trino source with a controlled, calibrated beam from an accelerator.

The first such efforts will begin this summer at CERN (see box) and a year later at Fermilab. The Fermilab experiment, like CERN's initial effort, will send neutrinos a relatively short distance: less than a kilometer, from the Tevatron accelerator to a specially-designed detector made of stacked photographic plates. The neutrino source will generate only muon neutrinos, according to University of Kansas physicist Bill Reay, who heads the experiment. The detector will be sensitive only to tau neutrinos, hence any taus that show up must have been produced en route by oscillations from muon to tau. But the short baseline will also limit the range of neutrino masses the experiment can detect, because theory predicts that neutrinos with lower masses take more time to oscillate.

In fact, the short span of Reay's experiment allows enough time for oscillations only if one of the neutrino types carries a mass of about 10 electron volts, which fits nicely with some—but not all—of the observational data. It's more than a hundred times the mass that is required to explain the solar and atmospheric neutrino results. But a mass in that range is exactly what would be needed to satisfy cosmologists searching for sources of invisible mass, says Reay.

The other planned neutrino beam experiments could search for neutrino masses that Reay's experiment would overlook, since they span much longer distances and could pick up the oscillations of a neutrino weighing as little as a tenth of an electron volt. Although evidence of oscillations from these experiments might explain the solar neutrino problem, their immediate target is the atmospheric neutrino problem, says Penn's Mann. He explains that physicists think the case for oscillations is more secure for atmospheric neutrinos; what's more, muon neutrinos like those from the atmosphere are easier to generate in the laboratory than electron neutrinos like those born in the sun.

Nomadic neutrinos

Scientists at Brookhaven National Laboratory plan to start the first of these longer-baseline experiments next year. The Brookhaven group, collaborating with the TRIUMF laboratory in Canada and Los Alamos National Laboratory, will send a beam of muon neutrinos about 24 kilometers from the Advanced Gradient Synchrotron across Long Island to a giant tank of water rigged to pick up the flash of light generated when an occasional neutrino tangles with a water molecule. As in the other experiments, identity-shifting will be detected by differences between source and detector. Here, however, the evidence will be indirect, rather than direct.

The Brookhaven accelerator's relatively low energy means that any tau neutrinos spawned by oscillations won't have enough energy to trigger the detector themselves; as a result, the detector can pick up only muon neutrinos. Therefore, the evidence of oscillations from muon to tau neutrinos, if any, will take the form of a shortage of muon neutrinos captured over the experiment's 4-month run. That strategy makes it especially important to know how many neutrinos are in the original beam, says Penn's Mann, the experiment's principal investigator, and so the researchers will use two additional detectors to sample the neutrino beam closer to the source—1 and 3 kilometers away, respectively. "I will know precisely what to expect in the far detector from having looked at the closer ones," says Mann.

A proposed long-range experiment at Fermilab, in contrast, would generate a beam energetic enough for any tau neutrinos to be detected directly. On the other hand, the high energy of the beam means the neutrinos wouldn't have enough time to oscillate if they travelled only a few tens of kilometers. To be sensitive to very small neutrino masses, the experiment has to unleash the neutrinos for hundreds of kilometers. Argonne's Goodman, the experiment's principal investigator, would like to aim the beam at an existing detector called Soudan II, in Minnesota, 730 kilometers away. But that long baseline raises a new problem: By the time the beam reached the detector, it would have fanned out to a width of several kilometers, and most of the neutrinos would miss the detector completely.

To have a chance of catching even a few thousand neutrinos—the minimum needed to say anything about oscillation frequency and neutrino mass—Goodman and his colleagues would have to start with a far more intense beam than the Tevatron can now generate. And that means their experiment could only be done if the Tevatron gets a boost from the proposed $230 million Main Injector, which is due to be up and running by 1998.

The long-baseline experiments proposed at CERN and KEK won't be immune to such tradeoffs, either; compromises are inevitable when you are trying to make the best of existing equipment, says Fermilab neutrino theorist Steve Parke. "Brookhaven has a lower energy accelerator, so they try to justify a lower energy experiment, while Fermilab has a higher energy beam, so they try to justify that." Which plan is best? Parke says he doesn't want to take sides. Humbled by the loss of the Super Collider, he and many of his fellow physicists now hesitate to criticize any proposed experiment, even their competitors', if it promises a way out of the impasse in which their field is, for the moment, trapped.

–Faye Flam

ECOLOGY

Is Marine Biodiversity At Risk?

In the early 1970s, marine biologist Kerry Clark of the Florida Institute of Technology discovered a new species of sea slug in sea grasses in the Indian River lagoon on the Atlantic coast of Florida. Sea slugs are small, graceful creatures with brilliant coloring, and many species are rare. But at first this bright green species, which Clark named *Phyllaplysia smaragda*, the emerald sea slug, was relatively common. However, as the lagoon's shores were developed, the sea grasses shrank into the shallows and the slug's numbers dwindled. Clark hasn't seen one since 1982 and fears they're gone for good.

This tale of species found, then lost, is all too familiar to terrestrial ecologists, especially those in tropical rainforests, who have watched species vanish or hover at the edge of extinction. But it's a new story for many marine biologists. Except for large vertebrates like mammals and birds, marine organisms rarely appear on lists of extinct and endangered species. Indeed, although the fossil record is full of such extinctions, marine organisms were believed to be resistant to human-caused extinction, because many sea creatures have larvae that can drift long distances and most are thought to have large geographic ranges.

Now, a small but growing band of marine ecologists is sounding the alarm. The resilience of marine species may have been overestimated, they say, and human modifications of coastal environments, along with overfishing, may threaten marine biodiversity. These researchers are taking a new look at the question of extinctions in the sea, and some conclude that such extinctions may be common—but overlooked. "There's a perception of fewer extinctions in the ocean and I'm not sure the perception is right," says James Carlton, director of maritime studies at Williams College and Mystic Seaport (a program of marine studies in Mystic, Connecticut). Furthermore, ecologists argue, even if oceanic species are being lost more slowly than those on land, the marine environment operates differently. Other signs of decline, such as the shrinking percentage of coral cover seen on some reefs, may be more relevant indicators of deterioration in marine ecosystems.

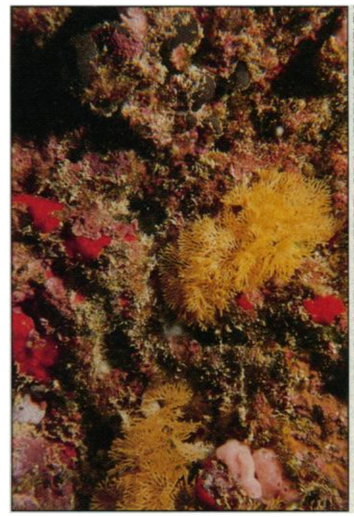
Still, studies of marine biodiversity are in their infancy, and many biologists remain skeptical about marine extinctions. The concerns are nevertheless being taken seriously by funders and other scientific organizations, who have been sponsoring a flurry of conferences and workshops on the changing diversity of the oceans. A symposium this week at the annual meeting of the American Association for the Advancement of Science (AAAS) is one example. Four federal agencies (the National Science Foundation, the National Oceanic and Atmospheric Administration, the Office of Naval Research, and the Department of Energy) have also banded together to sponsor a National Research Council (NRC) initiative to chart a research agenda.

Counting down. The NRC effort will likely span a wide range of research questions, but one issue sure to come up is extinction, although the numbers of recent marine extinctions are anything but dramatic. The first published account of a modern invertebrate extinction in an ocean basin, that of the Atlantic eelgrass limpet, was published only three years ago, and there are still no documented extinctions of marine fish in historic times. "Only about 14 or 15 species have been lost, mostly flightless birds, a few mammals, only one or two invertebrates. Even if there were 10 times as many extinctions, it wouldn't be a huge number," says Geerat Vermeij of the University of California, Davis. "There's just no evidence for human activity causing extinctions in the oceans in the last 300 or 400 years."

Yet the scarcity of documented marine extinctions may reflect nothing more than the difficulty of proving them, say biologists like Carlton, who co-chairs the NRC commitee with Cheryl Ann Butman of Woods Hole Oceanographic Institution. Only about 7% of the world's oceans has been sampled for biodiversity, and even moderately rare species are easy to miss.

In the case of the eelgrass limpet, Carlton, Vermeij, and colleagues were able to document the extinction because the literature and museum collections of the 18th and early 19th centuries indicate that the limpet was abundant on nearshore eelgrass from Labrador to Long Island—areas now reasonably well-sampled by biologists. The record is much worse for most organisms. Take the emerald sea slug: Clark can't find it in its original locality or elsewhere in the Florida Keys and Atlantic Coast, but he hasn't visited potential habitats in northwest Florida. Since the slug has free-floating or planktonic larvae, it's possible that the creature is quietly grazing on seagrasses in some undeveloped lagoon. For now, *P. smaragda* won't appear on any lists of extinct species.

But many ecologists remain convinced that nearshore marine species have suffered from coastal development. Clark says that in south Florida, he's watched as human activities have dramatically changed the nearshore habitats where he's been collecting for 20 years. He believes increased sedimentation is one of the chief culprits. Sea slugs, like many marine organisms including corals, prefer clear water with low levels of silt. Coastal construction increases the amount of silt flowing into the water from the land and appears to make habitats unsuitable, says Clark. Of 33 species in one group of sea slugs in Florida, 16 are in decline, according to Clark's data (in press at the *Bulletin of Marine Science*). As a result, he says, "I have no doubt that there are more [extinctions] out there that we missed."


ROY CALDWELL, UNIVERSITY OF CALIFORNIA, BERKELEY

"Rainforest of the Sea." A coral reef is a highly diverse ecosystem.

Following up the work on the limpet, Carlton combed the historical and recent literature looking for just such overlooked extinctions. In work published recently in *American Zoologist*, he reports two additional recent molluscan extinctions—a Chinese periwinkle and the marsh horn snail of southern California—and another "possible" extinction of a rocky shore limpet in California. That makes a grand total of four.


ROY CALDWELL, UNIVERSITY OF CALIFORNIA, BERKELEY

On guard. The stomatopod *Haptosquilla stoliurus (left)* may find it easier to defend its home in a coral reef from the invading *Gonodactylus viridis* than from human effects.

But the exercise persuaded Carlton of the difficulty of proving a marine extinction. He has begun to identify hundreds of molluscan species that were "missing in action"—described by 18th and 19th century systematists and never spotted again. These "species" could be extinct, have been misclassified originally, or be present but not sampled recently. Without a very time-consuming search, Carlton says, he simply can't be sure.

Of course, before researchers can estimate the amount of biodiversity that has vanished, they need to know what was there to start with—another vexing problem in the oceans. In the past few years, estimates of the number of deep-sea species alone have ranged from fewer than 500,000 to 10 million. Even on well-studied coral reefs it's tough to estimate how many species are present. "To identify every species in a reef, you'd have to blow it up, level it, to see what was living in the crevices," says reef biologist John Ogden of the Florida Institute of Oceanography. In work to be presented at the AAAS symposium this week, ecologist Marjorie Reaka-Kudla of the University of Maryland estimates that 35,000 to 60,000 described species live on coral reefs—but that this represents only 8 to 14% of reef biodiversity.

Long-range larvae? Even in the absence of large numbers of documented extinctions, however, some new research is beginning to question the view that marine species are resistant to extinction. This idea took hold because many marine creatures produce planktonic larvae; some may spend months in the plankton, voyaging thousands of miles. Such organisms have the potential for broad geographic distributions and large population sizes—which should be excellent insurance against a permanent vanishing act.

"There's been this overwhelming tradition of thinking of the sea as a giant bathtub in which things can slosh from India to England without any problem," says biologist Nancy Knowlton of the Smithsonian Tropical Research Institute in Panama (STRI). "But it isn't always so." Larval biologist Michael Hadfield of the University of Hawaii agrees: "The larval dispersal potential is high, but it may not be happening. Not all marine species have planktonic larvae, and some of those that do only hang around an hour or so and don't get far."

Take mantis shrimp. Many species of these crustaceans, called stomatopods, live in the crevices of coral reefs. Most species do have planktonic larvae, but work by Reaka-Kudla and colleagues has shown that many of the larvae spend only a few weeks in the water. Furthermore, they spend their days hovering close to the reef structure, venturing up into the waves only at night. So they don't travel far, says Reaka-Kudla. In general, small species are less likely than large ones to have long-lived planktonic larvae, she says. Therefore, she argues, small species —which are more numerous and also more likely to be overlooked—have more restricted geographic ranges and are more vulnerable to extinction. Sea slugs also fit that picture, says Clark. One-third of the 33 species he's studied in the Florida Keys have either no free-floating larval stage or their larvae spend only a few hours in the plankton.

For many organisms, the question of exactly how far their larvae travel has not been tested. But larvae or no larvae, researchers have evidence that at least a few marine species have relatively narrow geographic distributions—making them vulnerable to extinction due to local disturbances. For example, Michael Smith, senior research scientist at the Center for Marine Conservation in Washington, D.C., analyzed the ranges of 500 Caribbean fishes, using recently published literature. While most did have broad ranges, he found that 16% were restricted to the Caribbean Sea alone or to smaller geographical areas.

Among invertebrates, isolated cases of such narrow distributions are also trickling in, says Knowlton. For example, the Kumamoto oyster, *Crassostrea sikamea*, has planktonic larvae, but its native range was apparently restricted to the southernmost island of Japan, according to Dennis Hedgecock of the University of California. Although farmed for the restaurant trade on the U.S. West Coast—you'll pay extra for its delicate flavor—the Kumamoto now appears to be extinct in Japan, says Hedgecock.

Laws of the sea. Despite such tales, few marine biologists claim that marine extinctions are occurring at the same rate as those on land. Most biologists agree that marine species probably do have an extra measure of resilience. But biologists such as coral reef specialist Robert Buddemeier of the University of Kansas warn that numbers of extinctions in the sea may not serve as the same kind of ecological damage indicator as they do on land. "You don't want to get trapped into a linear comparison of terrestrial and marine ecosystems," says Buddemeier. "The marine system is less extinction-prone, but if you do start getting extinctions, it means you've got a problem on a much larger scale. The rules *are* different in the sea."

For example, in January a coral reef research and monitoring panel convened by the Department of State reported that many coral reefs in close proximity to large human populations are in decline; a colloquium on coral reefs held last June in Miami came to a similar conclusion, according to the draft report of the meeting. Reef biologists suggest that increases in nutrients, intense fishing (which decreases the numbers of predatory fish), plus natural disturbances such as storms combine to put reefs under stress. Specifically, says Jeremy Jackson of STRI, these factors tip the ecological balance in favor of corals' chief competitor, algae. The end result, already seen at some locations: large, fleshy macroalgae thriving atop dead coral.

"I can't point to a single species of coral which has gone extinct in the Caribbean," says Jackson. "But that doesn't mean that corals aren't in decline. I see it everywhere: The corals look like they need a shave—they're being overgrown with algae."

The visible danger sign is not the extinction of geographically restricted species, as might happen in a rain forest, but rather a widespread change in abundance of species, explains Knowlton. "It's different from a forest. You can chop a forest down, but the pieces you don't chop are more or less OK. In the ocean, it's more interconnected. You can have the whole system slowly drifting downward."

For those convinced that marine habitats are at risk, the next step is to find ways to protect them. In the Florida Keys, a new sanctuary has been set up to protect reefs. But how to manage a watery park poses a whole new set of questions, since neither currents nor organisms respect park boundaries, says Buddemeier. Although not everyone is convinced of the need for a more organized approach, many scientists are hoping that efforts like that of the NRC will outline the research needed to understand—and perhaps protect—the diversity of marine life.

–Elizabeth Culotta

Additional Reading

"The Crisis in Invertebrate Conservation," a series of symposium papers, *American Zoologist* **33**, 495 (1993).

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NEUROBIOLOGY

All Strung Out at the Synapse

Just as understanding how a telephone system works requires knowing what goes on inside the switchboards, understanding the nervous system requires knowing what happens inside the nerve endings. It's there—at the synapses where adjoining neurons talk to one another—that much of the biochemical machinery of communication is found. Although this machinery is complex, over the last few years, some progress has been made in understanding it. Neurobiologists have found well over a dozen proteins sitting in the chattering tips of the nerve cell. Synapses, however, are loaded with proteins, and finding one there is often the easy part; the tough part is pinpointing its role in communication.

But that task is not impossible. And, just to prove the point, two papers in this issue of *Science* provide new clues about one protein's role in the intimate conversation between nerve cells. On page 977, Konrad Zinsmaier and Seymour Benzer of the California Institute of Technology and their colleagues provide direct evidence that a nerve protein, known as a "cysteine string protein" because it has several cysteine amino acids strung together in its middle, is essential for neural communication in the fruit fly. And on page 981, a team led by Cameron Gundersen of the University of California School of Medicine in Los Angeles reports a finding that helps explain what the protein's role in neuronal communication might be.

"Whenever people find a protein in the nerve terminal they assume it's essential, but the proof of that [typically] comes much more slowly," says fruit fly neurobiologist Tom Schwarz of Stanford University in Palo Alto. But the new results make it clear, he says, "that without the [cysteine string] protein, the terminal is not very happy."

These latest findings also mark the cysteine string protein's transformation from a mere novelty to a protein of potentially great neurobiological importance. The proteins were discovered in fruit flies in 1990 by Zinsmaier, then a graduate student with Erich Buchner at the University of Würzberg in Germany. The long string of cysteines was intriguing, says Zinsmaier, because "there's absolutely no sequence like that in any other synaptic protein." Moreover, because the protein was concentrated in the synapses, it was an excellent candidate for a neural communications protein.

That candidacy, however, remained purely speculative until the Benzer group's current study, in which the researchers bred fruit flies that had been genetically engineered to lack the cysteine string protein. All the mutant flies suffered from paralysis that killed most of them before they hatched; the few survivors died from the same paralysis as adults. The larvae that die appear to develop normally, Zinsmaier says, "but the normal muscle movement is not there, and they cannot hatch."

The adult survivors eventually died, because they, too, lost control of their muscles. "They get sluggish, then they can't fly, then they can't walk, and eventually they can't even retract their proboscis," says Zinsmaier. In spite of these symptoms, the demise of the mutant flies is not due to problems with their muscles. Those problems are in neuronal communication, a suspicion the Benzer team confirmed by measuring the ability of neurons in