XV-50 Gulf of Mexico: LME #5

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The Gulf of Mexico LME is a deep marginal sea bordered by Cuba, Mexico and the U.S. It is the largest semi-enclosed coastal sea of the western Atlantic, encompassing more than 1.5 million km^2, of which 1.57% is protected, as well as 0.49% of the world's coral reefs and 0.02% of the world's sea mounts (Sea Around Us 2007). The continental shelf is very extensive, comprising about 30% of the total area and is topographically very diverse. Oceanic water enters this LME from the Yucatan channel and exits through the Straits of Florida creating the Loop Current, a major oceanographic feature and part of the Gulf Stream System (Lohrenz *et al*. 1999). The LME is strongly influenced by freshwater input from rivers, particularly the Mississippi-Atchafalaya, which accounts for about two-thirds of the flows into the Gulf (Richards & McGowan 1989). Forty-seven major estuaries are found in this LME (Sea Around Us 2007). Important hydrocarbon seeps exist in the southernmost and northern parts of the LME (Richards & McGowan 1989). A major climatological feature is tropical storm activity, including hurricanes. Book chapters pertaining to this LME are by Richards & McGowan (1989), Brown *et al*. (1991). A volume on this LME is edited by Kumpf *et al*. (1999).

I. Productivity

The Gulf of Mexico LME is a moderately high productivity ecosystem (<300 gCm^{-2}/yr^{-1}). Conditions range from eutrophic in the coastal waters to oligotrophic in the deeper ocean. Lohrenz *et al*. (1999) distinguished among local scale, mesoscale and synoptic scale processes that influence primary productivity in the LME. Upwelling along the edge of the Loop Current as well as its associated rings and eddies are major sources of nutrients to the euphotic zone. It has been suggested that this upwelling causes a 2- to 3-fold increase in the annual rate of primary production in the Gulf (Wiseman & Sturges 1999). The region of the Mississippi River outflow has the highest measured rates of primary production (Lohrenz *et al*. 1990). The Gulf's primary productivity supports an important global reservoir of biodiversity and biomass of fish, sea birds and marine mammals. Each summer, widespread areas on the northern continental shelf are affected by severe and persistent hypoxia (Rabalais *et al.* 1999a).

Oceanic Fronts (Belkin *et al.* 2009)(Figure XV-50.1): From December through March, two major fronts emerge over two shelf areas, the West Florida Shelf (WFS) and Louisiana-Texas Shelf (LTS). The WFS Front (WFSF) extends over the mid-shelf, whereas the LTS Front (LTSF) is located closer to the shelf break. Both fronts form owing to cold air outbreaks (e.g., Huh *et al*. 1978). Huge freshwater discharge from the Mississippi River Estuary (MRE) and rivers of the Florida Panhandle contributes to the fronts' development and maintenance. Compared to these northern fronts, the Campeche Bank Shelf-Slope Front (CBSSF) and Campeche Bank Coastal Front (CBCF) in the south are weak and unstable. The Loop Current Front (LCF) is always present at the inshore boundary of the namesake front, best defined in winter.

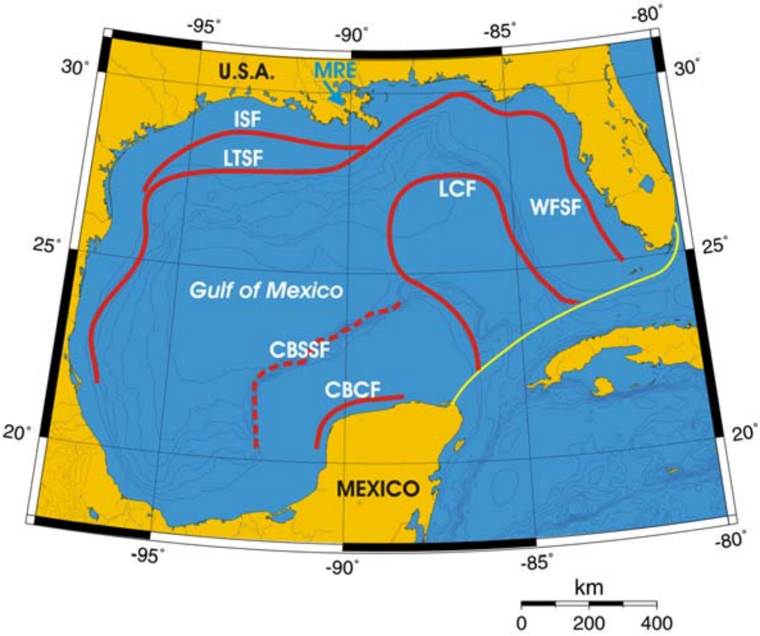


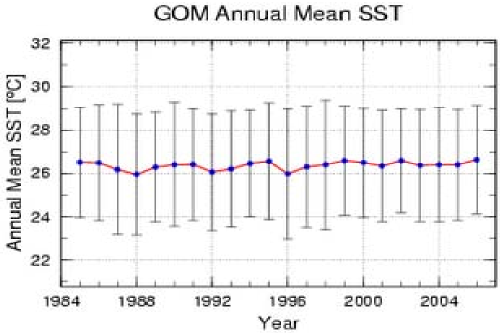
Figure XV-50.1. Fronts of the Gulf of Mexico. Acronyms: CBCF, Campeche Bank Coastal Front; CBSSF, Campeche Bank Shelf-Slope Front (most probable location); ISF, Inner Shelf Front; LCF, Loop Current Front; LTSF, Louisiana-Texas Shelf Front; MRE, Mississippi River Estuary; WFSF, West Florida Shelf Front. Yellow line, LME boundary. After Belkin *et al.* (2009).

Gulf of Mexico LME SST (Belkin 2009)(Figure XV-50.2):
Linear SST trend since 1957: 0.19°C.
Linear SST trend since 1982: 0.31°C.

The Gulf of Mexico thermal history is quite peculiar. The global cooling of the 1960s transpired here as an SST drop of <1°C, followed by a slow warming until present. The relatively slow warming of the last 50 years was modulated by strong interannual variability with a typical magnitude of 0.5°C. The all-time record high of 26.4°C in 1972 was a major event since SST increased by nearly 0.8°C in just two years. This event was probably localized with the Gulf of Mexico. An alternative explanation involves a gradual drift of a record-strong positive SST anomaly of 1969 from the Caribbean Sea LME. The time lag of three years between the Caribbean Sea SST maximum and the Gulf of Mexico SST maximum makes this correlation tenuous.

The relatively slow warming, if any, of the Gulf of Mexico is also evident from satellite SST data from 1984-2006 assembled and processed at NOAA/AOML (Figure XV-50.2a). Even though the annual mean SST change little since 1957, summer SST in the Atlantic tropical areas rose substantially since the 1980s, which is thought to have resulted in a recent increase of destructiveness of tropical cyclones, including those that hit the Gulf of Mexico (Emanuel 2005).

a



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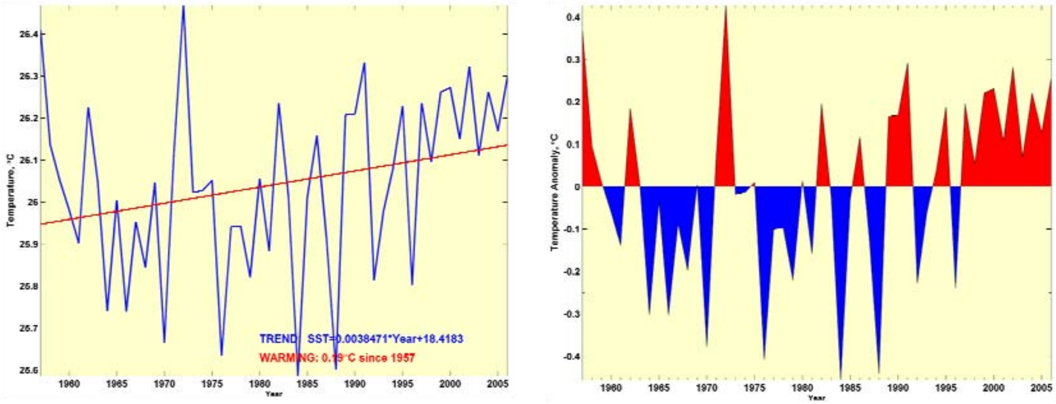

Figure XV-50.2a. Time series of annual mean SST in the Gulf of Mexico derived from satellite data, 1984-2006, processed at NOAA's Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida. Source: www.aoml.noaa.gov/phod/regsatprod/gom/sst_anm.php. Figure XV-50.2b. Gulf of Mexico LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

Gulf of Mexico LME Chlorophyll and Primary Productivity: The Gulf of Mexico LME is a Class II, moderately-high productivity ecosystem (150-300 gCm^{-2}/yr^{-1})(Figure XV-50.3).

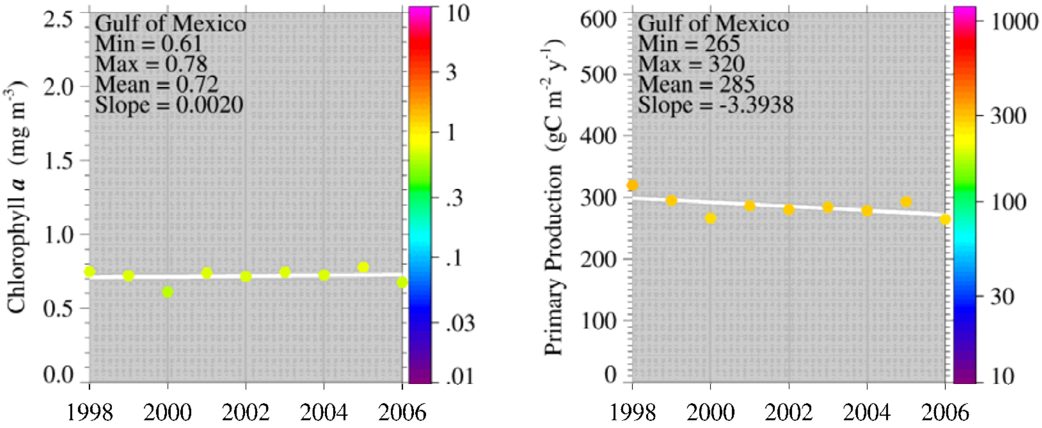

Figure XV-50.3. Gulf of Mexico LME trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

The Gulf of Mexico LME fisheries are multispecies, multigear and multifleet in character and include artisanal, commercial and recreational fishing. Species of economic importance include brown shrimp (*Farfantepenaeus aztecus*), white shrimp (*Litopenaeus setiferus*), pink shrimp (*Farfantepenaeus duorarum*), Gulf menhaden (*Brevoortia patronus*), king mackerel (*Scomberomorus cavalla*), Spanish mackerel (*S. maculatus*), red grouper (*Epinephelus morio*), red snapper (*Lutjanus campechanus*), seatrout, tuna and billfish (NOAA/NMFS 1999). Reported landings from this LME are dominated by herrings, sardines and anchovies (FAO 2003), but they underestimate total catches, due to non-inclusion of much of the discarded fish bycatch of shrimp trawlers (see e.g. contributions in Yañez-Arancibia, 1985). Total reported landings increased to over 1.5 million tonnes in 1984, and then declined to 780,000 tonnes in 2004 (Figure XV-50.4). Between 1969 and 1999, the annual value of the reported landings has been over US$1 billion (in 2000 US dollars) and reached US$2 billion in 1979 (Figure XV-50.5).

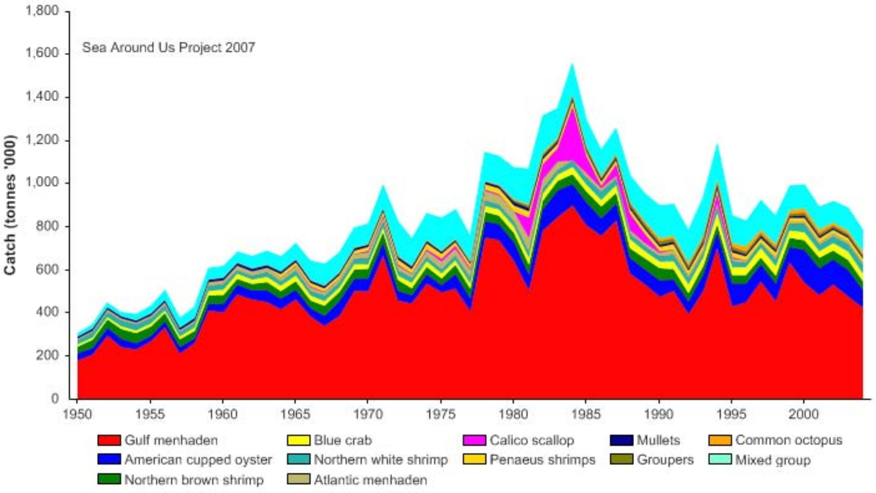

Figure XV-50.4. Total reported landings in the Gulf of Mexico LME by species (Sea Around Us 2007).

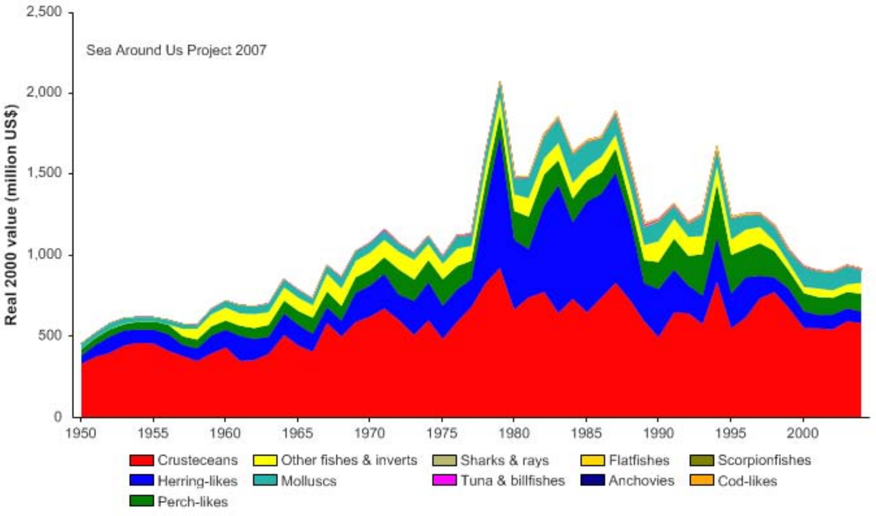

Figure XV-50.5. Value of reported landings in the Gulf of Mexico LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in the LME reached 8% of the observed primary production in 1994 (Figure XV-50.6), but this PPR underestimate due to the high level of shrimp bycatch not included in the underlying statistics. Mexico and the USA account for the majority of the ecological footprints in this LME.

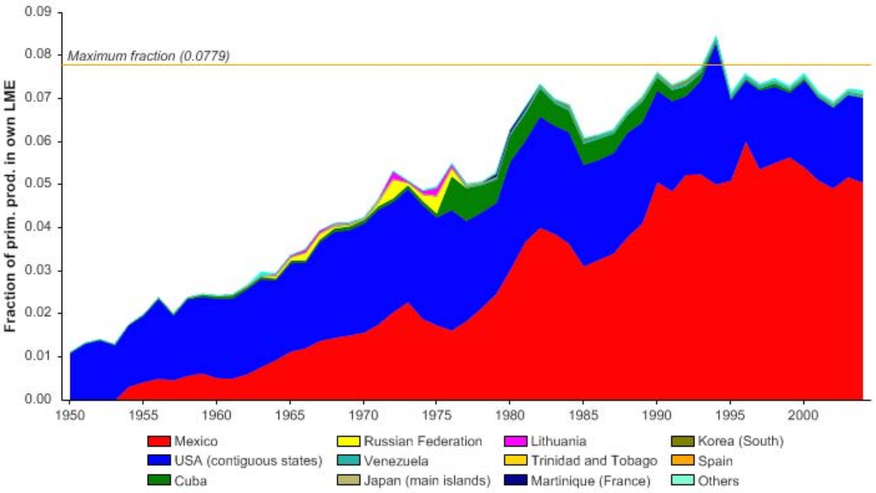

Figure XV-50.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Gulf of Mexico LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The mean trophic level of the reported landings (i.e., the MTI; Pauly & Watson 2005) has increased slightly from the early 1950s to 2004 (Figure XV-50.7, top). The very low value of MTI (2.3-2.5) is due to the high proportion of small low trophic pelagic fishes, especially Gulf menhaden and shrimps in the landings, and the exclusion of the shrimp trawler bycatches in valuation of the mean trophic level.

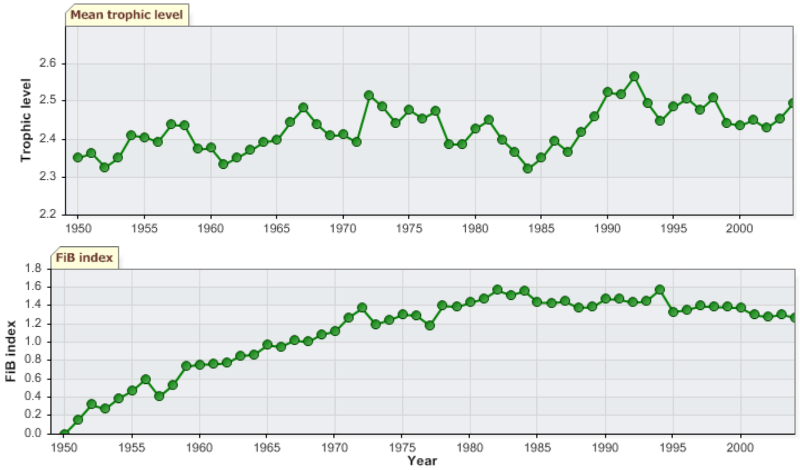

Figure XV-50.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Gulf of Mexico LME (Sea Around Us 2007).

As for the observed increase in MTI, this may also be an artefact, as can be inferred from the work of Baisre (2000). He found, based, on detailed catch data from Cuba that included bycatch and covered an extended period (1935-1995), that a ‘fishing down’ of food webs (Pauly *et al*. 1998) is occurring in the region. The decline of the FiB index from the mid 1980s (Figure XV-50.7, bottom) is likely a result of the diminished reported landings.

The Stock-Catch Status Plots indicate that collapsed and overexploited stocks now account for over 70% of all commercially exploited stocks in the LME (Figure XV-50.8, top), with overexploited stocks contributing 60% of the reported landings (Figure XV-50.8, bottom).

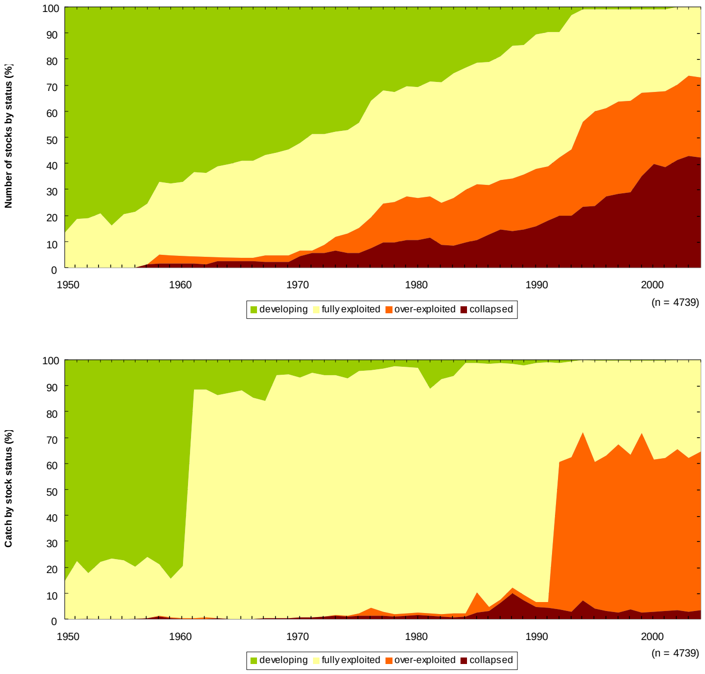

Figure XV-50.8. Stock-Catch Status Plots in the Gulf of Mexico LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of ‘stocks’, i.e., individual landings time series, only include taxonomic entities at species, genus or family level, i.e., higher and pooled groups have been excluded (see Pauly *et al*, this volume for definitions).

Overexploitation was found to be moderate as a whole, but severe on the Campeche Bank in the southwestern Gulf. Intensive fishing is the primary force driving biomass changes in the LME, with climatic variability the secondary driving force (Sherman 2003). In general, the fish stocks of this LME are impacted by excessive recreational and commercial fishing pressure (Birkett & Rapport 1999). Both the traditional and the more recent fisheries have reached their harvesting limits and several species are overexploited (Arreguín-Sánchez *et al*. 1999, Brown *et al*. 1991, NOAA/NMFS 1999, Shipp 1999). Spanish mackerel, shark and coastal pelagics showed severe declines under intense fishing pressure during the late 1980s (Shipp 1999). Other commercially important species that have been overexploited are the red drum and spotted seatrout, and there has been concern over the sustainability of the fishery for amberjack and gag grouper (Shipp 1999). The Gulf menhaden stocks fluctuated and then declined under heavy fishing pressure and other stresses (Birkett & Rapport 1999). Several stocks of reef fish, including red, Nassau and goliath groupers, are also overexploited (NOAA/NMFS 1999). The red snapper is considered the most severely overexploited species in the Gulf, and its recovery is deterred by the high mortality of its juveniles in shrimp trawl bycatch. Stocks of large migratory pelagic fish are also under threat from overfishing. Landings of bluefin tuna dropped precipitously in the late 1970s and the stocks are also considered to be severely overexploited. Likewise, other large pelagics such as swordfish and blue and white marlin are also thought to be overexploited.

In the early 1980s, the shrimp fishery on the continental shelf off Campeche in the southwestern Gulf of Mexico LME formed the base of the economy in this area (Arreguín-Sánchez *et al*. 2004). This fishery, particularly for the pink shrimp has collapsed, with annual harvests falling from 27,000 tonnes in the early 1970s to 3,000 tonnes or less (Arreguín-Sánchez *et al*. 1997). There has been evidence of marked declines in the abundance of pink and white shrimps in this area as a result of heavy fishing on juveniles inshore as well as on spawners in offshore areas (Gracia & Vasquez-Bader 1999). Also in this area, the red grouper and the brackish water clam fisheries collapsed in the late 1980s (Arreguín-Sánchez *et al*. 1999). As a result of these declines, the fisheries in the Campeche area focus on other, less valuable species, such as finfish and octopus (Arreguín-Sánchez *et al*. 2004).

Many of these fisheries are now under management (e.g., seasonal closures, size limits, quotas) and some have started to show recovery (Arreguín-Sánchez *et al*. 1999, Brown *et al*. 1991, NOAA/NMFS 1999, Shipp 1999). For example, Spanish mackerel, Gulf menhaden as well as white, pink and brown shrimps are now considered to be either in a state of recovery or at least are no longer overexploited. However, concern still exists over continued overcapitalisation and the shift of fishing to lower tropic levels and smaller sizes of fish, which are the prey of species supporting valuable, fully developed fisheries (Brown *et al*. 1991, UNDP/GEF 2004). Harvest of prey species may therefore have long-term negative impacts on the production of currently harvested species in the Gulf and should be accompanied by research into important ecological relationships and multispecies effects (Brown *et al*. 1991, Pauly *et al*. 1999). Several studies along these lines have already been undertaken (e.g., Browder 1993, Manickchand-Heileman *et al*. 1998, Arreguín-Sánchez *et al*. 2004, Vidal-Hernandez & Pauly 2004).

Excessive bycatch and discards are associated with the shrimp trawl fishery, in which small mesh nets are used. The 10:1 ratio of bycatch to shrimp implies that vast quantities of non-target species are caught in shrimp trawls. Juveniles of sciaenids (e.g., croaker, seatrout, spot) constitute the bulk of the finfish bycatch, with many billion individuals discarded every year (NOAA/NMFS 1999). The populations of species that are heavily fished as bycatch in the shrimp fishery have declined significantly, in parallel with the increase in shrimping effort (Brown *et al*. 1991). This loss through bycatch may slow the recovery of overfished stocks (NOAA/NMFS 1999). Results from mass-balance, trophic models suggest the ecosystem is rather robust as a whole, although continued increases in fishing effort, especially by bottom (shrimp) trawlers, will have serious impacts, reverberating through the entire shelf subsystem (Vidal-Hernandez & Pauly 2004).

III. Pollution and Ecosystem Health

***Pollution*:** Shoreline development, the oil and gas industry, pollutant discharges and nutrient loading are among the principal sources of stress on the Gulf of Mexico LME (Birkett & Rapport 1999). In general, pollution was found to be slight to severe in this LME. Most notable is the high input of nutrients and associated eutrophication and hypoxia in the northern areas of the Gulf. Agricultural activities, artificial drainage and other changes to the hydrology of the U.S. Midwest, atmospheric deposition, non-point sources and point discharges, particularly from domestic wastewater treatment systems, industrial discharges and feedlots all contribute to the nutrient load that reaches the Gulf (Goolsby *et al*. 1999). The outflows of the Mississippi and Atchafalaya Rivers, however, dominate the nutrient loads to the continental shelf (Rabalais *et al*. 1999a, 2002b). The input of nutrients in the Mississippi River has increased dramatically in the last century and has accelerated since 1950, coinciding with increasing fertiliser use in the Mississippi Basin (Turner & Rabalais 1991). The high input and regeneration of nutrients result in high biological productivity in the immediate and extended plume of the Mississippi River (Lohrenz *et al*. 1990).

Most of the primary production fluxes to the bottom waters and the seabed, fuelling hypoxia in the bottom waters. The areal extent of the hypoxic or 'dead' zone during the mid-summer of 1993-1995 ranged from about 16,600 to 18,200 km^2 (Rabalais *et al*. 1999a, 1999b). The EPA predicted size of the dead zone by the end of summer 2007 was 22,127 km^2 or more than 8,500 mi^2. This is the largest zone of anthropogenic coastal hypoxia in the western hemisphere. Evidence from chemical and biological indicators in sediment cores shows the worsening hypoxic conditions in this LME (Rabalais *et al*. 1996, 2002a). The U.S. EPA has classified the estuaries in the northern Gulf as poor in terms of eutrophication (EPA 2001). In addition, HABs are of concern in this LME. They debilitate fisheries for shellfish and affect tourism in Florida and Texas (Anderson *et al*. 2000).

Inadequate management of sewage in the region has led to sewage contamination of bays, lagoons and wetlands (Wong Chang & Barrera Escorcia 1996, Birkett & Rapport 1999). In some areas, microbiological pollution levels exceed permissible limits (Wong Chang & Barrera Escorcia 1996). For example, high coliform levels (up to 300 faecal coliforms MPN[1]/100 ml), greatly exceeding the sanitary regulation of 14 faecal coliforms MPN/100 ml, have been detected in waters of Mecoacán, Tabasco and Terminos Lagoons. In Galveston Bay, Texas, oysters have been severely affected by pollution, and many public reefs have had to be closed due to organic pollution from municipal sewage (Birkett & Rapport 1999).

Direct discharges and non-point sources of chemical pollutants are a major environmental threat in the Gulf of Mexico LME (Birkett & Rapport 1999). The high use of pesticides in agricultural areas has contributed to considerable levels of these substances in the Mississippi and other rivers. These contaminants ultimately reach the coastal waters. Heavy metals are released into the LME from numerous sources such as municipal wastewater-treatment plants, manufacturing industries, mining and rural agricultural areas. Elevated levels of heavy metals and pesticides have been detected in water and sediments, in some cases exceeding permissible limits (Villaneuva Fragoso & Paez-Osuna 1996, EPA 2001). The oil and gas industry has also had a significant environmental and ecological impact on the LME (Botello *et al*. 1996, Birkett & Rapport 1999). Furthermore, the Gulf is a major thoroughfare for shipping, and accidental oil discharges from tankers and oil installations are a constant threat. The Mississippi River also delivers hydrocarbons to the Gulf, primarily from non-point source runoff. The chronic exposure to oil residues from marine oil production is a significant source of stress on the coastal habitats.

There is evidence of bioaccumulation of heavy metals, petroleum residues and PCBs in the tissue of some finfish and invertebrate species (e.g., Botello *et al*. 1996, Villaneuva Fragoso & Paez-Osuna 1996, Birkett & Rapport 1999, EPA 2001). In 2000, 10 out of

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[1] Most Probable Number

14 fish consumption advisories for the coastal and marine waters of the northern Gulf coast were issued for mercury, with each of the five US Gulf states having one state-wide coastal advisory for mercury in king mackerel (EPA 2001). The widespread incidence of fish diseases (e.g., lymphocytosis, ulcers, fin erosion, shell disease) thought to be related to pollution has been reported in marine and estuarine species in the northern Gulf (Birkett and Rapport 1999). The overall coastal condition for the U.S. part of this LME, according to the EPA's primary indicators is: fair water quality, poor eutrophic condition, poor condition of sediment and fish tissue (in terms of contaminants) and poor condition of benthos (EPA 2001). In addition to the fish consumption advisories, the poor coastal condition has also led to many beach closures throughout the northern Gulf coast, which also has the lowest percentage of approved shellfish growing waters in the U.S. (EPA 2001).

Habitat and community modification: The LME's coastal and marine habitats are threatened by both natural processes and anthropogenic factors and their modification is severe throughout the LME (UNEP, unpublished). Hypoxia in the northern Gulf has reduced the suitable habitat for living organisms and modified the benthic communities in the affected area (Rabalais & Turner 2001). The more stressed community is characterised by limited taxa, characteristic resistant fauna and severely reduced species richness, abundances and biomass. The effects of hypoxia on fisheries resources include direct mortality, altered migration, changes in food resources and disruption of life cycles. Anectodal information from the 1950s to 1960s shows low or no catches by shrimp trawlers from 'dead' waters in this zone (Rabalais *et al*. 1999b).

Wetlands in particular have experienced severe loss and degradation due to coastal development, interference with normal erosional/depositional processes, sea level rise and coastal subsidence (EPA 2001). The EPA coastal wetlands indicator for the northern Gulf of Mexico shows these wetlands to be in poor condition (EPA 2001). The periodic sediment input to the Mississippi deltaic plain has been reduced by the construction of flood control levees and dams upstream, the changing agricultural and urban water-use practices and increasing alteration of the river system for navigation. The suspended sediment load of the lower Mississippi decreased by about 50% during the period 1963-1982 in response to dams built on the Arkansas and Missouri rivers (Meade 1995). Wetlands are being converted to open water at an alarming rate because wetland accretion is insufficient to compensate for the natural process of subsidence. In addition, large areas of wetland have been drained for industrial, urban and agricultural development. Wetland habitats are also being altered by increased salinities due to saltwater intrusion, which is destroying coastal flora. This loss of wetlands also increases erosion by waves and tidal currents and is exacerbated by sea level rise.

The effects of natural processes combined with human actions at large and small scales have produced a system on the verge of collapse. Wetland losses in the U.S. Gulf of Mexico from 1780s to 1980s are among the highest in the nation, with 50% having been lost in this time period (EPA 2001). The rate of coastal land loss in Louisiana, which contains the largest coastal wetland complex in the U.S., has reached catastrophic proportions. Within the last 50 years, land loss rates have exceeded 104 km^2yr^{-1}, representing 80% of the coastal wetland loss in the entire continental U.S. (Day *et al*. 2000).

In the coastal waters of the State of Campeche in Mexico, unregulated fishing, the use of destructive fishing methods, as well as cutting of mangrove for aquaculture and other purposes have destroyed fish habitats and reduced shrimp and other shellfish stocks (Yañez Arancibia *et al*. 1999). The Usumacinta/Grijalva deltaic system is also being modified because of changes in land use and the growing human population in this area.

As a consequence, coastal habitats and communities are being degraded and lost. For example, the populations of some species such as the horseshoe crab (*Limulus polyphemus*) and West Indian manatee (*Trichechus manatus*) have diminished as a result of habitat and community modification in this system. Activities related to the oil industry are also thought to have affected the distribution and abundance of commercially important fisheries resources such as shrimp on the continental shelf and coastal lagoons, particularly in the south of Tabasco and Campeche (Arreguín-Sánchez *et al*. 2004).

The LME's coral reefs are also threatened by natural and anthropogenic pressures. Almost all the reefs of the Florida Keys are under moderate threat, largely from coastal development, inappropriate agricultural practices, overfishing of target species such as conch and lobster as well as pollution associated with development and farming (Bryant *et al*. 1998). Other major threats in the last 20 years have arisen from direct human impacts such as grounding of boats in coral, anchor damage and destructive fishing (Causey *et al*. 2002). Reduced freshwater flow has resulted in increase of plankton bloom, sponge and seagrass die-offs as well as the loss of critical nursery and juvenile habitat for reef species, which affects populations on the offshore coral reefs. Serial overfishing has dramatically altered fish and other animal populations. Alien species introduced on the reefs in the last decade through ship hull fouling or ballast water dumping have placed additional stress on the reefs (Causey *et al*. 2002).

Stresses from distant sources are also involved in the degradation of the region's reefs. Waters from the Mississippi River periodically reach the Florida Keys while Saharan dust has been implicated in the origin of nutrients and possibly disease spores, particularly during El Niño years (Bryant *et al*. 1998). Florida reefs have been repeatedly stressed in the past 25 years by coral bleaching, which has contributed to the dramatic declines in coral cover in the Florida Keys National Marine Sanctuary since 1997 (Causey *et al*. 2002). Disease is also a serious problem. Two of the most important reef-building species (*Acropora palmata* and *A*. *cervicornis*) are now relatively uncommon due to white-band disease, while others have proved particularly susceptible to black-band disease (Bryant *et al*. 1998). Algae continue to dominate all sites, with average cover generally above 75% in the Keys and above 50% in the Dry Tortugas (Causey *et al*. 2002). The Flower Garden Banks off Texas, however, remain amongst the least disturbed coral reefs in the region and can be considered nearly pristine. Nevertheless, these reefs are threatened by atmospheric pollution and effluent discharges from nearby oil and gas development and marine transportation. The reefs off Veracruz in the southwestern gulf are influenced by high turbidity water from the coast and sewage and other effluents from the port and city of Veracruz, resulting in low coral diversity. The reefs on the Campeche Bank suffer from overfishing and the impacts of oil exploration (Almada-Villela *et al*. 2002).

Seagrass habitats have declined dramatically during the past 50 years, mostly because of coastal population growth and accompanying municipal, industrial and agricultural development. In addition, boat propellers have permanently damaged over 120 km^2 of seagrass in the Florida Bay (Causey *et al*. 2002). Loss of seagrasses in the northern Gulf of Mexico over the last five decades has been extensive and ranges from 20% to 100% for most estuaries, with only a few areas experiencing increases in seagrass.

Some experts believe that habitat loss is the greatest threat to the Gulf's biodiversity. Unsustainable resource use is also contributing to species loss in this LME. In 2000, the American Fisheries Society officially identified 11 of the Gulf's 15 managed grouper species as 'vulnerable to risk of extinction'. The only known nesting beach in the world of the Kemp's ridley, the world's most endangered sea turtle, is along the Gulf of Mexico coast. There has been considerable success, however, with the Ridley Head Start

Program and establishment of nests along Padre Island in addition to Rancho Neuvo, Tamaulipas, Mexico. Invasive species are also a major threat to biodiversity. Ballast water discharges from transoceanic vessels are now known to be the single largest source of introduction of aquatic non-indigenous species invasions worldwide and this threat is particularly serious in the Gulf of Mexico LME, since the region contains some of the world's largest ports (Nipper *et al*. 2005).

IV. Socioeconomic Conditions

The coastal areas of the LME are densely populated with about 55 million inhabitants. This population is projected to increase by 144% between 1960 and 2010 (Cato & Adams 1999). The LME is a major economic asset to the three bordering countries, with the value associated with various economic activities adding up to several billions of dollars (Cato & Adams 1999, Adams *et al*. 2004). Commercial and recreational fisheries, tourism and petroleum production are among the major economic activities. The Gulf is also a major source of employment. For example, coastal employment in the five U.S. Gulf states was more than 4 million in 1993 (Cato & Adams 1999).

In 2003, the U.S. domestic commercial landings from the Gulf amounted to about 800,000 tonnes valued at over US$680 million (NOAA/NMFS 2004). Nearly 3.3 million instate marine recreational fishers made about 23 million trips and caught over 160 million fish (excluding Texas) in 2003 (Gulf of Mexico Program 2002). The Gulf accounts for 30% of the U.S. offshore oil production and about 23% of its gas production. More than 80% of the economic activities of each of the six Mexican Gulf states are located in or associated with the coastal zone. These states contribute 12.9% of the total national gross internal product (Sánchez-Gil *et al*. 2004). The tourist industry encompasses thousands of businesses and tens of thousands of jobs worth well over 20 billion US$ annually (Gulf of Mexico Program 2002). Major port facilities and shipping lanes exist in the LME.

Many important ecosystem services derived from the LME are threatened or have already been lost (Birkett & Rapport 1999), with severe socioeconomic consequences. Overexploitation of fisheries has resulted in deteriorating quantity and quality of the catches and the imposition of restrictions and quotas (Birkett & Rapport 1999). Overfishing has also led to reduced revenue from fisheries, user conflicts and loss of employment in the affected states. The socioeconomic impacts of pollution as well as habitat modification and loss are also severe. Analyses of the distribution of shrimp catch on the shelf in relation to hypoxia suggest that the catch of shrimp was consistently low where hypoxia was extensive (Zimmerman & Nance 2001). On the other hand, to date, there are no clear indications of hypoxic effects in fisheries or fish populations in the published literature or data evaluated by Diaz & Solow (1999). Nevertheless, the lack of obvious detrimental economic effects does not preclude the possibility of future ecological and economic disaster, as seen in other water bodies (e.g., the Black Sea) affected by hypoxia (Diaz & Solow 1999).

Of particular concern are the potential health risks posed by marine biotoxins and HABs, fish and shellfish poisoning and pollution. The contamination of seafood by pesticides and heavy metals has led to loss in revenue from the closure of harvesting areas, consumption advisories and risk to human health. This has been accompanied by an increase in the costs of monitoring programmes and ecosystem protection and recovery. Human society and its infrastructure in the coastal zone of the Gulf have already been affected by wetland loss and will face considerably more threats as additional wetlands are lost. Increased vulnerability to storm surge, coastal flooding and shoreline erosion will result in damage to homes and loss of transportation and industrial infrastructure as well as long-term degradation of critical resources such as domestic and industrial water supplies. Coastal wetland deterioration will be devastating to culturally based subsistence users as well as the recreational and tourist economies based on these resources. If the recent loss of wetlands continues, it is estimated that Louisiana will lose about 2,500 km^2 more of coastal marshes, swamps and islands by 2050. The public use value of this loss is estimated to be in excess of US$37 billion by year 2050; the losses associated with cultures and heritage is immeasurable (Louisiana Coastal Wetlands Conservation 1998). Major efforts at addressing the degradation of the Gulf of Mexico LME (see Governance) are expected to reduce or reverse the current trends.

V. Governance

There is a multitude of programmes and policies to protect, restore and enhance the coastal and marine waters and habitats of the Gulf of Mexico LME. For example, the EPA's Gulf of Mexico Program, established in 1988, is conducting research, monitoring, restoration and management projects in selected sites through its National Estuary Program's Habitat Restoration Program and Gulf Ecological Management Sites Program. In 2001, the EPA sent to Congress the final 'Action Plan for Reducing, Mitigating and Controlling Hypoxia in the Northern Gulf of Mexico'. This Action Plan was the culmination of work undertaken by the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force and establishes the blueprint for addressing the hypoxia problem. The U.S. Gulf Restoration Network and the Gulf of Mexico Foundation are engaged in various programmes and projects aimed at protecting and restoring the Gulf's valuable resources (e.g., CWPPRA, CIAP. The National Marine Fisheries Service (NMFS) Southeast Regional Office is responsible for sustainable fisheries management, habitat conservation and protected resources management (Kemmerer *et al*. 1999). This office provides technical and administrative support to the Gulf of Mexico Fisheries Management Council.

In Mexico, the Programme of Ecology, Fisheries and Oceanography of the Gulf of Mexico (EPOMEX) was created in 1990 by the Autonomous University of Campeche. The main focus of this programme is to generate and integrate information for the proposal of management measures, development plans, ecological protection ranking, conservation and sustainable use of coastal marine ecosystems and their natural resources in the gulf. GEF is supporting the project 'A Transboundary Diagnostic Analysis (TDA) and Strategic Action (SAP) Programme for the Gulf of Mexico Large Marine Ecosystem' involving Cuba, Mexico and the U.S. The main objective of this project is to address critical threats to the coastal as well as marine environment and to promote ecosystem-based management of coastal and marine resources in the Gulf of Mexico LME. The expected outputs of this project will be a TDA and the development of a regional SAP for the LME. The full GEF intervention will address the priority transboundary and biodiversity concerns of the Gulf of Mexico LME in the context of fluctuating climate conditions.

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