The Call of

NEW FRONTIERS IN MARINE MAMMAL ACOUSTICS

The mysterious creatures knew nothing of the commotion they would cause the humans nearby. Going about their business, the animals had spent much of the morning emitting rapid clicking sounds in their daily quest for squid in the dark recesses of the sea.

Known as beaked whales, these charcoal-gray marine animals spend most of their time at great depths, partially explaining why they are one of the planet's least examined mammals and a rare treasure for human eyes.

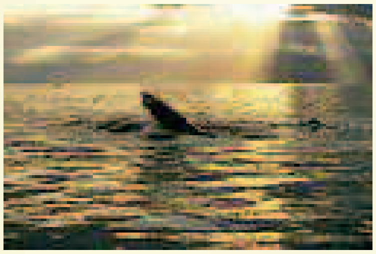
Since sunrise, a team of dedicated marine mammal observers on the Scripps Institution of Oceanography research vessel *Robert Gordon Sproul* had been scanning the glassy blue waters of the Gulf of California, also known as the Sea of Cortéz, for beaked whales and other marine mammals. For most people, the warm tropical air and water temperature would have been the makings for a laid-back vacation in one of the most beautiful destinations in the world.

the Whale

BY MARIO C. AGUILERA

But this was not a pleasure cruise. So when a pair of beaked whales emerged from the depths and broke the calm surface waters off Mexico's Bahia de los Muertos, or Bay of the Dead, the pulse of the vessel sprang to life. On one side of *Sproul*, three whale observers moved into position to keep the whales in their sights. They rapidly documented the time, precise GPS coordinates, the ship's distance and angle to the animals, and other facts for the marine mammal sighting log sheet.

At the same time, in a small shipboard laboratory, the beaked whales thrust another group of scientists into a state of optimistic excitement. They hoped to be the first to precisely track and record the animal's calls over long periods. The calls, an uneven series of clicks and clacks that sound like finger snaps, are sounds that few people—including whale experts—have ever heard, because of the difficulties of studying these elusive creatures. For John Hildebrand and his team of Scripps researchers who



study sea animal sounds, this was the next paragraph in the latest chapter of a new and quickly evolving scientific frontier called marine mammal acoustics.

If a curious series of events had not unfolded more than a decade ago, there is little doubt that Hildebrand would be far from the Gulf of California and marine mammal studies.

UNWELCOME NOISE

After studying undergraduate physics and electrical engineering at the University of California, San Diego, and receiving a doctorate degree from Stanford University, where he developed an acoustical microscope, Hildebrand hit his career stride investigating earthquakes at places where Earth's tectonic plates spread apart along the deep seafloor.

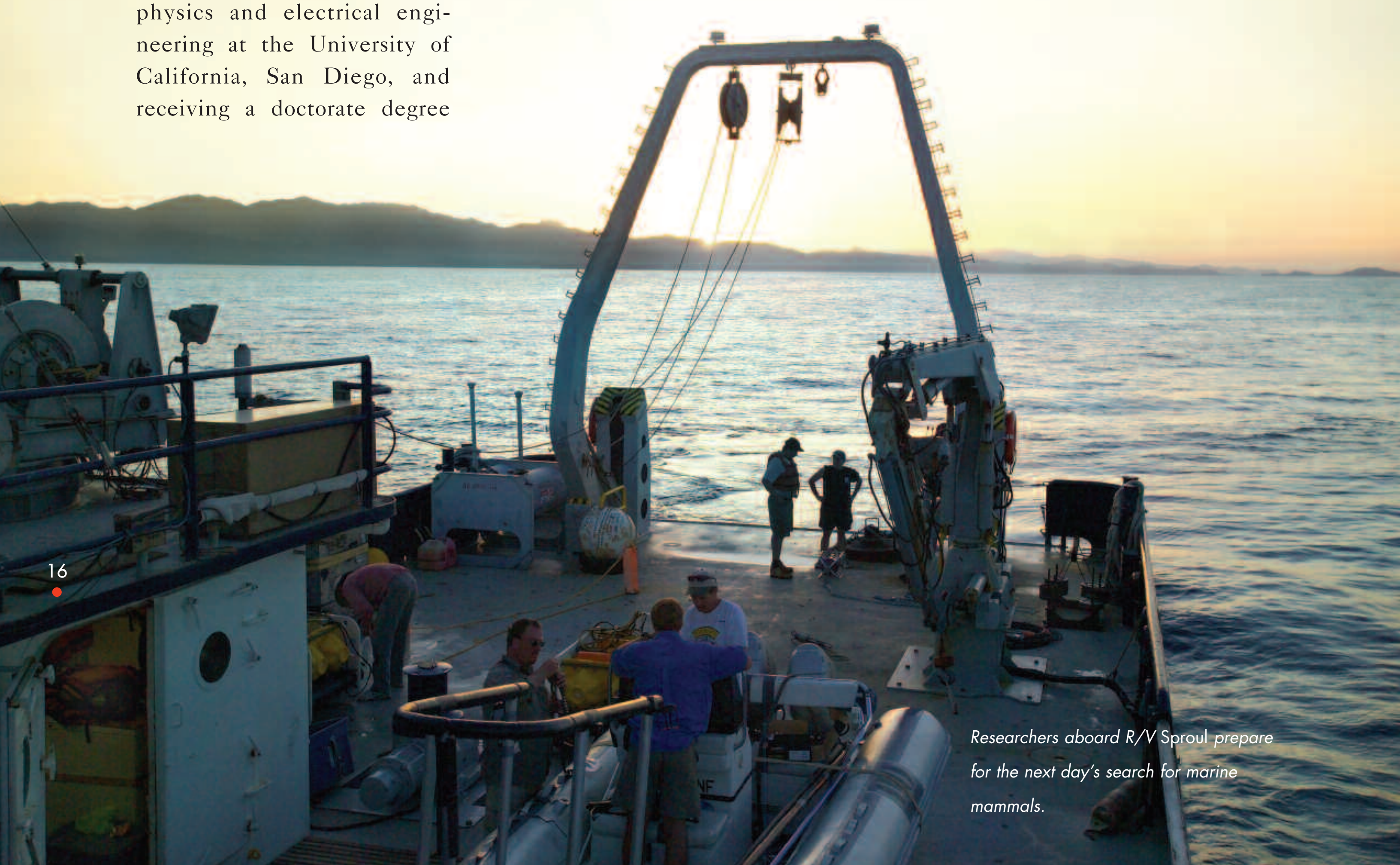
It was while Hildebrand was employing an array of acoustic listening devices at the Juan de Fuca Ridge off the Pacific Northwest coast that his research changed course. As he and graduate student Mark McDonald recorded earthquake signals beneath the seafloor, they also inadvertently recorded a wealth of whale communication sounds.

"I considered it just noise and I had zero interest in these sounds at the time," Hildebrand said. "I knew the sounds were there, but they were getting in the way of studying earthquakes."

McDonald, on the other hand, considered the signals an interesting intrusion and conducted follow-up research. He determined that the sounds were the communication calls of fin whales, one of the largest animals on Earth. Then he went one step further and plotted the calls using a software program that tracked earthquakes. Looking back, Hildebrand says had he known about this, he probably would have discouraged McDonald from this extracurricular research.

McDonald eventually worked the serendipitous information into his doctoral thesis, which became part earthquakes and part whales.

"Mark showed that these fin whales swam several kilometers apart, yet they were behaving in a coordinated fashion," said Hildebrand, an oceanographer at the Scripps Marine Physical Laboratory. "The fascinating thing is that they were synchronizing their breathing and there was no way they could see each other. They were communicating with a sequence of calls in a controlled,



Researchers aboard R/V Sproul *prepare for the next day's search for marine mammals.*

polite kind of way. Animal A would call. Animal B would call. Animal C would call. Then animal A would call again. Eventually the call sequence would stop and they would all come to the surface in unison to take a breath."

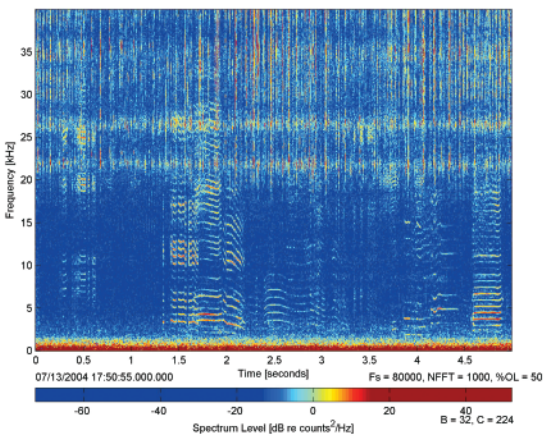
Hildebrand says that McDonald's interest "just pulled me into" the study of marine mammal acoustics. Hildebrand was unaware at the time that lying before him was a largely untapped and emerging field of science. "Neither Mark nor I realized how interesting this was going to become."

MAKING CONTACT

"There!"

Outside the bridge of *Sproul*, Annie Douglas from Cascadia Research, a research and education organization based in Olympia, Washington, has spotted a group of killer whales. She points excitedly in a northwesterly direction, alerting colleague Robin Baird via shortwave radio of the sighting. Baird is on a small, rigid hull-inflatable boat that allows him to make close contact with the animals.

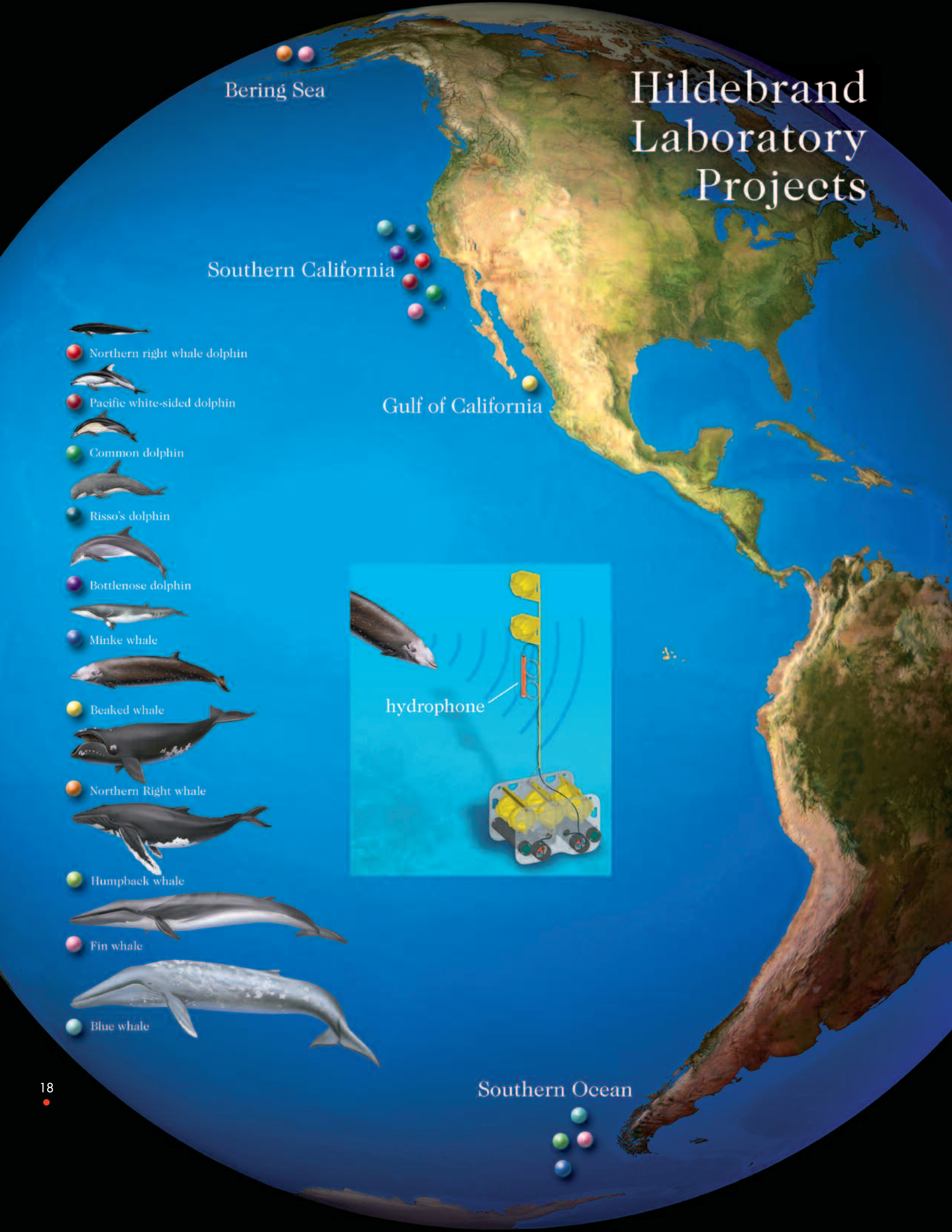
With the aid of a long pole and a suction device, Baird and colleague Greg Schorr attempt to attach tags to the whales to measure sea temperature, depth, and light levels. Data from the tags will help Cascadia researchers analyze the diving behavior and ecology of the animals. Successfully tagging a killer whale is a first for them in this region.

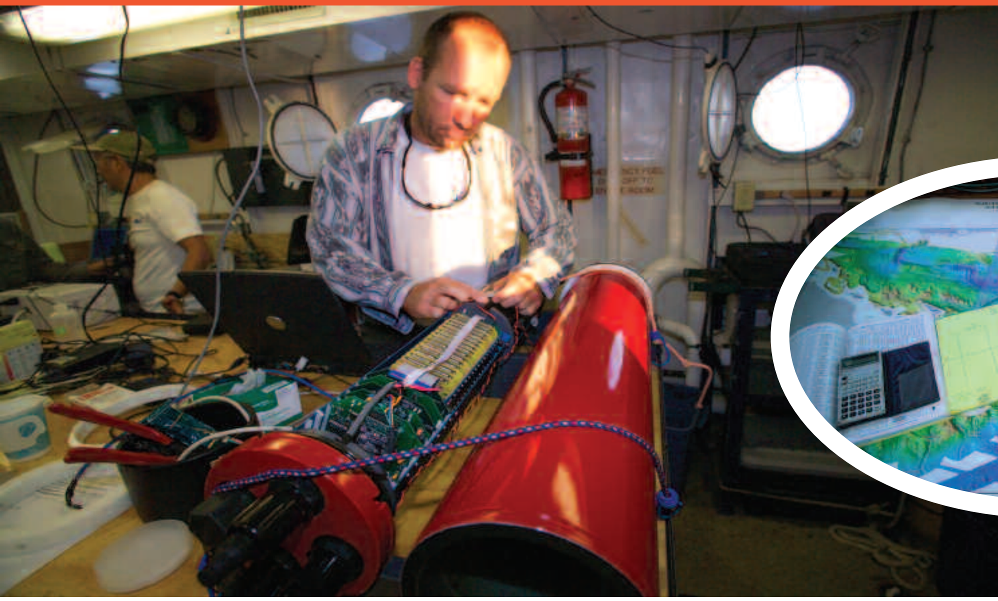


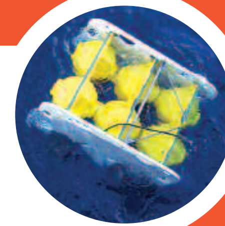
Above, *Scientists use a color-coded spectrogram to analyze the nuances of recorded animal sounds.*

Above, *After an animal has been spotted, John Hildebrand prepares a sonobuoy instrument for deployment.* **Below,** *Sean Wiggins (left) Jessica Burtenshaw, and John Hildebrand inspect a just-recovered high-frequency acoustic recording package.*

Hildebrand Laboratory Projects







With the sighting alert from the bridge, Hildebrand and his group jump into action. They use a variety of instruments to record animal sounds, from the newly developed to the alternately adapted to the tried and true. At their core is an underwater microphone called a hydrophone that converts sound energy into electrical signals.

For this expedition, Hildebrand's group makes use of several different hydrophone packages. Some are tethered behind the ship and capture sound signals as the vessel plods through the sea, relaying information directly to onboard computers. Others are deployed off a second inflatable boat, an improvised but necessary tactic developed on this trip in order to capture sounds not contaminated by the ship's engine noise.

Other hydrophones are tossed overboard within mobile, expendable instruments known as sonobuoys. When the instrument hits the water, a balloonlike float deploys as the hydrophone sinks to a specified depth. A radio transmitter wired from the hydrophone to the surface relays the data back to the ship.

But the true bread-and-butter of the Hildebrand research operation is the acoustic recording package, or ARP. With this device, Hildebrand's group is exploring uncharted waters in marine mammal acoustics.

Opposite page, *Illustration displays location and types of marine mammals studied by members of John Hildebrand's laboratory.* **Inset of illustration,** *The hydrophone of a high-frequency acoustic recording package records a sequence of whale calls.* **Above,** *Humpback whales in the North Pacific Ocean.*

CAPTURING THE SOUNDS

After the Juan de Fuca experience with fin whales, Hildebrand's interest in marine mammal acoustics blossomed exponentially. The whale sounds that were once "noise" quickly became precious gems of research data. He learned that long-term acoustic recordings could capture the various moans, clicks, whistles, and songs of whale communication and allow researchers to better understand whale habitats, population sizes, and interactions. Perhaps most important, the recordings could reveal how human-produced sounds affect the whales in their undersea world.

By 2000, Hildebrand's rapidly developed expertise in marine mammal acoustics led to support from the U.S. Navy, which was as-

Above left, *Sean Wiggins examines data disk drives inside an instrument that recorded animal sounds in the Gulf of California.* **Above middle,** *Maps and navigation charts aid researchers in search of marine mammals.* **Above right,** *A high-frequency acoustic recording package floats on the sea surface awaiting recovery.*

sessing the presence of marine mammals in its military testing range off southern California.

As Hildebrand and Scripps graduate student Erin Oleson forged ahead with the new project, they needed an instrument that could record marine mammal sounds over long periods of time. Sean Wiggins, who had received his Ph.D. from Scripps and had recently returned to join Hildebrand's group, tackled the challenge to develop a novel, self-sustaining, long-term hydrophone system for recording sounds unobtrusively—the ARP.

"Our instrument-development turnaround time needed to be unusually fast. The funding from the Navy appeared in March 2000. By June we had an instrument in the water recording baleen whales," said Wiggins, a project scientist and engineer.

The ARP features an undersea computer built for continuously archiving sounds. A tethered hydrophone floats several feet above the seafloor below two bright-yellow floatation devices. After several months of recording, the researchers can remotely signal the ARP to release and float to the surface, where they pick it up along with its treasure of animal sound data.

The invention had an immediate impact. The acoustic data showed that blue and fin whales were present in southern California waters a lot more of the year than decades of visual surveys had suggested. There also were differences in the number of calls heard weekly and daily across tens of kilometers.

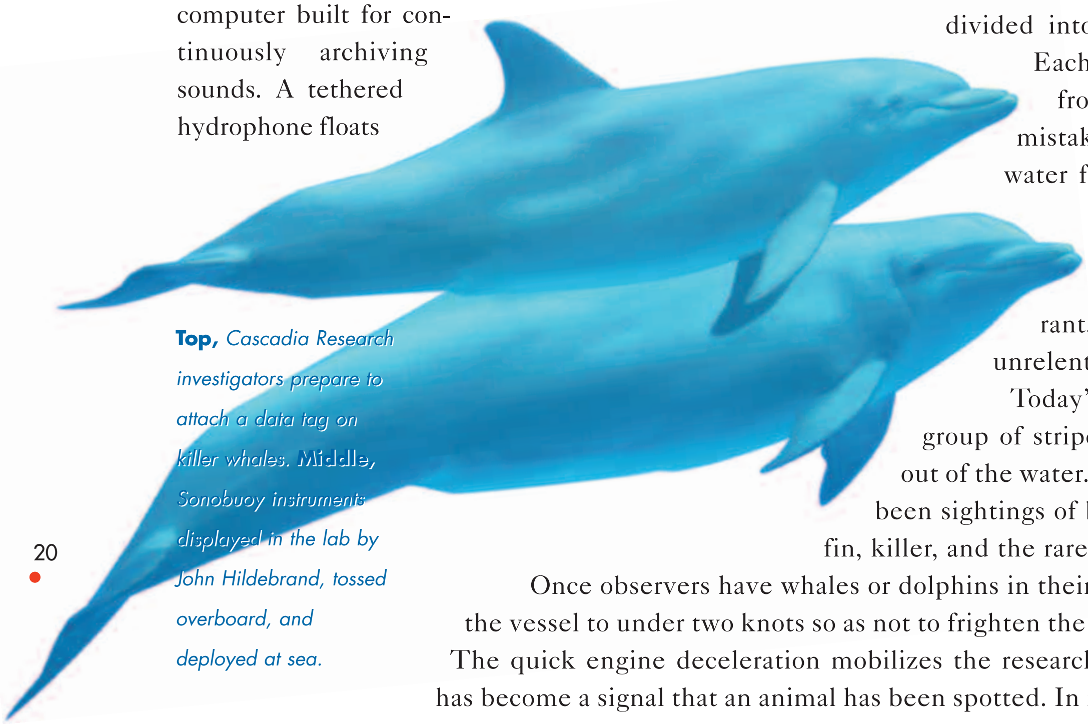
"These differences are likely related to the availability of food and the motivation for whales to produce different types of calls," Oleson said. "Some call types are correlated with the number of whales actually seen while others are not. What we can't tell yet is whether the differences in the number of animals that we hear are related to actual population abundance and density."

A BRIGHT AND NOISY FUTURE

Back on *Sproul*, observers spend each daylight hour meticulously and painstakingly watching the ocean surface for signs of whales and other marine mammals. The 360° field around the *Sproul* bridge is divided into sections for each observer. Each slowly scans his or her area from left to right, careful not to mistake a reflection or splash of water for a whale's fluke. Once this process is completed, it begins again—degree by degree, quadrant by quadrant, hour after hour under an unrelenting sun.

Today's most unusual sighting is a group of striped dolphins leaping playfully out of the water. Earlier in the week there had been sightings of bottlenose dolphins and blue, fin, killer, and the rare beaked whales.

Once observers have whales or dolphins in their sights, *Sproul*'s captain slows the vessel to under two knots so as not to frighten the animals away with ship noise. The quick engine deceleration mobilizes the researchers on board, as the slowing has become a signal that an animal has been spotted. In minutes, Hildebrand is readying and deploying a sonobuoy to capture new recordings from the just-spotted animals.

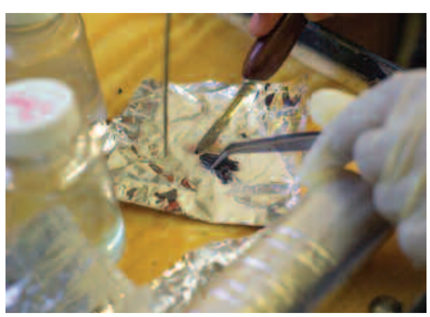


Top, *Cascadia Research investigators prepare to attach a data tag on killer whales.* **Middle,** *Sonobuoy instruments displayed in the lab by John Hildebrand, tossed overboard, and deployed at sea.*

Above, *During a research cruise to the Gulf of California, John Hildebrand scans the horizon in search of marine mammals.*

Hildebrand, Wiggins, and second-year graduate student Jessica Burtenshaw spend hours making detailed notes about the clicks and whistles funneling through the sonobuoys onto a computer monitor that displays a spectrogram of signals in multicolored plots. This cruise is part of Burtenshaw's research on the seasonal behavior of Cuvier's beaked whales and perhaps other species.

"We are just in the beginning, just trying to figure out what these animals sound like," she said.



Above, *Hildebrand and Sean Wiggins (left) prepare instruments inside R/V* Sproul's *laboratory while their colleagues from Mexico extract marine mammal tissue samples (right).*

Burtenshaw, who hopes to eventually use her scientific training to move into social applications, including public policy and management, says that identifying whale habitats is an important step for conservation and management. "One way of doing this is through acoustics to tell where the animals are going," she said. "Passive acoustic monitoring is a total-

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LISTENING AROUND THE WORLD

BUOYED BY THE SUCCESS of acoustic recording package (ARP) deployments off southern California, John Hildebrand and Sean Wiggins discovered they could take this novel device to many more places, geographically and scientifically. Wiggins subsequently developed the next generation of the instrument, the high-frequency HARP, which has the ability to record a new range of animals—the odontocetes, toothed whales such as dolphins that emit sounds above the one-kilohertz ceiling of the original ARP. HARP can record sounds up to 200 kilohertz in a customized system that holds 16 disk drives, or a mind-boggling 1.28 terabytes of animal sound data.

The instrument is the latest triumph for Wiggins, who, like Hildebrand, previously worked in earthquake studies. At one point in his career, Wiggins detonated high-power explosives to make seismic readings.

"I used to put sounds into the ocean," Wiggins says, "now I take them out."

Meanwhile, students in Hildebrand's laboratory have been using ARPs all over the world. In the Southern Ocean, graduate student Ana Širović is investigating calling patterns, population estimates, and other aspects of baleen, blue, and fin whales, using ARPs off Antarctica.

ARPs will be used in the Bering Sea off Alaska for a project in which graduate student Lisa Munger is collaborating with the NOAA National Marine Mammal Laboratory. The project will make some of the first recordings of the endangered North Pacific right whale, whose numbers are thought to have dwindled dramatically because of commercial whaling in the last century.

Melissa Soldevilla is studying dolphins off southern California. In collaboration with the California Cooperative Oceanic Fisheries Investigations, she hopes to understand how dolphin calls are related to different species and how human-produced noise is affecting their habitats.

Above, *A gam of humpback whales.* **Left,** *Inside his laboratory at Scripps, John Hildebrand displays several high-frequency acoustic recording packages (HARPs) being prepared for marine mammal studies.* **Below,** *An underwater microphone called a hydrophone (left), and a housing compartment that houses disk drives and electronics (right), make up key elements of a HARP.*

ly unobtrusive way of studying their habitat use."

It is sunset in the Gulf of California and another day of research settles down. The winds have died and calm seas gently rock *Sproul* against a spectacular purple-orange horizon. A sea turtle with red algal growth on its shell seems content to wallow in the twilight as groups of jellyfish with pink splotches float by, adding to the surreal stillness.

On board, things are different. Hildebrand's tall, thin frame is in constant motion. With a purposeful gait, he has been a figure of continuous activity, beginning at sunrise, whether searching for whales on the bridge, deploying sonobuoys, monitoring incoming animal calls, or going about the business of scientific research, advising students, and even teaching.

This perpetual energy is helping him spring forward in a wide open field that he is also helping to define. Additional acoustics projects have come from the Navy. New projects have been launched with the National Science Foundation. And, most recently, NOAA has expressed interest in supporting Hildebrand's investigations of animal population fluctuations.

New projects will take Hildebrand and his group to study false killer whales off Hawaii and back to the place where it all started, off Washington and Oregon. Advances in computer and electronics technologies will give them even more detailed information in the years ahead.

"The future is bright," said Hildebrand, who plans to support six students each year for the foreseeable future. "There are vast areas of research that need to be done in the study of marine mammal sound. The only way we are going to figure these things out is to get people trained to work on the problems. It's not unlike the way I was coaxed into the marine mammal world. I found that there are so many good problems to work on that I couldn't turn away."

MARINE MAMMAL **SOUNDS** AND HUMAN IMPACTS

OVER MILLIONS OF YEARS, marine mammals have evolved to make intricate and extensive use of sound in the ocean.

According to Scripps oceanographer John Hildebrand, these animals may use sound the way humans use their eyes.

"Whether it's finding food, finding each other, or navigating, sound is the way that marine mammals communicate," Hildebrand said. "The pathways for transmitting sound information to their brains are much more extensive than those used to transmit visual information. The opposite is true for terrestrial animals like humans."

As human populations have increased, so too has the amount of human-produced sound in the oceans, leading researchers and the public to consider how humans are affecting marine mammals.

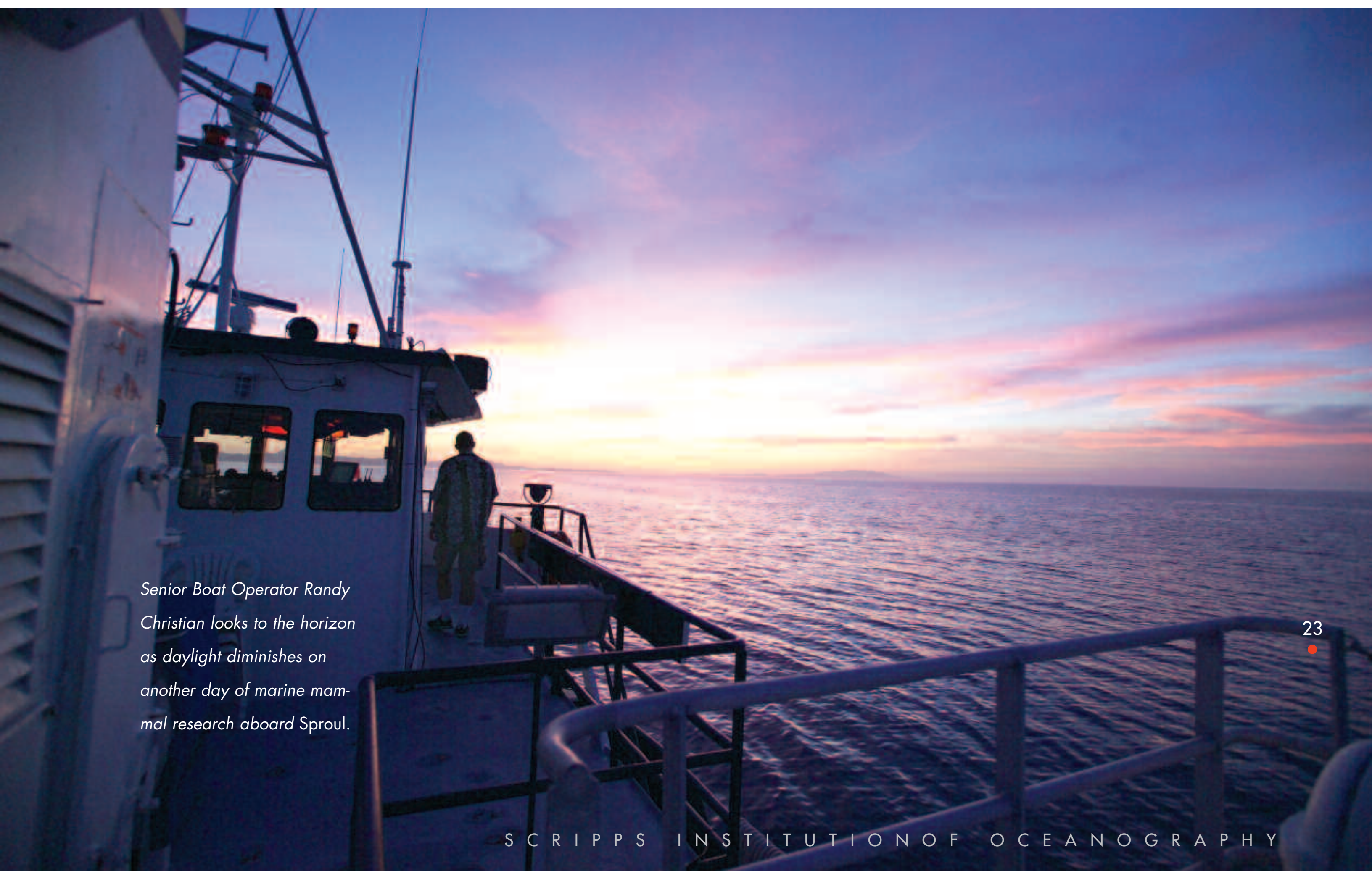
Noise-producing ships, for example, are a factor in degrading the overall sound environment in the ocean. Sounds from a whale seeking a mate, for instance, can be masked by such external noise.

Other human-produced sounds are even more intense and potentially disruptive.

Military operations involving sonar are a speculative cause of mass whale strandings at various locations in recent years. Sonar energy may inadvertently release gas bubbles within these deep-diving animals, similar to the kind of bubbles that produce "the bends," or decompression sickness, in human divers who ascend to the surface too quickly, or cause a behavioral change that leads to disorientation and beaching.

Scientific research using sound-producing air guns to study earth processes may also be affecting marine mammals. Hildebrand is well acquainted with this technique, as he worked in geophysics for a number of years and employed air guns, as other scientists at Scripps and elsewhere continue to do today.

"We need to understand the nature and extent of impact these sounds may have on marine mammals," Hildebrand said. "Then we may be able to design systems for this type of research that reduce the risk of injury to marine mammals."



Senior Boat Operator Randy Christian looks to the horizon as daylight diminishes on another day of marine mammal research aboard Sproul.