Applying Fuzzy Logic to Assess Human Perception in Relation to Conservation Plan Efficiency Measures Within a Biosphere Reserve

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Abstract The objective of this study is to present an efficiency-perception impact assessment based upon the integration of fuzzy logic (FL) of the “Productive Reconversion” conservation program (PRP) instituted by the Mexican government, in the upper Gulf of California and the Colorado Delta Biosphere Reserve. This approach enables environmental analysts to deal with the intrinsic imprecision and ambiguity associated with people’s judgments and conclusions. The application of FL to the assessment of program efficiency is illustrated in this work, demonstrating how subjective perceptions can be converted into quantitative values easy to evaluate during the decision-making process.

Keywords Fuzzy logic · Marine protected area · Biosphere reserve · Human perception assessment · Gulf of California

INTRODUCTION

The Upper Gulf of California and the Colorado River Delta Biosphere Reserve (UGCCRDBR) was created officially in 1993 to preserve and utilize its flora and fauna biodiversity under sustainable practices (DOF 1993). Fisheries are the most important socioeconomic activity in the region, where curvina *Cynoscion othonopterus*, sharks (including *Carcharhinus* spp., *Sphyrna* spp., *Rhizoprionodon* spp., and *Mustelus* spp.), skates and rays (including *Myliobatis* spp., *Rhinobatus* spp., *Dasyatis brevis*, *Mobula* spp.), and a fresh-frozen shrimp industry (Rojas-Bracho et al. 2006)

have long supported the local communities inserted in the Biosphere. Fishery activities in the region have had an adverse effect on endangered species such as “vaquita” (*Phocoena sinus*) and “totoaba” (*Totoaba macdonaldi*) (DOF 2002; Rojas-Bracho et al. 2006; Gerrodette et al. 2011). The decline of odontocete populations due to by-catch (Moore and Read 2008) is related to its decrease due to incidental catches (Gerrodette et al. 2011), habitat loss, environmental imbalance, and negative effects also seen in other fishery productions (Rodríguez-Quiroz et al. 2010). Due to the fisheries boom that has occurred in the last 20 years, fishing efforts have increased and have resulted in overexploitation of fishery resources in the zone (Aragón-Noriega et al. 2010a, b).

A debate has arisen on conservation policies that have affected fishing activities within UGCCRDBR. The establishment of the Biosphere Reserve in 1993 affected fishermen. In 2005, the Official Gazette of the Federation published polygon boundaries (Fig. 1) of the refuge in order to circumvent mortality rates (DOF 2005a, b). This event reduced the overall fishing area. The conservation strategy, however, has not been successful for populations of “vaquita”, which had dropped to 150 individuals in 2006 (Jaramillo-Legorreta et al. 2007) and have become the most endangered cetacean since the declared extinction by Turvey et al. (2007) of the Yangtze River dolphin or baiji (*Lipotes vexillifer*). So far, it is the most endangered cetacean, despite the recent recounting study carried out from October 16 to November 2008 that resulted in 245 individuals using combined visual and acoustic array methods (Gerrodette et al. 2011).

Pressure applied to the Mexican government to rescue the totoaba and vaquita from possible extinction forced them to limit fishing activities, using the strategy itself as a conservation management tool. In December 2007, the

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Fig. 1 Upper Gulf of California and Colorado River Delta Biosphere Reserve

Reconversion Productive Program (RPP) was implemented and managed by the National Protected Areas Commission (CONANP) under the surveillance of the Mexican Environmental Protection Ministry (SEMARNAT). The program is based on a fishing permit exchange by means of financial compensation in favor of other productive activities with a goal of reaching a zero rate of capture for the vaquita (PACE-Vaquita 2008).

“El Golfo de Santa Clara” (EL GSC) is a fishery town located in the northeastern region of the Gulf of California and is the most important fishery center enclosing 80% of all fishermen communities inside the UGCCRDBR, where the official vaquita refuge polygon has been set. The town contributes a total of 17.5% shrimp and 46.8% Gulf weakfish national production (SAGARPA-CONAPESCA 2007) and any fishing restrictions to regulate this area without planning will have an effect on the entire population of Mexico whether or not it is structured for species protection.

Human perceptions are inherently vague, inconsistent, qualitative, and subjective, and the impact perception of RPP on the surrounding fishery towns is no exception. Fuzzy logic (FL) is a mathematical expert system that has been used in mixed, imprecise, and uncertain environments, dealing with uncertainties expressed as interval values and fuzzy sets and its approach is based upon linguistic expressions involving input and output variables rather than numerical probabilistic, statistical, or

perturbation variables (Li and Huang 2010). It has commonly been used in informatics and robotic systems and has lately become a popular tool in environmental impact studies (Bojorquez-Tapia et al. 2002; Li et al. 2007; Gagliardi et al. 2007) and ecological and risk assessments (Adriaenssens et al. 2004; Salihoglu and Karaer 2004; Gevrey et al. 2006), as well as for the evaluation of tropical forest conditions (Ochoa-Gaona et al. 2010) and water resources management (Guo et al. 2010) having the advantage of rendering subjective and implicit decision-making more objective and analytical, with its ability to accommodate both quantitative and qualitative data (Ekmeçioğlu et al. 2010).

In classic set theory, an object can either be a member (membership = 1) or not (membership = 0) of a given set. In contrast, the central idea of fuzzy set theory is that an object may have a partial membership of a set, which consequently may possess all possible values between 0 and 1. The closer the membership of an element is to 1, the more it belongs to the set; the closer the membership of an element is to 0, the less it belongs to the set (Ochoa-Gaona et al. 2010). In other words, probability theory cannot be used to model because the combination of subjective categories in human decision processes does not follow its axioms, while FL theory matches everyday reality better than the standard set theory because not all the phenomena and observations can have only two definite states.

The survey used in this study was fed six criteria included in the three indices proposed by Bojorquez-Tapia et al. (2002) and was created to analyze impact perceptions.

This study is the first to use FL to assess the impact perceptions of the RPP in relation to the environmental, social, and economic effects that the conservation management tool has had on the upper Gulf region.

MATERIALS AND METHODS

Sample Size

We gathered information from a closed survey of direct interviews with 146 randomly selected artisanal fishermen of “EL GSC” following the Cochran (1989) method, in which the sample universe was predetermined by the total number of fishing permits allotted within the community and randomly selected (Greenberg 1993):

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

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 (Fronzel and Schmidt 2005), the sample size was then adjusted to 59 randomized surveys.

Fishers’ Survey

A semi-structured survey (Tambiah 1999) was applied focused on obtaining the perception of fishers in regard to the successfulness of the Reconversion Program. Surveys were distributed among 59 people in the fishery community in the El GSC town to record their impact perception of the conservation program in the upper Gulf of California and the Colorado River Delta Biosphere Reserve.

A set of eight questions was structured for the field questionnaires to feed the fuzzy membership function about the conservation status, purchasing fishing permits as a conservation effort, what impact fishing permits will have for the conservation of protected species and on commercial fishery species, individual and community quality of life, economic production alternatives, and economic growth after the implementation of the fishing permit exchange. An example of ten surveys to show how the answers and their numerical values were given are presented (Electronic Supplementary Material, Table 1). In this table, it is possible to distinguish how different values are answered to the m , e , d , se , ce , and me criteria by people. To reduce the possible bias of the information, a third local person was present in almost all of the interviews to establish a feeling

of trust between the interviewee and the interviewer. Before starting each interview, the purpose of the study was explained in detail and the interviewee was guaranteed strict confidentiality and anonymity (Mancini and Koch 2009).

Questions were grouped according to two topics: one measuring “conservation policy effectiveness perceptions” of the RPP (questions P1–P4) and the other measuring the “economic effects perceptions” (questions P5–P8). The perception efficiency of the RPP of the people surveyed was registered. Each result was integrated, analyzed, and discussed. The survey was focused on the people depending directly or indirectly on fishery activities to obtain the global opinion about the conservation efficiency strategy.

Fuzzy Logic

The central idea of fuzzy set theory is that an object may have a partial membership of a set, which consequently may possess all possible values between 0 and 1. The closer the membership of an element is to 1, the more it belongs to that set; the closer the membership of an element is to 0, the less it belongs to that set (Ochoa-Gaona et al. 2010).

To facilitate the creation of a guideline-based fishermen perception analysis, guidelines were categorized into five fuzzy sets: “very low” (from 0 to 0.19), “low” (from 0.20 to 0.39), “medium” (from 0.40 to 0.59), “high” (from 0.60 to 0.79), and “very high” (from 0.80 to 1.0). The quantitative criteria used were: magnitude (m), spatial extension (s), duration (d), synergic effects (se), cumulative effects (ce), controversy among stakeholders (cs), and mitigation efficiency (me) (Electronic Supplementary Material, Table 2). These criteria are not homogeneous and it is therefore possible to assign a weight to each criterion in order to allow possible aggregation. All decisions were balanced and when a lack of consensus during round tables with specialists without sufficient scientific evidence to eliminate scientific uncertainty was present, the precautionary principle was always applied (Immordino 2000). To obtain the general perception of fishermen and the perception of their own impact in association with “vaquita” and “totoaba”, an eight-question survey that incorporated seven quantitative criteria (Electronic Supplementary Material, Table 2) was designed in agreement with the typical outline used in environmental-impact assessments in Mexico. Three indices utilized by Bojorquez-Tapia et al. (2002) were applied during fuzzification: basic index (BI), supplementary index (SI), and the mitigation efficiency index (MI). The m , e , and d criteria were grouped into the BI index in which an ordinal scale was set from 1 to 9. The se , ce , and cs criteria were grouped into the SI and MI indices with an ordinal scale set from 0 to 9.

If no magnitude, spatial extension, or duration occur, then no synergic, cumulative, or controversy effects will take place in terms of mitigation efficiency. Example: Conservation status perception will always have magnitude, spatial extension, and duration, and must have a value between 1 and 9, and it is possible to have or not have synergy, cumulative, or controversy, which can have values from 0 to 9.

All criteria were standardized using a weighting factor and all final decisions were balanced under the precautionary principle (Immordino 2000).

Calculation

To qualify each question with the criteria established by Bojorquez-Tapia et al. (2002), we determined the degree of truth for the premises of the membership functions or questions applied (fuzzification) by way of the three operators: B_{ij} , SI_{ij} , and MI_{ij} were calculated according Bojorquez-Tapia et al. (2002) (Fig. 2). To produce new fuzzy sets (fuzzy inferencing), the operators were combined to relate inputs and outputs by constructing “IF–

THEN” rules based upon the expert knowledge and/or on the basis of the experimental results. Fuzzy subsets are utilized to set rules containing “IF.....THEN.....” statements in two parts (Erdik 2009) (Fig. 2).

The four fuzzy sets fixed by Bojorquez-Tapia et al. (2002) were modified in this step, integrating a gradual change between the L and H sets (Fig. 2). The linguistic variables modified from Bojorquez-Tapia et al. (2002) for the BI, b_{ij} , the supplementary index, si_{ij} , and the mitigation index mi_{ij} , are defined as:

$$b_{ij}, si_{ij}, mi_{ij} = \{VL \text{ (Very Low)}, L \text{ (Low)}, M \text{ (Moderate)}, H \text{ (High)}, VH \text{ (Very High)}\}$$

Since the three plan efficiency indices range in a [0,1] interval, and being U the universal set such that $U = x|x \in U$ and $\forall x [0,1]$, the ranges of the linguistic variables can be delimited as follows: $VL = \{x|x < 0.19\}$; $L = \{x|0.19 \leq x < 0.39\}$; $M = \{x|0.39 \leq x < 0.59\}$; $H = \{x|0.59 \leq x < 0.79\}$; and $VH = \{x|0.79 \leq x \leq 1\}$. Formally, the linguistic variables are related to the following fuzzy numbers:

Fig. 2 Logical steps for the calculation of basic index (BI_{ij}), supplementary index (SI_{ij}), and mitigation index (MI_{ij}) to obtain the decision area for each question surveyed

$$\mu_b(x), \mu_{si}(x), \mu_{mi}(x)$$

$$= \begin{cases} \mu_{VL} \begin{cases} 1 & \text{for } 0 \leq x \leq 0.09 \\ -4x + 0.2 & \text{for } 0.09 \leq x \leq 0.19 \end{cases} \\ \mu_L \begin{cases} 4x - 0.1 & \text{for } 0.19 \leq x \leq 0.29 \\ -4x + 0.4 & \text{for } 0.29 \leq x \leq 0.39 \end{cases} \\ \mu_M \begin{cases} 4x - 0.2 & \text{for } 0.39 \leq x \leq 0.49 \\ -4x + 0.6 & \text{for } 0.49 \leq x \leq 0.59 \end{cases} \\ \mu_H \begin{cases} 4x - 0.4 & \text{for } 0.59 \leq x \leq 0.69 \\ -4x + 0.8 & \text{for } 0.69 \leq x \leq 0.79 \end{cases} \\ \mu_{VH} \begin{cases} 4x - 0.8 & \text{for } 0.69 \leq x \leq 0.79 \\ 1 & \text{for } 0.79 \leq x \leq 1 \end{cases} \end{cases}$$

The fuzzy intersection operator (fuzzy AND connective) applied to two fuzzy sets and with the membership functions serve to connect statements into more complicated compound statements. The “and” operator is used to connect the antecedents and “min activation” is chosen for the “AND” operator. This procedure is called “min. inferencing”. If there are any consequents that are in the same subset, then the maximum MD of these consequents is taken for that subset, which is referred to as “max. inferencing”. Hence, the procedure “min–max inferencing” occurs. Each of the five triggered rules results in a fuzzy subset that is then combined by “max inferencing” by taking the pointwise maximum over all the fuzzy subsets assigned to the output variable by the inference rule. The fuzzy results are converted into a discrete numerical output (defuzzification) (Ochoa-Gaona et al. 2010) when the inference step is completed. An illustrative simple example is presented in order to show the application of the fuzzy inference system where two input variables represented by K_{ij} and SI_{ij} and an output variable represented by MI_{ij} are provided (Fig. 2). Although there are various defuzzification methods in existence, the most common method used is “center of gravity” (COG), which is the preferred method to arrive at defuzzification for this study (Fig. 2). The result is a consequent or fuzzy set arriving at a singleton value that is expressed as a discrete choice by means of the following formula:

$$\text{COG} = \frac{\sum_i \mu(MI_i)MI_i}{\sum_i \mu(MI_i)} \quad (2)$$

where COG is the defuzzified output value; MI_i is the output value in the i th subset; and $\mu(MI_i)$ is the MI of the output value in the i th subset. Summations in Eq. (2) should be replaced by integrals (Erdik 2009). Therefore, each decision area obtained (Fig. 3) after “inferencing” reveals the membership level of the answers in each fuzzy set.

RESULTS

The eight questions were partitioned into two groups. Each one was composed of four questions. The first group encloses the economic effects perceptions before, during, and after RPP implementation. On the other hand, the second group questions deal with the perception during and after the implementation of RPP as a conservation strategy and its effects on the environment.

Regarding the first group, the effects on the conservation status, threatened species, conservation efforts, and sustainability of commercial fisheries, was perceived positively. The question P1 (How do you perceive the conservation status of the upper Gulf of California and the Colorado River Delta Biosphere Reserve?) differs from any other on its integrative attributes of biodiversity and socioeconomic development. It obtained a decision area of 51% of the fishermen surveyed, in which answers were grouped within intervals ranging from the VL to the H set. The value obtained after defuzzification using COG was 0.421, equivalent to an M set (Fig. 3a). It reflects the statement that a protected natural area is perceived to reduce natural disaster and living environment improvement (Chen et al. 2005).

Questions P2 (How do you perceive the effect of purchasing fishing permits as a conservation effort within the upper Gulf of California and the Colorado River Delta Biosphere Reserve?) and P3 (How do you perceive the effect of purchasing fishing permits will have for the conservation of protected species in the upper Gulf of California and the Colorado River Delta Biosphere Reserve?) address the positive perception of fishermen and the community (Fig. 4) at large after permit exchange. In question P2, the decision area ranged from VL to H sets exhibiting a decreasing trend. In this case, 64% of fishermen reported that the preservation of the upper Gulf of California and the Colorado River Delta Biosphere Reserve would be a positive undertaking if past and current public policy changes focused on the preservation of natural resources. Fishing community perception results, in this instance, obtained a decision area ranging from VL to H sets that were visually grouped into balanced perceptions around the moderate M set. A value of 0.137 was obtained positioned inside the VL set after defuzzification (Fig. 3b). Question P3 revealed a dispersed perception within the fishery community that moved from the VL to L fuzzy sets. It showed that the RPP would produce a significant positive effect for the conservation of protected species. A value of 0.398 was obtained after defuzzification (positioned within the M set), integrating 64% of total fishermen perception (Fig. 3c).

Fig. 3 Decision area of the eight survey questions distributed among the EL GSC fishermen village to evaluate the impact perception of fishermen on in the upper Gulf of California and the Colorado River

Delta Biosphere Reserve marine turtles. *A* question P1; *B* question P2; *C* question P3; *D* question P4; *E* question P5; *F* question P6; *G* question P7; and *H* question P8

Question P4 (How do you perceive the effect of purchasing fishing permits will have on commercial fishery species within the upper Gulf of California and the Colorado River Delta Biosphere Reserve?), agrees with Aragón-Noriega et al. (2010a) in that fishing communities perceive that overfishing restrictions have a positive effect on fish populations, capture quotes, and economic development of their communities. This question obtained a decision area that was fragmented into two sections, the first ranging between the L to the M sets and the second ranging from M to VH sets, where both included 64% of the overall positive

perception response of fishermen. A value of 0.538 was obtained within the M fuzzy set after applying *COG* (Fig. 3d).

The second group of questions starts with question P5 (How do you perceive the effect on fishermen's quality of life after the implementation of the fishing permit exchange?). It resulted in dual segmented decision areas, where the first was positioned from the VL to the M sets and the second was positioned from the M to the VH sets. The grouping translated into a 97% negative perception of fishermen. A value of 0.493 membership degree was

obtained nestled within the M set after defuzzification was applied (Fig. 3e).

The sixth question (P6: How do you perceive the effect on fishermen community quality of life after the implementation of the fishing permit exchange?) revealed that 97% of fishermen possessed a negative impact perception to this scenario, moreover, when most of fishing permits exchanged are from parishioners who possess two or more permits and the fishermen who do not have permits but fish as workers will not have this benefit, and their perceptions resulted in a decision area from the VL to H sets and a value of 0.398 that was positioned within the M fuzzy set (Fig. 3f).

Question P7 (How do you perceive economic production alternatives to fishing that are stated within the RPP?) resulted in a 97% negative perception for the fishery community and a decision area ranging from the VL to the VH fuzzy sets for the proposed activities in the RPP, such as ecotourism, aquaculture, convenience stores, and restaurants. The representative value of fishermen perception was 0.504 after defuzzification, which falls within the M fuzzy set.

The last question (P8: How do you perceive the effect of economic growth after the fishing permit exchange was implemented?) shows that 97% of fishermen who perceived a negative impact revealed a triangular-shaped decision area ranging from the VL to the M sets. The fishing community perceived benefits for the owners of permits, but not for “true fishermen” (people that are employed in the “pangas” as fishermen but do not possess the permits). However, after defuzzification was carried out

by way of the *COG* method, the membership value was 0.295 and, therefore, was positioned within the L fuzzy set.

DISCUSSION

The current major problems in many fisheries include poor economic performance, loss of yield due to overfishing, bycatch of non-target fisheries, poor data, fishing impacts on marine ecosystems and habitat and poor compliance with regulations (Hillborn 2007). In the Pacific, the southeast and northeast regions account for more than half of the overfished stocks, but the total number of reported overfished stocks amounts to only 22% of the total captures (Alverson 2002). Problems above described, are not absent in the UGCCRDBR and since the reserve was established, the number of cooperatives and artisanal fishing boats has increased (Aragón-Noriega et al. 2010a) and only 12% of the fishing permits were exchanged after implantation of the RPP, exposing its initial weakness. The program suffers from inequality in constituent voices due to political and fiscal power discrepancies, differing degrees of clarity of purpose among interest groups, and pervasive scientific uncertainty (Brower et al. 2001).

Regularly, the establishment of a protected natural area is perceived to reduce natural disaster and living environment improvement (Chen et al. 2005). In our study, fishermen perceived a relatively positive effect albeit low preservation status under the guidance of the upper Gulf of California and the Colorado River Delta Biosphere Reserve in relation to its environmental policies (Fig. 4). In

Fig. 4 Fishery community answers percentage from the Gulf of Santa Clara concerning the socioeconomic and environmental impacts of the RPP as a conservation and economic developmental tool

addition, many conflicts arise between biodiversity conservation and community economy development. As stated before (Chen et al. 2005), the imbalance between the two aspects includes deeply rooted traditional ideas, low educational level, poor economical situation, and weak social mechanisms. These factors confine economic development and give rise to heavy threats to biodiversity conservation. In this sense, people who have lived in the EI GSC for more than 15 years (INEGI 2000, 2005) perceive the fisheries as not only the foremost activity in the region, they would not stop fishing because it is the only activity they feel comfortable with and they have fished for many years (Aragón-Noriega et al. 2010a, b). In contrast, the number of artisanal fishing boats has increased since 1995 from 635 to 2,070 in 2003, remaining stable until now. To stop the activity, a large number of suitable alternatives would be necessary to compensate for the current profitability of fishing activity. Additionally, fishers have directly witnessed the development of the region and the economic results of the implementation of the reserve, as well as the RPP, and their mistrust concerning the RPP is based upon the long-standing marginality they have suffered and the lack of positive effects forthcoming since the implementation of the UGCCRDBR. Furthermore, they do not perceive that the UGCCRDBR or the RPP, for that matter, has generated or will generate benefits after 26 years since the implementation of the UGCCRDBR. The Statistical Yearbook of the Sonora State (INEGI 2005) and the Official Census of Population and Housing (INEGI 2011) point out the poor quality of life in the region, where 75% of homes lack drinking water, electrical power, drainage, or worse, 77% still live without access to primary medical care services.

Even when the RPP suffers pervasive scientific uncertainty (Brower et al. 2001), FL could evaluate the success of the RPP within the fishery community and determine a positive impact on both protected and commercial species due to the fisheries permit exchange program. It is feasible for a stakeholder to make a decision. In Fig. 3b and d graphics, stakeholders can identify a duality in the perceptions and are useful to identify conflicts that may be worsened by a bad decision. In traditional statistics, as multivariate analysis in ecology, the CANOCO or CLUSTER analysis can show relationships among different criteria but FL remarks the distribution area of these relations.

The implementation of a marine protected area (MPA) is an essential tool for the conservation and sustainable use of marine and coastal biodiversity (Rodríguez-Quiroz et al. 2010). A co-management, within an MPA, to enhance collaborative approaches among fishermen (Hillborn 2007; Guidetti and Claudet 2009) will result in a reduction of bycatch and benefit protected and commercial species. Fisheries in the region may thus reduce the usual strong

competition for shared fishing resources. This is an important step to increase fishers' awareness towards fishery sustainability, which is an essential attribute for social acceptance and success of MPAs (Guidetti and Claudet 2009).

Although people need fish to survive, fishing in itself is the antecedent event that causes destructive environmental impacts on marine fauna and threatened species (Casale et al. 2004; Lewison et al. 2004; D'Agrosa et al. 2000; Lercari and Chávez 2007; Rodríguez-Quiroz et al. 2010; Aragón-Noriega et al. 2010a). These characteristics are common in complex systems that possess a number of attributes not found in less complex systems. Characteristics of complex systems involve a number of important implications in relation to conservation and environmental management (Berkes 2004) as can be seen in the fishing community that inhabits EI GSC and fish in the UGCCRDBR, maintaining a very complex relationship. As seen, the RPP did not consider cultural aspects, and possible local economic assessment was incomplete, giving rise to a command- and resource-control management system based upon a linear cause-and-effect mindset, as well as on mechanistic views of nature (Berkes 2004). This makes it necessary to assess whether local fishers may benefit from a co-management approach that involves fishers, MPA managers, and scientists, and to determine whether conservation goals could also be compatible with co-management of fishing (Guidetti and Claudet 2009). A cohesive social group should be located in which fishers, scientists, and managers work in conjunction in the field, especially in elusive communities where dynamics are in a continuous flux. Close cooperation and risk-sharing initiatives must be formed based upon mutual collaboration, transparency, and accountability (Hillborn 2007), including community-based preservation of common property, traditional ecological knowledge, environmental ethics, political ecology, environmental history, and ecological economics while addressing governance and communities at various scales appropriate to the problems of conservation in question (Berkes 2004). In addition, substantial input of resources such as land, human power, and financial support have to be considered (Lu et al. 2006). Co-management between SEMARNAT (Ministry of Conservation and Environmental Protection who regulates these matters) and local people must be enacted, including surveillance and enforcement of the proposed managerial measures if the goals and objectives of the UGCCRDBR are to be met (Santos et al. 2009).

Fishermen have little knowledge about the purpose of the biosphere reserve and more than 65% of the fishermen from "Golfo de Santa Clara" consider the objectives of the reserve to be fulfilled (Aragón-Noriega et al. 2010a). Nevertheless, official data remark the socioeconomic

Table 1 Percentage of present productive activities in EL GSC, Sonora, México

	Frequency	%	Cumulative percent
Bricklayer	10	16.7	16.7
Electrician	2	3.3	20
Gardener	1	1.7	22
Businessman	4	6.7	28
Mechanic	1	1.7	30
Farmer	4	6.7	37
Student	1	1.7	39
Painter	1	1.7	40
Worker	1	1.7	42
None	35	58.3	100
Total	60	100	

degradation of fishermen (INEGI 2005, 2011) and FL reveals that 20 years after UGCCRDBR implantation, fishermen do not perceive a better quality of life, an increase in income or public services, and the majority continues to fish as they did before doing alternative activities as bricklayers (~10%) (%), although most (~35%) do not have any activity (Table 1).

In general, fishers appreciate the effort of institutions for a fishery co-management plan and marine ecosystem protection (Hillborn 2007; Guidetti and Claudet 2009) but fisheries in the UGCCRDBR remain the main economic activity and reconciliation of this industry with sustainable environmental aspects are goals with a long-term challenge (Aragón-Noriega et al. 2010a). The governmental institutions for fishery management and marine ecosystem protection should represent a diversity of interests and cultures, and operate under varying legislative directives and statutory authorities (Kittinger et al. 2010), such as SEMARNAT.

Consequently, institutions for fishery management and marine ecosystem protection should be characterized by acceptable management policies to attain development, sustainability criteria, and scientific burden of proof (Kittinger et al. 2010), which is a key issue for the UGCCRDBR management. Our analysis showed how a fishing community perceives the negative impact that fisheries are still causing on threatened species in the Gulf of California (D'agrosa et al. 2000; Lercari and Chávez 2007; Lluch-Cota et al. 2007; Aragón-Noriega et al. 2010a; Rodríguez-Quiroz et al. 2010).

It is expected that an MPA would enhance local fisheries if a complete fishing ban were established and the protocol respected by fishermen under the surveillance of MPA staff and law-enforcement authorities. It would be a success story for MPAs in terms of fishery management in the

overall perspective of sustainability (as well as for biodiversity conservation) without neglecting sociocultural and socioeconomic factors (i.e., local communities) where MPAs have been or will be established (Guidetti et al. 2010). As seen in other MPAs, fines or penalties must be executed to comply with established regulations (Thur 2010) in the UGCCRDBR.

After the application of FL, it was determined that the perception of fishermen concerning both the RPP and the UGCCRDBR is negative in terms of quality of life. Moreover, they also perceive the fishery permit exchange as well as alternative activities proposed by the program as negative. Finally, they are unable to recognize that the RPP will, in fact, trigger economic development in the region.

The UGCCRDBR faces different challenges in terms of governance and management from those of local and community-level MPAs. These challenges include the management of multiple agencies, overlapping statutory responsibilities and juridical zones, socioeconomic and political pressures, and a broader and more diverse constituency (Kittinger et al. 2010). Fishery survival has been dependent upon fishery resource exploitation that tends to be more restricted and limited in accordance with current regulations. It is necessary to take into account that if conservation issues are, in fact, a matter for complex systems, they must be addressed simultaneously and at various scales (Berkes 2004). In this sense, the current RPP would benefit a small number of fishermen while excluding the majority that do not possess a fishery permit to exchange and, therefore, will not be able to partake in any of the new economic alternatives. These fishermen will face an unfavorable environment causing an increase in migration rates to other states where work can be obtained at lower employment levels as a consequence of insufficient educational skills. It is utmost important to improve the education system and the government should handle education as a priority, adding some specific knowledge about biodiversity protection into the school curriculum (Chen et al. 2005). Moreover, in view of the fact that the fishermen at large have suffered inequality since the planning stage of the RPP, where constituent voices were silenced due to political and fiscal power discrepancies, differing degrees of clarity in purpose among interest groups, and pervasive scientific uncertainty (Brower et al. 2001), besides the RPP lacked sufficient and adequate proposed activities, which has not been the case in other MPAs (Young 1999). The situation worsens when these new alternatives are created without first applying a market study to show their feasibility or to visualize them as potential economic development triggers. Combined, these measures lead to a need to exert greater effort and investment in community-based conservation initiatives that, in turn, might lead to a greater concern that these community-based conservation

measures might not work and that the emphasis on “community” and “participation” could dilute the conservation agenda (Berkes 2004, 2007) within the UGCCRDBR.

Within the MPA itself, it is necessary to incorporate dynamical interactions that occur between people and natural systems rather than viewing people merely as “managers” or “stressors” (Berkes 2004). To be effective, it must transpire within an adaptive co-management framework where fishermen agree to a potential reduction in their fishing endeavors or a modification in the fishing gear used if negative effects were detected (Guidetti et al. 2010). Moreover, it must foster alternative fishery-management regimens (Kittinger et al. 2010) where clear conservation goals and objectives have been formulated as a prerequisite for developing and agreeing to appropriate managerial measures (Santos et al. 2009). In this sense, there are incentives to reinforce conservation strategies joined to social development, such as payments for environmental services (Greiner et al. 2009), and incidental catch permits for federally protected species (Suzuki and Olson 2002). In addition, the execution of regulation enforcement in the form of fines and penalties must be put into effect within this particular MPA. Conservation solutions can be framed as long-term sustainability issues that take into account considerations of both global and local commons and biological conservation objectives as well as local livelihood needs (Berkes 2007).

CONCLUSIONS

The UGCCRDBR MPA has played a role in the protection and conservation of marine ecosystems. During a Management Program design, stakeholders can use the decision area graphics to analyze the perception level about actions proposed by them to the communities with the opportunity to diminish bad perceptions with alternative actions or new proposed development activities. In terms of conservation, the UGCCRDBR is generally perceived to be in relatively good condition. A positive perception of the MPA in regard to its benefit in the conservation of protected and commercial species has also been determined. Nevertheless, the MPA is not perceived as a socioeconomic trigger and, in combination with the implementation of the RPP, an overall perception lingers that quality of life will worsen in time for most fishermen. In this sense, FL is useful to resolve conflicts between biodiversity conservation and socioeconomic development (Lu et al. 2006). Implementation of any programs based on this method for nature conservation and regional socioeconomic development will be possible if the common resource pool, as well as the participation of multi-attribute and multi-stakeholder social

decision-making processes at all stages, are taken into account within and around the MPA.

The advantage of the method proposed is that any stakeholders, independently from their knowledge, perceptions, and beliefs, can decide based on the decision area and on the percentage from the “Gulf of Santa Clara” community concerning the socioeconomic and environmental impacts of the RPP.

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