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Social Vulnerability of the Fishing Community to Restrictive Public Policies: Case Study the Gulf of Ulloa, Mexico

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Abstract: The social vulnerability approach (SV) establishes that social inequalities and disadvantages have developed beyond monetary poverty in the last few years, since the process is built at different scales. In its objectives, the SV multidimensional measurement is considered to be a priority tool in monitoring the compliance of the first goal: to eliminate poverty in all its forms. Therefore, the objective of this research is to calculate the SV of the fishing communities of the Gulf of Ulloa (GU), Mexico by macro-markers, to subsequently contrast them with field micro-data, and finally to perform a behavior scenario that takes into consideration the current public policies that restrict fishing in such areas. The results showed substantial differences depending on the type of information used ($x^2_{0.05,8} = 41.53 > 15.51$). A corrected contingency coefficient of 0.83 was obtained, indicating that the calculus depends strongly on the data and scale used, and suggesting that macro-data may be masking the true SV values in the area in such a way that they could be severely underestimated. Although the context of micro-scale is not the only one, SV should be calculated to analyze the fishing communities, as coastal fishery represents almost the total livelihood of the inhabitants. Nevertheless, these communities confront numerous local and global threats, and these pressures on SV put their livelihoods, well-being, food security and traditional lifestyles at risk. Therefore, the role of researching human dimensions and governance is not only basic, but also urgent in order to turn to sustainable socioeconomic management.

Keywords: social vulnerability; public policies in coastal fisheries; Gulf of Ulloa

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1. Introduction

Social vulnerability (SV) generally refers to the potential negative effects that external human health stresses can have on communities, which include natural or human-caused disasters and disease outbreaks. Reducing social vulnerability can decrease both human suffering and economic loss. However, the SV approach has established that social inequalities and disadvantages have moved beyond monetary poverty in the last few years, as it is a process built at different scales that combines different levels. For example, micro-level refers to strategies and availability at home; mezzo-level refers to organizations and institutions; and macro-level refers to social structures, markets, and the State. In the objectives of sustainable development, the SV multidimensional measurement considers the initiative that marks the global agenda up to 2030, which includes this type of measurement as a priority tool for monitoring compliance of its first goal: to eliminate poverty in all its forms [1].

From the perspective of socioenvironmental systems, the main sources generating SV are socioeconomical, such as poverty; lack of education; precariousness of housing; gender inequity; productive chain disintegration; abuse of intermediaries; corruption of governmental and private agents; overexploitation of some resources; and precariousness of productive infrastructure [2]. Much of this social vulnerability reflects the level of education and organization of the same communities—particularly for fishery communities—deriving from fundamental factors, such as operational capacity limitation, and consequently, income decrease [3].

Despite the importance that SV studies of rural communities have gained in the last few years, their evaluation is performed based on qualitative or semiqualitative methods that regularly use secondary sources of data instead of gathering primary data, which do not capture political or ecological factors that affect vulnerability levels of the community [4].

Therefore, the objective of this research is to calculate social vulnerability of the fishery communities of the Gulf of Ulloa (GU) by general markers, to subsequently contrast them with field information at a local level, and finally, to perform a behavior scenario that takes into consideration public policies restrictive to fisheries, that are currently maintained in such areas.

2. Material and Methods

2.1. Study Area

The GU (Figure 1) is completely influenced by the California Current (CC) [5], and its southern limit adjoins the Bahía Magdalena-Almejas Lagoon system. During reflux, the gulf provides elevated concentrations of organic and phytoplankton material toward the adjacent ocean [6]. These attributes determine the consideration of the GU as a *Biological Action Center* (BAC). BACs are unique areas and are vital to sustaining commercial and sport fisheries, as well as for the structure and productivity of marine ecosystems [7].

The high biological production values in the gulf favor the presence of different fishery resources in such quantities that have maintained the most important fishery in the entity, contributing to approximately 25% of all artisanal fisheries in the state of Baja California Sur (BCS) [7]. Approximately 100 species are exploited in the area, distributed across some resources of great volume and low cost, such as small pelagic (sardines and mackerel); or those in low volume but of great commercial market value, such as lobster, abalone, shrimp; and many others that are in lower quantity, but that sustain the fishery activity in the area [8]. Coastal fisheries in the region are very important for the economy of the state and for the inhabitants of local communities because they generate direct employment, and in many cases, are the only economic activity of its inhabitants. This region has approximately 21 fishery locations that add up to 7940 inhabitants and a total of 1228 fishers. For the purposes of this research, 16 of the 21 locations recorded were considered. All of these locations are rural, except for Puerto San Carlos (Figure 1, Table 1). From this population, approximately 13% show high marginalization levels because they lack water, electricity, health and education services, and the other 87% show medium marginalization levels [9].

Deriving from the fishery resource heterogeneity in the GU, the competent authority has implemented different management strategies from traditional measures. These range from minimum capture size (e.g., lobster), fishing gear limitation (shrimp), permit concession (clams), up to more elaborate methods, such as management by administrative areas (sargassum), or with annual capture quotas per species, size, season, and area (e.g., abalone). However, as in all highly productive marine ecosystems, the GU is also a concentration area of species that are not subjected to fishing. Some of them may even be species under special protection, such as marine mammals and sea turtles.

In this context, as a consequence of the turtle mortality observed in the surrounding areas of the GU, starting from 2003, and faced with international pressure lead by U.S. conservation groups that formally requested trade sanctions against Mexico to stop the country's massive loggerhead sea turtle bycatch (https://seaturtles.org/title-16/, accessed on 24 June 2022), in April 2015 the GU was declared a Fishing Refuge Area (FRA) because of the interaction between coastal fishing and the yellow loggerhead sea turtle *Carettta caretta*. These measures were initially implemented for two years [10]; subsequently, the agreement was modified extending the restriction area [11]. Then, in 2018, it was modified again, extending its existing period for another five years [12]. This is currently in force, restricting the main productive activity in the region. It is worth mentioning that, for many inhabitants in the area, artisanal or coastal small-scale fishery (SSF) (general term for multi-specific fish) is the only economic activity that can be developed. Thus, the need to evaluate the SV of the communities who are direct users of this type of fishing resource, and who are facing those administrative measures that limit the only source of employment for the general village population.

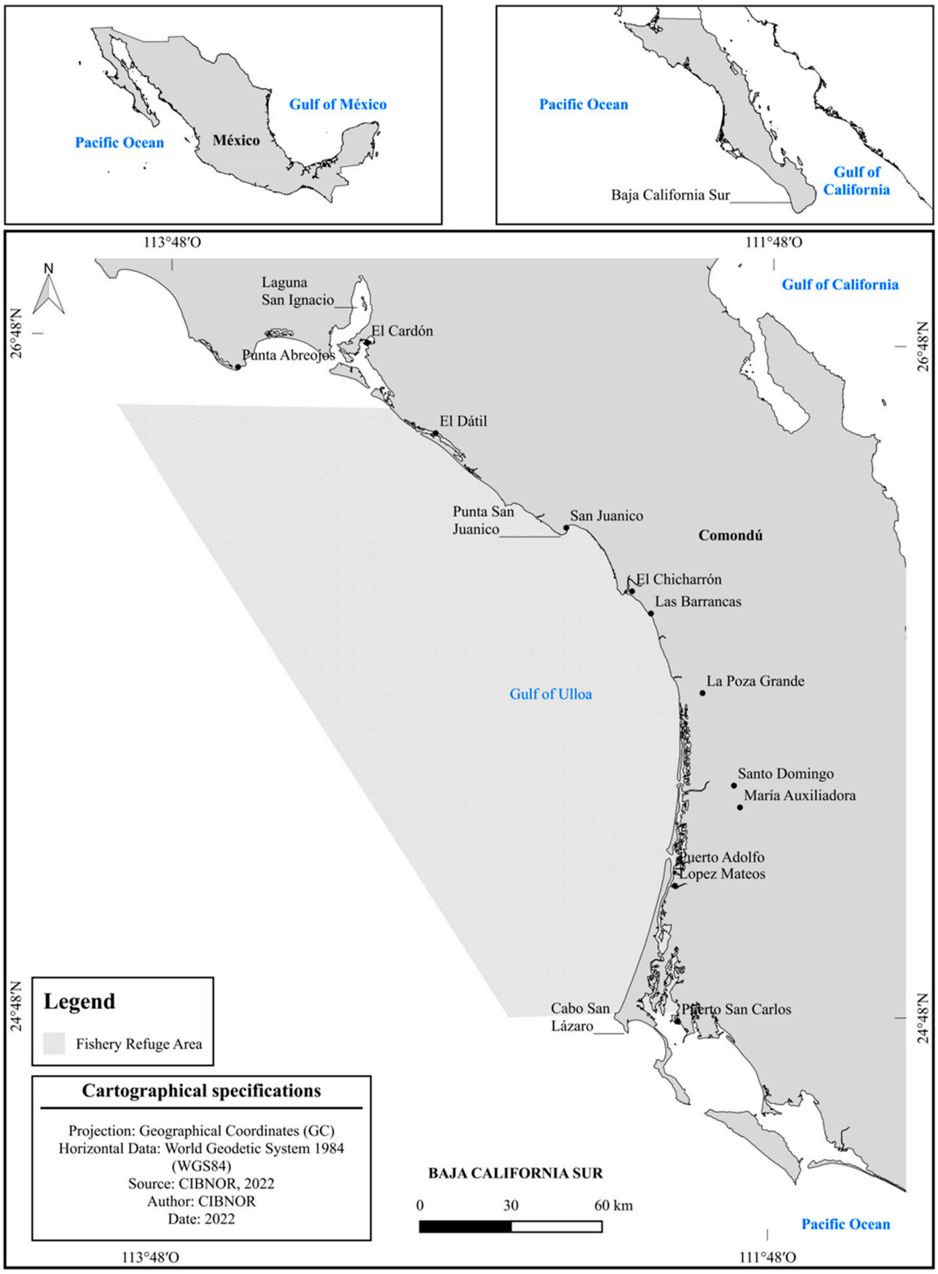

Figure 1. Area of study. Geographical location of the Gulf of Ulloa in the western coast of the state of Baja California Sur, Mexico. The main fishery localities bordering the polygons were considered when the Fishery Refuge Area was implemented.

Table 1. Localities of the Gulf of Ulloa fisheries contemplated in this study; number of fishers in each one of them; and number of surveys applied per locality in Baja California Sur, Mexico.

Locality		Number of Fishers	Surveys Performed
1	El Chicharrón	65	11
2	La Poza Grande	102	15
3	Las Barrancas	122	17
4	María Auxiliadora	25	7
5	Puerto Adolfo López Mateos	372	52
6	Puerto San Carlos	17	11
7	San Juanico	100	14
8	Santo Domingo	86	13
9	La Base	3	5
10	Ejido Luis Echeverría	14	5
11	El Cardón	75	12
12	El Dátil	84	12
13	Campo Delgadito	46	8
14	La Freidera	22	1
15	La Laguna	2	6
16	Punta Abreojos	93	17
Total		1228	206

2.2. Social Vulnerabity Index Calculus

Due to the lack of consensus on the SV concept, its calculation is difficult without a well-defined multiscale and conceptual framework. In this sense, a great variety of methods exist to evaluate it, and the majority are expressed as indexes focused mainly on community response in the face of natural threats. However, for the objectives of this study, no method was found considering SV facing sociopolitical threats. Therefore, this study used the proposal of the National Center for Disaster Prevention (CENAPRED for its acronym in Spanish), which is the governmental organization in charge of performing research on origin, behavior and consequences of natural and anthropogenic phenomena causing disasters. The results of this proposal have a bearing on developing technology; identifying danger; decreasing risks in alertness and disasters; and regular consultancy for decision-making and public policy design [13]. The method to calculate the social vulnerability index (SVI) proposed by CENAPRED, hereafter named Macro-social vulnerability index (Macro-SVI), has a municipal maximum spatial resolution scope and primarily uses secondary sources of data.

The Macro-SVI has three components: (C1) socioeconomical; (C2) prevention and response capacity; and (C3) local risk perception. These components have a weighting of 50%, 25%, and 25%, respectively, as shown in Equation (1).

$$Macro - SVI = (C1 * 0.50) + (C2 * 0.25) + (C3 * 0.25) \quad (1)$$

Finally, following Equation (1), the Macro-SVI results are expressed according to the corresponding category in Table 2.

Table 2. Macro social vulnerability scale.

Category	Very High	High	Medium	Low	Very Low
Values Macro-SVI	0.8–1.0	0.6–0.79	0.4–0.59	0.2–0.39	0–0.19

2.3. Calculus of C1 or Socioeconomical Component

The socioeconomical component includes 18 variables, grouped into five categories: health; education; housing; employment and income; and population size. Each variable's measurement range is described in [13]. Vulnerability values are from 0 to 1, where 1 corresponds to the highest vulnerability level and 0 to the lowest. Once the vulnerability value of each variable is established, an average for each category is obtained, and this is the value of the socioeconomic component.

To calculate the component of the socioeconomical variables, data were taken from the 2010 Population and Housing Census from [9] (Censo de Población y Vivienda 2010, Instituto Nacional de Estadística y Geografía); the State and Municipal Database System (Sistema Estatal y Municipal de Base de Datos, INEGI, 2010); and the 2016 Statistical Yearbook of the Health Ministry (Anuario estadístico 2016 de la Secretaría de Salud) of Baja California Sur.

2.4. Calculus of C2 or Prevention and Response Capacity

To calculate the prevention and response capacity, [13] uses a set of 24 close-ended questions with a Yes/No response, with an assigned value of 0 for Yes and 1 for No. In the macroscale, all the values of this component were made equal to 0, as at municipal level, all the responses were YES; in other words, the municipality contemplates the prevention and response capacity facing the risk situations.

2.5. Calculus of C3 or Local Risk Perception

This component refers to an imaginary joint action on environmental threats that exist in the community and the degree of the population exposure. However, on many occasions, the population does not have a clear perspective of the danger that a natural or anthropomorphic threat in their locality represents, which has a direct bearing on the response capacity facing a disaster, or restrictive instruction by the authority.

To calculate local risk perception at macroscale, the [13] method proposes a set of 25 questions, whose values are from 0 to 1. Considering that the risks of natural phenomena are the most frequent in the GU, this study took 10 questions that generally identify the perception that local fishers have about these risks. These questions were also used at microscale, which are dealt with in the next section. The quantification of this component by locality was made by adding the total of the surveys, standardizing the values from 0 to 1, by applying the normalization method MIN-MAX [14].

2.6. Calculus of Social Vulnerability Index at Microscale (Micro-SVI)

With the purpose of obtaining information at local scale in the area of study, the previously mentioned SVI calculus was performed, but using timely information taken in the field through ad hoc semi-structured surveys. The instrument is divided into three sections, focused on: (1) general and socioeconomic aspects of the interviewee; (2) fishery activity and perception on the established regulation measures in the area; and (3) climate variability aspects. The number of surveys per locality are shown in Table 1.

2.7. Fishing Restriction Scenario (SVI-Scenario)

Finally, a scenario of decreasing money supply—deriving from the restriction in economic activity—was calculated. For this purpose, a published model type, ECOPATH with ECOSIM [15], was developed and used for the demersal-pelagic system of the GU. This model used and combined the action of two forcing agents in the ECOSIM module: (1) an increase of 3 °C in sea surface (SST) over the average recorded in the California Current, based on the forecasts reported by the Intergovernmental Panel on Climate Change for the area of study [2], and (2) fishing effort. For the purpose of this investigation, this model was used keeping the SST forcing scenario and eliminating all the longline and gillnet fishery effort as established in the decree of the Fishery Refuge Area [12]. The simulation went on for 30 years with annual cuts. The average simulated captures per year were compared with those observed in the last 10 years, and their equivalent in constant value was calculated, finding an annual average percentage decrease that was subtracted from the socioeconomical component of the Micro-SVI.

2.8. Statistical Calculus and Spatial Representation of Social Vulnerability of the Fishery Communities of GU

With the three SVI calculus per locality, an associated analysis of nominal variables was performed by means of a contingency table (3 × 5) and the statistical chi-square (x^2) to subsequently calculate the contingency coefficient according to Equations (2) and (3). The table is 3 × 5 because the rows refer to the three calculations of the SVI (Macro, Mezzo, Micro scenarios), while the columns are the five categories of the SVI (Very high, High, Medium, Low and Very low).

$$C = \sqrt{\frac{X^2}{(X^2 + n)}} \quad (2)$$

$$MaxC = \sqrt{\frac{Min(r-1,\ c-1)}{1 + Min(r-1,\ c-1)}} \quad (3)$$

where

C = Contingency coefficient
$MaxC$ = Maximum theoretical coefficient
X^2 = Chi square value
n = Sample size
r = Number of contingency table rows
c = Number of contingency table columns

Finally, the SVI values per locality obtained in the three calculi—macroscale, microscale, and simulation scenario—were represented in isoline maps, using inverse distance weighting (IDW), with a power of two contained in the Quantum GIS (QGIS) version 3.4 Madeira program.

3. Results and Discussion

The results of Macro-SVI indicate that social vulnerability for the fishery communities of the GU is found within the low or very low categories (Figure 2).

However, the results of the Micro-SVI show social vulnerability increases beyond the medium and high social vulnerability in 14 out of 16 locations, of which only the communities of La Freidera, La Poza Grande, and Puerto López Mateos remain in low values (Figure 3). Nevertheless, considering the SVI for the economic income reduction scenario due to the restriction of the use of gillnet and line fishing, the rest of the 14 communities passed from high to very high SV values, except for the communities of La Freidera and La Poza Grande (Figure 4).

With respect to the contingency table deriving from the Macro-SVI, Micro-SVI, and the SVI-scenario for the fishery communities calculated (SVI-scenario), Table 3 shows the results of $X^2_{0.05,8} = 41.53 > 15.5073$ rejecting H_0; that is, the model used for the SVI calculus has an influence on the results obtained. Thus, the differences are not random products. Additionally, the coefficient of the maximum contingency indicates how strong the relationship between the two variables is, which is 83.42%. Therefore, a statistically significant relationship exists between the social vulnerability level and the model used.

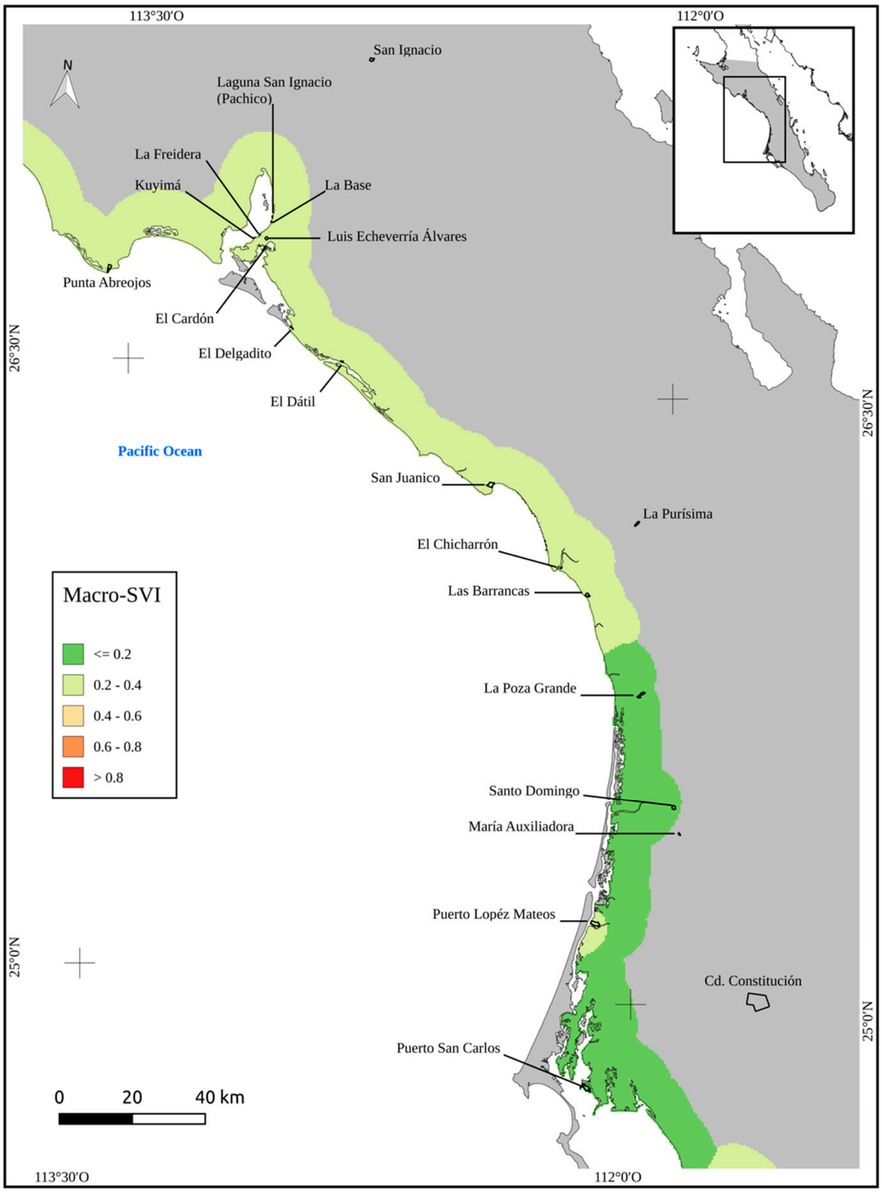

Figure 2. Macro-social vulnerability index (Macro-SVI) spatial expression for the fishery communities of the Gulf of Ulloa, Baja California Sur, Mexico, considering secondary source information.

The concept of social vulnerability is used in different disciplines and, to date, in our knowledge no consensus exists in regards to its meaning, even though coincidence has been identified in some of them. For example, the socioeconomical context grants relevance to SV as a determinant in its capacity to confront and recover from extreme events: the presence of a threat is recognized; the concept clarifies it is not a symptom of poverty nor margination, but integrates both and adds the capacity of the population to confront such threats [16]. In general terms, SV may be understood as the susceptibility of a community to suffer harm, facing external factors due to their internal characteristics that make them incapable of confronting the threat and recovering from harm; strictly speaking, it is a concept opposite to resilience. Ref. [17] proposed that research on vulnerability conveys the development of solid and credible measures, the incorporation of methods that include risk perceptions and governance research on the mechanisms that mediate vulnerability, promote adaptive action and resilience, and provide support for consilience and integration. For a truthful understanding of social vulnerability and measure, its intensity, parameters or thresholds should be established to indicate at which point to start or what the conditions are that generate important damage or loss [18]. Clearly, humans are an integral part of marine socioecological systems. Changes in these ecosystems impact human communities and, vice versa, changes on human communities impact marine ecosystems. Therefore, the interactive nature of these systems is the key to understanding and governance [19]. Vulnerability indexes have been designed in the fishery environment, and their purpose is to evaluate change in coastal management to help anticipate and mitigate SV [20]. Due to the complexity and speed of environmental and sociopolitical changes in marine coastal systems, a profound academic interest exists to evaluate and promote the adaptation capacity of the fishery communities [21].

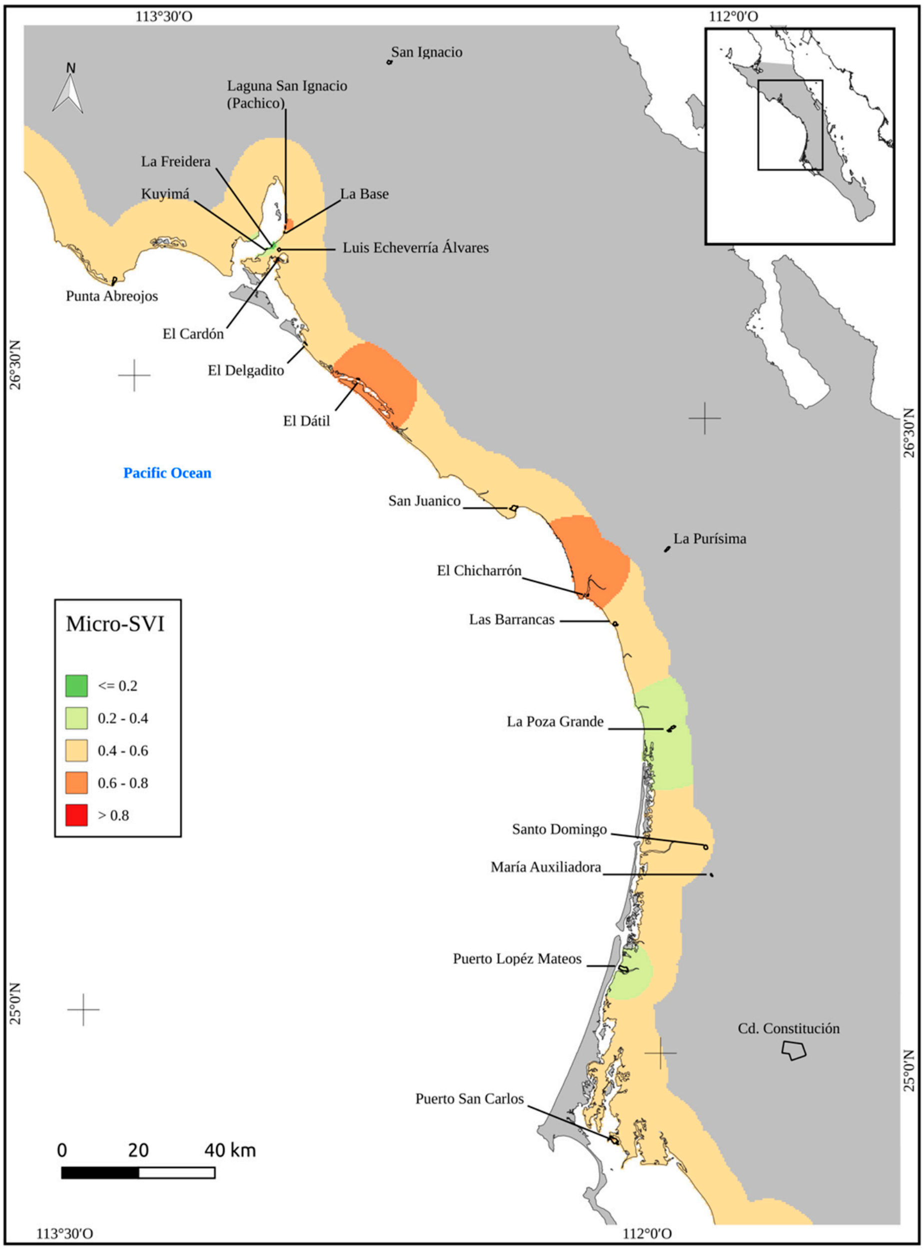

Figure 3. Micro-social vulnerability index (Micro-SVI) spatial expression for the fishery communities of the Gulf of Ulloa, Baja California Sur, Mexico considering primary source information acquired on site.

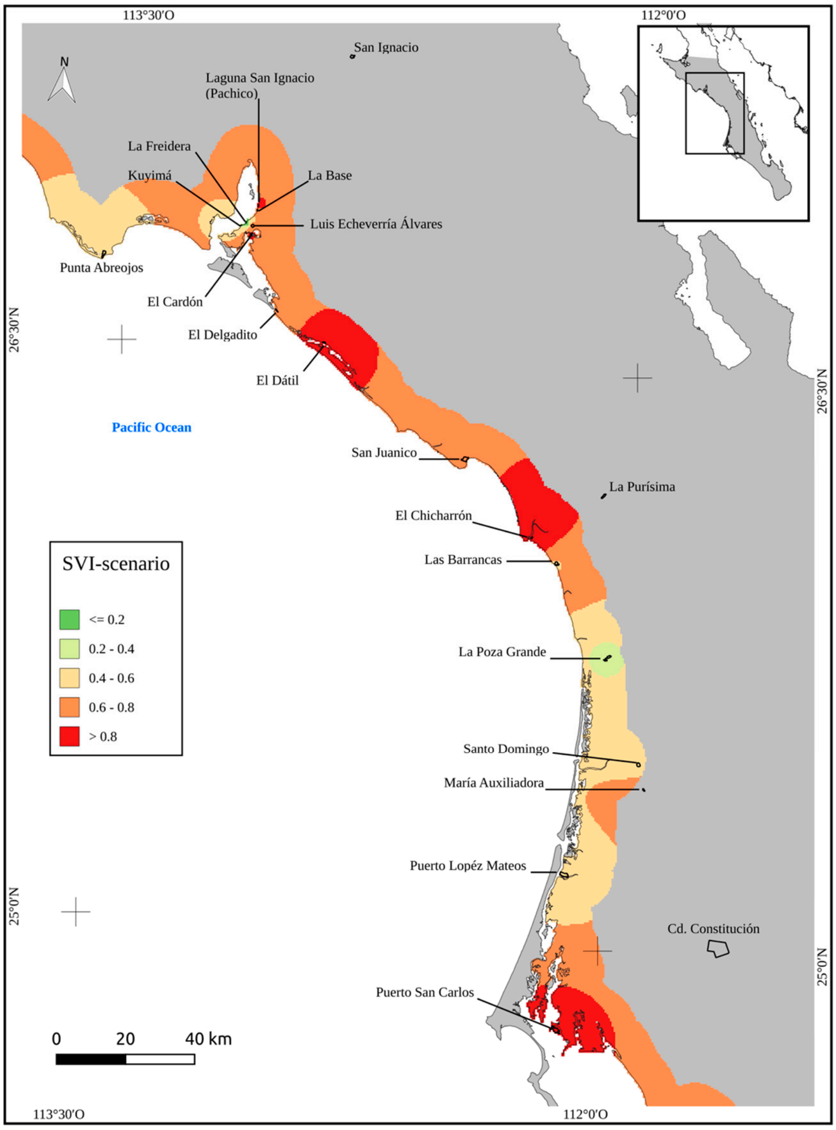

Figure 4. Spatial expression of the social vulnerability index-scenario for the fishery communities of the Gulf of Ulloa, considering primary source information taken on site.

Table 3. Contingency Table for social vulnerability (SVI) calculus for fishery communities in the surroundings of the Gulf of Ulloa off Baja California Sur, Mexico.

	Number of Localities by Category					
Model	**Very Low**	**Low**	**Medium**	**High**	**Very High**	**Total**
MACRO-SVI	6	10	0	0	0	16
MICRO-SVI	1	2	9	4	0	16
SVI-scenario	1	1	4	5	5	16
Total	8	13	13	9	5	

With respect to the method used, some clarifications should be made. The SVI proposed by [13] is a tool to make comparative evaluation of social vulnerability among municipalities with respect to natural danger. The method considers the socioeconomical characteristics of the population, its response capacity and local risk perception. The method describes the markers and components that integrate the index; however, in general, no solid arguments are expressed to justify the selection of markers, weight allocation for each marker and for the components, nor for their integration.

Based on the results obtained, the Micro-SVI model reflects more precisely the conditions in which the fisher community of the GU live. The information used for its calculations is timely and not masked with municipal information that could convey a sub-estimation, as observed clearly in the fishing sites of Adolfo López Mateos, El Chicharrón, El Dátil, La Poza Grande, and Puerto San Carlos.

Nevertheless, considering the lack of income scenario due to the restrictive measures applied to fishing (Figure 5), the vulnerability degrees are high and very high, of which the most affected localities are Ejido Luis Echeverría and El Cardón. In the socioeconomical component, the highest vulnerability levels were with respect to housing, employment and income. On the one hand, this result was largely due to the lack of access to water and drainage services, as well as to the material from which their houses are built. On the other hand, the percentage of the population that are economically active, who receive income of at least two minimum wage salaries, is the condition reached based on the simulated scenario.

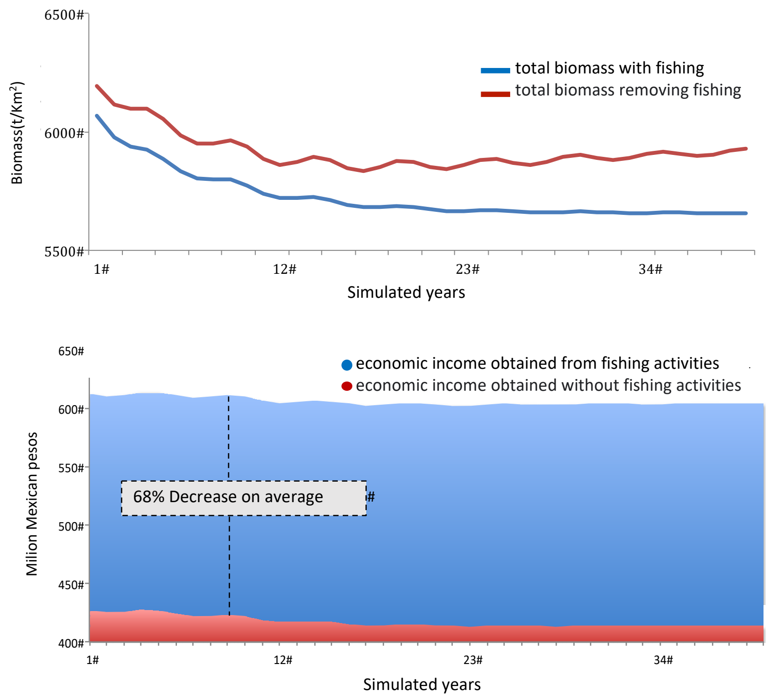

Figure 5. (**Upper panel**): Simulations of the total biomass obtained with and without the fishing activities considered in this study. (**Lower panel**): Reduction in economic income simulated by ceasing to receive the income derived from the fishing activity considered in this study.

In the literature, the discussion is that the SVI result is affected by the subjectivity of decision making for each step of its design, from the selection of the variables to the method to integrate them [22,23]. On some occasions, these subjective decisions are not justified, or are only vague [24]. Although a certain degree of subjectivity is required in any modeling exercise, its effects on the results should be considered before decision-making or formulating strategies based on such results [15].

The index proposed by CENAPRED, as many others, generates results that allow comparison between different units of analyses, or making comparisons in time. Thus, units can be defined as more or less vulnerable than others, and also evaluate whether any implemented strategy to decrease vulnerability in a certain area has provided the desired effect. Nevertheless, points of reference are not established for most of the markers, from which significant changes are generated in the populations. For example, the housing deficit marker shows inconsistencies described in the methods that should be considered when using this method for other evaluations.

Although certain social conditions cause the existence of weak population structures, and make communities vulnerable to a wide range of threats (poverty, minority status, and age), certain elements make the communities more vulnerable facing certain type of risks [25]. For example, the access to safe housing conditions could acquire more relevance if social vulnerability is evaluated when facing natural risks, such as earthquakes or hurricanes. Thus, defining the weight of each of the model subcomponents is important in the function of the risk or threat for which a vulnerability analysis should be performed.

Nonetheless, the results produced in this study, with the adaptations performed in the second model (Micro-SVI), serve as a baseline, as well as to evidence that the original model (Macro-SVI) may not reflect the real conditions of the timely or microscale analysis. According to [4], the community vulnerability indexes are useful tools for a fast evaluation. However, they should be validated and supplemented with ethnographic data before their implementation as management and political formulation tools, otherwise it could lead to wrong decision making that could potentially generate high socioenvironmental costs. To understand what makes marine socioecological systems resistant or vulnerable in a world of growing uncertainties requires natural and social collaborative efforts of scientists, users, resource administrators, and the community in general [19].

This research study indicates that although the microscale is not the only context, it is the determinant on calculating social vulnerability in the analyzed fishery communities, since coastal fishing represents almost the totality of their inhabitants' livelihoods. However, these communities confront numerous local and global threats, and pressures on SV endanger their livelihoods, well-being, food security and traditional lifestyles. Therefore, the role of research in human dimensions and governance is not only a priority, but also urgent in order to retake the course of a sustainable socioenvironmental management.

4. Conclusions

The social vulnerability of the GU fishing community was calculated through the method proposed by CENAPRED, which was created for medium and low-resolution scale calculations. Thus, it was adapted for a calculation with punctual information in order to have a better resolution at the local level and, with this adaptation, recalculate the SVI considering a simulated scenario of a decreased economic income derived from fishing restriction policies currently in force. By using the medium-scale information (required for the CENAPRED method), the SVI was found to be considerably underestimated. On one hand, when the adapted method allowed the use of punctual information, the levels of social vulnerability were medium and high in most of the sites. On the other hand, an increase to high and very high was observed as a result of the simulation scenario that considered a decrease in economic income of 68% by stopping fishing due to the establishment of restrictive public policies. This exercise allowed us to observe that (a) the social vulnerability index of the fishing community must consider the local dimension; (b) the implementation of public policies that restrict fishing as the main economic activity substantially enhances the increase in social vulnerability levels of the community already found in a precarious situation.

5. Recommendations

The method used for this research allows comparative analyses between different units and scenarios. However, the identification of social thresholds is recommended, as well as the construction of socio-environmental parameters from which degrees of resilience can be defined.

Further studies should explore the integration of other variables in the SVI model, such as the diversity of economic activities and gender. Additionally, methods to define how to weigh the different components should also be considered.

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