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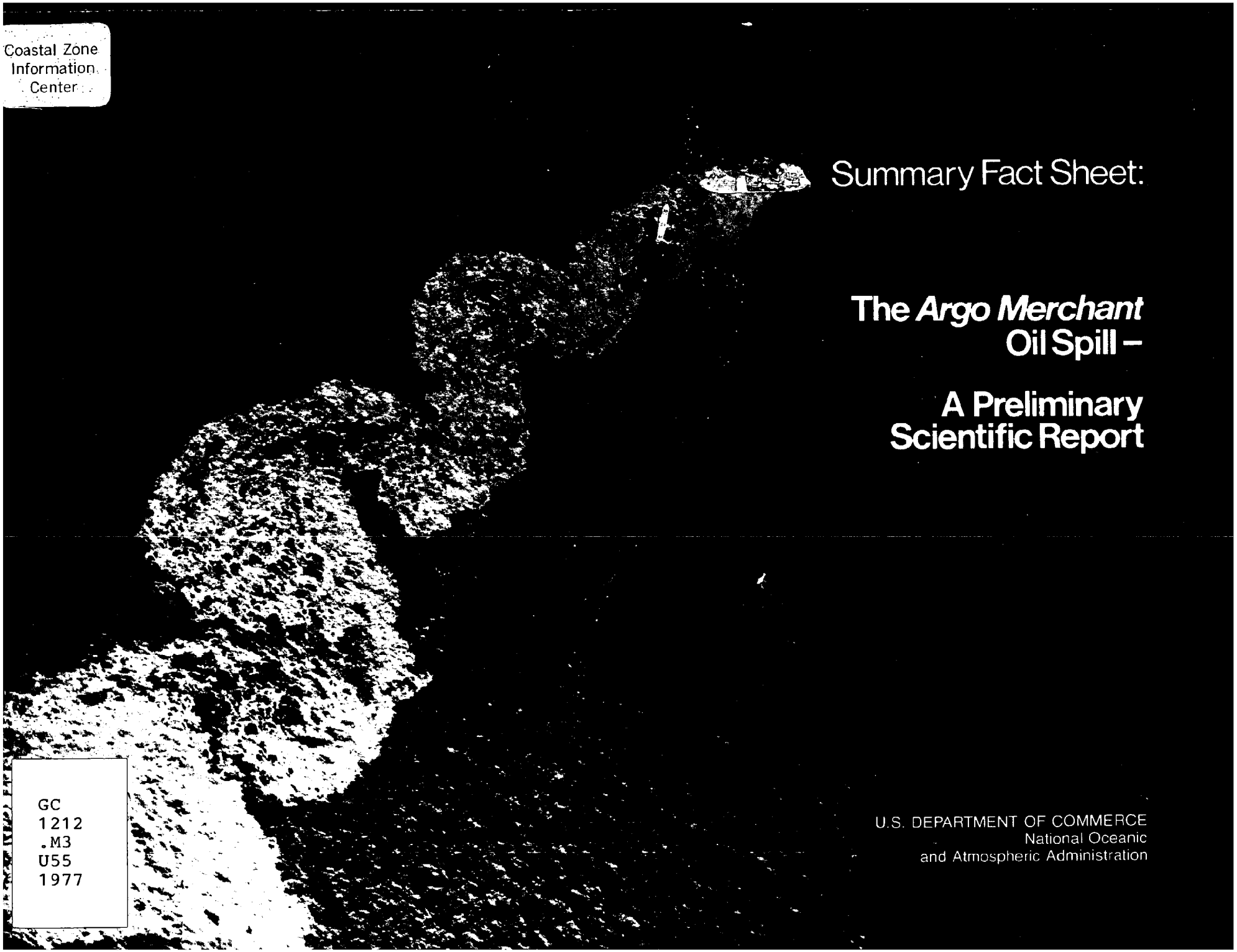

Summary Fact Sheet:

The *Argo Merchant* Oil Spill – A Preliminary Scientific Report

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U.S. DEPARTMENT OF COMMERCE
National Oceanic
and Atmospheric Administration

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This summary fact sheet constitutes Appendix VIII of *The* Argo Merchant *Oil Spill–A Preliminary Scientific Report.*

National Aeronautics and Space Administration aerial photograph taken December 19, 1976, shows plume of oil from grounded tanker Argo Merchant. *On this date, the ship had begun sinking at the stern, and had lost an estimated 1.5 million gallons of oil to the sea.*

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Jear dawn, at six a.m. Eastern Standard Time, Wednesday, ecember 15, 1976, the Liberian nker *Argo Merchant* went aground Fishing Rip, an area of treacherous oals 29 nautical miles southeast Nantucket. Within a few hours, the S. Coast Guard Atlantic and ulf Strike Teams were on the scene, empting to refloat the stricken ip, and prevent its cargo—7.7 llion gallons of number 6 fuel oil—m spilling into the sea.

But the *Argo Merchant* remained ground, and, buffeted by rough as and high winds, began to leak oil at afternoon. Attempts to offload e ship's cargo were thwarted by avy weather, and the tanker ntinued to leak. At 8:35 a.m. on ecember 21, the battered vessel gan to break up, spilling virtually all its oil into the rough waters f Massachusetts. The grounding the *Argo Merchant* had become e of the largest oil spills in ited States history.

It had also become the focus of a major scientific study, and an opportunity for scientists to test their understanding of the properties, behavior, and detailed ecological impact of oil spills. It would become an important source of new insights into such events; for, pervasive as spills seem to be, they have not been studied closely. The physical and chemical processes that drive the movement and evolution of spilled oil are not well understood. Neither are the ways in which oil contamination affects the crucial life forms that knit the intricate food web of the sea.

The urgent need for better comprehension of oil spills was recognized long before the *Argo Merchant* grounded on Fishing Rip. In an ambitious study for the Interior Department's Bureau of Land Management, the National Oceanic and Atmospheric Administration's Environmental Research Laboratories are providing the environmental data required to assess the consequences of offshore oil and gas development on Alaska's outer continental shelf.

A major element in this Outer Continental Shelf Environmental Assessment Program (OCSEAP) has been a search for improved understanding of the transport processes of spilled oil, and the rates at which the spill changes physically and chemically. Accordingly, the OCSEAP studies include extensive work on these subjects, drawing from both observational and modelling techniques for each of the nine Alaska outer continental shelf areas under consideration for petroleum development.

The need for field verification of the oil-spill models developed in this program led to the creation of NOAA-Coast Guard Spilled Oil Research (SOR) teams. Composed of scientists from NOAA (a Commerce Department agency), the Coast Guard, and the Alaska Department of Environmental Conservation, the SOR unit comprises five teams of two or more scientists operating out of Juneau, Fairbanks, Seattle, and Washington, D.C., with a backup team in Boulder, Colorado. They are highly mobile and specially trained to obtain critical scientific information from oil spills, wherever and whenever they occur.

Their ruling objective is to develop comprehensive information on the physical, chemical, and trajectory processes of various classes of oil spilled at sea, under various oceanographic and meteorological conditions. In the field, however, the SOR team may also act to focus research elements drawn to the incident, effectively transforming the spill into a comprehensive and coordinated environmental research project.

The *Argo Merchant* spill offered these investigators a unique opportunity to monitor a major spill under conditions analogous to those found off Alaska—a spill in cold water, complicated by winter storms, high winds, and heavy seas.

Within hours of the grounding, the SOR team had been notified of the potential for a major oil spill and had begun arriving at the scene, setting up an operations center in Hyannis. By Friday, December 17, the SOR team members had contacted other prospective investigators from NOAA's National Marine Fisheries Service, the Geological Survey, the University of Rhode Island, and Woods Hole Oceanographic Institution, to plan a coordinated series of physical, chemical and biological studies of the spill and its ecological impact. The document, *The* Argo Merchant *Oil Spill—A Preliminary Scientific Report*, describes the conduct and early results of these studies.

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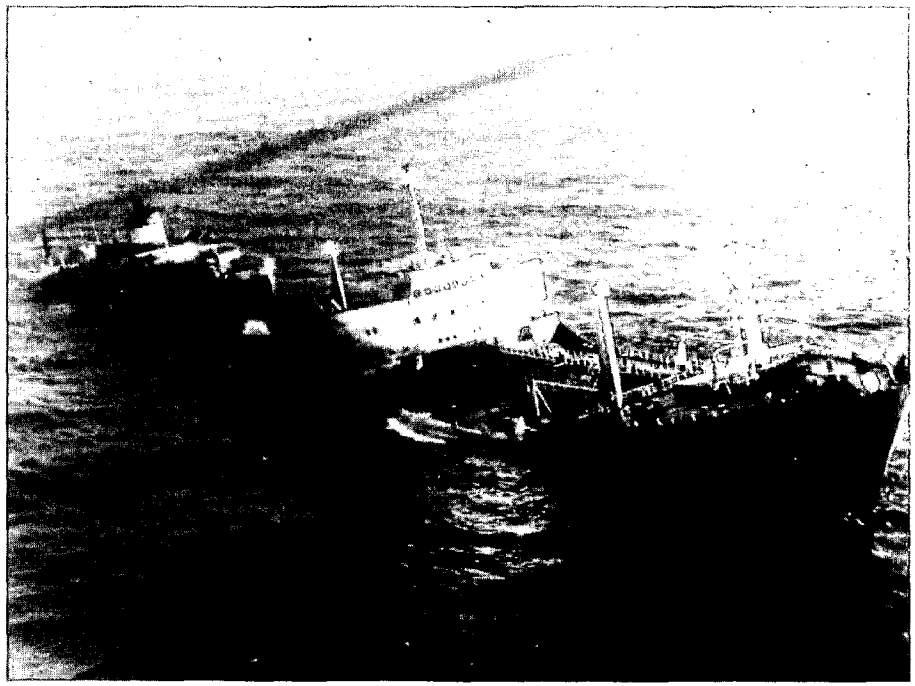

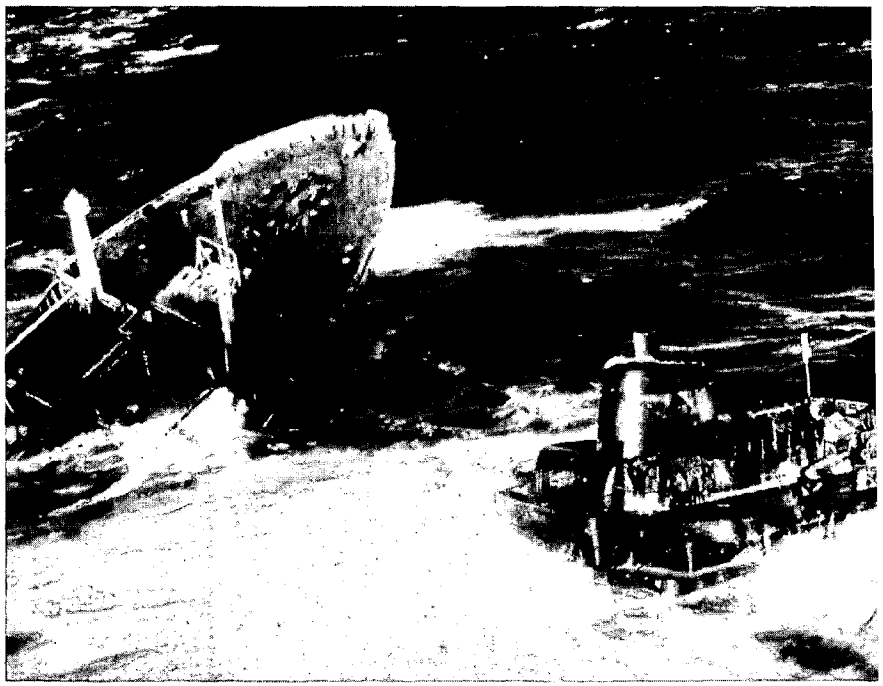

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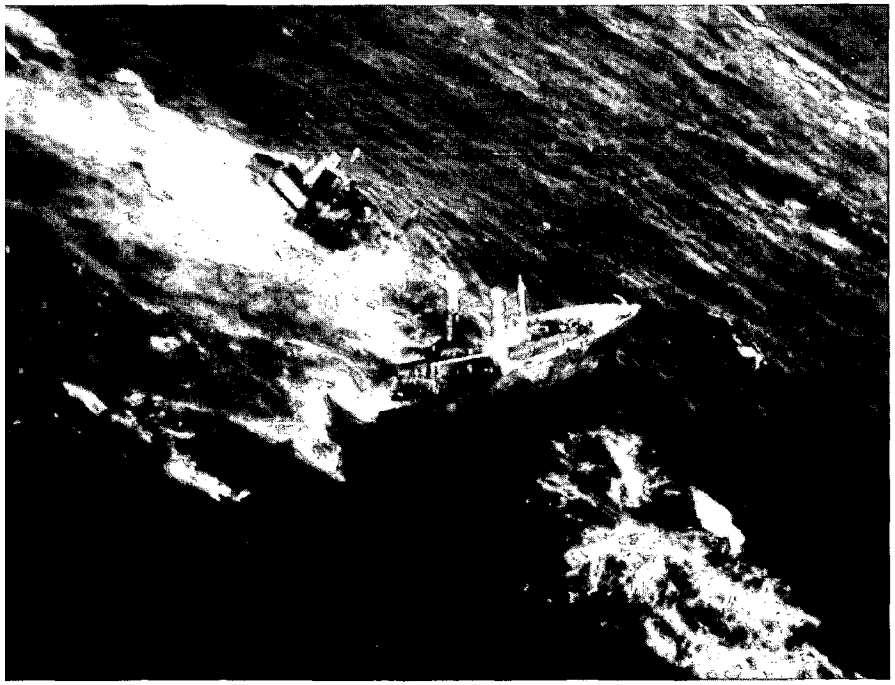
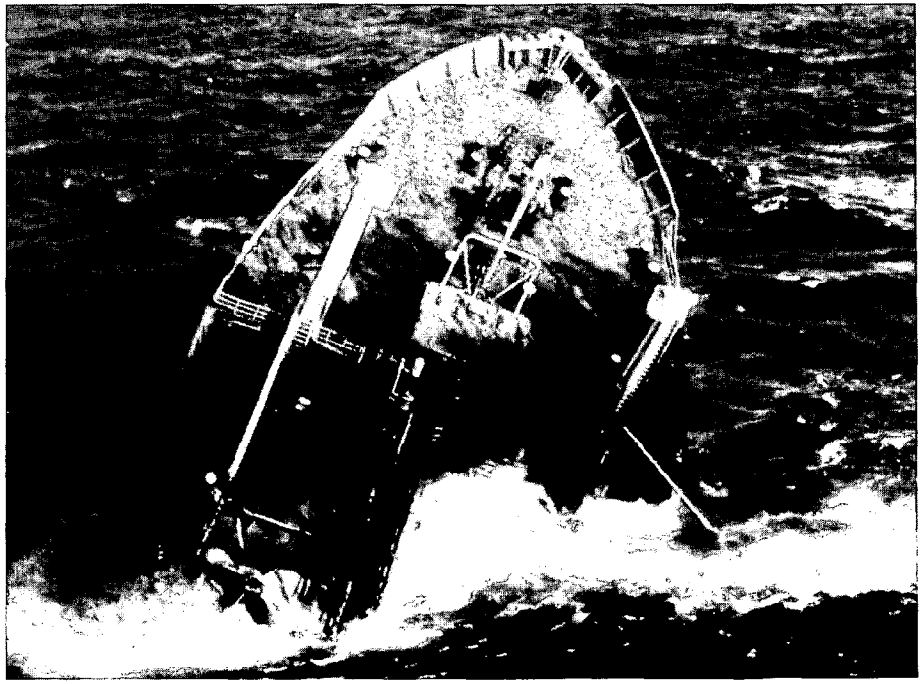




The Physical Setting

A major initial effort in this study was to develop an observational program capable of monitoring both the spill and the dynamics of its environmental setting —this in the face of generally poor visibility, high winds, and aircraft icing conditions. The research generally "piggy-backed" missions conducted for the Coast Guard's on-scene coordinator as part of that organization's oil spill monitoring and containment responsibilities.

Airborne surveys by the Coast Guard Oceanographic Unit provided real-time infrared and visual observations and photography of the impacted area. This information was transformed into daily spill maps, showing flight tracks, sea-surface temperatures, and the extent, nature, and concentration of oil. The mapping missions were flown daily until January 5 (with one outage caused by weather and another by engine failure) in an HU-16E Coast Guard amphibian, flying at 500 feet. At the same time, Coast Guard helicopters flew low-level missions to collect water and oil samples and to measure oil transport velocities.

The National Aeronautics and Space Administration, NOAA, and EPA also provided overflights of the spill area by appropriately instrumented aircraft, as did Bureau of Land Management contractors associated with the New England Outer Continental Shelf Physical Oceanography Study. These flights provided photographic coverage of the area, remote-sensor data on sea-surface temperatures and oil dispersion, dye-current measurements, and other environmental information. The aircraft were also used as platforms from which to launch expendable bathythermographs, drift cards, dye markers, and other current-sensing drifters. They permitted the SOR team to deploy drift cards between the oil slick and the beach, to provide an early warning system if the oil began to move toward shore.

On the surface, a fleet of Coast Guard cutters and research ships plied the impacted area around the *Argo Merchant,* seeking to determine the fate and effects of the spilled oil. The cutters *Vigilant, Bittersweet, Evergreen,* and *Spar* provided oceanographic measurements, as did *Oceanus,* from Woods Hole Oceanographic Institution, *Endeavor* from the University of Rhode Island, and NOAA's fisheries research ship *Delaware II.* The leased tug, *Whitefoot,* was used to emplace current meter moorings and collect sediment samples.

Current meters were deployed both by Coast Guard aircraft and ships, to determine regional water motion at specified depths. Moored meter arrays deployed soon after the spill, and their records are being recovered now. Surface water motion was measured with dye markers and drift buoys, large plywood sheets, drift cards, and sea bed drifters, which float near the sea floor.

Landsat II and NOAA-5 imagery also supported the study as did special forecasts for the wreck site issued by NOAA's Natio Weather Service Forecast Office in Boston.

As the spilled oil began to congeal into large, flat freeforms, 5(90 feet in diameter and several inches thick, the investigation focus on these "pancakes," and the thin slick intermittently observed between them. On December 31 a satellite-tracked buoy was planted a 25-by-75-foot pancake estimatec to contain half a million gallons of oil. As the pancake drifted, the bi radioed positional and other environmental data to receivers aboard NASA's *Nimbus VI* satellite

Divers from the Navy's Atlanti Fleet Audiovisual Command probed and photographed the slic from below, obtaining unique data the underside of oil in the ocean, and its behavior. From below, they reported, the oil "looked like burned carbon," and seemed corrugated by wave action, splittin and coalescing above the divers "like mercury." The oil apparently consolidated and thickened as it aged, and lost at least some of

; more aromatic components. The ivers found no oil on the sea floor near ıe spill site except immediately ound the *Argo Merchant's* bow ection, which, in dragging the bottom, ıay have mechanically forced ome oil contamination of the sea floor.

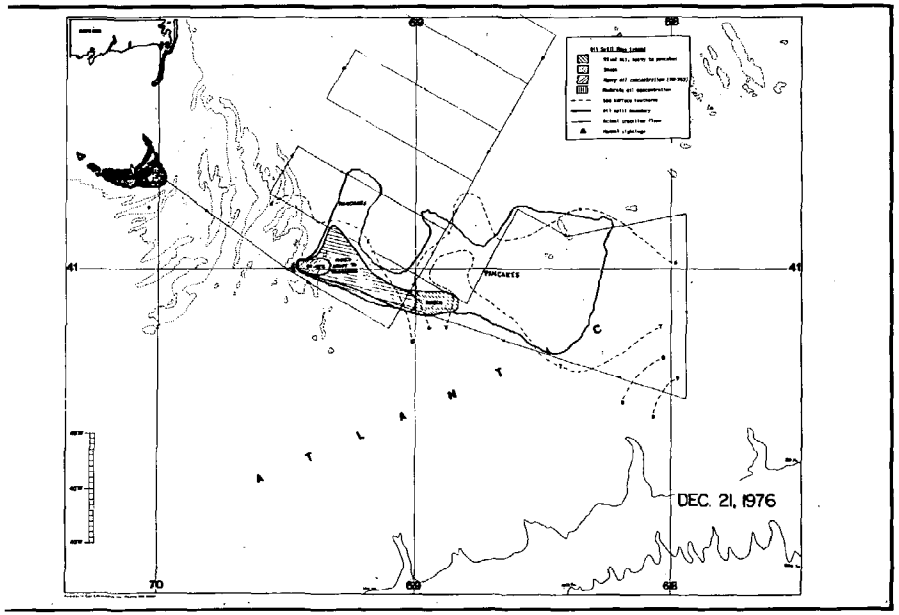
As the oil drifted southeastward om the wreck, and moved off ıe continental shelf and into the tlantic circulation patterns, ıe weather became less a forcing ıctor and the slick movement as dominated by general oceanic currents. A general westerly current pattern previously described for Georges Bank was not established; in fact, in addition to the measured wind drift of the oil, a net surface current of the order of 0.6 knot to the southeast was established.

In depths of less than 150 feet (50 meters) of water, it appeared that the net currents responded well to the wind. The pancakes of oil emanating from the wreck were observed to build up in thickness as they moved away from the wreck. After a week or two, thick patches of oil originally an inch and a half to two inches thick had become six-to-ten-inch-thick patches.

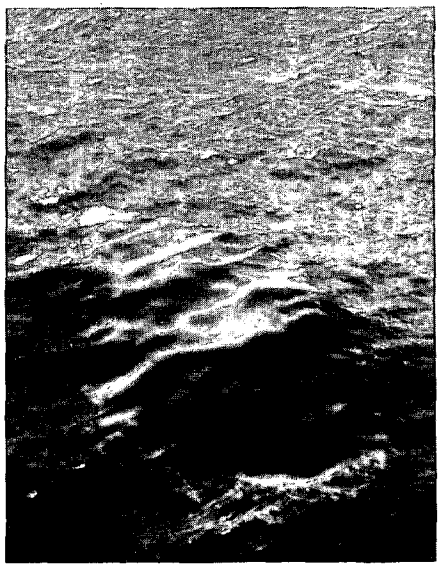
On March 10, large tar balls began coming ashore on the southwest coast of Nantucket Island. The balls were reportedly as much as a foot in diameter; one, found on the eastern shore of Nantucket, weighed 70 pounds. The material was deposited in a widely scattered pattern around centers about 100 feet apart. The tar was relatively fresh and contained no entrained sand or other materials, suggesting that it had been floating and weathering after a recent spill.

Samples of the tar were given to Woods Hole Oceanographic Institution for chemical analysis. This work may be able to document the tar as being derived from crude or refined petroleum; but it will not be able to establish conclusively whether the tar originated with oil spilled by the *Argo Merchant* or with another spill of Number 6 fuel oil.

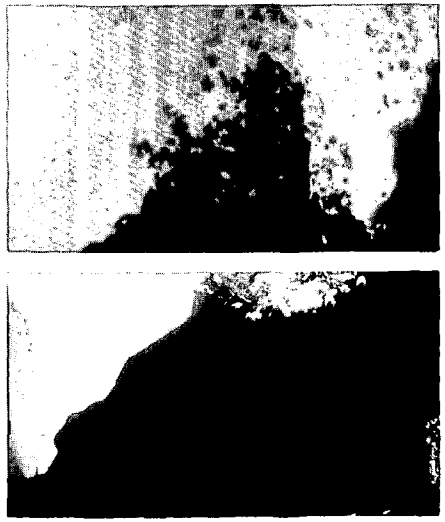
ıily spill map prepared by Coast ıard Oceanographic Unit was crucial tool in planning and coordinating scientific response to spill. Mapping missions were flown daily until January 5.



Number 6 oil from the Argo Merchant *tended to form large, floating "pancakes" like the one shown in this view from a Coast Guard helicopter.*



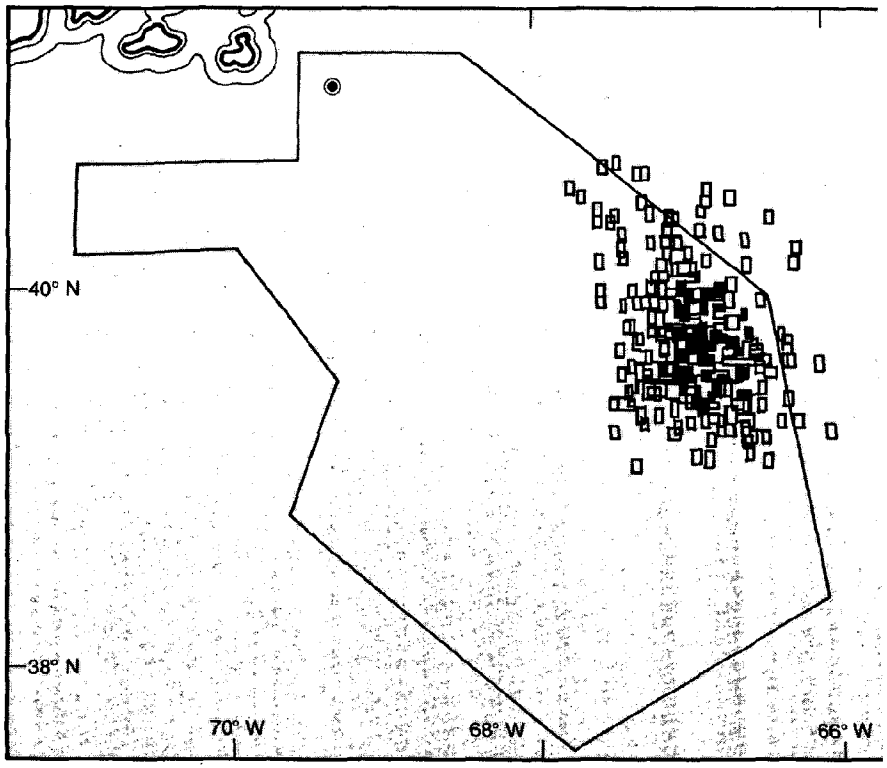
Navy divers obtained unique photographs of the oil from below, showing, among other things, that SCUBA-exhaust bubbles tended to break up the oil (upper photograph), which then reformed (lower photograph).



Oil Trajectory Models

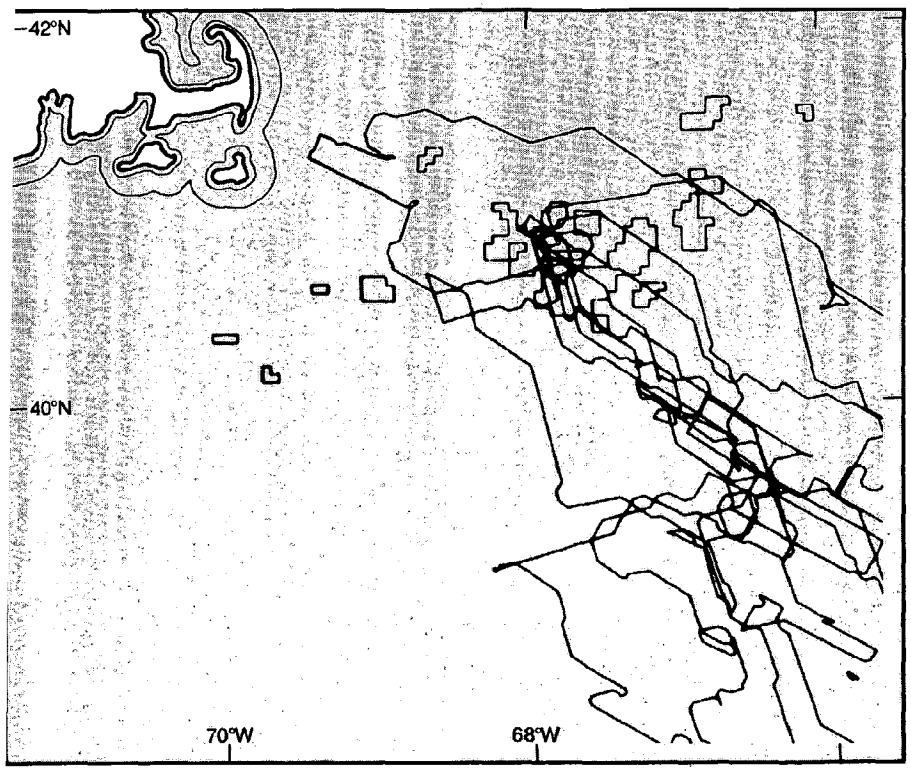
A parallel effort compared the results of simulations obtained with various computer models—sets of mathematical equations capable of simulating physical events—with the day-to-day behavior of the real oil slick. Models from the Coast Guard Research and Development Center, the Geological Survey model used in assessing spill hazard for the North Atlantic outer continental shelf lease area, and models developed by the University of Rhode Island and by NOAA's Center for Experiment Design and Data Analysis were applied in the study. These models represent slightly different approaches to the difficult problems of diagnosing and predicting the trajectories of spilled oil, a major element in assessing the probable impact of petroleum development off Alaska. The oil-trajectory models under development for the Alaska OCS program were not tested on the *Argo Merchant* spill, which was used mainly to develop detailed information for future use in this continuing effort.

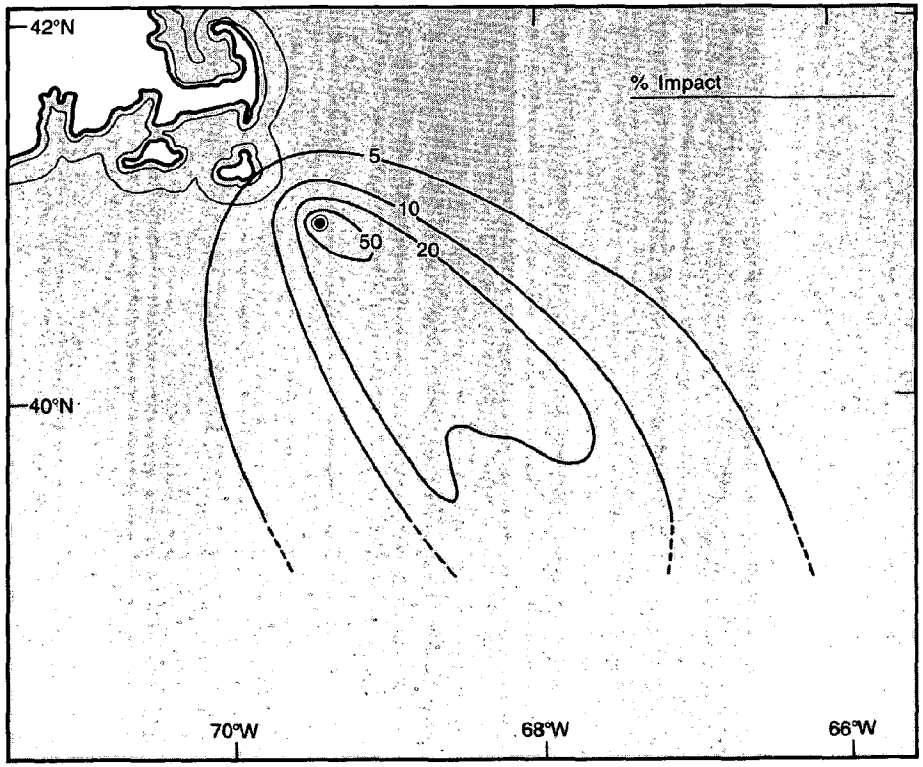
In general, the models tested on this spill were "off-the-shelf" items, capable of producing reasonable results in wind-dominated situations like the *Argo Merchant* spill, which involved a smooth coastline and where currents were not a decisive factor. All of them simulated the movement of oil from the grounding point reasonably well, pointing up their ability to simulate spill trajectories in a wind-dominated regime—winds off Nantucket in this period were in the 20- to 40-knot range. But modellers generally felt that a more difficult test of their ability to predict oil trajectories will come in a *current*-dominated situation, near a complicated shoreline. The consensus among modellers was that the *Argo Merchant* spill had added much new data on which to build better simulations of oil in the sea—for example, detailed measurements of the interaction between oil slicks and waves, and better knowledge of the "slippage," differential motion, between the water and the oil.



Tests of how well numerical models –mainly "climatological" ones– predict oil trajectory produced these runs, from left, from the University of Rhode Island, Geological Survey, and NOAA's Center for Experiment Design and Data Analysis.

This last was considered a ıajor contribution to modellers. For ɔme time, a factor of three percent of ıe wind speed has been added ı spilled-oil movement, to account ır its tendency to move slightly ıster than the water supporting it. The *rgo Merchant* study indicated ıat this wind factor probably represents the combined effect of energy transfer from waves interacting with the oil, and wind-induced surface currents. The researchers found that, when drift cards or bottles were the source of current data, the three-percent figure should be replaced by a figure of from 1.1 to 1.25 percent to avoid double accounting of the wind-induced surface currents.





Oil Spill Chemistry

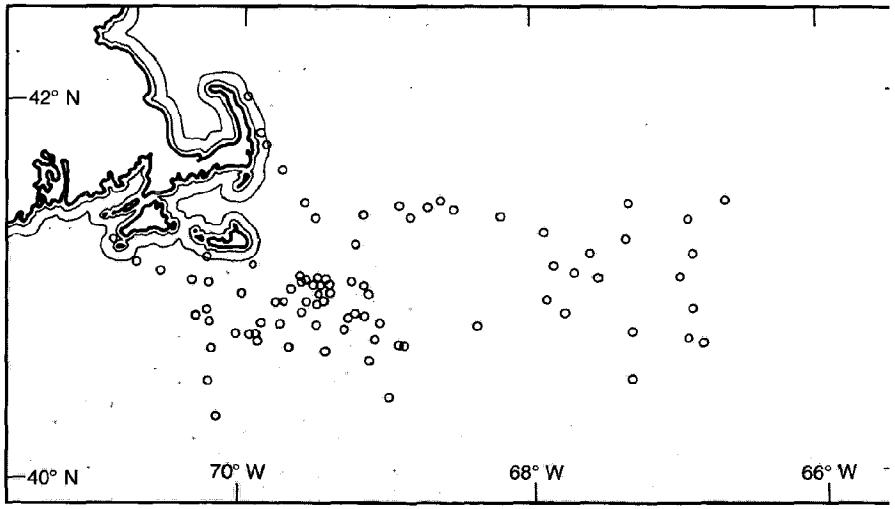
Meanwhile, a special effort was mounted to begin a thorough study of the chemical processes operating in the oil spill. Because these processes are crucial links between spilled oil, seafloor sediments, the water column, and, to some degree, life in the sea, they are essential ingredients in any attempt to develop fully three-dimensional oil-spill trajectory models. They are also among the least-understood processes involved in the dynamics of an oil spill.

Knowledge of the stages by which oil is degraded by the marine environment, or accommodated into it, is extremely thin. Chemists cannot say, for example, at what rate a number 2 fuel oil will enter the water column under a given set of conditions. Such predictions would require a much greater understanding of how the complex molecular systems of petroleum hydrocarbons are changed by evaporation, emulsification, microbial degradation, and other processes.

Investigators at the scene of the *Argo Merchant* spill took numerous samples of spilled oil, sediments, and water, and subjected them to preliminary laboratory analyses. In addition, samples have been sent to the NOAA National Analytical Facility in Seattle, Washington, for a more detailed assessment of the amount of petroleum hydrocarbons in samples taken at the spill site.

Preliminary analyses indicate that if oil from the *Argo Merchant* entered the water column in any significant amounts, only the light aromatic fractions did. The investigators found no evidence of any significant amounts of the heavy multi-ring aromatic hydrocarbons entering the water column. Some of the scientists studying the samples believe the oil detected in these samples is actually the "cutter stock," a lightweight petroleum compound—number 2 fuel oil—added to thin number 6 fuel oil and make it easier to handle.

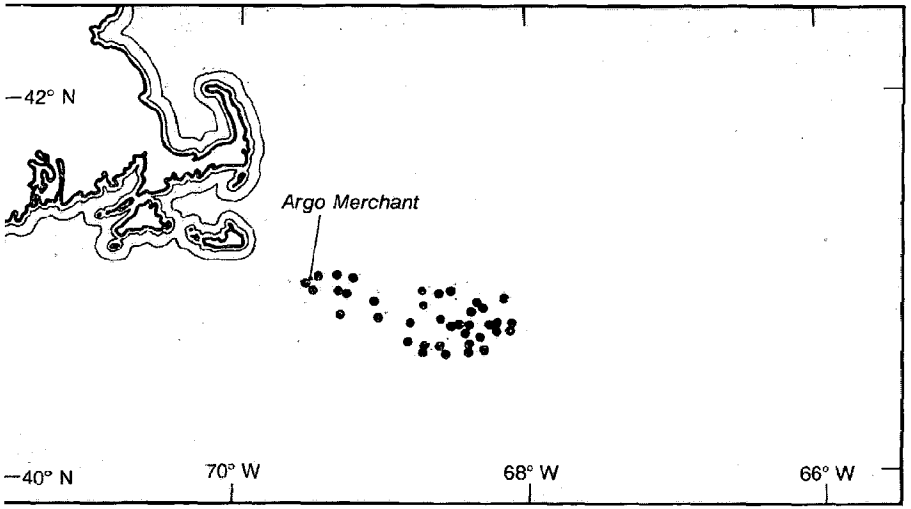
In no water sample was the oil contamination greater than 250 parts per billion. Highest concentrations were found directly under fresh oil slicks at depths of six to twelve feet. These concentrations decreased to background levels in a few days through turbulent mixing of the wate column.

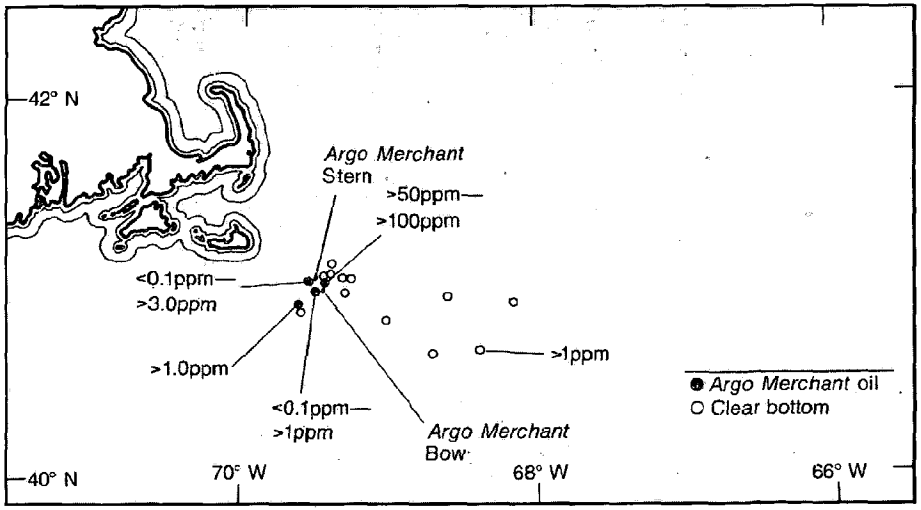


Samples for chemical analysis were taken at a number of stations in and around the spill area. Map at left shows water-sampling stations, the center map, benthic survey stations made by the University of Rhode Island ship Endeavor. *Map at right shows where sediments were sampled, and where values of 0.1 part per million or more were found.*

Sediment oil-contamination
ıs high as 100 parts per million was
ɔund in samples taken as far
ıs 10 miles from the grounding point,
nainly at stations to the southwest.
'roject scientists tentatively
:oncluded that the sunken bow
:ection mechanically worked oil into
he sediments as it moved over
he sand bottom. Some of these
ediments appeared to have been
esuspended in the water column and
'ansported by the area's
southwesterly bottom currents.
The report emphasized that the extent
of sediment contamination by
the *Argo Merchant* spill has not yet
been assessed fully, and will
be the subject of continuing study.

No visible oil was detected
on the bottom within a quarter mile of
the wreck. In some cases,
comparatively high levels of oil
contamination found in sediments
turned out to be from other sources,
pointing up the need for better
baseline hydrocarbon information.





Biological Effects

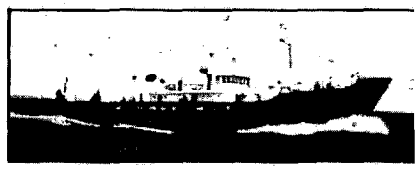
Fisheries biologists from NOAA's National Marine Fisheries Service conducted two cruises aboard the NOAA ship *Delaware II*, the first from December 22 to 24, the second in early January. This effort sought to assess the impact on life forms in and around the spill area. Not much research had been conducted on the effects of oil on northeastern continental shelf species. Most studies had been concerned with onshore and near-shore impacts. Laboratory studies indicated, however, that crude oil can damage fish eggs and cause large-scale mortalities in cod and herring embryos, and that the zooplankton food of fish fish larvae suffer high mortalities when exposed to crude oil.

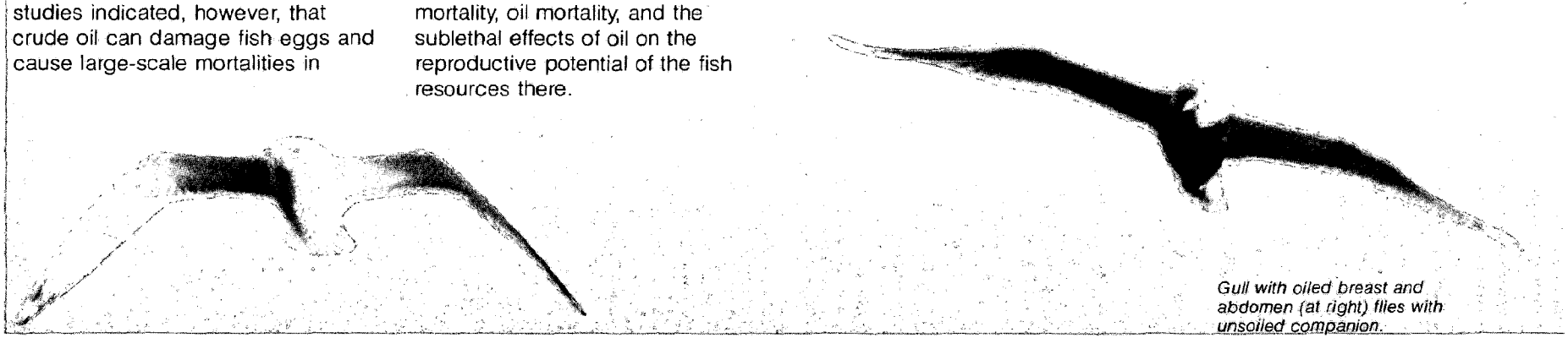
The *Delaware II* cruises occupied three types of station: control stations, believed to be outside the effect of the spill; stations outside the immediate area of the wreck but beneath the drifting oil slick, where contamination was possible; and areas where contamination was likely within about 20 miles of the wreck. Additional samples were taken by the University of Rhode Island ship *Endeavor* in late December.

The Fisheries Service is just beginning an extensive sampling program aimed at assessing the full impact of the *Argo Merchant* spill. This will require a year or more to complete, since it involves sorting out the complex interactions among levels of fishing mortality, natural mortality, oil mortality, and the sublethal effects of oil on the reproductive potential of the fish resources there.

In general, preliminary findings of this survey showed some low levels of oil contamination for some zooplanktonic species on Nantucket Shoals, with higher incidence of ingested particles and contaminated mandibles on zooplankton along the slick boundary. A transitional community between the shoals and channel outside the slick showed more than half of some zooplanktonic species to be affected, mostly by ingested oil particles. Channel-community sampling, where biomass is characteristically lower, showed low levels of contamination outside the slick, and high numbers of ingested particles inside the slick.

The biological survey also found significant contamination of copepods in and out of the slick area, as well as particle-ingestion by some other species. Apparently, oil contamination occurred in the major zooplankton components of the food web near the *Argo Merchant* spill site. However, the impact of this contamination was unclear. Observed contaminants could affect feeding and reproductic and mandibular contamination could interfere with feeding. One difficulty in making an assessment here is that the toxicity of ingested oil is not well understood, but seems depend on how much of the volatil aromatic compounds are released as the ingested oil ages. This will be the subject of further study by fisheries scientists.





Gull with oiled breast and abdomen (at right) flies with unsoiled companion.

Two specimens of phytoplankton (drifting plants) showed no response to the spill, but this sample was too small to support a real assessment of the spill's impact on area phytoplankton.

Some 98 percent of the pollock eggs sampled at one station near the spill were dead or moribund, and, adjacent to the spill, oil globules were found adhering to the surface membrane (or chorion) of 93 percent of the pollock eggs. Only 64 percent of the cod eggs in this group were similarly contaminated. In one group of pollock eggs sampled inside the spill zone, 60 percent of the pollock embryos had strikingly abnormal cell patterns."

NOAA ship Delaware II, *used by fisheries biologists to sample marine life in and outside the spill area, and an oil-fouled collecting net.*

Averaged over all sampling stations, pollock eggs were 46 percent dead or moribund; cod-egg moribundity ran about 20 percentage points lower on average. The fisheries researchers are attempting to assess, in a series of laboratory tests, the differences in oil-adherence characteristics of different eggs, since it appears that oil adhered to pollock eggs in substantially greater amounts than to cod eggs.

Six species of fish larvae—sand launce, cod, pollock, rockling, hake, and herring—were sampled. Of these, only sand launce was abundant at the control station, and this abundance decreased sharply within the spill area, suggesting some connection. While not important commercially, sand launce is basic food of predatory fish and marine mammals in the area, making it an important species in the northeastern marine ecosystem.

A number of fish were taken for examination. Of 305 fish stomachs examined, only three contained oil-like material. Studies of shellfish showed that respiration rates were altered in samples taken from the contaminated area. Hematological measures in sampled flounder showed a disruption of the ionic balance in blood serum ad depressed respiration rates—that is, oxygen consumption. Both are symptomatic of physiological stress. Other indicators being looked for include a possible drift from aerobic (oxygen-based) to anaerobic (oxygen-less) metabolism, and the induction or repression of enzymes.

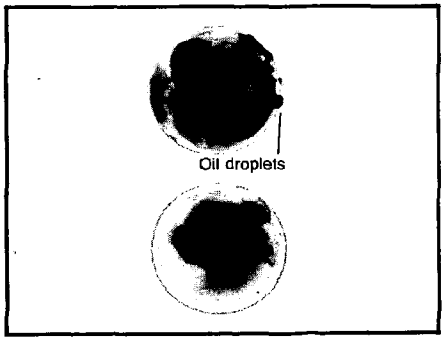
On first glance, the impact of the *Argo Merchant* spill on seabirds *appeared to be small. Shortly* after oil began to flow from the wrecked tanker, birds were seen with oil stains on breast and abdomen. Later, birds were seen heavily stained, and some badly oiled gulls began to land on the cutters and research ships, some accepting food by hand. Kittiwakes seemed less affected, probably because they were never seen feeding in oiled water, or landing on the water to feed.

In general, the density of bird life in the spill area was light, suggesting little impact. Nevertheless, a number of oiled birds washed ashore at Nantucket and Martha's Vineyard, and as far away as Dartmouth, Nova Scotia, suggesting that the oil affected some species —principally murres—well away from the spill site. There was no information on the extent of damage downstream, and no way to obtain it. But there was conjecture that stricken birds had been blown southeast with the oil. Scientists speculated that murres, which spend more time on the water than other pelagic sea birds, could have been hard hit by the spill; but how great the impact was will probably never be known for sure. Again, a major problem in assessing the spill's impact was the dearth of baseline information on bird populations in the area.

Marine mammals in the area did not seem disturbed or injured by the oil, and tended to stay clear of the pancakes. But here again, the investigators noted the sparseness of baseline data and inadequate observations would prevent any true assessment of the impact on marine mammals.

Oil contamination was found in some species of zooplankton sampled near the spill. Enlarged photograph of Centropages typicus *shows rounded particles of oil stored in body.*

Pollock eggs sampled near the spill showed signs of oil contamination, and some genetic effects. Shown here are (top) a pollock egg with oil droplets adhering to the surface membrane, and (bottom) an abnormal embryo in about the tail-bud stage, with no oil droplets on the egg.



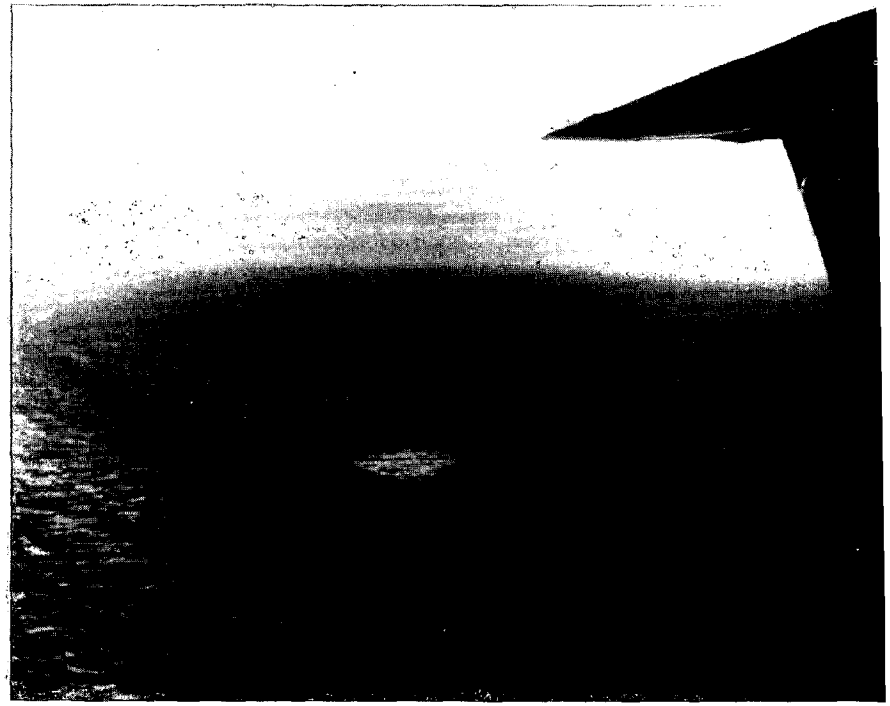
Effects on Fishing Activities

Project investigators believe that, while the full impact of the *Argo Merchant* spill cannot be fully assessed in the short time since the incident, any effects will mainly involve area fisheries. Maximum petroleum hydrocarbon levels observed were 250 parts per billion, and these comparatively low levels were probably soon reduced to background values in a few days by turbulent mixing of the water column. Thus no long-term hydrocarbon contamination of the water column occurred as a result of the spill. But the full impact on fisheries remains to be assessed in continuing studies by fisheries biologists.

Continued Study

Selected water and fish samples will be analyzed at the NOAA National Analytical Facility in Seattle to complete studies on the fate and weathering of *Argo Merchant* oil. In addition, the *Endeavor* will return to the scene of the wreckage to measure the extent of bottom contamination in that area.

Additional MARMAP (Marine Resources Monitoring, Assessment, and Prediction) cruises are planned over the next 18 months to determine the actual and potential impact on the rich spawning grounds of the southeast Georges Bank. The fisheries researchers will also study selected species for genetic damage, disruption of normal physiological processes, pathobiological conditions, and contamination by petroleum hydrocarbon.



Chronology

Activities set in motion in response to the grounding of the *Argo Merchant* and the scientific research efforts by the NOAA-USCG SOR team from the time of the accident until March 10, 1977, are summarized below. Hours are Eastern Standard Time, on a 24-hour clock.

December 15 The *Argo Merchant*, carrying 7.7 million gallons of No. 6 fuel oil grounds on Nantucket Shoals, resulting in one of the largest oil spills in United States history. Distress call received by USCG at 0700. USCGC *Vigilant* on scene. National Weather Service starts special forecasts for Fishing Rip area. NOAA-USCG SOR Team sets up headquarters in Hyannis, Massachusetts, at 2100.

December 16 USCG assumes full control and responsibility for the *Argo Merchant* under Intervention Convention at 1457. Weather conditions worsen. All personnel evacuated from the tanker at 2300.

December 17 SOR Team personnel attend coordination meeting at 1600 at Woods Hole Oceanographic Institution (WHOI) to develop scientific response.

December 18 USCG reports large amount of oil spilled and geysers of oil shooting upward. Heavy oil plume 7.5 miles long to the northwest. Ship listing 20°. Seas building up. Oil "pancakes" sighted by USCG 27 miles east of ship.

December 19 USCG reports that 1.5 million gallons of oil have entered the sea and that the *Argo Merchant* is sinking at stern. Super-tanker fenders rigged along side the tanker at 1430 in preparation for offloading to barges.

December 20 WHOI vessel *Oceanus* begins cruise 19.

December 21 Heavy seas. *Argo Merchant* splits aft of kingpost, releasing approximately 1.5 million gallons of oil. *Oceanus* returns to Woods Hole after taking water and sediment samples to northeast of slick.

December 22 Bow section of *Argo Merchant* splits again. NOAA Vessel *Delaware II* and USCGC *Evergreen* depart for scientific cruises. Scientific meeting in Boston called by EPA Administrator.

December 23 U.S. Navy divers take movies of underside of slick and botton. No visible oil on bottom.

December 24 *Delaware II* completes cruise DE 76-13.

December 25 Forecast of onshore wind condition. USCG contractors notified of possible beach cleanup operation at 1600. Overflight on which "pancake 1" is identified.

December 26 Forecasting of onshore winds continued. 3000 drift cards deployed as early warning system at 0940 between slick and shore. "Pancake 1" located again by USCG overflight.

December 27 Another 3000 drift cards deployed between spill and Nantucket at 0912. First attempt to burn oil. *Evergreen* cruise ends. *Oceanus* cruise 20 begins.

December 28 USCGC *Bittersweet* replaces *Vigilant* as on-scene vessel. *Endeavor* cruise EN002 begins. On-Scene Coordinator's status meeting and press conference at 1000.

December 29 Bow section starts to move under the influence of current.

December 30 *Endeavor* cruise EN002 ends.

December 31 *Argo Merchant* bow section holed by 20-mm cannon fire to prevent drifting and remove navigational hazard. Second experiment to burn oil from the *Spar*.

January 3 Coordination meeting at WHOI. Bow section observed moving again.

January 4 Coordination meeting at WHOI continued. *Delaware II* cruise DE77-01 begins.

January 9 Bow section totally underwater.

January 10 *Delaware II* cruise DE77-01 ends.

January 26 *Endeavor* cruise EN003 begins.

January 29 *Endeavor* cruise EN003 terminated because of weather.

February 8 Bow section of *Argo Merchant* relocated 1 mile to the southeast of stern and found empty of oil. *Endeavor* cruise EN004 begins.

February 11 Oil found in bottom sediments near bow section.

February 12 *Endeavor* cruise EN004 ends after completing initial benthic survey.

March 10 "Tar balls" up to a foot in diameter reported washing ashore on Nantucket Island's southwest coast. Samples sent to WHOI to determine whether origin is crude or refined petroleum; analysis will not be able to establish whether the material came from the *Argo Merchant* spill.

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