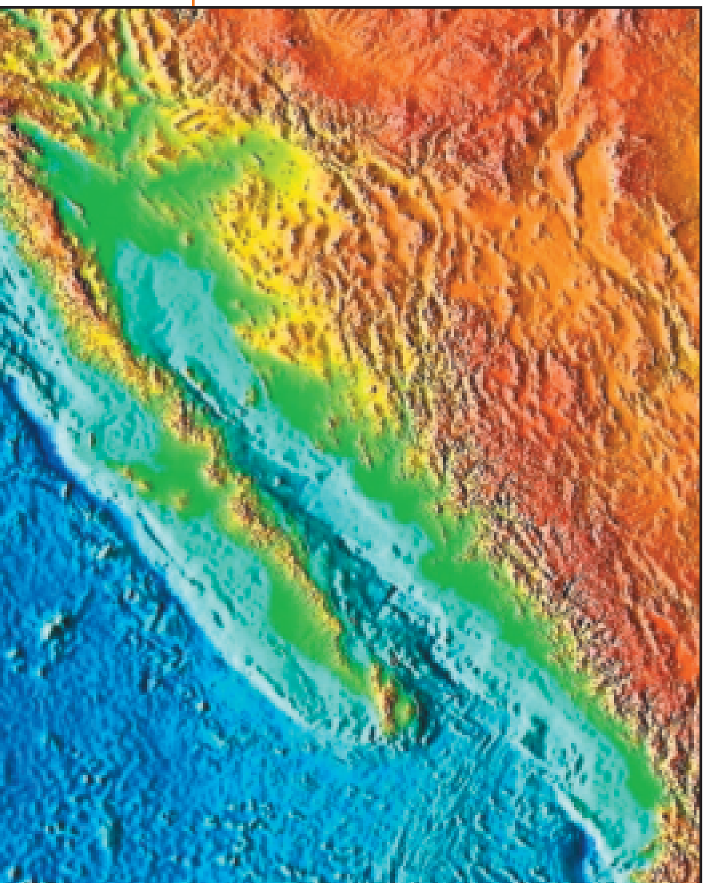
Gulf of California



highlights

- An increasing trend in the average temperature and increasing seasonal amplitude of temperature and wind occurred from the mid-1970s to the late 1990s but the recent trends are either reversed or are unclear. Figure 134 shows the change in sea surface temperatures (SST), the winter ocean upwelling index (UI) and the Pacific Decadal Oscillation (PDO).

- The number of native and non-native harmful algae (toxic) species, and the length and frequency of bloom events has increased in some areas. Mass mortalities of several marine mammals (whales, dolphins and sea lion) occurred in 1995, 1997, and 1999, possibly caused by harmful algal blooms.

- In the last five years, the fishery for small pelagic fishes changed from being based almost entirely on Pacific sardine (*Sardinops caeruleus*) to a multi-species fishery with important contributions of tropical sardines (*Opisthonema libertate* and *Cetengraulis mysticetus*).

- Giant squid (*Dosidicus gigas*) catches in the Gulf of California have been increasing steadily in recent years, except during the 1997/98 El Niño when these squid left the Gulf of California for the west coast of Baja and were found northward as far as Oregon.

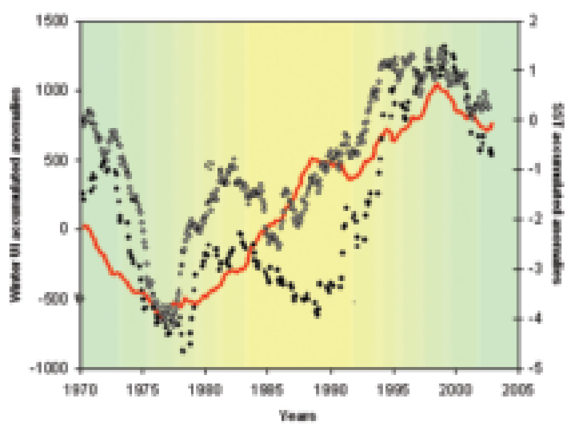


Figure 134 Cumulative sea surface temperature anomalies in the central gulf (o), winter upwelling index (_), and the PDO (red).

background

The Gulf of California is a 1,130 km long and 80 to 209 km wide semi-enclosed sea located between the mainland of Mexico and the Baja California peninsula. The 8° range of latitude includes both subtropical and subarctic influences so plants and animals of both sources are found here. Depth ranges from less than 10 m in the north to a maximum of ~3600 m at the mouth. Located between the shelf-like northern province and the deep southern province is an archipelago containing sills, channels, basins, and two large islands, Angel de la Guarda and Tiburón. The Gulf of California is biologically productive and as a consequence, it is the most important fishing region for Mexico.

Figure 135 Gulf of California

Status and Trends

Hydrography

The Pacific basin fluctuates at interannual and interdecadal scales, exerting differential influence on different regions as has been demonstrated for the gyre in the Gulf of Alaska, the California Current system, and the Kuroshio Extension. Despite not being fully demonstrated, the possibility of having a similar situation in the Gulf of California is sound. Among the few observational data series for longer than a decade, local wind at the eastern coast of the central Gulf of California shows strong fluctuations with periods of nearly five years. A coastal upwelling index and sea surface temperature show a clearly increasing seasonal amplitude signal during the mid-1970s to the late 1990s. One major observation has been that during the early 1990s the upwelling was stronger than optimum for the sardine reproduction, coinciding with a severe collapse to less than 10% of the historical catch.

Chemistry

No reports on chemistry are available.

Plankton

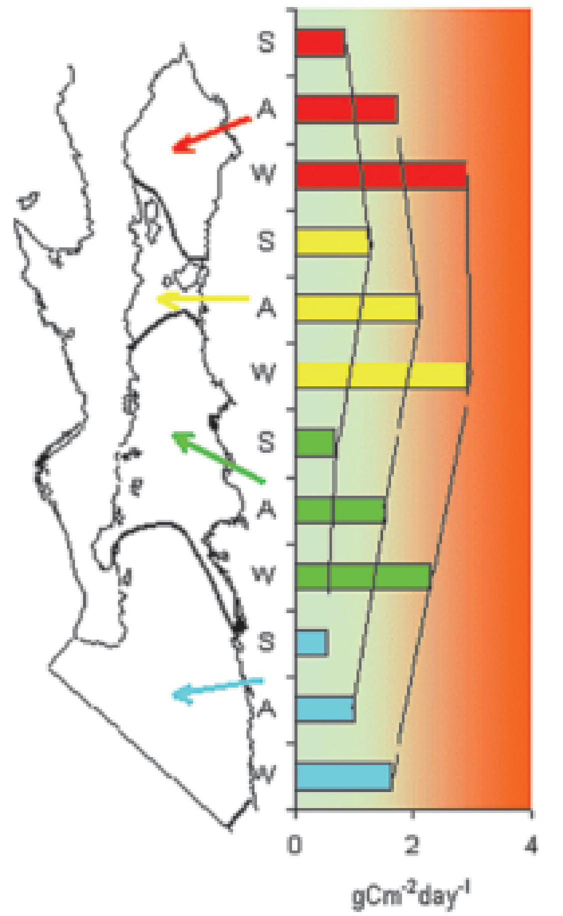
Phytoplankton Direct observations of phytoplankton dynamics in the Gulf of California are scarce and isolated and most of the dynamics are based on satellite-derived information. Despite the inherent limitations of this type of information, ocean colour observations from satellites are especially useful in the Gulf of California due to (almost) year-round cloud-free conditions.

Estimates based on the 1996 to 2002 period indicate total annual primary production for the entire Gulf of California to be 477 gC m^{-2} y^{-1} with year-to-year variations of up to 25%. Productivity levels change a lot between regions and seasons.[347] Figure 125 shows average summer (S), annual (A), and winter (W) primary production for four regions within the gulf.

Although there are some technical problems comparing different satellite sensors since they were first used to examine ocean colour, preliminary observations suggest increasing seasonal amplitude (higher primary productivity during winter and lower during summer) during recent years. If correct, this would support the tendency for greater seasonal amplitude of wind-driven ocean upwelling mentioned previously.[348]

Harmful Algal Blooms (HABs) are difficult to analyze for the Gulf of California due to data constraints. However, researchers have been able to identify some patterns by pooling observations into a long and relatively consistent time series of discolouration events in surface waters during the last 22 years in Mazatlán Bay, Mexico. Within the Gulf of California, the species responsible for HABs respond very quickly to environmental change.[349] Although the Gulf of California is often considered a region of relatively low human impacts, there are emerging effects of coastal pollution, agricultural run-off, and expanding aquaculture facilities that are responsible for some coastal eutrophication in the Gulf of California, with a consequential increase in HABs.[350,351]

Different to what happens in other regions of the Pacific, during El Niño years the number of HAB events decreases. However, a tendency to increase the length of the events after each major ENSO has been detected. In the long term, the number of toxic species and the length of the events and their frequency tend to increase.[352]



[Figure 136] Gulf of California primary production (grams of carbon per metre squared per day) in (S)ummer, (A)utumn and (W)inter by region.

The occurrence of events of more than 30 days duration seems to be a common phenomenon since 2000. The number of discoloration days per year increased two to three times during the last five years reaching 273 days y^{-1}. 46% of discoloration days observed over the last 22 years occurred within the last five years.

The recent occurrence of non-native species affecting phytoplankton community structure in tropical[353,354] and temperate waters is evident (e.g. *Pseudonitzchia australis*). *Cochlodinium cf. catenatum*, an ichthiotoxic species, is the most recent introduction of a non-native species. Since 2000, it has produced huge blooms that cause mortality of fish along the coasts of Colima, Jalisco, Nayarit, Sinaloa and Baja California Sur.

Zooplankton It has been suggested that zooplankton biomass during ENSO events remains largely unchanged. Several studies[355,356] found no differences between the period of the 1982-1983 ENSO and "normal" years the central gulf. Increased biomass was observed in the southern gulf during spring of 1984 and during other surveys.[357] This differs from the strong biomass reductions documented for nearby regions such as the west coast of the Baja Peninsula.[358]

Fisheries

Shrimp (*Farfantepenaeus californiensis, Litopenaeus vannamei* and *Litopenaeus stylirostris*) is one of the most important living marine resources for Mexico in terms of income and employment. The fishery began in 1921 and became industrialized by the late 1930s. Historical catch records are available from the early 1960s, and from then to the early 1990s a decreasing trend dominated. Since then a recovery tendency is apparent except for 1998-2001. This fishery has historically shown very high interannual variability, apparently associated with sea temperature and precipitation.

The fishery for small pelagic species is the largest in México, providing up to 40% of the total national marine catch during some years, most of it from inside the Gulf. It developed during the 1970s, steadily increasing to more than 300,000 t in 1988-89. Between the late 1980s and recent years, the catch decreased to less than 30,000 t in only three seasons, rapidly recovered in two years, decreased again during the 1997/1998 El Niño and since then has been steadily increasing to an historical maximum in 2002. Though this is a multispecies fishery, the most important species has always been the Pacific sardine (*Sardinops caeruleus*). Traditionally the Pacific sardine contribution has decreased during ENSO events while other species such as anchovy (*Engraulis mordax*) and thread herring (*Opisthonema libertate*) increase in proportion. The community has rapidly returned to the normal composition, but in recent years (1998 - 2002) a more sustained change occurred with an increased contribution of a traditionally rare species (*Cetengraulis mysticetus*).

The fishery for giant squid (*Dosidicus gigas*) in the Gulf of California began in the early 1970s and catches increased to more than 22,000 t by 1980. In 1982 the fishery collapsed and the population virtually disappeared from the Gulf for many years. The species reappeared in 1989 and the fishery started again the following year. Catches increased rapidly to 100,000 t in 1997. During the 1997-1998 fishing season, an extraordinary shift in the location of the fishing grounds took place as the stock left the Gulf of California for the west coast of the Baja Peninsula and the US.[359] It returned to the central Gulf of California by 1999 where catches remain high. While the strong ENSO of 1997/98 might explain this short-term change in distribution, other sources of variability must be important. A similar collapse occurred in 1981, one year before the 1982-83 El Niño. Causes of the high variability in the squid fishery are not well understood. Hypotheses include changes in ocean circulation, biological causes (migratory responses to prey availability-mainly small pelagics' variable reproductive success and recruitment,[360] and changes in fishing effort due to market demand.[361]

Marine Birds and Mammals

The Gulf of California is a region of very high marine mammal diversity (31 species; 4 pinnipeds and 27 cetaceans). Some evidence indicates that, at least in some areas within the gulf (i.e. Canal de Ballenas), the numbers of cetaceans and sometimes marine birds increases during ENSO years.[362] Changes also occur in blue whale distribution and abundance,[363] but there appears to be no effect on California sea lions (*Zalophus californianus*).[364,365]

Seabirds The influence of food on reproductive success in pelicans (*Pelecanus occidentalis*) and other species is especially clear during an El Niño event when decreased abundance of food (forage fishes) results in reduced reproductive success of pelicans. Effects of the 1997/98 ENSO were the most severe ever observed. In 1998, only about 1,740 eggs were laid and only several young were fledged at 12 colonies where usually some 30,000 young are produced. Since then a recovery is noted.

Pinnipeds Historical time series of California sea lion reproduction (number of pups) from the large island region show a striking similarity with sardine catch tendency, probably meaning interaction between species or a common forcing source. Currently, the Gulf of California sea lion, the most abundant pinniped, has a resident population of more than 20,000 animals mostly distributed in the northern part of the Gulf.

Cetaceans It has been suggested that marine mammal mass mortalities are becoming more frequent. During the last 10 years we have witnessed at least 3 major mass mortality events, most likely cause being harmful algal blooms: in 1995 367 dolphins (*Delphinus capensis, Tursiops truncatus and Stenella coeruleoalba*), 8 whales (*Balaenoptera physalus, B. acuterorostrata* and *B. edeni*), and 51 sea lions (*Z. californianus*), in 1997 4 whales (*B. physalus*), 168 dolphins (*D. delphys and T. truncatus*), and 9 California sea lions, and during 1999 nearly 100 whales inside the gulf (*Balaenoptera* spp.).

critical factors causing change

Variability of the physical environment of the Gulf of California is controlled mostly by tidal forcing, by the influence of the Pacific Ocean at the entrance to the Gulf, by the wind regime, and by heat exchange between the sea and the overlying atmosphere.

The major source of interannual variability in the Gulf of California is caused by ENSO. These events have a strong influence on the oceanography, species abundance and distribution. As time series in the region are relatively short, no solid conclusions about decadal and multi-decadal variability can be made but there is some evidence suggesting synchrony with the PDO phases.

Industrialized fisheries and coastal zone usage are also driving forces of change, although a formal evaluation of their effects has not yet been conducted.

issues

The Gulf of California holds multiple problems and opportunities, such as sustainable food production, social and economic development, conservation challenges, and high primary production with a potential role on climate change mitigation. ENSO strongly influences the Gulf of California, but we lack elements to understand how it will respond to long-term variability such as the Pacific Decadal Oscillation or the regime-scale variability.[366,367,30]

Beyond interannual variation, analyses are extremely difficult within the Gulf of California region because of a general lack of long timeseries observations or ecological proxies, and very few locally measured physical variables. Modeling approaches are not easily adopted since in general terms global data-bases and circulation models do not resolve the Gulf of California geographic scale.

How can we monitor, test, and eventually forecast the responses of the Gulf of California environment to human influence and natural variability at different scales from the interannual to global warming? How can we develop strategies to use and conserve the Gulf of California, recognizing at the same time its ecological importance and its social and economic regional relevance?

Three possible routes to deal with these questions are the development of paleoclimate and paleoecological reconstructions, the implementation of interdisciplinary coupled models, and the use of the comparative approach based on the experience already gained by other regions of the world dealing with highly exploited inner seas, such as the Baltic and the Mediterranean.

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