristics. We then assessed fishery changes before and during the first and most restricted lockdown and community responses to the pandemic impact. These were used to generate a score value that ranked the adaptive capacity of each community. Through a regression tree we identified key SI that most influence the communities' response to COVID-19 impacts. Our results show that the 'fishing area related to distance from the coast' was the most important sensitivity indicator as offshore fisheries were riskier (i.e. higher travel costs) than inshore fisheries. The communities that responded better to COVID-19 impacts had high social capital (i.e. self-organization and social learning); while, the least successful communities responded passively. The adaptive strategies of SSF here identified included diversification of fishing activities (i.e., shifting to fishery areas closer to the coast), selling marine products at local markets, fishing fewer days, establishing agreements with authorities, using technology (i.e., digital platforms) in creative ways to enhance local seafood value chains, and combining different types of knowledge from different actors. These strategies fostered the re-organization of the supply chain in which a shift to local markets became a trend. We include a list of recommendations for decision-makers and principal insights related to community resilience.

## 1. Introduction

Small-scale fisheries (SSF) support the livelihoods of approximately 108 million people globally [7], and account for about 16 % of global fisheries catches and almost 20 % of the total landed value [85]. SSF are mostly located in developing countries and are characterized by multi-species coastal fisheries with limited management capacity (e.g. enforcement and monitoring) [14,21,27,73]. SSF fishing communities are often highly dependent on marine resources for subsistence as few other livelihood alternatives exist [33,51,9]. Peru is the world's second largest fishing nation [48] and SSF play an important role in the national economy, food security and cultural identity [20,54]. Peruvian SSF

account for 73 % of the fishing sector's contribution to national employment [20] and produce 96 % of the seafood consumed domestically [67]. These fisheries will also likely continue to grow in importance as Peru has one of the fastest rates of growth in fish consumption worldwide projected to increase up to 27.6 kg / person in 2025 [36], with Lambayeque and Piura regions having the second and third highest fish consumption along the Peruvian coast reported (26 kg / person) in 2020 [75]. While important, these fisheries are subject to poor management and resource over-exploitation [27]. In Peru there is also limited understanding of self-governance, such as exploring self-devised control rules [62] and of vulnerabilities, including understanding the socio-ecological vulnerabilities and adaptation strategies of SSF

\* Corresponding author at: Carrera de Biología Marina, Facultad de Ciencias Veterinarias y Biológicas, Universidad Científica del Sur, Panamericana Sur, Km 19, Lima, Peru.

E-mail address: [jalfaros@cientifica.edu.pe](mailto:jalfaros@cientifica.edu.pe) (J. Alfaro-Shigueto).

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communities to oceanographic changes [44].

The COVID-19 pandemic (hereafter ‘the pandemic’) has impacted the fisheries sector and fish supply chains at international, regional and local levels, causing an economic crisis that increased poverty and food insecurity globally [25,84,90], causing unprecedented impacts on SSF which were already marginalized [10,45,48,55,64,66]. Some fisheries have shown an adaptive capacity by responding to or bouncing back from the pandemic impacts; thus minimizing these impacts, like direct sales of seafood to consumers, and switching target catch species [18, 83]. Attributes such as self-organization, livelihood diversification, social learning and memory in fishery communities have been shown to foster their resilience [23,34,58].

Understanding and promoting attributes that enhance adaptive capacity are a fundamental step in fostering resilience, particularly in times of abrupt change or uncertainty [34,82,86]. In this study we aimed to understand the vulnerabilities of five SSF communities (hereafter ‘communities’) in northern Peru revealed by the crises caused by the pandemic. We assessed the adaptive capacity of these five communities

and identified key sensitivity factors that influenced their response to the immediate impacts of the pandemic. The results of this study can assist managers, policy makers and social institutions to identify and enhance resilience-building strategies in communities.

## 2. Materials and methods

### 2.1. Study area

This study was conducted in five communities in northern Peru: San José (Lambayeque region), Lobitos, Cabo Blanco, Los Órganos and Máncora (Piura region) (Fig. 1). These two regions have the highest numbers of fishers and one of the highest levels of dependence on fish protein for nutrition in Peru [75]. SSF in Peru are defined according to national regulations as fisheries operating from vessels with a maximum total length of 15 m and a capacity of 32.6 m<sup>3</sup>, equipped with one or multiple manually operated fishing gears (DS-012-001-PE; [30]).

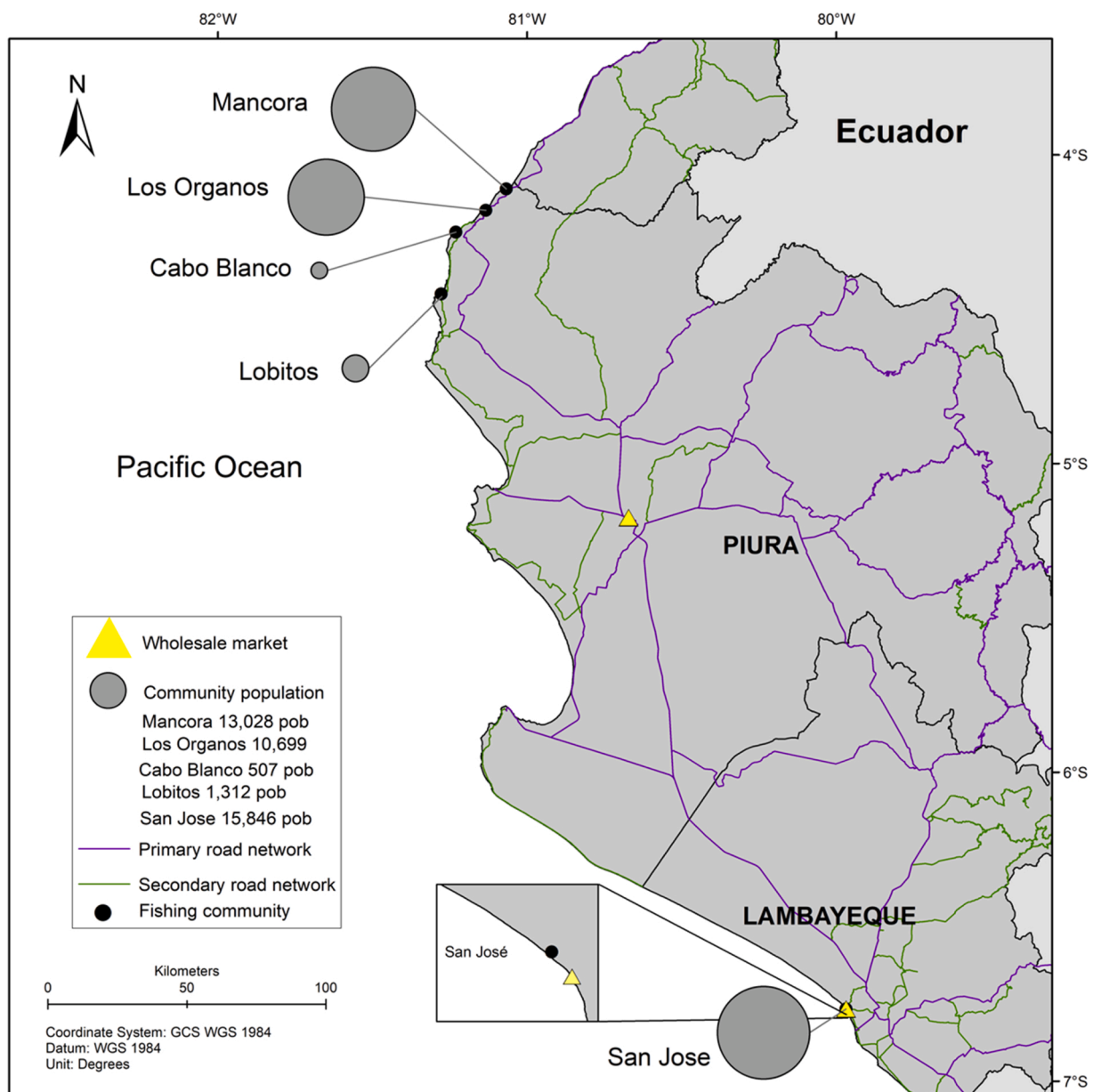


**Fig. 1.** The five small-scale fishing communities in which the study was conducted and the two wholesale markets in Piura and Lambayeque region. The size of the gray circle is proportional to the population size.

## 2.2. Period evaluated

In mid-March of 2020, the World Health Organization declared COVID-19 a pandemic, and on 15 March 2020, the Peruvian government declared a state of national emergency (DS-044–2020-PCM; [68]). From this date through 3 May 2020, the Peruvian government declared a national lockdown (i.e. social isolation; hereafter ‘the lockdown’) in which people could only circulate on public roads for the provision of and access to essential services and goods (i.e. food, health care and fuel), and the closure of international borders. Commercial businesses such as restaurants were closed, including cevicherías (seafood restaurants) that in Lima alone account for over 12,000 restaurants [20]. Therefore, two periods that represent the benchmarks to assess the changes and responses to the impact of the pandemic were evaluated: Before the lockdown (from 1 February to 15 March 2020) and during the lockdown (from 16 March to 16 May of 2020). A progressive reactivation of activities began on 3 May 2020, when commerce by delivery was implemented (DS-080–2020-PCM; El [69]).

## 2.3. Definition of key concepts and approach description

Vulnerability in social-ecological systems has been defined as a function of exposure, sensitivity, and adaptive capacity [56]. Exposure quantifies the intensity or severity of a crisis or abrupt change (i.e., the pandemic impacts) which is a large perturbation beyond the normal range of variability in which a system operates [34]. Sensitivity describes the present state of the system based on the specific properties that respond to the exposure factors arising from the perturbation [53]. Adaptive capacity is the ability to respond to challenges through learning, managing risk and impacts, developing new knowledge and devising effective approaches [59]. Adaptive capacity is a latent potential until it is applied in response to a change and is determined by access to assets (human, social, physical, financial and natural), leadership, learning and knowledge, and capacity to self-organize (reviewed in [11]).

We assessed the vulnerability of each of these five communities. First, pandemic impacts were identified, and their adaptive capacities assessed. For this, each of these communities were scored by evaluating quantitative (i.e., comparing fishery reports before and during the pandemic lockdown) and qualitative (i.e., opinions, views, and actions during the pandemic lockdown) data. A baseline of information for each fishery community was established (i.e., socio-economic, fishery-related and commercialization attributes), and a regression tree - guided by adaptive capacity score values - identified key baseline attributes that influenced the response of each community to the impacts of the pandemic (i.e., sensitive indicators). Finally, vulnerability of each community was assessed as a function of their sensitivity and adaptive capacity.

## 2.4. Adaptive capacity assessment

We identified the pandemic impacts and the community responses to these impacts through structured and open interviews (i.e., qualitative data) and fishery reports (i.e., quantitative data). We employed multiple methods (i.e., assessing quantitative and qualitative data) to cross-check their impacts and adaptive capacities [57].

For the qualitative data, we conducted a multi-mode approach including interviews by telephone and messages (via the WhatsApp platform), a remote focus group meeting, and in-person interviews [82]. During the lockdown, especially in the first month, we had weekly or bimonthly updates on pandemic impacts and potential solutions through messages and telephone conversations with two observers from each community. These observers had varied backgrounds, including as fishers and fish sellers, and included both men and women. Also, a remote video focus group meeting was held on 15 May 2021 with these same observers. Interviews examined 1) the impacts COVID-19 had on

each community and 2) solutions each community implemented to mitigate the effects of COVID-19 on fisheries. Finally, we had telephone and in-person interviews with leaders of fishing associations from the five communities.

The qualitative information from the focus groups was transcribed and analysed using the software package QDA Miner Lite version 1.2. For each section (i.e., pandemic impacts and their responses), we organized the data by categories and codes that were immediate, short, and defined the action or experience [52]. Coding was data-driven (i.e., developed through reading the transcribed material) [52]. We complemented this information with the other approaches (i.e. messages and interviews). Then, we grouped the number of responses that each fishing community adopted to mitigate the impacts of the pandemic. Each response was assigned a value score of one.

For the quantitative data, four-weekly landing reports were collected by two trained local observers from each community. These reports included the number of fishing vessels that departed from each port (number of fishing trips), and total landings (i.e., by species and total biomass). To assess if any changes occurred, we compared the average daily number of fishing trips and the amounts of landings by port before and during the lockdown for each fishery community. The comparison, therefore, was within the fishing community and not between fishing communities. We checked for normality using the Shapiro-Wilk test, and, depending on their p-value ( $< 0.05$ ), we used a two-sample t-test or Mann-Whitney-Wilcoxon test to assess if there were differences before and during the lockdown. Communities that had statistically significant declines during the lockdown (i.e. daily number of fishing trips and the landings decreased significantly during the lockdown compared to before); communities that had neutral changes (non-significant differences), were assigned a score value of 1; and communities with a statistically significant increases were assigned a score value of 2.

From these approaches (i.e. scoring quantitative and qualitative data), we generated a final score value that is the unweighted mean of the quantitative and qualitative score values. In this way, this score measured the adaptive capacity of each community, with final scores grouped into three categories: high (2.1–3.0), medium (1.0–2.0) and low (0.0–0.9) adaptive capacity.

## 2.5. Sensitivity variables

To establish a baseline for each community, we characterized them according to socio-economic attributes (i.e., livelihoods, locality services and population size), fishery-related activities (i.e., fishing area, fishing gear, condition of landing point, associativity and formalization), and commercialization (i.e., financing, sales and connectivity to market) (detailed explanation in Table 1). These characteristics were subdivided into eleven categories with a total of thirty-two variables (Table 1). These sensitivity variables were later assessed to identify those which had a central role in influencing the differences in responses observed among these communities in response to the pandemic and lockdown (i.e., sensitive indicators).

These sensitivity variables (except for population size, and market connectivity) were obtained from the first National Census of Artisanal Fishing in the Maritime Field [43]. This census presents information about communities along the Peruvian coast in which a total of 2183 fishers from these five communities were surveyed (San José: 1020, Lobitos: 112, Cabo Blanco: 439, Los Órganos: 213, Máncora: 399). Census data were retrieved from the National Institute of Statistics and Informatics (INEI, by its acronym in Spanish, <https://www.inei.gob.pe/>). Community population size was obtained from the most recent population census (INEI, 2017; <https://www.inei.gob.pe/>). To determine the distance to wholesale markets in the Piura and Lambayeque regions (i.e. TERPESA and ECOMPHISA, respectively), we used Google Maps indication tool which measures the distance from one locality to another through road networks. To determine the type of road network (i.e. primary or secondary) between communities and markets, we used a

**Table 1**

Sensitivity variables describing each fishery community baseline in northern Peru divided in three dimensions, eleven categories and thirty-two variables.

| Dimension                  | Categories                 | Variables                                                                                        | Explanation                                                                                                                                                                                                                                                                                                                                                        | References                                                                           |
|----------------------------|----------------------------|--------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Socio- economic            | Livelihood                 | Main fisher's activity                                                                           | Demographic factors are related to vulnerability among fishermen and fishing communities.                                                                                                                                                                                                                                                                          | Tuler et al. [88], Marschke and Berkes [58], Marshall et al. [60], Seara et al. [82] |
|                            |                            | Educational level: secondary                                                                     | Diversifying household livelihood activities can decrease sensitivity.                                                                                                                                                                                                                                                                                             |                                                                                      |
|                            |                            | Net income: > 1000 s/.                                                                           | Fishers with higher occupational identity had higher levels of adaptive capacity.                                                                                                                                                                                                                                                                                  |                                                                                      |
|                            | Locality services          | Spouse occupation: housewife                                                                     | Older fishers tend to have more years of fishing experience and be less adaptable to change.                                                                                                                                                                                                                                                                       | Brooks et al. [15], Cinner et al. [23]                                               |
|                            |                            | Women participate in derived-fishery activities                                                  |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
|                            |                            | Fisher's motivation: familiar tradition                                                          |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
|                            | Population size            | Fisher's experience: > 10 years                                                                  |                                                                                                                                                                                                                                                                                                                                                                    | Cinner et al. [22]; Mamaug et al. [56]                                               |
|                            |                            | Fisher's age distribution                                                                        |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
|                            |                            | Family dimension                                                                                 |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
| Fishery-related activities | Fishery area               | Basic (water, electricity and sewerage)                                                          | People are generally better able to adapt when they have assets to draw on during times of change.                                                                                                                                                                                                                                                                 | Estrella and Swartzman [32], Jara et al. [44]                                        |
|                            |                            | Health (hospital and medical centers)                                                            |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
|                            | Fishery gear               | Fishing supply (ice, oil and gasoline)                                                           | Larger communities have a greater accessibility to resources, greater diversity of economic activities. Therefore, less sensitivity to perturbations.                                                                                                                                                                                                              | Castillo et al. [19]                                                                 |
|                            |                            | Population size (number of habitants)                                                            | Fishing area near the coast imply a lower fishing effort, which reduces the sensitivity of artisanal fishermen. Artisanal fisheries have exclusive rights up to 5 nm from the coast.                                                                                                                                                                               |                                                                                      |
|                            | Condition of landing point | Type of fishing gear (i.e., bottom longline, squid handlines, gillnets, purse seine, handline)   | Handlines are associated to coastal fisheries and in some cases to vessel propulsion system (i.e., sailing); thus this type of fishery gear is related to lower operational costs compared to the others.                                                                                                                                                          | Jara et al. [44]                                                                     |
|                            |                            | Infrastructure (administrative office, dock, warehouse, handling room, storage chamber, parking) | The rapid accessibility of the landing of fishery resources allows a greater diversification of those resources, which generates higher economic income for artisanal fishermen. Having a better infrastructure is also key in the reduction of other impacts such as storms, large swells, erosion and flooding. Better infrastructure decreases the sensitivity. |                                                                                      |
| Commercialization          | Associativity              | Basic services (water, electricity, waste collection, bathroom)                                  | Associativity is a form of organization. Self-organization has proven to decrease sensitivity.                                                                                                                                                                                                                                                                     | Marschke and Berkes [58]                                                             |
|                            | Formalization              | Communication services (radio, internet and phones)                                              |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
|                            | Financing source           | Belongs to a fisher organization                                                                 | During the pandemic, fishery activities were allowed; therefore, an accreditation is a way of proving authorities your activity. Increased formalization decreases sensitivity.                                                                                                                                                                                    | Marschke and Berkes [58], Kalikoski et al. [49]                                      |
|                            |                            | Assist to assemblies (participation)                                                             |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
|                            | Sale                       | Contribute a fee (commitment)                                                                    | Fishers that depend less on middlemen and use approaches that include selling directly to consumers and forming a cooperative with hundreds of members are less vulnerable.                                                                                                                                                                                        | Njenga and Davis [63], Cinner et al. [23], FAO [46]                                  |
|                            |                            | Accreditation document for fishing activity (fishery permits, fisher's license)                  |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
|                            | Access to market           | Self-financed                                                                                    |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
|                            |                            | External actors (i.e., merchant)                                                                 |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
|                            |                            | Sold at wholesaler at landing point                                                              |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
|                            |                            | Sale was made individually                                                                       |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
|                            |                            | Type of road network (primary or secondary)                                                      |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |
|                            |                            | Distance to wholesale market                                                                     | Basic infrastructure such as roads may increase people's assets by improving market accessibility, while serving as a catalyst for other types of development (e.g., access to education, healthcare, and markets). Yet during pandemics the vicinity of wholesale markets can increase the risk of contagion.                                                     |                                                                                      |

map from the Ministry of Transport and Communications (<https://portal.mtc.gob.pe/estadisticas/descarga.html>) included in Fig. 1.

## 2.6. Identifying key sensitive indicators

We built regression tree models that graphically depict quantitative relationships between sensitivity variables and adaptive capacity score values for each community. These models were used to identify key socio-economic, fishery-related, and commercialization attributes that influenced the response of each community to the impacts of the pandemic (i.e. sensitive indicators). These two regression trees were constructed at different scales: (1) individual fisher level (individuals across all communities), and (2) community level (community level across all communities). Regression trees produce a hierarchical map of binary choices showing which attributes best partition the data according to the score values. This method has been used for analyzing complex social-ecological datasets particularly when modeling nonlinear data containing multiple interacting variables (e.g., [28,41, 65,89]). Regression tree models were prepared using the regression tree algorithm in the rpart package in R [87]. For statistical analyses and

generation of graphics, we used the statistical programming language R version 3.6.0 [26].

## 2.7. Sensitivity for each community

Once key sensitivity indicators selected through regression tree models were identified, each of these were grouped into one of two sensitivity categories (low, high) following the explanations detailed in Table 1. The sensitivity of each community was then calculated by scoring each of the key sensitivity indicators (i.e., 0–1) (Table 2). For example, for the key indicator 'fishing area related to distance from the coast', Cabo Blanco had a score value of one (low sensitivity), as this was mostly within a 5 nm area, while Máncora had a score value of two (high sensitivity) since its fishery area was mostly beyond 5 nm. For each community, we calculated the unweighted mean for the sensitivity scores.

## 2.8. Assessing vulnerability

Vulnerability assessment (VA) is increasingly developed and utilized

**Table 2**

Indicators of sensitivity obtained from regression tree model and explanation of its score value.

| Sensitivity indicator                        | Low (1)                                                          | High (2)                                                                      |
|----------------------------------------------|------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Fishing area                                 | Largest percentage of fisheries in the 5 nm area.                | Largest percentage of fisheries beyond the 5 nm area.                         |
| Fishing gear                                 | Largest percentage of fisheries used handlines.                  | Largest percentage of fisheries used other gear.                              |
| Financing source                             | Largest percentage of fisheries self-financed.                   | Largest percentage of fisheries financed by external actors (i.e., merchants) |
| Sale                                         | < 90 % fisheries sold their catch individually.                  | > 90 % of fisheries sold their catch to a middleman.                          |
| Fisher's motivation                          | Largest percentage of fisheries motivation was family tradition. | Largest percentage of fisheries motivation was financial need.                |
| Fisher's age distribution                    | Older fishers (i.e., average age higher than 40 years)           | Younger fishers (i.e., average age lower than 40 years)                       |
| Population size                              | Population larger than 10,000 inhabitants                        | Population smaller than 10,000 inhabitants                                    |
| Communication                                | More than 50 % of the services                                   | Less than 50 % of the services                                                |
| Level of infrastructure of the landing point | More than 80 % of the infrastructure                             | Less than 80 % of the infrastructure                                          |

in various sectors and fields of society, including coastal communities (e.g., [22,29]). We used the framework named “tool for understanding resilience of fisheries” (VA-TURF) [56] which has been used to understand the vulnerabilities of SSF under climate change scenarios [44,56]. VA-TURF calculates vulnerability as a function of exposure, sensitivity, and adaptive capacity [56].

The Potential Impact (PI) (i.e., average of exposure [E] and sensitivity [S]) (1) combined with the Adaptive Capacity (AC) defined the overall Vulnerability (V) (2). For this, exposure (i.e. pandemic) had a value of one for all communities.

$$PI = (E + S)/2 \quad (1)$$

$$V = [PI + (1 - AC)]/2 \quad (2)$$

We calculated (1) and (2) for each of the communities and rescaled the vulnerability index from 0–1. The final quantitative values were also organized into three qualitative vulnerability categories: “high” (1 – 0.9), “medium” (0.6 – 0.8), “low” (0.3 – 0.5) and “very low” (0 – 0.2) [44]. A summary of the methodological approach is shown in Fig. 2.

### 3. Results

#### 3.1. Impacts and coping strategies

Through qualitative data, we identified five perceived impacts that were further subdivided into eighteen impacts in these five communities (Table 3). The most common impact present in all five communities was related to sales and commercialization for which a decline in resource price was the main sub-impact, followed by the oversupply of local demand. Within this category, two communities experienced other unique sub-impacts. The border closure with Ecuador was perceived only by Mánora, while the closure of the wholesale market was only perceived by San José. These responses could be explained by the unique geographic locations of Mánora and San José since these are the closest communities to Ecuador and a wholesale market, respectively (Fig. 1). Also, San José fishers sold most of their resource to the nearby wholesale market (Fig. 3D).

The next most important perceived impacts were related to fishing, the behavior of local authorities, and fear of contagion. Fishery-related impacts included reduced fishing effort by Cabo Blanco, which was related to authorities banning fisheries. For Mánora the perceived impact was travel costs of fishing trips because the Mánora fishing area is the most oceanic (Fig. 3B). This results in a more expensive fishery due to operational costs (e.g., gas, ice). This, combined with the border closure with Ecuador and resource prices declines, created a scenario in which offshore fishing was risky. Fear of contagion was mostly perceived by San José. Fear of contagion when selling the resource at the wholesale market was perceived since this practice is more common than in the other communities – such that fishers become merchants when selling their product at the nearby wholesale market (Fig. 1).

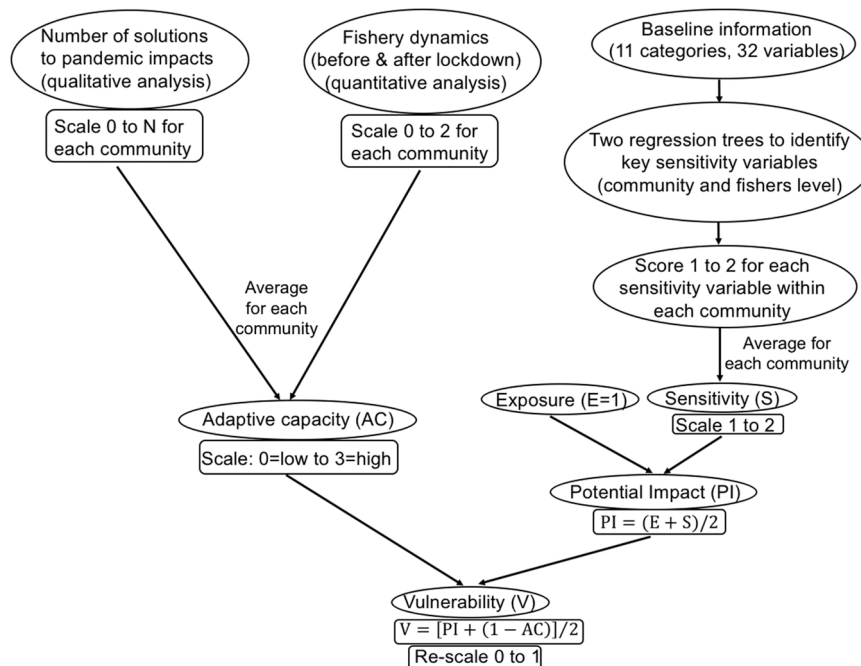


**Fig. 2.** Flowchart and summary calculations of the VA-TURF assessment used in this study. (Figure adapted from [44]).

**Table 3**

Impacts of COVID-19 and solutions of small-scale fishery communities in northern Peru obtained from conversations with community members. CB: Cabo Blanco, SJ: San José, Lo: Lobitos, Ma: Máncora, Or: Los Órganos.

|                 | Categories                  | Code                                                                   | CB                                        | SJ | Lo | Ma | Or |   |
|-----------------|-----------------------------|------------------------------------------------------------------------|-------------------------------------------|----|----|----|----|---|
| Impacts         | Fishing-related             | Reduced fishing effort (number of boats and fishing days per week)     | X                                         |    |    |    |    |   |
|                 |                             | Travel costs of fishery trips                                          |                                           |    |    | X  |    |   |
|                 | Local authorities behaviour | Authorities ban fishing                                                | X                                         | X  |    |    |    |   |
|                 |                             | Services                                                               | Lack of ice (transport resources)         |    | X  |    |    |   |
|                 | Sale & Commercialization    | Border closure with Ecuador (prevented export of resources)            |                                           |    |    | X  |    |   |
|                 |                             | Local demand oversupplied                                              | X                                         | X  |    | X  |    |   |
|                 |                             | Resource prices dropped                                                | X                                         | X  | X  | X  | X  |   |
|                 |                             | Wholesale market closed                                                |                                           | X  |    |    |    |   |
|                 |                             | Merchants: None or decreased                                           |                                           |    | X  |    | X  |   |
|                 |                             | When fishing                                                           |                                           | X  |    |    |    |   |
|                 | Fear of contagion           | Entry of infected into the community                                   | X                                         |    |    |    |    |   |
|                 |                             | Sale of resource at wholesale market                                   |                                           | X  |    |    |    |   |
|                 | Actions to minimize impacts | Change in fisher's individual behaviour                                | Change of fishery area and target species |    | X  |    | X  |   |
|                 |                             |                                                                        | Sale at local markets                     | X  | X  |    |    | X |
| Sale strategies |                             | Use of middlemen to reduce contagion at wholesale markets              |                                           | X  |    |    |    |   |
|                 |                             | Use of digital social network platforms (i.e., Facebook)               |                                           |    |    |    | X  |   |
|                 |                             | Communal agreements (i.e., fishing fewer days to stabilize prices)     | X                                         | X  |    |    | X  |   |
| Agreements      |                             | Agreements with local authorities (i.e., municipality) to reopen trade | X                                         |    |    |    |    |   |

Through conversations with local observers (i.e., qualitative data), we identified six actions to minimize pandemic impacts (hereafter 'coping strategies') in these five communities (Table 3). The two most common coping strategies were (1) the sale of fish products at local markets and (2) fishing for fewer days because of a local agreement among fishers. This last measure was put in place to stabilize prices. Cabo Blanco fishers stopped fishing for six days after local authorities banned fishing (i.e., impact). An immediate response to this situation was dialoguing with authorities to find a solution which resulted in an agreement (i.e., fishers agreed to temporarily fish no more than 3 day/week and to implement biosecurity measures). The municipality agreed to allow merchants access to landing sites (which was closed due to the pandemic), thus allowing commerce at an inter-regional level. The community of Los Órganos used a Facebook page called "Flattening the curve" to facilitate online local sale of marine resources. San José and Máncora responded by changing fishing areas as these communities present the most offshore fishing areas (Fig. 3B); therefore, they changed to more nearshore locations to reduce the operational costs. Also, one solution identified by fishers from San José was to change from selling their products directly at the wholesale market to depending upon middlemen to reduce the potential for COVID-19 infection at wholesale markets which was perceived as an impact (Table 3).

These results were used for the qualitative assessment of adaptive capacity. Accordingly, Cabo Blanco, Los Órganos and San José had the highest number of coping strategies and therefore these communities had the highest score value. Máncora followed these communities with an intermediate score value; while Lobitos exhibited no coping strategies and therefore had the lowest score (Table 4).

For the quantitative assessment of adaptive capacity, fishery reports were evaluated. We observed that four of the five communities experienced declines in the average number of fishing vessels that departed during the lockdown (Máncora was the exception). Only Lobitos and San José had statistically significant declines in the number of vessels departing ( $p < 0.05$ ) (Fig. 4). As for landings, all communities experienced decreases, except for Cabo Blanco which showed a significant increase, while San José, Los Órganos, and Lobitos showed statistically significant decreases in landings (Fig. 5; [39] found similar results for Los Órganos during the pandemic). Cabo Blanco and San José shared the same impact: local authorities banned fishing. However, Cabo Blanco stopped fishing for several days and re-organized which resulted in an agreement with local authorities to reopen economic activities. San Jose re-activated more slowly. Also, this community had the most fear of contagion at two levels (i.e., when fishing and at the wholesale market) which prevented fishers from reactivating activities. This demonstrates the differences in the fishery reports for these two communities.

Máncora showed the least impact in fishery dynamics, after Cabo Blanco; this could be explained by the solution of changing fishing area and target species so that their fishery could be sustained at a nearly pre-COVID level. Lobitos was the most passive community in terms of implementing solutions; thus, fishing activities were negatively affected. As a result, Cabo Blanco had a two-point value score, Máncora was assigned one-point value score and the other communities had a zero-value score (Table 4).

For the final score value (i.e., average of quantitative and qualitative score values) that assess adaptive capacity, Cabo Blanco had the highest score (i.e., highest adaptive capacity), followed by Los Órganos, San José and Máncora with a medium score, and Lobitos with a low score (Table 4).

### 3.2. Key sensitivity indicators

At the fishery level, the regression tree analysis identified fishing area related to distance from coast (with a threshold of 5 nm offshore) as the most important sensitivity indicator that influenced the response of each community to the impacts of the pandemic, followed by fishing gear (i.e., handline, followed by gillnet), source of fishery finance, individual sale, and, lastly, fisher's motivation and experience (Fig. 6A).

The two most important sensitivity indicators are related. The inshore fisheries of Cabo Blanco and Lobitos primarily, and Los Órganos secondarily, had less fishery-associated economic risks than the offshore fisheries of Máncora and San José (Fig. 3B) since these inshore fisheries have fewer expenses due to their proximity to fishery areas [44]. As a result, fishers invested less in gasoline for the vessel and ice to preserve their catch. Also, Cabo Blanco differed from the other four communities in its use of sailing to navigate [19], further reducing fishing trip costs. The type of fishing gear used, which was the second most important sensitivity indicator, showed some association with fishing area related to distance from the coast. Inshore fisheries (i.e., Cabo Blanco and Lobitos) used mainly handlines; while offshore fisheries (i.e., San José and Máncora) used primarily gillnets (Fig. 3B).

The source of fishery finance was another important sensitivity indicator, and this was associated with fishing area related to distance from the coast. Offshore fisheries (i.e., Máncora and San José) financed their activities mostly through loans (i.e., from middlemen) (Fig. 3D). During the pandemic, this financing represented higher risks due to higher costs of offshore fishing trips and market instability. On the other hand, inshore fisheries (i.e., Los Órganos, Cabo Blanco and Lobitos) are most frequently self-financed given its lower associated costs (Fig. 3D).

At the community level, the regression tree analysis identified population size as the most important variable, followed by communication

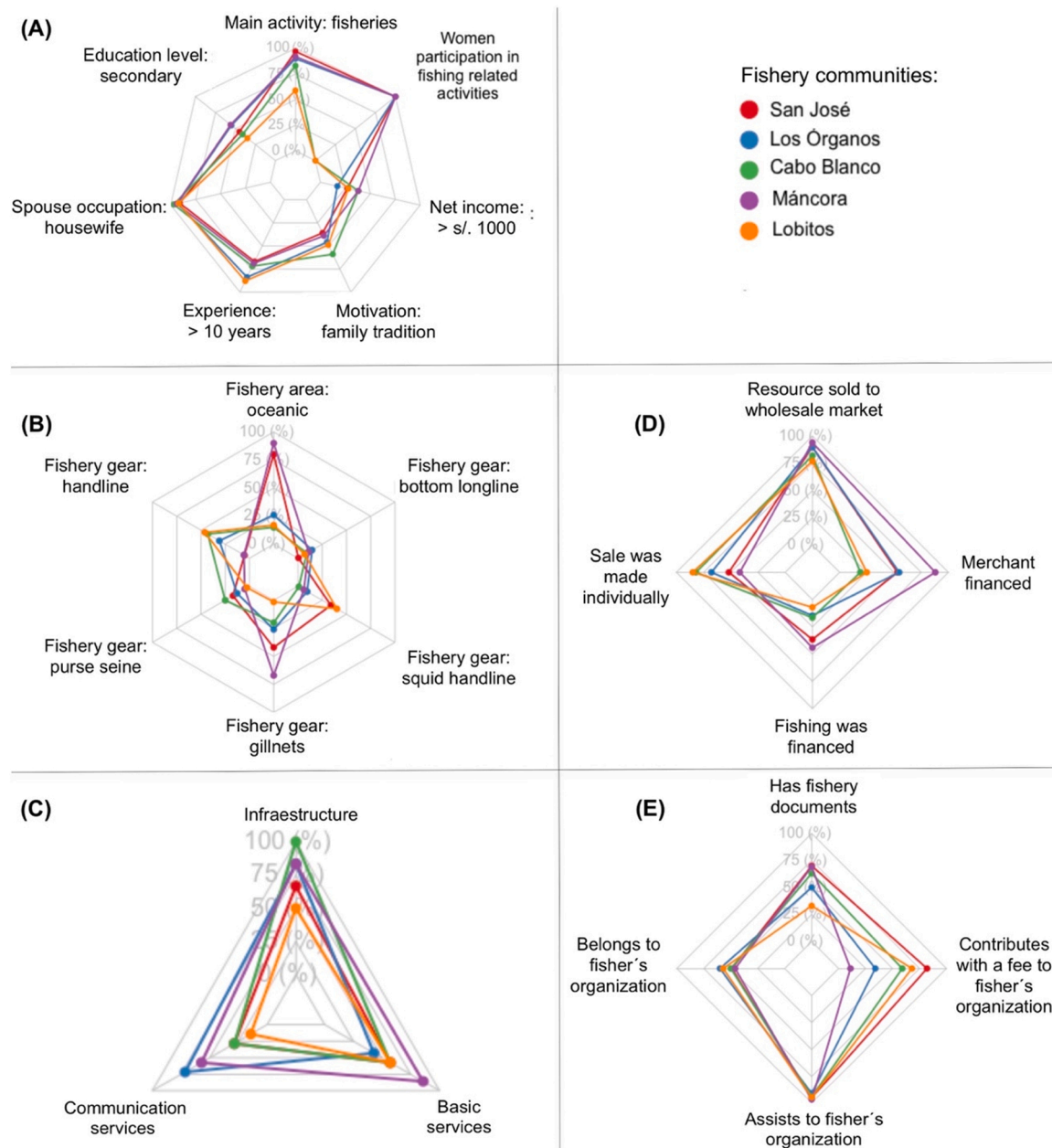


**Fig. 3.** Sensitivity variables for each fishery community baseline. (A) Livelihood, (B) Fishery characteristics, (C) Condition of landing point, (D) Commercialization and (E) Organization & Formalization at five northern Peru small-scale fishing communities.

**Table 4**

Adaptive capacity score value for the five small-scale fishery communities in northern Peru in which the highest values represent a higher adaptive capacity to COVID-19 impacts.

| Response variable                                               | San José | Lobitos | Cabo Blanco | Los Órganos | Máncora |
|-----------------------------------------------------------------|----------|---------|-------------|-------------|---------|
| Change in daily average number of vessels departed and landings | 0        | 0       | 2           | 0           | 1       |
| Number of Solutions                                             | 4        | 0       | 3           | 3           | 1       |
| Average                                                         | 2        | 0       | 2.5         | 1.5         | 1       |
| Final score                                                     | Medium   | Low     | High        | Medium      | Medium  |

and infrastructure level of the landing point (Fig. 6B). Lobitos, for example, had the second smallest population size (Fig. 1). This community is the most isolated; only accessible through a secondary road network with poor landing infrastructure and communication (Fig. 1). Smaller communities such as this have a lower accessibility to resources and reduced diversity of economic activities. They are more sensitive, therefore, to perturbations which are exacerbated by poor conditions at the landing point (Table 1).

Considering the two types of sensitivity indicators (i.e. fishers and community level), Los Órganos and Cabo Blanco had the lowest sensitivity, while Máncora and Lobitos had the highest sensitivities of the five communities (Tables 4 and 5). The detailed baseline information, including the 32 attributes for each fishery community can be found in Supplemental Information (Supplemental Table 1, Supplemental Fig. 1).

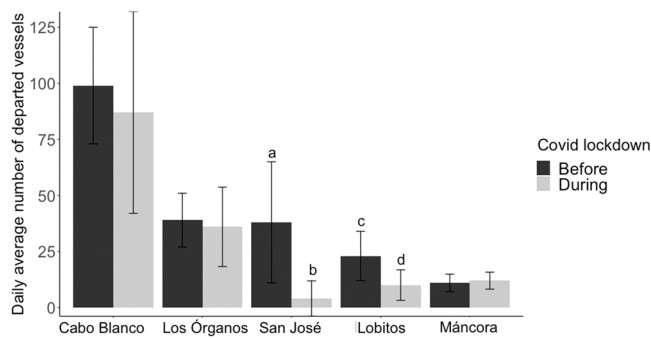


**Fig. 4.** The daily average (and standard error) number of fishing vessels that departed from landing points before (from 1 February to 15 March 2020) and during (from 16 March to 16 May 2020) the national lockdown. Letters represent significant differences (“a” significant different from “b”, “c” from “d”). Only calculates the days in which vessels departure.

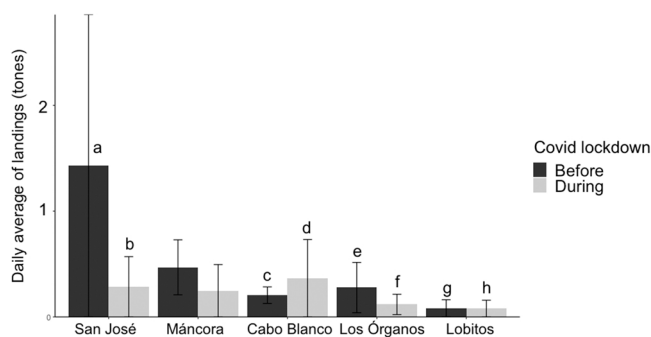


**Fig. 5.** The daily average (and standard error) fishery landings before (from 1 February to 15 March 2020) and during (from 16 March to 16 May 2020) the national lockdown. Different letters represent significant differences (“a” significant different from “b”, “c” from “d”, and so on). Only calculates the days in which landings occurred.

### 3.3. Vulnerability assessment

Lobitos was determined to be the community that was most vulnerable to the pandemic due to a lack of adaptive capacity and high sensitivity, while Cabo Blanco was assessed as the least vulnerable given its high adaptive capacity and low sensitivity. San José and Los Órganos showed low vulnerability while Máncora presented a medium vulnerability due to its reduced adaptive capacity and high sensitivity (Table 5).

## 4. Discussion

SSF support the livelihoods of many coastal communities in low-income countries [45]; yet these communities have limited resources to cope with economic shocks [3]. Our study investigated the vulnerability of Peruvian SSF during the pandemic – a massive shock to these communities – by using an innovative methodological framework with a robust statistical design. Shocks represent a unique opportunity to explore the underlying reasons why some fishing communities are better able to cope than others to crises events. This study used a systemic approach by including a baseline for each community and identifying sensitivity indicators that strengthened the research by including structural drivers that increase vulnerability or reduce adaptive capacity [5,6]. These results ultimately provide insights into the sustainability and resilience of SSF, and steps that can be taken to foster adaptive capacity and reduce sensitivity during times of abrupt change.

### 4.1. Sensitivity indicators: reduced risks and opportunities during the pandemic

The high level of investment of Máncora's offshore fisheries, due to operational costs (e.g. gasoline, ice), and the highly-migratory behavior of the species targeted (i.e. yellowfin tuna and thresher sharks), meant that this fishery represented a higher risk. The offshore gillnet fishery in Peru is estimated to be profitable only in 52 % of fishing trips [2]. But the Peruvian offshore artisanal fishery is the most profitable SSF in the nation, generating on average USD 452 million in exports annually from 2012 to 2016 (REDES, 2018). Fishers are motivated to pursue this offshore fishery because their target catch can garner high export prices [17,38]: thresher shark fins are traded internationally, and yellowfin tuna is exported to Ecuador. During the pandemic, high value fisheries that usually enter export supply chains were more negatively impacted (since exportation was halted or suffered slowdowns during the lockdown) [1,80] compared with lower value species that are commonly sold in local markets [16,55]. In northern Peru, El Niño and La Isilla were more severely impacted by the pandemic since they relied more heavily on the international market to sell their fishery resources [6,39]. In the case of Máncora, one of the most important fishery communities for pelagic offshore sharks in Peru [38]), the closure of the world's largest seafood markets in China [50], in which most fins are consumed, impacted this community. Furthermore, offshore fisheries were more severely affected as the biggest impediments to fishing operations during the pandemic were the lack of ice, gasoline, and other supplies [1]. Also, fishers perceived it as unsafe to expose themselves to long fishing trips due to higher risk of contagion [5]. These factors caused a cessation in offshore fisheries with a positive ecological impact on fish stocks as fishing mortality was reduced [1]. However, short-term cessations such as the one provoked by the COVID-19 lockdown in early 2020 cannot recover marine resources and the ecosystem [24], such as of endangered species with slow life-history traits.

During the pandemic, Máncora's response in relation to the most important sensitivity indicator (i.e., fishery areas) was to change to an inshore fishing area. This response to pandemic impacts indicates that this fishing community had a short-term adaptive capacity and high flexibility: by changing their fishery area to a more coastal area, they reduce risks. In the La Isilla community (northern Peru), offshore fisheries pivoted to nearshore artisanal raft fishing at the onset of the pandemic [5]. Diversifying fishing activities spreads the risks and reduces vulnerability [34,58]. In this study we show that by changing their fishing practices, the community was able to continue fishing, and as a result, their landings were not affected significantly. This behavior could have been drawn from social memory from past perturbations (El Niño events), but further research is needed to confirm this. In northern Peru, livelihood strategies to cope with the negative effects of El Niño events include fishing for different resources and traveling further to fish (related to changing their fishery areas) (Kluger et al., [94]).

### 4.2. Adaptive capacity response to the impacts on the market and supply chain

During the pandemic, SSF were impacted through the collapse of prices due to a disruption in demand and supply chains [10,16,45,46,55]. In this study, most fishing communities (i.e., Cabo Blanco, San José and Los Órganos) developed coping strategies to these impacts including the sale of their products at local markets, and by fishing for fewer days. Their sale at local markets soon created an oversupply, and prices dropped as a result [45,46]. Therefore, fishing communities opted to fish for fewer days per week to reduce surplus and thus stabilize prices. Cabo Blanco had an additional response to restore the supply chain at the regional level: agreements with local authorities (i.e., municipality) to reopen commercialization. Some of these coping strategies are recommended by the Food and Agriculture Organization to mitigate the impacts of COVID-19 in fishing communities [45]. These actions

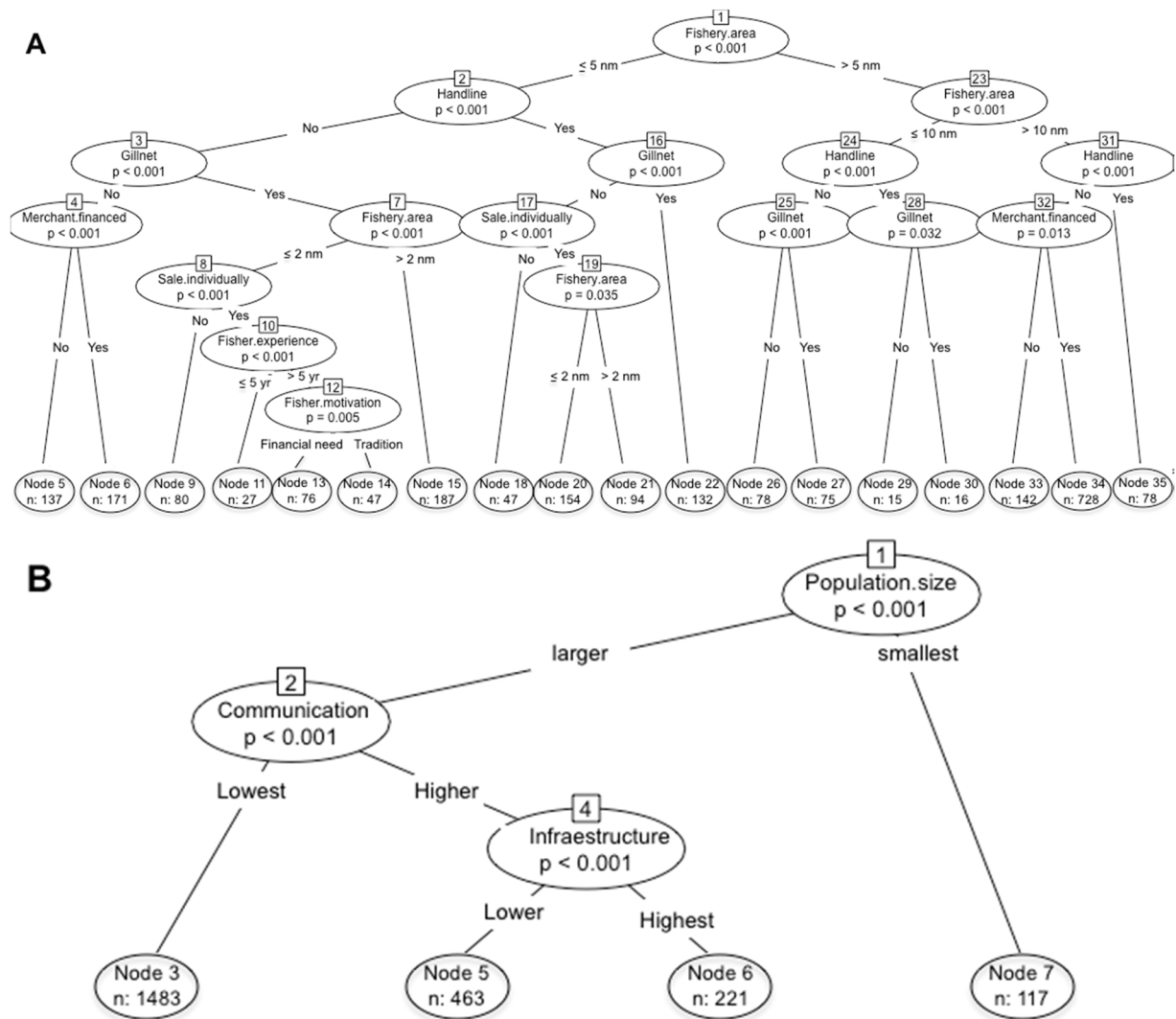


**Fig. 6.** Regression tree showing key baseline attributes (i.e. sensitivity indicators) that have a central role in influencing the response of each fishery community to the negative impacts of Covid-19 pandemic, in five small-scale fisheries in northern Peru. A) Fishers level, B) Community level: communication and infrastructure of the landing point.

**Table 5**

Average scores of exposure, sensitivity, adaptive capacity and the calculated (and re-scaled) vulnerability value to the COVID-19 impacts for the five small-scale fishery (SSF) communities in northern Peru.

| SSF         | Exposure | Sensitivity | Adaptive Capacity | Vulnerability |
|-------------|----------|-------------|-------------------|---------------|
| Cabo Blanco | 1        | 1.1         | 2.5               | 0             |
| San José    | 1        | 1.6         | 2                 | 0.3           |
| Los Órganos | 1        | 1.1         | 1.5               | 0.4           |
| Máncora     | 1        | 1.6         | 1                 | 0.6           |
| Lobitos     | 1        | 1.6         | 0                 | 1             |

demonstrate the ability of some communities to self-organize - an attribute of resilience [12,34]. One of the observers from Cabo Blanco, a leader of and communicator for the community expressed several times that the strategy of fishing fewer days to maintain prices carried an important lesson since having fewer fishing trips, fish stocks could recover, yielding more fish to catch. He said, “[w]e fish less and earn more” concluding about the pandemic, “[n]o hay mal que por bien no venga” or translated to English “every cloud has a silver lining”. This study does not conclude that the fish stock increased in such a short time. What is important, though, is the positive perception that the observer from Cabo Blanco had about a perturbation in which even

negative drivers of change provided opportunities for his community.

Trust is a key underlying condition in establishing dialogue and making possible rapid responses. This trust is developed over time. In Cabo Blanco, fishers trusted the members of their fisher organization and indicated that their peers would cooperate toward the benefit of others and their communities [76]. Also, fishers and local authorities (i. e., the municipality) have a close relationship and the municipality has demonstrated its interest and support for them. El Alto, the closest location to Cabo Blanco and the town in which fishers live, is one of the few municipalities in Piura region that has won a national prize for their good practices which is promoted by the Ministry of Development and Social Inclusion. Furthermore, of the five communities assessed in this study, only the municipality of El Alto has signed a Conservation Agreement (in 2021) with the fishers from Cabo Blanco, expressing their mutual support and commitment, with actions under this agreement currently being implemented. Thus, a pre-condition for self-organization between actors is trust – an important asset to draw upon in difficult times.

#### 4.3. Social learning and memory

Crises can trigger learning and generate knowledge [91]; and

communities that develop capacities for learning and experimentation become more resilient [12]. Memory is also a key component of resilience because it supplies the experience of previous self-organizing processes that become embedded in a historical and evolutionary context [34]. Resilient communities can handle surprises and prepare for change by learning from perturbations and developing a social memory that seeks opportunities for renewal [34,40,58]. Cabo Blanco overcame barriers by using their strong social capital to self-organize by establishing agreements within the community and with local authorities [74]. These experiences can in turn become part of their social learning (i.e., a change in understanding through social interactions; [79]) and social memory which potentially increases their adaptive capacity in future scenarios [34].

Combining different types of knowledge for learning is a critical factor required for reorganization during periods of rapid change [34, 35]. Mutual learning systems are characterized by sharing of knowledge from different actors (e.g. local resource users with external groups) resulting in novelty [31]. This is exemplified by the response of Los Órganos which used digital social network platforms to locally sell their marine resources - a unique adaptive strategy among the five SSF communities. This strategy was the result of integrating knowledge from external actors - persons who shared their technology skills with fishers. Leadership experience may be a pre-condition that made this intervention more likely to occur, as the person who introduce this novel solution to the community was the former president of the fisher organization who has held this position several times.

#### 4.4. The case of Lobitos: conditioned to a passive response

Cabo Blanco and Lobitos shared similar sensitivity indicators (e.g. fishing area, fishing gear, fishery self-finance, small population), yet Lobitos lacked an adaptive capacity. This could in part be explained by its unique history. At the end of the 19th century, Lobitos was a small fishing settlement that transformed into the first oil settlement in Latin America [61]. For almost a century (1900–1968) Lobitos was economically and socially dominated by four different and powerful transnational oil companies. The local community suffered social injustice: labor conditions were poor (i.e., low remuneration, no days-off or overtime, job insecurity, and no retirement) and claims for basic labor rights often ended unresolved or turned violent [8]. Oil extraction has not led to improvements in Lobitos as evidenced by its continued isolation and poor level of development [37,61]. In the 1960 s, a military base was established in Lobitos which forced some locals to move to a nearby area and military members forced local fishers to stay late so they could buy fish at a below-market price. If fishers refuse to sell their catch, they could be temporarily imprisoned [8]. There is now also a large offshore oilfield near Lobitos in which oil spills have occurred periodically with limited actions to prevent their recurrence. Coastal communities can feel powerless in the face of such disasters, and research has shown that powerful oil companies often exclude local communities from decision-making and communities see themselves as passive recipients of decisions made on their behalf [4]. As a result, fishers in Lobitos have historically been a group with little power and with actions imposed upon them by powerful outside groups [77]. This may help explain their limited social and economic capacity [37] and their more passive response to the pandemic.

#### 4.5. The case of Cabo Blanco: lessons from the past and for the future

During crises, highly selective, low-impact and clean-energy fishing practices (i.e. handlines and sailing) with inshore fishing areas proved to be less economically risky, and therefore more resilient. This is the case of Cabo Blanco which had the lowest vulnerability and a high adaptive capacity during the pandemic. A recent study determined that Cabo Blanco has a strong social capital within the community and their fishers' organizations [76]. However, this pre-COVID study that assesses

the wellbeing of two fishery communities with sustainable low-impact fishing practices, determined that Cabo Blanco is in a social-ecological trap due to low natural capital (i.e., their target resources are becoming less abundant, less diverse, smaller, and harder to catch), limited financial (e.g., low saving capacity and monthly income) and human capital (e.g. basic level of education) assets. Thus, the authors suggest that this community is highly vulnerable to external environmental (e.g., El Niño) drivers, among others. However, in this study this community was resilient during an extreme event by using its high social capital. Other fishery Peruvian communities might be in a similar social-ecological trap, as De la Puente et al., [27] suggests that the growing fishing effort of the SSF is unsustainable and uneconomic.

This highlights the complexity and dynamism of fishery communities and the importance of monitoring extreme events. Most pandemic case studies around the world showed that fishery communities were negatively affected [1,10,39,6]. For example, in Peru overall fishing effort dropped approximately 80 %, after the quarantine declaration (Aroni, [92]). But while most communities struggled during these hard times, Cabo Blanco excelled at staying afloat. Yet, their social capital by itself might not be enough to increase their wellbeing over the long-term [76]. Even worse, their limited assets can erode their social capital (Villasante et al., [93]). Thus, it is crucial that support be given to these communities by improving other key assets (e.g., human, financial, institutional) that can support their wellbeing and further enhance their social capital.

#### 4.6. Study limitations and recommendations for future studies

In this study, each community was unique and presented a diversity of supply chain characteristics, socio-economic attributes, fishery-related activities, and commercialization paths. Thus, one limitation of this study was the limited number of observers per community. The impacts and coping strategies for each community that we recorded and detailed were therefore probably incomplete. This limitation was acknowledged by implementing a multi-modal approach - including interviews, and follow-ups by telephone and messaging (via the WhatsApp platform), a remote focus group meeting, and in-person interviews - to have a more comprehensive picture of COVID-19 impacts on each community. In so doing, the most relevant and well-known impacts and coping strategies were likely identified and documented.

The demand and supply sides of the fish food chain have been disrupted, affecting every activity and stakeholder along the supply chain [1]. Future studies should therefore interview actors from multiple nodes in the supply chains toward developing a more comprehensive picture of the food supply system. More in-depth future studies could also disaggregate the different adaptive capacities of individuals and groups within SSFs (e.g., between genders, ages) to better understand how these actors coped or innovated [6].

Finally, future studies should monitor communities through time so that the long-term effect of the pandemic can be studied. For example, future research could determine if in future shocks (e.g., health or climate change crises) communities used their social memory to cope with challenges or if local markets that were created during the pandemics have persisted or vanished and the underlying reasons why they followed those trajectories.

## 5. Conclusions

This study identifies key sensitivity indicators and short-term adaptive responses to the negative impacts of the COVID-19 pandemic in SSF communities in northern Peru. The location of fishing areas was the most important sensitivity indicator, and communities used varied coping strategies to adapt to changing conditions. Social capital (i.e., self-organization and social learning) increased the resilience of SSF to the impacts of the pandemic. Most coping strategies resulted in the development of local and domestic markets. Several studies have

highlighted that during the pandemic, shorter supply chains were a common strategy implemented by stakeholders (e.g., [5]). This is concomitant with supply chain network theory in which efficient supply chain systems demonstrate a short characteristic path length [42]. This crisis also opened opportunities to transform the seafood food system to be more sustainable, inclusive, and resilient, as a seafood distribution model that reduces waste and long-distance distribution, serves local and regional food systems, creates more transparency, and delivers seafood directly to consumers, presents a segment of the food system that has not been fully embraced [80].

Based upon these study findings and conclusions, lists of recommendations for consideration by decision-makers and principal insights related to community resilience to future crises are offered below.

### 5.1. Recommendations for decision-makers

1. To increase adaptation in fishery communities during rapid change, strategies can include diversification of fishing activities and supply chains (e.g., selling marine products at local markets).
2. During times of change and uncertainty in the food sector, reorganization of the seafood supply chain is an adaptation.
3. Create safe spaces in which communities can develop the capacity for experimentation and social learning to become more resilient.
4. Communities that historically have been disempowered should be supported to built-up social capital.
5. Promoting the inclusion of different types of knowledge from different actors enhances innovation, adaptability, and renewal. During COVID-19, this exchange of knowledge was used to diversify distribution strategies in sea-food value chains.
6. Technologies (e.g., digital platforms) can be used in creative ways to enhance local seafood value chains by facilitating fishers-to-final-consumer distributional networks.
7. Governments should foster and built trust with communities to facilitate coordinated change during crises, thereby increasing resilience. Thus, trust should be a variable monitored by the Peruvian government so efforts could be allocated to improve upon it [76].

### 5.2. Community resilience insights

1. During crises, highly selective, low-impact and clean-energy fishing practices (i.e., handlines and sailing) with fishing areas closer to the coast proved to be less economically risky, and therefore more resilient.
2. Communities that historically have been disempowered might develop limited social capacity and their response to crises may be more passive.
3. Increased social capital, such as self-organization and social learning, increases adaptability and builds longer-term resilience in fishery communities.
4. In social learning, combining different types of knowledge from different actors is a critical factor for reorganization during periods of rapid change.
5. Digital platforms can provide powerful tools to create and establish shorter supply chains.
6. Trust is a key pre-condition to draw on in difficult times to self-organize.
7. Even negative drivers of change provide opportunities for renewal.

### CRedit authorship contribution statement

AGP collected data, performed the analysis, developed the visualization and with JCM led the writing of the manuscript. AGP, JAS and DCST conceptualized and designed the research. DCST collected data and supported in the analysis. JCM supervised the visualization of data. JAS and JCM supervised and provided insight. All authors contributed to

the writing and the revision of the article.

### Data Availability

Data will be made available on request.

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### Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2023.105503.

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