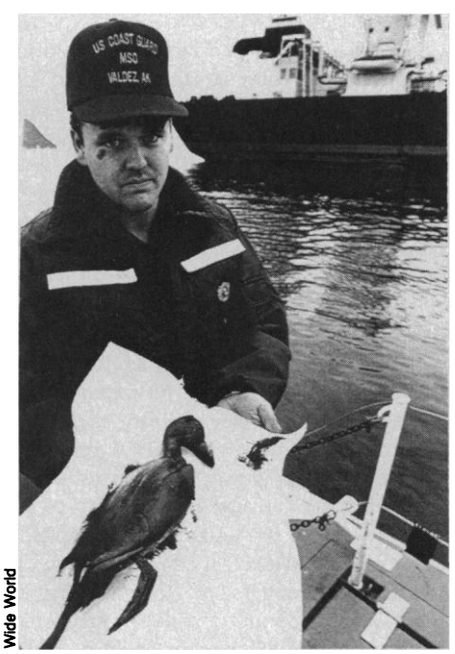
Long, Slow Recovery Predicted for Alaska

The effects of the Alaskan oil spill may last for a decade or more; the full extent of damage may never be known

THE BODY COUNT is just beginning following the worst oil spill in U.S. history. Dead birds are washing up on the beaches of Alaska's Prince William Sound, sea otters have been hit, and an untold number of fish have died. At this stage, however, it is far too early to judge the actual extent of damage caused by the 240,000 barrels of crude oil that spilled from the *Exxon Valdez* on 24 March. Indeed, given the rugged coastline and vast area affected—and the fact that there are few baseline data—the full extent of damage may never be known.

Nonetheless, biologists and oceanographers who have studied previous spills expect the damage to be extensive, with some effects lasting for at least a decade and perhaps two. "I don't think that anyone would argue that the spill is less than a full-scale disaster," says John Teal, an ecologist and senior scientist at Woods Hole Oceanographic Institution.

By Friday, a week after the spill, the slick had spread over nearly 900 square miles. Hundreds of miles of shoreline were covered with oil, in places as much as 6 inches deep. At Green Island in the middle of the Sound, Department of Interior scientists counted 1000 oiled seabirds, both dead and alive. Sea otter deaths were difficult to gauge, though many animals had been affected, and the spill seemed to be headed for Orca Bay, home to more than half of the region's 10,000 or more otters. Once covered with oil, sea otters are unable to regulate their temperature and perish.



Wide World

The early victims *are obvious; less visible effects may persist for several years.*

While the focus now is on the number of birds and marine mammals killed and the miles of coastline blackened by tar-like goo, it is the less visible effects, such as the accumulation of oil in the bottom sediments, that are of perhaps the greatest concern, for they largely determine how long it will take the rich ecosystem to recover.

The Alaska spill looks particularly severe, for several reasons. One is simply the sheer quantity of Alaska crude oil that gushed into Prince William Sound—about 35,000 tons—as well as the failure to contain the spill within the first few days (see page 20). At this point, with most of the oil converted to "chocolate mousse," an emulsified mixture of oil and water, mechanical skimming is unlikely to be successful, and the time has long passed when the oil could be effectively burned or broken up with chemical dispersants.

Few options remain, other than to protect sensitive areas, like the Sound's salmon hatcheries, as the slick wends it way out into the Gulf of Alaska. In time, wave erosion and photochemical and microbial actions will degrade the remaining oil.

Compounding the difficulty is the fact that the spill occurred in a relatively enclosed area. Previous spills have shown that deleterious effects are greater in calm waters, where the oil tends to accumulate in the fine sediments. Once mixed or buried in the sediments, oil can remain a continuing source of pollution for years.

"The claim will be that the oil has been partly degraded and evaporated into the air, and that not much will go to the bottom. But that is not correct," says Howard Sanders, a marine biologist and senior scientist emeritus at Woods Hole Oceanographic Institution and a veteran of many oil spills. "That's a heck of a lot of oil in a very limited area," adds Sanders, who predicts that "the bulk of the oil will end up in the benthos."

"That's certainly going to happen here, particularly because you are in a near-shore region," agrees Robert Howarth, a marine ecologist at Cornell University. "Once you get oil into fine-grained sediments, it is pretty damned persistent anywhere, and in cold water, more so. In those kinds of waters I would be guessing, but I'd say it would probably be longer than 20 years."

Sanders, in fact, predicts that the effects of the *Exxon Valdez* spill could be longer lasting than those of the *Amoco Cadiz*, the biggest tanker spill in history. The *Amoco Cadiz* broke up in open sea on 16 March 1978 off the French coast, where currents and winds dispersed the slick. Nonetheless, effects could still be detected along the coastline 7 years later.

In addition, by the end of the week the oil had formed a continuous slick without breaks in Prince William Sound, David Kennedy, scientific support coordinator for the National Oceanic and Atmospheric Administration's (NOAA) team, told the *New York Times*. As a result, Kennedy said, highly toxic volatile compounds, which would ordinarily evaporate, were trapped beneath the solid slick, where they seemed certain to enter the food chain.

Finally, the subarctic conditions in Prince William Sound will slow recovery. Both photochemical and microbial degradation occur more slowly in cold water and with diminished light. Moreover, much of the marine biota off Alaska is longer lived and has longer generation times than similar biota in warmer waters. If a population crashes, it will thus take longer to rebuild.

Despite a number of well-publicized spills in recent years, surprisingly little is known about their long-term effects. Only a half-dozen or so tanker spills have been studied in detail, and most of those occurred in temperate waters. What is clear is that the severity and duration of effects have varied enormously from spill to spill, depending on local conditions, including the amount and composition of the oil, whether the spill occurs in open or enclosed waters, and meteorological conditions (see box). Nonetheless, it is possible to sketch in broad strokes what is likely to happen over the coming weeks and years in Prince William Sound.

In the short term, massive mortality is expected among seabirds, marine mammals, and fish. "As long as there is oil floating around, it's going to be a real disaster," says Teal. "Animals are going to get oiled. Fish are going to be affected, [as will] anything

up near the surface." The Interior Department is conducting daily overflights to take a census of birds and sea otters. NOAA is tallying the effects on sea lions, seals, porpoises, and whales, and the Alaskan Fish and Game Department is keeping track of fish.

Rescue centers have already been set up in Valdez to clean birds and sea otters. Collecting either from the numerous, rocky beaches is a logistical nightmare, however, and these rescue efforts are likely to have little overall effect.

Perhaps the overriding concern is whether the slick will foul the Sound's salmon hatcheries. Unwilling to wait for Exxon to act, local fishermen immediately set up booms to protect the three hatcheries at risk, which to date have been spared direct effects. But within a few weeks young salmon will be released from the hatcheries into the Sound. And in June, some 50 to 60 million salmon will return to the Sound for spawning. Whether they will be disoriented by the residual oil is not clear. And if they are contaminated with oil residues, the salmon cannot be sold, which would be a severe blow to the local fishing industry.

Within the water column, some of the microscopic plants and animals at the base of the food chain will also be killed immediately. Longer term effects are trickier to predict. Until recently, it was assumed that oil did not persist in the water column long enough to have lingering toxic effects. But, says Howarth, that may not be the case.

Work by Paul Boehm, a chemist now at the consulting firm Arthur D. Little, showed that following the 1976 *Argo Merchant* spill off Massachusetts, oil was detectable in the water column for up to 5 months. In the warmer waters off France, oil was detectable in the water column for 2 months following the *Amoco Cadiz* spill.

Says Howarth: "I think we should be very concerned about this spill because it's a cold water spill. There's good reason to think it's going to put more oil in the water column and keep it there longer, which is exactly what you don't want. There's a good chance you're going to have toxic concentrations of oil in the water column for maybe 3 to 5 months. And that will presumably affect larval and juvenile fish and fish eggs."

Whether adult fish will also be affected is unclear, says Howarth, who concedes that in a field rife with uncertainty and prone to tremendous arguments, the water column effects on fisheries are perhaps the most controversial. "I would not be surprised if there is a decade-long effect on fisheries [from the Alaska spill], but I would be hard-pressed to support that with data."

All agree that the duration of the effects will depend, to a large extent, on how much

The Legacy of Past Spills

No two oil spills are alike, and their biological effects have varied enormously, depending largely on the extent and duration of the oiling. In a 1985 report, *Oil in the Sea*, the National Research Council (NRC) recounted case histories of five major tanker spills. Remnants of effects can still be measured, many years later, at four of the five sites. The following descriptions are based on that report.

Florida. The barge *Florida* ran aground in West Falmouth Harbor in Buzzards Bay, Massachusetts, on 16 September 1969. Both the oil and its effects lasted for at least 10 years. After the barge lost 630 tons of light refined oil, researchers documented an immediate kill of small fish, benthic invertebrates, and marsh organisms. In the sediments, recognizable oil persisted for at least 8 years, causing a reduction in both species diversity and abundance. The greatest impact was on the macroscopic animals in the benthic community. At heavily oiled sites the plants and animals in the benthos were nearly eradicated 48 hours after oil reached the sediments.

At lightly oiled sites, benthic recovery was complete within 1 year. At moderately and heavily oiled sites, a normal recovery pattern was not evident for 3 years. The hardest hit sites did not recover during the 4 years of one study.

In the intertidal areas, marsh grass was completely killed in heavily oiled areas. By 1981, 12 years after the spill, recovery was not yet complete, "although most areas seemed normal in appearance at first visual inspection," according to the NRC report. Bivalves were particularly susceptible: 77 bushels of soft-shell clams and 11,200 bushels of seed clams were killed in Wild Harbor. In the marshes, fiddler crabs were killed, and the survivors showed increased susceptibility to oil and behavioral changes. Their recovery was not complete 7 years after the spill.

Arrow. The *Arrow* tanker ran aground in Chedabucto Bay in Nova Scotia on 4 February 1970, releasing about 10,000 tons of heavy refined oil. Much of the oil was swept out to the Atlantic Ocean by high seas, although 300 kilometers of coastline were coated with a "resistant pavement of tar," according to the NRC report. Within 6 years the tar on the beaches had been greatly reduced by both wave erosion or burial, but high concentrations of oil persisted below the surface.

Much of the oil was filtered from the water column by animals and then passed to the bottom sediments in fecal pellets. In sheltered lagoons, oil was still visible in the sediments 10 years after the spill. Some plants, including the rockweed *Fucus spiralis*, were killed off completely and had not reappeared 6 years after the spill. Others showed significant population declines. Barnacles and other rocky shore animals generally fared well, except where their habitat had been altered by the loss of rockweed. At oiled sites 6 years later, species diversity among benthic plants and animals was still down. The population of soft-shell clams remained stressed, showing lower shell growth and lags in tissue growth.

Amoco Cadiz. The largest tanker spill to date occurred in the open waters of the English Channel on 16 March 1978. The supertanker *Amoco Cadiz* released some 223,000 tons of light crude oil when it ran aground on the rocks near Portsall, France. Prevailing winds kept the slick near the coast for 1 month. Eventually, a 300-kilometer stretch of the Brittany coast was oiled.

Because of heavy waves, a considerable amount of oil was entrapped in the water column, which may explain the unexpectedly high mortality among subtidal organisms. Much of the oil that did come ashore eventually became buried in the sediments or entrapped in salt marshes.

Across a large area, oil reached the muddy bottom sediments of the channel and of tidal rivers, in some places penetrating to 7 centimeters. Near shore there were massive kills of heart urchins, razor clams, and amphipods, which are small crustaceans. In intertidal areas, rocky beaches fared relatively well but sandy beaches retained buried oil for several years. Immediately after the spill, beaches "were littered with dead animals," according to the NRC report. In exposed intertidal mudflats, almost all the fauna were killed.

Marshes were severely affected where oil came ashore, showing no recovery 2 years later. Efforts to clean up the marshes compounded the problem, with heavy traffic hastening the erosion of fine sediments. Says the NRC committee: "The combined results were so large . . . that several decades plus active conservation measures may be required for return to prespill conditions." ■ **L.R.**

oil settles in the fine, muddy sediments, as well as on the geographic distribution of such sediments. In other spills, the most persistent effects have been in the intertidal and subtidal benthic communities. At rocky beaches, of which there are many on the Sound, the effects will be much shorter lived.

As the oil coats particulate matter in the water column, it will be ingested by zooplankton and then excreted. This "rain of fecal pellets," says Sanders, is a major route of oil to the bottom. As oil accumulates on the bottom, the benthos could then become anaerobic, he adds, making it unfit for marine fauna and for some marine flora.

Oil accumulation in the sediments is likely to bring a shift in species composition, as benthic fauna are killed off and are replaced by opportunistic species that can tolerate pollution. The net effects on the ecosystem, however, are unclear. Benthic plants and animals form the basis of the food chain; thus, a change in species composition could affect fish. Moreover, some benthic organisms, like clams, are valuable in their own right.

Herring could be particularly at risk, since they deposit their eggs in the bottom sediments, predicts Sanders. If the eggs are coated with toxic oil compounds, he adds, they almost certainly will not hatch. "It could kill the entire stock of herring." Herring spawning in the Sound has just begun. On Monday, Alaska's Fish and Game Department banned this year's catch.

Ted Cooney, a biological oceanographer at the University of Alaska at Fairbanks, is far more optimistic. Because the Sound exchanges water with the Gulf of Alaska, the organisms killed off in the water column will be replaced by new seed stock carried in from the ocean. "It is not a situation in which all the recovery and growth has to come from the survivors," he says. "The salmon will be feeding on a new batch of plankton next month."

Cooney is one of a team of University of Alaska researchers gearing up to study the spill. They have already begun collecting water samples and this week will launch their research vessel for 7 days. They intend to measure hydrocarbon in the water column and to monitor the status of the plankton. They will also assess the spill's impact on benthic communities, monitor microbial degradation, and, in coordination with state and federal agencies, monitor the effects on birds and marine mammals.

All agree that the rich ecosystem of Prince William Sound will eventually recover. The only question is when. ■ **LESLIE ROBERTS**

Eliot Marshall contributed to this article.

Bevill Wants Foreign SSC Funding Up Front

If Representative Tom Bevill (D–AL) has his way, no money will be spent to build the Superconducting Super Collider (SSC) until firm commitments from foreign participants are secured. Bevill, who chairs the House Appropriations Committee's energy and water subcommittee, is concerned that the United States will not have much bargaining leverage if Congress allows construction to go forward without written agreements.

Bevill told Energy Secretary James Watkins at a recent hearing on the Department of Energy's budget that he did not want to fund the SSC at the expense of other projects and that he did not want the project to add to the federal deficit. Bevill said he would like to see foreign funding cover as much as 40% of the project's cost. So far, DOE has indicated that contributions from other countries might be on the order of $1 billion, out of a total of $6 billion.

Watkins, urging the committee to allocate $160 million to construction, sought to convince Bevill that foreign governments wanted the United States to start to build the SSC before they would enter into formal pacts. Bevill, however, contends that the Congress' commitment of $100 million for research in the current fiscal year should be read as a sign that the country is serious about the project. The appropriations subcommittee, Bevill told *Science*, will likely hold the SSC budget to around $100 million for R&D in fiscal year 1990.

■ **MARK CRAWFORD**

DOE Boosts Research for Defense Cleanup

The Department of Energy (DOE) is launching a new R&D program to develop new technologies to clean up chemical and radioactive contamination produced by the government's nuclear weapons complex.

Energy Secretary James D. Watkins, in a four-page letter to John D. Dingell, chairman of the House Energy and Commerce Committee, said the R&D program would focus on four areas: waste minimization, biological remediation to neutralize wastes in place, robotics, and the application of advanced technologies now used for other industrial processes.

The research effort, which will be conducted by the national labs, is part of Watkins' overall plan for managing wastes at government facilities that process radioactive materials used to make nuclear warheads. Watkins told Dingell that he will have a 5-year plan ready in August for tackling the cleanup.

For now, he says, the department's "immediate goal . . . is to confine and contain the present wastes and reduce further contamination." Watkins has named Leo Duffy as his defense waste cleanup czar. Duffy previously served as a vice president of Roy F. Weston, Inc., a company that provides nuclear waste cleanup services.

■ **MARK CRAWFORD**

Somali Scientists Freed

Somalia, as promised, has released 12 scientists, engineers, and physicians imprisoned for political reasons. The release of political prisoners is part of a series of human rights initiatives the government announced earlier this year, following sustained pressure by international human rights groups as well as the U.S. Congress, which put a hold on general economic assistance to the country.

The release of the scientists was confirmed on 22 March by the human rights committees of the National Academy of Sciences and the National Institute of Medicine.

■ **CONSTANCE HOLDEN**

Truly in Line for NASA Post

Rear Admiral Richard Truly is reportedly in line to take command of the U.S. civilian space program—if the White House can find a way to protect his military pension.

Truly is now associate administrator of the National Aeronautics and Space Administration (NASA) in charge of space flight, and as such was responsible for bringing the shuttle program back to life after its January 1986 disaster. The President's staff apparently has put his name at the top of the list of candidates to succeed NASA Administrator James Fletcher, who departs on 8 April. Among Capitol Hill space experts, Truly is regarded as a solid manager and a frank spokesman.

In an attempt to keep military and civil functions in space separate, the law creating NASA requires that the agency be directed by a person not on active military duty. Truly is a Navy employee on loan to NASA. He is said to be ready to accept the new job, but would like to take his pension with him.

■ **ELIOT MARSHALL**