Part Five

SOCIOECONOMIC ASPECTS OF THE GULF OF MEXICO

TOWARDS INTEGRATED MANAGEMENT OF THE GULF OF MEXICO LARGE MARINE ECOSYSTEM

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WORLD SUMMITS ON SUSTAINABLE DEVELOPMENT: RIO (1992) AND JOHANNESBURG (2002)

The Gulf of Mexico is currently experiencing rapid environmental deterioration leading towards possible collapse on several different fronts. This ecosystem's fragile productive chains are permanently compromised, leaving no use opportunities for future generations. Fisheries, forestry and coastal resources, as well as other production areas such as the oil industry, tourism and agriculture, have affected the ecosystem and also had their productivity affected. The multiple problems identified in the last few decades regarding the marine and coastal environments and the production activities conducted in the Gulf of Mexico are linked to a number of international agreements on resource and environmental conservation. Mexico was one of the signatories of such agreements, but actions to reverse the deterioration have been few and, in general, conducted in an isolated rather than integrated manner.

At the 1992 Rio Earth Summit, the United Nations Conference on Environment and Development (UNCED) adopted resolutions on various aspects of significance for these ecosystems. However, advances of Agenda 21 on these matters have been slow. At present, the implementation of the Johannesburg Plan from the World Summit on Sustainable Development (WSSD), which made a call to the international community to "maintain the productivity and biodiversity of important and vulnerable coastal areas, including areas within and beyond national jurisdiction", opens a window of opportunity for orienting specific actions promoting integrated management of marine and coastal resources and of river basins associated with the Gulf of Mexico. We should also point out that Mexico participates in other alternative commitments made by the world community and global instruments such as the United Nations Convention on the Law of the Sea (UNCLOS, 1982), the Convention on Biological Diversity (CBD), the Global Program of Action for the Protection of the Marine Environment from Land-Based Activities, the United Nations Framework Convention on Climate Change (UNFCCC), the FAO Code of Conduct for Responsible Fisheries (1995), and the most recent agreement, called the Cartagena Protocol on Biosafety (regarding Living Modified Organisms - LMO). These instruments affect the access to genetic resources, biodiversity conservation and reversal of environmental deterioration in different manners. Notwithstanding the existence of these numerous agreements that consider different aspects involving ecosystem conservation, biodiversity and access to genetic resources, their actual implementation in Mexico is slow. This is partly due to intricate legal and normative conditions regarding the environment and to the distance between the role of society and productive users of coastal, marine and river basin natural resources associated with the Gulf of Mexico ecosystem.

GENERAL CHARACTERISTICS OF THE GULF OF MEXICO LARGE MARINE ECOSYSTEM

The Gulf of Mexico Large Marine Ecosystem is located between the east coast of Mexico, the northwest coast of Cuba, and the south coast of the United States of America. It is semi-enclosed with a small entrance and exit in the central-western portion of the Atlantic Ocean, and a connection with the Caribbean Sea towards the south. The coast of the Gulf of Mexico is bordered by 27 large systems (estuaries, bays and coastal lagoons), which serve as areas of refuge, foraging and reproduction for numerous species representative of the most important coastal fisheries. Although the biological richness of these coastal systems and the role they play in the Gulf of Mexico's ecological functions are not fully understood, it is known that the coastal marshes of Tabasco and Campeche are home to 45 of the 111 aquatic plant species reported for Mexico, making them the most important reservoir of such plants in Mesoamerica. Regarding freshwater fishes, more than half of the 500 species known for Central America are found in the coastal wetlands of the Gulf of Mexico. This value as habitat is their greatest contribution to the ecological economy of the Gulf, regardless of their energy and economic links with high-value fisheries (Toledo 1998a).

In addition, river basins in the Gulf of Mexico cover over two-thirds of Mexico's continental landmass and are responsible for 62% of the country's fluvial discharge. Ninety percent of the natural gas and more than 80% of all hydrocarbons are produced on the rich continental shelves of this region (Toledo 1998b). Hydrocarbon production in the Gulf of Mexico exceeds 400,000 tons per day and there is intense traffic of oil tankers transporting more than 5 million barrels a day. Approximately 7 million barrels a year are discharged into the ocean when tanks are washed (Botello *et al.* 1998).

The Gulf of Mexico has been used intensively for maritime transport and has 43 ports that handle 152,458,000 tons of freight (Rivera and Villalobos 2001). The most important are the ports of Veracruz, Altamira, Coatzacoalcos and Progreso.

OVERFISHING, CONTAMINATION AND LOSS OF BIODIVERSITY IN THE GULF OF MEXICO

An integrated ecosystem approach seeks to identify origins of existing problems and their relationship to the production activities that cause them. Some of the most relevant factors that have a direct effect on environmental deterioration in the Gulf of Mexico are overfishing, pollution sources and loss of biodiversity due to the introduction of invasive aquatic species.

OVERFISHING

The health status of populations subject to fishing in both marine and continental waters has been widely documented (Arreguín *et al.* 1999; Shipp 1999; Fernández *et al.* 2000; Rivera and Villalobos 2001; Álvarez-Torres *et al.* 2002; Hernández and Kempton 2003). These authors have indicated that commercially important fish, crustacean and mollusc species in the Gulf of Mexico are overexploited or in a state of severe deterioration. This is mainly the result of an increase in fishing effort and commercial fisheries overcapacity (latent fishing effort), and is translated into a clear decline in resources, as well as impacts on non-target species, benthic communities and the ocean bottom (INP 1998, 2001; SEMARNAP 2000a).

Mexican industrial fisheries are concentrated on the Pacific region and in the Gulf of California. In the Gulf of Mexico the most important industrialized fishing fleet is for shrimp fisheries and is located mainly in the states of Tamaulipas and Campeche. On the other hand, small and medium-sized artisanal fishing boats are widely distributed around all the country's coasts. A little less than half (46%) of the artisanal fishing fleet is located on the coast of the Gulf of Mexico. Yearly growth of the fishing fleet amounts to 1,800 new boats, so that the cumulative growth rate for the 1970-2001 period was 700% (SAGARPA 2002). Income derived from fishing is not evenly distributed and exhibits a fivefold difference between the average income of fishermen in the Gulf of California and in the Gulf of Mexico (INEGI 2000).

The three most important commercial or industrial marine fisheries in the Gulf of Mexico by catch volume in the 2001 were shrimp (6,603 tons), octopus (6,587 tons) and grouper (6,312 tons). These are the most valuable fisheries for the Gulf of Mexico for the gross value of their catches. These marine resources reached a production of 13,722 tons, 6,516 tons and 7,837 tons, respectively, over 10 years ago (1991). In the case of shrimp fisheries those figures represent a drop of over 50%, perhaps due to the increase in the fishing effort applied to this resource, which currently involves 742 boats along the entire coast of the Gulf of Mexico, especially in Tamaulipas-Veracruz, Campeche and Contoy (Caribbean). Octopus fishing is carried out with 514 boats on the Yucatán and Campeche shelves, while grouper is fished by 539 boats on the Yucatán shelf.

The leading artisanal fisheries in the Gulf of Mexico, according to statistics for the year 2001, were octopus, with 13,998 tons caught with 2,418 small craft, shark, with a total catch of 8,308 tons, and shrimp, with 4,419 tons. For the latter two there are no records on the number of boats involved in the activity. Similar to industrial fisheries, catch levels were 12,904 tons for shark and 6,576 tons for shrimp, whereas octopus fisheries exhibited an increase in the catch effort, with 8,815 tons recorded in 1991 and 12,503 tons in 1996.

CONTAMINATION

The Gulf of Mexico receives discharges from the major rivers of North America; the Mexican portion of the Gulf receives 60% of the country's river discharges and has 75% of its total area of estuarine environments (Botello *et al.* 1998). Virtually all the settlements in river basins emptying into the Gulf of Mexico, as well as important coastal cities such as Tampico, Tuxpan, Veracruz, Coatzacoalcos, Ciudad del Carmen and Campeche discharge untreated domestic waste in their waters. Densely populated areas far from the high plateau use this region as a final discharge site. For this reason the Gulf of Mexico exhibits marked and evident bacterial contamination from the northern part of Veracruz in the Laguna Tamiahua to the southern portion of that state in the Río Coatzacoalcos River, as well as in the Laguna del Carmen-Machona in Tabasco, Laguna de Términos, Laguna Balchacah and Laguna Puerto Rico and the Boca de Atasta in the State of Campeche. Analyses of sediments, organisms and the drinking water network of this region's main localities reveal high and constant bacterial contamination by total and fecal coliforms at sites near urban centers, as well as in areas with low population density (Wong and Barrera 1998).

The phenomenon of hypoxia in the Gulf of Mexico, documented by Rabalais *et al.* (1991, 1995), occurs repeatedly affecting large areas of the northern part of the Gulf near the continental shelf every summer. Due to those circumstances, loss of macrobenthic fauna diversity and abundance has been recorded with oxygen decreases to 0.5mg/L, close to anoxic conditions.

Moreover, high hydrocarbon concentrations have been recorded (Botello *et al.* 1998) in the Río Tuxpan River, Port of Veracruz, Laguna del Ostión, and Coatzacoalcos and Tonalá rivers in the State of Veracruz; del Carmen-Machona and Mecoacán lagoons in Tabasco; Laguna de Términos system in Campeche; and the Laguna Bojórquez in Quintana Roo. Fifty percent of the coastal systems studied exceeded the allowable limit of 10 parts per billion (ppb) of hydrocarbons established by UNESCO for uncontaminated surface waters, with 48 ppb detected in the Laguna de Términos. Records of hydrocarbons in the open sea both in the Gulf of Mexico and the Caribbean Sea are significantly higher than the normative value of 10 ppb. Campeche has an average of 48 ppb, Veracruz, 15.1 ppb and the Caribbean, 15 ppb. Waters in the Gulf of Mexico exceed the allowable limit for contaminated water to a greater extent than the Wider Caribbean. Recent studies indicate the presence of polycyclic aromatic hydrocarbons (PAHs) in both sediments and organisms (fish, molluscs and crustaceans), which implies health risks due to these compounds' elevated toxicity and carcinogenic potential (Botello and Ponce 1998). Lagoons in the State of Tabasco exhibit levels below the standard established by UNESCO and may be considered not contaminated by hydrocarbons (Botello *et al.* 1998).

Gold-Bouchot *et al.* (1999) reported that average total hydrocarbon concentrations in sediments from the Santa Anita, Tres Brazos, del Carmen-Machona, Mecoacán, Pom lagoons and Laguna de Términos were below the accepted value of 70 μg/g (dry weight), but it is exceeded in the Laguna Julivá, where there are oil wells. This indicates that the presence of oil in the region is obvious and although hydrocarbon concentrations are relatively low, their presence continues to be a cause for concern in the majority of the studied lagoons.

LOSS OF BIODIVERSITY

The loss of biodiversity is attributed to different factors, among which the introduction of aquatic exotic species stands out as one of the most critical environmental hazards currently faced by aquatic habitats, species and biodiversity in general, with serious ecological and economic impacts. The impacts of these introductions vary according to geography, time and species (Courtenay 1995). It can be added that the lack of records on invasive species is a result of a lack of biological, taxonomic and biogeographic data.

Maritime transport (ballast water from boats) and aquaculture are currently considered to be the most important vectors for the introduction of aquatic invasive species, as well as intentional introductions of exotic species (algae, molluscs, crustaceans, fish) for production purposes in new areas or as accidental introductions (escapes). In either case transmission and transfer of associated species can occur, including disease vectors. Only two of the marine species cultured in Mexico are native. Several species were deliberately spread under the auspices of federal programs. While some introductions date back over a hundred years (*e.g.* carp and trout), other species were only introduced recently (*Procambarus clarkii*, *Cherax quadricarinatus*), despite various reports on certain numbers of viruses, bacteria, fungi, protozoa and metazoa (Owens *et al.* 1992; Edgerton *et al.* 1995; Álvarez-Torres *et al.* 1998), which in some cases, such as Ecuador, have already caused severe outbreaks of epizootic disease and the presence of exotic pathogens (Romero and Jiménez 2002). Because of the great interest in these species, particularly in the State of Veracruz and others bordering the Gulf of Mexico, it would be advised that environmental authorities verify the current situation in terms of compliance with existing norms regarding their introduction, mobilization and culture. Authorities need to ascertain that existing aquaculture farms operate according to such norms and have appropriate infrastructure and safety measures in place to avoid escape and dispersion of introduced species into the aquatic ecosystems of the Gulf of Mexico.

The movement of species outside their natural distribution range for cultivation purposes is a determining vector in the dissemination of exotic species, and pathogenic agents in particular. In the Gulf of Mexico there are 18 farms and a total of 884 hectares devoted to culture of the Pacific white shrimp (*Litopenaeus vannamei*), using hundreds of millions of organisms in every culture cycle. On the slope of the State of Tamaulipas there are 13 farms and 697 hectares of cultures, whereas in the states of Veracruz, Tabasco, Campeche and Yucatán there is a modest number of farms, with an approximate total of 190 hectares (SAGARPA 2002). Although there are laboratories producing shrimp larvae and postlarvae on the coast of the Gulf of Mexico, shrimp farming in the Gulf states depends on the supply of shrimp postlarvae from the Pacific. Therefore, strict supervision of the sanitary conditions of these shrimp in culture farms is necessary, to avoid transmission of diseases and epizootics from this species to Gulf species (Álvarez-Torres *et al.* 2000). Regarding pathogens introduced in Mexican national waters of the Gulf of Mexico through aquaculture, there is the rapid spread of the Taura Syndrome Virus (TSV), first detected in Ecuador in mid-1992, reported a year later in Peru and Colombia, in 1994 in Honduras, Guatemala, El Salvador, the U.S.A. (Hawaii and Florida) and Brazil, and on the coasts of Mexico in early 1995 (Álvarez-Torres *et al.* 1996). An example of its devastating effects can be found in the records of shrimp culture production in the State of Sinaloa, which decreased 31.2% in 1996 relative to 1995, due to this disease (Álvarez-Torres *et al.* 2000). Other viruses and pathogens have been introduced via aquaculture activities, *e.g.*, white spot. Scientific evidence available throughout the world shows the existence and detection of at least six variants of the White Spot Syndrome Virus (WSSV) originating in six geographic regions: China, India, Thailand, Texas, South Carolina and a last one detected in a zoo in the United States, with which Qiong *et al.* (1999) conducted experimental infections that determined the degree of pathogenicity using the Pacific white shrimp (*L. vannamei*) and the Gulf of Mexico pink shrimp (*Farfantepenaeus duorarum*). In this experimental study rapid cumulative mortality rates of 100% were recorded in Pacific white shrimp (*L. vannamei*) and 35-60% in pink shrimp (*F. duorarum*). The White Spot Virus coming from Texas proved to be the most virulent. White spot and yellow head viruses have been reported since 1995 in culture farms in Texas where they have caused high mortality rates, which were confirmed by studies on infectivity, Transmission Electron Microscopy (TEM) and Polymerase Chain Reaction (PCR) (Nunan *et al.* 1998). This reveals that another possible pathway for the introduction of these viral diseases to the United States is through frozen shrimp imports. During the Meeting of the Mexican National Aquaculture Health Program organized by the then Dirección General de Acuicultura (General Direction of Aquaculture) of the Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP; Secretariat of Environment, Natural Resources and Fisheries) in October 1998, Garza and collaborators at the University of Tamaulipas reported the presence of the Taura Syndrome Virus and of *Baculovirus penaei* in Pacific white shrimp (*L. vannamei*) and Pacific blue shrimp (*Litopenaeus stylirostris*) cultured in farms in the State of Tamaulipas, as well as in white shrimp on the coast of the Gulf of Mexico. Results of analyses conducted on cultured *L. vannamei*, collected since December 1997 by the Instituto Nacional de la Pesca (INP; National Fisheries Institute) in farms on the Gulf of Mexico, show the presence of abnormalities and malformations due to pathogens and congenital defects (Chávez-Sánchez *et al.* 2002). The presence of the Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV) originating from the Pacific coast has even been recorded in samples of white shrimp (*Litopenaeus setiferus*), brown shrimp (*Farfantepenaeus aztecus*) and pink shrimp (*F. duorarum*) of the Gulf of Mexico (Chávez-Sánchez *et al.* 2002).

The presence of exotic Asian viruses causing the white spot and yellow head syndromes may have a devastating impact because the defense mechanisms of American shrimp are unable to recognize them. The white spot syndrome was first reported in 1992 in Taiwan and northern China. During 1994 and 1995 it spread to Thailand, India, Japan, Korea, and later Texas, USA. For that reason, the SEMARNAP published two Official Emergency Standards, NOM-EM-001-PESC-1999 and NOM-EM-003-PESC-2000 (SEMARNAP 1999, 2000b) to prevent its introduction in Mexico. The South Carolina Department of Natural Resources has classified the white spot syndrome virus in Category I, i.e., as a pathogen with a potential risk of reinfection or magnification of prevalence in infected wild populations by acute outbreaks in shrimp culture facilities, with no treatments for prevention and control available to this date. The Yellow Head Virus (YHV) and white spot diseases were detected in farms in South Carolina and in 1998 positive cases of white spot were detected in *L. vannamei* cultures, as well as in wild *L. setiferus*. Even more serious is the fact that Sandifer (1998) has identified WSSV genetic material in samples of other wild crustaceans in the same region, such as the shrimp *Palaemonetes* sp. and some crabs such as *Uca* spp., *Callinectes sapidus* and *Menippe mercenaria* (Álvarez-Torres *et al.* 2000), exhibiting the huge potential of transmission to other crustacean species native to the Gulf of Mexico.

Other introductions are attributable to the aquarium industry (e.g., *Melanoides tuberculata*). Due to their high competitiveness, the majority of exotic species has spread over more than half of Mexico’s territory. Other concurrent threats are the transfaunation of exotic and native species to different parts of the country, importation of special virus-resistant varieties that may be carriers of other diseases, culture of marine species in brackish or fresh water (e.g., shrimp), culture of freshwater species in brackish or salt water (e.g. tilapia) and natural, intentional or accidental spread of species originating from other countries (e.g., Australian freshwater lobster *Cherax*).

Finally, considering that both the aquaculture and aquarium industries generate millions of dollars, every introduction of a new species ought to cost them at least a small fraction of that, including research to determine whether the species they wish to introduce are potentially invasive (Mendoza 2001).

Procambarus clarkii is a species native to the central and southern United States and northeastern Mexico. The introduction of *P. clarkii* to several Mexican states was promoted with the consequent displacement of native species, partly because it is a carrier of a fungal disease caused by *Aphanomyces astaci*, which devastated a large part of the European freshwater crustaceans. The only species recorded in the San Juan river basin in 1982 was the native species *Procambarus regiomontanus*. In 1985 three males and one female of *P. clarkii* were recorded coexisting with *P. regiomontanus*. From 1987 to 1989 *P. clarkii* increased in numbers at a spectacular rate, leading to the sudden collapse of *P. regiomontanus* populations. Observations made in 1992 revealed that *P. clarkii* represented between 95% and 100% of the freshwater shrimp present in the region (Rodríguez-Almaráz and Campos 1994). Nowadays, thanks to its dispersal ability as well as its continuous introduction by humans, *P. clarkii* is present in all the states of northern Mexico (Campos and Rodríguez-Almaráz 1992).

Thiara snails (*Thiara granifera* and *Melanoides tuberculata*), capable of reproducing both sexually and by parthenogenesis and whose dispersal is facilitated by migratory birds, have established themselves widely across different countries in the American continent. In the last few years they have spread to 16 states in Mexico, which has caused a decrease and even the disappearance of various native gastropod populations (Contreras-Arquieta and Contreras-

Balderas 1999). Colonization rates greater than 1 km/year have been registered (Pointer *et al.* 1998) and densities of up to 51,650/m^2 have been recorded in some regions. This represents a grave threat since they are intermediate hosts of trematodes that have affected at least 39 species from 10 fish families in Mexico (Scholz *et al.* 2003). Some of these species are endangered, while others are important in aquaculture or sport fishing. Nevertheless, the most serious risk is that among its definitive hosts are certain bird species and even humans.

TOWARDS THE INTEGRATED MANAGEMENT OF THE GULF OF MEXICO LARGE MARINE ECOSYSTEM

In a global scale there are 64 large marine ecosystems responsible for most of the world's annual food production from fisheries. These are interconnected marine and oceanic ecosystems, from the river basins to coastal zones containing lagoons and estuaries, the continental shelf, enclosed and semi-enclosed seas and the external edges of the most important ocean currents. Alarming data on the overexploitation of fisheries and marine resources, habitat destruction, accelerated contamination and severe deterioration of coastal and marine ecosystems have already been reported for the Gulf of Mexico.

Given that scenario, it is necessary to adopt new integrated management schemes to organize human activities in these ecosystems, with the objective of avoiding more serious economic and social consequences. Thus, an assessment methodology consisting of five modules has been used, with the objective of encouraging countries which share a geographic area within a Large Marine Ecosystem to adopt practical governance strategies based on integrated management of the ecosystem. This approach reaches out and encourages the participation of interested users, as well as that of the academic community, and also implies the development of institutions for adaptive management (Duda and Sherman 2002).

The integrated ecosystem management concept or approach seeks to ensure intergenerational sustainability of the ecosystem assets and services or processes, including hydrological and productivity cycles. From the fisheries perspective it has been concluded that maintenance of fisheries production requires the conservation of the ecosystems that produce these resources. This approach represents a change in paradigm, going from a single species vision or short-term sectorial thematic approaches currently widely used, to a broader vision entailing an integrated ecosystem management approach that moves spatially from small to larger scales and from short-term to long-term management practices.

The integrated ecosystem management approach acknowledges the interconnections between living and non-living systems, as well as with humans and economic and social systems, considered as part of the ecosystem. Specific studies on the major forces that generate changes in biomass production have been conducted as part of this approach. For instance, research has been done on changes in biodiversity among dominant species in fish communities in a Large Marine Ecosystem as a result of overexploitation, natural climate and environmental changes or coastal pollution (Sherman 1999).

MODULAR INTEGRATION OF INFORMATION

A five-module approach to the integrated assessment and management of a Large Marine Ecosystem has proven to be useful in several marine ecosystems. These modular integration processes are adapted to specific situations of the Transboundary Diagnostic Analysis and

Strategic Action Plan for groups of countries sharing a Large Marine Ecosystem. They are based on available information and capabilities, and are critical for integrating science and management in a practical way and to establish governing regimens suitable for a particular situation. The five modules (productivity, fisheries resources, contamination/ecosystem health, socio-economics and governance) have been adjusted for use in several demonstration projects in large marine ecosystems.

PRODUCTIVITY MODULE

Runoff from rivers emptying into the Gulf of Mexico both in its northern portion, in the United States of America, and in its central and southern portions, in Mexico, has a marked influence on the system's productivity, overall hydrological dynamics and variability of discharges into the Gulf. However, the aggregate effect of discharges from the Papaloapan, Coatzacoalcos and Grijalva-Usumacinta rivers is less than that of the Mississippi River on the entire northern Gulf of Mexico (Rabalais *et al.* 1999), whereas on the upper Mexican coast discharges from the Rio Grande, Soto la Marina, Pánuco and Tuxpan rivers influence the hydrology of the inner shelf and also supply sediments to the outer region of the western Gulf of Mexico (Escobar and Soto 1997).

Productivity can be related to the carrying capacity of an ecosystem for supporting fisheries resources. Measuring an ecosystem's productivity can also serve as a useful indicator of increased coastal eutrophication problems. In several large marine ecosystems excessive nutrient loads in coastal waters have been correlated with algal blooms leading to mass mortality of living resources, emerging presence of pathogens (cholera, vibrio, red tide, toxins) and explosive growth of non-native species.

The Gulf of Mexico Large Marine Ecosystem is an important center of marine biodiversity, production of sea food, as well as oil and gas. It is distinguished by its bathymetry, hydrography, productivity and trophodynamics, with an average annual productivity of 300 g C/m^2/year. The interaction of numerous processes such as tides, upwellings, meteorological forces, regional circulation, topographic effects, rivers and cyclonic circulation currents make it more difficult to comprehend the processes controlling primary productivity in the Gulf of Mexico. Nevertheless, it is possible to generalize some aspects that define such productivity. There is a broad spectrum of productivity ranging from the eutrophic conditions of estuarine systems and coastal waters to oligotrophic conditions of deep waters, so that the productivity in coastal waters is remarkably variable (Lohrenz *et al.* 1999). Many are the questions concerning the factors that determine the Gulf of Mexico's primary productivity. It is critical to have information on nutrients input mechanisms in order to identify limiting nutrients affecting production in different regions and periods. The effects of nutrients should be examined within the context of other important environmental and ecological variables (light, availability, grazing) to enable the prediction of the ecosystem's responses to natural and anthropogenic changes.

FISHERIES RESOURCES MODULE

Changes in biodiversity among dominant species in a fish community of a large marine ecosystem have resulted from overexploitation and natural environmental changes caused by climate change or coastal pollution. This module includes assessments of independent deep trawling fisheries, acoustic evaluations for pelagic species and to obtain time series and analyze changes in fish biodiversity, as well as in abundance. This can be evaluated in real time.

Despite its low level of primary productivity, the Gulf of Mexico supports one of the world's most important reservoirs of fish, seabird and marine mammal biodiversity and biomass. However, its productivity is at risk due to overfishing to a degree at which fisheries exhibit evidence of overcapitalization and shifts towards trophic levels that generate changes in the structure of food chains, which result in serious economic losses.

CONTAMINATION AND ECOSYSTEM HEALTH MODULE

Contamination has been one of the main reasons why there have been changes in biomass and productivity. Ecosystem health is a concept attracting broad interest, but its scientific definition is problematic. In order to be healthy and sustainable an ecosystem must maintain its metabolic activity level and internal structure and organization, as well as be resistant to external stresses over relevant time and spatial scales. Ecosystem sampling strategies focus on parameters related to overexploitation, protection of species through authorities and legislation, as well as by other biological factors and physical components on the base of the food chain.

The geological substrate of the Gulf of Mexico Large Marine Ecosystem contains rich deposits of oil and gas, but this benefit brings the threat of pollution. On the other hand, the natural beauty of the coastal region has also allowed the development of a significant tourism industry along a large portion of the gulf. This industry is also threatened by anthropogenic activities such as oil extraction and increased urbanization.

In this module concerned with pollution and ecosystem health, fish, benthic invertebrates and other biological indicators are used to measure the effects of contamination on the ecosystem. These include the pathological assessment of fish, monitoring of contaminants in the water column, the substrate and selected groups of organisms, as well as their effects on estuaries and adjacent areas. The implementation of protocols to evaluate the frequency and effect of harmful algal blooms, emerging diseases and numerous other problems is included in this module. Finally, the Gulf of Mexico represents an important opportunity to monitor climate change in relation to cyclonic currents and the advection and transport of nutrients from the discharges of rivers that empty into the Gulf of Mexico.

SOCIO-ECONOMIC MODULE

This module is characterized by a greater emphasis on the practical application of scientific evidence for the management of a large marine ecosystem. Explicit integration of economic analyses with scientifically based assessments is supposed to ensure that prospective management measures will have a reasonable cost. Economic and policy analysts should work hand in hand with ecologists and other scientists to identify and assess management options that are both scientifically credible and economically feasible regarding the use of ecosystem assets and services.

The impact of human activities is the natural point of departure to characterize the ways in which the ecosystem is affected and the expected sensitivity of these functions to types and levels of human activity. Population growth dynamics, coastal development and land-use practices in river basins are clear examples. Integrated work among natural and social sciences experts is necessary to distinguish apparent effects, such as eutrophication associated with red tide events or changes in fish populations' structure, which are confused by complex cycles or dynamics in the natural system itself. Moreover, it is necessary to clearly separate and quantify activities that affect the natural system, such as municipal water discharges, agricultural waste and fisheries effort. Similarly, we have to evaluate impacts and predict economic effects derived from the uncontrolled degradation of natural systems, as well as demonstrate the advantages and benefits of integrated management. Our initial analysis should be centered in the social and economic sectors that will suffer the greatest effects, such as fisheries, aquaculture, public health, recreation and tourism.

In terms of ecosystem services, it is also necessary to conduct an assessment and give special consideration to how natural systems generate economic benefits. Many of these environmental services and assets provided by natural systems are not commercialized in markets or included in those assessments, but they should not be overlooked. Finally, it is necessary to evaluate the above-mentioned findings along with the scientific characterization of the Gulf of Mexico Large Marine Ecosystem within a framework of integrated research and analysis, which will allow the full evaluation of human practices, their effects, and management options for the region. This is a novel work method in recent research on the human dimension of global environmental change and human interactions with natural marine systems.

GOVERNANCE MODULE

As a result of Mexico's participation in the Earth Summit held in Rio de Janeiro in 1992 and in the more recent World Summit on Sustainable Development in Johannesburg in 2002, specific actions have been agreed upon. They include compliance with the mandate of restoration of overexploited marine populations to achieve maximum sustainable yields, the use of the ecosystem approach, and determination of manners to increase and manage current marine protected areas while a restoration mechanism for them is established and implemented.

This module is based on experiments performed for the integrated management of various large marine ecosystems. Several agreements have been reached for this purpose between the Ministries of Fisheries, the Environment, Energy, Mining, Economics, Finance and Foreign Affairs, among others, of the countries surrounding a large marine ecosystem. These have the objective of initiating the joint assessment of resources and management activities as a part of institution-building. Therefore, it is necessary to explore the governability profiles of large marine ecosystems to determine their usefulness and promote long-term sustainability of ecosystem resources.

APPLICATION OF THE LARGE MARINE ECOSYSTEM APPROACH

Mexico, Cuba and the U.S.A. have become increasingly aware of the threats, risks and other issues related to the management of the Gulf of Mexico Large Marine Ecosystem. Among these the deterioration of coastal areas adjacent to urban centers due to pollution, habitat loss and unsustainable exploitation of marine and coastal natural resources stand out.

As mentioned throughout this chapter, the most relevant aspects in Mexico are related to overexploitation by both the industrial and artisanal fisheries sectors, in the absence of long-term regional actions and agreements for the achievement of shared sustainable extraction. Among the most outstanding consequences are an increase in algal blooms, low oxygen events, oil spills, boat groundings on delicate coral reefs and continuous oil exploration and contamination along the coast and beyond, with the respective risk of contamination threats to coastal and marine biodiversity in a basin that is highly vulnerable to storms and fluctuating climate conditions. An apparent rise in the frequency of marked environmental changes in this ecosystem is evidenced by fluctuations in the distribution and abundance of fish, birds and mammals. This causes serious problems requiring different management levels for coastal and marine areas of the Gulf of Mexico Large Marine Ecosystem.

The modular approach for large marine ecosystems is designed to link scientific assessments to states of change of coastal ecosystems, with the objective of supporting long-term sustainability and environmental quality. These efforts are geared towards intrasectorial integration in coastal productivity, fisheries and ecosystem contamination/health relative to socio-economic benefits and government systems. The application of such assessments within the sphere of an ecosystem and its management is partly supported by funds from the Global Environment Facility (GEF) in collaboration with the national governments of the participating countries located within the boundaries of any one of the large marine ecosystems in Asia, Africa, Central and South America and Eastern Europe.

GEF’s operational strategy calls for the development and implementation of projects within the International Waters Program (IW), that can attain global benefits, to be implemented by countries with a more structured approach to restore and protect the environment in international waters. The goal of the International Waters Program is to give countries the necessary support to make pertinent changes in human activities carried out by different sectors, to promote sustainable maintenance of a particular body of water and the numerous basins of each country. GEF has given special priority to the change of sectorial policies and activities responsible for the most important and serious basic causes of transboundary environmental concerns. It determines the baseline and additional actions needed to modify sectorial policies or activities and to find base investments, so that GEF can fund incremental costs of the additional measures agreed upon. One of the central areas of GEF funding is geared to mitigating stress factors on Large Marine Ecosystems (LMEs) and fostering priority actions to improve environmental quality and sustainable development of resources within an LME, which are important for economic growth and security of food supplies in developing countries in Asia, Africa, Central and South America and Eastern Europe (Duda and Sherman 2002).

Based on the above, Mexico, USA and Cuba submitted a project to GEF in 2000 for the Integrated Management of the Gulf of Mexico Large Marine Ecosystem. Its initial phase (2002), called PDF-B (Project Development Fund), was approved. This phase is expected to develop a Transboundary Diagnostic Analysis (TDA), which will serve as the basis for a Strategic Action Plan (SAP). This will be the basis for a 5-year long Large Marine Ecosystem Project. During this period it will be feasible to achieve the mentioned modular integration, making use of the great mass of existing information on this ecosystem and linking each of its components, with the objective of accomplishing its integrated and sustainable management.

CONCLUSIONS

Twelve percent of Mexico’s population lives in coastal states and by the middle of the 21st century at least one out of every five Mexicans will depend directly or indirectly on the resources of the Gulf of Mexico. If Mexico succeeds in structuring a sustainable social project during the coming years, a large proportion of the natural capital required to reach its goals will be found in the Gulf. Nevertheless, one of the most critical elements in this pathway will probably be the deep contradiction existing between the speed of disturbances by human activities and the slow rate of control and reaction to changes. The challenge is greater when we face a highly interconnected, fragile and vulnerable ecosystem. Likewise, we can not ignore the contradictory political, commercial and other interests regarding the Gulf of Mexico's marine and coastal resources. These aspects clearly reveal the problems linked to the deterioration of environmental quality in the Gulf of Mexico. Hence the importance, according to an integrated vision, of undertaking local, national and regional actions that lead to joint solutions for the integrated management of the Gulf of Mexico Large Marine Ecosystem.

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