EFFECTS OF THE MARCH 18, 1973 OIL SPILL NEAR CABO ROJO, PUERTO RICO ON TROPICAL MARINE COMMUNITIES

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ABSTRACT

During the early morning hours of March 18, 1973 the Greek tanker, ***Zoe Colocotronis*** *spilled 37,000 barrels of Venezuelan crude oil into the coastal waters of southern Puerto Rico. About 24,000 bbl of oil washed ashore at Cabo Rojo, contaminating sandy beaches, turtle grass, and rocky shore communities.*

*Within 48 hours following the spill, dead and moribund invertebrates, representing several distinct phyla were being deposited along the beach and intertidal zone. Population analysis of the affected mangrove prop root and sublittoral turtle grass (****Thalassia****) communities revealed a sparse and impoverished fauna. Subsequent survey trips have revealed marked increases within certain affected populations. In one area (1.0 hectare) the red (****Rhizophora mangle****) and black (****Avicinnia nitita****) mangrove trees have defoliated and died during the three years following the spill. Analysis of the sediments in this area indicates significant levels of petroleum hydrocarbon residues were present as of January 1976.*

INTRODUCTION

Although much has been written concerning the effects of oil and oil spills upon natural biological systems, there is a paucity of information on tropical ecosystems.

Major spills in the temperate zone have been well documented, emphasizing the effects upon intertidal and sublittoral biological communities.[2, 3, 5] Only in Chan's work on the San Francisco spill was there adequate baseline data on the intertidal communities that were affected to make a statistical comparison of pre-spill to post-spill community analysis.[2, 3]

Unfortunately, in most spills, baseline or pre-spill information on the affected communities is inadequate for statistical comparison, or is lacking entirely. Therefore, the emphasis must be placed on comparing the affected populations with a control site. However, the pitfalls are numerous. First, to find a control site that is comparable is difficult due to natural variation in species diversity, abundance and microniches. Second, in order to accommodate these differences, many replicate samples must be taken with the expenditure of an inordinate amount of resources both of personnel and money.

Many of these same problems were faced by the VAST/TRC investigators who were under contract to the Environmental Protection Agency to determine the impact of the *Zoe Colocotronis* spill that affected the tropical marine communities near Cabo Rojo, Puerto Rico. On March 18, 1973, the tanker *Zoe Colocotronis* off-loaded 37,000 bbl of Venezuelan Crude to free itself from a shoal south of Punta Montalva on the south shore of Puerto Rico. The predominant easterly trade winds moved the oil from the spill site into Bahia Sucia with subsequent contamination of the extensive beach and mangrove forest shoreline.

When compared to temperate marine ecosystems, tropical systems are unique, having a greater species diversity, a greater number of major faunal phyla, and available ecological niches. The coastal systems, mangrove forests and *Thalassia* beds, are particularly important for stabilizing coastal shoreline, producing detritus and providing habitats for exploitable finfish and shellfish species.[8] In consideration of these factors, it is important to document the impact of oil spills upon these systems. Only after adequate scientific assessment of the effects of oil spills can decisions be made and contingencies be established to protect these communities. Given that the course of events at the time of spills is such that protection of a wide expanse of critically important ecological areas is nearly impossible, this information can be used to develop and implement a priority scheme for cleansing these areas after contamination.

In the case of the Cabo Rojo spill, extensive contamination of the mangroves, beach shoreline, and sublittoral *Thalassia* beds was caused as the oil moved laterally along the shore, due to the wind shifting a few degrees each day.

Description of area and analytical methodology

Cabo Rojo (the Red Cape), located on the southwest corner of Puerto Rico, is a sandy barrier beach that juts out approximately eight kilometers into the Caribbean Sea (Figure 1). At the tip is a rocky outcropping that rises out of the sea. The outcrop is connected to the island proper by an isthmus of salt flats and mangrove forests. Between these mangroves and the mangroves bordering the entire north shore of Bahia Sucia is a *Thalassia* bed which is part of an even larger *Thalassia* area extending many kilometers eastward. Heavy accumulations of dead *Thalassia* blades along with flotsam and jetsam are normally present along the beach and in the mangroves. The classical distribution of mangrove species is evident with the red mangrove, *Rhizophora mangle*, seaward and the black mangrove, *Avicinnia nitata*, and white mangrove, *Laguncularia racemosa*, inland.

Within 24 hours of the spill, the authors were on the scene. Walking surveys into the accessible areas were initiated and maintained for the first 7 days following the spill until the arrival of the VAST/TRC biologists. These surveys consisted of documenting the occurrence, location, abundance, and type of dead or moribund animals being washed ashore.

The VAST/TRC biologists conducted two surveys: Survey I commenced one week following the spill, and Survey II commenced thirteen weeks following the spill. Sampling sites were established in the affected mangroves, and *Thalassia* beds by the survey team (Figure 1). The control or

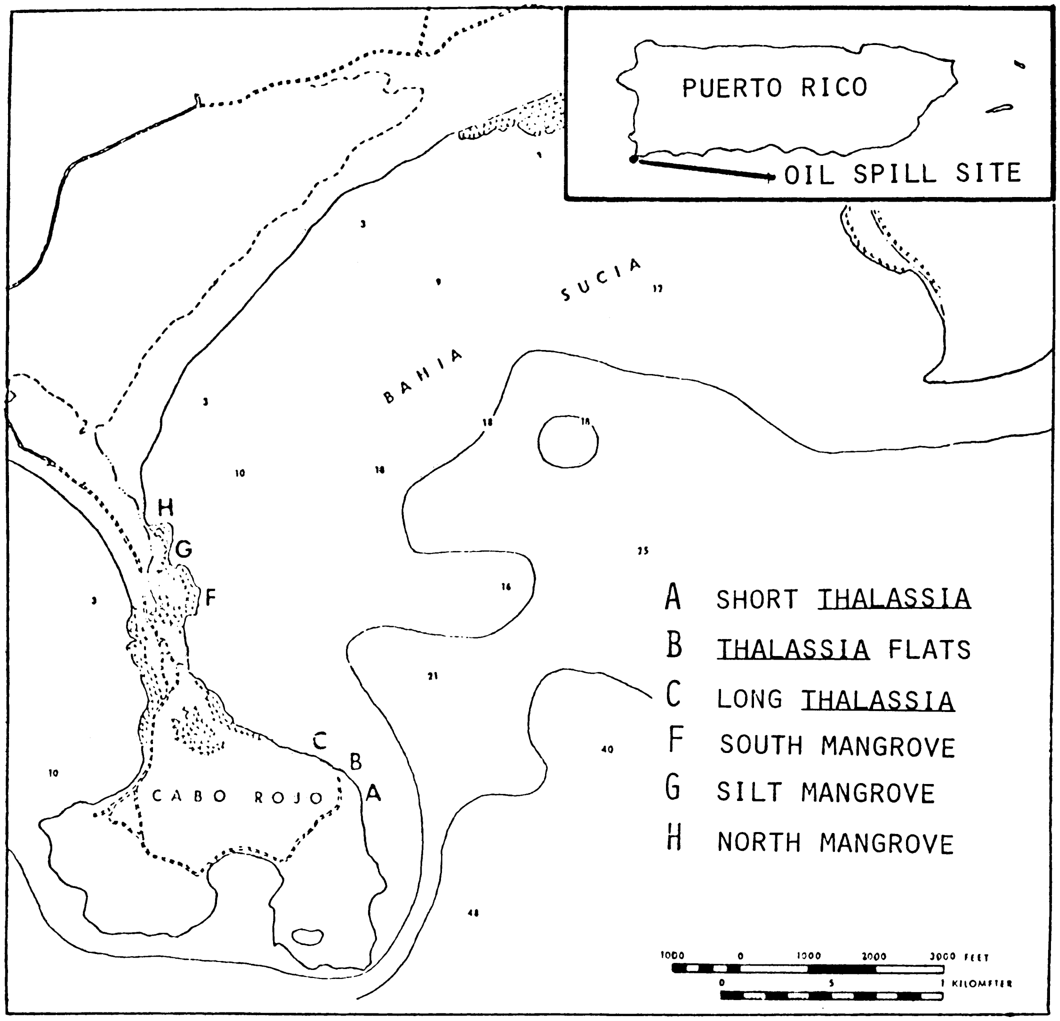

Figure 1. Location of sampling stations in Bahia Sucia; inset indicates oil spill site relative to island of Puerto Rico

unoiled sites for each of these biological communities was established near the Isla Cueva on the south shore of Puerto Rico and east of Cabo Rojo. Since the beach area was disrupted and inaccessible due to the intense effort of the cleanup operation, no sampling of this area was attempted. Therefore, it was decided to concentrate on the mangroves and *Thalassia* beds because of their high productivity and ecological importance.

The authors have made several subsequent visits to the area during the past two years since the VAST/TRC surveys to visually and photographically document the shoreline communities. In January 1976, soil samples were collected along a transect in a portion of the mangrove forest (approximately 1 hectare) which had died following the spill. This same mangrove portion is located at the southern end of the beach and had been heavily inundated with oil (40-60 cm deep). Control samples were collected from an uncontaminated mangrove area. These soil samples were extracted and analyzed by fluorescence spectrophotometry, gas chromatography, and nuclear magnetic resonance spectrometry. The analytical techniques are discussed in detail in Gruenfeld and Frank.[6]

Sampling in the *Thalassia* beds was performed in three distinct areas; the long *Thalassia* where the grass blades and stems were considerably larger and longer (approximately 60-80 cm), the short *Thalassia* where the grass blades were considerably shorter (20-50 cm) and *Thalassia* flats where the beds consisted of plants growing on hard, flat, coral-sand substrate. The epibenthic macro-invertebrate community was sampled by counting and identifying the organisms within a six meter circle (area = 28.27 m^2). Each area was marked by a stake for relocating the site for Survey II. The infauna was sampled by three cores (10 cm × 13 cm) per station followed by screening (1.5 mm and 1.0 mm mesh size).

Three stations were established by VAST/TRC in oil-contaminated mangrove areas (Figure 1). At each station, three prop roots were cut well above the water level, and wrapped in alcohol-soaked cheesecloth and aluminum foil. Infauna was sampled by coring similar to the methods used for the *Thalassia* beds. The biological specimens on the prop roots were identified and enumerated to those levels attainable using the taxonomic keys available. For most communities, the lowest common taxonomic level (the "family") was used for comparison.

Results and discussion

Epibenthic communities (*Thalassia* beds). The epibenthic communities of the *Thalassia* beds gave the first indication that the oil was affecting biological populations. During the first 48 hours following the spill, very few dead organisms were observed by the authors during the daily shoreline reconnaissance. The few dead organisms present were not fresh kills and did not result from the oil spill.

On the third day, the shoreline reconnaissance revealed a variety of dead or moribund invertebrates being deposited along the shoreline from the *Thalassia* beds just offshore. Large numbers of sea cucumbers, conchs, prawns, sea urchins, and polychaete annelids were being washed ashore. A rowboat survey of the long *Thalassia* beds revealed that many of the same organisms were dying and disintegrating in the *Thalassia* beds as well.

The toxic effect that the oil had on these organisms was unsuspected, as Venezuelan crude is low in aromatics and other soluble toxic compounds common to other types of crudes. It was surprising to the authors to be observing the mortality; however, the intensity of the onshore winds and shallowness of the near shore waters apparently caused dissolution and oil droplet entrainment into the water column. The physical entrainment and slight solubility combined to produce an acute toxic effect on certain faunal constituents of the epibenthic communities.

Survey I of the VAST/TRC epibenthic samplings revealed no differences between the oiled *Thalassia* (short grass area) and the controls, in terms of numbers of organism type and abundance (Table 1). There was lower diversity and abundance in the long *Thalassia* beds. It was on the shoreline adjacent to the long *Thalassia* that the authors observed the dead and moribund invertebrates.

During Survey II, the presence of sea urchins, chitons, and hermit crabs increased the diversity in the long *Thalassia*. Abundance was still low compared to the controls. For the short *Thalassia*, there were slight differences between the affected areas and the control.

On subsequent visits in January 1974 and 1976, populations of sea cucumbers and sea urchins, particularly *Tripneutes esculentus* and *Diadema antillarum*, were observed in the affected area. Repopulation of the area is evident, at least for certain species that were initially affected. The queen conch, *Strombus gigas*, a species affected by the oil, was not evident during the more recent visits. However, this may be due to fishing pressure and cannot necessarily be attributed to the oil spill alone.

Infaunal communities. There was no meaningful difference in diversity or abundance between the oiled stations and the controls for both the short and long *Thalassia*. Any effect that the oil might have had in depleting the infauna was masked by the variation at the control site (Table 2).

During Survey II, thirteen weeks after the spill, differences were observed in diversity and abundance in the long *Thalassia* infaunal community. At this station there was a decrease in diversity and numbers compared to the control site. This decrease was attributed to the paucity of polychaete and molluscan species previously observed.

In the *Thalassia* flats, the diversity and abundance of infauna had decreased since Survey I. These flats result from accretion and deposition of coral sand in the rhizome matrix of the *Thalassia*.[7] The growth of the blades and stems impedes the sand-carrying currents, which then deposit additional sand in and around the plants.

During the spill, the *Thalassia* flats were contaminated by oil entrained into the water column by surf action, causing the leaves to become brown or black from oil coatings. A considerable amount of *Thalassia* died and was removed by wave action, exposing extensive areas of denuded vegetation and rhizome matrix. By January 1974, this exposed area had rejuvenated *Thalassia* growth. By January 1976, the *Thalassia* flats had renewed plant growth with coral-sand deposition.

Since Survey II there has been no further sampling for infaunal community analysis; thus, repopulation or recolonization of this community can only be assumed from the re-establishment of substrates conducive for a diverse infaunal community.

Mangrove prop root communities. As shown in Table 3, the prop root communities were affected by the oil coatings that the roots received during the spill. During Survey I, only half of the faunal groups were present on the oiled roots as on the controls. Also, there were 50% fewer numbers on the oiled roots compared to the controls. During Survey II, repopulation was evident with certain groups (polychaete annelids and amphipods) present on the oiled roots that were not present during Survey I.

Table 4 illustrates the comparability between the faunal and floral groups that were affected by two major oil spills that contaminated mangrove prop root communities. In 1970, Rutzler and Sterrer noted the dramatic effect of the *Witwater* spill in Panama two months after the spill date. Presumably, the mixture of diesel oil and Bunker C from the *Witwater* contained more light and soluble compounds, and thus more toxicity, compared to the Venezuelan crude of the *Zoe Colocotronis*. Nevertheless, the innate toxicity associated with each oil type was not extremely selective relative to the kinds of biotic groups affected. Table 4 indicates a high degree of commonality of the biotic groups that were affected.

Mangrove. At Station G, approximately one hectare of mangrove forest has died since the oil spill. Thorne[10] has indicated that mangroves are sensitive to frost and drought. Cabo Rojo is too far south for frost to occur. Drought does not influence red mangroves, which are more adapted to the marine environment than the other mangrove species. Since the red mangroves at Cabo Rojo were most severely affected, it can only be assumed that the oil deposited in the soils and on the prop roots by itself or in combination with natural factors created a stress condition on the mangrove trees. Table 5 reveals the large amounts of petroleum hydrocarbon residues in the soils.

Table 1. Epibenthic *Thalassia* communities sampled by walking survey (area, 28 m²)

	Long *Thalassia*				Short *Thalassia*				*Thalassia* flats	
	S I		S II		SI		S II		S I	S II
	0	C	0	C	0	C	0	C	0	0
Total faunal groups	0	7	4	3	6	8	4	4	1	2
Total individuals (abundance)	0	26	4	4	27	43	11	8	6	3

0 = oiled; c = control (modified from TRC - VAST report)

Table 2. Benthic infauna *Thalassia* communities per 3,063 cm³

	Survey I				Survey II			
	Long *Thalassia*		Short *Thalassia*		Long *Thalassia*		Short *Thalassia*	
	0	C	0	C	0	C	0	C
Total faunal groups	12	12	24	7	13	8	7	10
Total individuals (abundance)	24	55	90	19	40	29	15	24

0 = oiled; C = control (modified from TRC - VAST report)

Table 3. Mangrove prop root communities

	Survey I						Survey II					
	North		South		Silt		North		South		Silt	
	0	C	0	C	0	C	0	C	0	C	0	C
Total faunal groups	1	9	4	9	0	11	7	4	6	6	1	4
Total individuals (abundance)	1	172	8	169	0	136	24	53	32	53	1	16

modified from TRC - VAST report

Birkeland, *et al.*[1] reported that *Rhizophora mangle* trees sprayed with 300 ml of diesel and Bunker C mixture had fewer leaves and more bare branches after a year compared to the control trees. Also, the sprayed trees showed no growth on the trunk or branches. Some of the trees had only the prop roots treated. The results were mixed, with the small treated tree deteriorating to about half its original size in leaf coverage while the largest trees (3 m in height) remained in good health.

Only the prop and submerged roots of the inner mangroves were oiled at Cabo Rojo. Most of these trees were ten meters in height.

Table 4. Major fauna and flora groups of the mangrove prop root communities shown to be affected by oil spills

Witwater	*Zoe Colocotronis*
(Rutzler & Sterrer, 1970) Survey I	(TRC-VAST report 1976) Survey II
13 December 1968	26 June 1973
Algae	Algae
Sponges	Sponges
Bryozoans	Hydrozoans
Bivalves	Bivalves
Barnacles	Barnacles
Polychaete Annelids	Polychaete Annelids
Tunicates	Tunicates

Table 5. Extractable hydrocarbon concentrations (ppm) in mangrove soil; samples taken at 10 m intervals along transect at station G (north mangrove), January 1976

Amount (ppm)	Vegetation strata
10.4	Sesuvium
948.0	*Aviciennia*
1,082.0	*Aviciennia*
823.0	Dead *Rhizophora*
2,083.0	Dead *Rhizophora*
7,335.0	Dead *Rhizophora*
34,664.0	Dead *Rhizophora*
71,863.0	*Rhizophora* seedings
84,134.0	Re-colonizing *Rhizophora*

CONCLUSIONS

The *Zoe Colocotronis* spill study has produced scientific data that supports the following conclusions:

1. The oil spill had an acute effect upon the mangrove and *Thalassia* communities, as evidenced by the extensive mortality to indigenous populations and the general disruption to the environment.

2. Certain thriving natural populations living in healthy ecological surroundings can recuperate from the impact of a single spill which has been effectively cleaned up. Those populations with planktonic larvae, i.e., echinoderm and molluscan species are repopulating and/or recolonizing the affected areas.

3. This study emphasizes the importance and benefits of a thorough and comprehensive cleanup of critical and sensitive ecosystems such as mangrove forests. The die-off of the mangroves at Cabo Rojo may have resulted from the hydrocarbon residues in the soil and on the prop roots.

4. The post-spill observations at Cabo Rojo illustrate the need for furthering the development of technology to effectively and efficiently remove oil from unconsolidated substrates with thick vegetative growth, such as mangroves, fresh water red maple swamps, and cedar/cypress swamps.

5. This study also points out the importance and benefits of long term post-spill observations which have been lacking for most major oil spills.

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