


CONSERVATION SCIENCE IN MEXICO'S NORTHWEST

ECOSYSTEM STATUS AND TRENDS IN THE GULF OF CALIFORNIA




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FISHERIES OF NORTHWEST MEXICO

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The northwest region of Mexico supplies the most abundant share of fish products in the country. Most of the region is a temperate-tropical transitional area. Coastal wind-induced upwelling occurs seasonally along the west coasts of both the Baja California Peninsula and the continent. Permanent topographical upwelling takes place in two large areas. Fisheries are mostly industrial, Sonora being the largest producer in Mexico, followed in the region by Sinaloa, Baja California Sur and Baja California. The most abundant fishery is that of small pelagic fishes, while the jumbo squid fishery follows some years. The most valuable fishery in the country is that of the penaeid shrimp in the Gulf, together with a rapidly expanding aquacultural component. Abalone and lobster fisheries are the main economic activity for some 10,000 inhabitants in 30 settlements at the west coast of the Peninsula. Other small scale fisheries include blue crabs, sea snails, clams and the large number of scale fish and sharks, skates and rays fisheries. These create the largest number of jobs and produce the most of fresh fish products for the local and regional markets. It has been claimed that coastal food webs have been "fished down" in the Gulf; however, other studies based on widely accepted methodology have shown opposite results, concluding that there is no sign of fishing down.

1. PHYSICAL SETTINGS

The northwest region of Mexico supplies the most abundant share of fish products in the country. Most of the region is a transitional area, the eastern boundary of the North Pacific Gyre (Lynn and Simpson 1987) where the temperate California Current mixes with tropical ones resulting in a wide, productive area (Badan-Dangon 1998). Coastal wind-induced enriching upwelling occurs seasonally along the west coasts of both the Baja California Peninsula and the continental Sonora and Sinaloa states. At the west coast, atmospheric forcing is strongly seasonal; the California Current (CC) does reach the tip of the Peninsula and the mouth of the Gulf of California; modified water of the CC is recognizable in the vicinity of the Revillagigedo Islands (Lluch-Cota *et al.* 1994) about 19ºN, particularly from February to June when SSTs are lower, upwelling is maximum and the current intensifies.

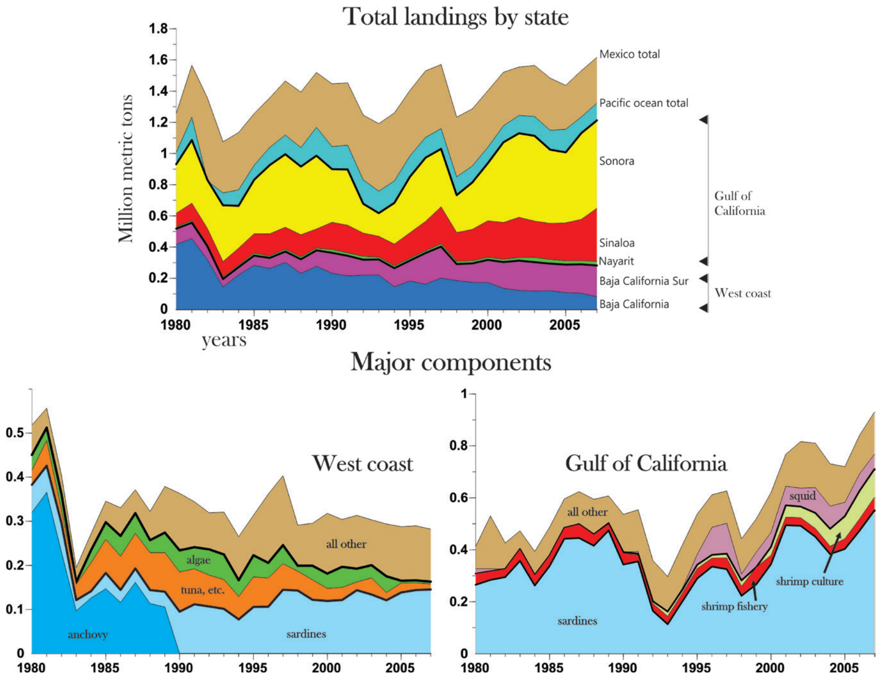
Inside the Gulf, weak southeasterly winds blow through the summer and stronger northwesterly ones during winter, mostly polarized along the Gulf axis (Merrifield and Winant 1989, Marinone *et al.* 2004). Rainfall takes place mostly during the summer (Salinas-Zavala *et al.* 1998), together with the northwestward transport of large amounts of water vapor (Carleton *et al.* 1990). The Gulf of California is a Class I, highly productive ecosystem (> 300 gC/m2-yr) based on global SeaWiFS primary productivity estimates, one of the five marine ecosystems with highest productivity and biodiversity (Enríquez-Andrade *et al.* 2005). The northern Gulf has two main natural fertilization mechanisms: year-round tidal mixing around the large islands leading to an area of strong vertical mixing and continuous flow of cool nutrient-rich water into the euphotic layer, and a thermal refuge for temperate species during the warm part of the year or along warm interannual events (Lluch-Belda *et al.* 2003); the second, wind-induced upwelling along the eastern central Gulf, enriched waters from the islands and the east coast reaching the peninsular side and remaining trapped contributing to higher primary production per unit area. Also, because this enrichment system operates only during winter, there is a strong annual gradient of pigment concentration in most of the Gulf (Lluch-Cota *et al.* 2004).

Permanent topographical upwelling resulting in high productivity year-round takes place in two large zones, Punta Eugenia-Sebastián Vizcaíno at the west coast and around the large islands in the Gulf (Lluch-Belda *et al.* 2003).

2. FISHING ACTIVITIES

Accordingly, temperate affinity species as small pelagic fishes, spiny red lobster, abalone and giant kelp are abundant at the cooler west coast of the peninsula; at the large islands area within the Gulf small pelagic fishes conform the bulk of the landings, while tropical kinship ones as penaeid shrimp, giant squid, tuna and billfishes are to be found in warmer waters in the Gulf and the south west coast of the Peninsula (see Figure 1).

The region has over 60% of the shrimp trawlers in the country; 73% of the tuna boats; all the sardine boats; 20% of the scale fishing boats and 28% of pangas (small boats powered by outboard engines). Clearly, industrial fisheries dominate the stage (see Figure 2).



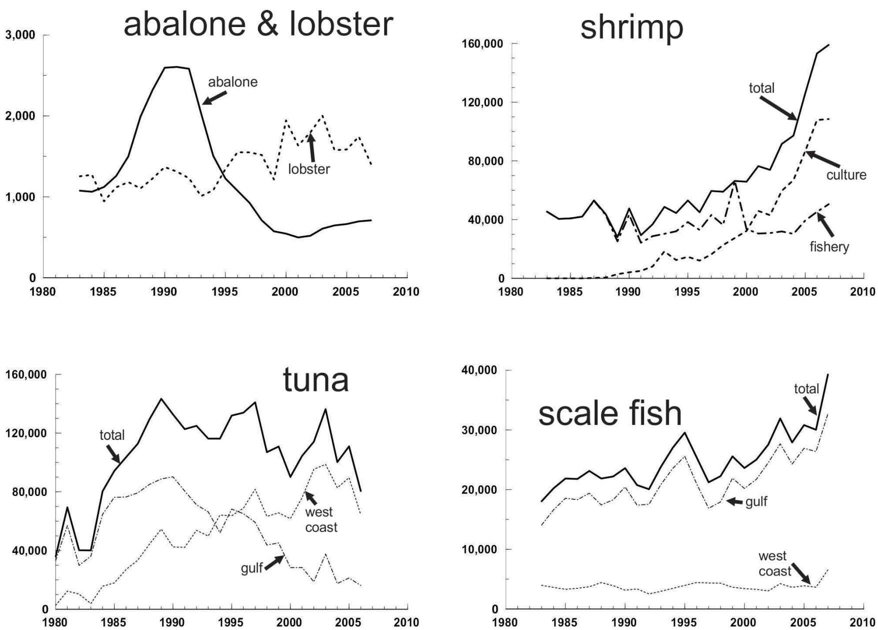


FIGURE 1 (ABOVE). Catch trends of the main fisheries at the Baja California Peninsula and Gulf of California, by state and coast. FIGURE 2 (BELOW). Catch trends of some of the main fisheries at the northern Pacific of Mexico.

There is a register of 74,639 persons involved in fishing activities in northwest Mexico, of which 46% are in Sinaloa, 28% in Sonora, 14% in Baja California Sur and 11% in Baja California; estimates do not differ significantly from 1997 to 2002.

The west coast of the Baja California Peninsula includes landings from both Baja California and Baja California Sur states; the share of the first one was maximum around 1981, mostly driven by the anchovy fishery, which vanished in 1990. Since then, landings at that state have been slowly declining, sardines remaining as the main volume contributors. Tuna and other large pelagic are also considerable, and tuna ranching has become an important activity. Algae, mostly *Macrocystis* whose volumes have been important have declined in recent years, mostly after the closure of the 'Productos del Pacífico' plant in 2004, which landed some 3,000 t (metric tons)/year. A new company (Albiomar) has begun operations, about 3,000 t/year. Landings of another species, *Gelidium*, have continued normally.

Within the Gulf, Sonora is by far the largest producer in Mexico, landings of the country fluctuating at its pace. By far the most abundant fishery is that of small pelagic fishes, mainly sardines, that has recently reached over 500,000 t. In terms of volume, the recently developed giant squid fishery (*Dosidicus gigas*) follows some years, although landings are extremely variable. The most valuable fishery in the country is that of the penaeid shrimp in the Gulf, together with a rapidly expanding aquacultural component whose production has already surpassed the wild capture fishery.

Many species comprise the rest of the landings, including scale fishes; sharks, skates and rays; a number of mollusks including the highly valuable abalone at the west coast, several clams and oysters; crustaceans other than shrimp, including the also highly prized spiny lobster fisheries and sizeable amount of blue crabs; other invertebrates as sea cucumbers and sea urchins and, recently, a medusae fishery in development.

3. THE ABALONE AND LOBSTER FISHERIES

Both fisheries have been the basis for the development of about 30 settlements at the west coast of the Peninsula; the main economic activity for some 10,000 today inhabitants. Both fisheries were a concession to fishery cooperatives with exclusive fishing rights until the mid 1970s. Area concessions have been in effect since then.

The abalone fishery began during the mid 19th century by Chinese and later Japanese fishermen. Since 1940 it has been undertaken by Mexican fishermen. Regulations of the fishery began quite soon; minimum size limits were established in 1926, based on those in effect in California; a closed season was decreed in 1956 (January to March) and was changed for July to August in 1972, based on spawning activity. Also in 1956 new larger size limits were imposed, that were raised again in 1981. In spite of such measures, landings declined since the early 1970s with no recovery of previous levels until now.

During the high landings period the main species was the pink abalone (*Haliotis corrugata*), while the green abalone (*H. fulgens*) has dominated since the 1970s, declining after 1990 (see Figure 2).

Today, the fishery develops within the frame of a comprehensive management system, involving yearly biomass estimated for each field, catch quotas stemming from such estimates and explicit considerations on the effects of environmental variability.

As a result of this system, and of favorable environmental conditions, the fishery is in a process of slow, but consistent recovery from its historical minimum.

The west coast of the Peninsula is the major production area for lobster; three species are harvested: *Panulirus interruptus* (California spiny lobster), *Panulirus inflatus* (Blue spiny lobster) and *Panulirus gracilis* (Green spiny lobster); the first one comprises 95–97% of the total landings. The fishery is under the concession of 26 cooperatives (5 in the northern area, 10 at the central and 11 at the southern ones), (Vega-Velázquez *et al.* 1996).

Minimum cephalotorax size of 82.5 mm and closed seasons per area are the main regulations in the fishery. Cooperatives may operate with different levels of organization, from those with little control and no processing plants to those fully integrated, with reception and processing plants. Most production is exported as cooked tails and live to markets to orient and a small portion to Europe.

The fishery has a history spanning more than 100 years, one of the oldest and best organized in Mexico (Vega-Velázquez and Lluch-Cota 1992, Vega-Velázquez *et al.* 1996, Vega-Velázquez *et al.* 1997). It was underexploited up to 1940, after which it increased to more than 1,000 t/year until the mid 1970s; since then it has been mostly leveled off at about 1,500 t/year (see Figure 2).

The fishery in the central area (Punta Abreojos to Isla Cedros) was certified for sustainability by the Marine Stewardship Council in 2005 and recertified during 2011, including the small fishery at Isla de Guadalupe. This is the first fishery that has passed the MSC certification process twice in Latin America.

4. SMALL PELAGIC FISHES

Fishing for small pelagic fishes in Mexico started off Ensenada, Baja California, as an extension of the California sardine fishery in the late 1920s. During a couple of decades catches oscillated between 1,000 and 12,000 t/year, until the collapse of the

California Current System sardine, in the early 1950s (Radovich 1982). After the collapse, the fishing industry moved southward looking for new fishing grounds, establishing a small scale fishery off Isla Cedros in the early 1960s, inside Magdalena Bay in the late 1960s (Felix-Uraga 2006) and later, during the early 1970s, all the way around the Peninsula to the central Gulf of California (Cisneros-Mata *et al.* 1996).

In the early 1970s, fishing for northern anchovy increased in Ensenada as a response to the Peruvian anchovy collapse, opening new markets for the reduction industry (Lluch-Cota *et al.* 2006). This fishery grew to over 260,000t/year in 1981, decreasing rapidly afterwards to only 4 t in 1998; this collapse resulted in closure of virtually the entire industrial infrastructure in that port.

Isla Cedros reported catches for only a few years, and today is considered as an important potential fishing ground after several direct and indirect biomass estimates during the last decades. Inside Magdalena Bay the fishery has remained nearly stable, with annual average catches of 10,000 t for the 1972 to 1993 period, and up to 35,000 t/y for the 1994 to 2006 period.

Inside the Gulf, the Pacific sardine fishery became the most abundant in the country, contributing with up to 40% of total national marine catch in some years. The Pacific sardine is the dominant (50–80% of total landings) in a multispecies purse seine fishery that operates from ports in the central and southern Gulf of California, from November through July (Nevarez-Martínez *et al.* 1999). Sardines and other small pelagic fishes are also caught in relatively small numbers near the mouth of the Gulf for use as bait by vessels targeting tuna (Rodríguez-Sánchez *et al.* 2002). After being established in the early 1970s, landings peaked in 1988–1989 at nearly 300,000 t. After that, in the early 1990s, a dramatic collapse occurred to less than 3% in two years, resulting in the loss of around 3,000 jobs, and about half of the fleet and processing plants (Lluch-Cota *et al.* 1999). After that, the fishery rapidly recovered to around 200,000 t and showed alternating high and low catch periods of 3 seasons each, until the most recent season, 2008-2009, that reached an unprecedented peak of almost half a million t. The other component of the northwest Mexico small pelagic fishery occurs off Mazatlán, in the southernmost part of the Gulf of California, based on less than 10 boats and catching mostly tropical species, with nearly stable catch levels.

By early 2009 the fleet was composed of 96 boats, more than half of them operating in the central Gulf. About 85% of the total catch is used for reduction to fishmeal, mostly for animal feeds. Sardines are also packed in cans for sale to domestic and foreign markets, and recently a new market opened due to the development of tuna ranching demanding live or frozen sardine. This market is attended by the Ensenada fishery. One interesting aspect is that during years of poor sardine abundance, low catches are compensated to some degree by increases of other small pelagic fishes such as the tropical thread herring *Opisthonema* spp. (Lluch-Belda *et al.* 1986) and, starting in the early 1990s, the tropical anchovy *Cetengraulis mysticetus*. For this reason, the reduction industry is not as strongly affected by low abundance periods as the canning industry, in which there has historically been a clear preference for sardines (Lluch-Cota *et al.* 2007).

Regulation is based on the Norma Oficial Mexicana (NOM) 003-PESC-1993, which recognizes that the abundance of sardine and other small pelagic species fluctuates with environmental conditions but can also be influenced by fishing. The NOM specifies a minimum size limit of 150 mm in length for sardines, regulates fishing gear and fleet capacity, and requires that the fishery be closed in times and areas where the majority of sardines are spawning. The fishery does not yet have a formal fishery management plan, although one was proposed by Nevarez-Martínez *et al.* (2003) and is presently being completed. Since 1993, the Centro Regional de Investigación Pesquera in Sonora, a branch of the Instituto Nacional de Pesca (INAPESCA), has conducted a pre-season exploratory fishing survey in the fishing grounds, in cooperation with the fishing industry, in order to forecast expected catches for the year. If the abundance of fish on the grounds is low, the INAPESCA and the industry can agree to more extensive time and area closures.

Recently, the interest for adoption of ecosystem based management (EBM) is growing among scientists and resource administrators. Bakun *et al.* (2009) discussed some of the characteristics of small pelagic fisheries that should be taken into consideration to develop EBM. These include evaluating the openness of the system (interaction with wider oceanographic conditions in the surrounding coasts) and the large moving capabilities of these animals, the inclusion of the large abundance fluctuations exhibited by these species instead of the traditional conception of equilibrium conditions, and the understanding of their real trophic role in the ecosystems. The Gulf of California sardine fishery was certified for sustainability by the Marine Stewardship Council (MSC) in 2011. This is the first fishery targeting small pelagic fishes and using the catch mostly for industrial purposes (reduction to fishmeal and oil) to be certified under MSC standards in the world.

The large fluctuations registered for the two largest fisheries, the anchovy off Ensenada and the Pacific sardine inside the Gulf, are similar in intensity to those of other areas of the world, and it is likely that they covariate with other fisheries in the 40–60 year band frequency (*i.e.* The regime frequency, Lluch-Belda *et al.* 1992); however, Ensenada trends are confusing since large portion of the industry disappeared in the 1990s, and in the Gulf there seems to be strong variability at a higher frequency that might confound the regime signal. Bakun *et al.* (2009) noted that contrary to what happens in the California Current system, the Gulf represents the tropical (warmer) distribution limit of the northeast Pacific sardine (Lluch-Cota 2000); while warm periods appear to be beneficial for the California Current sardine (Lluch-Belda *et al.* 1989, 1992), its has been observed that high temperatures associated with ENSO diminish or even suspend the annual southward migration of the sardine within the Gulf, thus reducing catches (Lluch-Belda *et al.* 1986, Huato-Soberanis and Lluch-Belda 1987) and affecting reproduction (Lluch-Cota 2000).

One interesting, still unsolved, issue relevant for management is whether the Gulf of California sardine should be considered a separate stock from that of the western Baja California Peninsula. Even though California sardines are harvested in the Gulf, they have been considered implicitly separated by assumed isolation from the west coast populations (Schwartzlose *et al.* 1999). The same is true for mackerel (*Scomber japonicus*) and northern anchovy (*Engraulis mordax*) population, among others. However, recent investigations indicate substantial interchange of both water masses and organisms between the west coast of the Peninsula and the Gulf of California (Lluch-Belda *et al.* 2003).

5. THE JUMBO SQUID FISHERY

The jumbo squid is an endemic species of the Eastern Pacific Ocean, distributed from California (approx 40°N) to the south of Chile (45°S) (Nigmatullin *et al.* 2001). During recent years a significant northward expansion of its area of distribution has been observed, with frequent records in the states of Oregon and Washington (USA), and more sporadic in British Columbia (Canada), reaching Alaska (Cosgrove 2005, Gilly 2005, Wing 2006, Zeidberg and Robison 2007), as also occurred during the 1930s and 1940s (Levy 2007). This expansion is evident at the west coast of the Baja California Peninsula, mainly around the Biological Action Centers (Lluch-Belda 2000), meaning a potential fishing for Mexico. The fishery has become one of the most relevant ones at the region. It began around the early 1970s by small pangas; in 1980 permits were granted to large boats and landings reached 22,000 t, but the fishery collapsed during 1982 and no squid was available for almost a decade. The decline has been blamed on overexploitation and market conditions by different authors.

Squid reappeared in 1989 and by 1994 the fishery was operating at the central region of the Gulf with a seasonal pattern that is consistent up to date: during the summer months it is undertaken around Santa Rosalía (Baja California Sur) by pangas, while the catches during the winter months are located around Guaymas (Sonora), mostly by shrimp trawlers working together with pangas (Markaida and Sosa-Nishizaki 2001). Recently, catches at the west coast of the Peninsula have been more frequent, mainly during strong ENSO events; the last two years the Mexican Government released some permits to catch jumbo squid in Ensenada, B.C. Additionally, a small fleet of shrimp-modified-boats from Mazatlán, Sinaloa, is fishing between Mulegé and Loreto along the Peninsula east coast. They operate with squid-machines provided with small jiggings to catch small and median squids sizes that are exported to the European market. Also some fishing cooperatives in the north of Sinaloa, near Topolobampo, have begun fishing jumbo squid using the same fishing-pattern of Sonora State.

Landings have exceeded 100,000 t some years, but the wild abundance fluctuations result in severe uncertainty for the industry. While no satisfactory explanation is available, the variation has been blamed on environmental changes, maybe related to El Niño and La Niña (Lluch-Cota *et al.* 1999, Morales-Bojórquez *et al.* 2001, Nevarez-Martínez *et al.* 2002), while others suggest that it is related to migratory patterns or reproductive success (Klett-Traulsen 1981, Ehrhardt *et al.* 1982, 1986, Ramírez and Klett-Traulsen 1985).

6. SMALL SCALE FISHERIES

Small scale fisheries, also known as artisanal or, in Mexico, ribereñas (coastal) are difficult to define, but essentially consist of those whose catches are not large, have diverse infrastructure facilities and organization for the production, processing and marketing. Under this vague definition are considered fisheries as the Marine Stewardship Council certified spiny red lobster and the abalone fisheries, blue crabs, sea snails, clams and the large number of scale fish and sharks, skates and rays fisheries that operate with scarce infrastructure.

Nonetheless, these are the fisheries that create the largest number of jobs and produce the most of fresh fish products for the local and regional markets (Fuentes-Castellanos 1996). The target species are often considered to be overexploited, their profits are low and the social sector working in it is usually devoid of governmental support (Lluch-Cota *et al.* 2006, González-Becerril *et al.* 2007).

Knowledge about these fisheries is generally low (except for those of abalone and lobster); research has mostly been limited to the biology of the species, few on population dynamics of the target species and very little about their social and economic aspects (Cisneros-Mata 2002, INP 2006, Jiménez-Quiroz and Espino-Barr 2007). For the most, fisheries are regarded as local, not regional, with the consequence that they are not considered given their fragmented production.

In general there is urgent need to develop adequate modes and operations to manage these fisheries in the context of sustainable and responsible fishing.

Information on natural protected areas, delimitation of fishing zones, participative and transparent management are claims from the legal fishing sector to the governmental agencies, together with support programs and effective monitoring and inspection schemes (SEMARNAT 2006). There are also conflicts with the aquaculture sector, part of them because of the pollution arising from these activities, with the tourism sector stemming from infrastructure building and modification of the coastal environment and with the conservation sector, because of the establishment of no take areas on previous fishing zones (Rivera-Arriaga and Villalobos 2001).

Small scale fisheries contributed with some 13% of the fishing production in the northwest, about 108,000 annual t with a diminishing trend. Averaged west coast landings have been 9,053 t/year, including 2,268 of algae, 2,340 of sea cucumber, 1,272 of lobster, 1,252 of oysters, 929 of abalone, 538 of blue crab and 454 of snails. Gulf landings, on the other hand, amount to an estimated average of 55,538 ton/year, mostly of mojarra, spanish mackerel, mullets and sea basses. Other species represent 22,013 t.

Catches may differ according to space/temporal distribution of species (Cudney-Bueno and Turk-Boyer 1998, Espino-Barr *et al.* 2007), but factors related to varying existence of local, regional and international markets, as well as the experience and tradition of fishermen in each locality should also be taken in account (Ramírez-Rodríguez and Hernández-Herrera 2000).

The high diversity of small scale fisheries implies the usage of a wide variety of fishing gear and techniques: gillnets, line and hook, traps, etc. of which there is a limited knowledge of their efficiency and selectivity for specific target species (Ramírez-Rodríguez 1996, 1997). The National Fisheries and Aquaculture Commission (CONAPESCA) has information about 22 small scale fisheries harvesting 138 species; out of these, ten include marine scale fishes and include 79 target species.

7. SHRIMP FISHERY

The multi species shrimp fishery (blue, *Litopenaeus stylirostris*; white, *Litopenaeus vannamei* and brown, *Farfantepenaeus californiensis*; together with other less important species) was analyzed since the 1970s and found overfished by an excess of fishing power and too small mesh size in the trawl nets (Lluch-Belda 1974). Since then effort has increased further in number of large boats and their fishing power, but most of all, in the number of outboard powered pangas, now fishing for offshore shrimp. According to data in Páez-Osuna *et al.* (2003), total shrimp catch has been declining by an average of 600 ton/yr in the period of 1980-2001, while shrimp aquaculture has increased by 30% per year since 1990 and now exceeds the catch. Total shrimp production has practically doubled in the last 20 years (see Figure 2). In addition to the excess effort and small mesh sizes resulting in growth overfishing, natural variation may further impact shrimp abundance, as suggested years ago (Castro-Aguirre 1976) and recently (Castro-Ortiz and Lluch-Belda 2008). Galindo-Bect *et al.* (2000) found a significant correlation between total shrimp catch at the Upper Gulf and the rate of freshwater discharge by the Colorado River. Arias *et al.* (2004) stated that although the damming of the Colorado River may have been the principal cause of the decline in the shrimp fishery, the escalation in the number of fishing vessels and fishing gear types could have also influenced it.

Catches of offshore shrimp could improve substantially both in volume and individual sizes if fishing effort were to be reduced to adequate levels and mesh sizes regulated for optimum selectivity. While it would appear that the trend has been to let more fishers participate as a means of further distributing the benefits, it is becoming increasingly clear that such a process has involved extra financing through tax exemptions and subsidies and is no longer viable.

The impacts of the trawl fishery on the ecosystem are a major concern. Anecdotal information suggests that sweeping changes in benthic community structure have taken place over the past 30 years of these disturbances. Industrial shrimp trawling exacts a harsh toll on the Gulf's marine environment, as more than a thousand shrimp trawlers annually rake an area of sea floor equivalent to four times the total size of the Gulf. This constant bottom trawling is considered to damage fragile benthic habitats (Brusca *et al.* 2001).

Damage to the physical habitat and to non commercial, small invertebrate species has been proposed by internationally recognized specialists (Brusca *et al.* 2001), but no data are available to evaluate its extent; this is one of the areas of research that has been neglected for years. Recently, however, a comparative study between trawled and non-trawled areas has revealed no significant differences (Sánchez-González *et al.* 2009).

Conservation International Mexico (2003) has estimated that each kilogram of shrimp caught in the industrial fishery is accompanied by at least 10 kg of by-catch. Estimates for the Gulf of California have ranged from 1:2 up to 1:10 (Chapa 1976, Rosales 1976), with some larger figures at times. This proportion is similar to those reported for tropical areas around the world (1:10), while temperate ones have an average of 1:5; other fishing grounds as those of Venezuela (1:40) and Thailand (1:14) show considerably larger proportions (Cascorbi 2004).

By-catches are quite variable, depending on areas and seasons; while at the beginning of the shrimp season the proportions in catch may be lower, they tend to increase towards the end, when shrimps have been fished out. It has been shown that the proportion of by-catch in shrimp fisheries varies widely between years (Barrett and Ralph 1977, Da Silva 1986, Del Valle 1989, Solana and Arreguín 1993, Sheridan 1996).

Some species are of specific concern, such as marine turtles and juveniles of totoaba (*Totoaba macdonaldi*), both vulnerable to trawl nets. Cisneros-Mata *et al.* (1995) estimated that an average of 120,300 juvenile totoabas was killed by shrimp vessels each year from 1979 to 1987. Other icon species, such as dolphins, are rarely killed by these gears.

While the problem is similar as in the rest of equivalent areas of the world, it remains as an unsolved issue, in spite of the advances that have been made on the adoption of excluders to reduce non targeted species. The National Fisheries Institute of Mexico (INP) began developing fish excluders together with Conservation International since 1992 at the Gulf, particularly directed to the protection of totoaba (Torres and Balmori-Ramírez 1994, Balmori-Ramírez *et al.* 2003) and the efforts have continued working closely with the FAO on an international project to develop suitable excluders.

8. SHRIMP AQUACULTURE

Mexico is the second most important producer of cultured shrimp in the western hemisphere; thus, it is the most relevant aquacultural industry in the country, both in terms of volume and revenues. Up to 2005, annual production of cultured shrimp ran above 90,000 t (about 57% of the total shrimp production), with an estimated value of over 4,000 million Mex pesos (about 300 million USD).

Commercial shrimp culture began in Mexico during the mid 1980s, particularly in Sinaloa, afterwards extending to Sonora and Nayarit even though it is known that, from the climatic standpoint, the northwest is not the most favorable region in the country.

The development of the industry has been increasing steadily, incorporating new technological advances that have permitted moving from extensive to intensive operations. It is a consolidated industry, with the development of a sizeable collateral net of goods and services; nevertheless, there have been episodes of great losses, mostly due to white spot syndrome. Further, operating costs are higher than in other countries and, recently, market prices for those sizes of shrimp produced by aquaculture have tended to decline. Other problems for the industry involve environmental concerns about eutrophication by discharge waters.

Nearness to the main US market somehow balance negative factors, supported by the fact that Mexican shrimp has higher prices and demand than that of other countries. Further, within the framework of the North American Free Trade Agreement (NAFTA) there are no import tariffs. Cultured shrimp is also exported to Japan and the European Union.

There are 884 shrimp farms at the northwest, 721 of which were active along 2008. They show different intensification levels, basically grouped in three categories: extensive, semi intensive and intensive. Extensive farms have large ponds, use less than 5 postlarvae/m^2 and obtain less than one tonne per hectare (ha); feed is scarcely used or not at all. Semi intensive have smaller ponds (10–15 hectares or less), 5–20 postlarvae/m^2 with yields of 1-2 t/ha and feed is used. Finally, intensive farms are the smallest ones (2–3 ha or less), use more than 20 postlarvae/m^2, have yields of more than 3 t/ha, use feed and agitators.

Depending on temperature seasonality, farms run one or two production cycles, the warmer season being the most favorable. Most farms sell the product directly, few ones to their own, integrated plants.

9. STATUS OF FISHERIES

Sala *et al.* (2004) stated that coastal food webs have been "fished down" in the Gulf, based on interviews with fishers, fisheries statistics and field surveys, looking at the effects described by Pauly *et al.* (1998). According to these authors, the decline in fish stocks has been accompanied by a marked shift in the composition of the coastal fishery and a decrease in the maximum individual length of fish catches by approximately 45 cm in 20 years. Large predatory fishes were among the most important catches in the 1970s, but became rare by 2000. Species that were not targeted in the 1970s have now become common catches. However, other studies based on widely accepted methodology have shown opposite results, concluding that there is no sign of fishing down (Pérez-España 2004, Arreguín-Sánchez 2005).

Arias *et al.* (2004) recalls that the American Fisheries Society's official list of marine fish at risk of extinction includes 6 species of large groupers and snappers, 4 of which are endemic to the Gulf of California and adjacent areas. Of these, 2 are regarded as endangered, while the remaining 4 are considered as vulnerable, given the fact that these species are sensitive to overharvesting because of late maturity and the formation of localized spawning aggregations (Musick *et al.* 2000). Large, slowly growing fish are particularly evident in showing the effect of fishing on a population: decrease in abundance and in average individual size; both are unavoidable consequences when aiming at maximizing yield. What occurs in the Gulf of California is the same process as those in Puget Sound, Florida and the southern Gulf of México, the other "hot spots" described by Musick *et al.* (op. cit.).

Of particular concern has been the totoaba, a very large endemic species that was heavily fished during the 1930s–1940s. Although overfishing has been blamed for the early decline of the fishery, the reduction in the flow of the Colorado River may have been a major cause of depletion through the alteration of the estuarine habitat of the river delta, its normal spawning and nursery area (Arias *et al.* 2004). The totoaba fishery declined since 1970 due to diminishing populations and to restrictions imposed (in 1975) when catch levels threatened the population. Despite closures, the gill net fishery continues catching juvenile totoabas as by-catch on a small-scale.

Gill nets also incidentally capture vaquitas and sea turtles. Between March 1985 and January 1994, 76 vaquitas were killed incidentally in totoaba gill nets (D'Agrosa *et al.* 1995). The total estimated incidental mortality caused by the fleet of El Golfo de Santa Clara was 39 vaquitas per year, over 17% of the most recent estimate of population size (D'Agrosa *et al.* 2000). The vaquita population was estimated to be less than 600 (Jaramillo-Legorreta *et al.* 1999), and recent estimates set the number at 245 (CI= 68 – 884; Gerrodette *et al.* 2011) therefore, considering normal replacement rates (maximum rate of population growth for cetaceans is of 10% per year), this incidental loss may not be sustained. Vaquitas, on the other hand, have been a very restricted population since they were described, at least. CONABIO (2005) reports results of several projects suggesting that a number of genetic and morphological characteristics point at a population with very restricted genetic diversity.

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Exploring Mexico's northwest, the Baja California Peninsula, its surrounding oceans, its islands, its rugged mountains, and rich seamounds, one feels diminished by the vastness and the greatness of the landscape while consumed by a sense of curiosity and awe. In a great natural paradox, we see the region's harsh arid nature molded by water through deep time, and we feel that its unique lifeforms have been linked to this desert and sea for thousands of years, as they are now.

These landscapes of fantasy and adventure, this territory of surprising, often bizarre growth-forms and of immense natural beauty, has inspired a wide array of research for over two centuries and continues to inspire the search for a deeper knowledge on the functioning, trends, and conservation status of these ecosystems in both land and ocean.

This book offers a compilation of research efforts aimed at understanding this extraordinary region and preserving its complex richness. It is a synthesis of work done by some exceptional researchers, mostly from Mexico, who indefatigably explore, record, and analyze these deserts and these seas to understand their ecological processes and the role of humans in their ever-changing dynamics.

Elisabet V. Wehncke

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