1.2.5 Perspectives on Fates and Effects: Study Needs in the Southern Gulf of Mexico

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1.2.5.1 Abstract

The effects of pollutants on marine organisms and ecosystems have been well documented. However, for the northern Gulf, until the launch of the Gulf of Mexico Research Initiative (GOMRI), relatively few papers had been published on the effects of pollutants, particularly pollutants related to the oil industry, in the GOM. Papers describing studies in the southern GOM are fewer, but there is a history of studies funded by Petróleos Mexicanos (PEMEX), with oceanographic cruises each year covering most of the Mexican Gulf. Regretfully, most of that information has not been published, because it is considered proprietary. There are clearly knowledge gaps, particularly for the southern GOM. One interesting finding is that there are some differences in the approaches being used in the northern and southern Gulf to assess the impact of the oil industry.

1.2.5.2 Introduction

The effects of pollutants on marine organisms and ecosystems have been well documented. However, for the northern Gulf, before the DWH oil spill, relatively few papers were published on the effects of pollutants related to the oil industry in the GOM. Now GOMRI-funded research has resulted in many studies on the effects of petroleum, in different forms, alone or mixed with dispersants. Papers describing studies in the southern GOM are fewer, but there is a history of studies and oceanographic surveys funded by PEMEX. However, most of that information is considered proprietary. This report emphasizes studies done in the southern Gulf, but also mentions studies for the northern Gulf reported through late March 2017 in the GOMRI database.

Changes in community structure of different types of marine organisms have been used to assess the impact of pollutants, particularly in sediments. In the southern GOM, changes in free-living nematode community structure related to total hydrocarbon concentrations in sediments were reported by Gold-Bouchot and Herrera-Rodríguez (1996) in the area close to the offshore oil-producing zone. Clustering of the sampling stations was related to organic matter content and granulometry, and in three of the four cruises, total hydrocarbons in sediments also influenced clustering. Hernández-Arana et al. (2005) reported changes in the community structure of macrobenthos in sediment samples collected along four transects crossing the oil-producing zone in the southern Gulf during two cruises, one in the rainy season and the other during the winter storm season. Sampling was designed to take into account depth and changes in sediment type (terrigenous versus carbonated). A pattern of pollution was found, with pollutant concentrations increasing in the oil-producing zone. Using univariate (ANOVA) and multivariate (Bio-ENV) statistical techniques, a relationship between microbenthic fauna community structure and environmental variables and oil-industry-related variables (barium and chromium concentrations) was found. Kuk-Dzul et al. (2012) reported changes in microbenthic community structure in coastal lagoons along the northern coast of the Yucatan Peninsula. Canonical correspondence analysis showed a significant relationship of microbenthic fauna with environmental factors such as salinity and pH, but also with low molecular weight polycyclic aromatic hydrocarbons (PAHs). Brown et al. (2000) reported the effects of pollutants in sediments, and other environmental factors, as driving forces for the structure of microbenthic communities in estuaries in the northern Gulf. Different impacts of oil and dispersants on deep corals were studied by DeLeo et al. (2016), and particularly growth rates of deep corals (Prouty et al. 2016), histology (Silva et al., 2016), community structure (Fisher et al. 2014; Hsing et al. 2013; White et al. 2012) and deep corals and other benthic communities (Fisher et al. 2016).

In the case of certain groups of benthic organisms in the northern Gulf, the effects of oil on meiofauna (free-living nematodes and copepods) diversity were reported by Landers et al. (2014a), and effects of metals on meiofauna were reported by Landers et al. (2014b). Effects on salt marsh crabs (Zengel et al. 2016a), and on the effect on larval settlement and condition of blue crabs (Grey et al. 2015) have been reported, as well as effects of oil on crab transcriptome (Yednock et al. 2015). The decline of benthic foraminifera was one of the effects found after the DWH oil spill (Schwing et al. 2015). Oil and chemically-dispersed oil affected oyster larvae (Laramore et al. 2014) as well as oyster physiology (Soniat et al. 2011). The effects of oil on periwinkles were also studied (Zengel et al. 2016b).

Fish have been extensively studied after the DWH oil spill. The physiological effects of oil on mahi-mahi embryos and larvae was reported by Xu et al. (2016), and the effects on fish assemblages by Able et al. (2015) and Fodrie et al. (2011). Organismal and population responses were summarized by Fodrie et al. (2014), and external skin lesions were described by Murawski et al. (2014). Genetic response in fish exposed to oil was described as very complex by García et al. (2012). Responses in different tissues at several biological levels in killifish were reported by Dubansky et al. (2013).

Several authors report on the effects of oil and dispersants on zooplankton at different levels. Thus, photochemically-enhanced toxicity of oil to copepod nauplii was reported by Almeda et al. (2016). Long-term impacts of overfishing and pollution on plankton trophodynamics were reported by Walsh et al. (2016). Effects on ctenophores by oil and chemically-dispersed oil were reported by Parsons et al. (2015). Effects on feeding of copepods (Almeda et al. 2014a) and growth rates of barnacle nauplii (Almeda et al. 2014b) have been studied, as well toxic effects in general (Almeda et al. 2014c). Changes in community structure were studied by Carassou et al. (2014). Bioaccumulation of PAHs and its effect on survival of both adults and larvae of zooplankton (Almeda et al. 2013a) and other toxic effects on zooplankton (Almeda et al. 2013b) have been published.

Phytoplankton have received less attention. Changes in phytoplankton community structure before and after the DWH spill were reported by Parsons et al. (2015), and toxic effects on microalgae by Garr et al. (2014). A description of general impacts is given by Ozhan et al. (2014). Toxicity and mutagenicity of water from the GOM and their implication for possible impacts on resident organisms was assessed by Paul et al. (2013).

A novel approach has been to use the community structure of parasites in fish and other organisms to evaluate the impact of pollutants. The parasites and symbionts of the pink shrimp (*Farfantapenaeus duorarum*) were used in Campeche Sound, as well as the Mexican flounder (*Cyclopsetta chittendeni*; Centeno-Chalé et al. 2015). Vidal-Martínez et al. (2015) related the probability of occurrence of *Oncomegas wageneri* (Cestoda: Trypanorhynca) among other factors to the concentration of hydrocarbons. In the coastal lagoons of the northern Yucatan Peninsula, Pech et al. (2009) used the checkered puffer (*Spheroides testudineus*) and its parasites as environmental indicators. Gold-Bouchot et al. (2017) used transcript abundance and pollutant analyses of two fish species to assess environmental impacts in the Veracruz Reef System.

Histopathology has also been used as a tool to evaluate the effects of pollutants. Gold-Bouchot and coworkers (1995, 1996) used the histopathology of the eastern oyster (*Crassostrea virginica*), to assess the impact of the oil industry in three coastal lagoons in the southern Gulf. Strong dose-response curves were reported for cadmium and the Unresolved Complex Mixture (UCM) of hydrocarbons in the oyster soft tissue.

Biomarkers at different levels of biological organization have also been used as tools for the evaluation of pollution effects. Zapata-Pérez et al. (2005) used ethoxycoumarin O-deethylase (ECOD, an enzyme closely related to EROD, in the Cytochrome P-450 group) activity and vitellogenin induction in pink (*F. duorarum*) and white shrimp (*Litopenaeus setiferus*) to evaluate the status of shrimp populations exposed to pollutants. Relationships between enzyme activity and gene expression and hydrocarbons were found. Gold-Bouchot et al. (2007) used biomarkers in the eastern oyster in Laguna de Términos, a protected area in the southern Gulf in the delta of the Grijalva-Usumacinta River. The catfish (*Ariopsis felis*) was used to evaluate the effects of pollutants in coastal lagoons from the Yucatan Peninsula (including Laguna de Términos) by Zapata-Pérez et al. (2007). Endocrine-disruption was evaluated by determining transcript abundance of the vitellogenin gene, and a relationship to total DDT and PCB concentrations in the liver was found.

Currently there are two ongoing projects in the southern Gulf with relevance to the fate and effects of marine pollutants. One is the GOMRI-funded "The Center for the Integrated Modeling and Analysis of the Gulf Ecosystem" (C-IMAGE-II), hosted by the University of South Florida, a collaboration between US and Mexican researchers including research cruises through the entire Gulf. The second is: "Implementación de redes de observaciones oceanográficas (físicas, geoquímicas, ecológicas) para la generación de escenarios ante posibles contingencias relacionadas a la exploración y producción de hidrocarburos en aguas profundas del golfo de México [Implementation of oceanographic observation networks (physical, geochemical, ecological) for generating scenarios in the face of possible contingencies related to the exploration and production of hydrocarbons in deep waters of the Gulf of Mexico]," a project funded by CONACYT and lead by CIGOM. This project involves over 100 Mexican scientists and international collaborations with institutions in the United States and Europe.

One interesting effort being carried out in Mexico is the validation of environmental quality indices for tropical marine ecosystems, such as the TRIX, a trophic index for marine waters developed in Europe by Vollenweider et al. (1998). This index uses values for inorganic nutrients (total nitrogen and phosphorous), chlorophyll *a*, and oxygen saturation. For benthic communities, the BENTIX Index (Simboura and Zenetos 2002) is also being adapted to the species found in the southern Gulf. The adapted index has been named Benthic Index for the Campeche Sound (BICS) (Daniel Pech, ECOSUR, personal communication). It would be expected that both adapted indices would be useful also in the northern Gulf, as the fish species that have been used in studies in the southern Gulf are also present in the northern Gulf. The presentation included in this report contains some examples of the kind of studies being done now in the southern Gulf.

1.2.5.3 Future Directions

Some knowledge gaps in the literature search done for this chapter were found, particularly for the southern GOM. One interesting finding is that there are some differences in the approaches being used in the northern and southern Gulf to assess the impact of the oil industry. More collaboration between researchers in Mexico and the United States would be desirable to exchange experiences, and particularly design joint projects. Some gaps detected for the southern Gulf are as follows:

- There are no published data on the use of epigenetics and metagenomics in fish or other marine organisms to assess the impact of hydrocarbons or other pollutants associated with the oil and gas industry.
- Adaptation of the TRIX and BENTIX indices must be completed and published, so their use in the northern Gulf can be evaluated and used.
- There is a lack of baseline studies related to the influence of the variability of environmental driving forces on environmental impact assessment.
- Finally, there are no Gulf-wide efforts that allow the study of the GOM as an LME, with the only exception being the C-IMAGE-II consortium and CIGOM, which is primarily focused on the southern Gulf. Thus, meso- and macroscale studies are needed.

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