FEATURES

VOYAGE INTO DARKNESS

Researchers are learning that Arctic organisms aren't dormant during the long polar night

By **Eli Kintisch**, *on the* RV Helmer Hanssen, *northwest of Svalbard, Norway*

It is lunchtime, but the sun is nowhere in sight. Just the moon and stars illuminate a black sky above a blacker sea as we motor a small skiff along an island fjord. The five of us—three researchers, a crew member, and a reporter—are encased in bulky, full-body survival suits in deference to the sub-zero January temperatures here in the high Arctic. Our eyes acclimate slowly. Forty minutes into our foray, we see a green aurora above a majestic rock wall that appears, out of nowhere, along the shore. "Can you believe we're being paid for this?" one scientist marvels. A black-and-white seabird called a little auk emerges from the gloom. It dives nonchalantly into the shadows to hunt, pursuing tiny crustaceans the size of rice grains.

Not long ago, researchers would have considered such a scene unlikely. They generally believed marine life this far above the Arctic Circle was dormant during the long polar night, when temperatures plunge and the winter sun disappears below the horizon for roughly 4 months. "The thinking has been: Those who can, migrate out of the Arctic [in winter]. Those who can't … turn off," says marine biologist Jørgen Berge of the University of Tromsø - The Arctic University of Norway (UiT).

Now, Berge and other researchers are challenging that paradigm. On voyages deep into the polar night—when research vessels have traditionally stayed away—they're finding that Arctic waters can pulse with life, even in the dead of winter. They've documented foraging birds and fish, masses of surprisingly active zooplankton, and even signs that some animals are continuously growing and reproducing despite the cold and darkness. "We make fantastic discoveries every time we do a cruise," Berge says. Those findings are driving a "reevaluation" of how Arctic ecosystems behave during the polar night, writes marine biologist Geraint Tarling of the British Antarctic Survey in Cambridge, U.K.

Much about life in the polar winter still remains "essentially … a black box," Berge says. That is why, earlier this year, he led a 17-day research cruise from northern Norway into the Arctic Ocean, an environment he calls "the least known realm on the planet." The 28 researchers aboard the ship had goals that included testing new technologies for monitoring remote seas,

PHOTO: KAJETAN DEJA

Northern lights bathe the high Arctic city of Tromsø, Norway, the departure port for a recent polar night cruise by the *RV Helmer Hanssen* (opposite page).

obtaining better measurements of the polar night's eerie "lightscape," and gaining a better understanding of how Arctic organisms cope with the sun's absence.

There was also a sense of urgency: Climate change is remaking the Arctic, and melting ice will allow more light to penetrate winter seas. "This will have a major impact on the ecology," Berge says. "So understanding the relationship between light and organisms is crucial to understanding the biological future of the Arctic."

AS BERGE TELLS IT, the emerging subfield of polar night biology was born almost by luck. The conventional wisdom was that the high Arctic only came alive each spring, after there was enough sunlight to fuel the growth of phytoplankton, the tiny marine plants that anchor the polar food web. As a result, biologists tended to launch their Arctic expeditions during the eight lighter months of the year—when the sun is sometimes above the horizon for 24 hours—and stay away during the roughly 4 months of constant night.

In 2007, however, Berge and colleagues retrieved some unexpected data from a sensor moored in a fjord off Svalbard, a rocky archipelago that sits about halfway between the Arctic Circle and the North Pole. The device used sound to track the movements of marine organisms, and readouts showed zooplankton periodically migrating up and down the water column. That's typical behavior during much of the year, when the creatures rise en masse to the surface at night and sink deep during the day, in part to avoid predators. But these movements were occurring in January, when Arctic zooplankton were expected to be dormant. "We were flabbergasted," recalls Finlo Cottier, a physical oceanographer with the Scottish Association for Marine Science (SAMS) in Oban, U.K.

Other surprises followed, sometimes aided by fate: In 2012, a cruise scheduled for November was delayed until January 2013 because of ship repairs, enabling biologists to discover unexpected bioluminescence and zooplankton at odd depths, whetting their appetite to learn more. Since then, each winter a tight-knit group of researchers—mostly Norwegian, British, and American—has reunited in Norway to sail into the dark.

The goal of this year's expedition was to explore several Svalbard fjords, as well as waters adjacent to the Arctic's floating sea ice. Our vessel was the 64-meter-long *Helmer Hanssen*, named for an early 20th century Norwegian who explored the region by wooden ship and ice sledge. In

PHOTO: HINRICH BASEMANN/CORBIS

contrast, we enjoyed cozy, quiet cabins, shockingly good Wi-Fi when the satellite cooperated, and hot Norwegian food, courtesy of a chef who jammed on his electric guitar off shift. The *Helmer Hanssen* also boasts well-stocked labs, cranes able to deploy sensor-laden buoys into the sea, trawl nets for sampling seafloor life, and autonomous undersea vehicles bristling with cameras and sensors.

Still, conditions can be harsh. Team members spent hours on icy decks wrangling wet nets and gear, or below decks fighting seasickness and claustrophobia in labs that often smelled like fish. (“I keep wanting to take a shower, but then I know there’s a trawl coming up so I put it off again,” said fish biologist and UiT graduate student Marine Cusa.) Cruise leaders had to cope with storms that repeatedly reshuffled their plans. Eventually, they stopped printing out revisions, opting instead to write changes on a whiteboard.

WHEN I COMPLAIN of seasickness during breakfast one morning, a researcher points to a porthole. “The best thing is to look out at the horizon,” advises marine biologist Kim Last of SAMS. Everyone laughs, because there is nothing to see. During early January here, at about 79° north, the sun never rises; it stays at least 11° below the horizon. With luck, at high noon you might see a gorgeous but short-lived red and purple sky, caused by sunlight reflected around the curve of Earth.

Scientists want to quantify that darkness, to know just how much light is available during the polar night. The measurements aren’t easy. Satellite instruments, which rely on light reflected from land, and conventional light meters aren’t sensitive enough to count the relatively few photons. So the researchers have hacked a device—originally designed to detect fluorescence in biomedical labs—that provides accurate readings.

One day, Last and biologist Jonathan Cohen of the University of Delaware (UD), Newark, pull on heavy winter gear and climb up to the top deck, above the bridge, to take a daily light measurement. The captain has turned off the radar so the scientists won’t be exposed to its powerful microwaves. Crouched behind a bulwark as the wind howls, Cohen programs the sensor with a small keyboard. No flashlights, he warns bystanders.

Repeated measurements show that average winter light levels are tens of millions of times lower than those measured during the Arctic summer. Still, there are subtle patterns within the winter lightscape: “Fifty shades of gray,” Berge jokes. Sunlight reflected from below the horizon makes the day a little brighter than the night, for example, and the aurora, the moon, and even the stars add measurable photons.

Polar night cruises give researchers a rare chance to study the winter habits of a wide range of marine organisms, including (from top, clockwise) fish such as cod, flamboyant cnidarians that sift food from the water column, and little auks.

PHOTOS: (TOP) KAJETAN DEJA; (BOTTOM, LEFT AND RIGHT) GEIR JOHNSEN/NTNU/UNIS

THOUGH SCARCE, the rays are enough to shape the behavior of many Arctic organisms. In particular, studies of common, shrimplike crustaceans known as krill are yielding new insights into light sensitivity.

During a snow squall, one of the ship’s cranes hauls up a net shaped like a dead giant squid. Kneeling, Last peers into a canister at the net’s dripping bottom. Bioluminescent krill, collected from a depth of 100 m, coat the can with a blue glow. He wraps the container tightly in a black trash bag to protect the animals from light and hurries a few decks down to a darkened walk-in refrigerator. There a graduate student sorts the krill while wearing a headlamp that glows red, a wavelength the crustaceans can’t see.

To study their light sensitivity, researchers glue live krill to an apparatus that uses electrodes to measure how their nerves respond to flashes of light of different wavelengths. Last year, Cohen showed that krill react most strongly to the bluish wavelengths that penetrate deepest into the water column, reaching a depth of 25 m even during the polar night. The experiments, combined with a model of the underwater light field, strongly suggest the krill can “cue upon ambient light during the dark polar night,” Cohen and his colleagues reported in *PLOS ONE* last year.

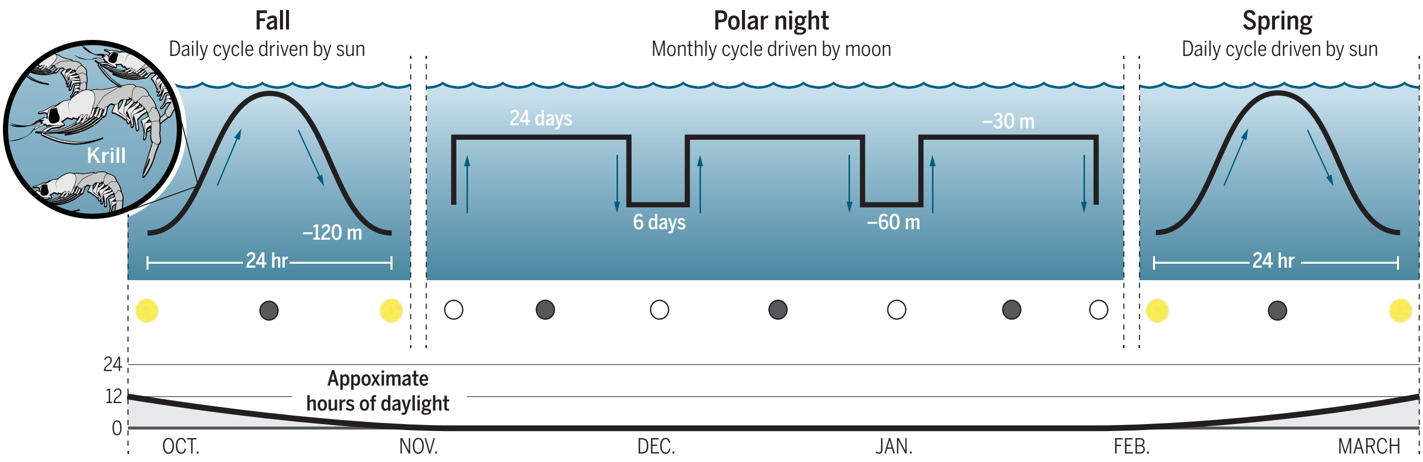
Other research has highlighted the unexpected role of the moon’s glow. One study by Last and his colleagues—dubbed “the werewolf paper”—analyzed several decades of acoustic data on the movements of krill and other zooplankton at 28 sites in the Arctic Ocean. They found that in December 2015 and January a daily migration can occur on a 24.8-hour cycle—which synchronizes the organisms’ movements with the rising and setting of the moon—rather than a 24-hour, sun-based cycle. The zooplankton also performed a “mass sinking” to a depth of about 50 m every 29.5 days in the winter, which coincides with the brightest full moon, the researchers reported in January in *Current Biology*.

On this cruise, Last and his colleagues explore whether krill “have an inherent rhythm” shaping their ability to sense the subtle light differences between night and day during the winter. Many animals have biological clocks that keep track of the time of day, helping regulate gene activity and other functions. To see whether the crustaceans have similar internal clocks, the researchers keep some in cold storage until a time corresponding to the crustaceans “night”—say, 12 hours after a noontime capture—then measure their sensitivity to light. They do the same for another set, but take the measurement during the krill’s “day.”

Late one night near the end of the cruise, Cohen and Last sit reviewing data from the experiment on a laptop. Their eyes widen. Indeed, the numbers suggest the krill be-

Rhythms in the dark

In the Arctic fall and spring, krill and other zooplankton dive when the sun is out to avoid predators, and rise to the surface at night. During the polar night, the zooplankton tend to stay deeper in the water column. They rise and fall with lunar cycles, sinking deep to avoid the light of the full moon.



come more sensitive to light during their night hours. "Yes!" shouts Cohen, as he and Last exchange a high-five. The finding may help explain how the creatures have evolved to most efficiently use what scant light exists here, a crucial aspect of survival.

SCIENTISTS ARE also examining how larger animals, such as cod and birds, can eat during the dark winter, when prey can be invisible. Deep in the ship, Marine Cusa, the fish biologist, spends a good chunk of the cruise cutting open the stomachs of cod collected by trawl nets and using a microscope to examine the contents. What she sees at first seems to confirm that the fish can use the meager light of polar night to hunt. Cod netted from a southern fjord that gets more winter light are stuffed with prey, but those caught farther north in Rijpfjorden, which gets less light, are nearly empty.

Later, she realizes that something is "really weird" about that pattern. On a winter cruise just 3 years ago, polar cod netted from Rijpfjorden had full bellies. What might explain the difference? Acting on a hunch, she climbs three flights up to the ship's instrument room—think laptops, body odor, and dirty coffee cups—and checks an online lunar calendar. "Please be full, moon, please be full," she pleads. Sure enough, the moon was full when researchers caught the 2013 batch of Rijpfjorden cod; on this year's cruise, it wasn't. "Dun-dun-dun," she announces later. "Maybe it's the moonlight that helps them hunt!"

Other creatures are also feeding in the darkness. Berge and his colleagues have found plenty of fecal pellets in the winter waters, apparently from krill and other zooplankton. "If there is shit in the water," he says, "someone is shitting, and if someone is shitting, someone is feeding."

That is true of the few species of Arctic birds that don't flee the polar night. In 2014 and 2015, the researchers observed six species actively foraging, including little auks. Many are known to rely on visual cues, but the darkness doesn't seem to bother them. When researchers caught several and examined their stomachs, they discovered plenty of prey; one guillemot had recently swallowed 214 krill. The birds also appeared to be specializing on specific organisms, not catching a random assortment. Such data "confirm active feeding by top predators," Berge wrote last year, but don't reveal how they're doing it.

SUCH FINDINGS are prompting new ways of thinking about the Arctic. One idea is that the existing notion of seasons, which focuses on temperature, should be expanded to include levels of light, especially in the water column. The middle of the dark polar night can be relatively warm compared with later months, for instance. In contrast, the spring bloom—which is triggered by increased light—often occurs when temperatures are still at a minimum.

Textbooks suggest that the bloom kicks off the growth and reproduction cycle of most Arctic organisms. But scientists have netted eggs and larvae that suggest the creatures are not only feasting in the darkness, but reproducing, too.

Such activity might mean that the Arctic has alternating ecological regimes, Berge says. In brighter months, it supports a food web that is driven from the bottom of the food web, by phytoplankton flourishing in the sun. But in winter it shifts to a "top-down" regime in which organisms thrive without primary production. "It could be a system that changes between two states," he says. The zooplankton's winter diet, however, is still a mystery. One scientist on the cruise was filtering seawater for microbes, which might be the missing source of energy.

Revising ecological dogma in the Arctic will require more data covering greater spans of ocean, over longer time periods. So polar researchers are designing instruments that could increase the data yield from each cruise. During this trip, for instance, scientists spent one afternoon testing a "jetyak"—an autonomous kayak that could be programmed to conduct biological surveys away from the light pollution of a ship. Although it performed what one researcher called some "crazy" turns, the team concluded it could be a useful platform.

WHEN THE SHIP FINALLY DOCKS at the Svalbard town of Longyearbyen, most of the scientists amble to a bar for a long-awaited drink. But Last and Cohen stay aboard, racing to complete preparations for a new experiment aimed at understanding the genes governing the krill's biological clock. At regular intervals, they freeze freshly caught krill in order to stop the ticking of the clocks at different points. Later, back in the lab, colleagues will run tests to see which genes are active at which times.

"If we hadn't learned what we did on this cruise we wouldn't have done this last experiment," a bleary-eyed Last says. He hopes it will reveal a little more about how the creatures survive their long night. If so, a journey into darkness will have shed a bit more light on the Arctic. ■

ILLUSTRATION: C. BICKEL/*SCIENCE*