PIONEERING SCIENCE on the Frozen Frontier

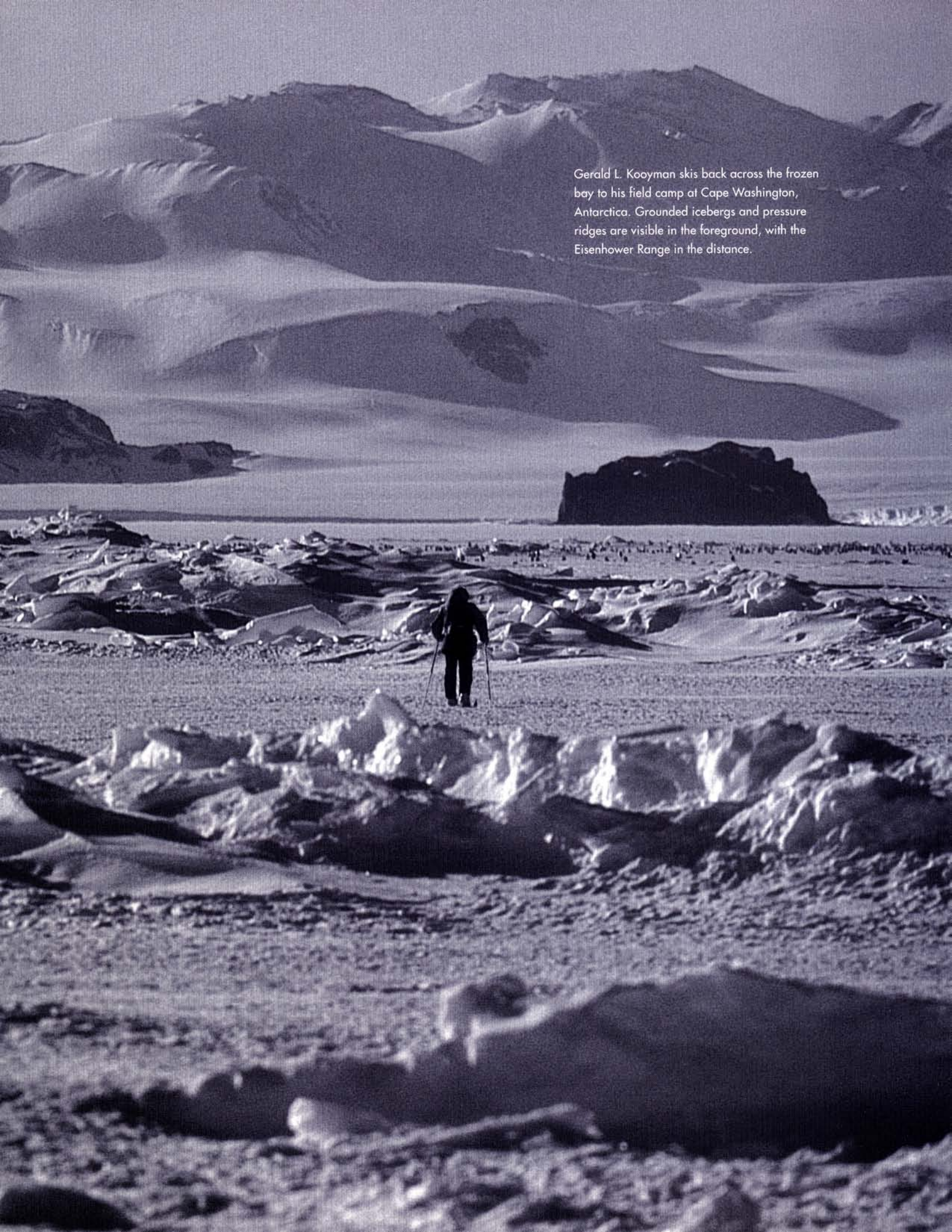
"Antarctica contains the earth's last truly pristine habitats. Only there can a field biologist observe animals in an environment unimpacted by man," asserts Gerald L. Kooyman.

A realm of superlatives, Antarctica is the southernmost, coldest, highest, driest,

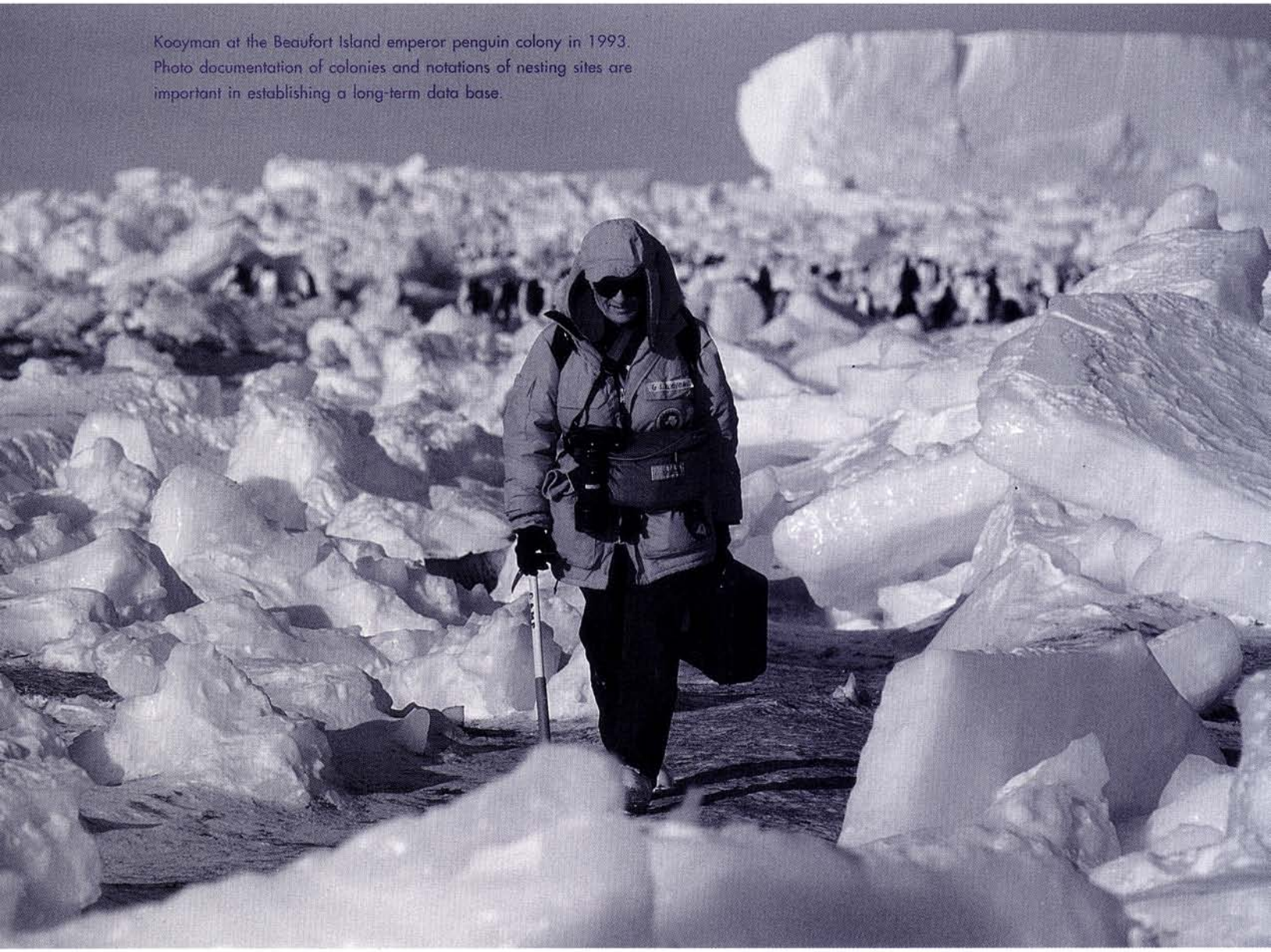
BY JOE HLEBICA

and windiest continent, so remote and extreme that it seems otherworldly.

Kooyman, a pioneer in antarctic studies, has spent 30 years investigating the diving physiology of marine mammals and birds at the bottom of the world. He was among the first to conduct field studies on Weddell seals and emperor penguins, two species found only in Antarctica.



Gerald L. Kooyman skis back across the frozen bay to his field camp at Cape Washington, Antarctica. Grounded icebergs and pressure ridges are visible in the foreground, with the Eisenhower Range in the distance.



Kooyman at the Beaufort Island emperor penguin colony in 1993. Photo documentation of colonies and notations of nesting sites are important in establishing a long-term data base.

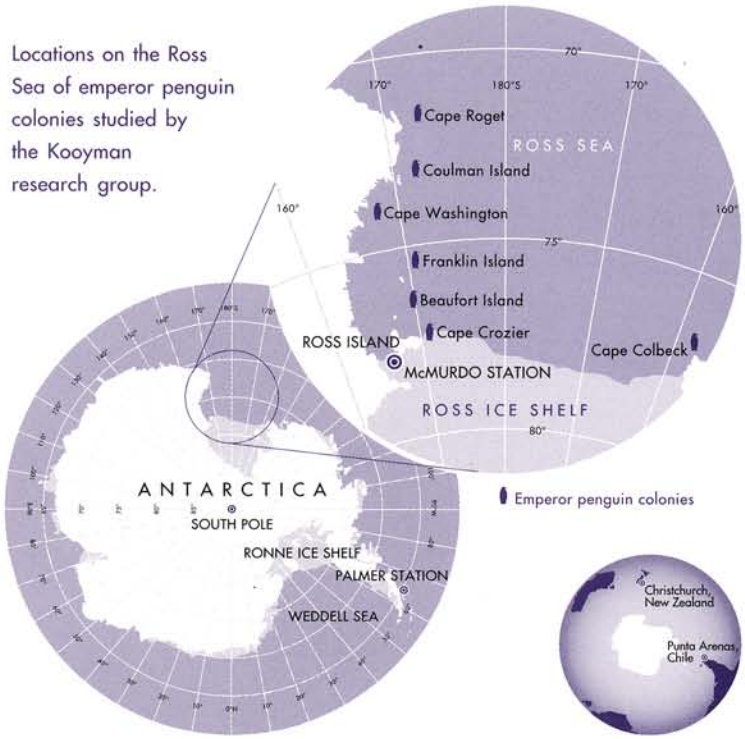
But, according to Kooyman, things have changed during the last 30 years. Now, for example, each year more tourists visit Antarctica than scientists. More research stations exist and more remote areas are being accessed by a new generation of experienced aviators flying more suitable aircraft. Everything was new during his first trips to Antarctica in the 1960s. Kooyman recalls, "We couldn't do anything that wasn't 'a first.' Now, on the other hand, it's difficult not to feel pressed out a little. Everyone is getting into this field. I keep having to think of new approaches."

He describes his early research on the Weddell seal *Leptonychotes weddelli*, "I got interested in them during my first trip to Antarctica in 1961 as a technical assistant working for Donald Wohlschlag of Stanford University. I was taking a year off from graduate school at Berkeley, and was looking for a doctoral thesis. I saw that no one was studying the seals, so I wrote a thesis proposal and received a grant from the National Science Foundation."

In his book *Weddell Seal: Consummate Diver*, published in 1981, Kooyman recounts this first trip to Antarctica.

"We arrived at McMurdo Station–which reminded me of a frontier-town movie set–in a military cargo plane. When they opened the doors and the frigid outside air cooled the warm, moist air inside, it began to snow in the plane's huge cargo bay."

According to Kooyman, McMurdo Sound was one of the most isolated wildernesses on earth, yet "all the inconveniences were overshadowed by the excitement of



Locations on the Ross Sea of emperor penguin colonies studied by the Kooyman research group.

Kooyman in 1964 working with a first-generation time-depth recorder (TDR) for use on seals. Modern TDRs have been reduced significantly in size and weight, making diving studies possible on smaller diving animals such as penguins.

being on both a geographical and scientific frontier."

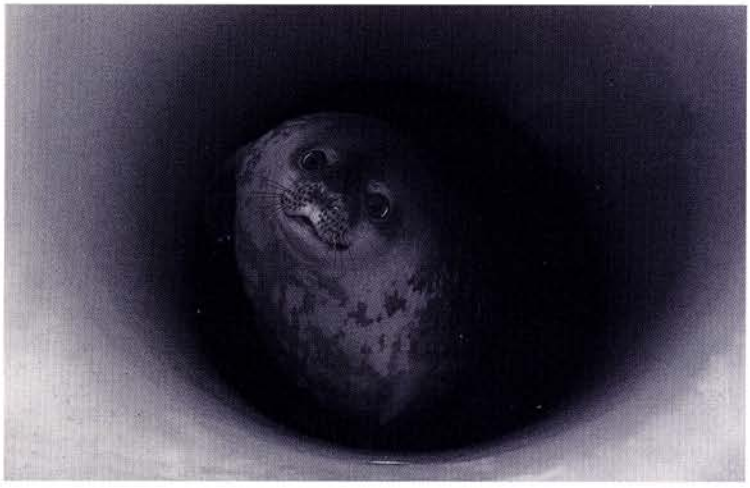
About the annual sea-ice sheet on which research sites have been established seasonally, Kooyman asserts, "The ice provides a stable foundation on which to set up a complex laboratory over deep water of at least 1,900 feet...I do not believe there is anywhere in the world where oceanic stations can be established with such safety, for such extended periods, and at such low costs. McMurdo Sound is one place where an unusual set of circumstances has reduced the complexities of such studies, and provided us with a window into the underwater world."

From those early days as a graduate student, and through the ensuing 20 years as a researcher at Scripps, Kooyman concentrated on the diving physiology of Weddell seals. According to him, two facts made these animals ideal subjects for field studies: their habit of emerging from isolated holes in thick, stable ice, and their indifference to humans. "What was equally amazing," he notes, "was that no scientists had taken advantage of these attributes."

Providing seals with holes in the ice from which they could emerge was the best way of ensuring contact with the animals.

"At my first site, the ice was 13 feet thick. It took two weeks of backbreaking labor to make the hole. My tools were a chain saw, ice tongs, and, for the last few feet, explosives. Now they use a powered augur, which cuts the holes in 20 minutes."

In those early years, Kooyman began making significant contributions to science in Antarctica. As an example, Kooyman cites an instrument known as a capillary depth



Weddell seal ascending through the dive hole in the floor of a research hut.

Kooyman photographs the Beaufort Island emperor penguin colony while an inquisitive individual looks on.

tube, used to measure depths reached by seals, penguins, and other diving animals.

"When I first conceived the Weddell seal project, the major obstacle was obtaining small, cheap, depth recorders. Then I read a report by Per F. Scholander, an eminent respiratory physiologist and director of the Scripps laboratory that I later joined. Scholander reported using a long, glass capillary tube, closed at one end, the interior of which was dusted with a water-soluble dye, as a depth recorder. The maximum depth was recorded by leaving a ring at the point of maximum compression inside the tube."

Kooyman also studied the diving physiology of penguins during some of his earliest trips to Antarctica. In 1969 Kooyman redesigned the capillary depth tubes he was using on Weddell seals, and put them on penguins. To his knowledge, it was the first time a depth recorder had been put on a bird. The record depth he then measured remained the deepest record for any diving bird until a couple of years ago, when the Kooyman group recorded a deeper dive that exceeded 1,640 feet.

Weddell seal peeks from the safety of its hole. These seals are shy animals with a pleasant demeanor.

Kooyman's original design for a time-depth recorder (TDR) was constructed with the help of a Tucson, Arizona, jeweler and Kooyman's wife Melba who searched through Tucson scrap-metal yards for brass tubing used in the prototype.

Now considered "father of the TDR," Kooyman points out that none of these devices was commercially available during his early research. In recent years, research and development on TDRs have resulted in a sustainable business for designers and their companies. TDRs can now be mail-ordered and are routinely used by scientists conducting similar studies. Though his designs were a real breakthrough at the time, Kooyman's early-generation TDRs were somewhat awkward mechanical devices compared to his latest design–plastic-coated electronic instruments not much larger than a matchbox. They are

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Emperor Penguins:
On Thin Ice in a Warming World

For more than a generation, Gerald L. Kooyman's work has dealt with respiratory function in aquatic vertebrates, particularly the structural nature of the lung and how it relates to gas exchange and ventilation. He has furthered the understanding of behavioral, physiological, and anatomical adaptations in vertebrates that swim at high speeds and dive to great depths. In recent years, he has focused on Antarctica's emperor penguins, which he considers a highly reliable indicator of how animal populations may be affected by global warming.

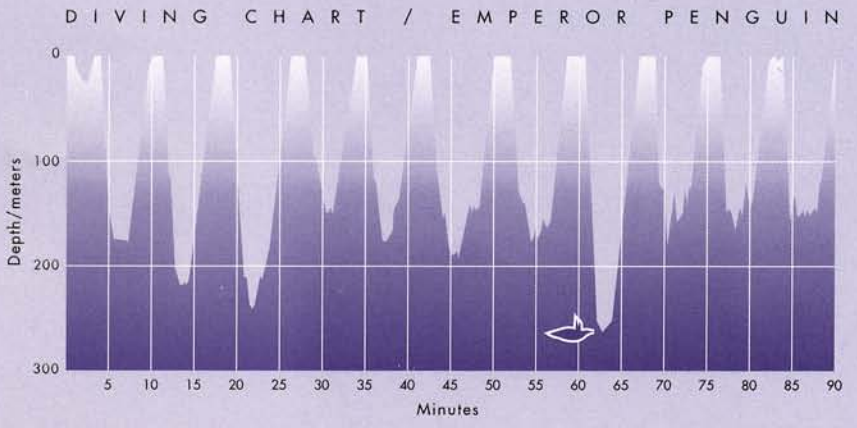
As debate continues throughout the scientific community over the causes, effects, and significance of global warming, Kooyman asserts, "In a way, it doesn't necessarily matter whether there is global warming or not. What really matters is whether animal populations are changing. If so, the question is why? Is it because there is a decline in prey species, and is that caused by environmental changes, or by human impact?

"As far as environmental changes that may be occurring, I believe emperor penguins can be a very good indicator species because no matter what species you study in most places, you can't get away from human impact, which pollutes the data so badly. Among emperor penguins in the Ross Sea, though, there's no environmental impact right now, and I think it's one of the only places about which that can be argued."

Kooyman's research has brought much to the surface about the natural history of emperor penguins. Until recently, scientists thought that these flightless, aquatic birds remained relatively close to their home colonies throughout their lives. However, Kooyman has discovered that they range all over the Ross Sea–an area the size of France–in search of food, typically fish. Researchers now wonder how they navigate through the trackless pack ice.

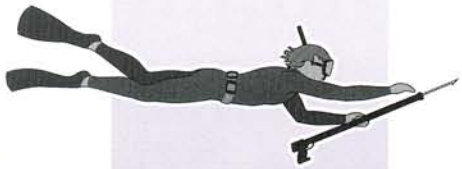
In hopes of understanding this incredible feat, Kooyman's group is using special instruments to track the wanderings of emperor penguins via satellite, while other instruments and underwater videos are used to calculate swimming velocities. In addition, their physiological responses to diving stresses are being studied. Emperor penguins have made dives of at least 20 minutes, according to Kooyman's data. The object of his physiological studies is to understand how these birds are managing their oxygen stores, "Something," Kooyman points out "we don't understand very well for any diving animal."

Gerald L. Kooyman taking a census of the Bartlett Inlet emperor penguin colony (above), and conducting a chick survey from the top of an iceberg at Cape Washington, Antarctica.



Diving profile for a single emperor penguin as recorded by a time-depth recorder (TDR); inverted peaks indicate depths reached during a 90-minute series of dives.

Twin-Otter aircraft have opened previously inaccessible penguin colonies to study thanks to the aircraft's range and short take-off and landing capabilities.



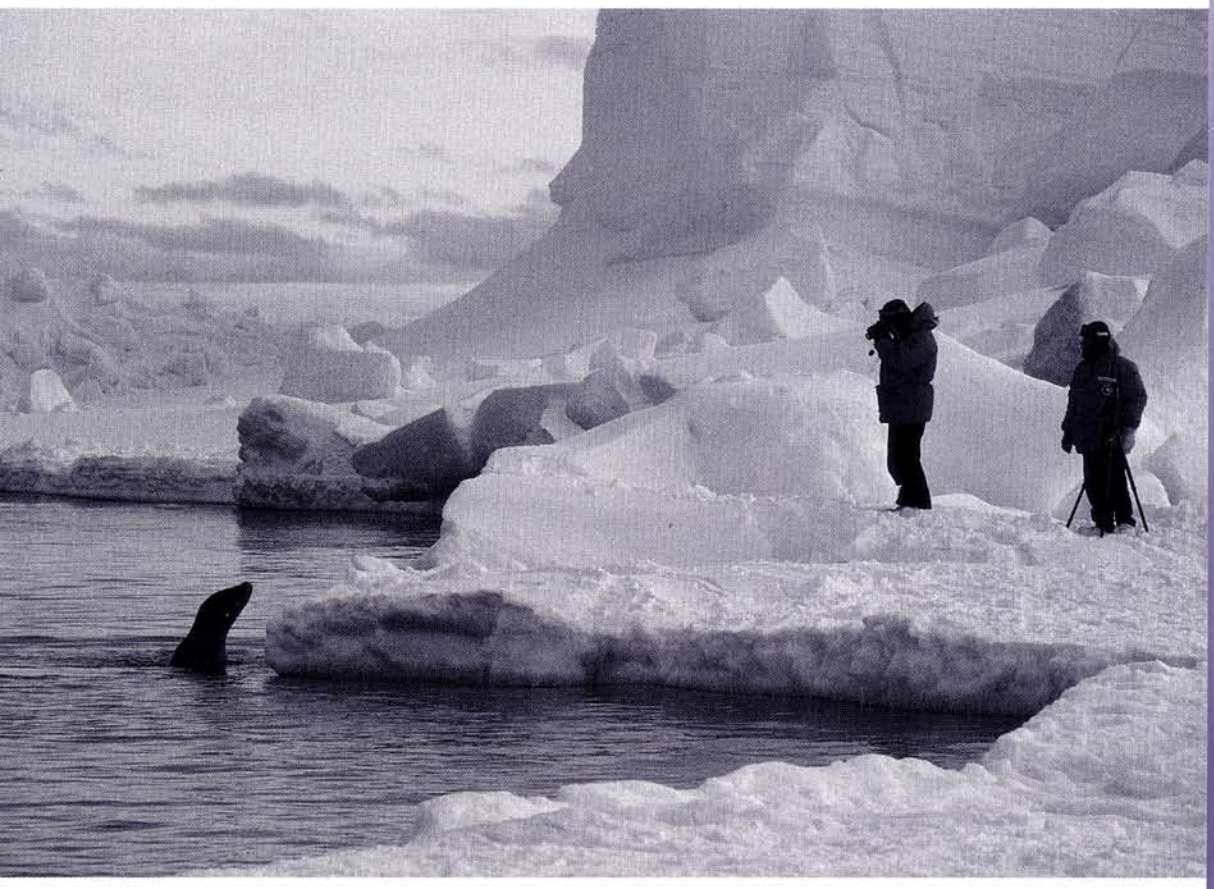
Experienced free diver
Approximately 50 feet
Duration 1 minute

much easier to attach to diving animals, thanks to a special insoluble glue, which took years to develop. Kooyman is pleased with the result. "Part of the beauty of this glue is it doesn't harm the animal. If the instrument isn't recovered, it's sloughed off when the animal molts."

To make invaluable first-hand observations of diving seals and penguins, Kooyman has logged many hours submerged beneath the ice. While the large, predatory leopard seal *Hydrurga leptonyx* presents a major threat to divers in Antarctica, the aptly named 'leopard seal exclusion cage'–also introduced by the Kooyman group–makes diving relatively safe.

Other dangers remain, however. The water can be so cold that, in Kooyman's words, "It feels like a nail being driven through your forehead."

In addition, equipment failure can result from exposure to below-freezing temperatures. Kooyman's



Kooyman and colleague Paul Ponganis are eyed by an aggressive leopard seal. Precautions must be taken near the ice edge, as leopard seals often threaten researchers and will sometimes chase them several yards over the ice.

Emperor penguin
Approximately 650 feet
Duration 5 minutes

Weddell seal
Approximately 1,300 feet
Duration 20 minutes

Diver and animals not to scale

son Carsten (whose Norwegian namesake, Carsten Egeberg Borchgrevink, was one of the first explorers to set foot in Antarctica 100 years ago) is an accomplished antarctic diver who has joined his father on a number of expeditions. He once experienced a diving emergency situation when his scuba regulator froze up and began to free-flow, draining his air supply.

"I was photographing near the bottom in about 65 feet of water," recounts Carsten, "when I heard a hissing noise and bubbles suddenly came boiling out of my regulator. It was very difficult to breathe so I immediately began an emergency ascent. I worried about the rate I was ascending, but I knew I was running out of air. Fortunately, the visibility was five or six hundred feet, so I could see my exit hole in the ice at the surface the entire time. In fact, the water was so clear my brother Tory was standing at the hole looking at animals on the bottom through a pair of binoculars! My tank was drained by the time I reached the surface just a few moments later. Not until I was out of the hole and safe did I stop and realize how dangerous the situation was."

Emperor penguin swimming under water with a time-depth recorder (TDR) attached above tail. Improvements in computer technology have made recorders small enough to attach to penguins without hindering their movements.

Kooyman obtains video footage of diving emperor penguins in order to determine the birds' wing stroke frequencies while they swim under water.

At the urging of Kooyman and others, Twin-Otter aircraft were introduced to the U.S. Antarctic Program so that he and his colleagues could be flown to remote sites in the Ross Sea and the interior of Antarctica. Though landings for larger aircraft on sea ice are risky, pilots claim that they can land the smaller, lighter Twin-Otter on ice as little as 18 inches thick. Now, laments Kooyman, "Demand for Twin-Otters is sometimes so great that we have a hard time getting access to them."

One place where Kooyman and his team enjoy little competition for space is on the Ross Sea, where they have concentrated their studies on the emperor penguin, *Aptenodytes forsteri*, found in greater numbers there than anywhere else. This was the site of their most recent expedition, where they spent the austral summer of 1994 gathering data and taking a census of the largest known emperor penguin colony, estimated at more than 50,000 birds.

Despite ever-present dangers, Kooyman considers himself fortunate to be an antarctic researcher. His experience has taught the scientific community much about the conduct of science and the day-to-day business of living in one of the world's most adverse environments.