Sound provides new insight into the lives of blue whales

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The blue whale (Balaenoptera musculus) is the largest animal that has ever lived on Earth, yet we still have many unanswered questions about its biology and ecology. New research leverages audio recorded by an underwater microphone on MBARI's cabled observatory to better understand the behavior of these behemoth. Credit: NOAA

The blue whale (Balaenoptera musculus) is the largest animal ever to inhabit Earth. Despite its gargantuan size, many aspects of its biology, behavior and ecology still elude us. This magnificent mammal spends most of its time below the ocean's surface, out of sight from scientists seeking to unlock its mysteries.

But even when we cannot observe blue whales by sight, we can hear their powerful vocalizations that travel hundreds of kilometers. Using sound recordings from the heart of Monterey Bay National Marine Sanctuary, MBARI researchers and their collaborators have discovered new dimensions of blue whales' lives. We have learned how blue whales cooperate to forage and how they tune into the productivity of their ecosystem to decide when to embark on their annual long-distance migration for breeding.

An underwater microphone (hydrophone) on MBARI's cabled observatory has been a valuable tool for studying whales that gather seasonally in the fertile waters of Monterey Bay. The microphone records the calls of whales—acoustic data that offer insight into the animals' behavior.

"Because whales and other marine mammals use sound in the essential life activities of communicating, foraging, navigating, socializing, and reproducing, there is a wealth of expressed consciousness in the ocean soundscape. We aim to tap that wealth to better understand and protect ocean life," said John Ryan, a biological oceanographer at MBARI.

Previous research by Ryan and collaborators at Stanford University—including incoming MBARI Postdoctoral Fellow William Oestreich—coupled the hydrophone's extensive archive of acoustic data with field studies to better understand blue whale behavior.

"Our past research efforts with collaborators from around Monterey Bay opened the door to understanding the behavioral context of patterns in the acoustic data collected on blue whales with MBARI's hydrophone. This context has set the stage for a series of studies which leverage the incredible long-term view on behavior that this acoustic record provides," said Oestreich.

Now MBARI's acoustic data have contributed to two new research studies about blue whales led by graduate students at Stanford University's Hopkins Marine Station in Pacific Grove, California.

A study by David Cade, published in *Animal Behaviour* in December, examined feeding aggregations of blue whales in Monterey Bay. Cade was recently a postdoctoral researcher in Ari Friedlaender's Bio-Telemetry and Behavioral Ecology Lab at University of California, Santa Cruz, and is now a postdoctoral researcher in Jeremy Goldbogen's lab at Hopkins Marine Station.

Leveraging biologging tags, acoustic prey mapping, hydrophone recordings of social cues, and remote sensing of ocean currents, the research team, including Oestreich and Ryan, investigated the ecosystem dynamics underlying unusually dense aggregations of blue whales—up to 40 of the giants within a one-kilometer radius area.

"We are only just beginning to study the role of these giant, but ephemeral, krill patches that can feed a super-group of blue whales. These 'hotspots' likely play a critical role overall in a blue whale's ability to find enough food before it swims south for the winter. The MBARI hydrophone is giving us new insights into not only blue whale behavior, but what that behavior can tell us about the prey conditions in Monterey Bay that are critical for the entire ecosystem," said Cade.

The combination of oceanographic conditions and seafloor terrain (bathymetry) concentrated large numbers of shrimp-like crustaceans called krill, which are the primary food of blue whales. The immense size of the krill swarms allowed these "supergroups" of blue whales to forage together without exhausting the food supply.

Ryan and Oestreich were studying all types of blue whale vocalizations, including one that is associated with foraging.

"In the hours immediately preceding these remarkable aggregations of foraging blue whales, MBARI's hydrophone recorded anomalously dense clusters of a specific blue whale call type. This exciting finding raised a number of questions and hypotheses concerning the role that these vocalizations play in blue whales' foraging and sharing of information," recalled Oestreich.

The hydrophone recordings revealed that, counterintuitively, the whales exhibited a social foraging strategy. The research team observed that rather than competing for food, blue whales called to other whales to signal food was present. The blues' bellows invited others to join the feast.

Modeling of social interactions indicated that using social information from other whales reduced the time required for individual whales to discover and exploit the dense patches of food that they need to survive. The whales' foraging became more efficient, without any apparent costs to the caller who first found the patch of food.

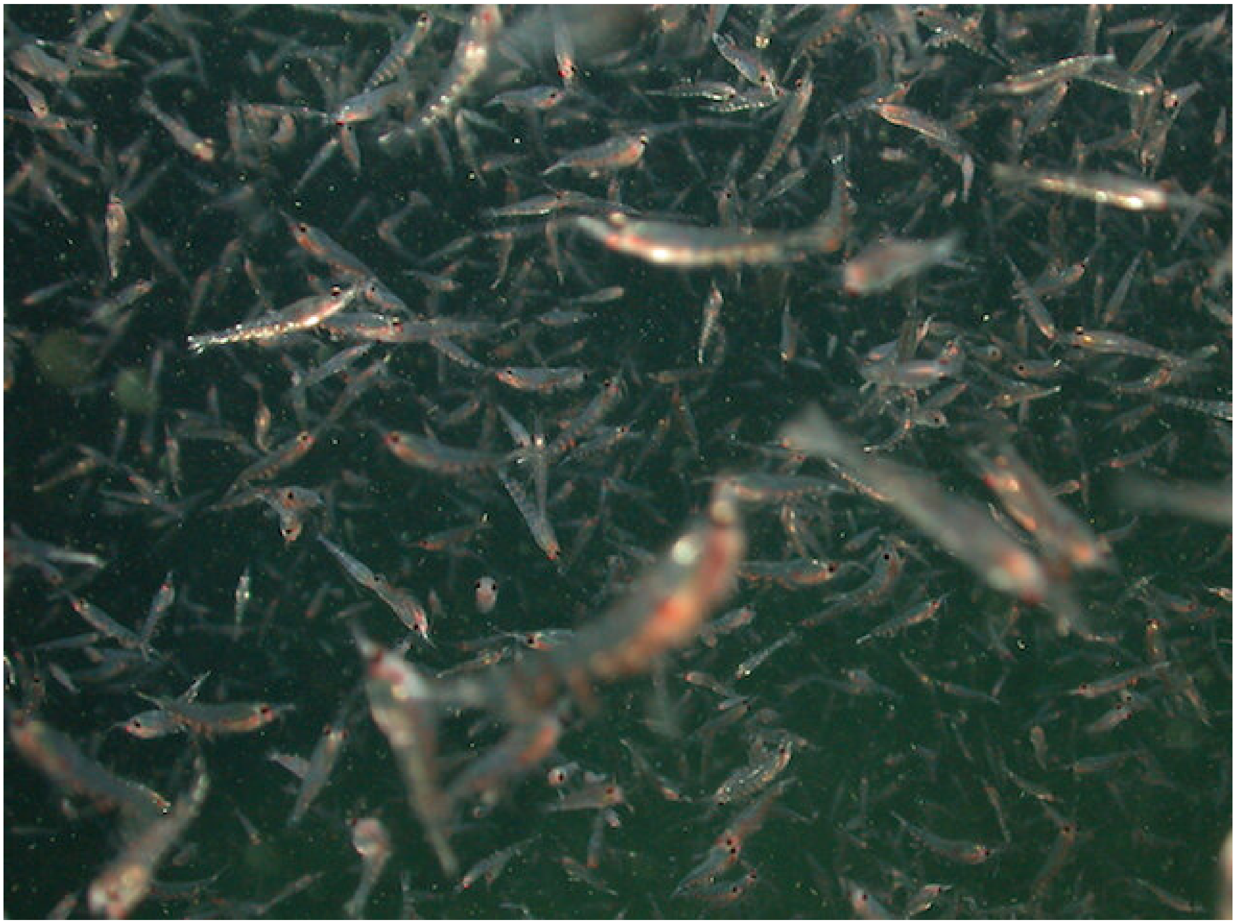
A second study, led by Oestreich and published this month in *Functional Ecology*, also utilized MBARI's acoustic archive to gain new insight into blue whale behavior.

In 2020, Oestreich and a team of researchers from MBARI and Stanford University documented distinct seasonal changes in blue whale vocalizations that reveal when these gentle giants begin their annual migration. During summer and early fall, blue whales sing more during the night. Later in the fall and into winter, the whales begin singing more during the day. This change coincides with the time of year when the whales reduce feeding and begin their annual southward migration. Data from biologging tags confirmed that the acoustic signature detected by the hydrophone reflected changes in the whales' behavior.

Now, Oestreich and his collaborators have used MBARI hydrophone data to understand how blue whales change the timing of their migration back to breeding areas from year to year.

We have long known that whales time their migratory movements with natural cycles in their marine habitat, especially seasonal changes in productivity. But how populations adjust the timing of their migrations in response to year-to-year environmental variability remained unclear.

The data, collected from summer 2015 through spring 2021, recorded the bellowing vocalizations of blue whales in the Monterey Bay region. Sound signaled when whales stopped foraging on the local abundance of krill to begin their southward breeding migration. To the team's surprise, the start of the whales' migration could vary up to four months from year to year.



Krill are small shrimp-like crustaceans that are the primary food source of blue whales. Dense aggregations of krill occur seasonally in Monterey Bay, sustaining populations of many marine animals. Credit: MBARI

Considering that the blue whale breeding season itself spans only approximately four months, this large variation in the timing of migration was initially puzzling. Here, data about ecosystem changes from year to year offered important clues.

Migration timing closely followed conditions within the whales' foraging habitat. Specifically, blue whales lingered longer off central California when the ecosystem provided more opportunity for them to build energy stores. A later transition from foraging to migration occured in years with an earlier onset, later peak, and greater accumulation of biological productivity.

These findings suggest that in years of the highest and most persistent biological productivity, blue whales wait to begin their southward migration. Researchers believe the whales do not simply depart toward their southern breeding grounds as soon as sufficient energy reserves are accumulated. Rather, the whales delay their migration when food is plentiful to maximize their energy intake on their foraging grounds.

"We previously showed that blue whales use long-term memory to time their arrival on foraging grounds based on when they expect food to be available because they don't have advanced information about what foraging conditions will be like when they arrive. Yet when making the decision of when to depart foraging grounds, they have much more immediate information to rely on to determine whether it's best to stay or leave. This allows these whales to be incredibly flexible in when they initiate their southward migration to return to breeding areas," explained Briana Abrahms, an assistant professor in the Department of Biology at the University of Washington and a coauthor on the study on migration timing. "It's really exciting to learn so much more about how and when these animals decide to make such massive movements in the ocean."

The use of flexible cues—likely including foraging conditions and long-distance acoustic signals—in timing a major life history transition may be key to the persistence of this endangered population as it navigates an ecosystem that experiences large natural and anthropogenic changes.

"This research indicates that blue whales are more flexible in their foraging and migratory behavior than previously realized. Such flexibility is critical for adaptation to an era of rapid global change—whether this behavioral flexibility allows blue whales to adapt to long-term changes in their foraging habitat remains to be seen," said Oestreich.

Open access to scientific data is a fundamental value for MBARI and part of the institute's mission. As part of MBARI's commitment to open collaboration, the original audio recordings for the entire study period are available through the Pacific Ocean Sound Recordings project via the Registry of Open Data on the Amazon Web Services (AWS) cloud.

"Scientific discovery and progress require transparency, reproducibility, and extensibility. Toward fulfilling these requirements, we share all of our audio recordings—150 terabytes and growing—together with an analysis toolbox," said Ryan. "Our most recent confirmation of the value of open data occurred last week, when a tenth grader from Canada contacted me to show me how he had extended research from one of our published studies."

MBARI also streams live underwater audio to the Soundscape Listening Room to share the wonder and excitement of the ocean soundscape with the public. The live soundscape can be full of ocean "voices"—from the complex song compositions of humpback whales to the chatter of dolphin pods. The listening room also includes archived sounds for listening when the live stream is quiet.

MBARI technology has proven invaluable to researchers studying the behavior of endangered blue whales. MBARI will expand these efforts in 2022 with the new Blue Whale Observatory. This new project—led by Oestreich and Ryan with marine ecologist Kelly Benoit-Bird and researcher Chad Waluk—will examine blue whale ecology in depth by integrating interdisciplinary sensing of the whales, krill, and their ecosystem. The observatory will leverage an array of technologies to bring together the pieces of a complex, important, and beautiful puzzle.

More information: David E. Cade et al, Social exploitation of extensive, ephemeral, environmentally controlled prey patches by supergroups of rorqual whales, *Animal Behaviour* (2021). DOI: 10.1016/j.anbehav.2021.09.013

William K. Oestreich et al, Acoustic signature reveals blue whales tune life-history transitions to oceanographic conditions, *Functional Ecology* (2022). DOI: 10.1111/1365-2435.14013

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