The Gulf of California Sardine Complex: Challenges to Sustainability

Masters of Advanced Studies, Capstone Thesis

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Introduction

The Gulf of California is a UNESCO world heritage site recognized for its high biodiversity and endemism (Roberts et al. 2002). Is one of the most productive marine ecosystems in the world and produces approximately 50% of Mexico's total fishery catches. Among the different fisheries in Mexico, small pelagic fisheries constitute 25–40% of Mexico's total national landings, and the Gulf provides, on average, over 70% of these landings (Cisneros-Mata et al. 1996, Sanchez- Velasco et al. 2000). According to worldwide trends, approximately 85% of the total catch of small pelagic fisheries is used for reduction to fishmeal, and a small percentage is packed in cans for sale into domestic and international markets. For instance, in 2006, 20–30 million tons of fish or 36.2% of the total world fisheries catch was destined primarily for conversion to fishmeal to feed pigs, chickens, and farmed fish. Aquaculture farms are the largest consumers of fishmeal in Mexico (Alder & Pauly 2006 and Tacon & Metian 2009).

Although robust information about the Gulf of California Sardine Fishery (hereafter GCSF) remains limited, based on the results of this project, it appears likely that current practices are reflective of global trends.

The prime species of commercial value is the Pacific Sardine *(Sardinops sagax caerulea)* because of its larger proportion in the catch and higher preference by the fleet. Consequently, most of the total variability across sardine populations has resulted from changes in this species (Nevarez-Martinez 1990). It has been called the "sardine fishery", but in fact, is a "fishery complex" that involves the South American pilchard (*Sardinops sagax*), Leatherjacket (*Oligoplites saurus)* Pacific thread herring (*Opisthonema libertate*), Red-eye round herring (*Etrumeus teres*), Pacific anchoveta (*Cetengraulis mysticetus*), Californian anchovy (*Engraulis*

mordax), Chub mackerel (*Scomber japonicus*), among others, according to the National Fisheries Chart (*Carta Nacional Pesquera*)[1]

Historical Trends and Patterns in Mexico's Sardine Fishery

The sardine fishery moves south and north as fish populations migrate south throughout the winter and spring and northwards in late spring and summer. Most fishing takes place along the east side of the central Gulf when the Pacific sardines are spawning (Lluch-Belda and Schwartzlose 1986). Mexico's sardine fishery developed during the 1970s and reached its highest productivity during the 1988–89 seasons. Since then, the average catch has remained above 50% of the historic maximum (approximately 300,000 tons). At the beginning of the 1990s, however, a dramatic collapse occurred to less than 3% of the historic maximum in a time span of only two years. It subsequently experienced a fast recovery with catch reaching 97% of historic maximum in three seasons, and decreased again during the El Niño of 1997/1998. Since that time the sardine fishery has gradually increased to return to a near-historic maximum (Lluch-Cota et al. 2007).

In 2008, 815,520 metric tons of sardines were caught in the Gulf of California and in 2009 the fishery reached a catch record of 872,640 metric tons. In a worrying but not surprising sign of the increasing reliance on this fishery, from 2000-2010 the average landings of the sardine fishery have doubled the average the landings from 1990-2000 (Anuarios de Pesca. CONAPESCA 1990-2010).

Small pelagic fishes form the basis of many important coastal marine ecosystems. They are a fundamental food source for a variety of larger fish (many of them also of economic

[1] http://conapesca.sagarpa.gob.mx/wb/cona/actualizacion_de_la_carta_nacional_pesquera_2010

importance), marine mammals, and seabirds (Anderson and Gress 1984, Burger and Cooper 1984, Furness 1984, MacCall 1984, Furness and Barrett 1991, Furness and Nettleship 1991, Montevecchi and Berruti 1991, Velarde et al. 1994, Sanchez-Velasco et al. 2000). Fishing these species at conventional maximum sustainable yield levels (MSY) can have large impacts on other parts of the ecosystem, particularly when they constitute a high proportion of the biomass in the ecosystem or are highly connected in the food web (Smith et al. 2011).

Regulation and Certification: the Current Situation

According to Article 29 of the General Law of Fish and Sustainable Aquaculture ('Ley General de Pesca y Acuacultura Sustentables 2007', or Nueva Ley DOF 24-07-2007), Mexico's National Fisheries Institute (INAPESCA)[2] is responsable for guiding and coordinating all scientific and techonological research related with the Gulf of California Sardine Fishery under a Fishing and Aquaculture Management Plan[3]. Despite these regulations, the sardine fishery does not have yet a fishery management plan.[4] Consequently, it appears that neither the Official Mexican Norm (NOM 003-PESC-1993) nor the annual programs are being implemented, with serious implications for the monitoring and administration of the GCSF.

Notwithstanding the vast number of important publications about GCSF, there is no robust stock assessment for identifying regional resource trends. However, some studies have demonstrated that the fishery has collapsed over the last thirty years (Velarde et al. 2004), suggesting increasingly unsustainable fishing practices around the GCSF. Additionally, certain

[2] INAPESCA: Instituto Nacional de Pesca
http://www.inapesca.gob.mx/portal/documentos/publicaciones/4ForoIXTallerPelagicosMenores4.pdf
[3] Refer to Art.39 of 'Ley General de Pesca y Acuacultura Sustentables' for information regarding fishing and acuaculture management plan conditions.
[4] http://www.conapesca.sagarpa.gob.mx/wb/cona/02_de_mayo_de_2011_mazatlan_sin Accessed December 13, 2011.

fish industry at the Gulf of California receives generous federal subsidies for fish processing and port facilities (Young 2001). This imposes large economic costs for coastal economies and produces larger environmental problems for marine ecosystems. For instance, many fisheries around the world have collapsed due to widespread failure to manage marine capture fisheries effectively. Many causes have been cited for the collapse of fisheries including the Californian, South African, Moroccan, and Mediterranean sardines, and Peruvian anchovies. The majority of these causes reflect the dominance of biological advice with a corresponding paucity of sociological and economic information (Stephenson and Lane, 1995), to assessment errors (Walters and Maguire, 1996), or to the immense uncertainty inherent in current fisheries assessment and management (Ludwig et al., 1993; Hilborn, 1997).

Even with the acknowledgement of fishery management limitations and scientific evidence of preceding collapses, in July 2011 the Marine Stewardship Council[5], a non-governmental organization, certified the GCSF as 'sustainable'. This certification was given with a significant amount of uncertainty, not only in the level of the fish stocks, but also in the evaluation per se. According to MSC's scoring methodology (performance indicators (PI) and scoring guideposts (SG), a fishery can be certified after achieving a score of 80 in each of three MSC Principles (presented below).

Similar cases of previous fisheries certified by MSC are gaining the opposition not only from conservation groups as Greenpeace, the Pew Environment Group, and some national branches of the WWF, but also from highly respected scientist from University of British Columbia Fisheries Centre and from the Scripps Institution of Oceanography, who openly questioned MSC practices in a paper in Nature in 2010 'Sea Food Stewardship in Crisis'

[5] MSC: Marine Stewardship Council (*www.msc.org)*

(Jacquet et al. 2010) in pointing out that *"the main consumer-targeted certification (MSC) is failing to protect the environment and needs radical reform"*.

As mentioned before, 70% of the GCSF catch is destined for fishmeal. Unfortunately, the MSC evaluation process does not take into account the end-use of a product. Jacquet et al (2010) suggest that the GCSF should not have been certified based on current market demand: *" We propose that any fishery undertaken for fishmeal should not be viewed as responsible or sustainable, and should not qualify for MSC certification"*. One of the alternatives exposed in this paper that could compensate the currently uneven situation that provides market advantages to big companies is to offer the MSC certification to cooperatives of small producers and to exclude large-scale producers from being certified (Jacquet et al. 2010)

Project Overview

This study examined Gulf of California Sardine Fishery as a case study for the sustainability of the Mexico's largest fishery by volume. The main objective of my research is to understand ecological and social-cultural issues related to the GCSF.

The project is based on the assumption that the GCSF should be properly managed to avoid ecological and socioeconomic crises (Brusca 2010).

MATERIALS AND METHODS

Study Site

I focused my research on the Midriff Island region of the central Gulf of California, where 99% of GCSF total landings are reported (CONAPESCA 2010). The Midriff islands are a highly variable ecosystem, located between 28^0 and 29^0 45'N and 112^0 and 114^0 W, and includes the coasts of Lower California and Sonora and 39 islands and islets (Case et al. 2002).

The Midriff Islands have a significant history of human-environmental interactions. Recent efforts for protecting the biodiversity of the midriff islands resulted in the creation of two primarily marine Federal Protected Areas: San Lorenzo Marine Archipelago National Park and Bahía de los Angeles, Canal de Ballenas y Salsipuedes Biosphere Reserve (Decreed on 2005 and 2007 respectively. CONANP)[6].

For this project I focused research within two fishing communities from the midriff islands: the permanently settled town of Bahia de Los Angeles and a temporary fishing camp at Las Animas Bay.

Figure 1: Field sites. Bahia de Los Angeles (BLA) and Las Animas, Baja California Norte, Mexico.

Artisanal Fishers GCSF Perspective

In order to capture local fishermen's perspectives about the Sustainability of the GCSF, I designed a questionnaire that consisted of sixteen open and closed types of questions (Appendix I). The questionnaire was strategically designed to capture important information regarding the sustainability of GCSF that was not considered in CONAPESCA databases or in the MSC certification criteria.

Interviews were conducted with fishermen from Bahia de Los Angeles and Las Animas area (n=21, 80% of the interviews were in Bahia de Los Angeles and 20% in Las Animas Bay).

[6] www.conanp.gob.mx

Fishermen were formally interviewed over a seven-day timeframe, in addition to informal talks with family members, apprentice fishermen, community representatives, and local officials. Interviews ranged between 30 to 45 minutes, occurred face to face, and were conducted in Spanish. Fishers were randomly interviewed at shore, while fishing on their 'pangas', and at their homes once the fishing activity was over in the afternoon, typically after 5pm.

A Baja North map as well as marine animals booklets were provided to all participants in order to facilitate the interview. Additionally, a digital voice recorder was used with those participants that agreed to be recorded. Each fisherman was informed that participation in the study was voluntary and that names were kept confidential as requested.

CONAPESCA Capture Data

I analyzed the reported sardine landings databases from 1990-2010 from 'Anuarios de Pesca' or the Fishery Yearbooks from CONAPESCA. The yearbooks are organized by principal species and also by entity. The landings database by species is divided by destination: direct human consumption or Industrial (or non-human consumption).

Furthermore I used Geographic Information Systems (GIS) mapping software to analyze the intensity of the landings per entity from 1991-1999.

For the purposes of this analysis – to identify trends – I captured the landings of sardines over the last twenty years (1990-2010) as well as the economic value. The values of the principal fisheries are reported in Mexican pesos and are also allocated by destination.

Landings-ENSO fusion

A strong correlation is has been shown between small pelagic fishes abundance and El Niño/La Niña-Southern Oscillation, or ENSO (Schwartzlose et al. 1999, Sanchez-Velasco et al. 2000 and Velarde et al.2004). In order to analyze this phenomenon in the GCSF in the last 20

years, I used the reported sardine landings databases from 1990-2010 from CONAPESCA and the Monthly Multivariate ENSO Index (MEI).

MSC Certification

I analyzed Scientific Certification Systems (SCS) electronic report version 5 'MSC Public Certification Report Pacific Sardine Fishery, Gulf of California, Mexico'. Scientific Certification Systems is reported to be *"an accredited MSC certification body, and in direct accordance with MSC requirements"* [7] used for making assessments on the sustainability of different fisheries. The data derived from the certification is unclear and incomplete. For instance, a lack of information regarding specific sardine populations, their role in the ecosystem, and their natural variability are important data missing in these evaluations. Additionally, the evaluation and certification of the fishery assumes that the sardine catch of a previous year would not affect catch levels into the future.

RESULTS

Artisanal Fishers GCSF Perspective

The youngest fisherman interviewed was 21 years old and the oldest was 74, with an average age of 46 years. The majority of the fishers learned their trade from their fathers and grandfathers as well as from local fishers. More than half of fishers have been fishing for more than 20 years; some of them have been fishing for over 40 years. Fishers target different species depending on the season. During the interviews the majority of fishermen were catching octopus by using pot traps or cages in small boats known locally as pangas in the Bay of Los Angles and outlying islands. None of them self-identify as a member of a particular ethnic or social group (i.e. Seri, Yaqui, Quiche, etc.).

[7] www.SCScertified.com

Half of the fishermen were members of fishing cooperatives. The benefits that fishers mentioned for being in a cooperative were: obtaining fishing permits and acquiring loans to buy equipment (i.e. a loan for buying a new motor or fishing net). Fishers reported an increase in the number of fleets and a decrease in the numbers of fish in recent years than previously when they became fishermen. One fisherman spoke of a time during his childhood when he used a shovel to pick up all the fish that had accumulated on shore due to the great abundance of the Gulf of California. *'Nowadays the Gulf of California is still vast; when one species is scarce we can fish another different, nevertheless we know the resources are finite and we need to adopt more sustainable fishing practices'.*

Fishers were asked if when they go fishing they identify sardine vessels fishing and where. 55% of fishers answered Las Animas, 28% San Rafael and 17% Salsipuedes.

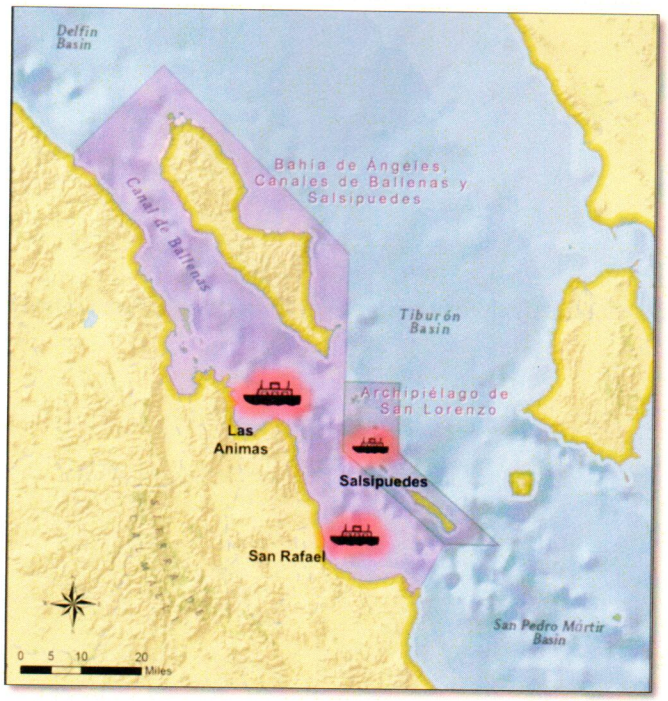


Figure 2: Fishing Sites. Sites where sardine vessels fish according to the fishermen interviewed.

Fishers were asked if the Sardine fishery affects their fishing in a positive or in a non-positive way and how. The majority answered that Sardine vessels not only break their nets but also overfish the sardines, causing the decrease of other fish of commercial value such as sharks, flounder and jack.

Fishers were asked if they identify any other animal different than sardines in the sardine vessels fishing nets. The results are presented in Figure 3.

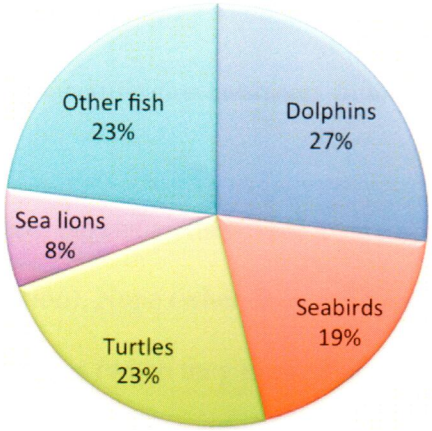


Figure 3: Bycatch. Incidental catch identified in the sardine vessels fishing nets by the fishermen interviewed

Artisanal Fishers GCSF awareness regarding the MSC certification

Fishers were asked if they know that the GCSF was certified as sustainable

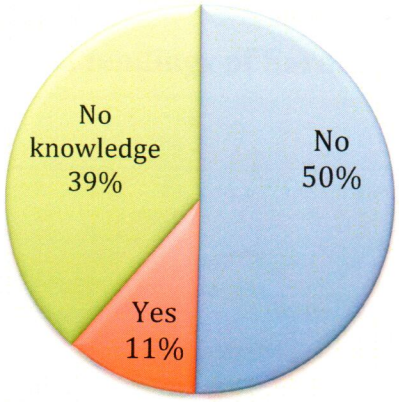


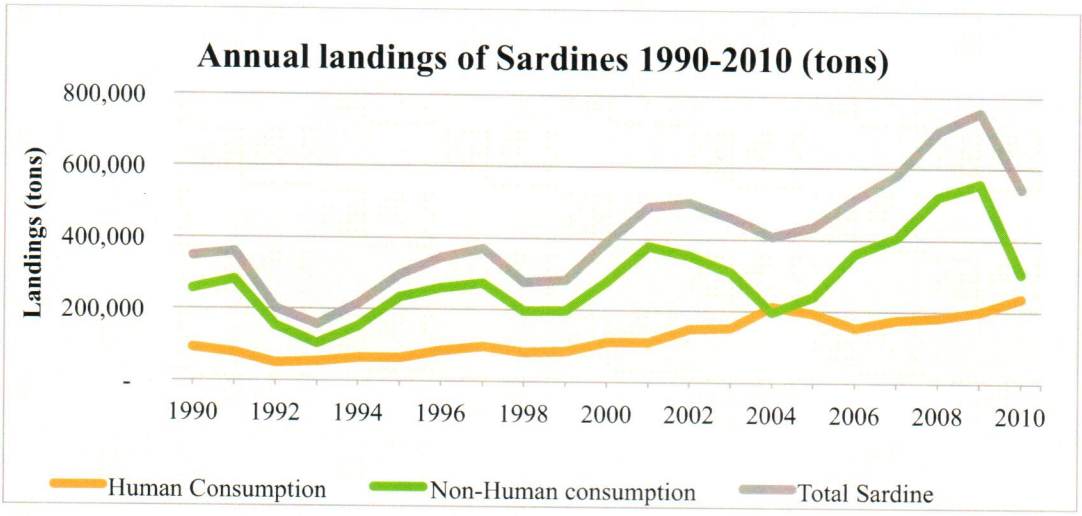
Figure 4: GCSF certification awareness within fishermen interviewed

Fisherman responded: No (when they were aware about MSC certifications, but didn't know about GCSF certification), None (when they were not aware about MSC certifications, nor the GCSF certification), and Yes (when they know that SCF was certified as sustainable).

CONAPESCA Capture Data

In average in the last 20 years, 70% of the GCSF landings destination is for Non-Human Consumption and only 30% is for Human Consumption.

a)



b)

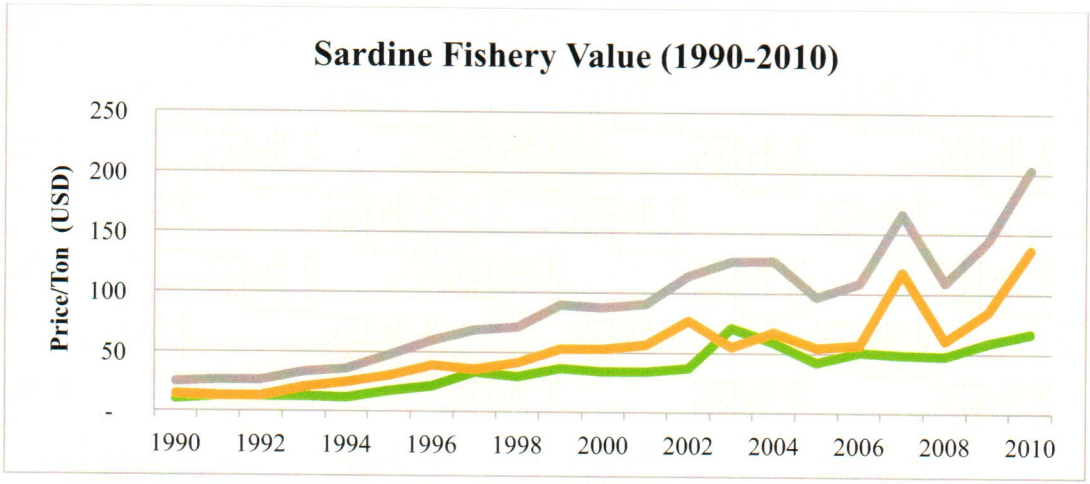


Figure 5: a) Annual landings and b) Value of Sardine Fishery 1990-2010 (tons)

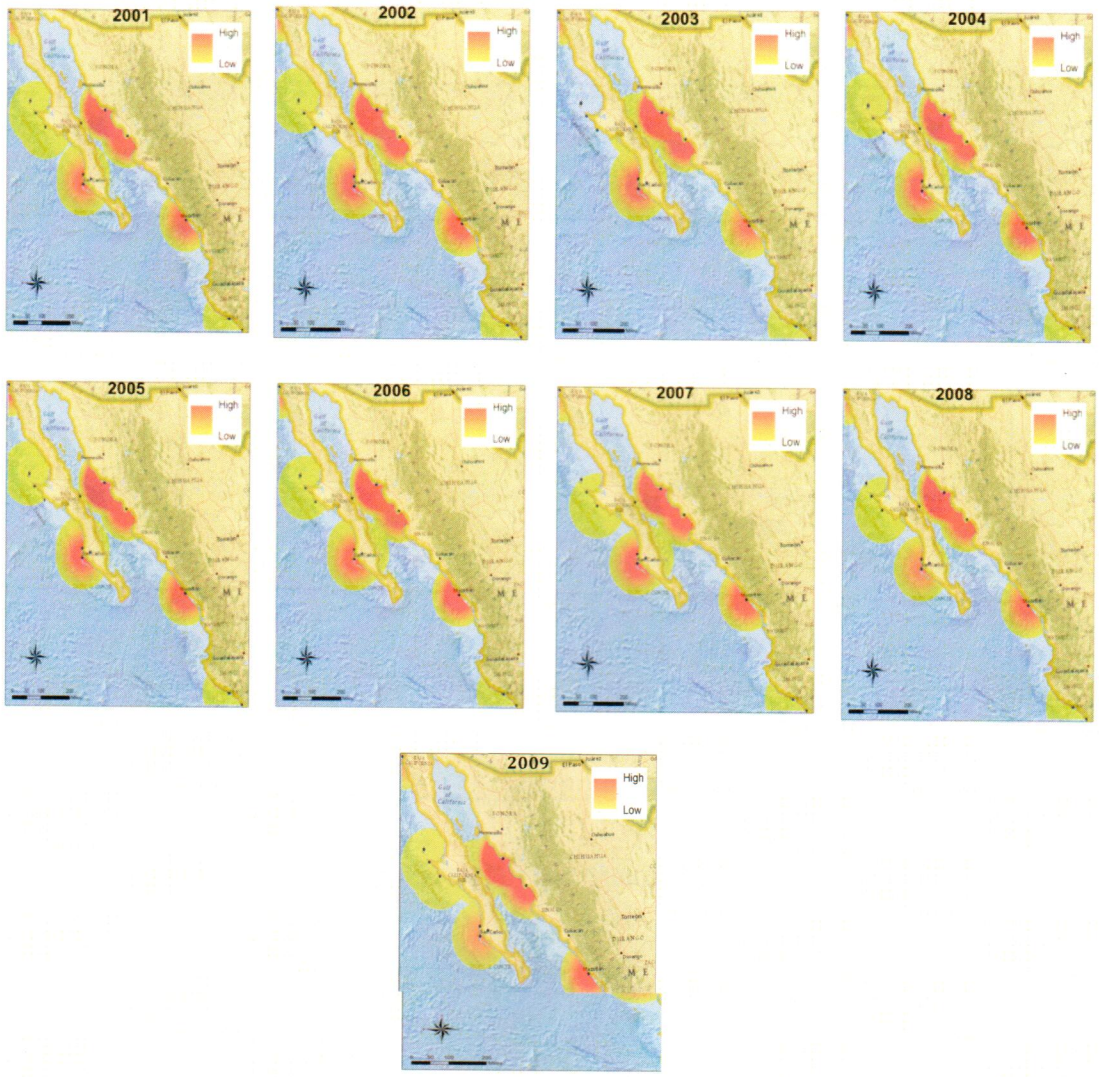


Figure 6: Intensity of Sardine fishery total landings. CONAPESCA 2001-2009

Landings-ENSO fusion

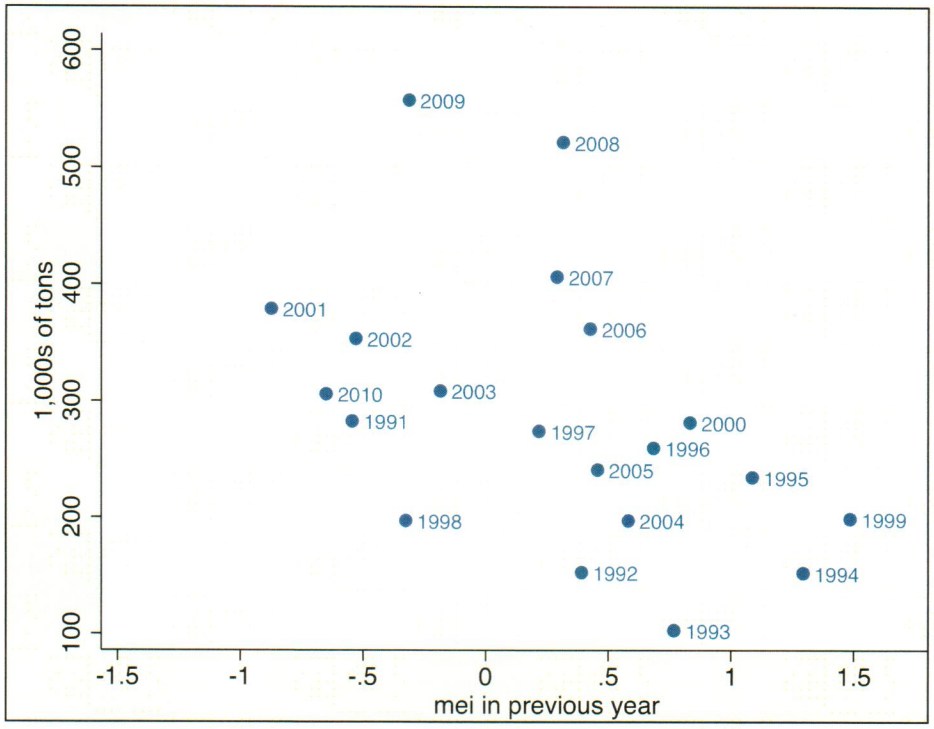


Figure 7: Sardine landings 1990-2010 and Monthly Multivariate ENSO Index (MEI)

MSC Certification

A quarter (9) of the 31 PI's scored below the standard: (a) Assessment of the stock status, (b) Retained species outcome, (c) Retained species Management, (d) Bycatch Management, (e) Bycatch Information, (f) Endangered, Threatened and Protected species outcome (g) Trophic Function Management, (h) Fishery specific objectives, (i) Fishery research plan. More over 70% of the PI's previously mentioned belongs to MSC Principle 2: Ecosystem (figure 8).

Principle	Wt (L1)	Component	Wt (L2)	PI No.	Performance Indicator (PI)	Wt (L3)	Weight in Principle	Score	Principle Score
One	1	Outcome	0.5	1.1.1	Stock status	0.5	0.25	90	23.75
				1.1.2	Reference points	0.5	0.25	85	21.25
				1.1.3	Stock rebuilding				0.00
		Management	0.5	1.2.1	Harvest strategy	0.25	0.125	80	10.00
				1.2.2	Harvest control rules & tools	0.25	0.125	80	10.00
				1.2.3	Information & monitoring	0.25	0.125	90	11.25
				1.2.4	Assessment of stock status	0.25	0.125	75	9.38
Two	1	Retained species	0.2	2.1.1	Outcome	0.333	0.0667	75	5.67
				2.1.2	Management	0.333	0.0667	70	5.67
				2.1.3	Information	0.333	0.0667	90	6.00
		Bycatch	0.2	2.2.1	Outcome	0.333	0.0667	80	5.33
				2.2.2	Management	0.333	0.0667	70	4.67
				2.2.3	Information	0.333	0.0667	70	4.67
		ETP species *	0.2	2.3.1	Outcome	0.333	0.0667	75	5.33
				2.3.2	Management	0.333	0.0667	80	5.33
				2.3.3	Information	0.333	0.0667	80	5.67
		Habitats	0.2	2.4.1	Outcome	0.333	0.0667	95	6.33
				2.4.2	Management	0.333	0.0667	95	6.33
				2.4.3	Information	0.333	0.0667	95	6.33
		Trophic function	0.2	2.5.1	Outcome	0.333	0.0667	80	5.33
				2.5.2	Management	0.333	0.0667	75	5.00
				2.5.3	Information	0.333	0.0667	[illegible]	5.67
Three	1	Governance and policy	0.5	3.1.1	Legal & customary framework	0.25	0.125	95	11.88
				3.1.2	Consultation, roles & responsibilities	0.25	0.125	85	11.25
				3.1.3	Long term objectives	0.25	0.125	100	12.50
				3.1.4	Incentives for sustainable fishing	0.25	0.125	85	10.63
		Fishery specific management system	0.5	3.2.1	Fishery specific objectives	0.2	0.1	75	7.50
				3.2.2	Decision making processes	0.2	0.1	85	8.50
				3.2.3	Compliance & enforcement	0.2	0.1	80	8.00
				3.2.4	Research plan	0.2	0.1	70	7.00
				3.2.5	Management performance evaluation	0.2	0.1	85	8.50

Overall weighted Principle-level scores	Principle Score
Principle 1 - Target species	84.4
Principle 2 - Ecosystem	81.0
Principle 3 - Management	85.1

*Endangered, Threatened and Protected (ETP)species.

Figure 8: Performance Indicator and Principal Scores. Adapted from Scientific Certification Systems (SCS) electronic report version 5

DISCUSSION

Artisanal Fishers GCSF Perspective

Bahia de Los Angeles is a fishing town that relies on the productivity of the Gulf of California. Most of the Fishermen started fishing at early age, they learned fishing techniques from their parents. Based on my fieldwork, it seems to me that there exists a gap between generations of different fishermen.

In other words, there were not many young fishermen that will follow the fishing traditions. Perhaps this is due to the evident lack of law enforcement, the decreased availability of fish in the ocean and decreased tourism in the area, which has forced young men to move to different cities to find work or to seek a better life. On the other hand, many of the people I spoke to were proud of their heritage as fishermen and remained close to family and extended family networks throughout Bahia de Los Angeles and to other towns across Mexico. Everyone in town knew everyone else and fishermen appeared to care about others' welfare, even among rival cooperatives. At the same time, many homes visited in Bahia de Los Angeles did not have electricity, and many of the town's population appeared materially impoverished.

Evidence that sardine vessels are fishing inside the Federal Protected Areas demonstrates a lack of marine governance and law enforcement over industrial fishing operations in the Gulf of California. According to the fishermen interviewed, sardine vessels are catching other species including marine mammals, sea birds, sea turtles, and other kinds of fish (i.e flounder and jack) as bycatch or tangled in nets. The impact of the sardine fishery on the Midriff Islands' ecosystem is likely significant to a degree unrecognized in available scientific literature and among fisheries management organizations in North America.

In July 2011, the Gulf of California Sardine fishery was certified as sustainable without any consideration or input from local fishermen, who are the most vulnerable community to current industrial sardine fishery practices. According to interviews with artisanal fishermen, the sardine fishery is not sufficiently regulated. Sardine fishing vessels regularly enter Federal Protected Areas and are fish other species of fish, causing a correspondingly negative effect on landings of other species, as well as reducing a major food source for targeted species.

CONAPESCA Capture Data

There are important restraints on CONAPESCA databases. For instance, stock size or biomass assessment, fishing sites, financial support per fishery, permits per fishery, bycatch of the fishery, international or local fishery certifications (i.e. MSC) information is missing. This is puzzling and unfortunate. CONAPESCA yearbooks should be reported annually, yet delays prevent information from reported in an adequately regular manner (i.e. 2011 CONAPESCA yearbook is missing on the CONAPESCA website). Moreover, the transparency of the information is restrained from March 30th trough July 1st due to an 'Electoral ban':

> *Lo sentimos, el contenido de esta sección no puede ser mostrado de momento, en cumplimiento a la veda electoral dispuesta por el Instituto Federal Electoral (IFE), por el periodo del 30 de marzo al 1° de julio del 2012/ We are sorry, the content of this section cannot be shown according to the electoral ban disposed by the Institute of Federal Election from the period of March 30th trough July 1st*

Unexplained data gaps and unreasonable restrictions to accessing fisheries information prevents a fuller account of the current status of Mexico's industrial fisheries, and feeds suspicion that there is something to hide. More accessible Annual Reports will be of great value to a more accurate assessment of current commercial fishing trends.

Landings-ENSO fusion

Significant fluctuations in the catch of sardines have been reported since the beginning of the fishery not only by scientists but also by CONAPESCA annual reports. The effect of water temperature has been reported to have effects on sardine abundance, when for instance sardines biomass decreased during El Niño phenomenon in 1997-1998 (Lluch-Cota et al. 2007 and

Velarde et al.2004). In Figure 7 above, we can see the relationship between sardine landings (which may closely reflect the sardine biomass) fluctuations with El Niño/La Niña-Southern Oscillations. Is important to consider this information from a fisheries management perspective. Establishing fishing quotas or other fisheries management alternatives are moderately challenging in a source like sardines that fluctuate drastically over the time. If Article 29 of the 'Ley General de Pesca y Acuacultura Sustentables 2007' (Nueva Ley DOF 24-07-2007), as well as NOM 003-PESC-1993 are implemented, a fishery management for the Gulf of California Sardine fishery should consider El Niño/La Niña-Southern Oscillations in the eventual plan.

MSC Certification

The certification of the most important fishery in volume for Mexico took place without having a fishery management plan and without considering the possible impacts of the local communities of the Gulf of California. None of the fisherman interviewed were involved in the certification process, and 80% didn't know that the sardine fishery was certified as sustainable, which reflects the lack of transparency of the decisions that have been taken on one of the most important resources for Mexico. Furthermore, the certification report has a lack of transparency. For instance, in the principle of Ecosystem in the component of Bycatch, it is neither clear what kind of Bycatch was detected on the sardine fishery nor the amount of Bycatch collected by the fishery. According to MSC certification 'rules', a fishery that obtains a certification must design a plan to mitigate those performance indicators where the fishery failed. In the case of the sardine fishery the information regarding the plan are unclear in time and in its structure and financing.

The Gulf of California Sardine is not the only fishery that has been certified by MSC without accomplishing important sustainable goals. Consequently, a number of recognized

scientists have challenged MSC. In one case, a researcher pointed out that the main consumer-targeted certification or MSC is failing to protect the environment and needs radical reform. As previously mentioned, over the last 20 years, 70% of the total catch of sardines has been used for non-human consumption, through being converted to fishmeal. Unfortunately, MSC does not take into consideration the end-use of a product. From my perspective and others (see "Sea Food Stewardship in Crisis' in Nature, Jacquet et al. 2010), a fishery whose catch is converted into fishmeal cannot be considered sustainable and should not qualify for MSC certification.

CONCLUSIONS and RECOMENDATIONS

In a world where one in seven billion people is in hunger (FAO 2010), we should explore better and sustainable practices than converting an excellent source of protein and vitamins provided by fish such as sardines into a non-human consumption powder or fishmeal. Paradoxically the Marine Stewardship Council does not consider the end-use of a product in any of its certification principles. This begs the question: what is the value of a certification scheme that does not effectively define or consider sustainability?

Not only did MSC certify the GCSF as sustainable without considering the end-use of Gulf of California Sardines, but also without an accurate assessment of the stock status and a fishery management plan implementation. Sardines do not always live in isolation; therefore identifying and understanding other clupeoids that are part of the school (Whitehead P.J.P. 1985) is essential when designing a fishery management plan for the GCSF.

"Where knowledge is insufficient, robust and precautionary fishery management measures that favor the ecosystem should be adopted" (Pikitch. et al 2004).

Given that Sardines are an important forage fish for larger forms of marine life, and given that ordinary fisheries management plans focus on maximizing the catch of a single target species without considering habitat, predators, and prey of the target species and the ecosystem components, I will suggest an ecosystem-based fishery management approach, which: a) Avoids the degradation of ecosystems; b) Accounts for the requirements of other ecosystem components (i.e nontarget species, protected species, habitat considerations, and trophic interactions); c) Obtains and maintains long-term socioeconomic benefits without compromising the ecosystem and; d) Generates knowledge of ecosystem processes sufficient to understand the likely consequences of human actions (Pikitch. et al 2004).

CONANP reserves are presently situated in the Midriff islands: the San Lorenzo Marine Archipelago National Park and the Bahía de Los Angeles, Canal de Ballenas and Salsipuedes Biosphere Reserve. These important reserves protect a diverse marine population including many endangered species including whale sharks, fin whales, California sea lions and five species of sea turtles. Nevertheless from my perspective the investment and efforts of protecting this species will fail if sardines – their 'food' or 'forage fish' – are not protected.

Enriqueta Velarde and Exequiel Ezcurra have identified a strong correlation between sardine abundance and the reproductive success of seabirds such as Heermann's Gulls and the springtime sea surface temperature anomaly in the Gulf region. Their research has contributed to the sustainable management of GCSF by developing two statistical models that use oceanographic conditions and seabird breeding and feeding data to predict total fishery catch and catch per unit effort (CPUE) of Pacific sardine in the central Gulf. Unfortunately the models are not currently being implemented by the GCSF (Velarde et al 2004).

Nowadays, the lack of accurate biomass estimation for Pacific Sardine (as well as the 'Sardine Complex') and the deficient transparency of the information of GCSF, contribute to a prevailing 'cloud of uncertainty'. An improved design and implementation of an ecosystem-based fishery management plan as well as an awareness campaign are vital efforts for protecting the unique ecology of the Gulf of Mexico and for mitigating a catastrophic consummation of one of the most important resources for Mexico.

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REFERENCES

1. Alder, J., and D. Pauly. 2006. On the multiple uses of forage fish. Research report 14. Fisheries Centre, the University of British Columbia, Vancouver. Available from http://www.fisheries.ubc.ca/publications/reports/report14_3.php.
2. Anderson, D. W., and F. Gress. 1984. Brown pelicans and the anchovy fishery off southern California. Pp. 128-135 *In* Marine birds: their feeding ecology and commercial fisheries relationships (D. N. Nettleship, G. A. Sanger, and P. F. Springer, eds.). Canadian Wildlife Service Special Publication (Canada Minister of Supply and Services, Cat. No. CW66-65/1984).
3. Brusca, R. C. (ed.). 2010. *The Gulf of California: Biodiversity and Conservation*. ASDM Studies in Natural History. Arizona-Sonora Desert Museum Press & University of Arizona Press. 336 pp.
4. Burger, A. E., and Cooper, J. 1984. The effects of fisheries on seabirds in South Africa and Namibia. In Marine Birds:Their Feeding Ecology and Commercial Fisheries Relationships, pp. 150–160. Ed. by D. N. Nettleship, G. A. Sanger, and P. F. Springer. Special Publication Canadian Wildlife Service, Ottawa.
5. Case, T. J., M.L Cody, and E. Ezcurra (eds.). 2002. A New Island Biography of the Sea of Cortes. Oxford University Press, New york.
6. Cisneros-Mata, M. A., G. Montemayor-Lopez, and M. O. Nevarez-Martinez. 1996. Modeling deterministic effects of age structure, density dependence, environmental forcing and fishing in the population dynamics of the Pacific sar- dine (*Sardinops sagax caeruleus*) stock of the Gulf of California. California Cooperative Oceanic Fisheries Investigation Report **37**:201–208.
7. Furness, R. W. (1984). The birds of Foula. Brathay Trust, Ambleside.
8. Furness, R. W., and D. N. Nettleship. 1991. Seabirds as mon- itors of changing marine environments. Acta XX Congresus Internationalis Ornithologici **4**:2239–2240.
9. Furness, R. W., and R. T. BARRETT. 1991. Seabirds and fish declines. Natl. Geogr. Res. Explor. 7:82- 95.
10. Hilborn, R. (1997) Uncertainty, risk and the precautionary principle. In Pikitch, E.K., Huppert, D.D.and Sissenwine, M.P., eds. Global Trends: Fisheries Management (Proceedings of the Symposium held at Seattle, Washington, 14±16 June, 1994). Am. Fish. Soc. Symp. 20, 100±106.
11. Jacquet, J., Pauly, D. and Ainley, D. et al. (2010) Seafood stewardship in crisis. Nature 467, 28–29.
12. Lluch-Belda, D., B. F. J. Magallon, and R. A. Schartzlose. 1986. Large fluctuations in sardine fishery in the Gulf of California: possible causes. California Cooperative Oceanic Fisheries Investigation Report **37**:201–208.
13. Lluch-Cota, S. E., Aragón-Noriega, E. A., Arreguín-Sánchez, F., Aurioles-Gamboa, D., Jesús Bautista-Romero, J., Brusca, R. C., Cervantes-Duarte, R., et al. (2007). The Gulf of California: Review of ecosystem status and sustainability challenges. *Progress In Oceanography*, *73*(1), 1–

26.
14. Ludwig, D.E., Hilborn, R. and Walters, C. (1993) Uncertainty, resource exploitation and conservation: lessons from history. Science 260, 17, 36.
15. McCall, A. D. 1984. Seabird-fishery trophic interactions in eastern Pacific boundary currents: California and Peru. Pp. 136-148 In: Marine Birds: Their Feeding Ecology and Commercial Fisheries Relationships. (D. N. Nettleship, G. A. Springer, and P. I. Springer, Eds.). Ottawa, Canada: Canadian Wildlife Service.
16. Montevecchi, W. A., and A. Berruti. 1991. Avian indication of pelagic fishery conditions in the Southeast and North- west Atlantic. Acta XX Congresus Internationalis Ornithologici **4**:2246–2256.
17. Nevárez-Martínez, M.O, R. Morales-Azpeitia, M. Martínez-Zavala, M. de los Angeles-Martínez-Zavala., Santos-Molina J.P. y M.A. Cisneros-Mata. 1993a. Pesquería de pelágicos menores en el golfo de California. Temporada 1990/91. SEPESCA, Instituto Nacional de la Pesca, Centro Regional de Investigación Pesquera (Guaymas, Sonora, México).
18. Norma Oficial Mexicana (NOM) 003-PESC-1993.
19. Nueva Ley DOF 24-07-2007. Ley General de Pesca y Acuacultura Sustentables 2007.
20. Pikitch, E. K.; Santora, C.; Babcock, E. A.; Bakun, A.; Bonfil, R.; Conover, D. O.; Dayton, P.; Doukakis, P.; Fluharty, D.; Heneman, B.; Houde, E. D.; Link, J.; Livingston, P. A.; Mangel, M.; McAllister, M. K.; Pope, J.; Sainsbury, K. J., 2004: Ecosystem-based fishery management. Science 305, 346–347.
21. Roberts, C. M. et al. Marine biodiversity hotspots and conservation priorities for tropical reefs. Science 295, 1280–1284 (2002).
22. Sanchez-Velasco, L., Shirasago, B., Cisneros-Mata, M.A. and Avalos-Garcia, C. (2000) Spatial distribution of small pelagic fish larvae in the Gulf of California and its relation to the El Niño 1997–1998. J. Plankton Res. 22:1611–1618.
23. Schwartzlose, R. A., Alheit, J., Bakun, A., Baumgartner, T. R., Cloete, R., Crawford, R. J. M., Fletcher, W. J., Green-Ruiz, Y., Hagen, E., Kawasaki, T., Lluch-Belda, D., Lluch-Cota, S. E., MacCall, A. D., Matsuura, Y., Nevarez-Martinez, M. O., Parrish, R. H., Roy, C., Serra, R., Shust, K. V., Ward, M. N., and Zuzunaga, J. Z. 1999. Worldwide large-scale fluctuations of sardine and anchovy populations. South African Journal of Marine Science 21: 289–347.
24. Smith D. M., C. J. Brown, C. M. Bulman, E. A. Fulton, P. Johnson, I. C. Kaplan, H. Lozano-Montes, S. Mackinson, M. Marzloff, L. J. Shannon, Y.-J. Shin, J. Tam. (2011) Impacts of Fishing Low-Trophic Level Species on Marine Ecosystems. *Science* **333**:6046, 1147-1150.
25. Stephenson, R.L. and Lane, D.E. (1995) Fisheries management science: a plea for conceptual change. Can. J. Fish. Aquat. Sci. 52, 2051±2056.
26. Tacon, A.G.J. and Metian, M. 2009a. Fishing for aquaculture: Non-food use of small pelagic forage fish—A global perspective. *Rev. Fisher. Sci.*, 17: 305–317.
27. Velarde, E., E. Ezcurra, M.A. Cisnero-Mata, and M.F. Lavín. 2004. Seabird ecology, El Niño anomalies, and prediction of sardine fisheries in the Gulf of California. Ecol. Appli. 14: 607-615.

28. Velarde, E., M. S. Tordesillas, L. Vieyra, and R. Esquivel. 1994. Seabirds as indicators of important fish populations in the Gulf of California. California Cooperative Oceanic Fisheries Investigation Report **35**:137–143.
29. Walters, C. J., and J. J. Maguire. 1996. Lessons for stock assessment from the northern cod collapse. Reviews in Fish Biology and Fisheries 6:125–137.
30. Whitehead P.J.P. FAO Fisheries Synopsis No. 125. Vol. 7. 1985. Clupeoid fishes of the world (suborder Clupeioidei). An annotated and illustrated catalogue of the herring, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. Part 1: Chirocentridae, Clupidae and Pristigasteridae. 303 pp
31. Young, E., 2001. State intervention and abuse of the commons: fisheries development in Baja California Sur, Mexico. Annals of the Association of American Geographers 91 (2), 283–306.

Appendix I

Edad

1 ¿Cuando sale a pescar, usted ve barcos sardineros pescando? Si ☐ No ☐

Me podria mostrar en el mapa donde los ha visto ☐

2 ¿Usted identifica alguno de estos animales en las redes de los barcos sardineros: Aves marinas ☐ Tortugas ☐ Delfines ☐ Otra especie diferente a la sardina ☐

3 La pesqueria de sardina del Golfo de California fue recientemente certificada como sustentable, ¿usted tenia conocimiento de esto? Si ☐ No ☐

4 ¿Usted conoce que proceso le dan a las sardinas? Si ☐ No ☐

Consumo Humano ☐ Harina de pescado ☐ Enlatado ☐

5 ¿Esta pesqueria afecta su actividad de pesca Si ☐ No ☐

¿Como? ☐

6 ¿Usted se identifica con algun grupo social de los siguientes? Seri ☐ Yaqui ☐ Quiche ☐ Cochimi ☐ Mestizo ☐

7 ¿Cuantos años/meses lleva pescando? ☐

8 ¿Cuando sale a pescar, que pesca? Nombre del pez: ☐ Camaron ☐ Otro ☐

9 ¿Que tipo de red/equipo utiliza para pescar? ☐

10 ¿Que hace con la pesca del dia? Alimentacion ☐ Venderla ☐ Intercambio ☐ Otra ☐

11 ¿Como sabe a donde ir a pescar? Lo aprendi por mi cuenta Si ☐ No ☐

Alguien me dijo donde encontrar el recurso Si ☐ No ☐

Quien ☐

12 ¿Cuales de los siguientes puntos han cambiado desde que se inicio como pescador a el dia de hoy: # de barcos/lancas ☐ Peces ☐ Animales Marinos ☐ Clima ☐ Comunidad Pesquera ☐

13 ¿Que es lo que hace cuando hay una baja o mala temporada de pesca? ☐

14 ¿Usted pertenece a alguna cooperativa o grupo? Si ☐ No ☐ Nombre ☐

15 ¿Usted o su cooperativa recibe algun tipo de apoyo por parte del gobierno? Si ☐ No ☐

De ser asi, que tipo de apoyo recibe: Gasolina ☐ Efectivo ☐ Otro ☐

16 ¿Cuales son los retos o desafios a los que se enfrenta como pescador? ☐