Monitoring and Ecosystem Indicators in the Gulf of Mexico and Mexican portion of the Caribbean Sea

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Dr. Norma Patricia Muñoz Sevilla
Secretary of Research and Postgraduate Studies
National Polytechnic Institute
Oceans and Coasts Ecosystem Health: Priority Issues in the Gulf of Mexico and Mexico’s Caribbean Sea

1) POLLUTION
   a. Hypoxia
   b. Nutrients
   c. Eutrophication & algal blooms
   d. Oil spills
   e. Microplastics

2) LIVING MARINE RESOURCES
   a. Illegal fishing, Ghost fishing, IUU
   b. Invasive species, noise pollution

3) CLIMATE CHANGE (Hydrometeorological extreme events, hurricanes, flooding, sea level rise, erosion, storm surge)
Pollution is not just hazardous chemicals--

Pollution -“the introduction by man, directly or indirectly, of substances or energy into the marine environment, resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fisheries, impairment of quality for use of seawater, and reduction of amenities.”

(GESAMP, Joint Group of Experts on the Scientific Aspects of Marine Pollution, a United Nations sponsored advisory group)
The list of pollutants grows, many are persistent, and they influence social and natural ecosystems, especially in populated, coastal urban areas.

- Organic loading, waste products
- Greenhouse gasses
- Pathogens
- Petroleum hydrocarbons
- Polycyclic aromatic hydrocarbons
- Halogenated hydrocarbons
- Heavy metals
- Nutrients
- Radionuclides
- Endocrine disruptors
- Litter
- Light
- Noise
Developing indicators for the Gulf of Mexico

Drivers
Natural & Societal
These are the fundamental forces

Pressures
Human activities
natural processes,
These are what cause stressors

Stressors
Anthropogenic and Natural,
These are what the ecosystem sees

State Impacts
Condition of the environment
Impacts are how the State differs from the Goals

Response
What society does.
Responses reduce, mitigate or adapt to impacts

Economic
Fishing Overcapacity, Subsidies, Illegal, Unreported, Unregulated fisheries

Demographic & Societal Drivers
Global demand for food, growing Population,

Natural Drivers

INDICATORS

Fishing
Aquaculture
Agriculture, Oil exploration, Coastal development, Transportation, Petrochemical, Industry and Tourism

Chemical
Oil & Chemical Spills, Air pollutants, Nutrient inputs, Pesticides, Xenobiotics

Physical
Habitat alteration, turbidity, sedimentation, salinity changes, flooding

Biological
Invasive species, overfishing, pathogens, disease, HABs

INDICATORS

Quantity Structure, Quality, Functioning
Impacts on the Ecology

Protection, Control, Economic Instruments, Participation

INDICATORS

Impacts on the Economy

INDICATORS

Impacts on the Society

INDICATORS
Identified main priorities and challenges under a climate change scenario

Sea Level Rise
Flooding

Storm surge
Marine Transgression

Hurricanes

Pollution HABs,
Hypoxia, Marine debris

Erosion
Sediment management

Ocean acidification

Invasive species
Nitrogen Inputs to the Mississippi Watershed

Goolsby et al. 1999
Figure 1. The frequency of mid-summer hypoxia (oxygen < 2 mg l\(^{-1}\)) over the 60 to 80 station grid on the Louisiana and Texas shelf during the summer from 1985 to 2008. Stations C4, C6B, and C8 are labeled on the C transect. Modified from Rabalais et al. (2007).
Extensive, Severe Low Oxygen Waters

Figure 7. The measured and estimated size of the hypoxic zone from 1979 to 2012 and the predicted size for 2014.

The predicted hypoxic area is about the area of Connecticut. If the area of hypoxia becomes this large, then it will equal about three times the size of the goal of the Hypoxia Action Plan (HAP; less than 5,000 km²).
Coastal Condition Index

Five modules

- Water Quality
- Sediment Quality
- Benthic community
- Coastal habitat
- Fish Contaminants

Figure 4. Percentage of coastal area of Gulf Coast region achieving each ranking for all indices and component indicators (EPA 2012).
Gulf of Mexico LME Program
Terminos Lagoon Pilot Monitoring

- Stations were probabilistically assigned to each zone
- Roughly proportional to surface area
- 45 sampling stations total

Fig. 3. Overall condition of the Terminos Lagoon.
Harmful Algal Blooms

1) Early detection
2) Prediction of duration and trajectory
3) Timely access to information on past events and environmental variables
4) Identify environmental conditions that favours HABs to occur

- Complementary tool for monitoring and to identify possible occurrence, its intensity and movement
- Foster wide coverage in short periods of time
**Optic Properties**

**Ligth absorption**
- **Phytoplankton**: 443 y 615 nm
- **Detritus**
- **(CDOM)**
- **Water**
Algal blooms detection using ocean color images

Steidinger y Haddad (1981): Observed spot with sensor CZCS, associated to *Karenia brevis*.


Hu *et al.* (2005): Combination of fluorescense images (FLH), upgraded real color (ERGB) & Chl a to detect red tides.


Cannizzaro *et al.* (2008 y 2009): Detection technique with Chl a, FLH & retrodispersion for *K. brevis* blooms

Classification criteria:

\[
\text{chl } a > 1.5 \text{ mg m}^{-3}, \quad \frac{b_{bp}(550)}{b_{bp}} \text{(Morel, 1988)} < 1, \quad \text{FLH} < 0.1 \text{ mW cm}^{-2} \mu \text{m}^{-1} \text{ sr}^{-1}
\]
Gulf of Mexico Dynamic Regionalization

1) Oceanic Region
2) Loop current
3) Caribbean Sea
4) North Oceanic Transition
5) US Platform
6) Texas-Louisiana
7) Alabama-Florida
8) South Oceanic-Coastal Transition
9) Veracruz-Tabasco
10) Campeche Sound
11) Yucatan

nlw412: yellow substances signal associated to the coast
nlw488: absorption of Chl a without the CDOM signal
4. Discussion

The dynamic nature of regions is a natural consequence of aqueous media due to the modification of association intensities.
Algal blooms preliminary bio-optic properties study

1er phase: 15 stations different conditions & type of blooms
2da phase: severe HAB, pre-determined monitoring using satellite images

Results:

- Preliminary description optical behaviour for AB del comportamiento óptico de los FA
- Viabilidad de identificar florecimientos por satélite
- Protocolo metodológico de muestreo y recomendaciones
Deepwater Horizon Sequence
Deepwater Horizon Sequence

Map showing the location of the Deepwater Horizon incident site in the Gulf of Mexico, with areas shaded to indicate the extent of oil spill. The map includes a forecast for May 2, 2010, with areas marked as light, medium, or heavy oil spill regions. The map also highlights critical birding, breeding, and stopover areas for birds.
Oilmageddon Sequence and its Transboundary consequences
Oil Spill, BP managed Deepwater Horizon, Macondo Platform (2010)
LIVING MARINE RESOURCES

a. Marine litter
b. Illegal fishing
c. IUU
d. Invasive species
GLOBAL Challenge; Biodiversity loss
Marine litter (micro-plastics), habitat loss
Biodiversity Loss

Illegal fishing, shark finning, (pollution, noise)
LION FISH INVASION
(PTEROIS VOLITANS)
CLIMATE CHANGE AND EXTREME METEOROLOGICAL EVENTS

a. HURRICANES,
b. SEA LEVEL RISE,
c. FLOODS,
d. EROSION,
e. STORM SURGE
Hurricanes, storm surge, flooding, etc.
STORM SURGE

Wind and Pressure Components of Hurricane Storm Surge

- Storm motion
- Wind-driven Surge
- Pressure-driven Surge (5% of total)

Water on ocean-side flows away without raising sea level much
As water approaches land it "piles up" creating storm surge

15 ft Surge
17 ft storm tide
2 ft normal high tide
Mean sea level
COASTAL EROSION and SEA LEVEL RISE

Cortesía Antonio Marquez (UAMI)

Figura 5. La destrucción de la infraestructura adyacente a la costa, es otro de los problemas que se manifiestan con el ascenso del nivel medio del mar. (Barra de Túrtico, Tabasco).

Mecoacán, Tabasco

Barra de Machona

Grijalva Este, Tabasco

Barra de Laguna de Machona, Tabasco
Climate dynamics and impact scenarios in coastal areas
Sea Level Rise and Storm Surge

This graphic shows factors that contributed to the top 10 high-water events measured at New York's Battery Park from 1900 to present. The water height for each event is shown here against the benchmark of mean lower low water averaged between 1983 and 2001. Sea level rise (about a foot since 1900) is depicted as a component of storm surge. Although Sandy's surge peaked close to high tide, other events had even higher tide levels.

Click image to enlarge. Credit: Carlye Calvin and Bob Henson, UCAR; data courtesy Chris Zervas, NOAA National Ocean Service.
Global losses due to the five major hydro-meteorological events in 2005.

Source: Cepal, 2009
What we are doing: Ocean Policy implementation

General Objective 1: Improve living conditions and human wellbeing

General Objective 2: Strengthen local economies, regional and sectoral productivity.

General Objective 3: Ensure the structure and function of marine and coastal ecosystems.
MexICOOS

An international cooperation project to set up the

Mexican Integrated Coastal and Ocean Observing System
A model of coastal and ocean observing system that provides continuous information

MEXICOOS

- Natural hazards (met-ocean monitoring) / alerts
- Oil spill drift forecast
- Environment monitoring & evolutions forecast & management
- Renewable marine energies
- Turbidity / sedimentology
- Eutrophication, Harmful algal blooms, ..
- Hydrodynamics and biogeochemistry around islands (Indian and Pacific Oceans)
Future development of MexICOOS
Conclusions

Urgent need to:

- Invest in ocean observing systems
- Develop a strong baseline to monitor the ocean ecosystem health
- Support countries to build enhance or implement their Ocean and Coastal Observing Systems
- Implement the network of infrastructure for harmonized monitoring
- Develop robust indicators based on pressure-status-response models
- Obtain good quality near real time data
- Strengthen networking and observing systems
- Use of simple sound science based indicators