Elephant seals drift off to sleep while diving far below the ocean surface

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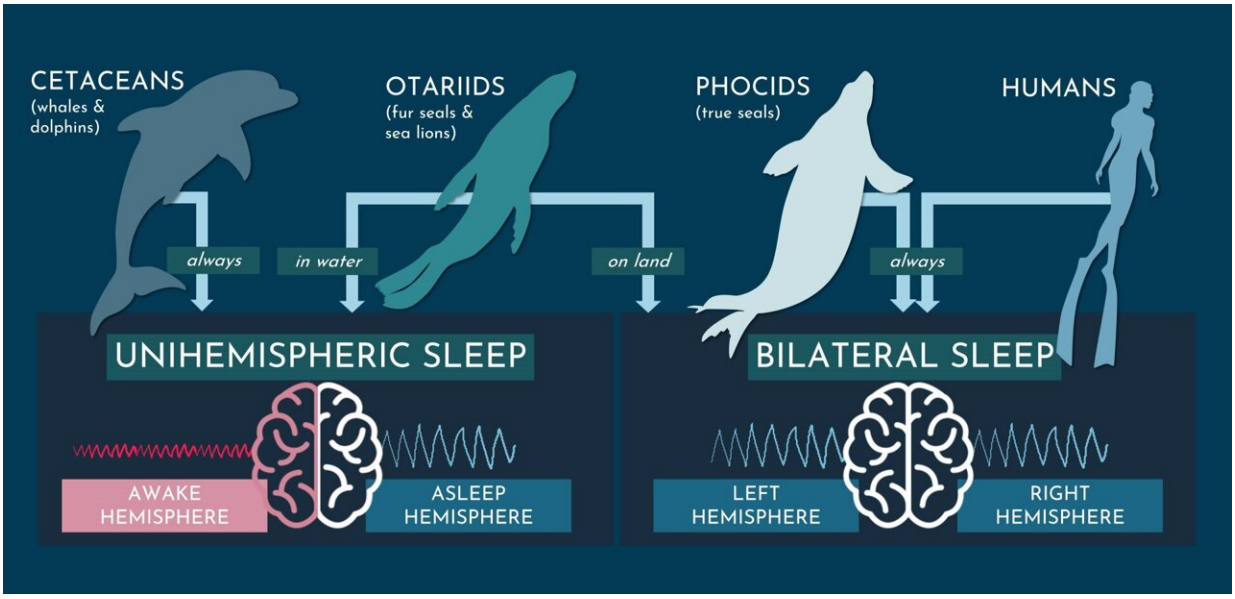


Cetaceans (whales and dolphins) and otariids (fur seals and sea lions) keep one side of their brains awake while the other is asleep (unihemispheric sleep). In most other mammals, including phocids (true seals) and humans, both hemispheres of the brain are asleep at the same time. Credit: Graphic by Jessica Kendall-Bar

For the first time, scientists have recorded brain activity in a free-ranging, wild marine mammal, revealing the sleep habits of elephant seals during the months they spend at sea.

The new findings, published April 20 in *Science*, show that while elephant seals may spend 10 hours a day sleeping on the beach during the breeding season, they average just 2 hours of sleep per day when they are at sea on months-long foraging trips. They sleep for about 10 minutes at a time during deep, 30-minute dives, often spiraling downward while fast asleep, and sometimes lying motionless on the seafloor.

First author Jessica Kendall-Bar led the study as a UC Santa Cruz graduate student working with Daniel Costa and Terrie Williams, both professors of ecology and evolutionary biology at UCSC.

"For years, one of the central questions about elephant seals has been when do they sleep," said Costa, who directs UCSC's Institute of Marine Sciences. Costa's lab has led the UCSC elephant seal research program at Año Nuevo Reserve for over 25 years, using increasingly sophisticated tags to track the movements and diving behavior of the seals during their foraging migrations, when they head out into the North Pacific Ocean for as long as eight months.

"The dive records show that they are constantly diving, so we thought they must be sleeping during what we call drift dives, when they stop swimming and slowly sink, but we really didn't know," Costa said. "Now we're finally able to say they're definitely sleeping during those dives, and we also found that they're not sleeping very much overall compared to other mammals."

In fact, during their months at sea, elephant seals rival the record for the least sleep among all mammals, currently held by African elephants, which appear to sleep just two hours per day based on their movement patterns.

"Elephant seals are unusual in that they switch between getting a lot of

sleep when they're on land, over 10 hours a day, and two hours or less when they're at sea," said Kendall-Bar, who is currently a postdoctoral fellow at UC San Diego's Scripps Institution of Oceanography.

Elephant seals are most vulnerable to predators such as sharks and killer whales when they are at the surface in the open ocean, so they only spend a minute or two breathing at the surface in between dives.

"They're able to hold their breath for a long time, so they can go into a deep slumber on these dives deep below the surface where it's safe," Kendall-Bar said.

Kendall-Bar developed a system that can reliably record brain activity (as an electroencephalogram or EEG) in wild elephant seals during their normal diving behavior at sea. With a neoprene headcap to secure the EEG sensors and a small data logger to record the signals, the system can be recovered when the animals return to the beach at Año Nuevo.

"We used the same sensors you'd use for a human sleep study at a sleep clinic and a removable, flexible adhesive to attach the headcap so that water couldn't get in and disrupt the signals," Kendall-Bar said.

In addition to the EEG system, the seals carried time-depth recorders, accelerometers, and other instruments that allowed the researchers to track the seals' movements along with the corresponding brain activity. The recordings show diving seals going into the deep sleep stage known as slow-wave sleep while maintaining a controlled glide downward, then transitioning into rapid-eye-movement (REM) sleep, when sleep paralysis causes them to turn upside down and drift downwards in a "sleep spiral."

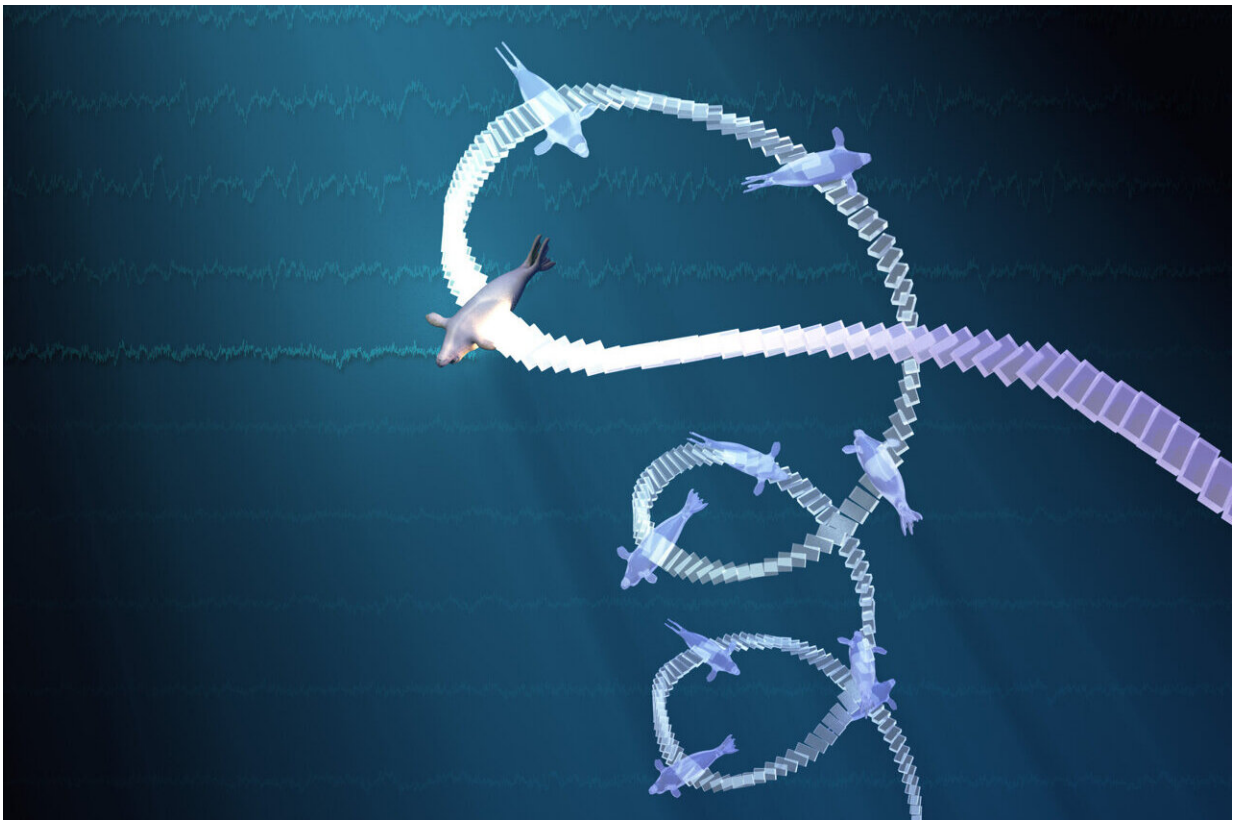
"They go into slow-wave sleep and maintain their body posture for several minutes before they transition into REM sleep, when they lose

postural control and turn upside down," Kendall-Bar said.

At the depths at which this happens, the seals are usually negatively buoyant and continue to fall passively in a corkscrew spiral "like a falling leaf," Williams said. In shallower waters over the continental shelf, elephant seals sometimes sleep while resting on the seafloor.

"It doesn't seem possible that they would truly go into paralytic REM sleep during a dive, but it tells us something about the decision-making processes of these seals to see where in the water column they feel safe enough to go to sleep," said Williams, who directs the Comparative Neurophysiology Lab at UCSC.

In developing the new EEG instrument, Kendall-Bar first deployed it on elephant seals housed temporarily in the marine mammal facilities at UCSC's Long Marine Laboratory. The next step was to deploy it on animals in the elephant seal colony at Año Nuevo Reserve north of Santa Cruz, where researchers could observe the animals on the beach.



When elephant seals go into rapid-eye-movement (REM) sleep during deep dives, sleep paralysis causes them to turn upside down and drift downwards in a “sleep spiral.” This data-driven graphic shows sleeping postures every 20 seconds, with accompanying 30-second segments of EEG traces in the background. Credit: Jessica Kendall-Bar

"I spent a lot of time watching sleeping seals," Kendall-Bar said. "Our team monitored instrumented seals to make sure they were able to reintegrate with the colony and were behaving naturally."

Some of those seals took short excursions into the water, but to observe diving behavior the researchers used a translocation procedure developed by Costa's lab. Juvenile female elephant seals outfitted with the EEG sensors and trackers were transported from Año Nuevo to Monterey and

released on a beach at the southern end of Monterey Bay. Over the next few days, the animals would swim back to Año Nuevo across the deep Monterey Canyon, where their dive behavior is very similar to that seen during much longer foraging trips in the open ocean.

With data on brain activity and dive behavior from 13 juvenile female elephant seals, including a total of 104 sleep dives, Kendall-Bar developed a highly accurate algorithm for identifying periods of sleep based on the dive data alone. This enabled her to estimate sleep quotas for 334 adult seals using dive data recorded over several months during their foraging trips.

"Because of the dataset that Dan Costa has curated over 25 years of working with elephant seals at Año Nuevo, I was able to extrapolate our results to over 300 animals and get a population-level look at sleep behavior," said Kendall-Bar, who now plans to use similar methods to study brain activity in other species of seals and sea lions and in human freedivers.

Williams called Kendall-Bar's work on the project a tour de force. "It's an amazing feat to pull this off," she said. "She developed an EEG system to work on an animal that's diving several hundred meters in the ocean. Then she uses the data to create data-driven animations so we can really visualize what the animal is doing as it dives through the water column."

The results may be helpful for conservation efforts by revealing a "sleepscape" of preferred resting areas, Williams said. "Normally, we're concerned about protecting the areas where animals go to feed, but perhaps the places where they sleep are as important as any other critical habitat," she said.

More information: Jessica M. Kendall-Bar, Brain activity of diving

seals reveals short sleep cycles at depth, *Science* (2023). DOI: 10.1126/science.adf0566.
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