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Vertical migration timing illuminates importance of predator pressure in the ocean's twilight zone

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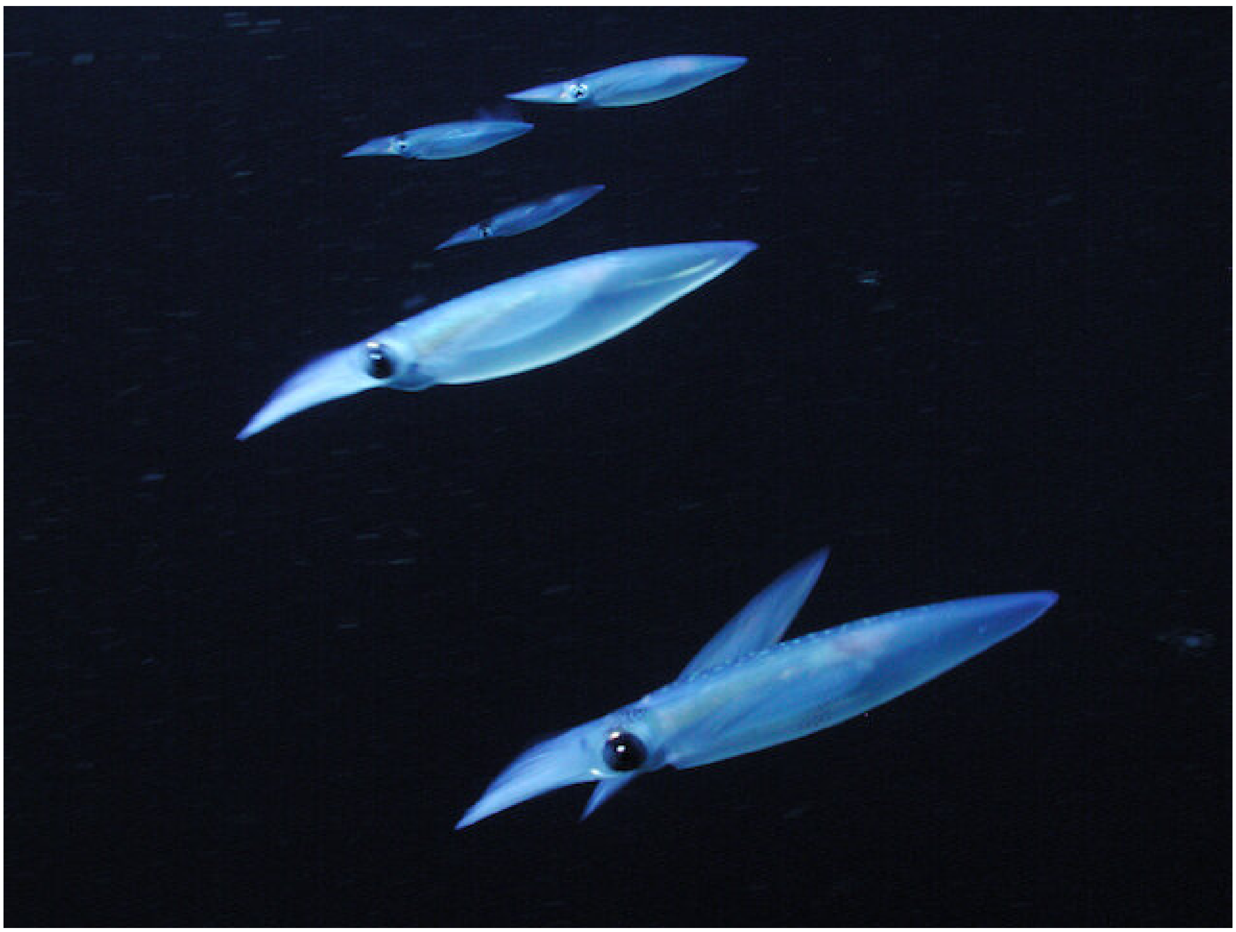


In the largest migration on Earth, countless fishes, squids, and crustaceans ascend from the ocean's twilight zone each night. New research led by MBARI ecologist Kelly Benoit-Bird asks "When?" to help answer "Why?" Credit: MBARI

At dusk, millions of fishes, crustaceans, squids, and other animals leave the ocean's twilight zone and swim to the surface. At dawn, they return to deeper waters. New research by MBARI Senior Scientist Kelly Benoit-Bird and Mark Moline—director of the University of Delaware's School of Marine Science & Policy—used autonomous robotics outfitted with acoustic technology to examine the timing of animals' movements out of the depths. Their findings shed new light on why deep-sea animals embark on their massive migration each night.

Sunset and sunrise guide the movements of animals between the surface and the twilight zone—a layer of water 200 to 1,000 meters (660 to 3,300 feet) deep known to scientists as the mesopelagic zone. Each night, the setting sun kicks off the largest migration on Earth. Mobile animals of all sizes and taxa swim from the twilight zone to shallower waters near the surface. With sunrise, they retreat back to the depths.

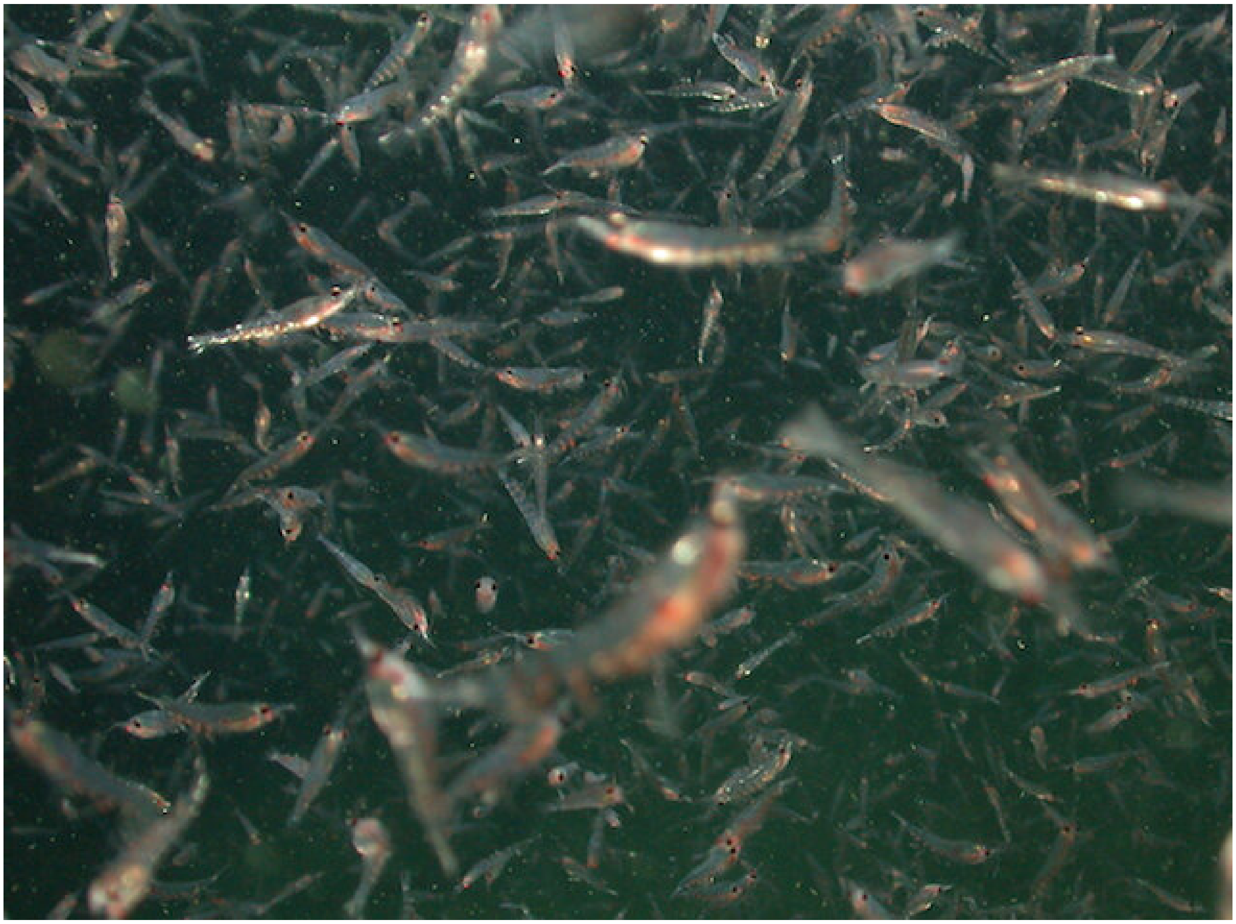
This phenomenon is called diel vertical migration and is thought to result from the competing need to feed in energy-rich surface waters while avoiding visual predators. Deep-sea animals stay in deeper waters during the day to avoid predators like tunas, salmon, and seabirds that rely on sight to see their prey. This dense aggregation of animals is often called the deep scattering layer. Night affords a cover of darkness so these animals can feast on the abundant food near the surface while avoiding the gaze of their predators. At dusk, the deep scattering layer rises hundreds of meters and dissipates.

Understanding exactly when individuals migrate can allow scientists to test hypotheses about why animals move up and down in the water column.

"We refer to it as the 'deep scattering layer," but it's not a layer, it's a group of individuals doing different things and making different decisions, so we were able to probe those decisions and understand why animals made them," said Benoit-Bird, who led a new paper in Limnology and Oceanography examining the timing of vertical migration.

Because movements of deep-sea animals occur over a short window of time—typically just an hour or less surrounding dusk and dawn—examining differences in the timing of migration has historically proved challenging. Most tools for studying the movement of the deep scattering layer can detect patterns for populations and communities, but not individuals, making it difficult to understand why deep-sea animals undertake their marathon migrations.

"When we see this from a ship, we only see animals in bulk. We see a layer, not an individual or its neighbor, not how its movement relates to their environment," explained Benoit-Bird. But a modified autonomous underwater vehicle (AUV) has become a critical tool for revealing the fine details of exactly when animals begin to move up from the deep sea.



At sunset, krill and many other animals migrate from the depths of the ocean's twilight zone to the surface, presumably using the cover of nightfall to feed on the abundance of food in shallower waters. Credit: MBARI

Ship-based acoustic systems are 400 to 500 meters (about 1,300 to 1,600 feet) away from the deep scattering layer. By adapting these sonar systems to a mobile robotic platform, Benoit-Bird and Moline could get much closer to the scattering layer—close enough to resolve animals as individuals, not just a collection. "It's like if we were trying to see a flock of birds from space, and now we're in an airplane right next to them," described Benoit-Bird. "They're both useful perspectives, but they're very different."

The Deep Ocean REMUS Echosounder (DOR-E) AUV carries two split-beam echosounders that can travel to depths up to 600 meters (almost 2,000 feet). By programming the AUV to swim above and through several sound-scattering layers, researchers can collect sonar data to identify individual animals and to track predators that dive into the layers to hunt. The AUV's 20-hour battery life means it can log acoustic information for almost an entire day, helping researchers understand the daily cycles and behaviors of pelagic organisms.

Benoit-Bird had previously used this modified AUV to detect discrete groups or "schools" of animals within the deep scattering layer. Building on these initial measurements of the internal structure of the layer, researchers learned that the schools of animals remained coherent during their migration to shallower water at dusk. In this recent study, Benoit-Bird and Moline wanted to examine which factors affect the variation in the timing of upward migration. To do this, they deployed the DOR-E AUV in the waters of the Santa Catalina Basin in Southern California.

"Their movements are not just pre-programmed "I go up' and "I go down,'" explained Benoit-Bird. "There's a lot more nuance and decisions to be made night to night and even minute to minute, based on how hungry they are and how much of a risk there is."

By surveying above the midwater scattering layer in the period just before and after sunset, researchers were able to observe tens of thousands of single targets rising from the layer. Analyzing that acoustic data, Benoit-Bird and Moline saw that smaller animals began their migration to shallower waters sooner than larger animals, and faster swimmers migrated earlier than weaker swimmers.

These findings support the prevailing hypothesis that diel vertical migration balances the tradeoffs of feeding in surface waters with reduced exposure to visual predators.

Larger, more easily visible animals should spend more time obscured in darker depths, and smaller animals should ascend to shallower waters earlier than their conspicuous counterparts. Indeed, Benoit-Bird and Moline found that the smallest animals in the Santa Catalina Basin began their upward ascent 20 minutes before sunset, but the largest animals began migrating up to 80 minutes after sunset.

By using a specialized autonomous underwater vehicle (AUV), researchers were able to closely observe deep-sea animals as they began their massive migration to the surface from the twilight zone. Understanding the timing of this massive migration is critical to understanding why deep-sea animals move between the depths and the surface. Credit: Kelly Benoit-Bird, MBARI

Animals' swimming capabilities also affected the timing of their upward migration to the surface. Squids generally were the first to depart the twilight zone, followed by fishes, then crustaceans. Squids are fast swimmers capable of jet propulsion when threatened. They are better able to elude predators than fishes or crustaceans, so they are the first to brave the ascent to the surface.

But the researchers were surprised by how dynamic the migration could be. "The most interesting thing we found was how dramatically animals can change their migration when predators are nearby," said Benoit-Bird.

The presence of Risso's dolphins (Grampus griseus), important squid predators, made squid stay deep rather than migrating. At times, the squid gave up the chance to feed for much of the night because of the risk of being eaten themselves.

Aggregations of squids showed a substantial delay in their vertical movement when Risso's dolphins were near, leaving the midwater layer 40 minutes later. The delay in their migration decreased the time squids spent at the surface and reduced their potential foraging gains. The presence of Risso's dolphins had no significant effect on the ascent timing of fishes or crustaceans, animals not often part of the dolphins' diet.

"Vertical migration is always thought about in terms of these animals being exposed to visual predators, but it's not just about visual predators," said Benoit-Bird. Deep-diving dolphins hunt their prey by sound, not sight. They send out clicks of sound and listen for the echoes that bounce off food nearby. "Risso's dolphins are not hunting squid by vision, so there are more factors at play that we need to consider."

Diel vertical migration has profound effects on ocean ecosystems, from the surface to the seafloor. It shapes the structure of deep-sea food webs by connecting the fertile waters near the surface to the depths below. It is also a critical component in the carbon cycle, providing a vector for sequestering carbon in the deep sea. "It's a biological conveyor belt that's an important way energy and carbon get moved around in the ocean," said Benoit-Bird. Studying this massive migration is ultimately critical to understanding ocean health and our changing climate.

More information: Kelly J. Benoit-Bird et al, Vertical migration timing illuminates the importance of visual and nonvisual predation pressure in the mesopelagic zone, *Limnology and Oceanography* (2021). DOI: 10.1002/lno.11855

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