The Fringe of the Ocean—Under Siege from Land

The ecology of the ocean margins, crucial to human life, is being disrupted by our activities—and perhaps by global change

Berlin

WHAT WAS THE LARGEST peacetime maritime operation in the history of Norway? An attempt to save salmon from foul-smelling phytoplankton. Although U.S. scientists might not have known the precise answer to that question, in the wake of the Valdez oil spill they might well have guessed that human activity was the ultimate culprit. And it was.

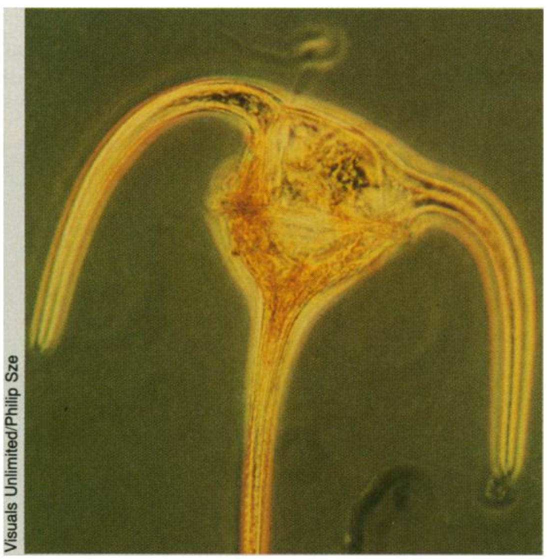
In the spring of 1988, salmon being reared off the neighboring Swedish coast started dying from a yellow-brown slick. As the coastal current swept the slick northward, it threatened Norway's much larger mariculture industry. The rescue operation was a massive nautical juggernaut in which huge numbers of salmon cages were towed deeper into the Norwegian fjords to save them from the foul slick.

In the end marine biologists found that the cause of the slick was a microscopic organism called *Chrysochromulina polylepis*. But this slick was just one of a number of remarkable toxic algal blooms that have appeared around the world in recent years. And those same marine biologists have a pretty good idea that the underlying cause of the blooms is excess nutrients being dumped in the ocean margins—by man.

And thats' only one threat to the ocean's delicate fringe. In addition, the damming of rivers has decreased the flow of fresh water into the sea, changing life for all the organisms that dwell at the edge of the ocean. These effects will have serious consequences for human beings, because the ocean margins are critical for human life. Although they cover only 10% of the ocean's surface and contain less than 1/2% of its volume, the margins are responsible for 30% of the oceans' productivity. And they are where the human population dwell: 70% of all human beings make their homes on coastal plains, within reach of the ocean margins.

That's why the organizers of a recent Dahlem conference* in Berlin devoted the meeting to what is going on in the ocean margins now. In particular, they were interested in whether the changes seen there might reflect global climatic changes, such as those stemming from the greenhouse effect. The large question of whether what is happening in the ocean margins is due to a global cause is hard to answer. Indeed, at the Dahlem workshop it was agreed that the extent—and even the existence—of global change remains debatable. But there was a strong consensus that whether they reflect global changes or not, there are things going on in ocean margins around the world that will have critical consequences—and soon.

Perhaps the most dramatic of these changes is eutrophication—the release of excess nutrients into the ocean margins, upsetting the balance of plants and animals. Eutrophication seems to be happening at the mouths of almost all the world's rivers. The extra nutrients are often remnants of fertilizers spread on the land, which find their way through the rivers to the sea. They may also be found in increased silt, the result of erosion upriver. They may even be human effluent. But whatever their source, the effect of extra nutrients is always the same; increased growth.



Visuals Unlimited/Philip Sze

The bloomin' sea. Ceratium tripos, *a dinoflagellate, is one of the microorganims that have been implicated in algal blooms.*

"We have a green hand in the sea," says Victor Smetacek, a marine biologist at the Alfred Wegener Institute for Polar and Ocean Research in Bremerhaven, Germany. Apart from a few isolated instances in which poisons have been dumped at sea, Smetacek cannot bring to mind any episodes in which human activity has depressed productivity. "It's quite unlike acid lakes," he says. Paradoxically, too much fertility may be as destructive as too little.

The most visible manifestations of that green hand are the red tides, yellow foams, and outbreaks of clinging emerald slime that constitute phytoplankton blooms. On a small scale, such blooms are part of the natural cycle of the sea, at least in temperate areas. During the short days and low light levels of winter, phytoplankton are unable to grow much. Then, in the spring, light enables the organisms to grow, and there is an orderly sequence of small blooms. These blooms stop as spring ends, and resume in the fall.

But by supplying extra nourishment, human activities have probably upset this orderly round in many parts of the world. Instead of a succession of small blooms, we now see massive outbreaks, which Smetacek has compiled in a casebook of "exceptional phytoplankton blooms." In addition to the effort to save the Norwegian salmon, the casebook includes an outbreak on the German coast of the North Sea in an area called the southern German Bight. In 1978, beaches in that area were fringed by foul-smelling foam piled more than a meter deep. The foam was created by surf beating on the remains of a phytoplankton species called *Phyaeocystis*, which surrounds itself with a gelatinous coat that makes planktonic herbivores avoid it.

In 1988 an outbreak of *Ptychodiscus brevis* was linked to mass deaths among dolphins off the Carolinas. This species of alga is normally restricted to Florida's Gulf Coast; Smetacek speculates that its spread to the Atlantic was helped by the extra nutrients available there.

There are many similar examples; worse, "they are increasingly toxic," says Mike Bewers, a chemical oceanographer who heads up marine chemistry at the Bedford Institute of Oceanography in Dartmouth, Canada. The reason lies—at several removes—in the chemistry of phosphorus. Diatoms use silicon to make their shells.

*The Dahlem Workshop on "Ocean Margin Processes in Global Change" was held in Berlin from 18 to 23 March. The results will be published by John Wiley & Sons, Ltd., Chichester, England.

Normally, there is a rough balance between the silicon available for building shells and the nutrients, such as phosphorus and nitrogen, that are available for growth. But when human activity supplies excess nutrients, the balance is upset. The diatoms use up all the silicon and begin dying off even though there is plenty of phosphorus and nitrogen around. Phytoplankton grow explosively on those nutrients, but eventually the phosphorus gives out—and that's when some species of phytoplankton begin exploiting a neat trick for getting more: They secrete toxins that kill animals, releasing the phosphorus those animals had locked up in their tissues. This allows the toxic algae to maintain their deadly bloom.

In spite of the striking number of recent blooms, one question raised at the Dahlem conference was whether the apparent increase wasn't really just a "global village" effect—that there seem to be more of them because communication and reporting are better than they used to be. There may well be a component of this, but it also seems that the blooms are indeed more common than they used to be. Smetacek has trawled the archives and finds sporadic reports of foam events since about 1930, although none before that time. Since 1978, however, there has been one every year. The green slime that appalled holidaymakers on the Adriatic last year goes back to at least 1911. Local fishermen, whose nets rip under the weight of the slime, call it "mare sporco," dirty sea.

If the trend is real, rather than simply an artifact of communications, what accounts for it? It isn't easy to prove that the exceptional blooms are caused by excess nutrients, but there is some suggestive evidence. The best "experiment" Smetacek can offer comes from the Seto inland sea of Japan. Red tides there increased from 40 a year in 1965 to more than 300 a year in 1973. In 1972 the authorities introduced controls designed to cut the nutrients entering the sea by half. The frequency of red tides peaked in 1975 and has been declining steadily since.

While the threat of toxic blooms is largely the result of a kind of feast—too many nutrients entering the ocean—the other main threat discussed at the Dahlem workshop comes from famine. As nutrients entering the sea have increased, the amount of fresh water carrying those nutrients has decreased, largely as the result of damming, with some dire results for the stability of the land and for fisheries.

Yousseff Halim, a physical oceanographer at the University of Alexandria in Egypt, points out that by the year 2000, some two thirds of the world's stream flow to the ocean margins will be controlled by dams. Halim gave an example close to home—the Nile, which before the completion of the Aswan High Dam in 1965 carried 43 billion cubic meters per year; since then it has carried 3 billion. As a result, the Nile delta is eroding, because the river no longer brings the silt needed to maintain it, and the fisheries of the eastern Mediterranean have collapsed as the lack of a single yearly deluge destroyed the existing ecosystem.

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—Victor Smetacek

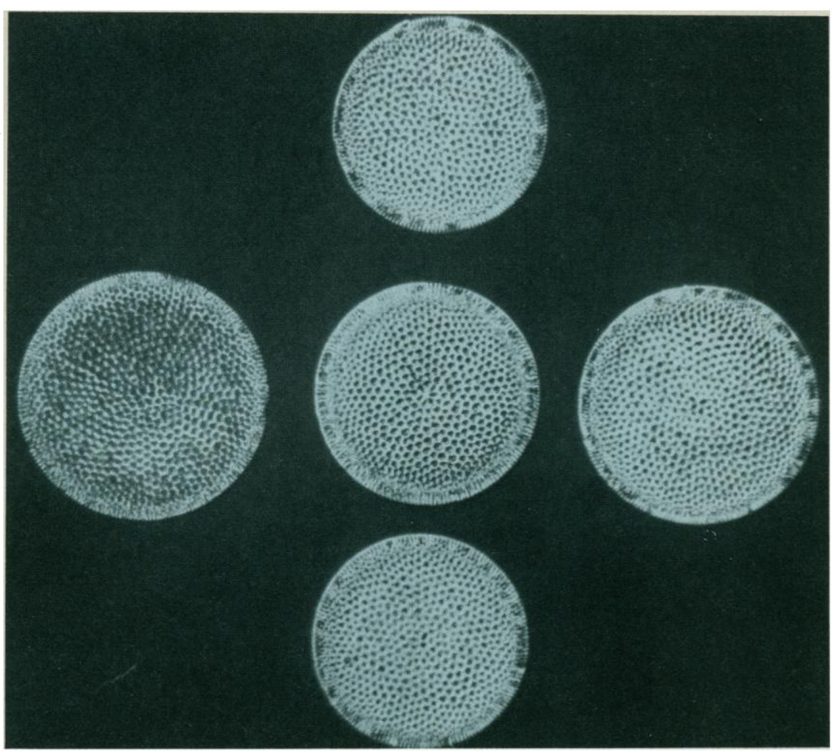
The consequences of damming aren't always as severe as these. Indeed, Halim stresses that, despite a decade of drought in the Sahel, Egypt—by being able to draw on water in the Aswan reservoir—has not suffered. "You must include that in the balance sheet," he says.

Yet the building of a dam always alters the coastal zone's ecology, because life there will have adapted to the timing, amount, and quality of water coming downriver before the dam was built; it will then be thrown into turmoil by changes caused by the dam. The Cabora Bassa dam on the Zambezi in southern Africa, for example, has affected the local seafood industry. Young prawns take a flood of fresher water as their signal to move from nursery grounds in the estuary out to sea—where they feed on the bloom fertilized by the flood. With the dam in place, however, fresh water comes sooner and the prawns are fooled: they move when they are too small, depressing the local catch.

Workshop participants had no difficulty tying these examples of toxic blooms and the ill-effects of damming on the world's ocean margins to human activity. But the deeper questions—whether the global climatic change that some researchers have postulated is having an effect on ocean margins, and whether the ocean margins will, in turn, make global change more or less severe—proved very difficult to answer.

For one thing, excess nutrients may cause toxic blooms, but they also might actually retard the greenhouse effect. More nutrients mean more plant life, which could raise the amount of greenhouse-causing carbon dioxide that is converted to carbohydrates, then buried in ocean sediments. That's an upbeat possibility. But the problem is, nobody knows whether the ocean margins are in reality a source or a sink for carbon. According to Roland Wollast, a marine chemist at the Free University of Brussels in Belgium, the people who model world climate simply ignore the coastal zones. "They just aren't in the models," Wollast says. But the coastal zones "must contribute" to the global carbon balance sheet—and they even might make the difference between profit and loss.

Then again, eutrophication might exacerbate global warming. Where there is more life, there is also more death. Death is followed by biochemical changes such as denitrification, which releases the



Dirty business. *Phytoplankton of the genus* Coscinodiscus, *build up into a slime so heavy that it has been known to rip fishermen's nets in the English Channel.*

nitrogen in proteins and other biological compounds. More than 90% finds its way back into the atmosphere as gaseous nitrogen, but some—perhaps as much as 8%—is converted to nitrous oxide. Because nitrous oxide is about 150 times as effective as carbon dioxide in trapping heat, that small proportion could make a big difference to global greenhouse warming.

"My gut feeling is that terrestrial [denitrification] is more significant [than denitrification in the oceans]," says Philip O'Kane, a mathematical modeler who is director of the Centre for Water Resources Research at University College in Dublin. "But there will be a large increase in denitrification related to the increased organic load associated with eutrophication. The global effect of that is unknown."

Another unknown is the role of dimethylsulfide (DMS), a planktonic compound that is at the heart of the atmospheric sulfur cycle. A square kilometer of *Phyaeocystis* bloom contains about 2 tons of sulfur, which is released as DMS when those cells die. DMS contributes roughly half the sulfuric acid in the atmosphere, and hence phytoplankton blooms could mean considerably more acid rain. But that remains unproven.

And if the issue of coastal effects on global processes is uncertain, the converse—how global warming could affect coastal processes—is doubly so. Even the high current levels of eutrophication could prove trivial by future standards if global change begins to affect fundamental processes within the oceans. John Walsh, a biological oceanographer in the Department of Marine Science at the University of South Florida, points out that only 10% of the new life in coastal zones depends on nutrients coming down rivers. The remainder uses nutrients from the open ocean. In Walsh's view, any changes man may make to the rivers will not necessarily be catastrophic. "But if global climate change alters the deep-sea circulation," Walsh says, "all bets are off."

■ JEREMY CHERFAS

Irrationality—Skeptics Strike Back

The way John Paulos tells the story, he was sitting around with a group of his friends one weekend. The group was a well-educated, bunch. They were carrying on a fairly arcane discussion about the difference between the meanings of "continually" and "continuously," and everybody was pitching in. After a while the TV was turned on. The local weatherman came on with predictions for the weekend. The chance of rain, he said, was 50% on Saturday and 50% on Sunday. Therefore the probability of rain for the whole weekend was 100%. Paulos—a mathematician at Temple University—says he was the only one who noticed the glaring error in the weatherman's logic.

But that's not unusual, according to speakers at a recent conference on scientific literacy and critical thinking. Even well-educated people can be led into fallacies by a lack of understanding of simple mathematical concepts such as probability. The theme of the conference, organized by the Committee for the Scientific Investigation of Claims of the Paranormal (CSICOP), which publishes the *Skeptical Inquirer*, was that unscientific thinking is pervasive in our society and that it undermines the population's ability to think rationally about many subjects.

Indeed the U.S. population may be heading toward new heights of belief in the paranormal. One poll cited at the conference, conducted by researchers at the University of Chicago, showed that 42% of American adults believe they have been in contact with someone who has died. And a Gallup youth survey showed that between 1978 and 1988, the proportion of young people who believe in astrology climbed from 40% to 58%.

The attraction of irrational and pseudoscientific beliefs is particularly strong for the poorly educated and is closely related to the current crisis in scientific literacy, said speakers at the CSICOP meeting. But participants warned that the problem is not limited to the poorly educated. Which may be why, as Andrew Fraknoi of the Astronomical Society of the Pacific pointed out, some normally skeptical members of the press "lose their minds when they hear of a ghost or a UFO."

Biologist Michael Zimmerman of Oberlin College reported that politicians are scarcely more rationally inclined than the general public. Zimmerman surveyed members of the U.S. Congress. When asked to agree or disagree with the assertion that "aliens made ancient monuments," not even two of three responding congressmen "strongly" disagreed. Elected officials in Ohio were even less confident that extraterrestials had not built the pyramids—only 45% strongly disagreed.

In another survey, Zimmerman found that 22% of Ohio high school biology teachers who responded to a poll said they teach creationism. A separate poll of newspaper editors revealed that only half disagreed with the statement that humans and dinosaurs lived at the same time.

Paulos argued that the absence of a "visceral understanding of probabilities" opens the way to being awed by coincidence. For example, it's easy to be impressed by the fact that someone in the U.S. dreamed of an earthquake the night before one actually occurred. But it would be even more surprising if no one dreamed of an earthquake that night, given that Americans log half a billion dreaming hours a night.

Paulos went on to assert that an inadequate understanding of mathematics can skew the debate on significant social issues. Stanford, he noted, has been accused of discriminating against women because proportionally fewer female than male applicants are admitted. But that result is unavoidable, Paulos claimed, because the ratio of applicants to openings is much higher in the fields that are attractive to women (such as literature and psychology) than in male-dominated fields such as mathematics and engineering.

As for making public debate of the issues more rational, some of the nation's leaders aren't offering much in the way of role models. Ronald Reagan couldn't decide whether he espoused modern science or ancient Babylonian superstition. Asked last year at a press conference whether he believed in astrology, Reagan declined to answer, saying, "I don't know enough about it to say if there is something there or not."

So the problems continue to grow. But if you're of a skeptical turn of mind, then there is another increase that might seem like a good sign: the growth in the number of debunkers. Since its founding in 1976, CSICOP has attracted almost 36,000 members. The organization now has 60 affiliates around the world, including one in the Soviet Union, where the era of perestroika and glasnost is accompanied by what CSICOP's chairman, philosophy professor Paul Kurtz of the State University of New York in Buffalo, calls "paranormal pandemonium." And the extraterrestials sighted in the land of Gorby are reported to be even bigger than the ones that land in Florida.

■ CONSTANCE HOLDEN