Ixtoc I: A Case Study of the World's Largest Oil Spill
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Source: *Ambio*, Vol. 10, No. 6, The Caribbean (1981), pp. 299-306
Published by: Allen Press on behalf of Royal Swedish Academy of Sciences
Stable URL: http://www.jstor.org/stable/4312725
Accessed: 13/05/2010 11:42

Ixtoc I: A Case Study of the World's Largest Oil Spill

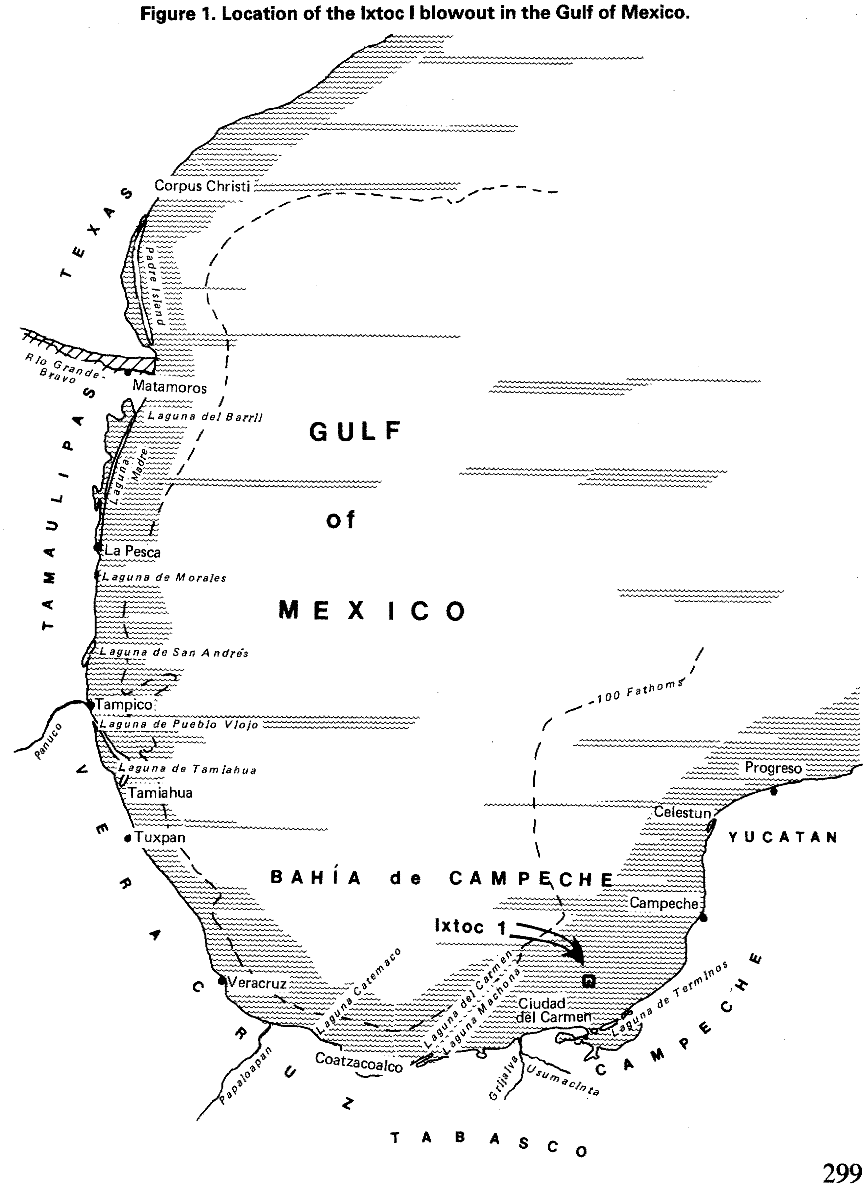
BY ARNE JERNELÖV AND OLOF LINDÉN

On June 3, 1979, the Ixtoc I exploratory well in the Bay of Campeche, blew out. It was finally capped on March 23, 1980, 290 days later, but during that time 475 000 metric tons of oil were spilled into the waters of the Gulf of Mexico. The full extent of the damage is still unknown.

On December 10, 1978, Petróleos Mexicanos (PEMEX) started to drill the Ixtoc I exploratory well at longitude 92°13′W and latitude 19°24′N, about 80 kilometers north-west of Ciudad del Carmen in the Bahia de Campeche (Figure 1). The water depth at the site is about 50 m. The drilling continued through the first part of 1979 and by the end of May a depth of 3600 meters had been reached. Early on June 2 at a depth of 3615 meters, the well started to loose drilling mud; circulation was totally lost about 3625 meters. Several unsuccessful attempts were made to regain circulation, but as the well appeared stable, it was decided to seal it by withdrawing the drill pipe and inserting a plug in the empty space. On June 3, during the attempts to seal the well, the extremely high pressure (about 350 kg/cm^2) caused mud to flow up the drill pipe and onto the platform. At 3:30 am the well blew out and caught fire. The explosion and fire destroyed the platform, which sank to the bottom and damaged the stack and well casing. This allowed the oil and gas to mix with water close to the sea floor, beginning the largest marine oil spill in the history of oil exploration.

Initially the spill was estimated to be about 4500 metric tons per day. However, by the beginning of August the well had lost over 225 000 metric tons—more oil than had been lost in any previous accident involving offshore drilling or transportation. When the well was finally capped on March 23, 1980—290 days after the blow-out—a total of about 475 000 metric tons of oil had been lost, according to PEMEX estimates (1).

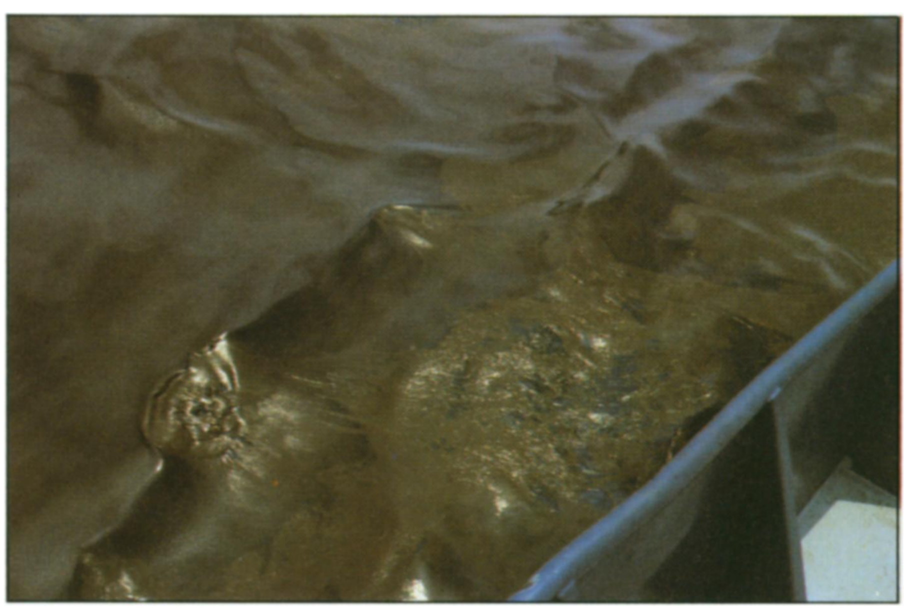
Figure 1. Location of the Ixtoc I blowout in the Gulf of Mexico.



Figures 2a and b. The blowout as seen from a helicopter. Wind and current carried the oil in a north westerly direction. The rig in the foreground (left above) is a relief drilling platform. 2b on opposite page is a close-up of 2a. All photos: Olof Lindén.

The oil that was lost during the blowout polluted a considerable part of the offshore region in the Gulf of Mexico as well as much of the coastal zone, which consists primarily of sandy beaches and barrier islands often enclosing extensive shallow lagoons. A number of studies were intitiated to assess the extent of the damage. One of these was set up by the United Nations Environment Program (UNEP) at the request of the Mexican government. A summary of the results of that study (2), which focussed mainly on the acute impact of the spill, is reported here.

Figure 3. A thick layer of "chocolate mousse" close to the blowout.



GENERAL BEHAVIOR OF THE OIL

The oil from Ixtoc I reached the ocean at a depth of 51 m and was injected into the water initially at a pressure of 350 kg/cm^2.

Figure 4. Booms and skimmers in operation. In the background can be seen another relief drilling platform.

The oil was saturated with gas and consequently hit the surface as a three-phase emulsion, water droplets and gas bubbles in oil, with a water content of about 50 percent. Due to the high pressure at which the emulsion was formed the droplets were small. Most of the gas was burned as it emerged but only a very small fraction of the emulsified oil was actually burned (Figure 2 a, b).

The oil was of a light type. Thus, a high proportion consisted of straight-chain and cyclic hydrocarbons with less than sixteen carbon atoms, both comparatively volatile and water-soluble. During the first part of the blow-out, the emulsified oil formed a surface layer 1–4 cm thick, 0.7–5 km wide and about 60 km long (see Figure 3).

The initial formation of an emulsion resulted in the oil from the blow-out having less contact surface with the atmosphere and more contact surface with the ocean water, compared with oil discharged on the water surface. Thus, considering its chemical composition, a larger part of the Ixtoc oil was dissolved in the water and a smaller part evaporated to the atmosphere when compared to other spills.

As the lighter fractions of the oil were lost through evaporation and dissolution, and as the gas bubbles left the emulsion, the remaining part gradually became heavier. As more and more water was incorporated in the emulsion, it gradually changed from water droplets emulsified in oil to oil droplets emulsified in water. Owing to their surface stickiness, the oil droplets accumulated particles from the water and thus gradually increased in density. Micro-organisms attached themselves to the droplets and zooplankton filter-feeders consumed both the droplets and the microorganisms, incorporating the oil residues in faecal pellets that increased the sinking rate of the oil. As the droplets increased in density, they gradually sank through the water column. In the Gulf of Mexico there is a stratification in the watermass due to temperature and/or salinity. This stratification is partly caused by the influx of fresh water via rivers and lagoons. There are indications that parts of the Ixtoc I oil sank in droplets through the less dense surface water and temporarily accumulated and floated on the strata with higher density. Eventually the oil increased in density and sank through the denser water strata. If the stratification was broken up due to wave action or changes in temperature, oil floating on the sub-surface layer could again reach the surface.

When it reached a beach, the oil was either deposited there, or made to sink in the shallow water, weighed down by the particulate matter in the zone where the waves broke. The oil on the beach was exposed to sunlight that raised its temperature and intensified weathering. It formed tarlike balls or cakes with little stickiness.

FATE OF THE OIL

From the start of the blow-out on June 3, 1979, to the final capping on March 23, 1980, a total of about 475 000 metric tons of oil was lost (1). Various attempts were made to stop the blow-out, and they gradually reduced the flow-rate of oil (Table 1).

Based on data from the Ixtoc I case, analogies with other oil spills and data in the literature, an attempt has been made to estimate the fate of the oil from Ixtoc I (Table 2). The emulsification brought down the amount of oil that was burned at the well site. The authors estimate that only a very small fraction of the oil, probably less than 1 percent, was actually disposed of when the gas was burned at the well. However PEMEX estimates that about 50 percent of the spilled oil burned at the well site (3).

Mechanical recovery in the Ixtoc zone removed 10 000 metric tons, about 4–5 percent (3). Evaporation, judging by data in the literature and experiments with the actual oil which took into account its physical and chemical characteristics, could have removed 45–70 percent. The initial emulsification was likely to result in an actual figure in the very low part of that range.

The fraction that went into solution in sea water was generally considered small. It seems likely that less than 100 ppm was actually dissolved and therefore the total amount is insignificant in this context.

Again taking data in the literature as a basis, it is thought that biological degradation, together with photochemical and chemical breakdown during the acute phase of the spill, would account for 10–15 percent of the oil.

The oil on Mexican beaches that the authors observed in early September was calculated to be about 6000 metric tons. Most of it had landed during the preceding four or five days. Based on reports from various groups and individuals, five times that figure is thought to represent a fair estimate of what had landed on Mexican beaches.

Investigations along the Texas coast show that approximately 4000 metric tons of oil or less than 1 percent was deposited there (4). The rest of the oil, about 120 000 metric tons or 25 percent, sank to the bottom of the Gulf.

THE CLEAN-UP

Ixtoc area

Operations to combat the oil within the Ixtoc I area were conducted from several auxiliary ships and barges. For confinement of the oil, high sea booms were anchored in fixed positions attached to the barges (Figure 4). For recovery of the oil, skimmers and absorbent devices were used (see Figure 4).

The recovery operations started in the late part of June and were cancelled in early October. The theoretical pick-up capacity of the equipment used was about 20 percent of the total outflow, but a number of obstacles meant that only 4–5 percent of the oil was actually recovered. One major problem was the weather. At wave heights higher than 3 to 4 meters the equipment was not operable at all; and the wind speed during the fall and winter in particular frequently caused wave heights higher than that. Another major problem was that it was not considered feasible to operate the system at night. A third limitation was the difficulty of rearranging the barges and booms as winds and currents changed. This caused part of the oil to drift past each side of the boom configurations. And finally, the oil-collecting equipment used broke down on a number of occasions.

In order to protect the lagoons from being contaminated by oil, booms were placed across most of the inlets along the coast. Because of the way the booms were deployed, however, they were seldom effective (Figure 5). Frequently the current passing through the inlets either ruptured the booms or pressed them under or over the water. As a boom is normally an effective barrier only at velocities below 0.7 knots at right angles to the boom skirt, the only way to use booms in most of the inlets would have been as deflectors placed at a comparatively narrow angle against the drifting direction. And the confined oil would have needed to be recovered using pumps or skimmers, without too much delay. This was not done.

On June 9 large-scale dispersant spraying commenced using specialized fixed-wing aircraft. The dispersants were initially sprayed in a zone 10 to 25 miles off the coast, but later, during the fall, dispersants were also sprayed close to the beaches, near the mouths of the lagunas, and around the well site. From late October dispersant spraying from boats gradually replaced spraying from aeroplanes. The exact quantity of dispersant used in the clean-up is not known. However, according to information received by PEMEX (3), at least 9000 metric tons were used. Of this, at least 6750 metric tons were Corexit products (5). This

Table 1. Oil released from Ixtoc I.

Period	Daily loss (metric tons)	Total accumulated loss
3 June–12 August	4 400	300 000
13 August–15 November	1 500	438 000
16 November–30 November	600	447 000
1 December–5 March	300	475 500
6 March–14 March	60	476 000

SOURCE: Reference 2.

Table 2. Fate of the Ixtoc I oil during the acute phase.

	Percent	Metric Tons
Burned at well site	1	5 000
Mechanically removed at well site	5	23 000
Evaporated to the atmosphere	50	238 000
Degraded biologically and (photo) chemically	12	57 000
Landed on Mexican beaches	6	29 000
Landed on Texas beaches	<1	4 000
Sank to the bottom	25	120 000

SOURCE: Ref. 2.

Figure 5. Attempts to prevent the oil from entering the lagunas using booms often failed because of strong currents.

means that the use of dispersant during the Ixtoc I blow-out was one of the largest in history.

About 30 000 metric tons, or about 6 percent of the oil from Ixtoc I, landed on the Mexican beaches of the Gulf (7). No clean-up at all was carried out over large areas. Here, the oil was left for natural degradation. However in some areas a type of clean-up technique was used that involved covering the contaminated sand with clean sand; bulldozers dug a trench some 1.0 to 1.5 meters deep and the oily sand was then shovelled into the trench and buried.

EFFORTS TO STOP THE FLOW OF OIL

In late June, about three weeks after the Ixtoc I blow-out, an unsuccessful capping attempt was made. The so-called blow-out preventer, which consists of valves situated on the well pipe over the sea floor, was closed. The valves were situated under the ruptured part of the pipe and had not been damaged by the blow-out. However, the capping failed due to the high pressure in the well, which caused oil and gas to leak outside the well casing below the blow-out preventer.

Several attempts were made to decrease the flow of oil from the well using large numbers of steel and lead balls with a weight of 1–2 kilograms each. The balls were forced into the well head but the high pressure of the leaking oil and gas ejected them. However, using this method a substantial reduction of the oil and gas flow was obtained in the middle of August when the flow rate decreased from 10 000 metric tons per day to about 4000 metric tons per day, according to PEMEX (4).

Next a funnel-shaped oil collection device a "sombrero", was placed over the well in another attempt to reduce the flow of oil. The Sombrero weighed about 310 tons in the air, was 12 meters wide and 6 meters high. It was positioned with its wide end down above the well head in the middle of October. The oil and gas contained under it was pumped through a flexible hose at the top to a platform. However due to logistic problems at the platform, only a minor part of the oil that could be recovered via the Sombrero was actually disposed of. In the early part of December rough seas damaged the device and it was removed from the well site.

The measure that finally capped the well on March 23 was the pumping of mud into the relief wells Ixtoc IA and IB. The drilling of these relief wells was started in the middle of June and the middle of July respectively. The first to be completed was the Ixtoc IB. A link between the relief well and Ixtoc I was established in December. However, it was necessary to complete the other relief well before the pressure was relieved. The Ixtoc IA reached the Ixtoc I formation in the second week of February. On March 23 the pressure of the mud that was pumped through the relief wells and into the formation finally reduced the flow of oil and gas to zero through the Ixtoc I well head. After this was done, the well was sealed with several cement plugs.

EXPOSED OR THREATENED ECOSYSTEMS

Offshore

The continental shelf, extending from the wide Campeche Bank in the east to the narrower but longer shelf in the west and north, is flat and covered by fairly uniform sediments. These bottom areas form highly favorable environments for diverse species of demersal fish, shrimps, molluscs, crabs and other invertebrates.

Little study has been devoted to the fish populations but it is believed that they have a commercial potential (biomass >8 kg/hectare). However, at present they are not being exploited to a very great extent.

The shrimp populations on the continental shelf are large and commercially very important, especially on the Cam-

Figure 6. The crab populations along several hundred kms of coastline were almost totally wiped out by the Ixtoc I oil.

peche Bank and in the area of Tampico. The three major species are the pink shrimp, *Penaeus duorarum,* the white shrimp, *Penaeus setiferus,* and the brown shrimp, *Penaeus aztecus.*

The total biomass of shrimp on the Campeche Bank was measured in one area near the Ixtoc I well at about 4 kg/hectare. Of this, the white and pink shrimp comprised approximately 37.5 percent each, while the pink shrimp made up the remaining 25 pecent, though in fishery statistics the latter account for 80–90 percent of the catch on the bank. Since 1964, the actual catch has been close to 15 000 metric tons per year.

Less is known about the shrimp stocks in the area of Tampico, but the present catch (1979/80) has been roughly calculated by Pesca, the Mexican Department of Fisheries, at 6000 metric tons per year. Here the main species is *Penaeus aztecus.*

The pelagic ecology of the Gulf of Mexico is marked by high primary productivity caused by nutrient input from a number of large rivers discharging into it, and by upwelling that occurs in a number of places. Primary production near Veracruz has been measured at as high as 5 g C/m^2/day. Pelagic fish stocks are thought to be considerable, although only a few are fished commercially: bonito, mackerel, sardine and other clupeids.

Coastal Coral Reefs

There are two clusters of coral reefs along the western Gulf of Mexico, one situated north and east of Tuxpan, and the other east of Veracruz. The Tuxpan reefs form the most northerly cluster of reefs in the western part of the Gulf and are situated some 10–20 km from the coast.

The Tuxpan reefs generally have a semilunar shape, with their major axes orientated north-south. Maximum development of the reefs occurs in the south-east sections, suggesting a strong influence by

Figure 7. Large and frequent plankton blooms occurred after the blowout both off-shore and close to the beaches.

the dominant currents from the south-east and by the periodic destructive cyclones from the north. The reefs rise from a depth of some 25 m to not more than 1.5 m and some have sandy bays rising above the water level. The average tides are approximately 0.5 m and the maximum 1.0 m. The Veracruz reefs have more or less the same configuration as those near Tuxpan but occur in two distinct barrier formations away from the coast: an inner and an outer.

The structure of the reefs is roughly similar to that found throughout the tropical Atlantic, and the communities associated with them are the same. Ernesto Chavez has described the communities occurring at Lobos reef, located 65 km north-east of Tuxpan (6). Usually associated with the reefs are seagrass beds which harbor extremely rich and productive communities on the leeward side, protected against the open sea. These seagrass beds, dominated by *Thalassia* or turtle grass, act as nurseries for commercially important species of fish and crustaceans. For example, the pink shrimp (*Penaeus duorarum*), the grass shrimp (*Palemouetes pugio*), the spiny lobster, the mud crab (*Neopanope sp*), and molluscs such as *Lucina spp* and *Chione spp*, abound in this area.

Sandy beaches

The Gulf of Mexico has two characteristic types of sandy beaches. The first type along the entire western shore, are generally long and wide stretches of beach composed of fine- to medium-grained sediments of mixed calcareous origin. These are exposed to the open sea and are pounded by heavy waves. There are wide, active surf zones and gently sloping swash zones. The fauna of these sandy beaches is fairly constant in species composition but highly variable in numbers. The characteristic species is the beach clam *Donax* that makes its burrow above the swash zone but is active in both the swash and surf zones, especially during the night. Other species were present during the investigations but only *Donax* occurred in very large numbers (approximately 10 000/m^2 near Rio Bravo). It is well known that the Kemp Ridly turtle, which may be on the verge of extinction, has one of its few remaining nesting sites along the barrier beach at Rancho Nuevo near Tampico. In 1979, approximately 10 000 baby turtles were removed from their nests near the high-tide mark by conservationists and transported to the open sea to avoid the possibility of contamination by oil.

The second major sand beach type occurs along shorter stretches of the coastline, especially in the area between Ciudad del Carmen and Campeche. Here the beaches tend to be shorter, more cuspate, partly sheltered and composed of poorly sorted calcareous sediments and shells. They are frequently interrupted by rocky headlands and are much narrower than the barrier beaches. Prominent sand dunes are also absent. The fauna of these beaches is also poorly developed.

Human activity on the beaches varies with the nature of the beach and its proximity to towns and fishing areas. Along the western shore, the barrier beaches are used extensively for recreation near major population centers (*eg* Veracruz, Tuxpan, Tampico). However, away from these centers, the beaches are generally deserted, except for some fishing activity.

Rocky shores

Rocky shores are not very common along the Gulf of Mexico and are found chiefly in the area south of Campeche where they are formed from raised reefs and are exposed to the open sea. The fauna and flora of these rocky headlands are not very rich because of the high solar heat burdens. They are dominated by small gastropods and encrusting algae. Subtidally, the diversity increases greatly.

Mangroves

Mangrove forests occur along the coast from the town of Campeche to north of Celestun. They are comprised of the common western Atlantic species, *Rhizophora mangle* (red), *Avicennia nitida* (black), *Laguncularia racemosa* (white) and *Conocarous erectus* (button). The mangroves cover a wide zone inland from the water's edge (up to 30 km) and show the characteristic zonation pattern of these species. There is very little human penetration into these mangrove forests and thus it is suspected that the stands are mature and free from any destruction. Although the mangrove's fauna could not be carefully observed, it is safe to assume that their primary and secondary productivity is very high indeed and that migrating fauna, such as shrimp and finfish, use it as feeding grounds for part of their life cycle.

Coastal lagoons

The entire Mexican coast from Carmen to Rio Bravo is punctuated by a number of coastal lagoons of which the three largest and most important are the Laguna de Términos (Carmen), the Laguna de Tamiahua (between Tuxpan and Tampico) and the Laguna Madre (between Tampico and Matamoros). These lagoons are characterized by two features: each has one or more corridors to the sea through a narrow opening across the barrier beach, and each is relatively shallow (only a few meters at most). In some there are extensive intertidal mud and sand flats and all are biologically very productive.

The Laguna de Terminos has an area of about 1800 km^2 and two openings to the sea. Brown and white shrimp from the Campeche Bank spend the early part of their life cycle in this lagoon and juveniles are fished commercially. There are large populations of the oyster, *Crassostrea virginica* and the clam, *Rangia cuneata*, and both are exploited for commercial purposes. It is clear that the lagoon is of great importance to the shrimp stocks of the Campeche Bank and has a high potential for further fishery development.

The Laguna de Tamiahua has an area of about 700 km^2 with one opening to the sea at its southernmost point (Barra de Villarrea). It harbors dense populations of *Crassostrea virginica*, of which, according to the Pesca authorities, 25 000–30 000 metric tons are harvested annually by 3000 oyster fishermen. This lagoon is the major producer of oysters in Mexico and may also be its most productive. In addition to oysters, juvenile white shrimp and two species of *Mugil* are fished.

The Laguna Madre is a large complex system of inlets, enclosed or semi-enclosed lagoons, tidal flats, marshes and islands. Its total area is estimated at approximately 3200 km^2. Productivity is high and oysters and shrimp are fished by more than a thousand fishermen from villages and towns scattered around the lagoon. Bird life in the Laguna Madre seems the most abundant of all the lagoons, and several water birds (especially terns, gulls and the endangered brown pelican) nest and feed within the system.

Rivers

In addition to the Lagunas, which tend to be estuarine, there are several reasonably large rivers that discharge directly to the sea and have estuarine conditions near their mouths.

The interrelationships between the different offshore and coastal ecosystems are very important, as can be seen, especially for freshwater run-off and lagoon hydrology, nutrient condition and productivity in the Laguna de Términos. Similarly, freshwater run-off directly by the rivers and through the lagoons affects surface sea currents and productivity in the Campeche area and plays an important role in determining shrimp (and possibly some fish) migratory patterns. In addition the dependence of the commercially important brown and white shrimp, at different stages of their life cycles, on the marine and lagoonal systems is well known and demonstrate the integrated nature of these coastal ecosystems.

BIOLOGICAL IMPACTS OF THE OIL

In general, the oil from the Ixtoc I blowout acutely affected the species and ecosystems in the Campeche Bay area through its chemical toxicity (in the vicinity of the well) and through its physical properties (stickiness) in a larger area offshore and along the coast. Thorough studies of the long-term biological effects of the spill have either not been carried out in Mexican waters, or the results of such studies are not yet available. A recently published study of the spill (8) does not provide any answers to this question either. Therefore we will discuss some of the effects the spill could theoretically have caused and give examples of direct observations of effects made by the authors in the field.

The commercially important species and ecosystems affected by the chemical toxicity of the oil were mainly the offshore shrimp and fish populations. Shrimp spawning in Campeche Bay may have been particularly affected. The pink and brown shrimps (*Penaeus duorarum, P aztecus*) have important spawning grounds south and east of Ixtoc I. The eggs, and more particularly the larvae, are known to be sensitive to petroleum hydrocarbons. When wind and current patterns changed in October, the oil slick moved south and south-east, thereby increasing the threat to these stages and possibly also to juveniles and adults. Laboratory experiments exposing larvae and adults of other crustaceans, including shrimp, to crude oil show that the acute toxicity levels are in the range of 0.1–10 ppm total oil. If we assume that 0.1 ppm was the acute toxic concentration (Ixtoc I oil is particularly rich in the highly toxic, low boiling aromatic fraction); a mixing depth of 25 m; a five-day persistency of the toxic oil fractions in the water solution; and a required concentration of 0.1 ppm to cause damage to shrimps, as well as to plankton or other pelagic organisms; then an area of 15 000 km^2 can be regarded as poisoned by the Ixtoc I oil. This is equal to 2.5 percent of the Mexican part of the Gulf.

The amount of oil that reached the bottom sediments of the Gulf is estimated to be of the order of 120 000 metric tons (see Table 2). Offshore, this oil was mostly in the form of small droplets, with larger aggregates sometimes forming nearer the shore. The average concentration over the entire area would have been below 1 g/m^2, which is not considered high enough to cause substantial damage to the benthic ecosystem. The shrimps' habit of burrowing in sediments and consuming them could have resulted in the uptake of petroleum hydrocarbons and tainting of the shrimps.

There was a lot of concern about the damage the oil might cause to the ecology of the shallow coastal lagoons. As it turned out however, very little oil was actually spread into the lagoons. It was prevented mainly by the water flowing out of them; a flow that was increased by the unusually heavy rains during this particular winter.

It is clear that the oil had a drastic impact on the littoral crab and on the mollusc fauna of the beaches which were contaminated. The populations of crabs, *eg* the ghost crab *Ocypode quadrata,* were almost totally eliminated over a wide area (Figure 6). The crab populations on coral islands along the coast were also reduced to only a few percent of normal about nine months after the spill. The abundant beach clams (*Donax*) as well as other molluscs of the sand beaches did not exhibit any drastic mortality following the spill.

In several places in the Veracruz area, such as on the coral island Isla Verde, dense mats of green algae were observed covering hard substrates such as corals and rock formations about 10 months after the blow-out. It seems likely that these effects were caused by repeated exposure to the oil, but it is still questionable whether they resulted from effects on the herbivores (mainly gastropods) or whether the sensitive balance between the algae and the coral polypes had been disrupted in some way. In the off-shore region there have been indications of an adverse impact on the base of the marine food-chains. Unusually large plankton blooms have been observed in the contaminated areas, possibly indicating eutrophication effects or that the zoo-plankton communities might have been damaged (Figure 7). This would very likely affect the exploitable populations of fish and shellfish.

Such large plankton blooms were observed north and west of Tampico in September 1979 and were very frequent on and around the Campeche Bank in the beginning of 1980.

Fishing was banned or restricted by the Mexican authorities in several severely contaminated areas north and south of Tampico in September. Fish and octopus catches reportedly dropped by 50–70 percent from the 1978 levels off Port Mansfield and Port Isabel, Texas, and off the Mexican coast from the US border south to La Pesca (9). The overall statistics for landing figures for 1979 and 1980 indicate that no decrease in the amount of fish and shellfish landed in Mexican harbors occurred, compared to figures for 1979 (10). However the fishery statistics are not a reliable indicator of damage to the fish populations. Shifts in landing places by individual boats, which are impossible to see in the statistics, may have drastic effects on the landing figures, and changes in foreign nations' fishery concessions would distort the figures on total catches. For example, Mexico excluded foreign fishing over her shrimp fishing grounds in 1979. Another shortcoming is that new species, previously not included in the statistics, may affect the total figures. For instance, octopus landings were included in the catch figures for the first time in the years following the blow-out. There are indications that all these factors have affected the figures for landings of fish in Mexican harbors, and therefore conclusive judgements based on statistics alone cannot be made. The actual extent of the damage caused by the world's biggest oil spill has yet to be determined.

References and Notes

1. According to Petróleos Mexicanos (PEMEX) official daily flow rate estimates, the total amount of oil lost from Ixtoc I was about 476 000 metric tons. The figures are quoted *eg* in Oil Spill Intelligence Report, March 28, 1980. However, after the final capping of the well, another figure (430 000 metric tons) was released by PEMEX as the total amount of lost oil.
2. This report is based on the findings of a mission to Mexico by the United Nations Environment Program (UNEP) with the co-operation of FAO, IMCO and IUCN. The mission had the following composition: A Jernelöv (Mission leader, UNEP), R Engdahl (IMCO), O Lindén (FAO), C Rees (UNEP) and B Wade (IUCN). The views expressed in this report are not necessarily shared by UNEP or the other UN agencies, nor by any of the governments involved.
3. Ing Garcia-Lara, Jefe de la oficina de Protección Ambiental, PEMEX, private communication.
4. E R Gundlach, K J Finkelstein, and J L Sadd. *Impact and persistence of Ixtoc I oil on the south Texas coast.* In Proceedings of the 1981 Oil Spill Conference, American Petroleum Institute, Washington DC, 1981, p 477–485.
5. Information given by G Lindblom in connection with the presentation of his paper at the 1981 Oil Spill Conference in Atlanta, Georgia, March 2–5, 1981.
6. Dr Ernesto Chavez, Jefe de Departamento de Ecologia, Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, Mexico City.
7. In early November, a covering of oil between 15 and 30 cm deep was reported from the western shore of the Yucatan from Ciudad del Carmen to Progresso. The report was made by the US Coast Guard (Oil Spill Intelligence Report, November 16, 1979).
8. Informe de los trabajos realizados para el control del Pozo Ixtoc I el combate del derrame de petróleo i determinasión de sus efectos sobre el ambiente marino. Programa Coordinado de Estudios Ecológical a la Sonda de Campeche 1980.
9. Oil Spill Intelligence Report, January 4, 1980.
10. Dr Carranza-Frazer, Director General del Instituto Nacional de Pesca, private communication.

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