

Sound Perspectives

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A Journey Through *Unseen Oceans*

The ocean is vast and mysterious, in no small part because light does not penetrate very far there, limiting our vision to just a few meters. Sound, however, travels both faster and further in water than it does in air. As a result, animals that live throughout the ocean's inky blackness rely on sound to communicate, navigate, and find food. For the same reasons, scientists like me also rely on sound to explore the ocean and communicate with our sensors. I'm a senior scientist at the Monterey Bay Aquarium Research Institute (Moss Landing, CA) where I use acoustic techniques to understand how animals of all sizes in the ocean survive and how toothed whales use biosonar to find their food. An important part of my work is the development of new technologies for accessing the largest living space on our planet. With new tools, I'll share a recent journey through these unseen oceans with you.

I watch the waves, rhythmic and soothing, before taking a deep breath to calm my nerves and descending to observe the life below. Looking upward, tiny ocean plankton, alien and spectacular in form, sparkle in the beams of light scintillating from above. Fish skitter around us, bumping into each other to avoid our incursion into their world. If we move carefully, the fish arrange into curious schools, making a single mammoth, roiling organism from many. A bright yellow torpedo-shaped object catches my attention in the distance, and I follow it downward as the sun sets, passing thousands of animals shuffling their way to the surface to catch their dinner under the cover of darkness. A few stragglers light up, startled by our presence. Down here, many animals make light or interact with it in unusual ways so even as it is perpetually dark and cold, the deep sea glows and sparkles with life. As I reach the seafloor, the swath of my sonar reveals underwater mountains and canyons, most of which remain unmapped. This dive from the surface of the ocean to the seafloor was different from any other that I've ever taken. It did not involve a submersible and it didn't start on a ship. Instead, this journey started a year earlier with an email that proved to be the beginning of a journey that would lead me to see the ocean and my own work in a different light.

That first email was from Joann Gutin, an exhibition writer at the American Museum of Natural History (AMNH; New York; amnh.org). Joann explained that they were working on a new temporary exhibit about the ocean and would like to talk. As a kid, I visited the museum's "Hall of Ocean Life" and was awed by the full-scale model of a blue whale hanging from the ceiling and intrigued by the dioramas of life tucked into its dimly lit corners. My interest piqued, I agreed to her request for a phone conversation. Joann told me that while the narrative for this new exhibit wasn't totally realized, they were trying to bring science out from behind the story, bring people into the picture, and share failures along the path to discovery. She noted that the museum is not an aquarium so they were grappling with how to make media experiences that would not be a second-rate experience but rather a space where visitors could be in the water column, experience how it would feel to be a scientist, and learn for themselves what there is to see. I answered Joann's specific questions about ocean life, referred her to cutting-edge work in ocean biology, and shared the names of other experts that could help guide their exploration.

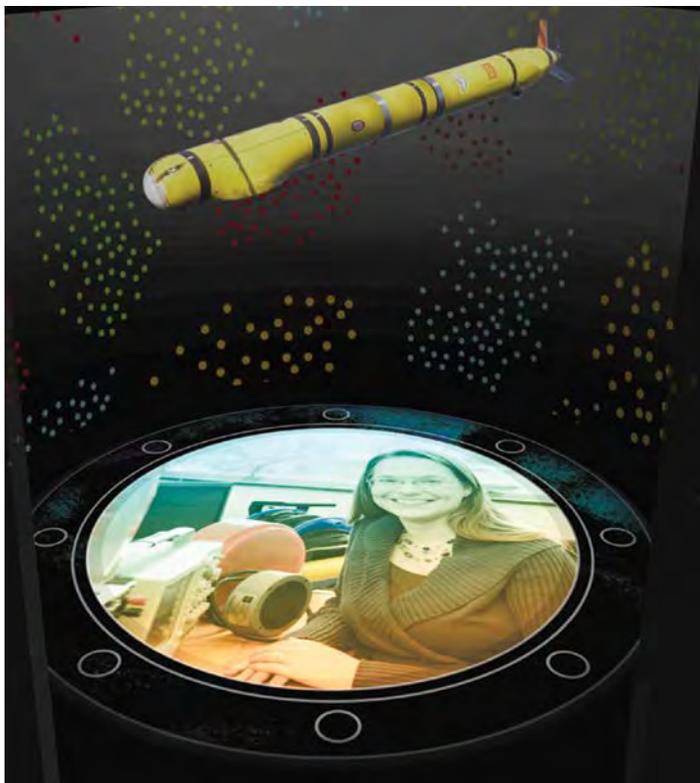


Figure 1. *Top:* a still frame from the virtual video of the Scientist at Work media installation used during the planning stages shows the model of the underwater robot used. *Bottom:* video shows the author narrating the video.

A few months later, Joann contacted me with a pitch about including my work as part of the exhibit. I asked a lot of questions! It was clearly going to be a significant time commitment, but the artists, educators, and exhibit specialists at the museum were engaging and creative. The team was working with much longer deadlines than any I had experienced in doing press or other outreach, and the scale of the potential audience was compelling. I couldn't say no. I was quickly set up with a team of storytellers including an exhibit writer, a documentary filmmaker, and an installation artist. They interviewed me several times by phone, each time getting deeper into the science, the technology, and the stories behind the data. Slowly, from these conversations came a compelling story about my work in midwater, acoustics, the technologies our team has been developing with collaborators, and my path in science. The communication team passed the storyboard and bullet points around, including me in the process of refining and framing until everyone was excited about it. Then, using fragments of the interviews they had recorded, they brought it to life in a

mock-up video that provided a visitor's eye perspective of the installation (**Figure 1**). After getting the sign-off from everyone, the team transformed this vision into reality.

In February 2018, a year into this effort, I spent an evening at the AMNH with other scientists who had contributed to the exhibit, the famed oceanographer Sylvia Earle, an artist, musicians, and dancers at a public event where we each shared our passion for the sea. As part of this celebration of the impending opening of the exhibit, our group of enthusiastic science nerds had the chance to walk through the nearly complete exhibit together (**Figure 2**). I was awed to see how the stories I knew, and many that I didn't, were pieced together into a journey through the ocean. There were opportunities for those at every level, literally and figuratively, to play and experience the ocean (**Figure 3**). Throughout, the process of discovery was woven into the stories of what we know, new technologies were on display, and a diverse range of scientists were profiled to help people imagine themselves in that role.

My part of the exhibit is fairly early in the journey through the "ocean." Connecting the shallow waters where plankton live to the deep sea is a layer of midwater animals that effectively scatters sound from sonars. These so-called "deep scattering layers" are extensive, covering the mesopelagic or



Figure 2. *Speakers at the Ocean Luminaries event at the American Museum of Natural History hamming it up in the exhibit just before its opening. Front row, left to right: Wallace Nichols, Kakani Katija, Kelly Benoit-Bird, and Tierney Thys; back row: John Sparks and Rashid Sumaila.*

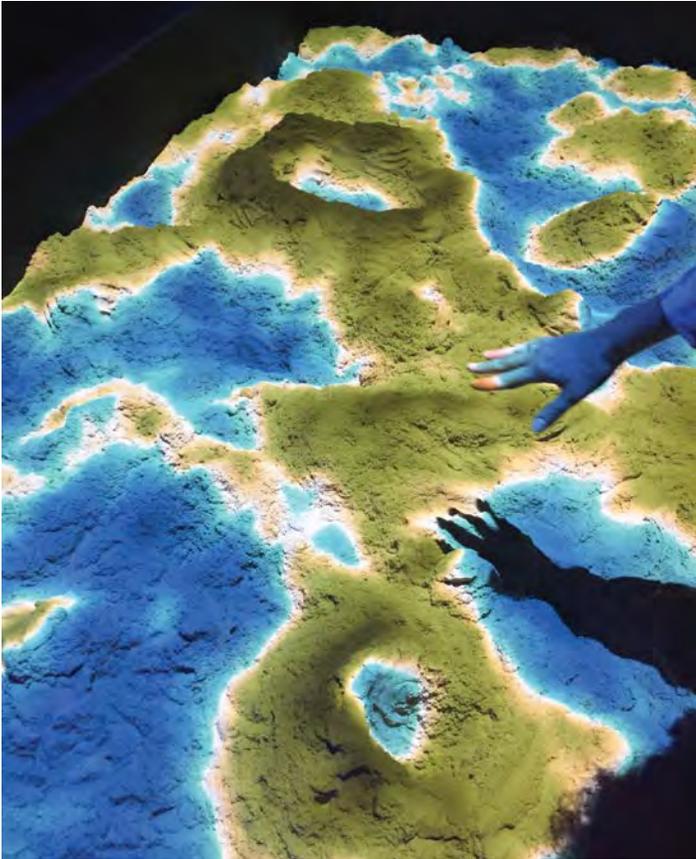


Figure 3. A scientist playing with kinetic sand that makes a dynamic seafloor map. As the sand is piled and dug into, it uses color to create a representation of a topographic map in real time.

midwater zone of entire ocean basins. Each night, these animals migrate hundreds of meters upward to hunt for food under the cover of darkness. This active conveyor belt of life plays an important role in the carbon pump that regulates the climate, and the animals serve as a critical food resources for many of the fish, including tuna and salmon, that end up on your dinner plate as well as for seabirds, seals, whales, and dolphins. Despite the large number of animals in these midwater layers, currently estimated at 10 billion tons, the mesopelagic zone is among the least investigated components of the open ocean ecosystem, largely due to the challenges of working in this deep, dark alien world. My colleagues and I developed a new approach, integrating traditional ship-based echosounders into a deep-diving autonomous vehicle that could take us into the layers to give us a fish eye or ear view (Moline et al., 2015). This allowed us to observe how animals were organized in midwater and, ultimately, to use sound to understand how predators find and use midwater resources while the mesopelagic zone animals avoid being

eaten. We learned that animals form groups to hide in open water (Benoit-Bird et al., 2017). This strategy is key to their survival but will also have large impacts on how impending fishing pressures impact the ecosystem. Through work like this, we are developing a better understanding of how animals and humans may compete for fish in the ocean in order to guide sustainable management.

To tell our story, the exhibit team developed a pod of sorts that welcomes the visitor with a model of our bright yellow underwater robot. On a scrim screen below the robot, a short video narrated by me explains the problem, how we came to a technical solution, the challenges we faced in the process, and the importance of the results. Dots representing animals rearrange themselves on the screen to show how our data has changed the view of organization in midwater as the back wall of the installation glows brightly, immersing you in our pointillist view of the mesopelagic zone (Figure 4). I was overwhelmed at seeing my research come to life in this multidimensional form. Experiencing my data in a way reminiscent of Tom Cruise's character in *Minority Report* interacting with complex information was remarkable and perspective altering. Thinking in four dimensions in a featureless environment is always a challenge for us terrestrial mammals as we venture into the ocean to understand its mysteries and, for just a second, I

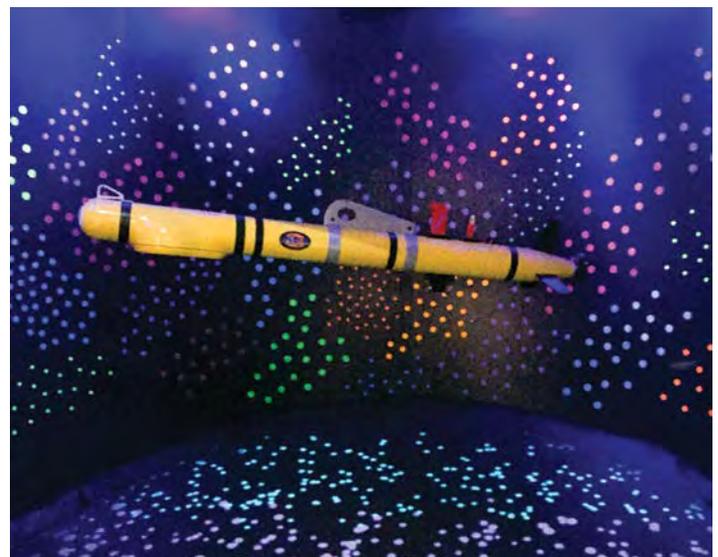


Figure 4. The installation lights up with dots that represent animals measured in our data, dynamically illustrating how our view of the organization of animals in the mesopelagic zone has been dramatically changed through measurements with new technologies, including the autonomous underwater vehicle represented by the model.

Unseen Oceans

was liberated from my disorientation. This science fiction turned visual reality proved the value of creative communication, not just to the intended audience but even to me, part of the team that generated the knowledge underlying the beautiful visualization.

Experiencing the exhibit along with a bunch of giddy scientists playfully exploring was fun. Having the opportunity to share my work with my family was incredible. Last summer, I entered the exhibit again, this time as a ticket holder with a dozen of my family members in tow. My 7-year-old's face lit up when he saw the replica of our robot down a corridor, and he animatedly chattered as he saw the stories I've told him come to life in a new way (Figure 5). One goal the designers had when conceiving the exhibit was to make the science and scientists real and approachable, allowing kids a chance to envision themselves involved in science. For my son, that isn't a big leap. But many children never have the opportunity to meet a scientist so each of the dozen or so individual profiles explains a little about their personal path. As I explain in the video piece of the exhibit, one of the challenges of being an oceanographer is that when you are out on a ship, you only have onboard the things that you've brought with you. What a gift it was to watch my dad, Bernard Benoit, surrounded by extended family, hear my voice explain that one of the greatest gifts I received is being the only child of a mechanic. I was always my dad's second set of hands and was introduced to tools and fixing things at a very early age. As the piece explains, it turns out that being a tinkerer is very useful as an oceanographer and that helped us overcome one of the biggest challenges of this project, the limits of existing technology.

The goal of the designers of the *Unseen Oceans* exhibit was that visitors would come in one way and leave another, using the space to tell the story, weaving together the narratives of science and scientist, organisms and environment into a dive from the surface to the deep, from what is familiar to what is extraordinary. The larger goal of *Unseen Oceans* is to take visitors from where they enter with a general interest in the ocean to caring about its stewardship to personal action to mitigate human impacts. The jury is still out on whether that journey was completed (evaluation of the effectiveness of the exhibit is currently underway), but so far, nearly 800,000 visitors have experienced this virtual descent into the depths of our planet. Countless classrooms have explored the companion materials of the exhibit, grade-level specific guides designed by educators to achieve science standards with



Figure 5. The author and her then 7-year-old son, Kaelan, start their journey to the bottom of the ocean while virtual waves lap their feet at the beginning of the Unseen Oceans exhibit at the American Museum of Natural History.

content provided and vetted by experts like me. Starting in August 2019, *Unseen Oceans* will make its way to new places in North America and Europe, introducing the importance of the ocean to human health to millions, some of whom may never visit its shorelines; the first stop is far from the coast in the Midwest of the United States!

I don't have to wait for assessment metrics to know my personal journey was a great success. Working in partnership with visual communicators and expert storytellers taught me a lot about my own work and about myself. It was fun to interact with the museum staff, challenging to be pushed to think about things in a new way and rewarding to share the results with others. Everyone on the team was dedicated to accuracy and respected my role in the process, making sure the outcome not only beautiful but informative. One member of the exhibit staff told me that she often wonders if she can be enough of a scientist to get things right and enough of

an artist to make sure people remember it. I wonder about that for myself. The scientist part comes naturally, but I'm learning how to incorporate the artistry and story that help people remember why the ocean matters. When the *Unseen Oceans* exhibit comes to a venue near you, I hope you'll find that it moves you through not just a voyage to the bottom of the sea but also a voyage of discovery and appreciation. It definitely moved me.

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