R&D Mexico

Autopsy of an Oil Spill

Researchers hope that data gathered from the ongoing, detailed analysis of the Ixtoc I oil well blowout will minimize the impact of future oil spills

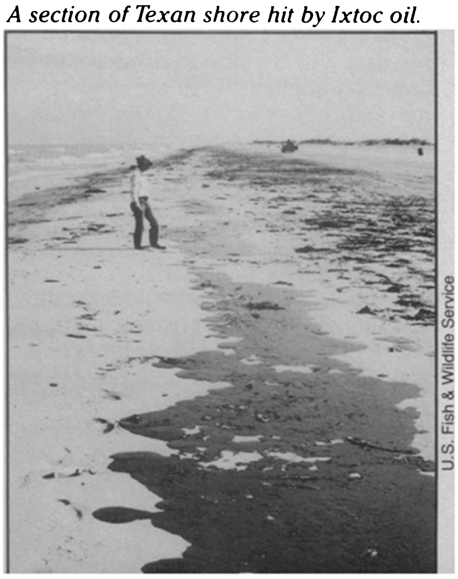
BY LINDA GARMON

Nearly three months had passed since the last observed tar ball washed onto Padre Island beaches north of Port Mansfield, Tex. More than a year had passed since the first oiled bird, a blue-faced booby, was found and brought to the island's cleaning station. "Much media attention was given to the first oiled bird," a U.S. Coast Guard on-scene coordinator wrote in the official activity report.

But this day's activity would pass with barely a notice. It was Oct. 1, 1980, and Captain Gerald Hinson had decided to terminate the USCG clean-up efforts in response to Ixtoc I, the Mexican oil well that nearly 16 months before had blown out in the Bay of Campeche, spilling 140 million gallons of oil into the Gulf of Mexico (SN: 12/15/79, p. 405).

For the USCG response team, Ixtoc I is over. But Ixtoc has left behind a legacy that is very much alive in both the scientific and political arenas of the United States and Mexico. "The Ixtoc I is important...as a case study for researchers, policy makers and response teams," says Richard S. Golob, director of the Center for Short-Lived Phenomena in Cambridge, Mass. "The incident has major implications for open-ocean spill response, blowout prevention technology, international pollution damage compensation, scientific spill research and outer continental shelf development [for oil and gas exploration]." Researchers are just now piecing together the complex Ixtoc I puzzle in an effort to address such issues.

A section of Texan shore hit by Ixtoc oil.



U.S. Fish & Wildlife Service

The first piece to that puzzle was molded by the events leading up to the June 3, 1979, blowout of the Ixtoc I, a Petroleos Mexicanos (PEMEX) exploratory well about 50 miles offshore from Ciudad del Carmen. By June, Ixtoc was drilling at a depth of about 11,800 feet below the seafloor with a bit screwed to the bottom of drill collars (a thick-walled pipe) suspended from the drilling rig by the drill pipe (a thin-walled pipe). Drilling fluid, commonly known as "drilling mud," was being pumped from surface mud tanks down the inside of the drill pipe, continuing down the drill collars and out through the bit. The mud then flowed up the annulus — the area between the outside of the pipes and the inside of the casing, or hole — and returned to the surface mud tanks.

Circulating drilling mud — composed of water, clay and certain chemicals — lubricates the drill bit, carries rock cuttings out of the hole and provides a column of fluid in the hole, the weight of which counterbalances potential pressure formations. The day before Ixtoc blew, the drill bit hit a pocket, or region of soft strata, and the valuable circulation was lost. This meant that rather than returning to the surface, the drilling fluid was escaping into fractures in the rock at the bottom of the hole. PEMEX officials decided to remove the bit, run the drill pipe back into the hole and pump materials down this open-ended drill pipe in an effort to seal off the fractures causing the loss of circulation.

During this pipe-removal operation, though, drilling mud suddenly began to flow, with rapidly increasing pressure and speed, up both the annulus and the inside of the drill pipe. Normally, this dangerous flow can be stopped by activating the shear rams of the blowout preventer (BOP) to sever and seal off the drill pipe. But the Ixtoc pipe removal operations had brought the drill collars in line with the BOP at the time of the mud flow. The BOP rams simply were not designed to sever the thick steel walls of the drill collars, so the flow continued.

Eventually, the mudflow was followed by a gush of oil and gas at an ever-increasing rate. The oil and gas fumes exploded on contact with the operating pump motors, a fire broke out and the drilling tower collapsed, causing damage to underlying well structures.

Thus began the largest oil spill in world history. Within one week, Ixtoc I had lost more oil than the December 1976 *Argo Merchant* spill of 7.6 million gallons off the Massachusetts coast; by late July, Ixtoc surpassed the 68 million gallons of oil that the tanker *Amoco Cadiz* spilled off Brittany, France, in March of 1978.

Ixtoc's record-breaking gush gave scientists the opportunity to brush up on oil-spill behavior. When oil is released into the environment, it is weathered by one of five processes: evaporation into the atmosphere, dissolution into the water, emulsification (formation of an oil-and-water emulsion called "chocolate mousse"), degradation by microorganisms or photochemical oxidation by sunlight and atmospheric oxygen. To study this weathering phenomenon, a team of National Oceanic and Atmospheric Administration scientists boarded the NOAA ship *Researcher* and sampled ocean water, oil, bottom sediments and organisms within a few hundred feet of the burning well. The NOAA team then sampled the oil during its long journey north toward the Texas coast to study how weathering would affect the Gulf-water distribution of the various hydrocarbon components in the Ixtoc oil.

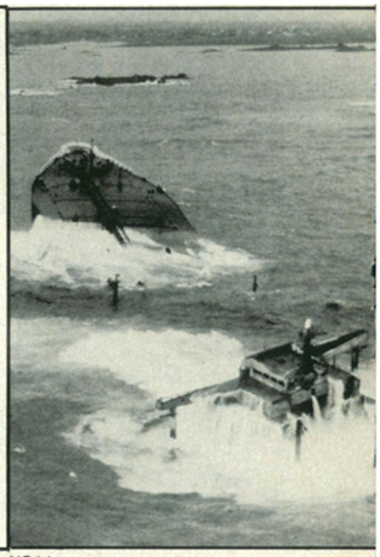
The result of that voyage is a "significant contribution" to the understanding of oil

R&D Mexico

The table (center) summarizes some of the differences between the oil spills resulting from the wreckage of the Amoco Cadiz *(right) and the blowout of the Ixtoc I well (left).*

Oil spill		AMOCO CADIZ	IXTOC-I
Nature of incident		stranding of a tanker	blowout (drilling well)
Location		Brittany coast, PORTSALL (France)	Gulf of Mexico (Mexico) 19°24.5′ N-92°12.6′ W
Date		3/16/78	6/3/79 to 3/20/80
Crude oils		"Arabian Light" & "Iranian Light" (about 1:1)	Ixtoc-I
Quantities discharged		223,000 t.	~ 600,000 t.
Density		0.85	0.84
Chemical Composition	Saturated	39% /1/	50% /3/
	Aromatics	34%	32%
	Resins & Asphaltens	27%	18%
	Nickel	14 ppm /2/	10.5 ppm
	Vanadium	45 ppm	55 ppm

Michel Marchand el al. CIRES, Boulder, Colo.

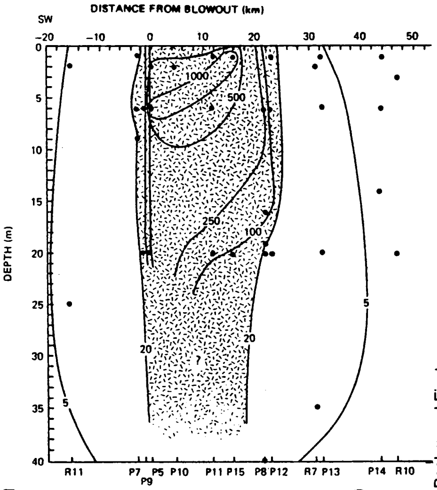


NOAA

behavior, says Donald Atwood, chief scientist onboard the *Researcher*. The ship's team discovered, for example, that photochemical oxidation plays a key role in transforming oil droplets into mousse. Prior to the Ixtoc expedition, scientists believed that mousse forms as soon as oil enters the water. The NOAA study indicates, however, that mousse does not form until the oil is three to 15 nautical miles from the well and that its formation is driven largely by photo-oxidation. "Sunlight drastically altered the oil," Atwood says. "It caused the hydrocarbon to lose some carbon atoms and take up some oxygen atoms, so that the oil became chemically more like soap and could emulsify." Photo-oxidation also appeared to alter the toxicity of the oil, making it more toxic in some cases and less in others.

Other *Researcher* findings include the observation that the oil-"eating" microbial populations within about 25 miles of the well head rapidly increased in size and that these microbes, like sunlight, promote mousse formation. In addition, the NOAA researchers found that the microbial degradation of oil was limited by the amount of nutrients — particularly nitrogen and phosphates — in the water.

But the finest feather in *Researcher*'s cap may represent the work of Paul D. Boehm and David L. Fiest of Energy Resources Co. Inc. At the recent American Chemical Society meeting in Las Vegas, Nev., these researchers presented their preliminary, though nonetheless significant, findings based on the series of water samples taken aboard the *Researcher* as it moved along the axis of Ixtoc's surface slick: a map contouring the subsurface concentrations of petroleum. This oil spill map, the first of its kind, indicates the concentrations of petroleum at particular ocean depths and at specific distances from the Ixtoc blowout. Such an avant garde oil spill characterization is important because "the fate of components of spilled oil ... [is] closely linked to the biological impact of these pollutants," Boehm and Fiest explain. The researchers attribute their success to the use of synchronous scan spectrofluorometry — an analytical device that identifies the component concentrations in a sample by the tell-tale fluorescence emissions after exposure to ultraviolet light.



Boehm and Fiest

Concentration contours of Ixtoc oil.

The contour map study was one of 12 presentations at the ACS meeting included in a special oil spill symposium. Several other of those presentations looked at methods of "fingerprinting," or identifying the source of an oil pollutant. Crude oil is an extremely complex mixture of hydrocarbon compounds made up predominately of hydrogen and carbon but also containing traces of sulfur, nitrogen and oxygen. All oils are composed of the same types of hydrocarbon compounds and differ only in often-subtle component quantities. Further blurring the picture of pollutant origin is the fact that marine oil can come from several different sources: In addition to oil spills, routine tanker traffic, natural seepage and land runoffs dump petroleum into the ocean.

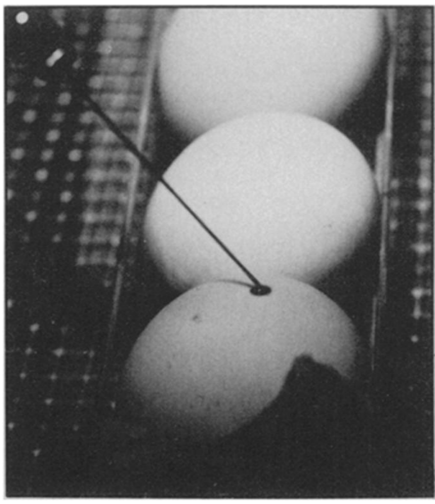
And therein lies a major challenge for oil spill analyzers. To draw an accurate picture of the fate of runaway oil, researchers first must be able to confirm that the oil slicks they are tracing in the ocean currents, the tar balls they are observing on shores or the petroleum concentrations they are extracting from marine organisms are from the suspected source. During the ACS oil spill symposium, I. R. DeLeon and colleagues of the Center for Bio-Organic Studies in New Orleans, La., suggested that the azaarene (nitrogen-containing aromatics, or ringed hydrocarbons) content in oil samples "may serve as useful passive tags for tracing petroleum sources in the marine environment." Analyzing oil for its azaarene content seemed particularly appropriate for Campeche Bay: While these compounds generally are present in oil in very small amounts, they are found at slightly higher concentrations in Ixtoc oil. Azaarene content also is of interest because certain of these compounds are known carcinogens.

Aromatic hydrocarbons, such as the azaarenes, usually are found to be more toxic than the non-ringed, or aliphatic, hydrocarbons of oil. Researchers at the Patuxent Wildlife Research Center in Laurel, Md., recently lent further credence to this canon of petroleum toxicity in their studies of the effects of oil on the hatchability of aquatic bird eggs. Small quantities of oil applied to the eggs of aquatic birds in the laboratory caused embryo mortality. For example, as little as 5 microliters of crude oil applied to the shell surface on the eighth day of incubation reduced hatching of mallard eggs by as much as 90 percent. But when the shell surfaces were coated with as much as 50 microliters of an aliphatic-only mixture, embryos did not die.

The results of studies of the effect of oil ingestion on the physiological condition and survival of birds were more encouraging. The Patuxent researchers were particularly interested in determining how two endangered species — the peregrine falcon and the whooping crane — would fare when Ixtoc oil reached their coastal habitats and covered their food supplies. Under the direction of Lucille F. Stickel, the Patuxent bird watchers studied the effect of oil ingestion on endangered species surrogates — kestrels for the falcons and sandhill cranes for the whooping cranes. Although data collected from these studies still are preliminary, it appears that adult birds could survive spill levels of petroleum hydrocarbons in their diet when not otherwise stressed.

But the final test never came. By the time the first cranes arrived about a year ago at their wintering areas in the Aransas National Wildlife Refuge north of Port Aransas, Tex., the current flow along the Texas coast had reversed, carrying the oil south. No oil reached the refuge. Moreover, prior to the current reversal, only about 20 Texas coast birds were known to have died as a result of direct oiling.

The impact of the Ixtoc spill on other wildlife, such as turtles and fish, is still being evaluated. Turtle authorities first sensed trouble for the endangered Atlantic Ridley sea turtles this summer when scientists fed their latest data on Gulf currents and oil patch locations into a computer model, developed by NOAA and USCG researchers, that simulates the trajectory of pollutants in the ocean. The spill trajectory model, based on studies of previous spills, predicted that the Ixtoc oil probably would affect the Mexican coast between Tampico and Lower Laguna Madre in July, threatening the Ridley sea turtles that breed along a stretch of beach near Rancho Nuevo, Mexico. The Ridley eggs usually begin hatching in mid-June and turtles continue to emerge until mid-August. The hatchlings then swim west and north in the Gulf waters for about two months. Experts, fearing that these young turtles might ingest the Ixtoc oil during their premiere swim, organized a turtle airlift that carried about 9,000 turtles to a patch of sargassum less than 25 kilometers offshore.

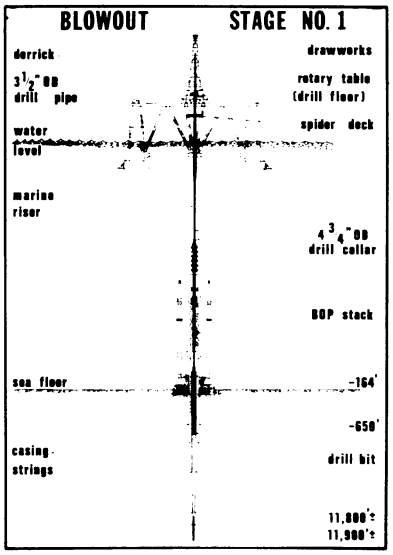


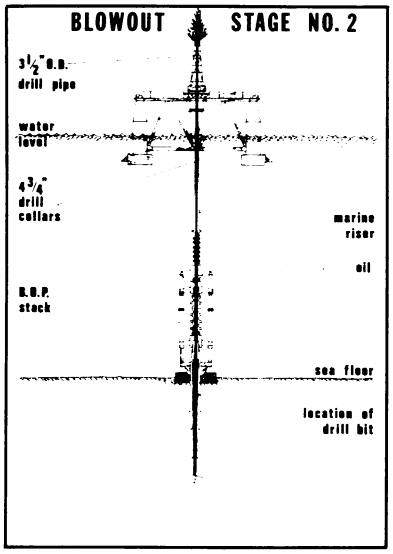
U.S. Fish & Wildlife Service

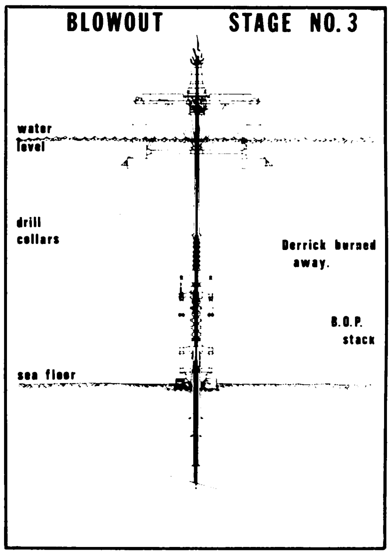
Studies show that the toxicity of the oil, rather than blocking of the shell's "breathing" pores, is what kills embryo mallards.

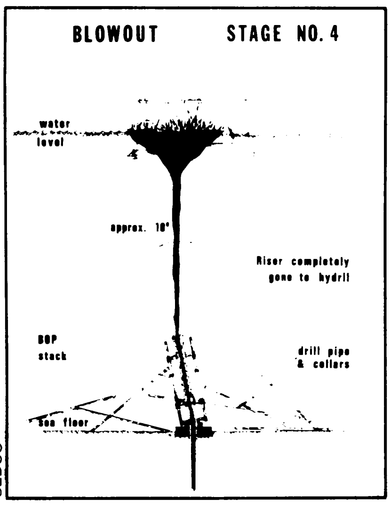
Whether the turtle airlift saved the Ridley population from fatal oil spill encounters remains to be seen. According to U.S. Fish and Wildlife officials, if the population of adults next spring is fewer than 1,500 — which would be the lowest recorded population in recent years — then turtle authorities probably could assume that at least the adults met with the oil slick. It will take about eight years, however, before the impact of the Ixtoc blowout on this year's hatchlings can be evaluated; at that time, the hatchlings will have matured and returned home to Rancho Nuevo.

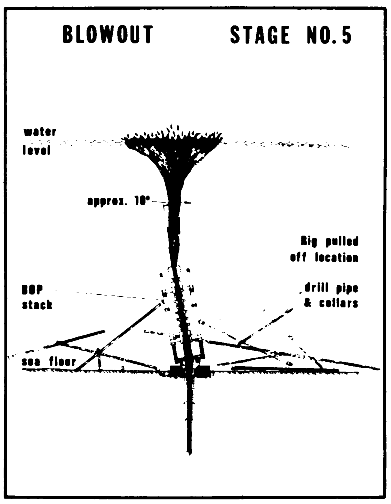
As with the Ridley hatchlings, the overall environmental impact of Ixtoc will take years to evaluate. Still, some researchers already say the Gulf of Mexico seems back











SEDCO

The drawings of the Ixtoc I well depict the chain of events that occurred in the Bay of Campeche from June 3 to July 12, 1979. Shortly after the pipe-removal operation had situated the thicker-walled drill collars in line with the BOP stack (Stage 1), drilling mud began to flow up the annulus and also out of the inside of the drilling pipe (Stage 2). Oil and gas followed the mud flow, and fire broke out (Stage 3). Underlying support structures collapsed (Stage 4), and the floating rig was pulled off location (Stage 5).

to normal. "If you go to the beaches of South Padre Island today," said ACS oil spill symposium participant Edward B. Overton, "you'll find good swimming and good fishing." Although it looks like "the end of the world" on the beaches during an oil spill, "The environment springs back," says Overton of the Center for Bio-Organic Studies. "In some people's minds, it's as though we create a sterile area after we've had a spill. This is not the case."

Other researchers do not share Overton's optimism. Some believe, for example, that the 37 tar mats, or areas of buried oil, in the subtidal region off the coast of Texas may present a continuing pollution problem. These mats reportedly measure about 60 meters long and 6 meters wide.

In addition, "Scientists still have not been able to account for the bulk of the 140 million gallons of oil that spilled from the Ixtoc I and that, according to NOAA, had covered up to 10 percent of the surface area of the Gulf of Mexico in the fall of 1979," Golob reported at the ACS meeting. Golob says that PEMEX unsuccessfully used a variety of cleanup techniques, including skimmers, dispersants and the Sombrero oil collection device — a 300-ton octagonal steel cone similar in shape to a Mexican hat — to recover the spilled oil. Even though local storms and hurricanes were in part to blame for the overall failure of these techniques, Golob says, "If the Mexicans — with equipment from the best manufacturers and expertise from the finest spill experts worldwide — were not able to deal with the Ixtoc I spill, then the cleanup problems encountered ... raise questions about the adequacy of existing equipment and technology to meet the demands of any massive open-ocean spill, whether from a well blowout or a tanker stranding."

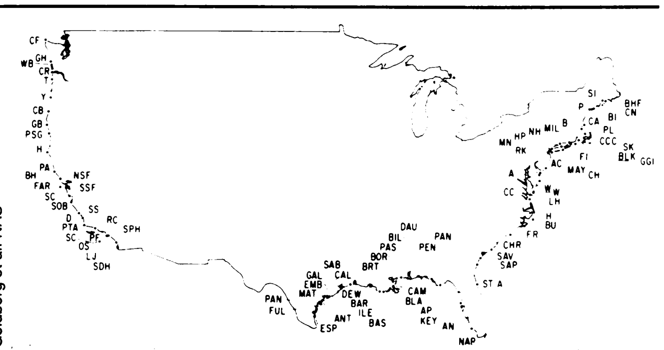
Golob says Ixtoc I analyzers should address not only those issues concerning blowout prevention and cleanup technologies, but also the political questions, such as compensation for damages from a transboundary incident.

These issues were discussed last December during the Senate hearing on the Campeche oil spill. The hearings were particularly timely because in just 13 days the U.S. Department of Interior intended to hold the first lease sale for marine oil and gas activities on Georges Bank — an area off the New England coast considered to be the world's most productive fishing ground and thought to contain only 3.4 percent of the oil and 4.4 percent of the gas recoverable from the Outer Continental Shelf. When the sale proceeded as scheduled, following the Dec. 11, 1979, lease sale of a similarly controversial tract off the coast of Alaska, groups that oppose rapid development of offshore drilling feared that Ixtoc already had left the political arena — months before the well was capped.

Overton, though, says that while an increase in ocean drilling, and therefore future accidental inputs of fossil fuels in the marine environment, is inevitable, "We learned from the *Amoco Cadiz* spill, we are learning from the Ixtoc I spill and we will learn from future spills. This is an ongoing study.... We have not forgotten Ixtoc." □

Mussel-bound monitors

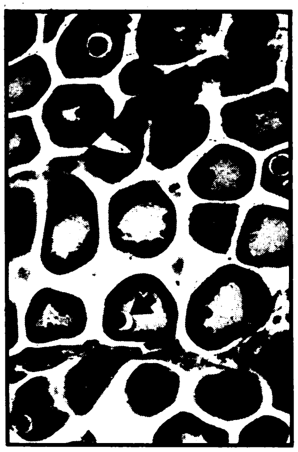
Where the ocean meets the shore is a dynamic environment highly susceptible to society's discards — fossil fuels, trace metals, halogenated hydrocarbons and radionuclides. Researchers recognizing the increasing threat to this precious environment have organized "Mussel Watch," a systematic and continuing program for monitoring coastal contaminants.

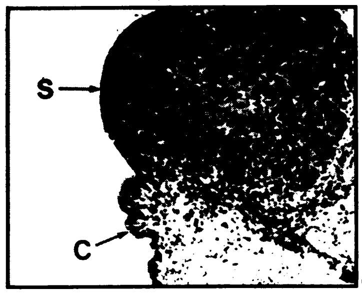


Goldberg et al. NAS

Mussel Watch is a strategy of using bivalves — mussels, oysters and clams — as vigilantes of marine pollutants. The program involves periodically analyzing tissues of bivalves from specific Mussel Watch stations to identify areas of elevated contamination and to provide baseline data from which future hot spots can be identified. As a routine part of the program, for example, oyster samples were taken from the shores of Port Aransas, Tex., before the Ixtoc I exploratory well blew out in June of 1979 and began spewing oil into the Gulf of Mexico. With this pre-Ixtoc baseline data in hand, mussel watchers on the Texas coast recently began analyses of post-Ixtoc oyster samples for fossil fuel compounds to aid in gauging the spill's impact.

If elevated concentrations of fossil fuel compounds are discovered in these samples, however, mussel watchers must consider all possible sources of contamination. The National Academy of Sciences estimates that 6.11 million metric tons of petroleum enter the worldwide marine environment each year from sources such as natural seeps (.6 million metric tons per year), industrial and municipal wastes (.6), river runoff (1.6), urban runoff (.3) and offshore production and tanker traffic (2.21). Oiled oysters can flag a problem but not its origin.





Photos: NAS

At U.S. Mussel Watch stations researchers find that bivalves subjected to pollutants are less susceptible to parasites (left) and can undergo digestive gland cell transformations (C to S above).

Another limitation of the Mussel Watch program is the fact that many different variables — bivalve size, sex, reproductive state and physiological condition, for example — may influence the levels of pollutants accumulated by mussels. Such observations have stimulated work in the development of an "artificial mussel," such as one made with polyurethane foam "tissues." These synthetic, pollutant-concentrating tissues would not be influenced by nature's variables.

Despite the limitations, bivalves could easily be global pollutant barometers, says Mussel Watch participant John W. Farrington, because they are composed of "cosmopolitan species." Explains Farrington, of Woods Hole Oceanographic Institution in Massachusetts, "Mussels and oysters have cousins worldwide; the mussel you see on the East Coast is close to the one you see in the Mediterranean, which is close to the one you see on the West Coast." The similarity between species helps to standardize the program.

Evaluating the merit of a global Mussel Watch program was one concern of the recent NAS-sponsored International Mussel Watch Workshop in Barcelona, Spain. Now, a second Mussel Watch conference is in the works, and organizers hope to hold it in Southeast Asia to encourage input from Third World countries there. Farrington says this region could benefit from Mussel Watch not only because the program offers a relatively simple and inexpensive screen, or first-step, analysis for pollutants, but also because "a whole chunk of the world's population is living on the coast there."