PART 4

Why does a whale's feeding behavior matter?

By Polly Shulman

The Other Half of the Equation: Krill

"The whale behavior is only half the story," says marine biologist Dr. David Cade. "If you want to study feeding, you also want to look at the context of how much prey there is, and where is it located, and how is that influencing what the whale is going to do."

To learn about krill distribution, Cade and the Stanford team attached an instrument called a multifrequency echosounder system, made up of two or more individual instruments called **echosounders**, to the back of their boat (**Fig. 1**). Each echosounder sends pings of sound into the water that bounce off whatever they encounter on their way down. Then it measures the **amplitude** (loudness) of the echoes and the time it takes for them to return to the instrument. The louder the echo, the more stuff is in the water, and the longer the wait, the farther down the stuff is, says Cade—"It's like how a bat or a dolphin senses its environment."

Figure 1. Echosounder. Once placed in the water, the instrument sends down pings of sound (orange curves) that bounce off whatever they encounter, then measures the amplitude of the echoes (blue curves) and the time it takes for them to return to the instrument. Higher-amplitude echoes mean there's more material; longer waits mean it's farther away.
Illustration by Alex Boersma

Different types of objects reflect different sound frequencies differently. Because the echosounder uses a range of frequencies, the scientists can differentiate krill from, say, fishes or squids. By moving the boat forward and pinging as they go, the scientists can create a map of krill depth and density along that path. Think of it as a cross section of the ocean sliced along the boat's possibly curving path, showing the krill distribution and density beneath that path. But the scientists aren't just measuring krill density underneath any old path—what they really care about is how the krill situation looks where the whale is foraging. So they follow the whale as closely as possible, pinging the water with their echosounder to learn what's down there.

Let's look at the graph we saw in Week 4 (Essay 4, "Giants of the Sea, Part 2: What happens underwater?"). That graph showed a single dive (**Fig. 2**). Here's a version with prey data layered on: The yellow line shows where and when a whale dives. The red areas are where the krill is denser. And the green dots are feeding events: where the whale opens its mouth and takes a big gulp of krill. "This doesn't line up quite perfectly in space and time, because we're trying to follow that whale from our boat from the surface," says Cade. "But you're going to get a sense of where this whale's choosing to feed, and why."

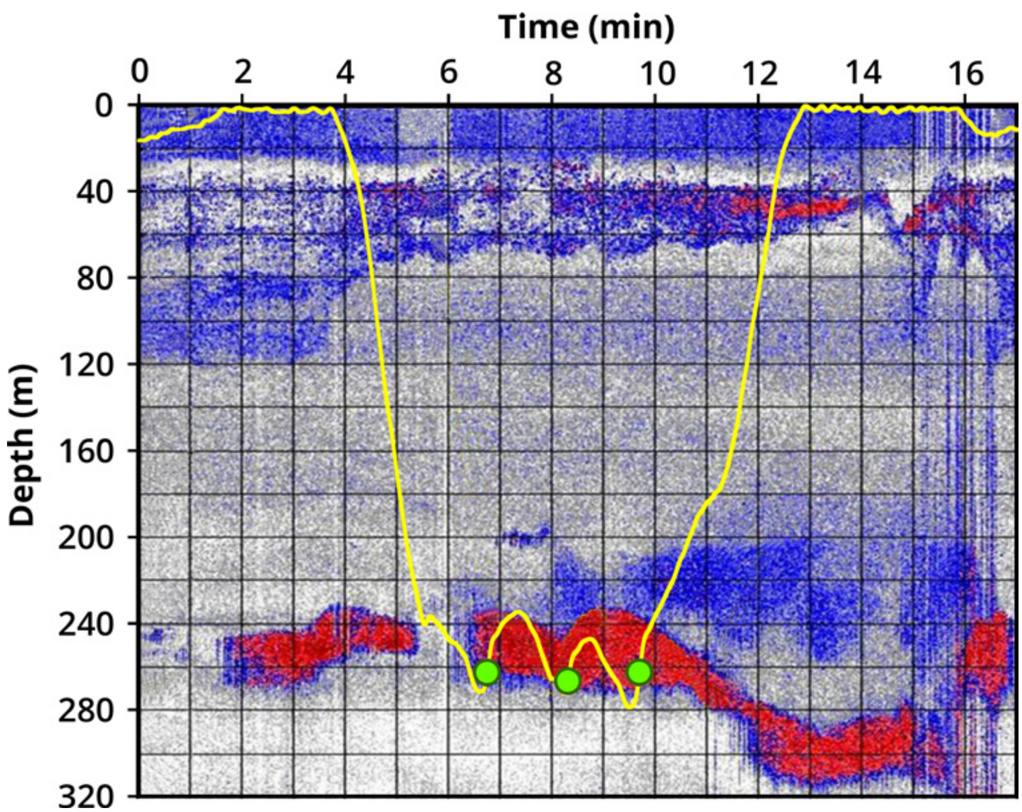

Figure 2. Prey distribution with dive profile. Yellow line: whale dives. Red areas: denser krill patches. Green dots: feeding events. This graph shows the activity of a whale with the identification code CRC-1009, a female that was first identified in 1994, making her at least 22 years old at the time the data were collected, and likely older.

To find out how prey density and distribution affect the whales' feeding behavior, marine biologist Dr. Jeremy Goldbogen and a team of colleagues analyzed tag data from 55 adult blue whales foraging off the coast of California over the course of several years. This group of whales included 14 animals they had followed in their boat with the echosounder. The whales, they found, used different **foraging strategies** depending on the richness of the krill patches they encountered. When the whales found nothing but relatively poor prey patches, they used a time-minimizing strategy: They spent a shorter period underwater, taking fewer gulps (two to three) and returning to the surface before they really ran out of breath, thus conserving oxygen. When they found rich, dense prey patches, however, they used an energy-maximizing strategy instead (here, "energy" refers to the calories in the krill). They stayed down as long as they could, performing as many gulps as they could cram in (four to eight) before they decided to return to the surface and replenish oxygen stores. And a few whales really pushed the limits when they found dense prey patches, using more oxygen than others to extend their foraging time. "Using a lot of oxygen on a long dive with many lunges may be inefficient in terms of oxygen because it takes a longer time to recover oxygen stores at the sea surface, but it may be worth it overall if the prey quality is very high," says Goldbogen. Because krill is unevenly distributed across space (with richer and poorer patches) and time (with seasonal blooms), the researchers hypothesize that switching between these foraging strategies gives blue whales the flexibility they need to gain as many calories as possible, allowing them to support their large body size and their long fasts and migrations.

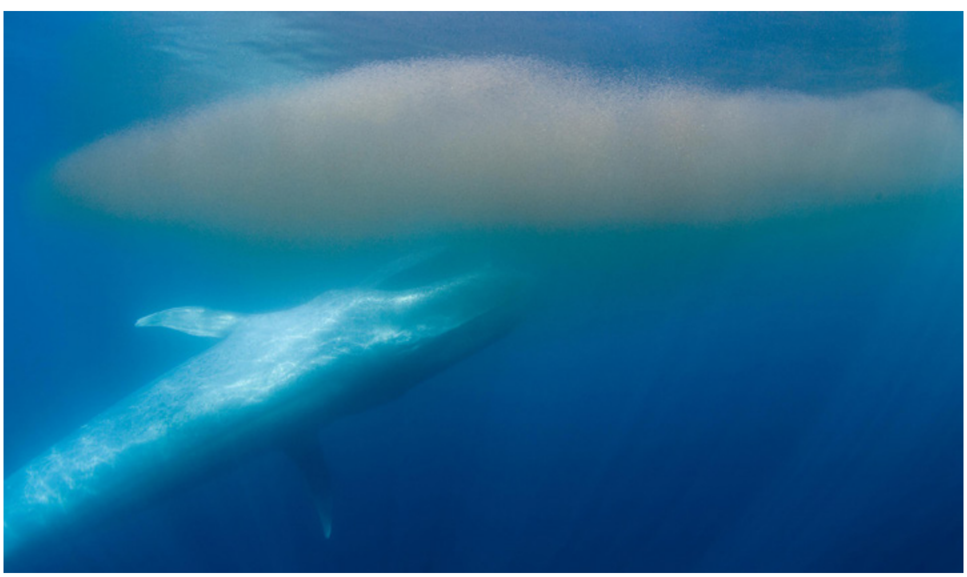

Figure 3. Dense krill patch. A whale opens its mouth to begin a gulp.

Going in for the Krill

Krill migrate vertically on a daily basis. Many marine predators, such as birds, seals, and some fishes, feed in shallower waters during the day, when sunlight makes food easier to see. To avoid those predators, krill spend their days hiding out in the depths where they form dense patches, confusing predators that single out individuals to target. But krill need to eat too, and their own food source—plankton—lives near the surface. That's where phytoplankton have access to sunlight for photosynthesis, and zooplankton have access to phytoplankton for meals. So at night, krill rise to the surface and spread out to feed on plankton.

Krill's defensive strategies help them avoid their usual predators, but the dense swarms they form in the depths during the day make perfect meals for deep-diving roquals such as blue whales (**Fig. 3**). The krill's dense patchiness by day offers the astonishing concentration of calories that blue whales need to fuel their gigantic bodies, and the whales appear to have evolved foraging strategies that take advantage of it.

Why Does It Matter?

As the largest animals thought ever to have lived on Earth, blue whales have no nonhuman predators. But that doesn't mean they're invulnerable. Like a lot of whale species, blue whales were hunted to near extinction in the 19th and 20th centuries, and although hunting of blue whales has not been allowed for the past four decades, their extremely low numbers and slow reproduction has made them slow to recover. Many human behaviors continue to threaten these giants of the deep:

Ship strikes: In "our increasingly urbanized oceans," says Goldbogen, blue whales cross paths with mechanical giants: ships. Modern cargo ships can be ten times the length of a blue whale. "With an increasingly interconnected world economy, where shipping is a huge part of how the world functions, we're only going to see more and more shipping traffic throughout the oceans," Goldbogen says. This becomes a problem when the shipping lanes intersect with blue whales' foraging hotspots (**Fig. 4**). Dense patches of krill tend to pile up around steep shifts in underwater topography, where upwelling brings nutrient-rich waters to the surface and phytoplankton can bloom. When shipping routes cross those areas, they increase the chance of a ship strike, when a ship hits a whale, injuring or killing it. "That's a really hard threat to actually quantify, because if you have a ship strike and kill a blue whale, sometimes those blue whales end up on the bows of ships, and they can be counted," Goldbogen says. "But sometimes they probably fall off."

Figure 4. Close encounter. When shipping routes cross blue whale migration paths, there's a risk of deadly collisions. © John Calambokidis, Cascadia Research

Entanglement: Whales can get caught in fishing gear, such as ropes and nets. "It's very, very difficult and dangerous to try and disentangle a whale," says Goldbogen, "and the result, if the whale can't shed that gear on its own, is typically a very slow death over weeks to months."

Pollution: As filter feeders, blue whales encounter pollutants such as microplastics, and the biologists' research on the whales' feeding mechanisms may help them understand how much of that material the whales expel or retain. Other avenues of inquiry include the use of crossbows to take small biopsies of blue whale blubber. "You can quantitatively measure the chemical signatures and derivatives of microplastics in the blubber," says Goldbogen. "As an animal that lives a very long time and also processes a huge amount of the ocean, blue whales might be sentinels for ocean pollution."

Noise: The researchers have been studying how acoustical disturbances such as military sonar and ship noise affect blue whales. The whales, they've found, sometimes stop foraging when it's noisy. "Because we have a very good idea of the density of food and the number of times whales are feeding during that foraging season," says Goldbogen, "we can actually start to quantify the energy lost to the whale from the cessation of foraging due to the acoustic disturbances." And noise may have other consequences too, such as disturbing whales' communications by masking their calls.

Changes in krill distribution with climate change: As we've seen, blue whales depend exclusively on a single food source: krill. But climate change is altering the ocean environment, which will likely affect the distribution of krill. For example, warmer surface waters may mean an increase in the upwelling of nutrient-rich waters, or they may lead to increased stratification that inhibits cold, nutrient-rich waters at the bottom from bringing those nutrients to the surface. Either way, warmer surface waters will change the abundance of nutrients available to the phytoplankton that krill themselves feed on, which will probably have a big effect on krill and therefore blue whales—and on everything else in the food web, says Cade. The danger to blue whales is amplified by their use of memory in foraging: What if they return to spots where they expect to find dense prey patches, only to discover that the food isn't there? "Unless blue whales can adapt their thinking or adapt the way they feed," says Cade, "they may be more susceptible to changes in prey conditions."

Changes in whale migration with climate change: Changes in krill distribution and in the ocean itself—such as changing temperatures, currents, and sea ice—are likely to affect whale migration as well. If whales take different paths across the ocean in search of food and breeding grounds, these changes may affect their encounters with other dangers, such as ships and pollution.

The more we know about where and when blue whales eat, says Goldbogen, the better we can adapt our conservation efforts. For example, by making sure shipping routes avoid prey areas during feeding season, we can reduce ship strikes, and by limiting sonar and other human-generated noise in the times and places where the whales are trying to feed, we can help them get the calories they need to survive. And since blue whales travel so far, live so long, and eat so much, they are themselves a rich source of information about the ocean and its ecosystems. With human activity changing the climate so fast, it's more important than ever to understand how blue whales live now so we can anticipate what will happen to them in tomorrow's oceans.

Related Links

Prey Distribution and Foraging Strategies
In a Science paper, Goldbogen and his colleagues report their findings about how blue whales change their foraging behavior depending on prey density.

Stop and Think

1. Return to the 12 hour graph that showed data for two different whales on two different days. Knowing what you know now, why do you think the two whales were diving to different depths during the days they were tracked? Explain your answer.

2. Based on what you've learned through the readings, videos, and data analysis, discuss how blue whales have evolved to be the largest animals that have ever lived. Use what you know about their environment, what they eat, and how they eat in your discussion.

3. How might this research be used to help in the conservation of blue whales? What lessons can be applied in studying other ocean organisms?