Fisheries and Biodiversity in the Upper Gulf of California, Mexico

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1. Introduction

The Upper Gulf of California (UGC) has been recognized by its high primary productivity and abundant fishing (Aragon-Noriega & Calderon-Aguilera, 2000). Sediments and nutrients from the Colorado River, and complex hydrodynamics render this as an important site for spawning, mating and nursing for numerous species of commercial and ecological importance (Cudney & Turk, 1998; Ramirez-Rojo & Aragón-Noriega 2006). Temperature, salinity and abundance of nutrients in this region vary depending on fresh water runoff from the Colorado River (Alvarez-Borrego et al., 1975; Hernández-Ayón et al., 1993; Lavín & Sánchez, 1999).

Commercial fishing of high market value resources such as shrimp takes place in the UGC by artisanal or small scale, and industrial fishing. Artisanal fishing is done on relatively small (30 feet) fiber glass boats or artisanal boats with outboard motors, usually operated by two fishers; their primary fishing gear is drift gillnets, which they use to catch croakers, Spanish mackerel and even shrimp. This type of fishing is carried out by cooperatives and individual fishers from the three ports of the UGC: Puerto Peñasco and El Golfo de Santa Clara, in the State of Sonora, and San Felipe, in Baja California. Because marine resources in the region are migratory, fisheries are seasonal generating bursts of accumulated fishing effort over a few months depending on availability of species (see Cudney & Turk 1998). Increasing demand of economically important species has motivated a steady rise in fishing effort and use of gear and fishing practices jeopardizing critical species such as totoaba, Totoaba macdonaldi, an endemic croaker declared under risk of extinction (Cisneros-Mata et al., 1995), and the rare vaquita, Phocoena sinus. Vaquita are accidentally caught in all kinds of gillnets used in the Upper Gulf (D'Agrosa et al., 1995; Blanco 2002).

Vaquita is the world's smallest cetacean; it is endemic to the Upper Gulf of California and has the most restricted distribution range of all marine mammals (Jaramillo-Legorreta et al., 2007). In a situation of increased mortality in fishing activities, the reasons why vaquita is under risk of extinction are its historical small population size (Jaramillo-Legorreta et al., 2007) and possibly reduced habitat (Lavin et al., 1999) with decreased flow of Colorado river inflow (Hanski, 1998; Fagan et al., 2005). They occur only in the northern quarter of the Gulf of California, Mexico, mainly north of 30°45′ N and west of 114°20′ W with a highly productive core area of about 2,235 km², between San Felipe and Rocas Consag archipelago, a small upwelling spot where they have being seen feeding (Rojas-Bracho et al., 2006).

The high productivity of the upper-most portion of Gulf of California maintains a diverse number of marine species which interact with the vaquita. This porpoise is known to feed on grunt, Orthopristis reddingi, and ronco croaker, Bairdiella icistia, as well as different species of market squid (Vaquita Marina, 2007). Vaquita competes with dolphins and rays for several food items in the area; historically it was predated by sharks and killer whales (Barlow, 1986); at present shark predation and competition with ray species has lowered because of reduced abundance of these species possibly due to over fishing in the region (Rojas-Bracho et al., 2006).

The Upper Gulf of California and Colorado River Delta was declared a Biosphere Reserve (henceforth, Reserve) on June 10, 1993; it has an extension of 934,756 hectares including marine and terrestrial environments (Diario Oficial de la Federación [DOF], 1993; Fig. 1). The Reserve was implemented to protect species inhabiting that region, some of which are commercially important, endemic or under risk of extinction (Instituto Nacional de Ecología [INE], 1995; van Jaarsveld et al., 1998). A management program was designed to promote sustainable use of the biodiversity and landscape (SEMARNAT, 1995; Rojas-Bracho et al., 2006; Aragón-Noriega et al., 2010).

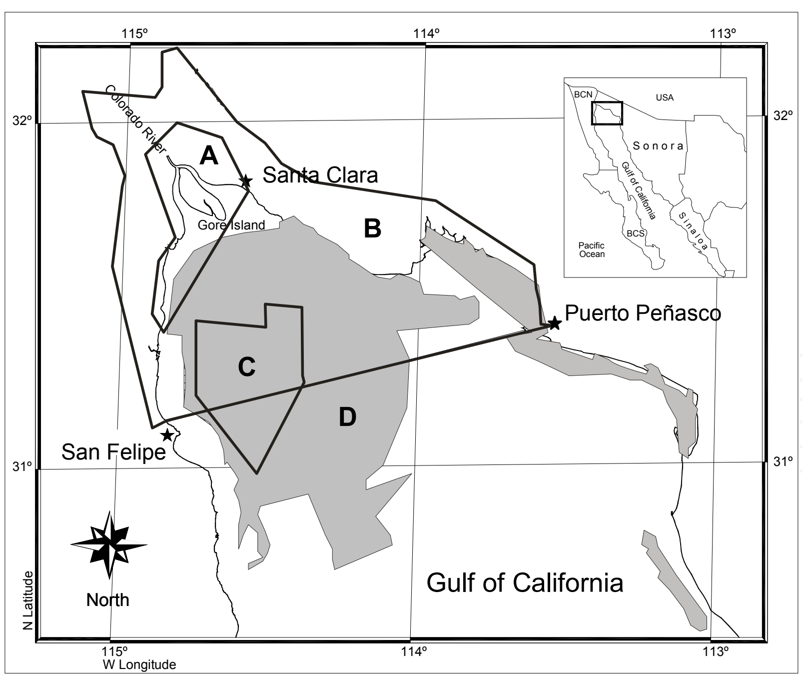

Fig. 1. The Upper Gulf of California. The thin line depicts the Biosphere Reserve declared in June 1993; the shaded area represents the vaquita refuge declared in December 2005.A) Core Zone, B) Buffer Zone in the Biosphere Reserve of the Upper Gulf of California, C) Vaquita Refuge Area, D) Shadowed are fishing grounds.

The Reserve hosts an important number of species with high commercial value. Such is the case of the gulf croaker, Cynoscion othonopterus, an endemic fish species that arrives massively into the UGC where it spawns during winter; and the blue shrimp, Litopenaeus stylirostris, which is highly priced in local and international markets (Rodriguez-Quiroz et al., 2010).

Implementation of Biosphere Reserve in June 1993 limits the use of gillnets (> 15cm mesh size) and fishing effort (up to 2,100 artisanal boats) to protect, most of all, totoaba and vaquita, considered under risk of extinction (INE, 1995; Greenberg, 2005). The most recent additional measure to protect vaquita and its habitat was a declaration in December 2005 of a Refuge to further limit fishing activities (Fig. 1). The Refuge, located in the western side of the UGC, comprises an area of 1,263.85 km^2 and is divided into two polygons: Polygon A – northern portion-, within the Reserve and with a surface of 897.09 km^2; and Polygon B – southern portion-, outside the Reserve and with a surface of 266.76 km^2. The Refuge was declared in the most likely distribution range of vaquita and includes a 65 km^2 zone where gillnets and trawl nets are prohibited (DOF, 2005).

Management of the Reserve and the Refuge imply a series of actions to achieve both protection of critical species and use of commercially important species. Consequently, fishing in the Upper Gulf becomes an economic activity with environmental implications. Conservation measures in the Reserve and the Refuge pose a challenge because they were designed to minimize negative impacts of fishing on vaquita. Several studies have been conducted in the area to determinate an average of accidental captures of vaquita in each fishing season since 1985; the most conclusive data was produced by D'Agrosa et al. (2000); who reported 39 vaquitas/year as by-catch before 1995. For those years less than 600 artisanal boats were in use, 1/3 of the boats registered in 2007 in the three fishing communities. Because of its critical condition it has been estimated that the maximum catch rate to avoid mid-term extinction is one vaquita per year (DOF, 2004). Mexican legislation recognizes that it is through participation of human communities affected by these measures that agreements can be achieved (see Palumbi et al., 2003). Therefore, solving this challenge will require a clear definition of common goals in fisheries management and conservation, expressed in a single policy (Davis, 2005).

Several management measures have been implemented both to protect vulnerable marine species and fishing resources. Amongst such measures we have: no-take zones (Mangel, 1998), subsidies (Munro & Sumaila 2002), buy-out of fishing gear and boats (Clark et al., 2005), fishing rights (Gonzalez-Laxe, 2006), and individual transferable quotas (ITQ) (Townsend et al., 2006). In the Gulf of California, some of these measures have been implemented to reduce fishing effort and protect soft bottom biological communities: buy-out of shrimp trawlers[1]; most recently, an ITQ program started aimed at rebuilding fishing stocks in the Gulf of California[2].

In this work we identify and analyze the most important artisanal fisheries of the Upper Gulf of California, which are in continuous interaction with the vaquita. We propose a scheme to reduce vaquita by-catch as a fishery management and biological conservation policy.

[1]http://www.conapesca.sagarpa.gob.mx/wb/cona/programa_de_retiro_voluntario_de_embarcaciones_cam
[2]http://www.conapesca.sagarpa.gob.mx/wb/cona/presentacion_del_ordenamiento_de_la_pesca_de_camar

2. Methods

Basic information used for the present analysis was generated in a series of studies conducted by World Wildlife Fund and Centro de Investigaciones Biológicas del Noroeste in the Upper Gulf of California during 2005. Additional information on fishing sites by species came from a previous report (Cudney & Turk, 1998). Artisanal fisheries data spanning since 1999 to 2007 were collected from official records in the ports of San Felipe, El Golfo de Santa Clara and Puerto Peñasco. Further information was gathered form a survey based on direct interviews to 146 artisanal fishers in those three fishing ports. Questionnaires were designed to compute direct cost structure during fishing operations, as well as fishing sites by species. A section of the survey was specifically designed to ascertain what types of activities alternative to artisanal fishing might be implemented in the Upper Gulf. Following Cochran (1989) we estimated sample size (n) for fishermen interviews:

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

where: Z= CI=95%; p and q = Equation distribution; E= 6% Precision level; N= Fishermen community size. Following Greenberg (1993), local fishermen at each port were randomly selected.

From artisanal fishing landing records declared by fishers in local government fishery offices we obtained the following: Capture site, species, weight of landings and first-hand or "beach" economic value of landings by species.

Artisanal catch by species was processed and spatially represented in a geographic information system (GIS), identifying fishing sites within the Refuge (Fig. 1), overlapping the vaquita refuge polygon through the use of a ArcView 3.2 software using a 2002 Conica Lambert projection in maps by fishery and community in the vaquita polygon. Relative size (percentage) of the fishing activities zones in the vaquita refuge were obtained from the overall projected fishing sites.

To assess impact of fishery management measures oriented to protect the vaquita population, we arbitrarily assumed reductions in the number of artisanal boats for the three fishing communities. We establish two scenarios according to Gerrodette et al. (2011) who considered the number of vaquitas in 254 individuals. A deterministic model to describe vaquita population is defined as (Haddon, 2001):

$$P_t + 1 = P_t + rP_t(1 - \frac{P_t}{K}) - q_t f_t P_t \tag{2}$$

where for year t, P is vaquita population size, r is the per capita population growth rate, K is carrying capacity, q is catchability, and f is artisanal fishing effort in the Upper Gulf of California. Here we define catchability as the number of vaquitas incidentally caught per boat in artisanal fisheries in a given year and C = qfP is the total number of vaquitas caught in that year. Because of recent efforts to reduce vaquita incidental mortality during the first decade of 2000, we assume that these efforts have resulted in a proportional reduction in q starting in 2011. This model can thus be utilized to assess incidental mortality of vaquitas under different scenarios with respect to the number of active artisanal boats in a period of 15 years (2011-2025).

For simplicity reasons, demographic and environmental stochasticity and their impacts in the vaquita population dynamics are neglected in our model, although we are keenly aware of their potential effects. Due to chance events alone, demographic stochasticity at very low population numbers might drive populations of marine mammals such as vaquita to extinction (Burgman et al., 1993).

3. Results

3.1 Fisheries analysis

A total of 2,554 catch reports by artisanal fishers were compiled and analyzed for the three fishing communities of the Upper Gulf. Additionally, a total of 146 fishers were interviewed. Based on catch volume and beach economic value, six artisanal fisheries are the most important in the Upper Gulf: Shrimp Litopenaus stylirostris, curvina Cynoscion othonopterus, bigeye croaker Micropogonias megalops, Spanish mackerel Scomberomorus spp., rays (several species) and sharks (several species) (Table 1). Due to its high value, shrimp represents the largest gross income to artisanal fishers. The curvina is the second most economically important species for fishers of El Golfo de Santa Clara, bigeye croaker for fishers of San Felipe, and rays for those of Puerto Peñasco.

Species	Golfo de Santa Clara		Puerto Peñasco		San Felipe	
	Catch	Value	Catch	Value	Catch	Value
Shrimp	279	3’847,477	53	588,833	399	5’176,521
Curvina	1,552	806,283	43	23,843	677	376,272
Bigeye croaker	508	212,350	87	24,044	726	201,748
Spanish mackerel	888	870,345	58	54,029	95	76,769
Rays	106	91,677	121	89,713	244	180,988
Sharks	3	2,539	26	19,146	24	17,799

Table 1. Catch (Kg) and value ($US) of the main species in artisanal fisheries landed in the three ports of the Upper Gulf of California during 2007.

There are 2,100 small boats working in the Upper Gulf of California and, as discussed later in this work, fishers use different kinds of gillnets to fish for a variety of species. Table 2 shows the number of artisanal boats officially registered in each community. The number of artisanal boats is greater for El Golfo de Santa Clara, where artisanal fishing is virtually the only economic activity. Two types of fisheries concentrate the largest authorized fishing effort, shrimp with 606 artisanal boats and fishes (curvina, bigeye croaker, Spanish mackerel, sharks and rays), with 882 artisanal boats. The greatest number of authorized artisanal boats for both shrimp and fishes are registered in San Felipe and El Golfo de Santa Clara.

Species	San Felipe	El Golfo de Santa Clara	Puerto Peñasco
Clams	15	12	39
Jumbo squid			4
Shrimp	318	232	56
Snails	1		42
Fishes *	295	412	175
Swimming crab	11	39	229
Mullet	10	76	8
Octopus	2		40
Sharks	10	26	69
Total	662	797	662

Table 2. Authorized artisanal fishing vessels by group of species in the three ports of the Upper Gulf of California. Source: Federal government offices in the communities of the Upper Gulf of California. *Curvina, bigeye croaker, Spanish mackerel, rays.

Our survey data and GIS analysis showed that fishing is conducted within the Vaquita Refuge Area and in the Biosphere Reserve. Approximately 62% of the total catch in the Upper Gulf of California was caught in the marine protected areas. Approximately 77% of the marine area of the Biosphere Reserve and the entire Vaquita Refuge Area are used for fishing (Fig. 2). In the Vaquita Refuge, 97% of the total area is fished for shrimp, 94% is fished for corvine, 85% is fished for shark, 79% is fished for bigeye croaker and 69% is fished for Spanish mackerel. In the Biosphere Reserve, 56% of the total area is fished for shrimp, 55% is fished for corvine, 44% is fished for bigeye croaker, 39% is fished for shark and 30% is fished for Spanish mackerel.

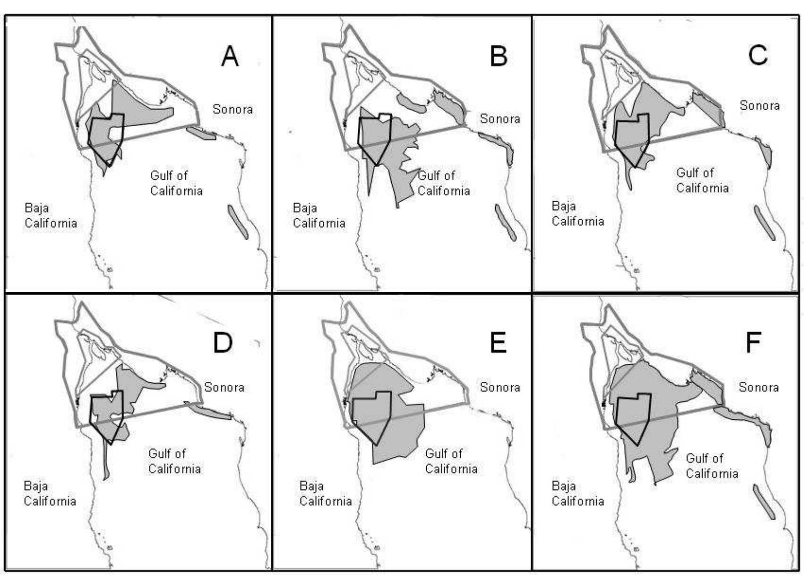

Fig. 2. Spatial distribution of artisanal fisheries as compared with the vaquita refuge declared in the Upper Gulf of California. A) bigeye croaker, B)sharks and rays , C) shrimp, D) Spanish mackerel, E) curvina, F) all fisheries.

Fishermen from Puerto Peñasco fish close to the Sonoran shoreline. 75% of the capture occurs inside the Biosphere Reserve and the fishermen fish in 20% of the northern area of the Vaquita Refuge. Fishermen from Golfo de Santa Clara carry out their fishing inside the marine protected areas and they fish in about half of the Vaquita Refuge Area. San Felipe fishermen fish near the Baja California shoreline in the UGC from the core zone to Puertecitos, which covers the entire Vaquita Refuge Area and 70% of the Biosphere Reserve (Fig. 3).

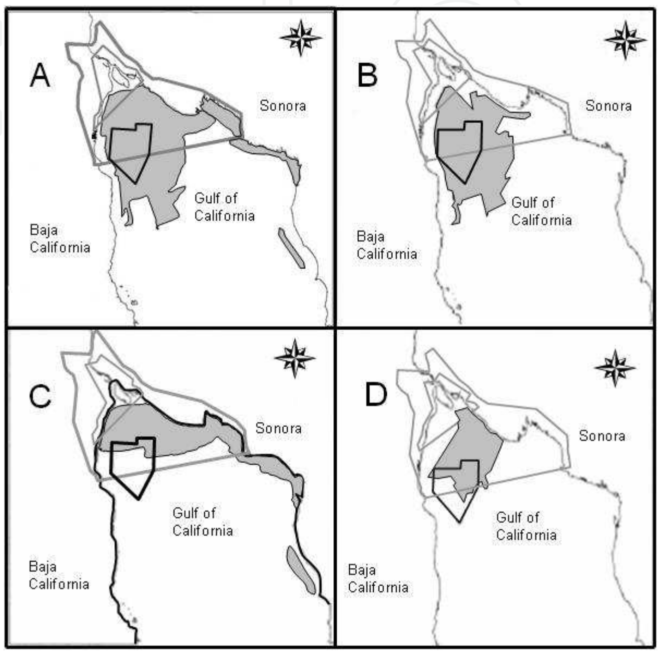

Fig. 3. Spatial distribution of the artisanal fisheries in the UGC by community. A) all communities; B) San Felipe; B) Puerto Peñasco; C) El Golfo de Santa Clara.

Within the Refuge, curvina represents the greatest annual catch with ~3,000 mt, followed by bigeye croaker with ~1,240 mt; other species amount to 2,192 mt (Table 3). In terms of economic value, shrimp represents 80% of ca. $US 1.7 million total gross incomes in the marine protected areas; sharks and rays represent the lowest gross income with only ~$US 385,000.

Indicator	Shrimp	Bigeye croaker	Curvina	Rays	Spanish mackerel	Sharks	Total
Catch (metric tons)	459	938	2,957	429	1,239	65	6,087
Value of catch *	4,791	528	2,765	357	1,812	66	10,319
Costs of catch *	3,073	165	489	29	131	9	3,897
Gross profit *	1,718	363	2,276	328	1,681	57	6,423
Return rate (%)	36	69	82	92	93	86	62

Table 3. Catch, first-hand value and operation costs by group of species in the artisanal fisheries of the Upper Gulf of California in 2007. Source: Local fishery offices in the communities. *US thousands of dollars.

Total annual catch in the marine protected areas from 1999 to 2007 were ~5,506 mt with a first-hand economic value of $US 8´563,000. The operation costs spent to obtain that total catch were $US 2´666,000 for a total gross income of $US 5´897,000, or a mean return rate of 68%. During that period we registered an increased fishing effort; gross profits provided high incomes. Therefore, estimated opportunity costs for artisanal fishers giving up their activities in the vaquita Refuge amount to ca. $US 1.7 million per year (Table 4).

	Catch	**Value of catch***	**Costs of catch***	**Gross profit***	**Return rate (%)**
1995	2,510	3,444	569	2,874	83
1996	2,354	2,323	1,185	1,138	49
1997	5,466	4,327	1,640	2,688	62
1998	6,450	9,451	1,945	7,505	79
1999	7,536	9,625	2,390	7,234	75
2000	6,786	9,907	2,726	7,181	72
2001	6,050	9,181	2,994	6,186	67
2002	7,492	12,882	3,131	9,750	76
2003	5,029	8,755	3,321	5,435	62
2004	5,407	8,082	3,493	4,589	57
2005	5,888	12,660	3,609	9,051	71
2006	4,525	10,356	3,755	6,601	64
2007	6,087	10,319	3,897	6,423	62
Average	5,506	8,563	2,666	5,897	68

Table 4. Catch (metric tons), first-hand value and operation cost by group of species in the artisanal fisheries of the Upper Gulf of California inside the vaquita refuge and the Biosphere Reserve from 1995 to 2007. Source: Local fishery offices in the communities.
*US thousands of dollars.

3.2 Social analysis

In our study, opinions of fishers can be interpreted as guidelines of a comprehensive strategy to achieve the purposes of the Reserve (Table 5). When asked what their activity would be if the most important fishery to them were closed, 56% of fishers responded that they would continue to fish anyway: 22% claim that they would fish on the same, and 34% other species. These responses were mostly responded by El Golfo de Santa Clara fishermen, who do not have enough employment alternatives as compared to Puerto Peñasco and San Felipe fishermen. A total of 23.8% expected an economic aid and 19.6% would ask for something else such as a credit for a new business or local employment (plumber, carpenter, construction, etc).

Option	Percentage	Frequency
Permit for another fishery	34.3	49
Economic compensation	16.1	23
Payment of permit cost	7.7	11
Continue fishing the same	22.4	32
Other	14.7	21
Nothing	4.9	7

Table 5. Response of fishers of the Upper Gulf of California to the question: If the most important fishery to you was closed, what would you ask in return?

When we posed the question: If you were asked to stop fishing, what would you do? A large number of them responded that they would switch to the tourism and trade sector (49%), 6% would like to work in aquaculture and maquilas, 25.2% in another fishery (clams, oysters, etc.) or the same, and the remaining 20.1% would seek employment in domestic duties (Table 6).

Option	Percentage	Frequency
Tourism	24.5	34
Trade	24.5	34
Work in a private sector	5.8	8
Other activity in fisheries	7.2	10
Would not stop fishing	18.0	25
Other	20.1	28

Table 6. Response of fishers of the Upper Gulf of California to the question: If you were asked to stop fishing, what would you do?

3.3 Vaquita recovery analysis

Our model was fitted to reported mean annual vaquita abundance, effort (number of artisanal boats), and incidental mortality (Fig. 4). For the four years where there is information on vaquita population size (P) and incidental catch (C), we estimated $q = C/(fN)$ and computed a weighted q (= 0.00011374) which was used for other years in the calculations. Using a fixed value for r (= 0.09531; Barlow, 1986) we fitted our model using least squares as criterion and found K = 4,640 vaquitas.

Our scenarios showed that it could take a large period of time for the vaquita population to recover to its 2010 size In scenario 1 (Fig. 4a) and according to response from fishermen (cf. table 6), starting in year 2011 we reduced the number of boats to 506, which is the quantity that would continue fishing and maintained constantly through year 2025. We observed that the number of vaquitas could recover in a relatively short time and could continue slow growth to over 349 individuals in 2025. In scenario 2 (Fig. 4b) we considered a 15% per year reduction of the artisanal fleet through year 2018 when the fleet reaches 506 boats and maintained it constant until year 2025. The model predicted a fast decrease in the vaquita population numbers until year 2015, stabilized thereafter and even showed a recovery of 6.3% per year through 2025 when the vaquita population reaches 242 individuals.

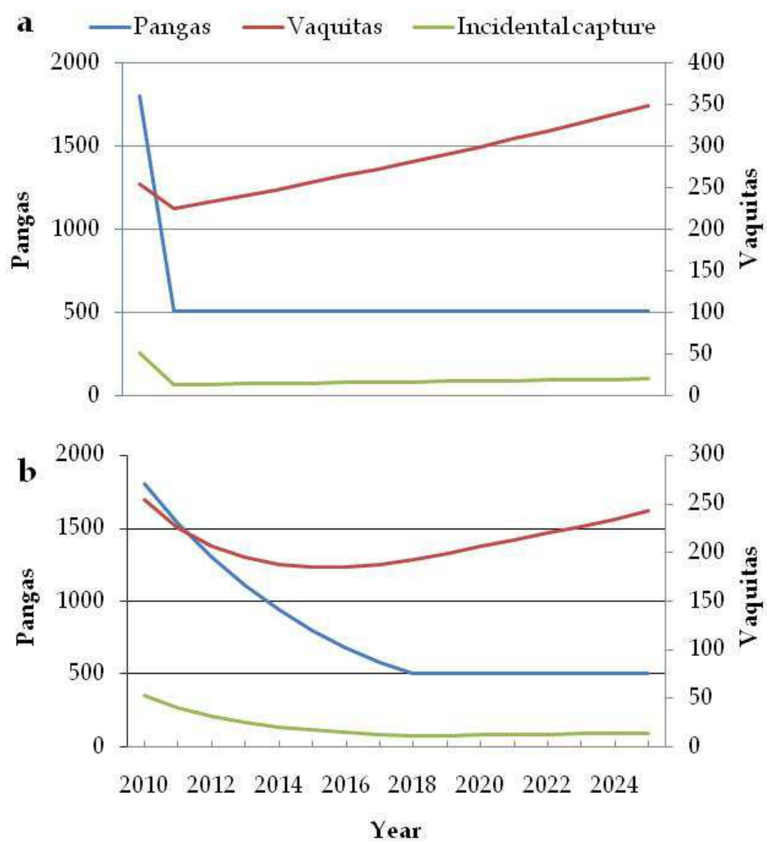

Fig. 4. Scenarios for vaquita recovery if artisanal boats are reduced in the Upper Gulf of California: a) 75% in year 2011; b) 15% yearly until 2018 and then maintained constant through year 2025.

Again, we caution that our model neglected consideration of potentially important ecological and biological aspects such as demographic and environmental stochasticity at low population numbers, as well as environmental forcing (Burgman et al., 1993). It has been well established that in theory an age-structured population will experience a sharp increase in extinction risk, even if growing geometrically, when subjected to stochastic shocks in its vital rates (Burgman et al., 1993; Caswell, 1989).

4. Discussion

Our study showed that both the Upper Gulf of California Biosphere Reserve and the recently declared vaquita Refuge are important grounds for artisanal fishing. Catch of shrimp, curvina and bigeye croaker have the largest distribution range in the Reserve and Polygon B of the Refuge. Shrimp generates the most important income for artisanal fishers. Our survey data indicates that 98% of artisanal fishers of El Golfo de Santa Clara and 100% of San Felipe fish on shrimp due to its high commercial value, gross revenues, and availability during the fishing season (September to January). This result is an important challenge to the fulfillment of goals of the Reserve and the vaquita Refuge, moreover because the number of registered artisanal boats is higher than recommended when the refuge was declared (DOF, 2005).

Operation costs determine to a great extent where fishing is conducted in the Upper Gulf of California and they depend mostly upon the distance of fishing sites to the ports and seasonal distribution of natural resources. San Felipe is the fishing port nearest to the recently declared Refuge; fishers residing in this port work in that vicinity throughout the year. Although El Golfo de Santa Clara holds the greatest number of registered permits and artisanal boats, fishers from this port do not fish near the Refuge because of high operation costs related to travel distance. Fishers of Puerto Peñasco fish near the sonoran coast to reduce operation coasts.

The high number of artisanal boats working in the Upper Gulf represents a clear threat to the vaquita (Rojas and Jaramillo 2001, Blanco 2002). The bulk of artisanal fisheries are done using gillnets to catch curvina (100%), shrimp (93%), Spanish mackerel (68%), bigeye croaker and rays (44%), and sharks (10%) (Vidal et al., 1994; D'Agrosa et al., 1995; Vidal, 1995). Gillnet mesh size varies from 5.7cm to 17.8cm; the highest vaquita mortality has been registered in gillnets with 11.43cm mesh size (Ortiz, 2002). These nets cover a great proportion of the water column where they are set and left for various hours (D'Agrosa et al., 1995). Length of these nets varies from 99 to 1,485 meters, the most common measuring between 594 and 990 meters with a mean height of 5.4 to 18 meters (Walsh et al., 2004). Because of the mesh size used, curvina and bigeye croaker fishing represent the biggest fishery-induced potential impact to the vaquita population (D'Agrosa et al., 2000; Rojas-Bracho et al., 2006).

To succeed, a strategy to protect vaquita from artisanal fishing should consider social aspects such as attachment of fishers to their activity. It is clear that 25% of the fishermen would not stop fishing because that is the only activity they feel comfortable with and have done for years. In that context, some fisheries must be assessed considering the species value and impact to the environment, and it would regulate fishing enforcement allowing a specific number of fishermen and fishing tools by species to fish within the Reserve and the vaquita Refuge.

The capture in the Biosphere Reserve and the Vaquita Refuge maintains a steady level of production with important economic incentives, which make it attractive to fishermen despite recent restrictions on their activity. However, the continued recruitment of new fishermen to the area will not enhance the welfare of the existing fishermen and there is no guarantee that the fishery will be sustained over the coming years (Ponce *et al*. 2006).

Our model results indicate that the vaquita population has never been too large (K < 5,000 individuals) and thus the importance of management actions to account for reductions of incidental kill in fishing activities, the only proven source of anthropogenic mortality. According to our scenarios, a fisheries management and vaquita conservation strategy can consider the reduction of the artisanal fleet by 15% every year until it reaches 506 boats in year 2018. Without compromising the vaquita population and the fishers in the region, this analysis could serve as a reference point to the buy-out program implemented since 2007, Parallel to this yearly reduction of the fleet, an integral strategy should incorporate a program to compensate and promote fishermen phase-out, including investments in equipment (sport fishing vessels with sustainable gears and refrigerated vehicles), infrastructure (storages, docks, freezers, added value of fishing products) and training in new activities. To support this program and according to table 4, ~\$US 6'423,000 should be invested in the initial years to finance fishing opportunity cost to prevent a massive return of fishermen to the activity in cases where the buy-out program fails in the short term. Jobs must be accompanied by education and long-term provision for new qualifications, because many of the fishermen do not have technical business skills or experience in tourism administration or other activities. Also needed is a periodic evaluation of criteria set out in all implemented actions to increase chances of the vaquita recovery (Aragón-Noriega et al., 2010).

Through implementation since 2007 of an integral vaquita recovery program 242 artisanal boats and 340 fishing permits have been bought-out; in addition, 190 permits have been converted to alternative fishing gears. Also, a shrimp farm was rebuilt and in agreement with artisanal fishers whom will exchange their gear and permit, this could represent an additional 150 to 180 fishing boats phased-out of the region (Rojas-Bracho et al. 2010).

5. Conclusion

Our contribution is significant because we now have more information about the habitat utilized by commercially important species. We have also collected and analyzed information that can be used to elucidate which kinds of fisheries represent more risk to endangered species. Not all fisheries are necessarily a threat to biodiversity. A better understanding of the fisheries can help determine which fisheries are the most important to consider when developing a conservation strategy (Rodriguez-Quiroz et al., 2010).

Conservation success of vaquita must be based on agreements which dignify inhabitants of the Upper Gulf. Governments of all levels and conservation organizations should promote development of the region. We must strive to improve the quality of life of fishers while recovering the endangered vaquita considering socio-economic, ecological and institutional factors. Our calculations can serve as basis of a gradual compensation scheme to reduce artisanal fishing in the vaquita refuge through a buy-out scheme in the long run.

Success of most fisheries management policies to conserve species is contingent upon vulnerability of the species, size of the protected area and viable, equitable economic alternatives to fishers. Contrary to this view and given the critical situation of the vaquita, clearly enforcement of the Refuge as a no-take zone by itself will not suffice to save vaquita from extinction.

Continuation of the recently implemented integral program that includes measures for sustainable fishing, economic alternatives, and buy-out of artisanal fishing units must be guaranteed. A constant monitoring of the program must be put in place in an adaptive manner so as to ensure efficiency of interventions.

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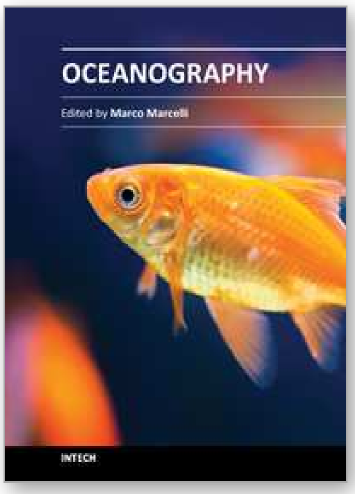

Oceanography
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How inappropriate to call this planet Earth when it is quite clearly Ocean (Arthur C. Clarke). Life has been originated in the oceans, human health and activities depend from the oceans and the world life is modulated by marine and oceanic processes. From the micro-scale, like coastal processes, to macro-scale, the oceans, the seas and the marine life, play the main role to maintain the earth equilibrium, both from a physical and a chemical point of view. Since ancient times, the world's oceans discovery has brought to humanity development and wealth of knowledge, the metaphors of Ulysses and Jason, represent the cultural growth gained through the explorations and discoveries. The modern oceanographic research represents one of the last frontier of the knowledge of our planet, it depends on the oceans exploration and so it is strictly connected to the development of new technologies. Furthermore, other scientific and social disciplines can provide many fundamental inputs to complete the description of the entire ocean ecosystem. Such multidisciplinary approach will lead us to understand the better way to preserve our "Blue Planet": the Earth.

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