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Shifting environmental and cognitive baselines in the upper Gulf of California

Hector M Lozano-Montes^{1*}, Tony J Pitcher², and Nigel Haggan²

Local fishers' knowledge (LFK) obtained from 49 fishers in the upper Gulf of California indicates that fishery resources have declined by at least 60% over the past 50 years, most likely due to overfishing and environmental changes associated with upstream damming of the Colorado River. LFK can provide supporting evidence of trends and changes. In marine ecosystems, for example, relative abundances obtained from LFK for several commercial and non-target species are closely correlated with stock assessment biomass, fishing effort, and landings reported by the Mexican Government. Rapid shifts in perception of the degree of degradation of this ecosystem, as well as greatly reduced nutrients and river flows (over just a few decades), should act as a red flag to the Mexican Government and management agencies. It is crucial for the restoration of this ecosystem that young fishers and the Mexican public are able to visualize previous states of their local ecosystems.

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We define where we are going by first defining where we are. This perspective represents an important problem in natural sciences, because when we measure how much an ecosystem or area has changed, we generally compare it with its previous condition. The risk is that, each time this is done, the baseline for the comparison may have drifted further from the original starting point, minimizing the true magnitude of past environmental changes. This phenomenon, described as a “shifting environmental baseline” or a “cognitive ratchet”, has long been recognized in fisheries science (Pauly 1995), and suggests that centuries of fishing may have had a much greater impact on world fish populations than was previously thought (Pauly *et al.* 1998; Pitcher 2001).

Although there is growing scientific recognition of this phenomenon (Dayton *et al.* 1998; Jackson *et al.* 2001; Baum and Myers 2004; Sáenz-Arroyo *et al.* 2005), we do not know the true baseline conditions for most aquatic ecosystems under exploitation. If the environmental baselines are shifting, then many ecosystem models that aim to evaluate changes to “natural” conditions have been built with erroneous starting points, compromising their value to management or restoration. At the moment, there is no clear solution to this problem, but ecological education, restoration of degraded habitats, and the passing on of knowledge about the past to younger generations are some measures that can slow or reverse the process of shifting baselines.

Previous research has shown that perception of how humans impact marine ecosystems in the southern Gulf of California has changed (Sáenz-Arroyo *et al.* 2005 a,b). In this region, elderly fishers can name five times as many species caught over the past 60 years than are caught at

present and remember catching up to 25 times as many Gulf grouper, *Mycteroperca jordani*, on their best-ever fishing day as young fishers. A similar depletion has been well documented in the upper Gulf, where, for example, the endemic giant Gulf croaker or totoaba (*Totoaba macdonaldi*) is facing extinction as a result of decades of intense fishing and habitat degradation (Cisneros-Mata *et al.* 1997; Román-Rodríguez and Hammann 1997). Moreover, recent evidence suggests that, not only is the southern Gulf of California losing diversity, but fauna in the central and northern Gulf are also in rapid decline (Cudney-Bueno 2000; Brusca *et al.* 2001; Arreguín-Sánchez *et al.* 2002; Hernández *et al.* 2002; Morales-Zárate *et al.* 2004; Lozano-Montes 2006), with species such as the Pacific sharp-nose shark (*Rhizoprionodon longurio*) and the endemic vaquita porpoise (*Phocoena sinus*) having nearly vanished already (Rojas-Brach and Taylor 1999; D'Agrosa *et al.* 2000; Vidal *et al.* 2001; Weiner 2002).

We collected local knowledge (LFK) from the fishing communities of the upper Gulf of California in an attempt to quantify important losses of abundance and diversity in the region over the past 50 years. It is particularly important to identify baseline shifts in countries such as Mexico, where approximately 65% of the population is under 30 years of age (INEGI 2002), and the past situation in terms of environmental health, species richness, and diversity is not fully visualized or understood.

Methods

The study area included the three main fishing ports of the upper Gulf of California, Mexico: San Felipe (Baja California), Puerto Peñasco, and Golfo de Santa Clara (Sonora). Data were collected by means of semi-structured, verbal interviews (according to the criteria proposed by Huntington [2000]) between April 10 and May 20, 2003. The questionnaire was designed to obtain infor-

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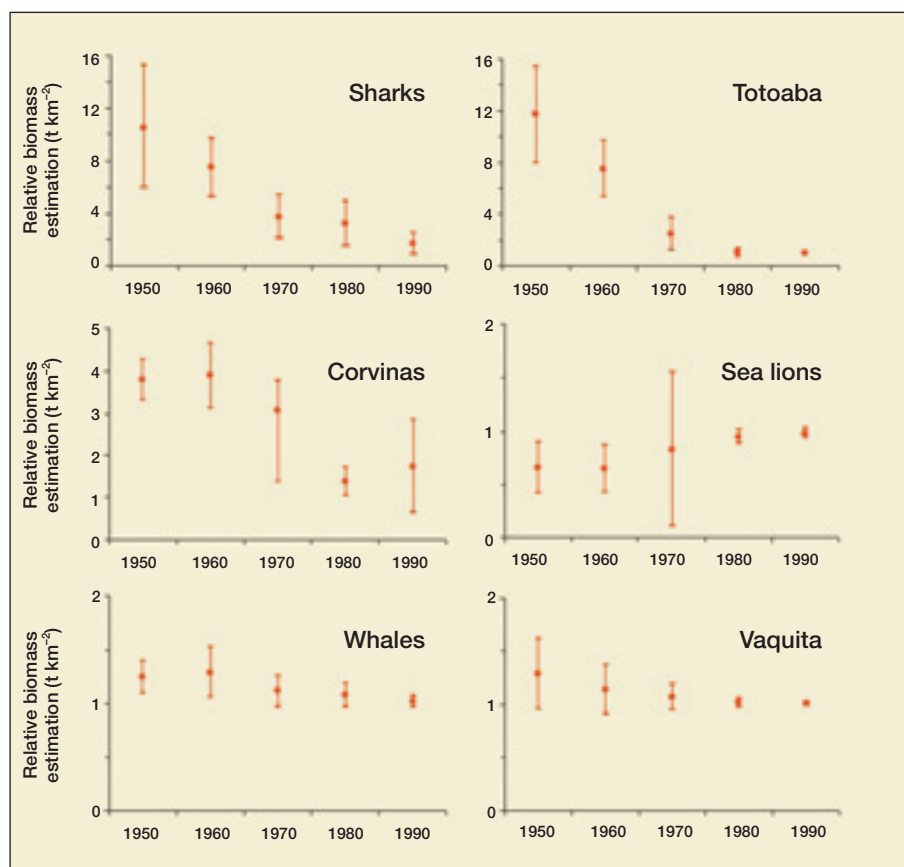


Figure 1. Past abundances (relative to 2000) for eight taxonomic groups in the upper Gulf of California (red dots) in tons per km², from interviews with 49 local fishers. Sample size for 1950 period = 18; 1960 = 33; 1970 = 36; 1980 = 44; 1990 = 49. Bars represent standard deviation of the mean.

mation about the resources, species abundances, fishing gear used, and most productive sites in the region, based on the impressions of fishers of different age groups. Common names for fish varied among the ports and villages, so the interview included 55 flash cards with pictures and common names of the principal species of sea mammals, birds, commercial and non-commercial fish, sharks, shrimp, and crustaceans. Interviewees were selected by snowball sampling (Berg 2001), a method that relies on referrals from initial subjects to generate additional subjects. The interviews followed technical and ethical recommendations proposed by Bunce *et al.* (2000). The LFK database was built from 49 interviews with fishers working in both industrial and small-scale fleets. All the interviews were carried out individually, primarily in the afternoon, just after the fishers completed their day's work and congregated on the beach to socialize. The age distribution of the fishers interviewed in each of the ports visited was young (15–30 years old, $n = 11$), middle-aged (31–55, $n = 19$), and older (> 55 , $n = 19$).

Each functional group included in the interviews was assigned an index of relative abundance compared to their status in 2000: increasing (+1), decreasing (–1), or stable (0). These perceptions were ascribed to five decades from 1950 to 2000 (except for totoaba). The

average relative abundance of the main living groups (totoaba, shrimp, corvinas, sharks, vaquita, and whales) was calculated according to local fishers' perception for each decade. All the fishers interviewed were considered “experts”; therefore, no weighting by experience was applied and the abundances estimated by “old/expert” or “young/novice” fishers were weighted equally.

The perceived abundances were converted to an absolute index by scaling the series so that the average and the amplitude of change could be compared with stock assessments (ie virtual population analysis, VPA) and biomass surveys. In cases with no absolute biomass, relative time series of biomass (catch per unit effort [CPUE], kg boat⁻¹) reported by the INP (Institute of National Fisheries, Mexico) was used to estimate the correlation with LFK trends. The agreement between both series was measured using the Spearman's rho non-parametric coefficient of correlation.

The LFK analysis also provided a guideline for specific areas that were more productive in the past (based on the regions described by Cudney-Bueno and Turk 1998), and were formerly used for daily fishing. One question in the LFK interviews focused on preferred sites for fishing. A Kruskal-Wallis test was also applied to assess differences in the number of fishing areas depleted over the past five decades.

Results

Estimating past abundances

The LFK results indicate that fishers perceive fishery resources to have declined by over 60% over the past 50 years (Figure 1 displays some examples). The relative abundance (1950–2000) for most groups shows a declining trend (a few groups, such as sea lions, *Zalophus californianus*, have been increasing). The results suggest several examples of shifting baselines. Young and middle-aged fishers questioned about the peak of the totoaba fishery (1940–1960) believed that totoaba was 2–5 times more abundant and important for the economy of the region in the past. By contrast, older fishers believed that the fish had been up to 20 times more abundant in the past than at present (Figure 1). The pattern for sharks (ie *Carcharhinus*

limbarus, *Heterodontus* spp) was similar, with the baseline again appearing to have shifted across the generations. A remarkable example arose in the remembered history of corvinas (*Cynoscion* spp). While young fishers had the impression that corvinas are more abundant today than they were during the 1980s, this point of view contrasted with those who fished during the 1950s and the 1960s. The latter fishers reported that the high abundance of this species during the 1960s created a problem during the gillnet fishery of totoaba (Figure 1). All fishers agreed that the vaquita (*Phocoena sinus*) had always been rare. This is in agreement with Ortiz (2003), who suggested that vaquita sightings have always been uncommon in the upper Gulf and that even at its peak (in the 1950s), there were no more than 2000–5000 animals.

Agreement between LFK and INP records

Figure 2 shows the relative abundance of shrimp, totoaba, sharks, and corvinas, according to the fishers interviewed, and the correlation between this data and biomass surveys, fishing effort (CPUE), and landings reported by the Mexican Government. In a few cases, such as for totoaba, data were sufficient to demonstrate an 84% correlation between stock assessment (VPA) biomass and the abundance estimated by interviews (Spearman's rho coefficient of correlation = 0.84, $df = 47$, $P < 0.01$). The well-documented recovery of corvinas that has taken place since the 1980s (Zengel *et al.* 1995; Cudney-Bueno and Turk 1998) was also supported by the LFK interviews (Figure 2). The significant positive correlation (Spearman's rho coefficient of correlation = 0.81, $df = 47$, $P < 0.01$) for corvinas indicated that the fishers' testimonies are in agreement for the 50 years of reported catch data. Flounders (*Paralichthys* spp) were the only group with a significant negative correlation (Spearman's rho coefficient of correlation = -0.58 , $df = 47$, $P < 0.05$), indicating that the average fisher's perception contradicts the trend in CPUE for this taxon. More information is required in both sectors to validate this trend. Overall, there is a satisfactory agreement among the LFK abundances and the reported trajectories of biomasses for the main target species in the region.

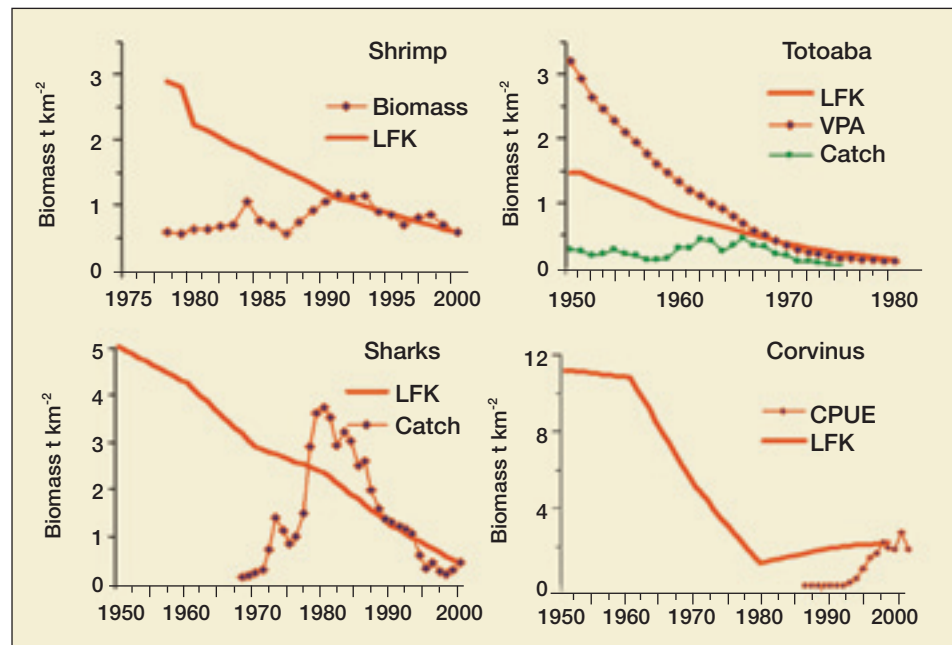


Figure 2. Concordance between relative abundances from LFK and biomasses estimated by INP surveys (shrimp) or stock assessment (totoaba) from 1950 to 2000. In cases with no absolute biomasses, a relative time series of biomasses (CPUE, kg per boat) was used for visual agreement.

Shifting environmental and cognitive baselines

The majority of fishers interviewed were of the opinion that physical and biological conditions in the upper Gulf had deteriorated. The main reason given was a combination of decades of intensive fishing and the effects of wetland habitat loss and salinity changes, which have resulted in the elimination of practically all the nutrients and freshwater delivered by the Colorado River. As younger fishers were less aware of this trend and more tolerant of the loss and collapse of their fisheries, these results reveal a linked environmental and cognitive shift in the baseline.

One question in the LFK interviews focused on preferred sites for fishing. The 49 fishers reported that, on average, 4.2 out of 11 main fishing sites in the upper Gulf had been depleted (Figure 3). The perception of this loss differed across the generations: according to older fishers, an average of 5.6 fishing sites (standard deviation = ± 2.8) had been depleted in the past 50 years, while middle-aged fishers and young fishers believed that an average of 4.1 ($sd = \pm 2.2$) and 2.7 ($sd = \pm 1.4$) fishing sites, respectively, had been depleted (Figure 3). A Kruskal-Wallis test showed a significant difference ($\chi^2 [2] = 12.75$, $P < 0.005$) in the number of depleted sites, as reported by three generations of upper Gulf of California fishers. The results taken from anecdotes and opinions of the three generations of fishers confirm that perspectives on the richness of the upper Gulf have changed. This can be interpreted as a shift in the cognitive baseline regarding fishing activities in the region.

Aside from the changes in the number of fishing sites over time, fishers reported an important change in the

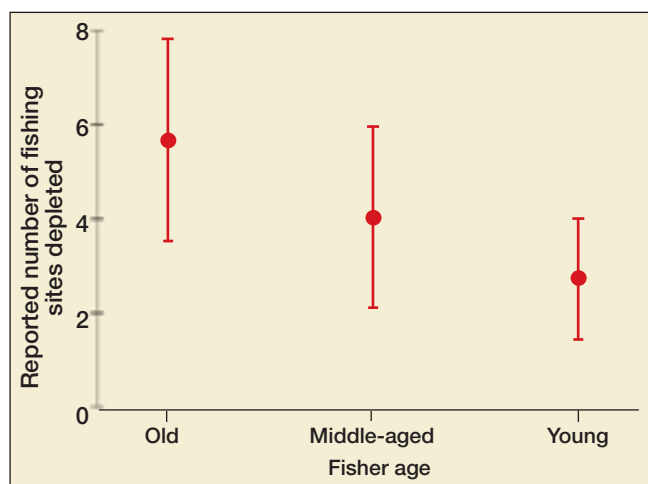


Figure 3. Number of fishing areas depleted in the upper Gulf of California, according to interviews with 49 local fishers. The difference in the reported number of sites depleted among the three generations was significant ($\chi^2[2] = 12.75$, $P < 0.005$), indicating a shifting of ecological baselines in the region. Fishers attributed the reduction of fishing sites to decades of overfishing and elimination of nutrients from the Colorado River. Bars represent standard deviation of the mean.

distribution of these fishing areas. Most fishers reported a depletion of the fishing sites located on the east coast of the upper Gulf (coast of Sonora), with major declines in catch from sites such as: “El Borrascoso”, “El Tornillar”, “La Choya”, “La Salina”, and “El Desemboque” (Figure 4). Older and middle-aged fishers from Puerto Peñasco and Santa Clara (Sonora) reported that these sites were once rich in totoaba, sharks (*Sphyrna* spp, *Mustelus* spp, *Carcharhinus limbatus*), Pacific sierra (*Scomberomorus* spp), and chano (*Micropogonias megalops*). In contrast, young and middle-aged fishers said that these species were not abundant on the east coast. In order to catch sharks, chanos, and sierras, fishers from the east coast need to go as far as 10–30 km west, sometimes reaching the west coast of the Gulf of California.

In contrast, the LFK analysis showed a relatively minor depletion at fishing sites on the west coast of the upper Gulf. Fishers interviewed said they preferred to fish at sites such as “Consang Rocks”, “El Coloradito”, “El Moreno”, and “Puertecitos” in that half of the Gulf (Figure 4). Fishers from San Felipe (Baja California, west coast of the Gulf), often expressed concern about the number of east-coast fishers from Puerto Peñasco and Santa Clara fishing for shrimp, sierras, and corvinas in “their” waters. Older and some middle-aged fishers from San Felipe mentioned that this conflict with the east-coast fishers was a relatively recent occurrence, beginning at the end of the 1980s. According to older fishers, totoaba, turtles, sierras, and shrimp used to be caught within 10 km of their fishing camps and there was no need to travel or “invade” the fishing sites of other fishing communities, much less travel 4–6 hours to the other side of the Gulf to fish.

Discussion

The LFK data suggest a shift in both environmental and cognitive baselines in the upper Gulf of California, at least among the past three generations of fishers. Furthermore, it was observed that young fishers were very tolerant of the collapse of their fisheries (ie totoaba, sharks, shrimp). In general, young fishers felt that older fishers always exaggerated the richness and diversity of the region, and did not believe that the upper Gulf once supported huge populations of totoaba, sharks, Pacific sierras, and other predators (suggesting equal richness in the abundances of their prey). This rapid shift in fishers’ perspective regarding the degradation of their environment (over the span of just a few decades) should serve as a wake-up call for the Mexican Government and management authorities. Restoration and conservation of the region depends on a knowledge of past abundance and of what the upper Gulf could produce today. The information gathered from local fishers could be incorporated into courses, seminars, or other educational media, to raise awareness of the ecological and economic value of the upper Gulf of California.

This analysis confirms that the artisanal fisheries in the upper Gulf are complex and highly diverse. Each community has its own seasons, regions, and fishing methods. Changes in tides, hours of daylight, and lunar cycles play a role in the fishing activities of this region. Also, this study revealed an intense desire on the part of the fishers to participate in, and be informed of, all the decisions and management plans for the upper Gulf of California (declared a Biosphere Reserve in 1993 by the Mexican Government, in an attempt to restore its ecology and economy).

In the absence of baseline ecological studies in the upper Gulf prior to the 1970s, the 49 fishers interviewed here represent a valuable source of information that was used to partially reconstruct relative abundances of fished and non-fished species from 1950 to 1990 in the region. The LFK analysis represents one of the few ways to estimate past abundances for many non-commercial species (seabirds, marine mammals, fishes, and invertebrates) in the upper Gulf. There are a few additional sources of information, such as archaeological and fossil records (eg Kowaleswski *et al.* 2001; Rodriguez *et al.* 2001) and travelers’ accounts (eg Sáenz-Arroyo *et al.* 2006). The relative abundances have been included in quantitative models to reconstruct, for the first time, the biota of the upper Gulf of California for the key periods of the 1950s and 1980s, with the objective of evaluating the impact of fishing and water diversion from the Colorado River (see details in Pitcher *et al.* [2005] and Lozano-Montes [2006]).

Results from a small number of interviews can be biased (Yli-Pelkonen and Kohl 2005), and our LFK results are based on a relatively small number of interviews ($n = 49$); this is less than 10% of the local fishers’ population. Furthermore, due to time and resource con-

straints, no recreational or aboriginal fishers (Cocopá people) were interviewed.

Nevertheless, LFK and social participation have a role to play in fisheries science. After all, fishers are in permanent contact with their resources and have accumulated knowledge that may be of great value in improving our understanding of marine ecosystems (Haggan *et al.* in press). In countries such as Mexico, there is a clear need for greater stakeholder participation in the management and decision-making process and for fisheries managers to use an interdisciplinary approach. It is critical for restoration and management that young fishers, and the Mexican public in general, visualize and understand how their local ecosystems have changed. Although the species richness of former times lives on in the memories of old fishers, these memories have not been relayed through the generations to today's young fishers. This LFK analysis illustrates that the fishers of the upper Gulf of California have a rich heritage and their knowledge offers an important perspective, which will be key in facing today's challenges in the management of natural resources. The shifting of ecological baselines could be one of the main reasons that our society tolerates loss of biodiversity and does not always appreciate the conservation efforts that must be taken in order to protect or restore our ecosystems.

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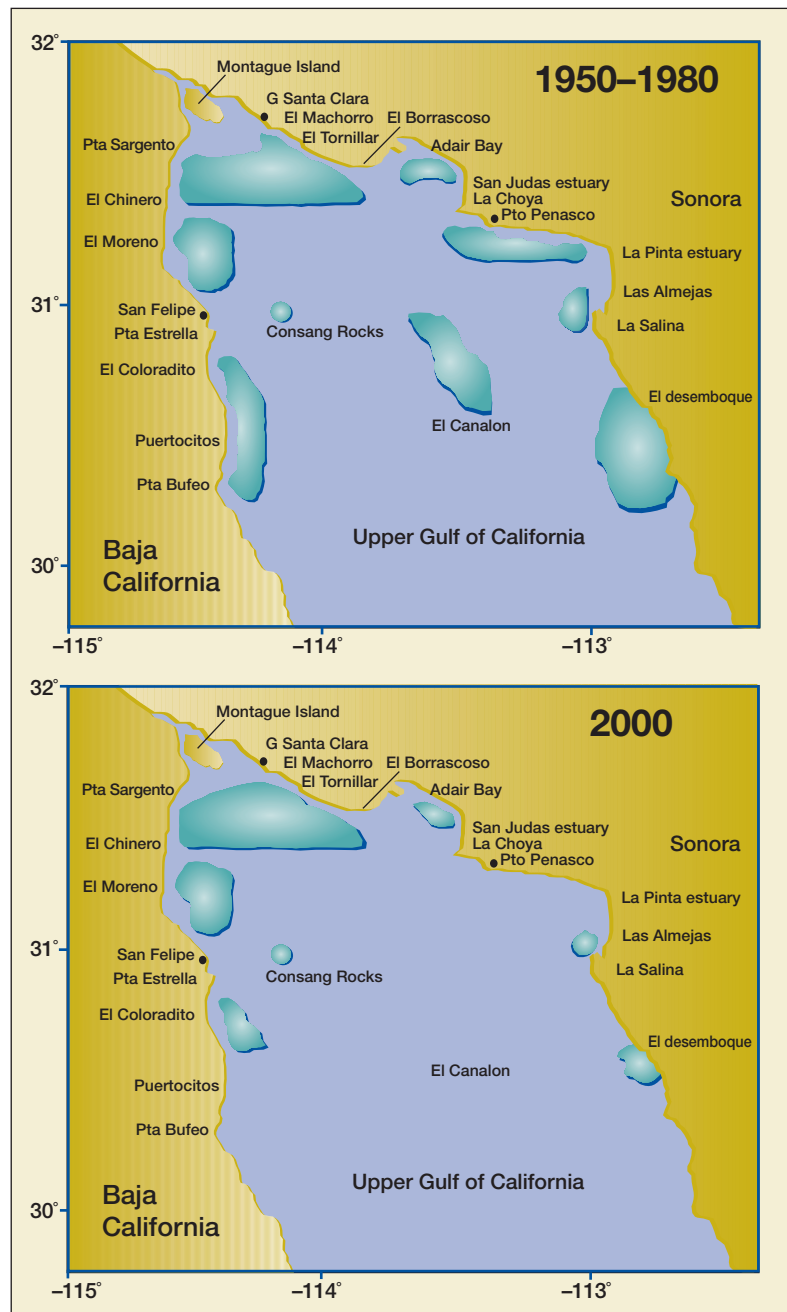


Figure 4. Depletion of fishing sites (shaded areas) of the upper Gulf of California in (a) 1950–1980 and (b) 2000, as described by 49 local fishers. According to their perspective, the east coast of the Gulf has been depleted in the past 50 years, shifting the best sites for fishing to the west coast.

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