# Sounding Out Science

by Marguerite Holloway, *staff writer*

Photography by Stephen Ferry

Standing in front of his favorite boulder, Alan J. Mearns of the National Oceanic and Atmospheric Administration holds aloft a series of pictures, comparing this year's scene with those of the previous six. The rock is certainly a nice one—potato-shaped as it is and covered with a fuzz of light-brown *Fucus,* or rockweed—but that alone cannot explain the photographic frenzy it triggers. Mearns takes another shot of the rock, capturing in the frame his colleague Gary Shigenaka, who is taking a video of the same outcropping, as well as Dennis C. Lees, who is studying the beach adjacent to the rock. Meanwhile, as a fourth scientist quips about the Heisenberg uncertainty principle and clamors to get a picture of Mearns taking a picture of Shigenaka taking a picture of Lees and the rock, a photojournalist records the whole assemblage.

This concept of an image inside an image and so on to infinity, what the French call *mis-en-abîme,* provides one of the keys to understanding what has happened in Prince William Sound, Alaska, since the *Exxon Valdez* crashed into Bligh Reef in 1989. More important, it sheds light on how to interpret "recovery," a term that in the Sound means very different things to different people. The tanker spilled about 37,000 metric tons of North Slope oil, coating a total of 1,750 kilometers of shoreline and killing thousands of birds and animals. The accident was followed by massive infusions of money, lawyers and scientific studies into the same wilderness—and these inputs were about as clarifying as the coat of thick black crude itself.

For years, lawyers watched scientists watching other scientists watching an ecosystem that is little understood and infinitely variable; everyone used a different-size frame to peer through. The state of Alaska, the people who live on the Sound and the area's fishermen all wanted to document not only the extent of the devastation but the endurance of the spill's deleterious effects. Exxon wished to show the effectiveness of its intensive cleanup as well as the evanescent quality of the oil, which is, after all, a natural substance.

Exxon lost, both in court and out. In addition to \$2.5 billion spent on cleanup, on claims and on reimbursing agencies for response expenses, the company is paying \$900 million to the Trustees—a panel of state and federal agency representatives—for "restoration," another ill-defined term that has come to include buying land so as to protect it. This 1991 out-of-court settlement includes a reopener provision: if, between the years 2002 and 2006, other impacts

*Prince William Sound is recovering,*
*seven years after the* Exxon Valdez *disaster.*
*But the spill's scientific legacy remains a mess*

PHOTOGRAPHS BY STEPHEN FERRY *Gamma Liaison*

**INTERTIDAL CREATURES on Rocky Islet in Northwest Bay are scrutinized and counted by researcher Dennis C. Lees.**

of the oil spill come to light, the Trustees get $100 million more. Exxon, which is also due to pay $39.6 million to the region's fishermen and to Sound residents, plans to appeal a $5-billion punitive settlement.

The studies that Exxon and the state of Alaska—including the departments of Fish and Game and of Environmental Conservation—conducted to prove their respective points were kept largely secret until legal settlements were reached. This secrecy reduced most of the pillars of science to rubble: out went scientific dialogue, data sharing and, for some parties, peer review. Millions of dollars were shelled out in duplicate studies—that reached opposite conclusions. In a scathing review of post-spill research in this year's *Annual Review of Ecology and Systematics,* marine biologist Robert T. Paine and his colleagues at the University of Washington quote a juror grappling with these apparent paradoxes. Originally cited in the *American Lawyer,* the juror at the $5-billion punitive trial summed up many observers' feelings about the science: "You got a guy with four Ph.D.'s saying no fish were hurt, then you got a guy with four Ph.D.'s saying, yeah, a lot of fish were hurt.... They just kind of delete each other out."

### Viewfinders

Now, seven years after the disaster, one can see the *mis-en-abîme* effect—or perhaps instead, the Sound uncertainty principle—at work. Scientists are still sparring, lawyers are still lurking around the edges of disputes, and both claim to be searching for the truth. Nevertheless, it is becoming obvious that, with a few exceptions, most of the frames people have been looking through as they study the Sound are too small to permit clear conclusions about the effects of the oil—suggesting that the next big spill may be a scientific fiasco as well. Further, it appears oil may not be the whole story: there may be much larger factors at play in the Sound.

Some of this perspective has become possible because Exxon recently published its studies in a thick blue volume, and the Trustees' tome came out this summer. Not surprisingly, almost every abstract in the Exxon book has the same refrain: by 1991 the Sound was well. To the oil company, recovery was defined as the reestablishment of a "healthy" biological community characteristic of the area. By this standard, even a biological community that was quite different from the one before the spill could, obviously, qualify as healthy.

If one scrutinizes Exxon's research, one can see how the company reached its conclusions. For example—and this will relate later to Mearns's favorite rock, still sitting at the beginning of this article but not forgotten there—the intertidal zone can appear very healthy, two years after the spill. This zone is usually one of the most biologically active and important in marine ecosystems. *Fucus* and other algae anchor to tidally flooded rocks there; barnacles, drills, periwinkles, mussels, sea anemones, starfish, sea urchins, baby herring, pink salmon eggs, tiny sculpins, hermit crabs and other creatures that are part of the immense food web thrive in this rich, diverse place. Ravenous sea otters rake the intertidal, as do oyster-catchers and Harlequin ducks, searching for mussels and other invertebrates.

Looking through tiny frames called quadrats, Exxon contractor Edward S. Gilfillan of Bowdoin College and his team saw something quite different from what other intertidal researchers saw. Biologists lay down a quadrat on the spot they want to investigate and count every organism inside the boundaries. They then repeat this procedure many times, comparing species composition and diversity between beaches—in this case, oiled beaches versus unoiled ones. Frames can also be placed at different elevations—the lower, the middle and the upper intertidal—or along "transects" perpendicular to the water. In places such as Prince William Sound, the intertidal is normally patchy and uneven, so that within a foot of a *Fucus*-matted rock, there may be a naked boulder; six inches to the right, there may be more *Fucus* and a bevy of barnacles.

At each of his sites, Gilfillan put down one baby quadrat, 12.5 by 25 centimeters, at four places along three transects. If he got, say, *Fucus* in one, none in the next and partial covering in the third, the beach looked extremely variable. And what he concluded, in essence, was that there was so much variability on any beach, it was almost impossible to distinguish oiled from unoiled sites: every beach resembled every other. Therefore, recovery had occurred.

### The Importance of Being Random

Further, because his many sites had been chosen randomly—the cornerstone of all good field biology—Gilfillan's results could be extrapolated to the entire region. "By 1990 between 73 and 91 percent of the area had recovered," Gilfillan notes, adding that people mistakenly describe the Sound as a fragile ecosystem. "As anyone who has been through an Alaskan winter knows, it is not fragile. The animals and plants there are very good at making good their losses."

Needless to say, Gilfillan's findings bemuse some observers—among them, Charles H. Peterson, a marine scientist at the University of North Carolina at Chapel Hill. Peterson, who was an expert witness in various Sound-related trials, points out that the Exxon approach not only exploits the Sound's patchiness, it mixes species together, wreaking havoc with biodiversity. For example, Gilfillan lumps different kinds of barnacles together in measuring total barnacle cover. And to him, the barnacle cover in 1990 looked much the same at oiled and unoiled beaches. In truth, Peterson explains, the lumping was misleading: the oiled sites principally contained one kind of barnacle—a little opportunistic gray species called *Chthamalus dalli*—whereas the unoiled beaches had larger, more diverse barnacles.

In another grouping, Exxon counted worms in the lower intertidal and mixed these figures into totals for the number of organisms. Yet, Peterson cautions, those worms congregate at oily sites. It is akin to saying you have 100 creatures at place A and 100 at place B; therefore, place A and B are equivalent. In fact, 99 of the animals in place A could be worms that love to eat the microorganisms that love to eat oil. "I have never seen a data set in my life that combines these communities," Peterson exclaims. "Some have argued that what Exxon did was create a study that was inconclusive by design."

Whatever the study was designed to do, its results gave Exxon evidence that all was well in 1991, so the company stopped monitoring the intertidal in quantitative ways. (Exxon researchers continue to conduct counts of sea otters and birds.) The Trustees, for their part—with Exxon's fiscal contribution—are still watching, waiting for the long-term negative effects they are sure will manifest themselves.

Ernie Piper of the Alaska Department of Environmental Conservation, normally loquacious, hesitates for a long time before answering a question about recovery. "In terms of the ecology, that, in many ways, it appears to me, is a lot more resilient than we deserved," he says slowly. "At the same time, there are lots of effects from the spill and the cleanup that are not going to go away."

"I think it is an improved picture," adds Robert B. Spies of Applied Marine Sciences in Livermore, Calif., and the chief scientist for the Trustees panel. "But it is still variable, depending on what resource you are talking about. Pink salmon have improved, yet we are worried about the herring." The Trustees also remain concerned about sea otter populations and the intertidal.

The state's principal study of the intertidal, directed by Raymond C. Highsmith of the University of Alaska–Fairbanks, resembled Exxon's in that it used randomly selected sites. It differed in that it incorporated more transects at each site and more spacious quadrats (40 by 50 centimeters). Highsmith and his colleagues—among them, Michael

**PICTURES INSIDE PICTURES reveal an obsession with frames and views in Prince William Sound.**

S. Stekoll of the University of Alaska–Fairbanks—found a counterpoint to Gilfillan. By 1991 they saw only incomplete recovery.

And there the study stopped. Despite all the money available, the Trustees deemed the work too costly at its original price: $10 million for three additional years. Even when the biologists proposed doing half the sites one year, half the next, it was still not cheap enough: "There is a lot of politics," Stekoll says, explaining that the Trustees are under great pressure to use the $900 million to acquire land for the state, thereby protecting it from deforestation. Two hundred million dollars have already been spent to do so, and there are plans to spend about $180 million more.

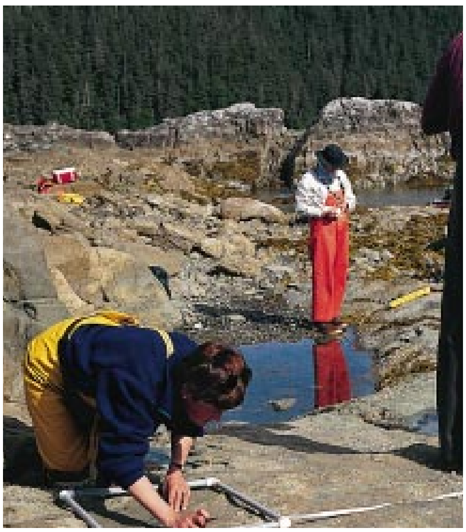
As unfinished business, nonetheless, the study permits the Trustees to defer conclusions about recovery. "I would like to bring closure to this intertidal thing. It is a question of priorities," Spies notes.

### The Way We Were

For the Trustees, "recovery" will occur when the Sound looks as it would have if the spill had not occurred. The biggest problem with this criterion is that no one really knows exactly what the Sound was like before the blanket of oil and scientists descended on it or how it would have evolved. The scientists have had to grapple with the absence of baseline data, except for a few specific species, including murres on the Barren Islands, killer whales, sea lions and, of course, the commercially crucial salmon.

To a lay traveler visiting Prince William Sound this summer for the first time since 1991, it appears beautiful and healthy. Although oil still lies under the boulders and cobbles on some beaches, it takes longer to find, and the oil is largely weathered—that is, nontoxic. Humpback whales can be seen in open water before they dive, flashing their *Fucus*- or barnacle-encrusted tails. Also visible are orcas, porpoises, seals, sea lions, puffins, kittiwakes, pigeon guillemots and river otters in coves or channels. In one unoiled eastern bay, sea otters float everywhere, bobbing like buoys, some with young on their chests, while myriad bald eagles make their high-pitched, halting cries. And the intertidal, even in places that were heavily damaged, seems more luxuriant than it did five years ago—with purple and orange sea stars and tousled green, brown and red seaweed.

This big picture, however, can be just as misleading as a little quadrat. And that is why Mearns's rock is so interesting. Mearns belongs to yet another intertidal team, funded by NOAA. The NOAA study was designed differently from those of Exxon and the state, because it was never intended to be part of damage assessment—that is, it was not driven by litigation. Instead its agenda was to describe differences in recovery between oiled beaches that were left alone and those that were cleaned with high-pressure jets of very hot water.



**INTERTIDAL VARIABILITY can range from a quadrat full of *Fucus* (*top*) to barren rock (*bottom*) a few feet away.**

Given that they spend most of their time on the beach staring into fairly big quadrats—50 by 50 centimeters—it is perhaps not surprising that Mearns and the rest of the NOAA team constantly joke about views and frames. Through these windows, this group—led by Jonathan P. Houghton of Pentec Environmental in Edmonds, Wash., and Lees of Ogden Environmental and Energy Services in San Diego—has watched recovery at many sites for the past seven years. Generally, they say, the intertidal looks good, although wide swings in species diversity and density persist.

The NOAA results suggest that hot-water cleaning sterilized the beaches; whatever survived the oiling did not survive the cure. The scientists report that a few years after the spill, the uncleaned beaches showed more health than did stark, cleaned sites. The finding—something oil spill experts warned about to no avail during the invasion of the cleanup crews—is not popular. Both Exxon and the state were, and are, under considerable public pressure to rid the Sound of every last inch of black veneer.

"Yeah, cleanup is disruptive, and if you clean up it is going to look like a very different shoreline," comments Piper of the Department of Environmental Conservation. But, he argues, as do some members of the NOAA team, hot-water washing just needs to be done more judiciously. One possible solution, Mearns suggests, is washing in strips, which would leave patches of beach oiled but alive so they can recolonize the bald spots.

The NOAA intertidal work has also

been criticized on statistical grounds. Gilfillan of Exxon argues that because the sites were not randomly chosen, they have little statistical power and therefore are not generalizable. (According to a recent paper by Gilfillan, in which he and three colleagues compare the three intertidal studies, the Exxon study was statistically the most powerful.) Stekoll concurs: "From a pure statistical viewpoint, you would have to say that it was not a design to extrapolate to the Sound."

Houghton and Lees retort that they have fully characterized the biology of recovery—even if their sites were selected by different criteria, such as accessibility and the availability of baseline information (sometimes frantically gathered just before the oil came ashore). Thus, they are permitted to describe what is happening throughout the area. Statistics aside, it is true that by virtue of having monitored consistently for seven years, the NOAA crew has tracked some fascinating shifts in the ecosystem. And this is where the shaggy rock enters the picture again.

**OIL SHEEN can still be found in the mud or under boulders in parts of the Sound.**

Mearns's subject sits in Snug Harbor, one of the loveliest places in the Sound. High mountains rise directly up from the shore, and a waterfall flows right onto the beach. Snug was heavily oiled and a large part of it left uncleaned, as "set-aside." Such places serve as important controls, allowing scientists to study how long it takes for oil to disappear naturally from various types of beaches. Nevertheless, set-asides are controversial: because most Alaskans wanted all oil removed, NOAA officials had to fight to get the few they have.

As a protected area, not scoured by winter waves, Snug is a particularly important reference. The harbor looks oil free these days, except for a small patch of asphalt, and the intertidal seems lush. But Mearns's photographs reveal that his Snug rock is going through a dramatic cycle. In 1990 its top was covered with young *Fucus;* in 1991 the rest of the rock sported a similar ensemble. Rockweed—a keystone of the intertidal ecosystem—was rebounding.

Or was it? If the NOAA workers had stopped there, they could have shared the stand with Gilfillan: the Sound looked recovered. But they went back, and in 1992 the rock had lost a lot of cover. The next year some scattered germlings covered the crown again; in 1994 it was naked; the cycle began anew in 1995. And this past summer Mearns found a fuller shag and a few small mussels in the crevices.

### Mystery of the Vanishing *Fucus*

The NOAA scientists have seen this pattern in cleaned places as well. The hypothesis they present is that most intertidal zones contain *Fucus* plants of different ages, whereas in the oiled and the cleaned sites, most, if not all, of the *Fucus* was killed in 1989. The slate wiped clean, every subsequent plant that recolonized the site was the same age, with the same life span. So when the *Fucus* dies, taking most of the creatures it protects with it, the system returns to ground zero. This suggestion is bolstered by recent research on the coast of Britain, where the *Torrey Canyon* tanker spilled 119,000 tons of oil in 1967. *Fucus* there, it seems, still goes through similar cycles. "Ten years after *Torrey Canyon* they said it was fine," Lees states. "Now they are going back and seeing flux still." In particular, *Fucus* and limpets seem to be in a race for space.

There are anecdotal reports, however, that such die-offs are being seen in other, unoiled environments. And despite observations in the Sound, biologists admit that they do not really know all that much about the omnipresent algae. As Jennifer L. Ruesink of the University of Washington remarks, scientists are not even sure how to measure the age of *Fucus.* Is it necessarily older when it is darker? Does the number of dichotomies, or branches off a stem, reflect its age in years, like tree rings? How do adults help or hinder the establishment of young plants?

Ruesink tried to answer some of these questions as she accompanied the NOAA crew through the Sound over the summer; she sat on top of the Snug rock as well as many others, meticulously counting strands of *Fucus,* plying them apart. Her preliminary findings are "equivocal." It looks as though *Fucus* may have slip-slided away, even at sites never touched by oil. So the mystery remains.

The *Fucus* provides yet another frame through which to view the *Exxon Valdez* disaster. The basic questions asked about this seaweed give the real story away: nobody actually knows much about anything in the Sound—or in any such complicated ecosystem, for that matter. Most of the studies conducted in the early years after the spill centered on one zone, or one species, at a time.

But, as David Duffy of the University of Alaska–Anchorage puts it, you have a problem if your species—say, the otter—starts eating your colleague's, the mussel. It is more appropriate instead to try to examine from the outset how the frames fit within one another—like zooplankton inside herring inside salmon inside bear. Indeed, the relation between links in the food chain is proving to be perhaps the most important information that could be gleaned from science in the Sound.

### A Bird's-Eye View

The opportunity for real insight may, however, have been squandered. "The tragedy is that people are trying to look at oil spill relations seven years after the fact," Duffy explains. "There should have been greater thinking about an ecosystem approach." Spies of the Trustees agrees: "We are very aware that looking on a species-by-species basis has limitations. We thought that that was very appropriate at the time of the spill to learn what was killed." Still, he notes, "we have got some very exciting projects right now that go beyond 'When did this resource recover?' to the basic processes going on in the ecosystem." The panel is funding several studies that take this wider perspective, looking at oceanographic trends in the Gulf of Alaska and at the food web. The frame is hundreds of kilometers a side.

For his part, Duffy is looking at birds, evaluating declines reported among kittiwakes and pigeon guillemots. "We don't know whether it is the spill, or the spill and environmental change, or just environmental change," Duffy says. "We have victims, we have the weapon, we have the [birds] at the scene of the crime, but we don't know whether something happened before that affected the population and that this spill was only the trigger. And we will never know."

What Duffy and others are piecing together is that the Gulf of Alaska, and Prince William Sound with it, seems to be going through a shift that predates the spill. Researchers have already had trouble teasing apart the pre-spill effects of an extremely cold winter in 1989; those of a 9.2-magnitude earthquake in 1964 that upturned the Sound, devastating the ecosystem and wiping out communities of people; and those of the 1982–1983 El Niño (a periodic oceanic disturbance that affects weather and ocean currents).

According to the only long-term study of bait fish in the region, the population of fatty pelagic fish on which sea lions, seals and many seabirds feed plummeted in the early 1980s. Today there are only 17 percent as many sea lions as there were 20 years ago. The shrimp fishery, which peaked at about 119 million pounds in 1976, was down to 10 million in 1982. "At that time, there was a lot of arrow slinging about overfishing," remarks Robert Otto of the National Marine Fisheries Service. "But the fact of the matter was that [shrimp] were declining both where they were fishing and where they were not."

Shrimp was the center of attention because it supports a large industry. But the problem did not stop there. Paul J. Anderson, also at the National Marine Fisheries Service, started sampling in the 1970s with a small mesh net and caught bait fish, such as capelin and candlefish. These so-called by-catch are routinely netted along with shrimp but are not typically counted, because they are not important to fish markets. They are, however, the meals for commercial fish and as such are as worthy of care as their flashier predators.

The by-catch turned out to be the big catch after all. What Anderson saw was that capelin fell off when shrimp did, whereas cod and pollack increased. At the same time, the crab fishery crashed, and salmon numbers rose (while prices, consequently, sank). "There was something that happened in the North Pacific that changed the whole ecological structure," Otto says.

"We may be right in the middle of a shift back; people just don't know," Duffy remarks. He speculates that salmon may be plentiful because it is simply a salmon period. "When the fishery was under the feds, it was downtime for salmon, and the government workers were criticized as idiots for not managing it well. Maybe the state is not good or bad. Maybe salmon are just doing what they do."

The changes in bait fish numbers could be the result of the growth of hatcheries. These outfits release young fish each spring to feed in the Sound and the Gulf

**PRESSING ALGAE for careful identification is still done, here by a member of the NOAA team, even after seven years of studies, because the intertidal seaweeds can be difficult to tell apart.**

of Alaska before they return home to spawn. These fish are, however, additions to the ecosystem—"extras" in a way—and they may be devouring bait fish that would have been available to wild fish and animals. Or the bait fish fluxes may be related to even bigger trends, such as those observed by Thomas C. Royer, an oceanographer at the University of Alaska–Fairbanks. Royer began taking water samples in 1970 and has concluded that the temperature fluctuates by two degrees Celsius every 15 to 25 years—shifts that could dramatically alter fish distribution.

In addition, he has gathered evidence that salinity shifts in 10- to 11-year cycles. Salinity differences could alter the way water flows through the Sound, changing the amount of nutrients available in the upper layers of the water column and disrupting the food chain. "I keep preaching that we need long-term studies," Royer comments, adding that many natural cycles are so long, however, that funders lose interest in them. "The funding for science is declining dramatically. There is just a great deal of frustration."

When there is suddenly a large influx of money into a poorly studied ecosystem—and finally the opportunity to do in-depth work—there is bound to be similar frustration. More money flooded into Prince William Sound after the *Exxon Valdez* spill than has flowed after any other. But, clearly, wherever litigation and science intersect, there is little hope for a frame with an expansive view. The federal rules governing damage assessment were recently modified to protect against another scientific fiasco after the next big spill; the new provisions try to ensure data sharing and to eliminate duplicative effort. Yet many observers doubt whether these changes will make any difference if billions of dollars are at stake. "I am not convinced at all that once we had the next big one everyone wouldn't go to their respective battle stations—'I have my science, and you have yours,'" comments David Kennedy of NOAA.

### A Delicate Balance

Beyond the quality of science lies the public interpretation of science. Even though NOAA has shown that cleaning up can do more harm than good, demands to clean up persist. The Alaskan native village of Chenega has paid close attention to the spill-related research. Many of the residents of this community on Evans Island in the Sound are concerned about the oil's persistence.

**SOUND-WIDE STUDIES that attempt to look at the bigger—albeit more confusing—picture have just recently started to receive financial support.**

Chenega residents thought the oil was having a biological effect, Piper says. "But there is nothing to show that it did. So are we going to spend a lot of money to clean up when there is no problem?" he asks. But science was not the point; ridding the beaches of unsightly oil was. "It was more an issue of trashing the neighborhood. It was a very legitimate complaint," Piper explains. And so the Trustees, who go through a public review process before they allocate their funds, will spend $1.9 million next summer to apply de-oiling compounds, at least one of which is known to be toxic to intertidal organisms.

Chenega is not alone. Ultimately, it is the frame of the television set and the mind-set of the media that dictate people's responses to images of oiled animals. The public wants the animals saved—at $80,000 per otter and $10,000 per eagle—even if the stress of their salvation kills them. "Scientists waste a lot of time saying, 'Do nothing,'" Duffy notes. "You have to balance the show and the science."