Life On and Below

Penguins that breed during the coldest mo
Seals that can dive to 600 meters . . . Fish
The strange and icy world of Antarctic biol

Fourth of a series.

by Kendrick Frazier

A snow-covered Weddell seal at the Hutton Cliff rookery.

When Edward Wilson, the naturalist-artist-explorer with the British National Antarctic Expedition of 1901-1904, visited a newly discovered rookery of emperor penguins at Cape Crozier, Antarctica, he was amazed at what he saw.

Wilson (who later perished on the ill-fated Scott South Pole expedition in 1912) found the birds holding downy chicks firmly between their feet. There were no nests. From the chicks' state of development that September, he concluded that they had been incubated during July and August, the coldest months of the Antarctic winter. In a now-famous report of his observations, he wrote that this behavior of the emperor penguins is "eccentric to a degree rarely met with, even in ornithology."

Wilson was right. The emperor penguin is like no other bird on earth. Its entire breeding cycle takes place under the most adverse conditions on the planet, during the long Antarctic night, when blizzards rage over the surface and temperatures drop to 60 or 70 degrees below zero F. In addition, emperor penguins can, and often do, spend their entire life without ever setting foot on solid land.

The breeding cycle seems almost astonishing. The male and female penguin leave the sea and hike over the sea ice to their rookery. When the sea ice is at its broadest, this distance may amount to 80 to 130 kilometers. The trip may take a month. Since emperor penguins can feed only when in the water, they must fast all the time they are away from the sea.

After the penguins reach the rookery and mate, the female lays an egg and gives it to the male to incubate. She hikes back to the sea to stock up on food, leaving the male behind to keep the egg warm for two months during the height of the dark, Antarctic winter. He holds the egg between the top of his feet against a bare patch of skin on the lower abdomen which has a flap of skin that falls over and protects it.

He stands there on the ice, stoically enduring the bitter cold and wind, living off only his stored-up body fat, and incubates the egg for 62 to 65 days. About the time the chick hatches, the mother returns, and the father heads back to the sea for a well-deserved meal.

The timing of the cycle means that the chicks hatch during the most extreme conditions any bird is known to experience. But it also means that after five months of post-birth development, they are ready to go out on their own in late December—just as the sea ice is breaking up under the warming summer sun and the ocean is most biologically productive.

The extraordinary achievement of the penguins in walking great distances and fasting as long as four months during the coldest months of winter has long fascinated zoologists. And it raises important questions about how they expend and conserve energy and control the release of heat from their bodies.

Using emperor penguins from nearby rookeries, a group of Duke University zoologists working in the biological laboratory at McMurdo Station, Antarctica, are trying to answer some of the questions.

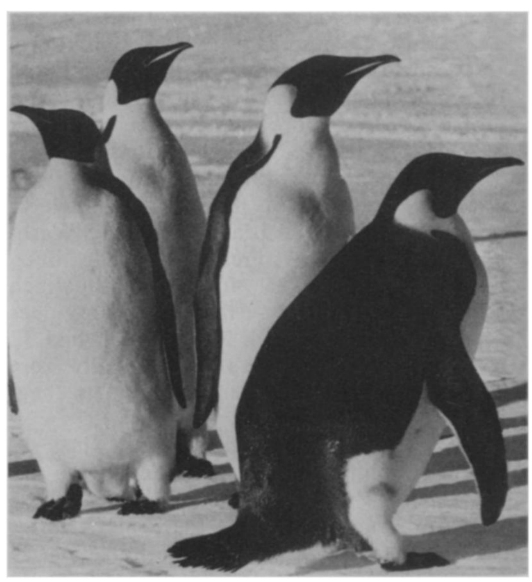
In one part of the research, penguins are placed in metabolic chambers where temperatures can be varied from minus 50 degrees C. to plus 10 degrees. Half a dozen measurements, including oxygen consumption and water loss, are taken to determine the amount of energy the penguins use for merely staying alive and warm at various temperatures.

The second part of the research program is measuring how much energy the penguins expend while walking. "In effect, we're working out the gas mileage of this bird," says biologist Mike Fedak, leader of the four-member penguin research group at McMurdo. Fedak and Ph.D.-candidate Berry Pinshow, and his wife, Hanna Pinshow, a biological technician, are carrying out the research with additional assistance from marine biologist Katherine M. Muzik, also of Duke. The entire project is under the supervision of the noted Duke animal physiologist Knut Schmidt-Nielsen.

In a small building adjacent to the biological laboratory, a penguin is placed on a treadmill, enclosed on all four sides. He has been trained to walk on the treadmill, wearing a mask through which air can be drawn at known rates so that all expired air is captured.

As the treadmill starts to move and the penguin begins to walk to keep pace with it, Hanna Pinshow, back in the laboratory, monitors a chart being drawn by gas-analyzing instruments that measure the oxygen intake and carbon dioxide outflow and then calculate the energy expended.

Full results of the two types of studies will await analysis of the entire season's data. After a few early meas-



Emperor penguins enjoying summer.

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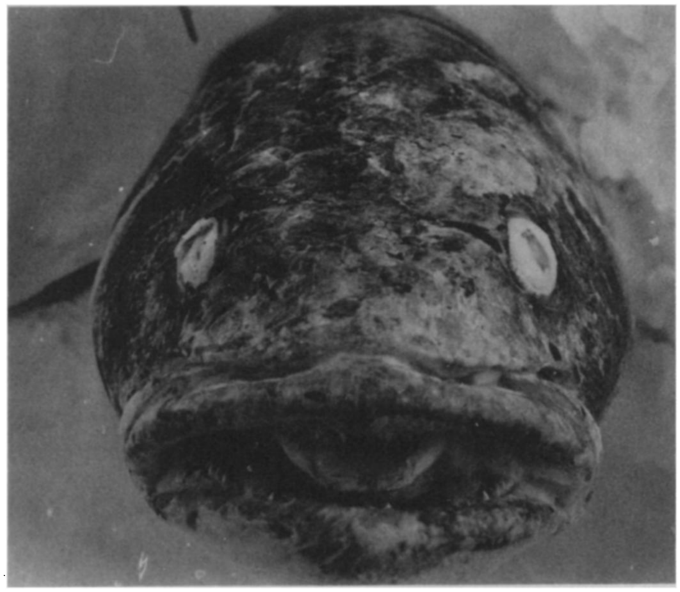
Photos by Ralph Payne and Ken Thornsley, U.S. Navy



Freeze-resistant Dissostichus mawsoni from 1,600 feet below McMurdo Sound.

urements had been taken, Fedak and Pinshow believed they had established that the penguins' metabolic rate was lowest at temperatures of minus 5 to 0 degrees C. and highest at warmer and cooler temperatures. But three days later they had run more of the data through the computer at McMurdo and found otherwise. "Everything we told you [about that] is wrong," said Fedak. "We found that their metabolic rate remains constant from minus 25 to plus 25 degrees C."

They seemed to feel their studies of penguin physiology would produce many more such surprises in the months to come. □

THE WEDDELL SEAL, like the emperor penguin, is the southernmost vanguard of all animals of its kind. Among seals, no species lives at a more polar latitude nor exists under more severe environmental conditions.

With the Weddell seal in the wintry darkness beneath the Antarctic ice and the emperor penguin in the wintry darkness above the Antarctic ice, nature has demonstrated a remarkable symmetry: Both animals are highly adapted, highly specialized to live at the very fringes of the mammalian and avian biospheres.

Observation has shown that the Weddell seal can dive to depths of 600 meters and stay submerged as long as 60 minutes. Its capability of storing oxygen in its blood is approximately five times higher than that of humans.

As with the penguins, evolution has not taught the Antarctic seals to have any fear of man (or of anything else above the surface of the sea). This has made them readily accessible to scientists wishing to study their behavior and physiology (at least during those periods when they are above the ice). The Weddell seals, in particular, are docile, agreeable animals, indifferent to the presence of humans and submissive to the needs of scientists to tag and instrument them with radio transponders and other such devices.

Not that they are without curiosity. During our visit to the Hutton Cliff Seals Rookery, 12 miles north of McMurdo Station, Antarctica, in December, one seal pup cautiously scooted up toward me and, while I was taking its picture, gently nibbled at my boot, as though to test it for food value.

And they do have the ability to impress their will on those they consider intruders. During the same visit, we witnessed an incident of territorial defense between two male Weddell seals. From an opening in the ice, a seal suddenly leaped from beneath the water out onto the surface, chased by a second one who, seeing he was victorious, returned beneath the ice. The first seal had had a good-sized chunk bitten out of its underbelly.

Recording the territorial behavior of Weddell seals near McMurdo is one of the goals of a continuing research project headed by Donald B. Siniff of the University of Minnesota. Every year since 1968 Siniff and his colleagues have journeyed to Antarctica to monitor the seals with a variety of electronic devices including underwater television cameras, hydrophones and radio beacons.

As a result of such techniques, "We have pretty well described the size of the males' underwater territories," says Siniff. "Each defends a territory about 20 to 30 yards across." These little territorial precincts, the scientists have discovered, are spread right down the length of the tide crack, the linear opening in the sea ice caused by tidal stress in McMurdo Sound.

"They're fairly sacred," adds Siniff. "One male will maintain his territory for about a month."

One of the tools used for such studies is a sonic tag strapped around the ankle portion of the seal's rear flipper. ("We've found that works like a charm," says Siniff). The device transmits a signal just above the seals' hearing range. Three hydrophones placed in a triangular array about 400 yards apart and 30 feet below the ice record the signals and allow easy tracking of the seals' positions.

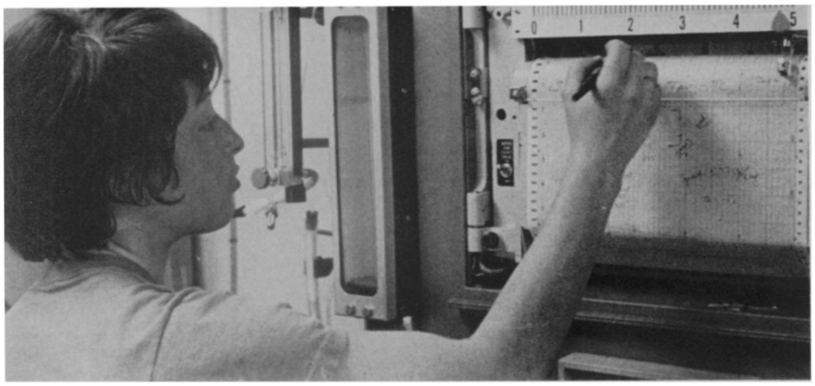
Hydrophones can also be used to record the sounds of the seals. They make a series of relatively high-pitched sliding tones, not quite as melodic or variable in range as the songs of the humpback whale, but very pleasant and interesting nonetheless.

Female Weddell seals spend considerable time on the surface of the ice—they can feed their pups only on the surface. But the male seals often spend anywhere from two to five days in the water without coming up onto the ice to rest. They generally come to the top of the water to breathe every 10 to 30 minutes.

One main subject of the last two seasons' research has been nonreproductive female seals. Observations in the previous years intrigued the biologists' interest. "We started seeing some interesting things in the population," says Siniff. "Many of the females of breeding age did not reproduce every year."

So the biologists started tagging these nonreproductive seals and keeping track of them to try to determine how many there are. They have found that there are apparently about as many nonreproductive females as there are ones who do reproduce each year. "This seems to be important in regulating the population," says Siniff.

The seal studies will go a step further next season. The University of Minnesota biologists will attempt to determine the frequency of sexual activity among the Weddell seals. This is obviously not an easy thing to do, but the group's electronics technicians have risen to the challenge. Next season the biologists will place what they call proximity tags on about 8 male and 20 female Weddell seals. They are



Hanna Pinshow monitors penguin oxygen consumption.

Yuan and Arthur DeVries at their Antarctic fishing hole.

designed so that when the male's transmitter gets within two feet of the female, it is activated. According to Siniff, the only time this can happen is when the two seals are copulating.

It's all in the interest of better understanding the population dynamics of the seals. But one can still harbor a little anthropomorphic sympathy for the vanished privacy of a romantic pair of Weddell seals rendezvousing in the icy Antarctic waters. □

EVERY SECOND OR THIRD day last October, November and December, Arthur L. DeVries and his wife Yuan DeVries, both Ph.D. biologists, drove a Sno-Cat four kilometers out onto the ice from McMurdo Station, Antarctica, to a red plywood hut. Inside, a hole about three feet in diameter has been cut through the floor of the hut and through the eight-foot-thick ice.

Arthur DeVries activates a gasoline-powered winch connected to a thin steel cable that passes around an overhead pulley and disappears through the hole and into the crystal-clear water. The lower end of the cable rests 1,600 feet below on the bottom of McMurdo Sound. Spaced at equal intervals along the lower part of its length are 20 large hooks baited several days earlier with 10-inch-long fish.

Anticipation builds as the winch slowly brings the hooks toward the surface. This is a fishing expedition, Antarctic style, whose goal is not sport but scientific study.

If the DeVrieses are lucky, the hooks will yield one or more of a four-foot-long, 160-pound Antarctic cod known as *Dissostichus mawsoni.* The cod is large enough that its blood can yield a couple of pints of a substance that holds answers to one of the more interesting mysteries of undersea life around Antarctica: Why the fish that inhabit the icy Antarctic waters don't freeze.

In McMurdo Sound, the southernmost part of the Antarctic Ocean, the seawater temperature is minus 1.9 degrees C.—the freezing point of seawater. Yet several Antarctic fish spend their entire lives in such cold water but do not freeze even when they are resting among large aggregates of ice crystals.

DeVries began his research on the problem in 1965. He eventually discovered the substance responsible for the fish antifreeze properties—a glycoprotein in their blood—and isolated it and did a preliminary characterization of its chemical and physical properties.

Now the DeVrieses, who are associated with the physiological research laboratory of the Scripps Institution of Oceanography, are studying the mechanism of the compound—how it prevents ice formation.

In addition to being an interesting problem in biochemistry, the research may have future practical applications in the field of cryopreservation.

"The lifetime of many organic materials such as prostaglandins (the new 'miracle drugs'), human and domestic livestock sperm, blood and whole organs can be greatly lengthened at low temperatures," notes DeVries. "The ability of the antifreeze molecule to retard the growth of ice and to prevent the buildup of high salt concentrations during freezing are two features that make these molecules promising candidates for cyropreservatives."

Some preliminary research on freezing milk, which is very difficult to preserve, with very low concentrations of antifreeze have been encouraging. The DeVrieses also believe the research may provide clues to plant biochemists searching for ways to make frost-resistant strains of citrus crops.

The glycoproteins that possess what DeVries calls "this amazing antifreeze property" are composed of a "glyco" or sugar part and a protein part consisting of the amino acids alanine and threonine linked in a long chain. The antifreeze is similar to the ethylene glycol used in automobile radiators, because the sugar portion of the antifreeze molecule is rich in hydroxyl groups.

In contrast to most proteins, which are compact spheres, the antifreeze molecules appear to be random coils, thus presenting large surfaces that can interact with the surrounding water or the surface ice crystals.

But exactly how this antifreeze lowers the freezing temperature of water is still not understood. One possible explanation is that the antifreeze arranges water about itself in such a way that the water molecules cannot be easily structured into ice crystals. But recent studies suggest that an alternative hypothesis is more likely: The glycoproteins bind to the surface of ice crystals and stop their growth by preventing water molecules from settling onto the crystal surface.

Still, unsolved questions abound. One of the most important is how the antifreeze is actually integrated into the cells of the fish to prevent entrance of ice crystals ("Maybe it's done during development," speculates DeVries). The DeVrieses also are trying to determine how fast the antifreeze is synthesized and then degraded (how long a given amount lasts) in *D. mawsoni.* And by keeping a number of fish alive in tanks of different temperatures, they hope to learn the effect of acclimation to warmth on the concentration of antifreeze.

Finally, there's yet another puzzle. An Antarctic fish called *Notothenia kempi* lacks antifreeze. "How it avoids freezing," says DeVries, "is a mystery we hope to resolve." □

Weddell seal at Hutton Cliff rookery.