to determine the stability of the snowpack. Lehning is also developing a new model that seeks to predict the influence of wind on snow deposits—a significant factor in avalanches because it affects the accumulation and characteristics of the snow.

Meanwhile, SLF is refining its ability to predict what happens once an avalanche is unleashed—how fast and far it will travel. In the past, models of avalanche dynamics have treated the snow as if it were a flow of shallow water down a steep slope. But such equations only offer a simple, if well calibrated, description of avalanche motion, because an avalanche is actually a complex granular flow. So Bartelt says his researchers are now trying to make avalanche models more realistic by using complex granular-flow simulation. Such models track the motion of individual "particles"—clumps of ice formed during the avalanche's downward motion. Granular flow models require so much computer power that it is not yet feasible to use them for practical avalanche prediction and warnings. But Bartelt says "we are using granular-flow models to make the existing hydrodynamic flow laws more rational."

The SLF recently asked the Swiss National Science Foundation to help fund a major new effort to develop state-of-the-art particle models of snow entrainment (how the avalanche picks up greater mass as it descends) and sliding friction in dense snow avalanches. Researchers also want to apply these techniques to model how snow flows around avalanche defense structures, including earthen banks built up to protect towns.

Besides modeling avalanches and studying their aftermath in the field, the SLF researchers also test their models with experimental avalanches. On a cordoned-off mountainside near Sion, scientists—positioning themselves in a small bunker near the end of the runout zone—set off real avalanches using dynamite charges and then use radar to measure the flow velocities and other equipment to measure the pressure the snow exerts on various structures placed in its path. When the next big avalanche season comes, the SLF researchers plan to be ready for it.

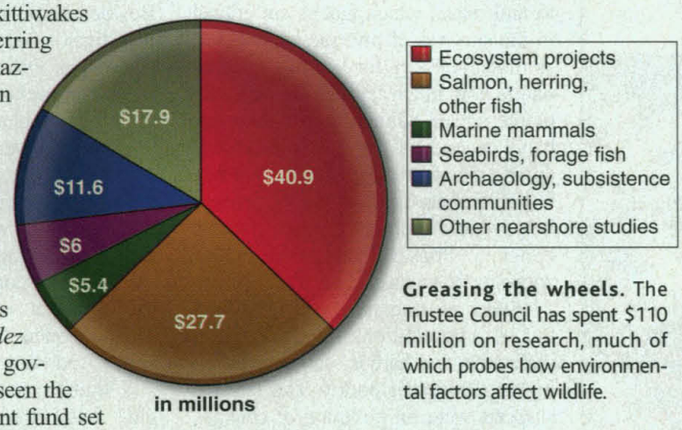
–ROBERT KOENIG

ECOLOGY

The *Exxon Valdez*'s Scientific Gold Rush

Ten years after the worst oil spill in U.S. waters, scientists are learning valuable lessons from the research done in the disaster's wake

ANCHORAGE, ALASKA—To study how seabirds forage, David Duffy used to have to chase after a flock in a skiff or bargain his way onto an oceanography ship to steal a few moments of observation time. No longer. Four years ago, the University of Alaska, Anchorage, ecologist found himself aboard whalers racing up to 60 kilometers an hour after radio-tagged kittiwakes and tracking schools of herring by sea and by air. "The amazing thing is, we were given enough resources" to mount the ambitious, expensive studies, says Duffy, now at the University of Hawaii, Honolulu. "It's like being let loose in the toy store."



Greasing the wheels. The Trustee Council has spent $110 million on research, much of which probes how environmental factors affect wildlife.

SOURCE: *EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL

Duffy's spree comes courtesy of the *Exxon Valdez* Oil Spill Trustee Council, a government body that has overseen the $900 million civil settlement fund set up after the infamous supertanker ran aground on 24 March 1989, disgorging 42 million liters of crude oil into pristine Prince William Sound. The fund was established to restore and conserve the sound's natural resources, but researchers like Duffy have snared a big chunk—$110 million over the past 8 years—to probe how the region's ecosystems have recovered from the spill. Their work is beginning to unravel how relationships spanning the food web—from the lowliest plankton to killer whales—and shifts in ocean temperatures have driven alarming species declines in the Gulf of Alaska, which supports some of the richest fisheries in the United States.

Scientists gathered at a symposium* here last month, 10 years after the worst oil spill in U.S. waters, to trot out findings from what may be the most expensive ecology program ever. After a rocky start afflicted by subpar studies done on the fly in the initial months after the spill, many researchers say the fund has transformed *Exxon Valdez* science from a scientific pariah to a respected effort. Marine ecologist Charles Peterson of the University of North Carolina, Chapel Hill, who's helped guide the program as a reviewer, calls the recent work "just magnificent."

But like most aspects of the *Exxon Valdez* disaster, the research program has sparked controversy. Some observers question its underlying philosophy, which is to restore resources by understanding them better. "We can't fix what was broken here. The notion that studying it was helping it is perverse," says University of Alaska, Anchorage, outreach adviser Richard Steiner, a longtime critic of the council-funded science. And some prominent ecologists question the vast expenditure on studying the fallout of a local calamity when research efforts on more-imperiled species and global problems like tropical deforestation are scrambling for funds. "I still have some big problems with this way of doing science, the philosophy of requiring a catastrophe of this sort to generate this effort to understand nature," says Jim Estes of the U.S. Geological Survey in Santa Cruz, California.

The research bonanza is now drying up, as the fund shifts its focus from restoration to long-term monitoring. As scientists debate the program's value, they acknowledge they may never see its like again: The law that brought the Trustee Council to life has been revised to encourage faster restoration efforts and fewer field studies in the wake of future environmental debacles.

Into the breach. Scientists were caught off guard in the hours after the tragic spill. Few data existed on the sound's ecology, so some, in desperation, scrambled out on the water to snap Polaroid photos of the shoreline before the oil started washing up. "It was a crisis atmosphere," says Stan Senner, science coordinator for the Trustee Council. The panic-driven initial studies often featured inadequate controls and ignored possible explanations other than oil for wildlife declines;

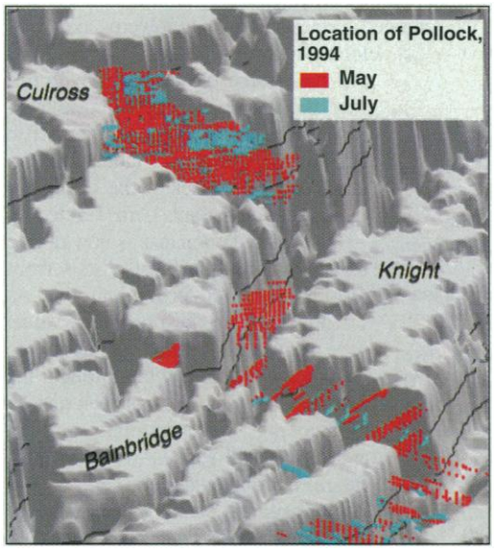
* Legacy of an Oil Spill—10 Years After *Exxon Valdez*, 23–26 March, Anchorage, Alaska.

data were later thrown out.

In the following weeks, an intense media circus shifted from dying birds and otters coated with oil to the lawsuits shaping up against Exxon. By the fall of 1989 scientists had been called in to review government studies, but lawyers with the Department of Justice and Alaska, says Senner, "guided the studies that were ultimately carried forward, and the thing they were after was recovery of damages." That meant focusing on charismatic species, like sea otters and seabirds, to which lawyers could attach a dollar value, and ignoring ecological interactions among species.

Barred by lawyers from both sides from sharing data, Exxon and government scientists carried out redundant studies. And many scientists outside Alaska who offered to help were rebuffed. "The agencies wanted to keep their fingers in the trough," asserts Chris Haney, an ornithologist with The Wilderness Society and a reviewer of the council's science program. All told, government agencies sank $86 million into narrowly limited studies in the first 2 years after the spill, Senner says, before a civil settlement between Exxon, the U.S. government, and the state of Alaska in 1991 at last took the lawyers out of the picture.

Bucking public pressure to spend the $900 million settlement only on purchasing land to set aside for conservation, the trustees—acting on behalf of the federal government and the state of Alaska—opted to carve out $110 million for research, restoration, and monitoring. Another $40 million may be spent by 2002.



Fish story. The council has lately funded solid research, such as these acoustic scans of pollock in Prince William Sound.

Ironically, it was Alaskan fishers, not scientists, who played a major role in steering the program onto a successful trajectory. In 1993, diseases devastated the Pacific herring population in Prince William Sound. Dealt a crippling blow, fisheries wanted to know whether the collapse as well as erratic yields of pink salmon were related to the spill. Scientists didn't know. Urged by fishers to troll the whole ecosystem for answers, the Trustee Council "stopped looking at how many dead bodies we had and started to really look at [ecological processes]," says Peter McRoy, an oceanographer at the University of Alaska, Fairbanks.

On the ropes. Climate change, more than oil, is putting the hurt to kittiwakes.

With the addition of more outside expertise, trustee scientific advisers laid a course for a series of major research undertakings that would undergo rigorous peer review, Senner says. The council is still bound legally to focus on restoring and "enhancing" natural resources. "We can't carry out a project that doesn't have an application somehow," Senner says. But his staff has managed to fold in basic science.

Taking stock. Now researchers are reeling in the data. The largest project, the $23 million, 7-year Sound Ecosystem Assessment (SEA), began collecting data in 1994 on everything from the sound's bathymetry to plankton and fish counts in an effort to understand which factors are critical to the survival of juvenile herring and salmon. The key for herring, it turns out, is how much fat they can store up before winter. Salmon fry, on the other hand, depend heavily on the timing of spring zooplankton blooms—a big bloom around the time the fry emerge helps shield them from predation, as hungry pollock will gorge out on the zooplankton instead of the fry.

Other projects have sought to find out why populations such as pigeon guillemots and harbor seals are declining or recovering poorly. The leading suspects were oil pollution or changes in food supply linked to long-term climate change. Paul Anderson of the National Marine Fisheries Service and his colleagues in the Alaska Predator Ecosystem Experiment focused on the influence of climate change on fish populations. They combed a database of over 10,000 trawler catches since the 1950s, looking for signs that a slight warming—about 2 degrees Celsius—in the Gulf of Alaska in the late 1970s has affected fish populations. They found a distinct shift from a preponderance of fatty fish like capelin, sand lance, and shrimp to a system now dominated by leaner pollock, flounder, and cod.

To investigate the impact higher up the food chain, Duffy and others are sampling what seabirds regurgitate, studying metabolism, and feeding chicks different diets in the lab to see how quickly they grow. With one more field season left, they're leaning toward climate change—not oil—as the key ecological force in the Gulf: The documented trend toward leaner fish seems to account for much of the seabird declines, Duffy says. Experts are impressed with the wide-ranging study. "We've tried to do it [off California] but we've never had sufficient funding or vessel time," says Bill Seideman, an ornithologist at Point Reyes Bird Observatory in California.

Some studies are beginning to pay off for the Prince William Sound community, too. The SEA results, for example, are helping hatchery managers decide when to release fry. And by probing how oil, a fish's age, and the time of year might make herring more susceptible to the pathogens that devastated stocks in 1993, researchers hope to refine models for predicting herring yields. Besides helping fishers, says co–principal investigator Gary Marty of the University of California, Davis, the herring work "is the most comprehensive disease study of any wild fish population."

The vast overhaul of Trustee Council research has not eliminated all controversy, however. Council-funded scientists still spar with scientists who receive money directly from Exxon to study lasting effects of oil on species. (The company disputes the trustees' assertion that only two species, bald eagles and river otters, have fully recovered after the spill.) And some scientists say the program still shuns outsiders. "It's mostly the same old," says University of Washington, Seattle, ecologist Dee Boersma, who has Exxon funds to study murres on the gulf's Barren Islands. According to Peterson, scientists in Alaska who had been studying the spill from the beginning often crafted stronger proposals.

Research spawned by future environmental disasters may be even more controversial. The regulations that guided the Trustee Council science were revised in 1996 to encourage more cooperation between a guilty party and the government to make restoration the top

CREDITS: (TOP TO BOTTOM) A. MAX KAUFMAN/USFWS/MBM; G. THOMAS, J. KIRSCH, J. ALLEN/PRINCE WILLIAM SOUND SCIENCE CENTER, CORDOVA, AK

priority. That can mean sampling a few species and using models to project damage to others instead of doing comprehensive field studies, says Roger Helms of the U.S. Fish and Wildlife Service (FWS), who adds that moving quickly to restoration is a worthy goal.

The new law made its debut with a small oil spill off the Rhode Island coast in January 1996. The postaccident research, Peterson says, amounted to "a few collections of dead things that washed up on the shore and a few other odd data sets." This approach is sure to miss chronic or subtle effects seen in the long-term Valdez studies, he says, calling it "a godawful disgrace." Doug Helton of the National Oceanic and Atmospheric Administration's Damage Assessment and Restoration Program demurs, arguing that the harm done by oil "doesn't all have to be shown with original research."

Council-funded scientists, meanwhile, are looking forward to a trickle of funding to keep portions of projects going. Last month, the trustees decided to use $115 million left over from the restoration fund to endow a long-term research and monitoring program starting in 2003 that will have a budget of up to $10 million a year. To give the program the credibility that has at times eluded earlier efforts, the trustees plan to ask the National Research Council to vet its design.

Early plans are to "take the pulse of the northern gulf" and to fund research on key species like sea lions and harbor seals, says Molly McCammon, the council's executive director. That, along with the solid work already funded, says council chief scientist Robert Spies, will "truly leave something behind of lasting value." —JOCELYN KAISER

GENE ENGINEERING

EPA, Critics Soften Stance On Pesticidal Plants

Four years after airing a controversial plan to regulate "plant-pesticides," battle-weary opponents are finding common ground

For 6 years John Sanford, inventor of the gene gun, led a handful of researchers on a mission to endow roses, petunias, and other ornamental flowers with genes that help plants resist mildew. Last year Sanford threw in the towel, selling his Waterloo, New York, firm—not because the research was sputtering, but because he feared a new rule from the Environmental Protection Agency (EPA) would put him out of business.

EPA intends to require companies to submit data showing that plants equipped with new or foreign genes coding for pesticides or other resistance traits are safe for humans and the environment. The agency also wants the seeds to carry a label saying they make their own antipest substance. "It's our legal mandate and obligation to regulate these substances," says Janet Andersen, director of EPA's Biopesticide and Pollution Prevention Division. But many scientists and politicians are pressing EPA to narrow the rule. "This new regulation has large implications for the U.S. biotech sector," Representative Thomas Ewing (R–IL), chair of the House Subcommittee on Risk Management, Research, and Specialty Crops, said at a 24 March hearing on Capitol Hill.

The gap between the feuding sides appears to be closing, however. At the hearing, EPA officials said they plan to make changes—for example, expanding a list of modifications exempt from regulation—before issuing a final rule this year. "We're very close to getting these things clarified," says R. James Cook, a plant scientist at Washington State University in Pullman and a spokesperson for 11 societies* that have banded together to fight the rule. EPA's relaxed stance, however, may raise the hackles of some groups that want to see even more stringent regulation.

Citing its authority over pesticides, EPA aired a proposed rule in November 1994 that it said would ensure the safety of plants altered to express pest-resistant traits or protective substances. The rule cast a broad net, covering everything from the genes for making *Bacillus thuringiensis* (*Bt*) toxins, bacterial proteins that kill most insects, to genes that would tell plant cells to self-destruct upon attack. Among the exemptions are traditionally bred plants and gene transfers within a species.

> **"Nobody's suggesting that if you insert a highly toxic substance into a plant that this shouldn't be regulated."**
>
> —Arthur Kelman

The rule has drawn fire from all quarters. Because it includes so many exemptions, the proposal is "far too weak," says Margaret Mellon of the Union of Concerned Scientists in Cambridge, Massachusetts. But she and others support the philosophy of the rule, which would protect against hazards that may arise if, say, a potent horseradish protein conferring disease resistance were spliced into vegetables eaten in greater portions.

Other critics, however, have assailed the rule's scientific basis. The main shot came from a consortium assembled by the Institute of Food Technologists in January 1996. The consortium issued a report that year calling the rule "scientifically indefensible" because, it argued, the EPA was essentially proposing to regulate the process—gene engineering—rather than the product. It has since suggested that EPA regulate only plants modified to express substances found to be toxic to other species. "Nobody's suggesting that if you insert a highly toxic substance into a plant that this shouldn't be regulated. That's risky," says plant pathologist Arthur Kelman of North Carolina State University in Raleigh.

He and others claim a broad rule could jeopardize confidence in the safety of the food supply. "The label 'pesticide' has the connotation of danger; it means 'kill.' That doesn't do much to lower the anxiety in the public," Kelman says. Walking a fine line, the Biotechnology Industry Organization backs oversight of what it, along with the societies, prefers to see labeled "plant-expressed protectants." Such regulation is "critical for public acceptance" of new products, says spokesperson Joseph Panetta.

EPA announced at the hearing that it is considering revisions that should help mollify critics. For instance, says James Aidala, EPA's associate assistant administrator, the agency is willing to adopt the term plant-expressed protectants. EPA also plans to broaden its exemptions, including a wider range of plants given viral proteins that—like vaccines—immunize them against viruses. "The rule is mainly about what doesn't need regulation," Aidala says.

Environmental groups say they are disappointed by EPA's narrowed focus. But Cook and his allies are optimistic. "If the EPA had started where they are today," he says, "we would probably not have issued the report in the first place." —MICHAEL HAGMANN

* American Institute of Biological Sciences, American Phytopathological Society, American Society for Horticultural Science, American Society for Microbiology, American Society of Agronomy, American Society of Plant Physiologists, Crop Science Society of America, Entomological Society of America, Institute of Food Technologists, Society of Nematologists, Weed Science Society of America