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# Lessons for Sustainable Development: Marine Mammal Conservation Policies and Its Social and Economic Effects

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Received: 19 May 2018; Accepted: 18 June 2018; Published: 27 June 2018



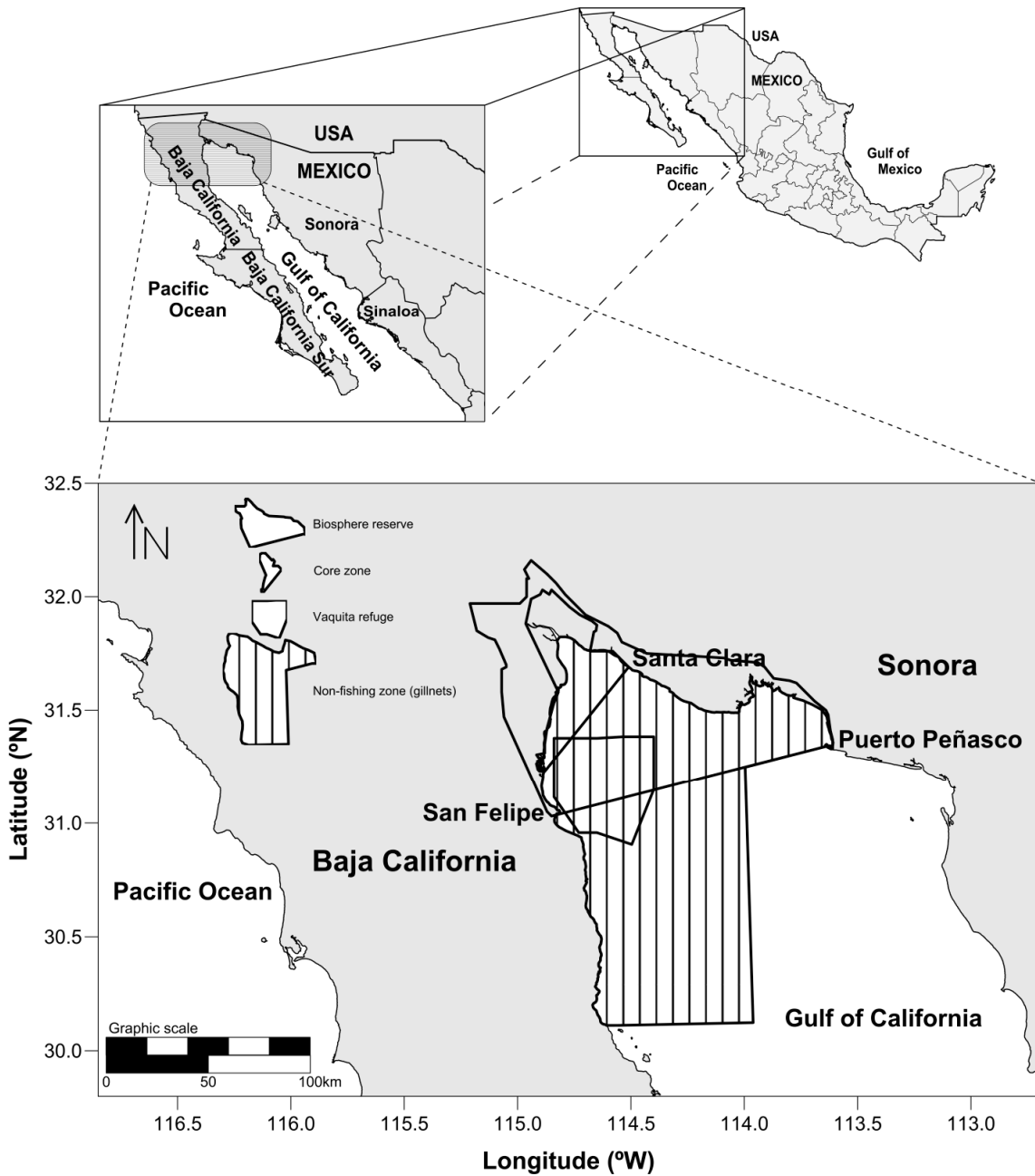
**Abstract:** The objective of this research is to assess the main social and economic effects on local fishermen in El Golfo de Santa Clara, as a result of the severe fishing restrictions enforced to protect the marine mammal “vaquita” (*Phocoena sinus*). Sustainable development includes natural resources conservation and the improvement of the social and economic conditions of local inhabitants. In Mexico, the vaquita is in imminent danger of extinction. It is a marine cetacean endemic to the Upper Gulf of California. Conservation measures to save this species, such as gear-switching and transformation subsidies from fishing activities to tourist services, have caused severe social and economic impacts on the local fishermen of this region. Presently, it is estimated that there are only 30 vaquita individuals left in the wild, and none are in captivity. In this study, we conduct surveys of the human local population involved in the incidental bycatch fishing of the vaquita, and also use secondary sources to come up with recommendations, based on taking into account stakeholder needs. For this fishing community the economic and social problems have worsened because currently there are limited economic activity options in the area for the human population, and the vaquita population continues to decline. Recommendations are offered to contribute to the ecological sustainability of this species, and for economic and social sustainability of local fishermen.

**Keywords:** environmental sustainability; marine mammal; economic sustainability; social sustainability; coastal fisheries; public policies

## 1. Introduction

El Golfo de Santa Clara (GSC) fishing community (Figure 1), located at the Upper Gulf of California (UGC) and the Colorado River Delta (CRD) Mexico, faces an ecological, social and economic conundrum related to local inhabitants fishing activities, their way of life, and marine mammal conservation, specifically that of the marine “vaquita” *Phocoena sinus* [1], the only cetacean species endemic to the UGC [2–4], which is critically endangered [5]. This small cetacean, with a distinctive black coloring around its eyes, is sometimes been referred as the panda of the sea, as it looks similar due to the distinctive coloring around the eyes to the famous and cute Chinese terrestrial panda, which was also in danger of extinction in the past. Fishing has been the principal contributor providing economic and social sustenance to the inhabitants of this region, given the economic importance of species, such as shrimp and croaker, in large quantities [6,7]. No doubt, due to the rise of these and other complementary fisheries, fishing efforts have increased, causing overexploitation and adverse

situations within the ecosystem, leading fishermen to cope with the complexity of sustainable fishing practices. Sustainable fishery development should ensure the functionality of ecosystems, considering that each economic activity in the marine and coastal areas depends on resource renewability [8]. In addition, for a holistic approach, it is essential to take into account the role of trade in relaxing the pressure on marine resource exploitation [9].



**Figure 1.** Biosphere reserve of the Upper Gulf of California and Colorado River Delta area, showing polygon of vaquita refuge.

The policies that have transformed the fishing activities within the UGC are openly debated. The most significant transformation experienced by fishermen was the passing of the federal decree making the region a Biosphere Reserve of the Upper Gulf of California and Colorado River Delta (BRUGCCRD) in 1993 (Figure 1), in order to protect and conserve the habitat, as well as vulnerable

species, such as the vaquita [10]. However, combined effects of the increased salinity resulting from the damming of the Colorado River in the United States and Mexico reduced its habitat, and incidences of bycatch in gillnets caused the population of vaquitas to decline, severely aggravating the survivability scenario of this unique species [11]. As a conservation measure in 2005, the *Official Journal of Federation* (the Mexican government gazette for laws and legal notices) unveiled a polygon area of no fishing in the vaquita refuge [12], with the priority of avoiding incidental mortality events. This further reduced fishing area for local inhabitants. However, even after the implementation of these measures, the vaquita population decline did not stop; instead, it dropped dramatically to 150 in 2007 [13]. Presently, there are 30 individuals left in the wild [14], making the situation extremely precarious; in fact, genetically there may be not enough biodiversity for survival, even if done so in captivity. Other authors, as well as ourselves and media, have warned that the vaquita is the most threatened cetacean worldwide, after the 2006 extinction of Baiji (*Lipotes vexillifer*) a cetacean of China [15]. This was the first large mammal to become extinct in modern times of which extinction is directly attributed to humans. It will be a severe embarrassment for Mexico if they fail to save the porpoise from extinction. The high priority to rescue the vaquita has induced the Federal Government to strengthen actions that require fishermen in this region to change their fishing gear or production activities to ensure the survival of the vaquita. In December 2007, a project of reconversion of fishing activities for other productive economic activities, such as tourism, which included the acquisition of fishing permits by the Mexican Ministry of Environment (SEMARNAT) in exchange for financial compensation. The action was intended to reduce fishing efforts, and thus shrink the numbers of incidental death by bycatch of the vaquita to zero. In this initial phase, 23 fishing permits were withdrawn from fishermen for financial compensation. In addition, on 7 March, 2008, the Federal Government agreed to invest \$10 million to continue the conversion program.

Despite interest the by SEMARNAT, many fishermen have refused to surrender their fishing permits, since fishing is the most entrenched economic activity in these communities, a situation that in addition to being an ecological concern, is further exacerbated by the impasse caused by the very limited economic opportunities in the area, generating a complex social conundrum. The objective of this research is to assess the main effects on the social and economic aspects of the local fishermen, as a result of the severe fishing restrictions enforced to protect the marine mammal vaquita (*Phocoena sinus*).

## 2. Materials and Methods

### 2.1. Study Site

GSC is a fishery town located in the northeastern region of the Gulf of California. It is the most important fishery town inside the biosphere reserve, including almost 80% of all fishermen of all the regional communities where the official vaquita refuge polygon was set. The fishing activities of the town of GSC contribute a total of 57% of the shrimp and 80% of the Gulf corvine fished in the entire region.

The region is located in an inverse estuary, with higher salinities in the inland portion than at the mouth, except for in years of abnormally high precipitation. Tidal currents during spring tides are typically 35 to 50 cm s<sup>-1</sup> near the surface, considerably less than in the main channel, where maximum current velocities can exceed 200 cm s<sup>-1</sup> [16]. The Upper Gulf of California (UGC) is relatively shallow, with a maximum depth of 30 m and an average depth of 15 m. The irregular bathymetry is characterized by channels and low, elongate, flat-topped sand bars parallel to the coast that extend from the mouth of the river to ~50 km to the southeast [17]. The climate is continental desert with little rain (85 mm annual average). The highest air temperature in summer is ~40 °C. The region is an inverse estuary, characterized by hypersaline water and associated gravity currents, which arise in arid regions where there is little precipitation or runoff and a high rate of evaporation [17].

Vegetation in the intertidal portion of the estuary consists almost exclusively of the grass *Dystichlis palmerii*, which grows sparsely within an approximate elevation range of mean high tide to ~1 m above

mean high tide. Prevailing winds in this region are normally out of the south from late spring through early fall, with velocities of ~10 to 30 km h<sup>-1</sup>; however, episodes of high winds (>40 km h<sup>-1</sup>), from the northwest and lasting from 1 to 3 days, typically occur every 1 to 3 weeks [18]. Maximum daily air temperatures during the study period ranged from ~15 °C (November) to >40 °C (June to August).

To accurately determine the effectiveness of the vaquita conservation policy purchasing of fishing permits (re-conversion of productive activities to another), we describe and analyze the social-economic situation of the people and the characteristics of fishery production in the most important fishery community of the UGC: GSC. Extracting information from primary and secondary sources was necessary to achieve the objective of the research. These resources are presented below.

## 2.2. Primary Sources

Surveys were carried out via interviews with fishermen, cooperatives, solidarity groups, civil societies, and non-affiliated fishermen. These were done by open interviews, randomly carried out following the method of Cochran [19], where the sample represents approximately 10% of the population. In the survey the following attributes were evaluated: Socio-demographic and population characteristics, fishing, fishing income, and costs per fishing trips [18]. With these surveys, a universe of responses from the main actors of the fishery was obtained, which describes the opinions on the schemes submitted by the policies imposed for protecting the vaquita and whether the productive economic options considered for UGC are considered viable. With this first set of data, the reciprocity of the economic compensation with the standard of life of the fishermen was examined.

### Sample Size

The information was collected from a closed survey of direct interviews with 146 randomly-selected artisanal fishermen of GSC following the Cochran [19] method, in which the sample universe was predetermined by the total number of fishing permits allotted within the community and randomly selected:

$$n = \frac{Z^2 q / E^2 p}{1 + 1/N(Z^2 q - 1 / Z^2 p)}$$

where  $n$  is the sample size;  $Z$  is the 95% CI;  $p$  and  $q$  are the equation distribution;  $E$  is the 6% precision level;  $N$  is the fishermen community size. To obtain a randomized experiment to begin identification and the problem of self-selection, the sample size was then adjusted to 59 randomized surveys.

Questions were grouped according to two topics: One measuring “conservation policy effectiveness perceptions” and the other measuring “economic effects perceptions”. The survey was focused on people depending directly or indirectly on fishery activities to obtain a global opinion about the conservation efficiency strategy.

## 2.3. Secondary Sources

(1) Beach landings. Through the Mexican Ministry of Agriculture and Fisheries (SAGARPA) the persistent fishery cooperatives were identified in three locations during the years of 1996 to 2007. At the fishing offices, information was extracted from the documentation of the arrival of small vessels (Form ROP-02), the following data were identified: (a) price for the beach product, (b) place of catch, (c) type of fishing gear, (d) vessel type, (e) number of people per boat, (f) number of trips, (g) total catches by species, (h) effort, and (i) length of the vessel at sea (fishing area).

In addition, important data regarding the fishing permits were incorporated such as: (a) names of cooperatives, (b) name of the vessel, (c) engine data, (d) locality, (e) for what kind of fishery the permission is intended, (f) validity, (g) fishing zones, and (h) gear. The objective was to determine the profitability of economically-important fisheries and to describe the economic situation of fishermen expenses in terms of profits for each fishing trip, in addition to determine the dynamics and organization of fishing cooperatives were determined.

(2) National Geographic Institute of Statistics and Informatics (INEGI). Employing statistical data of the Census of Population and Housing of 1990–2000 and the last Census of Population of 2005, a categorization of the population was carried out in terms of demographic and economic indicators. From these data, the following were analyzed (a) total population, (b) total male population, (c) total female population, (d) total population by sex and age. Together, it was possible to infer, (e) total households, (f) inhabited dwellings, and (g) private homes. In addition, data concerning (h) number of people who have medical services were reviewed, (i) public services, considering the type of service and the number of people who possess it or not, and finally (j) level of education. Systematization of information reinforces the data obtained in surveys and notices of arrival, determining the effect of coastal fisheries in these communities. The information of each was compiled into Excel (MS Office) to build a database, from which the compiled information could be processed more readily for analysis.

### 3. Results

GSC was identified due to its activities and production as the most important community in terms of fishing in the region, since it has the largest number of vessels engaged in fishing of finfish and shrimp (Figure 1). This community faces the issue that their traditional fishing activities could be affected by vaquita conservation policies, which implies that they need to find alternative productive activities options. The opinions held by the people varied depending on whether they were negatively affected by the policy, which affected more the persons directly related to the traditional fishing activities. This study shows that, for EGC, the community does not have major fishing vessels, lacks public infrastructure in regards to medicine and education, and is deficient in communication services, in addition to not being a tourist area.

#### 3.1. Socio-Economic Situation of Coastal Fishermen

The socio-economic information of the population was essential for understanding societal hierarchy and function, even in small, restricted communities, since this was manifested in the behavior of individuals. GSC belongs to the municipality of San Luis Rio Colorado, which is a rural community and it is considered the most important in the reserve, as regards population size, the number of people dedicated to coastal fisheries, and the degree of influence on the core area of the reserve. INEGI statistics show the population fluctuating over 25 years, GSC population tripled from 1980 to 2005, with a population of 910 inhabitants in 1980 and a significant growth to 1506 inhabitants in 1990, tripling to 3186 in 2005, the annual average growth rate in 2000 was 10.3% (Table 1).

**Table 1.** Demographic dynamics of El Golfo de Santa Clara.

Year	Population	Growth Rate Annual Average %
1980	910	-
1990	1506	6.5
1995	1830	4.3
2000	2777	10.3
2005	3186	2.9
2010	3967	3.9

Source: INEGI X, XI and XII Census of Population and Housing Census of Population 2005.

The analysis shows that only 438 residents had access to medical service, and only 16%, of them had access to a pension from the federal government; lacking a future retirement livelihood, most people will not have another choice but to continue exercising the activity that they have been doing for years. Another aspect that characterizes the GSC is the migration of people coming from other places to fish. A total of 1231 inhabitants were born outside the entity (Table 2). One of the surprising results from the data was the average duration of 6.62 years of schooling for most fishermen, which suggests that many of them leave school after the first year of secondary school

(12 to 14 years old), to dedicate themselves to fishing at a very young age. This is a disadvantage for inhabitants as it means that they are unable to compete for more favorable and longer-lasting jobs. Added to this deficiency, only 40% of the population is economically active. Moreover, 80% of this share devote their activities to fishing and the remainder (20%) to indirect fishing activities. Finally, 835 inhabited households lacked sewage, 53% had no running water and 24% lacked electricity. GSC is one of the towns in the UGC that is less likely to succeed by converting to other economic activities, due to its weak infrastructure and since the economic activity recommended within the PACE-Vaquita program is conversion to tourism.

In the GSC, 31.7% were locals and 68.4% were people who come from other entities, but the vast majority were stable community residents who have lived there for several years (Table 3). Coastal fishermen were the main opponents to the current policies of vaquita conservation, because they were who have suffered their consequences. Statistics obtained from surveys indicated that the average number of years fishing was, on average,  $17.4 \pm 4.34$  (Table 4). Estimates reaffirmed that individuals would not stop fishing, either because they dedicated most of their lives to this activity, or because they did not have other skills. Importantly, most of the fishermen spent enough years in this activity and interacted with system policies, since the beginning of the problems and controversy, since the decree of the Biosphere Reserve, to try to prevent the extinction of the vaquita. Table 4 highlights that, for the GSC, most of the fishermen were fishing from 11 to 15 years. Undoubtedly, these were also the main social actors that initially opposed fishing restrictions and violated such unilateral rules and laws. However, with the passage of time, they have also taken responsibility for conservation, but most of them with the intent of not stopping fishing.

**Table 2.** Physical environment and demographics of El Golfo de Santa Clara, Sonora.

Location	Total Population	Number of Individuals with Access to Health Services	Number of Individuals Born in the Entity	Number of Individuals Born Outside of the Entity	Mean Years of Schooling	Economically Active Population	Economically Inactive Population	Total of Inhabited Dwellings
GSC	3186	438	1516	1231	6.62	829	1065	681

Source: XI Population and Housing Census 2000 and Population Census of (INEGI).

**Table 3.** Birthplace of coastal fishermen from El Golfo de Santa Clara.

Place of Birth	Percent
Upper Gulf of California	31.7
Other places in Sonora	21.7
Others places in Baja California	10
Sinaloa	18.3
Another state	18.4

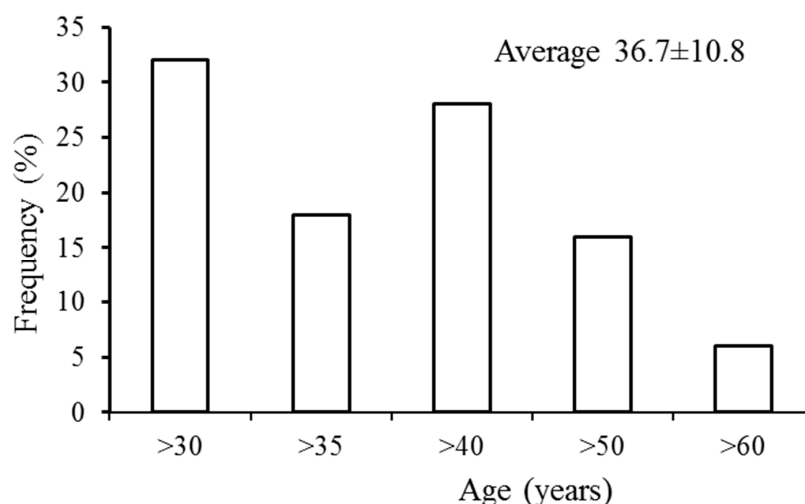
Source: Surveys conducted in the communities.

**Table 4.** Years dedicated to fishing in El Golfo de Santa Clara.

Years Scale	Percent
1–5	16.7
6–10	13.3
11–15	23.3
16–20	10
21–25	13.3
26–30	11.7
31–35	5
36–40	5
>40	1.7

Source: Survey conducted in communities.

Coastal fishing is done by people of different ages; for the GSC, the mean age was 36.7 years (Figure 2). Fundamentals that make sure that the population engaged in artisanal fishing begins at a very young age, settle slowly into hierarchical levels of resource extraction, noting that for the population it is a craft that has provided subsistence, not only for them, but for their families, and because of the lack of options, they have not found other viable economic activities.



**Figure 2.** Age of coastal fishermen. Source: Surveys conducted in the community.

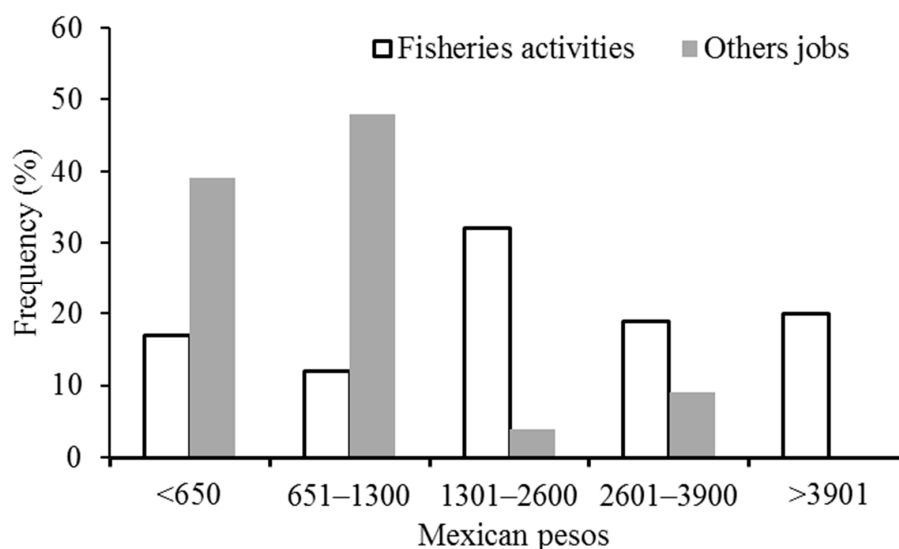
### 3.2. Fish Production

In the GSC, where 50% of coastal fishing production of the region is concentrated, fishing has increased from 750 tons in 1987 to over 4000 tons in 2002, and reached a total of 21,823 tons production in 2007; this result only considers the four most important species in the GSC (Table 5). In the period from January to September, 2007, production was 144,632 tons of shrimp, 872,020 tons of Bigeye croaker; 1,163,994 tons of Spanish mackerel (sierra) and 1654 tons of Croaker. However, it was not possible to obtain production records from October to December to establish a real and complete picture of the catch during the whole year. The shrimp catch is most important for commercial value and for generating greater income in the region.

**Table 5.** Total production: The most important species caught in the Gulf of Santa Clara from January to September, 2007.

Species	Volume	Value
Bay shrimp	144,632	19,817,562
Bigeye croaker	872,020	5,495,348
Spanish mackerel	1,163,994	18,827,311
Croaker	1654	7908

Figure 3 demonstrates one of the main reasons why the fishermen will not easily quit fishing. Through surveys, the average fishing total weekly income per year per fisherman was  $1975 \pm 715$  pesos, while an alternative economic activity generated an income of only  $985 \pm 397$  pesos. It is clear that the income generated by fishing was twice as profitable than any other activity in the region. Although fisheries have changed from decade to decade, due to the decline of a targeted fish population, and then other species arise, as mentioned in this study. So, fishing has always been an important activity to financially support the people living on the shores of the GSC (Figure 3).



**Figure 3.** Distribution of mean weekly income per fishermen per year. Source: Surveys conducted in the community.

### 3.3. Legal and Regulatory Issues

In order to regulate fisheries in the reserve, the Federal Government has proceeded to establish five standards in the form of Fishery Official Regulation (in Spanish) (NOM). These specific Fishery Official Regulations are the following: NOM-002-PESC; NOM-063-PESC; NOM-029-PESC; NOM-062-PESC and NOM-064-PESC. These regulations provide a series of progressive restrictions on fishing in the area, which, through the years, have changed the exploitation of resources. Despite the increasingly-restrictive conditions on coastal fishermen, they recognize the importance of the reserve and have the view that there are benefits and are willing to work to find conservation alternatives, as can be observed in Table 6.

**Table 6.** Response of fishermen to the question: If current exploitation of fisheries closed, what would you ask of the government?

Options at the End of Fishing (%)	Percent
Economic compensation	27
A permit for another fishery	33
The government will pay what it cost for the permit that had been granted	15
Nothing	7
Continue fishing anyway	8
Other	2
Provide another job	7
Did not respond	2

Source: Surveys conducted in the communities.

### 3.4. Expectations of New Conservation Policies

No favorable results for the conservation of the vaquita occurred from declaring a Biosphere Reserve of the UGC and CRD in 1993, as well as from creating the polygon refuge in 2005. Rather, the new policies exacerbated negative feelings within the fishing community, and perhaps may have triggered the precipitous decline of the vaquita in those ensuing years. Leading government institutions began to rethink policies for recovery of the endangered species. With the failure of the present environmental policies, new alternatives were evaluated. The alternatives proposed included technological transformation (change traditional fishing gear to more environmental friendly



gear) and productive reconversion. Both alternatives aimed at reducing the number of smaller vessels within the reserve area, especially in the core and polygon refuge. These efforts were carried out by the PACE-vaquita program. The reconversion program embodied the strategy of economic compensation in exchange for fishing permits, giving the fishermen options for a new way of living with an economic activity that does not harm the environment of the reserve and the existence of the marine vaquita. The first part of the compensation began in December 2007, from this month (up to June 2008), 23 permits were withdrawn from GSC. A payout of 40,000 US dollars per fishing permit was carried out.

The program PACE-Vaquita repeated the purchase of fishermen licenses at GSC to who opted for conversion, flaunting a total 1.5 million US dollars for the program. SAGARPA also supported the efforts to raise awareness among fishing communities that interact with the vaquita, and this resulted in the withdrawal of additional 207 vessels through the SAGARPA program and of an additional 15 smaller boats that opted for conversion. In addition, there were owners of vessels contemplating conversion but refused and preferred to continue fishing.

No doubt, the alternatives that were proposed were based on conservation efforts for the survival of the vaquita. However, the fishing community suffers the consequences of new public policy instruments, such as restriction of areas and in fishing gear, which negatively affect their economic activities and, therefore, such policies were rejected and not supported by the social groups affected.

#### 4. Discussion

In an increasingly altered world by human activities, in order to establish rules and actions to ensure a sustainable flow of ecosystem goods and services to society, the conservation of biodiversity is essential to sustain safe and flexible ecosystems. However, ensuring the wellbeing of the eco-systems depends on the decisions and actions that are taken. Fisheries have provided subsistence at a national, as well as state and local levels; they are even more important in places where there are few other productive options. Fishing is important in terms of providing high protein foods and it is a source of direct and indirect employment. The transformation of the situation of fishermen and the actions they have undertaken to be protagonists in the history of fishing, facing a substantial social and economic crisis, in the UGC. Disruption of fishing cooperatives is a significant change in the local communities, and it is a change that occurs in most of the fishing communities of the region, forcing the fishermen to work without a license, and for that reason there is always some unregistered captures [20]. In addition, and unfortunately, most, fishing permits are not held by fishermen, but by permit holders. Permit holders returning fishing permits to the government agencies, and in return receive money. In addition, as in many other cases, the weaker segment of society, in this case the fishermen as well as their families are unprotected, their activities are limited and they are forced to fish illegally. In the survey responses regarding fishing activity this is manifested as fishermen themselves indicated that their years spent fishing makes them ill-prepared for a future in another activity. The situation is very complicated and beyond just saving the vaquita, an endemic species that is really very charismatic. Moreover, simply focusing on a very vulnerable economic sector, fishermen as being the culpable party for the extinction seems unfair, when, in reality, the original blame begins further north, with the damming of the Colorado River using it for irrigation in the USA and the Mexican territory.

Regarding the subject of fisheries, shrimp fishing is economically among the most important, followed by croaker. Stopping shrimp fishing is almost impossible, because, for the Mexican market, this species is a valuable commodity. In 2006, Mexico consumed 100,000 tons of local shrimp, plus 20,000 imported tons to meet demands. Regarding fishing of croaker, it is the second species in terms of economic and commercial importance for the fishermen. Attempt to close croaker fishing is another sensitive issue, because this total catch is consumed in local markets, such as Mexico City and Guadalajara. The open season for fishing of this species coincides with the maximum amount of fish consumed in the season of lent in Mexico.

Previous studies dealing with the conservation of vaquita [11,13] adopted measures to protect and trying to reduce the threats against this species. However, we must admit that this is another case of failure in conservation planning, as exposed by Redford and Taber [21]. What is the real failure in vaquita conservation in the UGC? As mentioned earlier, social and economic aspects of fisheries were never considered. Even D'Agrosa et al. [11] and Jaramillo-Legorreta et al. [13] mention the need to develop an economically-viable alternative source of income [11,13], but what are these measures that have not been explored? Even now, after years of the acquisition program for fishing licenses, in order for lifelong fishermen to convert to tourism, no one expected the low success rate of the program (only 65 permits in the first round of the program). Further evidence of the failure of the program is the experience of fishermen that moved into the tourism business. With the money they received from selling their fishing permits, they built huts, but few customers use them.

Commercial fishing in small regions allows one to learn from mistakes, and perhaps help correct course and achieve conservation success [22]. However, without doubt, the current status of the vaquita is too critical to continue learning and critical action is necessary [13,23,24].

## 5. Conclusions

Research reveals that reconversion of fishing activities to productive activities, such as tourism services, is not a solution to save the vaquita from extinction. Unilaterally forcing fishermen to not use gillnets without taking into account stakeholder needs is not working [25]. Nor is it a solution for the many social problems of the UGC and GSC fishery communities, with a lack of many of the basic public services and infrastructure.

Another probable cause of the failure of the program is that the profit obtained by fishermen in fishing activities (higher income than in alternative activities) and the lack of attachment to the community make it difficult to comply with conservation policies aimed at achieving zero catch in vaquita protection zones.

Attain the vaquita zero catch requires real viable economic alternatives and proper management of social and economic aspects of the fishing communities involved. It is understood that there is pressure on authorities, as they have two years (probably at most, if not less) to find a solution before the vaquita will become the second species of cetacean to disappear from the face of the Earth due to human activities. However, clearly, the actions to limit the incidental death of vaquita for coastal fisheries have not resulted in a decreasing trend in the number of specimens of this species. Clearly, the solution to save the vaquita by reduction of the fishing fleet and bycatch has not worked, and the remaining questions to ask are what has been done to restore the ecosystem of the UGC? What is the relationship between ecosystem modification of the UGC and reduction in vaquita numbers? It is also necessary to thoroughly review other factors that are affecting this species.

Undoubtedly, the most serious of all is the lack of inputs of fresh water from the Colorado River to the UGC. In the year 1936, the US built the Hoover Dam between Arizona and Nevada, this damming prevents almost of the water from the Colorado River reaching Mexico. In addition, the remaining water is used on the Mexican side for agriculture and urban needs, so the effect combined precludes Colorado water from reaching the Gulf of California. The estuary condition of the UGC changed radically due to the severe modification of freshwater discharge.

In the Biosphere Reserve, the volume of water from the Colorado River that entered the estuary decreased from  $20,700 \times 10^6 \text{ m}^3 \text{ year}^{-1}$  before the construction of the Hoover and Glenn Canyon dams, to occasional flows of  $1850 \times 10^6 \text{ m}^3 \text{ year}^{-1}$ , due to surpluses of the Treaty of Limits and Waters between the United States and Mexico [26]. However, this allocation of water to Mexico does not reach the estuary because it is completely used for agricultural and urban needs on the Mexican side. Mexico built the Morelos Dam at the end of the Colorado River, in 1950. It is 1.1 miles south of the international boundary between Mexico and the USA.

Estuary habitat degradation by the unilateral decision of damming the Colorado River, preventing most of the water from reaching the Mexican side, and became a terrible ecological tragedy for this

region. Countless scientific studies have demonstrated the ecological damage that Mexico has faced due to the damming of freshwater. A healthy estuary environment requires moderate marine water salinity. Between 20 to 25 PSU (Practical Salinity Unit) are suitable for life adapted to estuary environments. However, in the estuary environment of the vaquita, the salinity ranges from 38 to 42 PSU, which are not characteristic of healthy estuary environments, but of actual marine environments. The common name in Spanish of this species, “vaquita marina” (“marine cow”), is incorrect, as the species has always been an estuary species nor a marine one. The vaquita is evolutionarily adapted and is associated with the estuary from waters provided by the Colorado River. The damming of the Colorado River has severely affected the health of the estuary, and the vaquita is an estuarine species; the logical conclusion is that damming is the main environmental factor causing the vaquita extinction.

## 6. Recommendations

It is proposed that the only solution to prevent the imminent extinction of this species of porpoise, which was first identified in 1958 [1], requires immediate implementation of the following measures:

1. As an insurance policy, capture and place in exceptional shelter facilities of at least 10 specimens of this species, for their care and reproduction. Preferably, in conditions as close to wild as possible without the dangers, thus facilitating possible re-introduction later. It is interesting to note that such an action is very similar to what the Chinese have done to save the panda from extinction, although it is a mammalian land species. The panda is a very emblematic species for China, almost serving as a symbol of Chinese good will and social and environmental responsibility. The vaquita marina, if it survives, has the potential of becoming such a symbol for Mexico.
2. Legal action by the Mexican government in international courts against the United States to allow enough fresh water to flow from the Colorado River with the required minimum agricultural and urban water necessities on the Mexican side plus the required minimum ecological flow.
3. Legal actions on the Mexican side allow the required minimum ecological flow towards the UGC.
4. The immediate implementation of habitat restoration measures for the vaquita.

Once reestablished, the optimal ecological flow conditions and the habitat restored for vaquita survival, environmental release of sheltered specimens and their offspring from captivity, could be performed. From this study, it is clear that not applying these three recommendations immediately then the unilateral implementation of restrictive measures on coastal fishermen will not save the vaquita from extinction and will only further economically repress one of the most vulnerable social sectors of Mexico.

**Author Contributions:** E.A.A.-N. and A.O.-R. designed the research and drew up the theoretical framework. N.M.-B. and L.F.B.-M analyzed the data and discussed the empirical results. M.V.C.-M. write and edit original draft. All the authors contribute to the formal analysis and all of them read and drew up the final manuscript.

**Funding:** The study was developed with the economic support of the CONACYT Basic Science project 178727, the CONACYT Basic Science project 251919 and the Red Temática de Investigación of CONACyT project 293368.

**Acknowledgments:** We want to acknowledge the time and effort devoted by 3 anonymous reviewers to improve earlier versions of our manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; nor in the collection, analyses, or interpretation of data; nor in the writing of the manuscript, and nor in the decision to publish the results.

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