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Artisanal fishing of Spanish mackerel *Scomberomorus sierra* in the Upper Gulf of California

Pesca artesanal de la sierra *Scomberomorus sierra* en el Alto Golfo de California

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ABSTRACT

Spanish mackerel *Scomberomorus sierra* (Jordan and Starks, 1895) is captured in the Upper Gulf of California by local fishers of three communities: San Felipe in Baja California, Golfo de Santa Clara and Puerto Peñasco in Sonora. Small-scale fishers have increased, Spanish mackerel capture maintain capture levels in the last fourth years. The Sustainable Fishery Index (SFI) identifies three production periods, one of low-capture before 1999 with 274.17 t year^{-1}; a second of fleet expansion with 602.03 t year^{-1} and a recovery period of the capture over 675.65 t year^{-1}. A GIS survey indicated that 80.44% of the Spanish mackerel fishery in the Upper Gulf of California occurs within marine protected areas, of which 68.82% is done within the Biosphere Reserve of the Upper Gulf of California and 69.31% within its Vaquita Refuge Area. Spanish mackerel captured in the marine protected area generate a gross profit GP of US$ 396,934 year, with a return rate of 87%. Exploitation of fishers' effort in the marine protected area need to follow an interdisciplinary and complex evaluation because there are endangered species in the region, and this requires an adequate management to enhance marine conservation without compromising fishermen individual interest.

***Keywords**:* Spanish mackerel, Upper Gulf of California, marine protected areas, sustainable fishery, gross profit, fishermen, conservation

RESUMEN

La sierra *Scomberomorus sierra* (Jordan y Starks, 1895) es capturada en el Alto Golfo de California por pescadores locales de tres comunidades: San Felipe en Baja California, golfo de Santa Clara y Puerto Peñasco en Sonora. La pesca artesanal ha aumentado mientras que la captura de la sierra mantiene estable en los niveles los últimos cuatro años. El Índice de Pesca Sostenible (SFI) identifica tres periodos de producción, uno de baja captura antes de 1999 con 274.17 t año^{-1}; un segundo de expansión de flota con 602.03 t año^{-1} y un periodo de recuperación de la captura superior a 675.65 t año^{-1}. Un estudio SIG indicó que el 80.44% de la pesquería de sierra en el Alto Golfo de California se produce dentro de áreas marinas protegidas, de la cual el 68.82% se realiza dentro de la reserva de la biosfera del Alto Golfo de California y el 69.31% dentro de su área de refugio de vaquita. La sierra capturada en el área marina protegida genera un beneficio bruto de 396.934 dólares al año, con una tasa de retorno del 87%. La explotación del esfuerzo de los pescadores en el área marina protegida debe seguir una evaluación interdisciplinaria y compleja porque hay especies en peligro de extinción en la región y esto requiere una gestión adecuada para mejorar la conservación marina sin comprometer el interés individual de los pescadores.

Palabras clave: Pez sierra, Alto Golfo de California, áreas marinas protegidas, pesquería sustentable, ganancia bruta, pescadores, conservación

INTRODUCTION

Small-scale marine fisheries provide an important source of food and income to coastal communities worldwide (FAO, 2022). Mexico has an important tradition in small-scale fishery, with the Gulf of California as one of its major areas of marine fishery production. The Gulf contributes 20% of the national production and over 50.000 small-scale vessels exploit local resources (Cisneros-Mata, 2001, SAGARPA, 2002). The Gulf is divided in fourth regions, based on biological, ecological and oceanographic characteristics. The Upper Gulf of California (UGC) is one of them, it has importance for species in the pelagic zone and for species who are estuarine-dependent (Galindo-Bect et al., 2002, Ramírez-Rojo & Aragón-Noriega, 2006).

On June 10, 1993, the UGC and Colorado River Delta was decreed as Biosphere Reserve by Mexican authorities. The marine and terrestrial environments extension covers 934.756 h (DOF, 1993; Figure 1). The Reserve was created to protect species inhabiting the region (Tognelli, Silva-Garcia, Labra & Marquet, 2005), some of which are commercially important, endemic or under risk of extinction (Cudney & Turk, 1998). The area is supported by a management program that was designed to promote sustainable activities by durable and conservational use of biodiversity (Rojas-Bracho, Reeves & Jaramillo-Legorreta, 2006, SEMARNAT 1995).

Because to the critical environments alongside the Upper Gulf coast, one of the most important economic activities in the region are fisheries and tourism (Godínez-Placencia, 1993). Two types of commercial fishing take place in the Upper Gulf: Artisanal (small scale) and industrial fishing. In the artisanal fishing only two fishermen worked manually the fishing gears. They use 7 m fiber glass boats with outboard motors. Artisanal fishing is done by cooperatives and individual fishers from Puerto Peñasco and El Golfo de Santa Clara in the State of Sonora and San Felipe in the State of Baja California.

The Spanish mackerel *Scomberomorus sierra* fishery represents 13% of the pelagic fish species capture in the UGC. Based on catch volume and beach economic value, this fishery represents one of the five most important pelagic fisheries. Fluctuations in the Spanish mackerel capture have occurred as other species in the region because of the overfishing by commercial trawlers, Colorado River flows, and illegal fishing.

The potential profit of this important species has motivated an increase in fishing effort which is jeopardizing critical species, such as the totoaba *Totoaba macdonaldi* (Gilbert, 1890) and the vaquita *Phocoena sinus* (Norris, 1958), who are rare and endemic of the northern part of the Gulf of California (Cisneros-Mata, Montemayor-López & Román-Rodríguez, 1995). Species accidentally caught in the UGC (D'agrosa, Vidal & Gram, 1995). These species are at risk of extinction due to their low population size and reduced habitat (Rojas-Bracho et al., 2006). A buy-out program to reduce fishing fleet is recently implemented to reduce fishing effort and protect soft-bottom biological communities.

There is a lack of information on the Spanish mackerel fishery in the Upper Gulf of California and Colorado Delta River. Information on the catch and effort of the fishery, and the state of exploited populations as a first step to implement a scheme of fishing and management alternatives that would aid in reducing artisanal fishing in the marine protected areas as a policy of biological conservation (Lunn & Dearden, 2006).

In this work, we identify and estimate the economic value of capture as one of the most important fisheries of the Upper Gulf of California Biosphere Reserve and of the recently created Vaquita Refuge, by the three communities within the protected marine areas. We also analyzed the current situation of the Spanish mackerel fishery in the UGC through primary (interviews) and secondary (official catch reports) data. We describe the basic variables such as Catch per Unit Effort (CPUE), effort, and catch fluctuations. We also identified the fishing ground for each community. Finally, we assessed the relative sustainability of the Spanish mackerel fishery by means of a sustainability index.

MATERIAL AND METHODS

A total of 2.554 catch reports by artisanal fishermen of the three communities of the UGC were compiled and analyzed. The data covered 1995–2005 of official records from San Felipe, Baja California. Puerto Peñasco and el Golfo de Santa Clara, Sonora. 146 artisanal fishers were interviewed in these three ports. Questionnaires were designed to compute the direct costs of fishing operations, as well as the impact on fishing sites. Following the Cochran´ method (Cochran, 1989), we obtained a value for the number of fishermen to interview, as follows:

$$n = \frac{\frac{Z^2 q}{E^2 p}}{1 + \frac{1}{N}\left[\frac{Z^2 q - 1}{E^2 p}\right]}$$

where: n = sample size; Z = CI = 95%; p and q = 0.5 equation distribution; E = 6% precision level; N = Fishermen community size. Based on the method of Greenberg (1993), fishermen were randomly selected.

From artisanal Spanish mackerel catch records declared by fishers at the federal government fishery offices in the communities, we obtained the following data: capture site, weight of landings, and first-hand or "beach" economic value of landings. With this information, we computed a gross income (disregarding investment costs) for each community.

Estimating growing and declining periods of the Spanish mackerel fisheries capture tendency in the Upper Gulf of California, from 1995 to 2005 was measured through the Sustainable Fishery Index, as detailed in Ponce-Díaz. Arreguín-Sanchéz, Beltran-Morales (2006): estimate growing and decreasing periods of the fishery.

$$SFI = Ln\ (C_{Xi}/C_{Xmean}),$$

where: C_{Xi}= Capture in the present year, C_{Xmean}= Capture mean through complete period analyzed.

The Spanish mackerel catch was processed and spatially represented in a GIS, identifying fishing sites within the Biosphere Reserve and Vaquita Refuge (Figure 1), and overlapping the area using ArcView 3.2 software and downloaded via 2002 Conica Lambert projection to maps of the total Spanish mackerel fishery and by community. The percentage of fishing within Biosphere Reserve and the Vaquita Refuge area was obtained from the overall projected fishing sites.

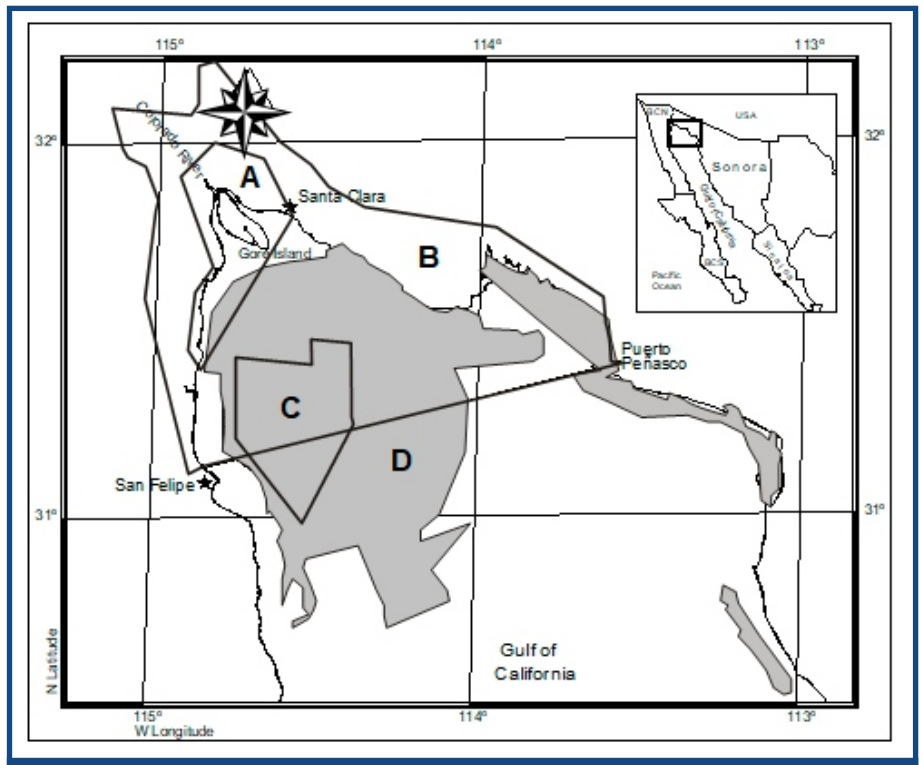

Figure 1. Areas of Biosphere Reserve of the Upper Gulf of California (June 1993) and Vaquita Refuge Area (December 2005). A) Nucleus Zone, B) Buffer Zone in the Biosphere Reserve of the Upper Gulf of California, C) Vaquita Refuge Area, D) Shadows are fishing areas. Note that the map was made in 2007. Source: own GIS data

RESULTS

Fishery analysis

The greatest number of authorized small boats for pelagic fishes was registered in el Golfo de Santa Clara (GSC), followed by San Felipe (SF) and Puerto Peñasco (PP) in that order. The number of small boats officially registered in each community has changed since 1995. In that year, PP had the highest number of small boats from the three communities. During the next two years, many small boats were authorized to join the fleet. In 1997, GSC and PP in the state of Sonora were authorized to increase their fleet by 41% and 98% respectively. SF in the state of Baja California had an increase of almost 1000% of the fleet. The next mayor increase of the fleet was made between the years of 2001 and 2003, when the number for small boats increased to 673 in PP, 557 in GSC and 840 in SF, and that number of small boats continues to the present (Figure 2A).

At the beginning of period analyzed, the increased fishing effort is correlated with the increased catches in GSC. The general tendency of catches over the thirteen-year period of this study was a general, but fluctuating, increase. The highest catches for the studied communities were obtained in 2000 for SF with 186 metric tons; for GSC in 2007 with 1239 metric tons, and for PP in 2005 with 58 metric tons. It is also important to note that the most Spanish mackerel catches were obtained by fishermen of GSC (Figure 2B).

Since increased effort also resulted in increased catches, the CPUE exhibited the same trend as the catches. Once again, GSC was the most important community holding the highest position over the course of this study. Here it is important to note that beside GSC community, none of the other communities recorded more than 1 ton/boat/year over the period of analysis, except SF in 1995 with 1.47 ton/boat/year (Figure 2C).

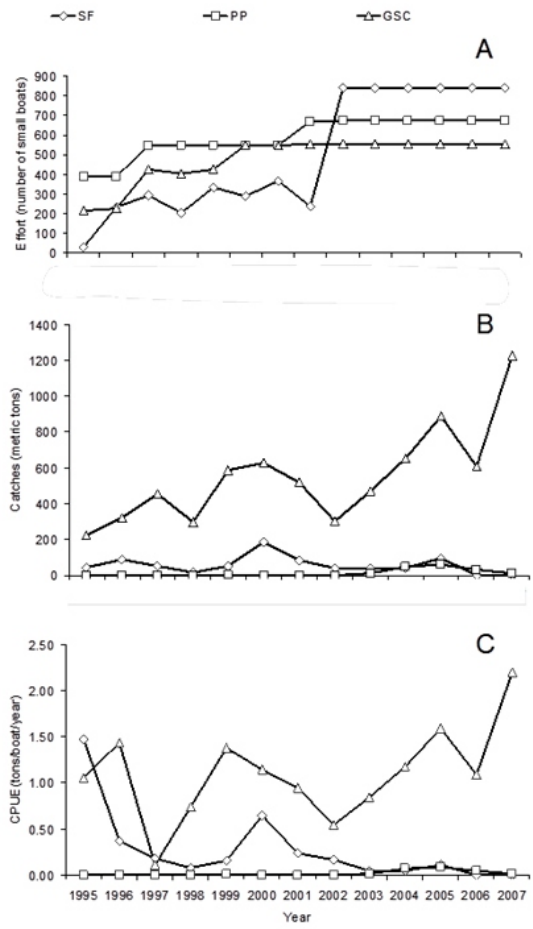

Figure 2. Fisheries features of Spanish mackerel in three communities of the Upper Gulf of California. A) tendency of effort; B) volume of capture; C) CPUE. SF, San Felipe; GSC, Golfo de Santa Clara; PP, Puerto Peñasco.

After we totaled the three communities´ catches and effort, we analyzed the tendency of the three communities as one (Figure 3). The effort of small boats doubles their number from 1995 to 1997 when the number of small boats increased from 635 to 1269. The rate of increase in small boats numbers was then modest until 2002, because in 2003 the number of permitted small boats increased to 2070. The number of small boats has remained constant since.

Spanish mackerel catches and CPUE exhibited comparable profiles, with important peaks in 2000 (815 t), 2005 (1041 t), and 2007 when production was 1239 metric tons of Spanish mackerel. The CPUE showed the same behavior, and difference in those years with respect to the media of 0.41 ton/boat/year was high. The CPUE of those years was 0.59, 0.50, and 0.60 ton/boat/year for 2000, 2005, and 2007, respectively (Figure 3).

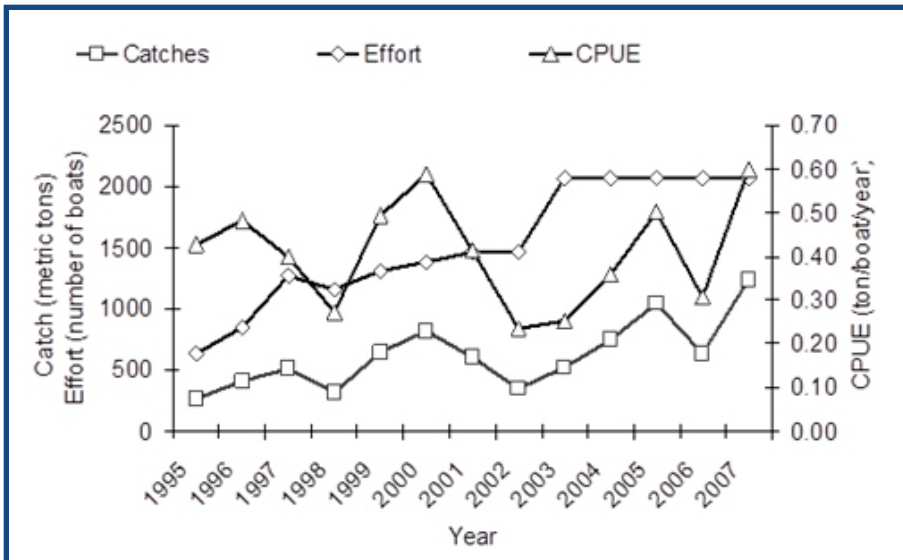

Figure 3. Tendency of the artisanal Spanish mackerel capture, effort, and CPUE in the Upper Gulf of California.

The sustainable fishing index calculated for the three communities' shows us that the Spanish mackerel fishery had three periods of capture intensity (Figure 4). The initial period, with a lower capture with respect to the historical average (274.17± 112.55 t year^{-1}) because of the reduced number of small boats before 1999 and a second period, with the onset of the expended fleets that led to higher levels capture from 1999 to 2000. In the next two years (2001-2002) capture levels declined from

overexploitation tied to the increased size of the fleet. A final period begun in 2003 with a substantial recuperation of the fishery (675.65 ± 180.28 t year^{-1} average) while the Spanish mackerel season and the capture area was extended.

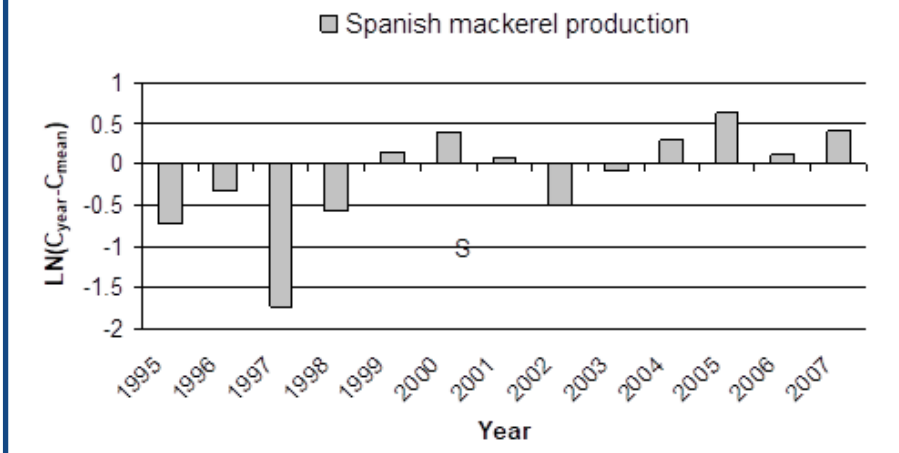

Figure 4. Sustainable fishing index of the Spanish mackerel capture in the Upper Gulf of California during the period of 1995 to 2005.

GIS Interpretation

Our survey data and GIS analysis showed that fishing is conducted within the Vaquita Refuge area and in the Biosphere Reserve (Figure 1). 80.44% of the Spanish mackerel catch in the UGC occurred in the marine protected areas, and 30.38% of the marine area of the Reserve is used to catch this specie (Figure 5). 68.82% of the Spanish mackerel artisanal catch is done in the Biosphere Reserve and 69.31% in the Vaquita Refuge Area.

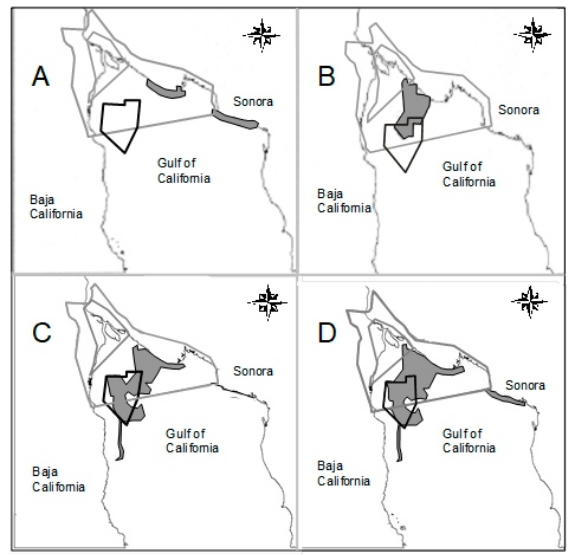

Figure 5. Spatial distribution of the Spanish mackerel artisanal fisheries as compared with the Vaquita Refuge Area declared in the Upper Gulf of California by community. A) Puerto Peñasco, B) Golfo de Santa Clara, C) San Felipe, D) All MPA's.

Fishermen from Puerto Peñasco fish close to the Sonoran shoreline. 50% of the capture occurs inside the Biosphere Reserve, and none in the Vaquita Refuge Area. Fishermen from El Golfo de Santa Clara do all their fishing inside the marine protected areas and they fish in 27% of the Vaquita Refuge Area. San Felipe fishermen fish near the Baja California shoreline in the UGC from the core zone to Puertecitos, covering in 60% of the Vaquita Refuge Area and 25% of the Biosphere Reserve.

Spanish mackerel economic value

The economic value of the Spanish mackerel fishery from 1995 to 2007 is shown in table 1. Spanish mackerel capture represented 26% of the total gross incomes in the marine protected areas in 2007, just below shrimp earnings who where 27% of the total gross incomes. The value of catch during this period was 460,000 USD. Operation costs of the artisanal fishery were relatively high, even though the travel distance from the three ports to the fishing sites is short. Spanish mackerel captured in the marine protected areas generated an annual profit of 397,000 USD thousand with a return rate of 87%. Even if fishing effort has increased, gross profits provide high incomes.

Table 1. Catch, first-hand value product and operation cost in the Spanish mackerel artisanal fishery of the Upper Gulf of California inside the Vaquita Refuge Area and the Biosphere Reserve from 1995 to 2005.

Year	Catch (metric tons)	Value of catch[1]	Costs of catch[1]	Gross profit[1]	Return rate (%)
1995	270.88	110815.77	1005.39	109810.38	99.09
1996	409.9	163959.6	3277.42	160682.18	98
1997	99.63	54343.09	8000.3	46342.79	85.28
1998	316.27	230015.27	13050.14	216965.14	94.33
1999	643.98	462491.85	23287.74	439204.11	94.96
2000	814.9	563023.2	36854.45	526168.75	93.45
2001	605.69	495565.36	54963.06	440602.31	88.91
2002	343.55	252980.67	77608.13	175372.54	69.32
2003	521.29	402811.91	111690	291121.91	72.27
2004	744.08	588502.01	117490	471012.01	80.04
2005	1041.18	1041181	121000	920181	88.38
2006	637.31	550404.09	126310	424094.09	77.05
2007	836.48	1069649.05	131060	938589.05	87.75
Average	560.4	460441.76	63507.43	396934.33	86.83

Source: Federal fisheries offices in the communities of the Upper Gulf of California. 1)

Social analysis

A final question asked to the fishermen exploiting the marine protected areas concerned alternatives to fishing to reduce the impact on endangered species in the region. Fishermen were asked about options for employment and how they would like to be assisted by governmental authorities. The largest number of them would switch to ecotourism and storekeeping (45.3%), 8.7% would like to work in aquaculture and maquilas, 21.7% in another fishery (mollusk, clams, oysters) or continue in the same fishery, and 17.1% would seek employment in an artisan employment (Table 2).

Organized by community, in PP and SF, a high number of fishermen would seek employment in the tourism sector and over 10% would continue in other fishing activity. In SF and GSC, more than 20% would seek employment as storekeepers and more than 15% will not stop fishing the same species that they capture now. In PP and GSC, less than 8% would seek employment in the aquaculture sector, but no one would consider this option in SF. About 25% in GSC and more of 10% in PP and SF would seek employment in the construction trades.

Table 2. Alternative employment for fishermen to reduce fishing effort in the Marine Protected Areas. Fishermen's propositions.

Options	Puerto Peñasco	Golfo de Santa Clara	San Felipe	Total
Tourism	28.6	16.7	28.9	24.7
Aquaculture	7.1	3.3	0.0	3.5
No stop fishing	3.6	16.7	18.1	12.8
Another fishing activity	14.3	1.7	10.8	8.9
Work in private sector	3.6	8.3	3.6	5.2
Storekeeper	7.1	26.7	21.7	18.5
Other (Trade)	14.3	24.9	12.0	17.1
Do not answer	21.4	1.7	4.8	9.3

DISCUSSIÓN

Marine protected areas are increasingly being used as a management tool to protect ecosystems, but there is some debate on whether marine protected areas should be used to protect and increase biodiversity or as a fisheries management tool or to serve both purposes (Monaco et al., 2007). Regardless of the objective of the implementation of a marine protected area, a high effort done within the marine reserve may limit the potential of fish and, in this case, the Spanish mackerel populations to increase in abundance (Sladek-Nowlis & Friedlander, 2004).

This study was motivated by issues of biodiversity conservation in which Spanish mackerel plays a role; we saw the opportunity to detail the basic aspects of the UGC fishery. Since Spanish mackerel generates important grounds for artisanal fishermen, there are important challenges to the fulfilling of goals of the Biosphere Reserve and the Vaquita Refuge Area, moreover, because the number of registered small boats is greater than those recommended when the Refuge was declared (DOF, 2005). Pressure on the fishery will continue as Mexican authorities reduce the size of the industrial fleets in the zone by buying their fishing permits and vessels, thereby forcing fishermen into small-scale fishing.

The distance to fishing sites from the ports and seasonal distribution of resources is an important constraint for fishers. San Felipe is the closest port to Vaquita Refuge, and fishermen operated their fishing gears during entire year. Fishers from El Golfo de Santa Clara do not operate on Vaquita Refuge because of high operation costs related to travel even though this port holds the greatest number of registered permits and number of small boats of the Area. Fishermen from Puerto Peñasco keep their fishing activity near the Sonoran coast to save gasoline and oil.

Spanish mackerel fishery is an attractive activity to the fishermen despite restrictions to its capture in the marine protected area. But the persistent recruitment of new fishermen to the area will not enhance fishermen welfare, and there is no warranty that the fishery will be sustained over the next years (Ponce-Díaz et al., 2006).

Spanish mackerel production requires adopting strategies that allow for the management and conservation of the ecosystem (Palumbi, Gaines, Leslie & Warner, 2003) but includes the fishermen points of view throughout all the negotiation process (Lundquist & Granek, 2005) as well as the views of law enforcement officials. This entails knowing what fishers would be willing to obtain in return for reducing fishing effort in the Vaquita Refuge Area process (Lundquist, Granek & Bustamante, 2005) (Davis, 2005).

Conservation success in this case must be based on agreements that dignify inhabitants of the UGC. Governments at all levels and conservation organizations are promoting development of the region. Fishermen quality of life must be improved while it is recovered the Spanish mackerel ecosystem and sustainability, considering socio-economic, ecological, and institutional factors (Davis, 2005, Harris, Jenkins & Pimm, 2005, Leslie, 2005). Success of most fisheries management policies to conserve species is contingent upon vulnerability of the species and size of the protected area (Carter, 2003, Clark, Munro & Sumaila, 2005, Mangel, 1998). As a first step towards instituting a monitoring and management strategy for the area further research will be needed to assess the ecological impacts of small-scale fisheries employing so-called "non-destructive" techniques (Lunn & Dearden, 2006).

In conclusion, we believe that a practical policy management for this fishery in the marine protected areas is needed to avoid the perception that marine protected areas are only suitable for biodiversity conservation, to address inconsistencies between conservation and fisheries approaches to the regional management of natural resources. Better collaboration and coordination between government agencies and society groups (non-governmental agencies and fishermen) will enhance fishing programs in the Upper Gulf of California and would help to reduce conflict in the two marine protected areas.

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