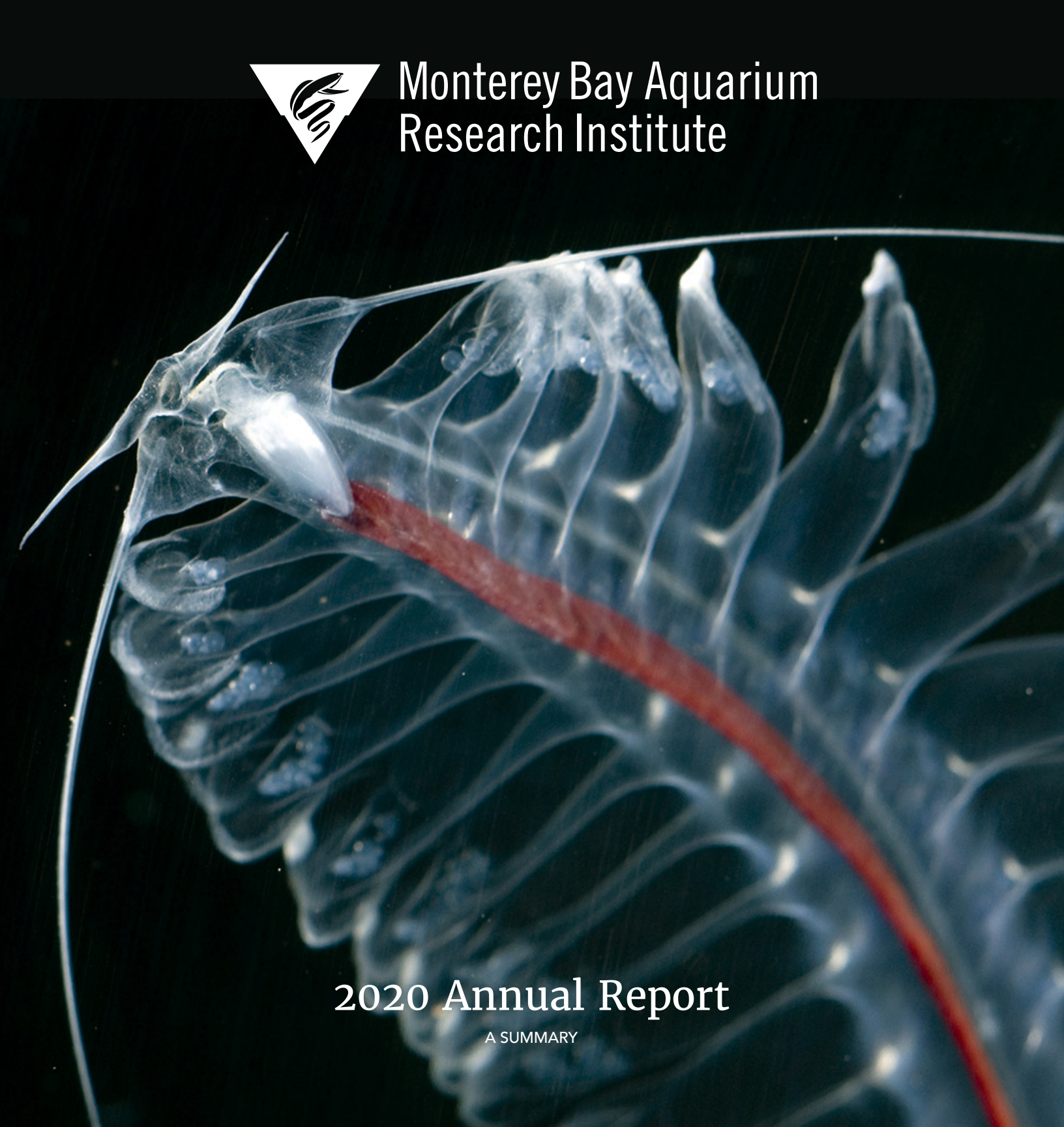
Monterey Bay Aquarium
Research Institute



2020 Annual Report

A SUMMARY

In previous years, MBARI has used a wide range of sensors and platforms to understand the ocean. In 2020, this ability to deploy autonomous platforms was even more important, with many field experiments continuing despite the pandemic.

annualreport.mbari.org/2020

Illustration by David Fierstein © MBARI 2019

Cover photo: *Tomopteris sp.* Photo by Rob Sherlock.

View from the Masthead

Advancing ocean science and engineering in a year like no other

It is often said that "necessity is the mother of invention," but at the dawn of 2020, I had no idea just how much that phrase would apply to the coming months.

Fast forward to the end of 2020 when, during a presentation to all staff, I remarked that the previous months had been more than a decade in the making, which I am sure seems paradoxical. I was referring to the fact that we had been working to craft and refine a vision for MBARI's future for many years to set the stage for the next generation of ocean scientists and engineers who will further MBARI's mission. Major issues, such as replacing the *Western Flyer* (our flagship research vessel), building new shoreside facilities, and drafting a staff succession plan are but a few of the elements of that emerging vision; 2020 was the timeframe we set to make key decisions on what direction MBARI would take in the years ahead. While the importance of this year was well known and long-anticipated from its outset, no one expected that it would unfold against the backdrop of a global pandemic.

This year, MBARI's ITD division worked remotely, along with most of MBARI staff.

Like all organizations, MBARI has contingency plans for meeting most imaginable challenges and emergencies, but we had no playbook for dealing with the emergence of COVID-19. Last March, in what seemed like the blink of an eye, MBARI's buildings had to be quickly shuttered, all sea-going activities stopped, and the staff sent home under a state-mandated shelter-in-place order as we, like everyone, tried to understand what exactly we were up against and how long the disruption would last. Months later, as summer set in, we were finally able to partially reopen and resume some operations, albeit under unprecedented conditions. And then came social upheaval, which brought into focus the systemic racism that plagues our nation, and record-breaking destructive wildfires that threatened communities surrounding MBARI. "Apocalyptic" was the word most often invoked to capture the essence of that moment.

Despite the gloom, despair, and angst that much of 2020 served, the challenges and setbacks also proved to be a surprising source of inspiration. As Wendy Schmidt, ocean champion and philanthropist, aptly remarked, "It morphed into an opportunity to make lemonade out of lemons." We found new ways of continuing our work at MBARI and with our colleagues from around the world. Video conferencing replaced in-person meetings and school. Travel largely stopped, but national and international workshops and meetings continued virtually—ironically making it possible for more people from more institutions to participate than may have been possible if gatherings were held in person. The United Nations launched the Decade of Science. We reaffirmed our commitment to diversity, equity, and inclusion.

MBARI staff deploy an LRAUV in the summer of 2020 during a global pandemic and local wildfire. Photo by Jared Figurski.

Brian Kieft, Brent Jones, and Brett Hobson recover a coastal profiling float from the R/V *Paragon* during the Summer 2020 CANON experiment. Photo by Brian Kieft.

Telepresence for reducing the number of people aboard ships became a new norm. And many of our long-term efforts to develop autonomous systems for observing the ocean proved their worth under circumstances we never imagined, giving us a tangible glimpse of the future.

This volume chronicles some of the achievements that we made during what is arguably one of the worst years in recent times. It reflects the resilience and resourcefulness of all of MBARI's employees—an incredible team from all corners of the institute who pushed ahead despite the barriers—all of whom were enabled by the Packard Foundation and other sponsors who sustain MBARI. I am proud of what we accomplished and the vision we are advancing for the institute. We succeeded in breaking new ground despite all of the challenges faced on professional and personal fronts. Monterey Bay and its contiguous waters continue to offer an unparalleled natural laboratory for fostering marine scientific and engineering advancements with global-scale applications.

As we await the end of the COVID-19 pandemic and return to some semblance of normalcy, I am more than optimistic that 2021 will be a far better year than the one we leave behind—not only for MBARI, but for the entire world. As I have said time and time again, and as the following pages clearly show, the age of ocean exploration and discovery is very much alive. There is no doubt that we have much more to learn about our ocean—the treasures it holds, the natural hazards it poses, the role it plays in sustaining all life, and the importance and urgency of protecting it for future generations. There has never been a better time to look to the sea for inspiration and solace, as well as for educational and employment opportunities.

Please join us as we look forward to better times and write the next chapter in MBARI's story. You can follow us by visiting our website and subscribing to our Facebook, Twitter, YouTube, and Instagram feeds. We love hearing from you and sharing our stories, and we are excited about the discoveries and adventures that lie ahead. See you on the water!

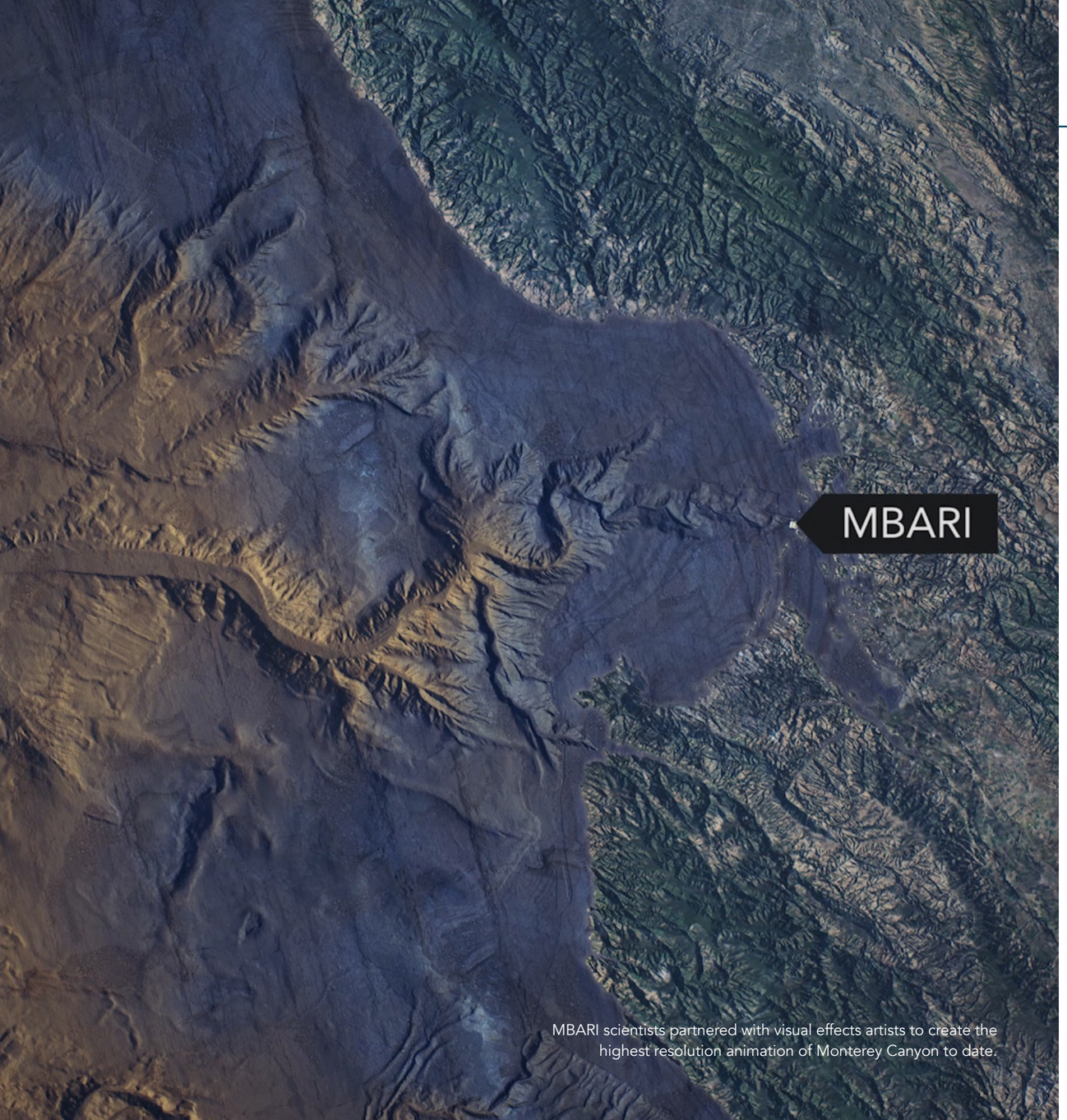
The Wave Glider floats on a calm Monterey Bay during the summer 2020 Monterey Bay area wildfires. Photo by Chris Wahl.

Chris Scholin

President and Chief Executive Officer

Related web content

Values Statement, Strategic Plan, and Technology Roadmap: www.mbari.org/about/vision



MBARI scientists partnered with visual effects artists to create the highest resolution animation of Monterey Canyon to date.

Transforming data points into pixels

Monterey Canyon is a magnificent submarine geologic feature rivaling the Grand Canyon in both size and beauty, but most people have never had a chance to see its majesty. This year, MBARI merged art with science to reveal the stunning topography of the geologic feature sitting right in our backyard.

Our seafloor mapping team realized that while MBARI's strength is gathering detailed mapping data at various high resolutions, an external partner would be essential for integrating those datasets into an immersive visualization. Enter Frame 48, a post-production company based in Los Angeles that typically works in film and television. Frame 48 used a platform designed for building video games so that animators could add lighting, texture, and camera movements in real-time. Great care was taken on details that would bring the canyon to life, down to the color of the sediment and the striations in the canyon walls.

The animation flies viewers out over Monterey Bay and through the canyon's main axis, providing educators, scientists, and science communicators with an invaluable tool to give Monterey Canyon the close-up it deserves. In addition to capturing the canyon's raw scale and grandeur, the animation sheds light on some of the battle scars carved into this feature over millions of years of geologic transformation.

Read the full article

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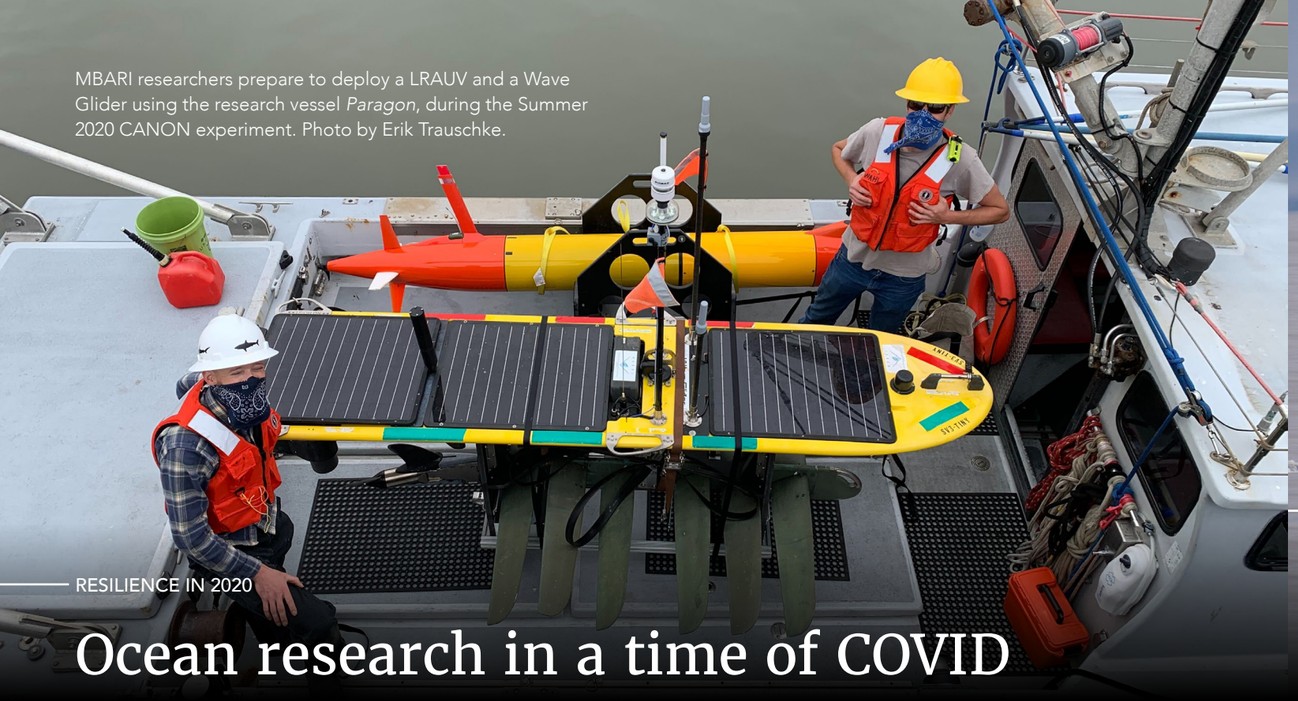


MBARI researchers prepare to deploy a LRAUV and a Wave Glider using the research vessel *Paragon*, during the Summer 2020 CANON experiment. Photo by Erik Trauschke.

RESILIENCE IN 2020

Ocean research in a time of COVID

Decades of developing tools to remotely study the ocean truly paid off in 2020 when the COVID-19 pandemic put a stop to most traditional seagoing research. At the same time, the institute made major adjustments to get ships back out to sea as quickly as possible.

MBARI was forced to swiftly suspend all seagoing operations in mid-March. That decision ultimately paled in comparison to the challenge of restarting operations months later.

To continue operations under pandemic guidelines, MBARI settled on a three-pronged approach. First, ship access was restricted to employees only. Second, a new telepresence capability was created to allow for virtual participation in scientific expeditions. Lastly, a routine testing protocol was devised to screen cruise participants for possible COVID infections.

Together with a detailed return-to-sea policy that established well-defined guidelines and procedures, those actions allowed MBARI to resume ship operations safely even as the pandemic persisted. In addition, some science programs continued to rely on a range of robotic and autonomous instruments—a long-time focus of MBARI engineering efforts—that allowed work to continue without the risk of spreading infections.

Researchers place a temporary tag on a blue whale to record its movement and vocalizations. Image by James Fahlbusch of Stanford University under NMFS research permit 1611.

BLUE WHALE SONGS

Listening and learning from blue whale songs

Blue whales are the largest animals on Earth, and their booming vocalizations travel hundreds of kilometers underwater. Researchers from MBARI, Stanford University, and other institutions have revealed a link between blue whale singing and other behaviors. By listening carefully to singing male whales, researchers can hear when the regional blue whale population transitions from foraging to migration.

MBARI technology and research have been instrumental in understanding the depths of blue whales' lives. Sounds in the ocean are recorded with a digital broadband hydrophone installed on MBARI's cabled observatory 900 meters (3,000 feet) below the surface of Monterey Bay. MBARI and collaborators use signal processing and machine learning to sift and sort the deluge of data from the hydrophone, about 24 terabytes per year. Little instrument, big data.

The ability to acoustically detect population-level transitions in behavior provides a revolutionary tool for studying the life history of a dispersed population of whales. Critically, this research also has implications for safeguarding an endangered marine mammal. For instance, real-time detection of the acoustic signature of migration can provide warnings to ship captains to take precautions that can reduce the risk of fatal collisions that threaten these gentle giants.

The depths of the ocean sit in perpetual midnight, yet life still thrives here. MBARI's submersibles are revealing the residents of the midnight zone, like this black-eyed squid (*Gonatus* sp.).

Finding resilience—and relaxation—in the midnight zone

Between a global pandemic and scorching wildfires, nature's unyielding power ravaged California's Central Coast in 2020. In the face of such awesome forces, we found hope and inspiration in the depths of Monterey Bay.

To humans, the deep sea is one of the most inhospitable environments on Earth. Below 1,000 meters (3,300 feet), temperatures hover just above freezing, distance from the surface extinguishes all sunlight, and pressure mounts—welcome to the midnight zone.

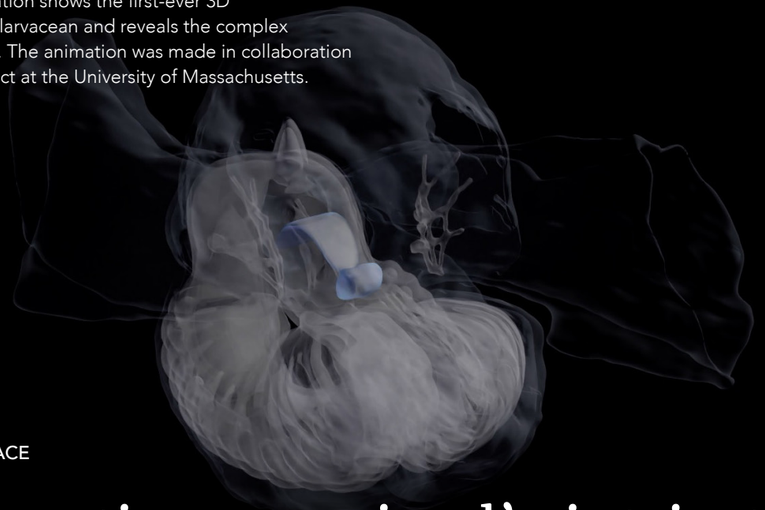
Remarkably, despite these difficult conditions, the midnight zone supports a dazzling diversity of life. Countless invertebrates and fishes make their home in these dark waters. Our scientists, engineers, and ROV pilots are constantly amazed by the curious creatures we encounter there. When life on land feels overwhelming, we find peace surveying the midnight zone.

Thanks to social media, we've helped audiences around the world escape into the midnight zone. We've leveraged our archive of high-definition video to connect to our followers on YouTube, Instagram, Twitter, and Facebook. Our Deep Relaxation series on YouTube invites us to slow down the pace of our busy lives with stunning footage of octopuses and big red jellies. We've also shared guided meditations to help our followers de-stress during these tumultuous times.

Through these channels, we hope others will be as awestruck as we are by the resilience of life in the midnight zone.

Read the full article

annualreport.mbari.org/2020/midnight-zone



This frame from an animation shows the first-ever 3D reconstruction of a giant larvacean and reveals the complex structure of its inner filter. The animation was made in collaboration with the Digital Life Project at the University of Massachusetts.

BUILDING A SNOT PALACE

Reconstructing an animal's intricate feeding filter

Many animals build complex mucous structures for feeding, health, and protection. Now, a unique laser-based system developed at MBARI makes it possible to create detailed models of these delicate structures and the animals that build them. This will help researchers better understand how the filters function and what roles they play in the ocean.

Initial use of this instrument, called the DeepPIV (PIV stands for particle imaging velocimetry), has allowed a three-dimensional reconstruction of the complex mucous feeding filters built by deep-sea animals called larvaceans. Larvaceans, which are abundant throughout the world ocean, remove vast amounts of carbon-rich food and microplastics out of the surrounding water. When a mucous filter becomes clogged, the animal releases the entire filter, which sinks rapidly to the seafloor.

The DeepPIV projects a sheet of laser light that illuminates particles in the water. By recording the movement of these particles on video, researchers can quantify tiny currents around marine animals, as well as water flowing through their filters and their transparent bodies. By assembling a series of these cross-sectional images, the team was also able to create three-dimensional reconstructions of individual larvaceans and their filters.

Some of the midwater animals that could be affected by deep-sea mining include squids, fishes, shrimps, copepods, medusae, filter-feeding jellies, and marine worms. Photos © E. Goetze, K. Peijnenburg, D. Perrine, Hawaii Seafood Council (B. Takenaka, J. Kaneko), S. Haddock, J. Drazen, B. Robison, DEEPEND (Danté Fenolio), and MBARI.

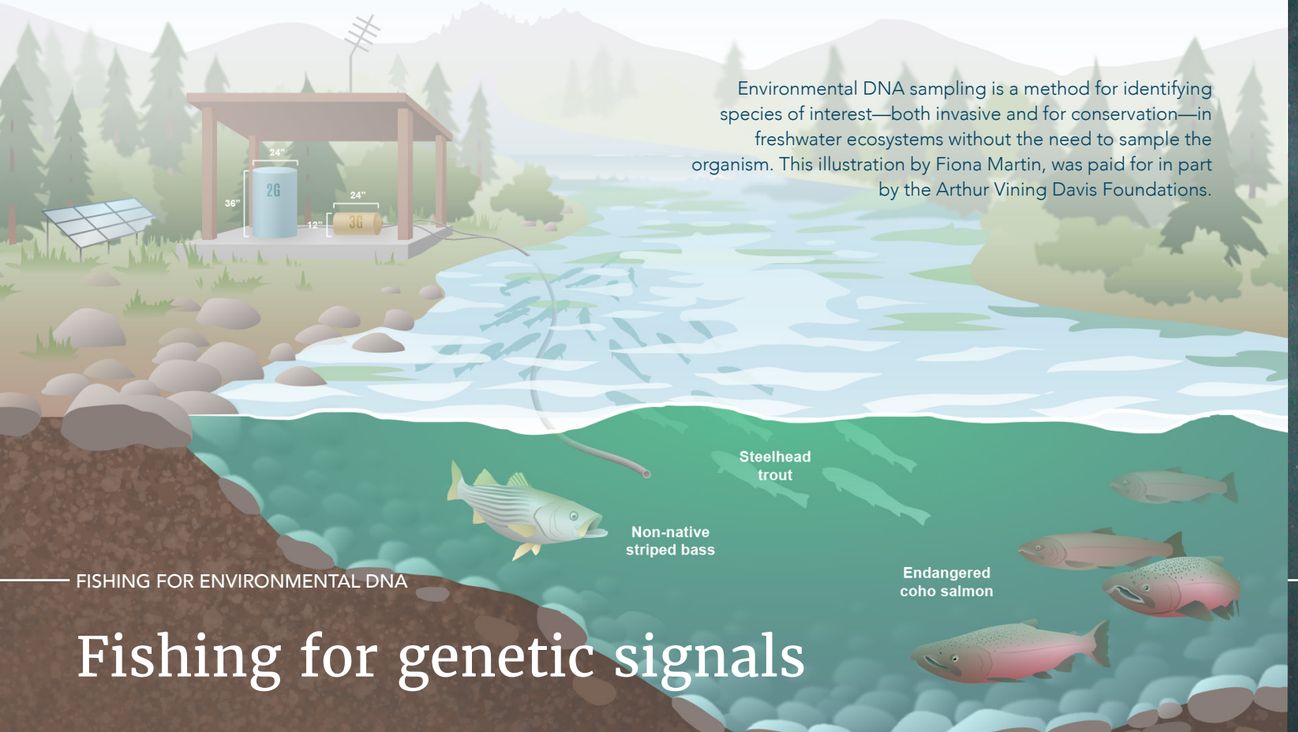
SEAFLOOR MINING IMPACTS

Deep-sea life is threatened by seafloor mining

Interest in mining the deep seafloor for copper, cobalt, zinc, manganese, and other valuable metals has grown substantially in the last decade. Metallic nodules are scattered on the seafloor in some areas. Elsewhere, precious metals valuable to the technology industry are found in hydrothermal chimneys. These finds have created a gold rush of sorts in the deep sea.

But harvesting this treasure could harm another natural treasure—the rich abundance of life on the deep seafloor and in the water column above. The deep midwaters of the world ocean make up the largest habitat on Earth. They contain 100 times more fish than the annual global catch, connect surface and seafloor ecosystems, and play key roles in climate regulation and nutrient cycles.

Most research assessing the impacts of mining and baseline survey work has focused on the seafloor and the habitat immediately adjacent to extraction activities. Scientists worldwide are pressing for a more comprehensive study of the risks, expanded midwater research efforts, and adoption of precautionary management measures now to avoid harm to deep midwater ecosystems from seabed mining.



Environmental DNA sampling is a method for identifying species of interest—both invasive and for conservation—in freshwater ecosystems without the need to sample the organism. This illustration by Fiona Martin, was paid for in part by the Arthur Vining Davis Foundations.

FISHING FOR ENVIRONMENTAL DNA

Fishing for genetic signals

Fish leave behind tiny clues pointing to their presence long after they swim away. These sloughed-off cells, waste, and tissue combined with free DNA, algae, and microscopic organisms make up a genetic soup of environmental DNA (eDNA), a kind of fingerprint that can be used for smarter freshwater management.

MBARI's Environmental Sample Processor (ESP) samples and archives eDNA so that researchers can see a series of biological snapshots from an aquatic system. One ESP recently collected more than 900 samples during a year-long test using eDNA to monitor a freshwater stream near Santa Cruz, California. Another version of the instrument, mounted inside an autonomous underwater vehicle, has been used to monitor harmful algal blooms in the Great Lakes. These efforts lead to informed, proactive solutions, whether in terms of managing a fish stock or in making smarter decisions about city water supplies.

MBARI's ESP technology is poised as the instrument that will bring eDNA analysis to broad applications in monitoring aquatic systems. Its ability to maintain a persistent presence with minimal in-person maintenance and resources makes it an economical long-term tool.

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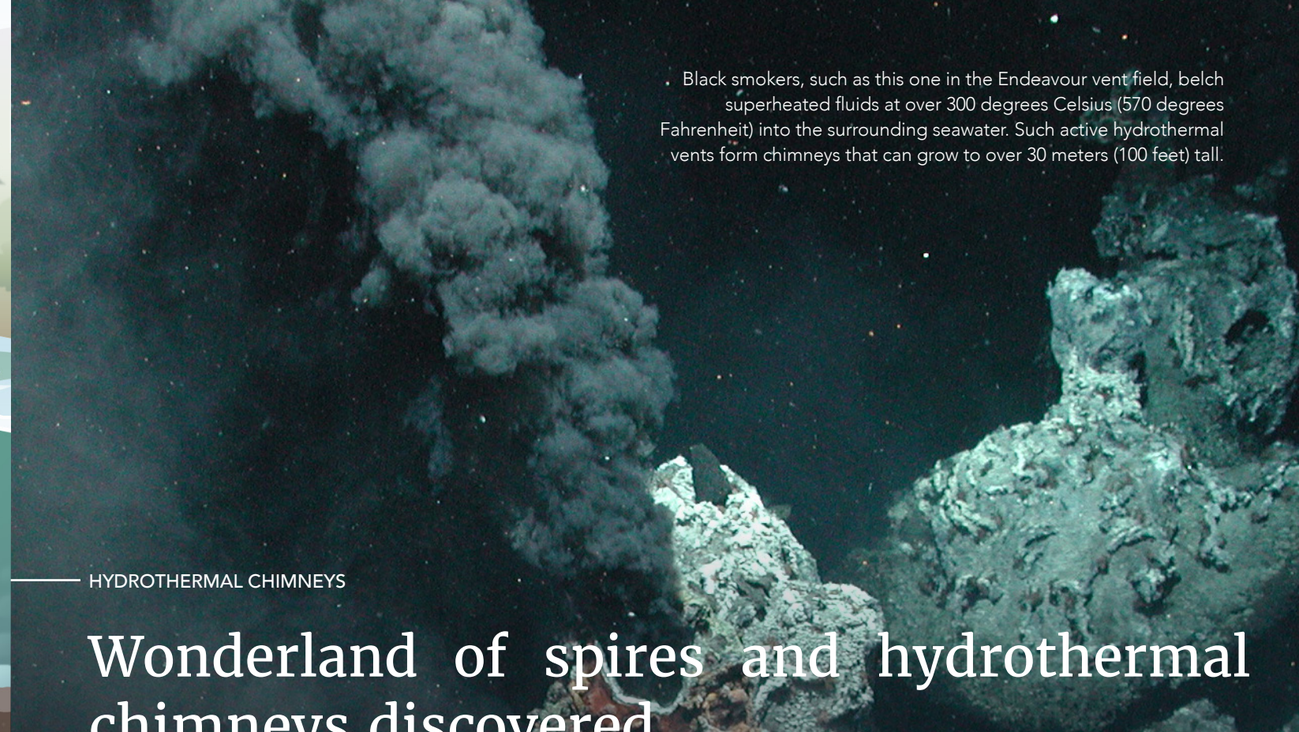

Black smokers, such as this one in the Endeavour vent field, belch superheated fluids at over 300 degrees Celsius (570 degrees Fahrenheit) into the surrounding seawater. Such active hydrothermal vents form chimneys that can grow to over 30 meters (100 feet) tall.

HYDROTHERMAL CHIMNEYS

Wonderland of spires and hydrothermal chimneys discovered

Advanced deep-sea mapping technology has enabled the discovery of hundreds of hydrothermal chimneys on the seafloor off Washington State's coast. Researchers were amazed to find 572 chimneys, many more than had been known, even though many of them were close to vent sites that had been studied for decades.

Although scientists had previously found many vents and chimneys at the Endeavour Segment of the Juan de Fuca Ridge, early surveys did not have high enough resolution to detect individual chimneys over large areas of the seafloor. It was not until MBARI's autonomous underwater vehicle (AUV) *D. Allan B.* mapped the area at high resolution that geologists were able to see the plethora of spires and chimneys in the Endeavour area. The AUV conducted 140 hours of dives and mapped about 62 square kilometers (24 square miles) of the seafloor in this area.

The AUV mapping data revealed many large and, presumably, active chimneys, the tallest being at least 27 meters (90 feet) high. Most are much smaller and presumably inactive.

annualreport.mbari.org/2020/hydrothermal-chimneys

On the Horizon

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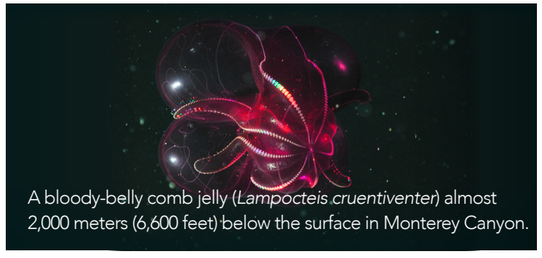


A bloody-belly comb jelly (*Lampocteis cruentiventer*) almost 2,000 meters (6,600 feet) below the surface in Monterey Canyon.

Into the deep

For the first time in nearly 20 years, a collection of rarely seen deep-sea animals will be the centerpiece of an exhibition at the Monterey Bay Aquarium. This breathtaking exhibition is made possible by partnering the Aquarium's animal-care expertise with MBARI's technology and scientific knowledge.

Visitors may come face-to-face with bloody-belly comb jellies, delicate larvaceans, and feathery sea stars in an exhibition designed to connect people with this unseen but significant habitat. The deep sea faces the same threats as the rest of the ocean—fishing pressure, habitat destruction, plastic pollution, and climate change—but is less resilient to those kinds of disturbances.

Into the Deep: Exploring our Undiscovered Ocean is set to open in the spring of 2022.

Telepresence gives us the opportunity to connect people around the world with MBARI research at sea. Photo by Duane Thompson.

Telepresence effort to connect scientists and citizens

When the COVID-19 pandemic limited participation aboard MBARI research vessels, a team of technicians, engineers, and researchers created a compact telepresence solution for use on both the R/V *Western Flyer* and R/V *Rachel Carson*, so that researchers could participate remotely.

This new telepresence capability has presented an exciting outreach opportunity. In 2021, MBARI will produce two ship-based livestream events from the *Western Flyer* for classrooms and the general public. The focus will be on MBARI's ongoing research efforts at Sur Ridge and will contain a mix of live video captured by the remotely operated vehicle *Doc Ricketts* as well as pre-produced content.

Looking ahead, MBARI is excited to invest in new ways to achieve ship-based research virtually and communicate ocean discoveries to a broader audience.

Ocean-going monitoring floats like this one are deployed from "ships of opportunity" as they transit the ocean. Image courtesy of SOCCOM (NSF Award PLR-1425989).

500 new floats to expand global ocean monitoring program

A $53 million grant from the National Science Foundation will make possible a new fleet of 500 robotic floats for monitoring global ocean health, which is key to the health of all life on Earth. Chemical and biological sensors on these floats will collect observations between the surface and a depth of 2,000 meters (6,560 feet).

Data from the floats will be made freely available for use by researchers, educators, and policy makers around the world. These data are used to monitor the growth and respiration of phytoplankton and long-term changes in the ocean, including ocean acidification and the expansion of low-oxygen zones.

MBARI will coordinate the new program, called the Global Ocean Biogeochemistry Array, and will work closely with the University of Washington, the Scripps Institution of Oceanography, the Woods Hole Oceanographic Institution, and Princeton University.

MBARI's M1 oceanographic mooring, located near the mouth of Monterey Bay. Photo by Todd Walsh.

Using DNA to unlock the story of life in Monterey Bay

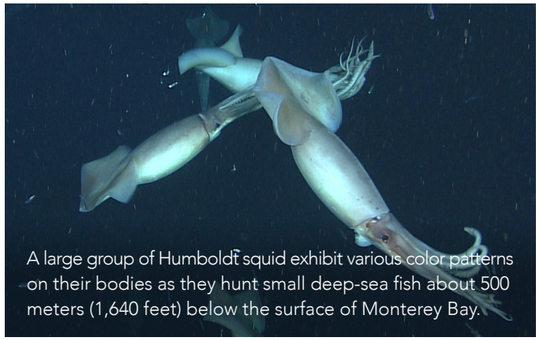
Researchers recently unlocked a treasure trove of biological data by applying new technology to long-archived samples from time-series sites in Monterey Bay. The samples, originally intended for phytoplankton studies, also captured the sloughed-off cells, waste, and free DNA from organisms passing through the water.

By analyzing this environmental DNA (eDNA), researchers found that dramatic shifts in community composition were closely related to various climate indices tracked through physical data. The results are promising for understanding the importance of Monterey Bay as a window into larger trends along the coast.

Now the team is looking to analyze additional archived samples in hopes of further linking biological changes to physical changes. Samples will also be collected farther offshore in 2021 to understand how community composition shifts over spatial scales.

Weird and Wonderful

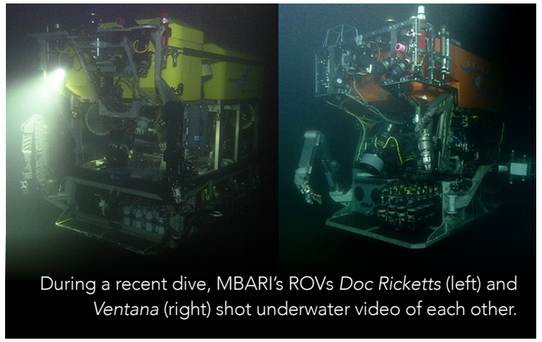
Read the full articles
annualreport.mbari.org/2020/weird



A large group of Humboldt squid exhibit various color patterns on their bodies as they hunt small deep-sea fish about 500 meters (1,640 feet) below the surface of Monterey Bay.

The secret language of Humboldt squid

Humboldt squid (*Dosidicus gigas*) are formidable predators whose group foraging behaviors often resemble a feeding frenzy. Despite this free-for-all appearance while feeding, Humboldt squid generally avoid direct contact or physical competition for prey. MBARI researchers suggest that, as they hunt, these squid communicate with each other using changing patterns of light and dark pigments on their skin. The squid exhibit changing color patterns most often when they are interacting with one another in groups. These changes in pigmentation may be an effective means of communication, analogous to humans using turn signals in traffic. Though the meaning of the signals remains unknown, this research suggests that Humboldt squid use changes in body patterns as a consistent and effective means of communication in the deep.



During a recent dive, MBARI's ROVs *Doc Ricketts* (left) and *Ventana* (right) shot underwater video of each other.

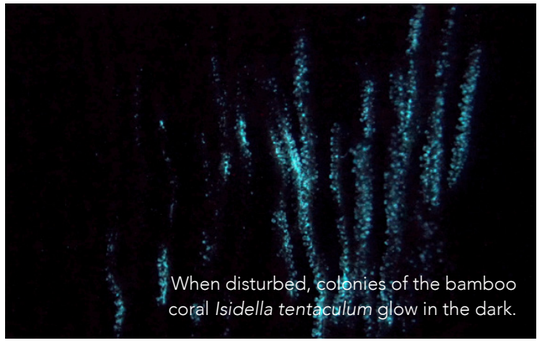
Dueling ROVs: Filming robots in Monterey Bay

MBARI's marine operations staff and remotely operated vehicle pilots performed an intricate underwater robot ballet 650 meters (2,000 feet) below the surface of Monterey Bay. Their goal was to capture underwater footage of MBARI's two large ROVs for future video productions by MBARI and the Monterey Bay Aquarium. Having one robot record another robot sounds simple, but this was an extremely challenging operation. From the surface above, ROV pilots aboard our two research vessels controlled this delicate robotic dance—being careful to avoid tangling the tethers that connect each submersible to the ship. Fortunately, the expedition went swimmingly, and the recorded video will be used for years to come.

MBARI's Creature feature page highlights some of our most iconic deep-sea critters, like the flapjack octopus, *Opisthoteuthis* sp.

Creature features and splashy stickers

As we explore the deep sea, our researchers often discover lifeforms that we've never seen before. But some animals—either for their wacky shapes, splendid colors, or their bizarre lifestyles—remain long-standing staff favorites. With the help of a science communications intern and fellow this summer, we featured some of the deep sea's most iconic critters on our "Creature feature" web page and social media sticker giveaway campaign. Local Monterey artist Emily Hess created original illustrations for the first-ever MBARI stickers, highlighting some of the most memorable and lovable deep-dwellers. They have proven very popular with our social media followers! Find exclusive imagery and information about how each animal thrives in the deep ocean on our Creature feature page.



When disturbed, colonies of the bamboo coral *Isidella tentaculum* glow in the dark.

Glow in the dark corals

A team of MBARI researchers filmed the dazzling light displays (bioluminescence) of various deep octocorals—soft corals, sea pens, and gorgonians—in their habitat for the first time. Working with our remotely operated vehicle (ROV) pilots, the scientists were able to equip the ROV *Doc Ricketts* with an extremely light-sensitive camera. Many bioluminescent species only glow when disturbed, so the researchers filmed the animals while gently touching them with the ROV's manipulator arm or a soft paintbrush. They found that several of the most common deep-sea corals can create their own light, including a number of groups not previously known to glow. Before this study, biologists already knew that some octocorals exhibited bioluminescence. But this research suggests that octocorals evolved the ability to glow very early in their evolutionary history.

In Memoriam

Awards

Frank Press

Former MBARI Board Member

A noted geophysicist and former member of MBARI's Board of Directors served on MBARI's Board from 1995 to 2004. From 1981 until 1993, Press served as president of the National Academy of Sciences, and in 1994 he was awarded the National Medal of Science. Shortly afterward he joined MBARI's Board of Directors. In 2004, MBARI researchers named a newly discovered species of deep-sea worm in his honor.

mbari.org/frank-press

Paul Tucker

Long-time MBARI Employee

Paul was at MBARI for nearly 24 years, retiring in September 2017. Paul worked just about every job on our vessels, including ROV pilot, deckhand, oiler, engineer, relief mate, and relief master. After that, Paul worked onshore, as an electro-mechanical technician in Facilities, for five years before leaving MBARI. Paul's energetic, enthusiastic, and friendly demeanor brought joy to many of us throughout the years.

mbari.org/paul-tucker

Kelly Benoit-Bird

Medwin Prize in Acoustical Oceanography

Acoustical Society of America

Bruce Robison

Honorable Mention in a film Robison narrated *Cephalopods: Aliens of the Deep*

Jackson Wild Media Awards

Darrin Schultz

Honorable Mention

Student presentation at the Deep-Sea Biology eMeeting

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Hopkins Marine Station,
Stanford University

John Zicker
Chief Data Scientist at conDati, Inc.

MBARI

Funded by the David and Lucile Packard Foundation, MBARI (Monterey Bay Aquarium Research Institute) is a private non-profit research center that conducts fundamental research and technology development in the ocean sciences. The overarching goals of MBARI are to develop innovative technologies for exploring and understanding the ocean and sharing the knowledge and solutions gained with the global science and conservation community as well as the general public.

MBARI's i2MAP autonomous underwater vehicle conducts video surveys of animals in the upper kilometer of the water column in Monterey Bay.

Photo by Kelly Benoit-Bird

Back cover: Aerial view of the research vessel *Rachel Carson* at sea. Photo by Todd Walsh © 2014 MBARI

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