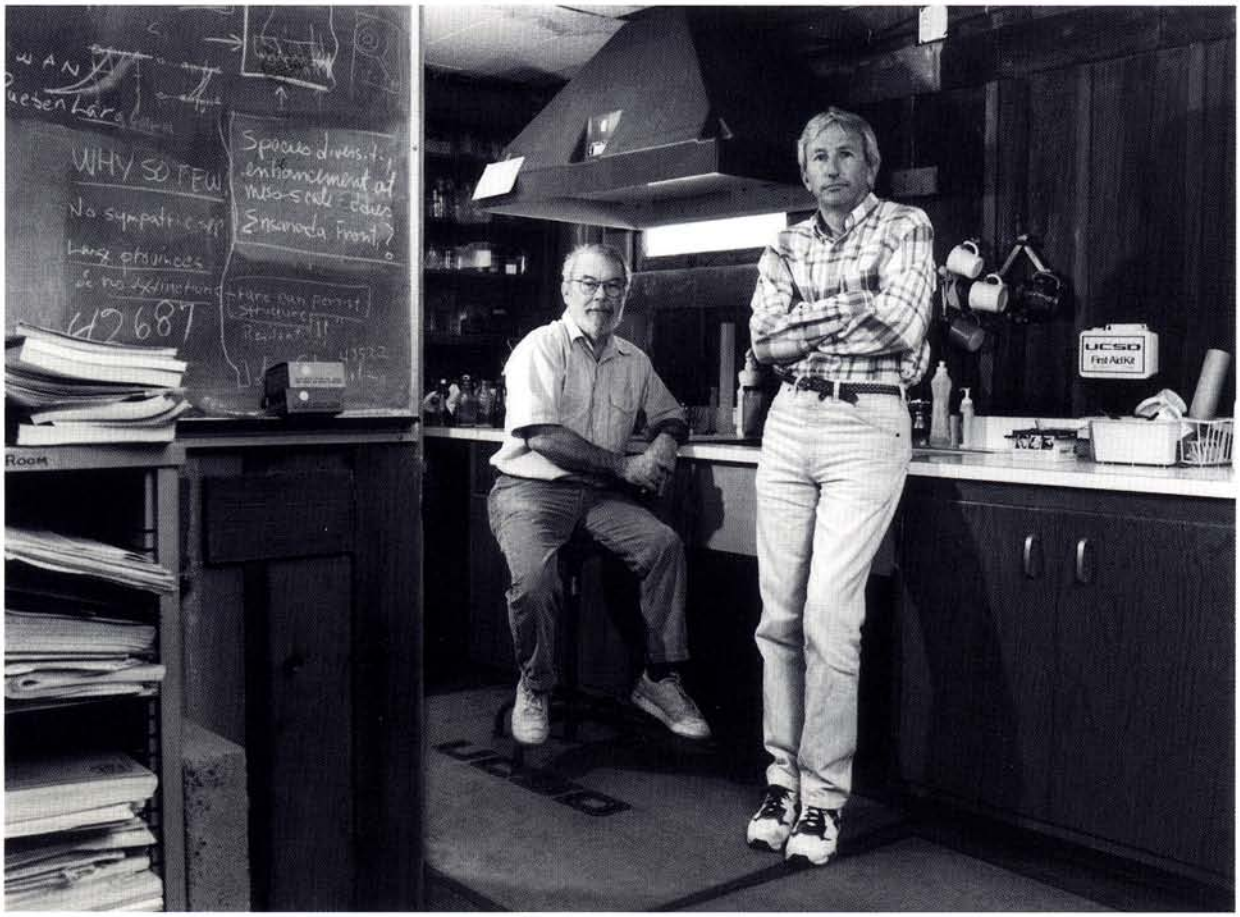
BY JANET HOWARD

VANISHING ACT

Critical Link in Marine Food Chain May Be at Risk

One has only to glance at the two jars of zooplankton sitting on a work table in John McGowan's cluttered cottage office to know something unusual has happened to the tiny, colorful creatures that form a vital link in the marine food chain.

The jar on the left, from 1954, is densely packed with the insect-sized animals that drift with the ocean currents and feed on single-celled plants called phytoplankton. The jar on the right, however, is nearly empty despite the fact that



John McGowan (left) in his laboratory with colleague Dean Roemmich. Built circa 1910, the laboratory is one of the first structures on the Scripps campus.

the sample was taken from the same location off the coast of southern California.

"These two samples were taken 40 years apart," said McGowan, picking up the jars for a visitor to get a closer look. "As you can see the difference between them is large–and in some ways frightening."

McGowan and Dean Roemmich, both scientists in the Scripps Marine Life Research Group, recently reported in the journal *Science* that the population of zooplankton off the coast of southern California has plummeted some 70 percent since 1950. Because zooplankton are a prime source of food for hundreds of species of fish and seabirds, a decline in their numbers could pose a threat to other marine life.

"Zooplankton is the main diet of many fishes, including sardine, anchovy, hake, jack mackerel, and Pacific mackerel," McGowan said. "Those are important fish in the California Current. So, this could have a very strong effect on fish survival."

McGowan and Roemmich discovered the zooplankton decline while analyzing data collected during more than 200 cruises conducted between 1950 and 1993 over a 50,000-square-mile stretch of ocean between San Diego and Pt. Conception, located north of Santa Barbara. The drop in zooplankton appeared to be linked to a warming of the top 600 feet of ocean in the region over the same time period.

The scientists found that the temperature of the surface layer of the ocean had increased an average of between 2°-3°F throughout the area, which extends about 300 miles off the coast of California. Because a warming of the ocean surface increases the density gradient between surface waters and deeper waters, Roemmich said it may restrict zooplankton growth by preventing nutrients such as nitrates and phosphates from being brought to the ocean surface. Such nutrients are needed to support the growth of phytoplankton, on which zooplankton feed.

Just exactly what caused ocean surface temperatures to increase in the first place, however, remains unclear. Even Roemmich and McGowan do not agree on whether

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DECADES OF STUDY TRACK OCEAN CHANGES

In 1949, California faced the collapse of the sardine fishery, which was then the largest single-species fishery in the world. Scientists could not agree on whether the decrease in stock size was caused by overfishing or by natural changes in the environment. To help solve the mystery, the state created the California Cooperative Oceanic Fisheries Investigations (CalCOFI), a consortium of industry, universities, and state and federal agencies. The program continues today as a partnership between Scripps, the California Department of Fish and Game, and the U.S. National Marine Fisheries Service.

Early CalCOFI investigations proved the futility of studying a single species without examining its ocean environment and the cohabitants of that environment. Thus, the focus of the program was soon expanded to include all organisms of the eastern North Pacific as well as all source waters of the California Current.

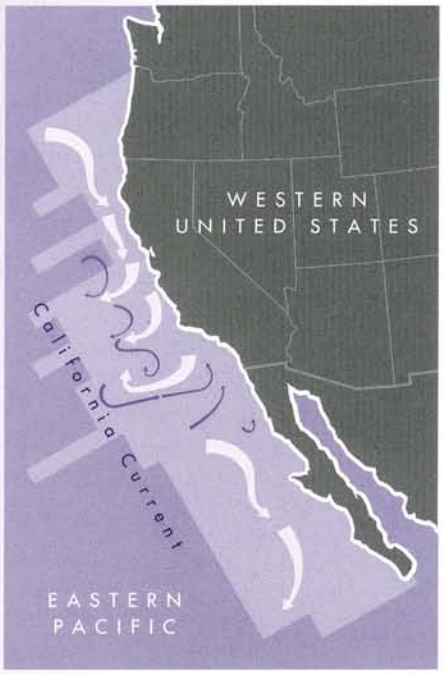
At the center of the investigations are the CalCOFI surveys, a shipboard monitoring program that makes seasonal measurements by hauling nets, temperature probes, and other instruments along precisely plotted pathways off the coast of California. As a result, tens of thousands of measurements of zooplankton abundance, temperature, salinity, oxygen, nutrients, and chlorophyll have been made in the California Current, extending back more than 45 years.

The record allows scientists to define the "normal" patterns of the physical, chemical, and biological components of the California Current. Perhaps more importantly, it provides a baseline against which to identify warming trends, such as that predicted from a buildup of greenhouse gases in the environment.

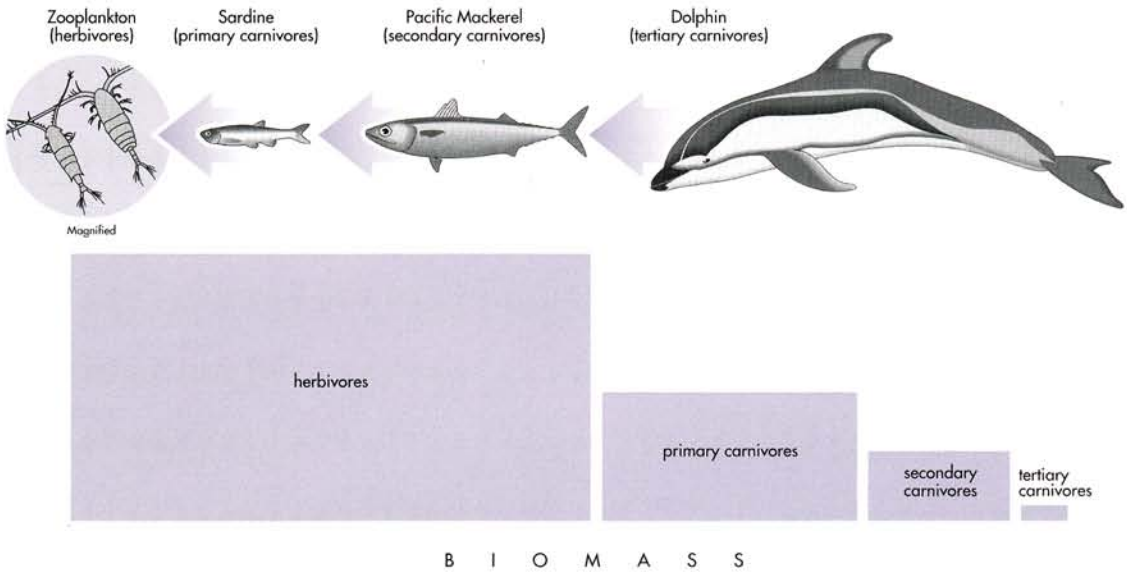
Models and methods for studying fish such as sardines and anchovies developed by the CalCOFI program are now used worldwide. Scientists in the program have developed new methods for estimating the size of adult populations, for determining the growth rates of larvae, and for estimating the numbers of larvae consumed by larger organisms.

Through the CalCOFI investigations, scientists came to understand that many environmental forces are exerted, not so much on adult fish, as upon larvae. Young anchovies, for example, were found to be weak and vulnerable creatures that perish unless they find dense concentrations of phytoplankton for food. When the ocean is calm, phytoplankton often concentrate in narrow layers below the sea surface, providing a source of food on which larvae can feed and grow rapidly. Storms, however, can disrupt the layers of plant life and prevent larvae from finding the high concentration of food needed for their survival. Thus, the strength and timing of storms can have a critical impact on the population of adult fish for several years.

In the end, an answer was found to the collapse of the sardine industry. CalCOFI investigators determined that the collapse was caused by a combination of natural changes in the environment and by overfishing.



Broad white arrows indicate the southward flow of the California Current, while thin dark arrows depict countercurrents and eddies. The map's shaded coastal waters–roughly equivalent to the land area of west coast states–indicates the CalCOFI study range.



Relative proportions of biomass are depicted by the shaded blocks, with herbivores (zooplankton), the block at left, comprising the largest mass, and top predators like the dolphin comprising the smallest populations. It is clear from this relationship that an immense population of zooplankton is vital as the base of this marine food chain.

the change is linked to an increase in global temperature.

"I don't think the temperature change is being caused by global warming," said Roemmich matter-of-factly. "The only reason this study could be of interest to the global warming scenario is that it tells you what the biological effect would be if you saw a 1° or 1 1/2° temperature change globally–and that is what the global warming people are predicting for the next 20 years or so."

McGowan, however, is not so certain. He fears the decline in zooplankton could be a sign that a buildup of heat-trapping greenhouse gases, such as carbon dioxide, spewed into the air each year from the burning of fossil fuels may be beginning to take a toll on the environment.

"This is not only an unusual occurrence, but also an unnatural one," he said. "There is a chance it is man-caused. In the next 5 to 10 years, we will probably know the answer."

Yet both scientists agree that they do not have any evidence with which to predict whether the population of zooplankton off the coast will continue to plummet or simply reverse itself as part of a natural cycle.

"If what we are seeing here is a manifestation due to man, then there is every reason to believe that the decline will continue and intensify," said Roemmich. "If it's simply a natural and changing cycle, then chances are it will go back to the opposite state at some point in time."

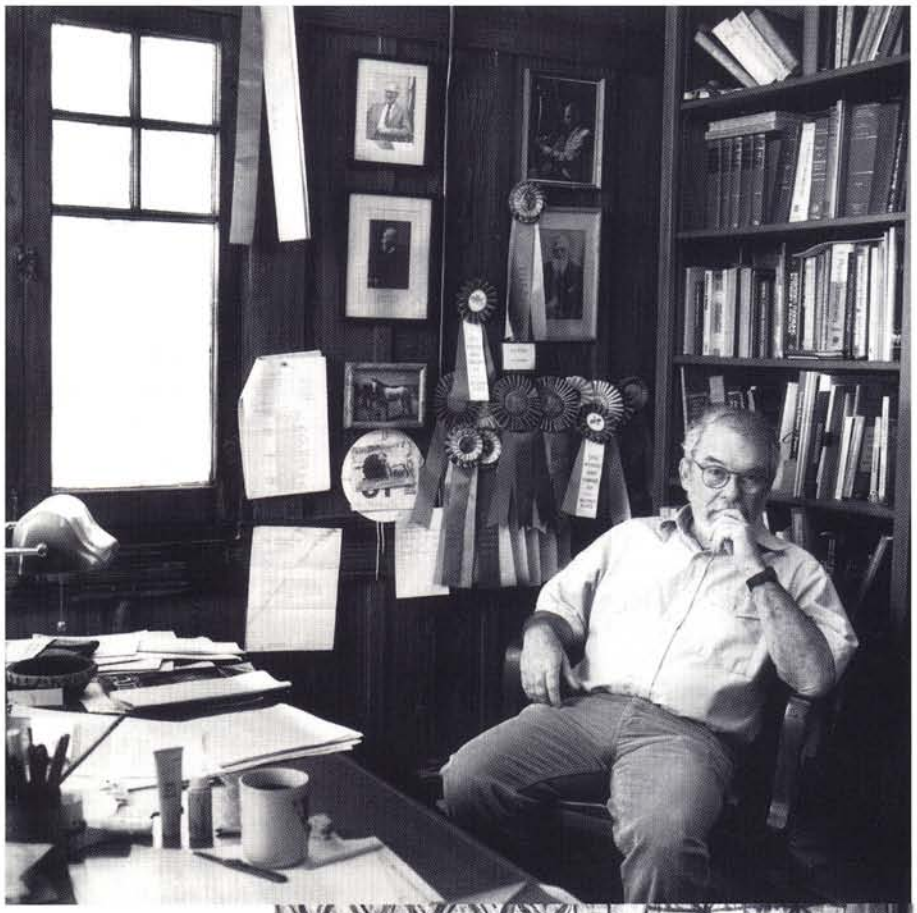
Roemmich and McGowan based their research on data collected as part of the California Cooperative Oceanic Fisheries Investigations (CalCOFI), a program conducted by Scripps, the National Marine Fisheries Service, and the California Department of Fish and Game. During a series of research cruises zooplankton samples and temperature readings were collected at the same sites by dragging nets and temperature probes through the water.

The time series shows many fluctuations in zooplankton populations, including declines associated with strong El Niño events in 1958-1959 and 1983-1984, which caused California waters to warm. But the observed overall 70 percent decline in zooplankton occurred over a much longer time-scale.

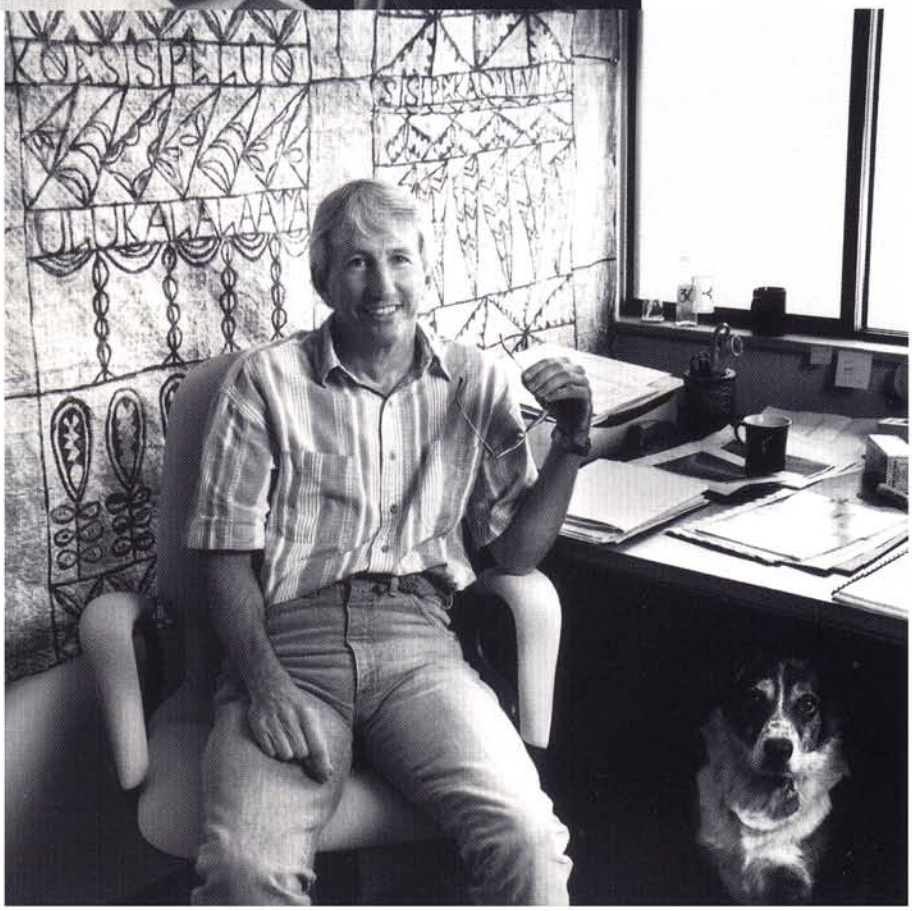
Because such long-term studies on ocean temperatures and biological abundance are rare, it is difficult for the scientists to determine if similar changes are occurring in other parts of the world.

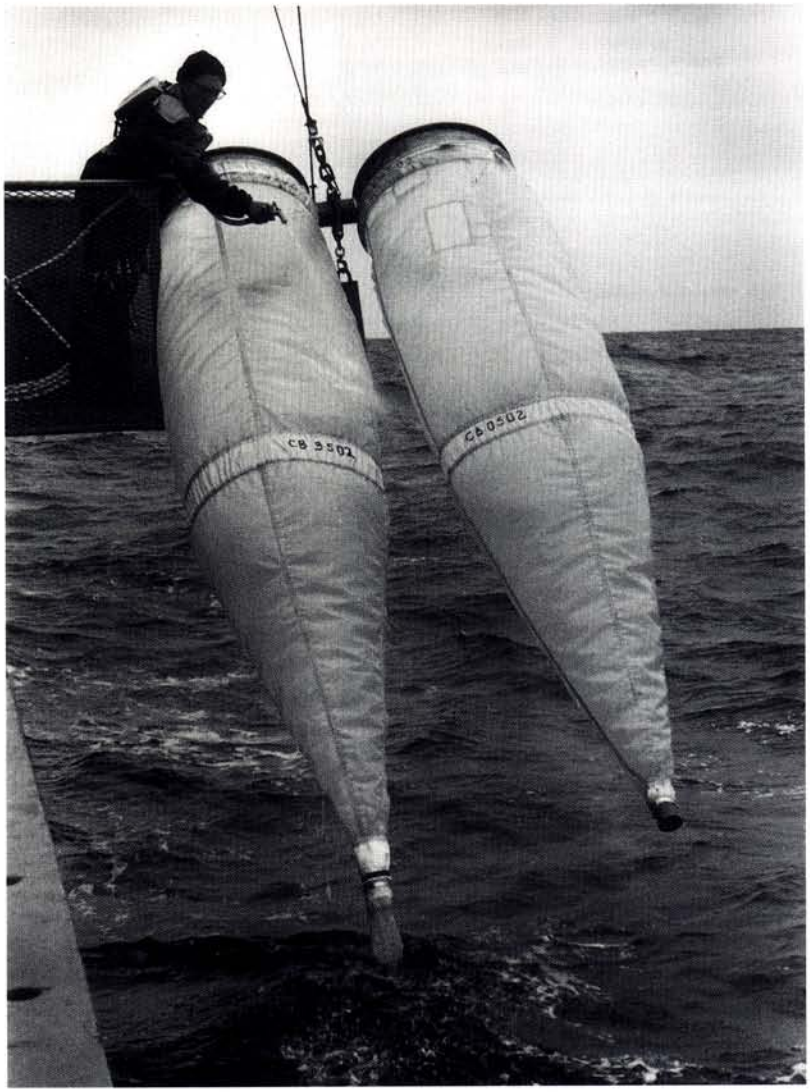
"There are temperature observations over a wider area of the eastern Pacific that indicate a larger area than the CalCOFI area has warmed," Roemmich said. "But it does not appear to be true of the whole North Pacific Ocean."

If the earth were to warm by 2°–4°F in the next few decades, as some global climate models predict,



McGowan in his office, horse-jumping ribbons in background. Roemmich (below) and sidekick Max.





Dimitry Abramenkoff and Jerry Graham (below) retrieve catches of plankton and fish larvae for CalCOFI population assessments during the early 1980s.

the biological impacts on the ocean could be 'devastating', according to the two Scripps scientists.

"For the first time, we understand what a relatively small physical change in the ocean can do to the biology," McGowan said. "If the ocean off California continues to be impacted, we can anticipate a collapse of fisheries. If it's on a larger scale than just the area studied by CalCOFI, then a large amount of the world's protein supply will be damaged and it will have serious economic ramifications."

Commercial fish harvests in the area studied by CalCOFI have declined about 37 percent since the mid-1970s, McGowan said. Some populations of seabirds that feed on zooplankton along the Pacific coast also appear to have been hurt by a decline in their food supply. One study by McGowan and Dick Veit, an ornithologist at the University of Washington, found that the population of a seabird called the sooty shearwater has declined by 90 percent since 1986. The plankton-eating bird was once the most abundant seabird found in the California Current. Larger marine life that feed on fish, such as whales, do not seem to have been affected to date.

A veteran of more than 20 CalCOFI cruises, McGowan first began taking CalCOFI samples as a graduate student in 1952. He had been introduced to zooplankton a couple of years earlier while completing undergraduate work at the Oregon Institute of Marine Biology in Charleston, Oregon.

McGowan soon found himself intrigued with the tiny creatures he captured in his nets.

"If you look at the living organisms, they are really beautiful creatures," he said. "They come in many different colors and they are very delicate. They really are quite spectacular."

A tenacious man (he took up horse jumping at age 58) with a graying beard and mischievous hazel eyes, McGowan couldn't seem more at home in his four-room wooden cottage at Scripps. Built in 1910, the cottage exudes the cluttered warmth of an old-time field station. Glass beakers stand in racks drying by the sink, yellowed papers hang from the drawers of large wooden chests, and graphic charts of data are strung haphazardly overhead. A picture of Charles Darwin graces one of the walls, standing guard over a bookshelf filled with such items as an old "Moon River"

record and books on such topics as paleobiology.

Dressed in a blue shirt with rolled-up sleeves, gray cotton slacks, and tennis shoes, McGowan props his feet up on an old wooden table and half-heartedly indicates he intends to clean up the place. But it is quite clear he does not plan to get to it anytime soon.

"What I like about it is you can pound nails into the walls," McGowan said with a chuckle. "You can't do that in Sverdrup or Ritter (halls)–their walls are made out of cement. But this is one of the old original cottages. I love it–it's very comfortable. It's nice and cozy in the wintertime and that big tree out there keeps it cool in the summer."

Such comforts were often far from available during many of McGowan's early excursions at sea. "There was one cruise I will never forget–it was absolutely ghastly," he said. "The ship was bad, the food was bad, and the weather was awful."

Apparently a Scripps researcher who was not on the cruise requested that the scientists take temperature profiles every half hour. That required using a now obsolete piece of equipment called a mechanical bathythermograph.

"Let me show you," said McGowan, disappearing to retrieve a huge torpedo-shaped object weighing about 75 pounds. "What you had to do is stand waist-deep in water in the stern of the ship, which was going up and down, and reach out and hook this thing onto a line and lower it down into the water. The ship was going 10 knots in the meantime and you just kept flying up in the air. And you did this every half hour."

To make matters worse, the instrument relied on small glass slides that had to be smoked in a ship laboratory with a camphor lamp. McGowan wrinkles his nose in distaste at the memory.

"It was just an awful ship. There were no lights on the fantail and nobody on the bridge even knew you were back there. It was dangerous as hell and cold, and we were sopping wet and that wretched smell of the camphor lamp. And then once you got the slide, you had to dip it in shellac. That stunk too.

"It was just bloody awful, and I never found out who made that request and I never found out what they did with the data–I'm still trying to figure it out."

While the conditions on scientific cruises today are significantly more comfortable than in the 1950s, McGowan said he was shocked on a recent cruise by the noticeable drop in the abundance of fish and bird life.

"We used to see flocks of seabirds everywhere we went, and you could stick a net in the water anywhere and find zooplankton," McGowan said. "One net tow would easily fill two quart jars. Now we're lucky if we can fill a pint."

McGowan handles a CTD rosette during a 1980 cruise. The device is used to measure salinity, temperature, and depth.