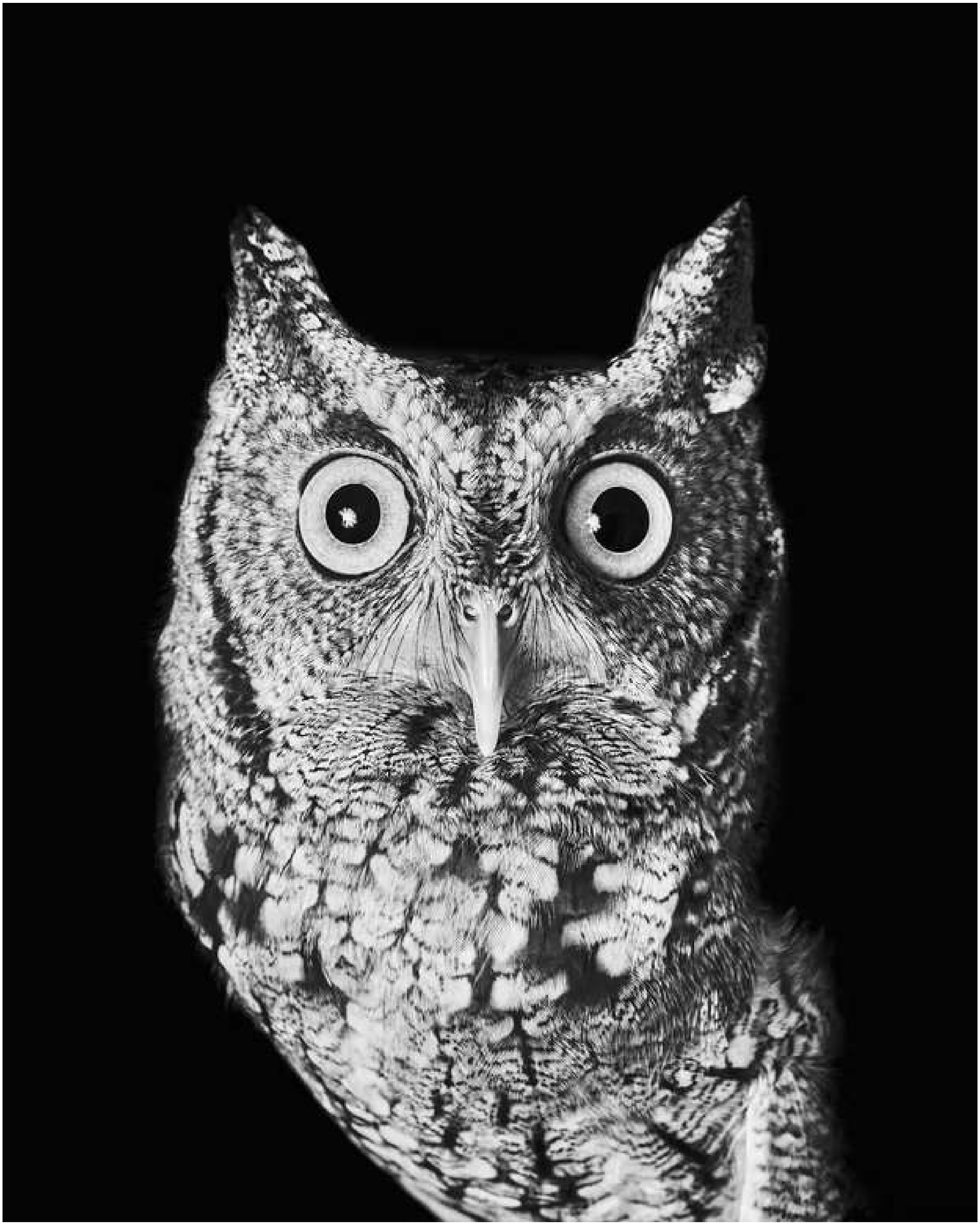
The Atlantic

SCIENCE

HOW ANIMALS PERCEIVE THE WORLD

Every creature lives within its own sensory bubble, but only humans have the capacity to appreciate the experiences of other species. What we've learned is astounding.

By Ed Yong
Photographs by Shayan Asgharnia



Shayan Asgharnia for The Atlantic

JUNE 13, 2022, 6 AM ET

SHARE

Within the 310,000 acres of Wyoming's Grand Teton National Park, one of the largest parking lots is in the village of Colter Bay. Beyond the lot's far edge, nestled among some trees, is a foul-smelling sewage-pumping station that Jesse Barber, a sensory ecologist at Boise State University, calls the Shiterator. On this particular night, sitting quietly within a crevice beneath the building's metal awning and illuminated by Barber's flashlight, is a little brown bat. A white device the size of a rice grain is attached to the bat's back. "That's the radio tag," Barber tells me. He'd previously affixed it to the bat so that he could track its movements, and tonight he has returned to tag a few more.

From inside the Shiterator, I can hear the chirps of other roosting bats. As the sun sets, they start to emerge. A few become entangled in the large net Barber has strung between two trees. He frees a bat, and Hunter Cole, one of his students, carefully examines it to check that it's healthy and heavy enough to carry a tag. Once satisfied, Cole daubs a spot of surgical cement between its shoulder blades and attaches the tiny device. "It's a little bit of an art project, the tagging of a bat," Barber tells me. After a few minutes, Cole places the bat on the trunk of the nearest tree. It crawls upward and takes off, carrying $175 worth of radio equipment into the woods.

I watch as the team examines another bat, which opens its mouth and exposes its surprisingly long teeth. This isn't an aggressive display; it only looks like one. The bat is unleashing a stream of short, ultrasonic pulses from its mouth, which are too high-pitched for me to hear. Bats, however, can hear ultrasound, and by listening for the returning echoes, they can detect and locate objects around them.

Echolocation is the primary means through which most bats navigate and hunt. Only two animal groups are known to have perfected the ability: toothed whales (such as dolphins, orcas, and sperm whales) and bats. Echolocation differs from human senses because it involves putting energy into the environment. Eyes scan, noses sniff, and fingers press, but these sense organs are always picking up stimuli that already exist in the wider world. By contrast, an echolocating bat creates the stimulus that it later detects. Echolocation is a way of tricking your surroundings into revealing themselves. A bat says "Marco," and its surroundings can't help but say "Polo."

The basic process seems straightforward, but its details are extraordinary. High-pitched sounds quickly lose energy in air, so bats must scream to make calls that are strong enough to return audible echoes. To avoid deafening themselves, bats contract the muscles in their ears in time with their calls, desensitizing their hearing with every shout and restoring it in time for the echo. Each echo provides a snapshot in time, so bats must update their calls quickly to track fast-moving insects; fortunately, their vocal muscles are the fastest known muscles in any mammal, releasing up to 200 pulses a second. A bat's nervous system is so sensitive that it can detect differences in echo delay of just one- or two-millionths of a second, which translates to a physical distance of less than a millimeter. A bat thus gauges the distance to an insect with far more precision than humans can.

Echolocation's main weakness is its short range: Some bats can detect small moths from about six to nine yards away. But they can do so in darkness so total that vision simply doesn't work. Even in pitch-blackness, bats can skirt around branches and pluck minuscule insects from the sky. Of course, bats are not the only animals that hunt nocturnally. In the Tetons, as I watch Barber tagging bats, mosquitoes bite me through my shirt, attracted by the smell of the carbon dioxide on my breath. While I itch, an owl flies overhead, tracking its prey using a radar dish of stiff facial feathers that funnel sound toward its ears. These creatures have all evolved senses that allow them to thrive in the dark. But the dark is disappearing.

A big brown bat's ability to echolocate allows it to thrive in the dark. (Shayan Asgharnia for *The Atlantic*)

Barber is one of a growing number of sensory biologists who fear that humans are polluting the world with too much light, to the detriment of other species. Even here, in the middle of a national park, light from human technology intrudes upon the darkness. It spews forth from the headlights of passing vehicles, from the fluorescent bulbs of the visitor center, and from the lampposts encircling the parked cars. "The parking lot is lit up like a Walmart because no one thought about the implications for wildlife," Barber says.

Many flying insects are fatally attracted to streetlights, mistaking them for celestial lights and hovering below them until they succumb to exhaustion. Some bats exploit their confusion, feasting on the disoriented swarms. Other, slower-moving species, including the little brown bats that Barber tagged, stay clear of the light, perhaps because it makes them easier prey for owls. Lights reshape animal communities, drawing some in and pushing others away, with consequences that are hard to predict.

> Every animal is enclosed within its own sensory bubble, perceiving but a tiny sliver of an immense world.

To determine the effect of light on the bats of Grand Teton, Barber persuaded the National Park Service to let him try an unusual experiment. In 2019, he refitted all 32 streetlights in the Colter Bay parking lot with special bulbs that can change color. They can produce either white light, which strongly affects the behavior of insects and bats, or red light, which doesn't seem to. Every few days during my visit, Barber's team flips their color. Funnel-shaped traps hanging below the lamps collect the gathering insects, while radio transponders pick up the signals from the tagged bats. These data should reveal how normal white lights affect the local animals, and whether red lights can help rewild the night sky.

Cole gives me a little demonstration by flipping the lights to red. At first, the parking lot looks disquietingly infernal, as if we have stepped into a horror movie. But as my eyes adjust, the red hues feel less dramatic and become almost pleasant. It is amazing how much we can still see. The cars and the surrounding foliage are all visible. I look up and notice that fewer insects seem to be gathered beneath the lamps. I look up even farther and see the stripe of the Milky Way cutting across the sky. It's an achingly beautiful sight, one I have never seen before in the Northern Hemisphere.

EVERY ANIMAL IS enclosed within its own sensory bubble, perceiving but a tiny sliver of an immense world. There is a wonderful word for this sensory bubble—*Umwelt*. It was defined and popularized by the Baltic German zoologist Jakob von Uexküll in 1909. *Umwelt* comes from the German word for "environment," but Uexküll didn't use it to refer to an animal's surroundings. Instead, an Umwelt is specifically the part of those surroundings that an animal can sense and experience—its perceptual world. A tick, questing for mammalian blood, cares about body heat, the touch of hair, and the odor of butyric acid that emanates from skin. It doesn't care about other stimuli, and probably doesn't know that they exist. Every Umwelt is limited; it just doesn't feel that way. Each one feels all-encompassing to those who experience it. Our Umwelt is all we know, and so we easily mistake it for all there is to know. This is an illusion that every creature shares.

Read: An ingenious injection can create infrared vision

Humans, however, possess the unique capacity to appreciate the Umwelten of other species, and through centuries of effort, we have learned much about those sensory worlds. But in the time it took us to accumulate that knowledge, we have radically remolded those worlds. Much of the devastation that we have wrought is by now familiar. We have changed the climate and acidified the oceans. We have shuffled wildlife across continents, replacing indigenous species with invasive ones. We have instigated what some scientists have called an era of "biological annihilation," comparable to the five great mass-extinction events of prehistory. But we have also filled the silence with noise and the night with light. This often ignored phenomenon is called sensory pollution—human-made stimuli that interfere with the senses of other species. By barraging different animals with stimuli of our own making, we have forced them to live in our Umwelt. We have distracted them from what they actually need to sense, drowned out the cues they depend upon, and lured them into sensory traps. All of this is capable of doing catastrophic damage.

A sea turtle's hatchlings can be diverted away from the sea by artificial lights. For mice, human-made noise
can mask the sounds of predators. (Shayan Asgharnia for *The Atlantic*)

In 2001, the astronomer Pierantonio Cinzano and his colleagues created the first global atlas of light pollution. They calculated that two-thirds of the world's population lived in light-polluted areas, where the nights were at least 10 percent brighter than natural darkness. About 40 percent of humankind is permanently bathed in the equivalent of perpetual moonlight, and about 25 percent constantly experiences an artificial twilight that exceeds the illumination of a full moon. "'Night' never really comes for them," the researchers wrote. In 2016, when the team updated the atlas, it found that the problem had become even worse. By then, about 83 percent of people—including more than 99 percent of Americans and Europeans—were under light-polluted skies. More than a third of humanity, and almost 80 percent of North Americans, can no longer see the Milky Way. "The thought of light traveling billions of years from distant galaxies only to be washed out in the last billionth of a second by the glow from the nearest strip mall depresses me to no end," the visual ecologist Sönke Johnsen once wrote.

At Colter Bay, Cole flips the lights from red back to white and I wince. The extra illumination feels harsh and unpleasant. The stars seem fainter now. Sensory pollution is the pollution of disconnection. It detaches us from the cosmos. It drowns out the stimuli that link animals to their surroundings and to one another. In making the planet brighter and louder, we have endangered sensory environments for countless species in ways that are less viscerally galling than clear-cut rain forests and bleached coral reefs but no less tragic. That must now change. We can still save the quiet and preserve the dark.

Every year on September 11, the sky above New York City is pierced by two columns of intense blue light. This annual art installation, known as *Tribute in Light*, commemorates the terrorist attacks of 2001, with the ascending beams standing in for the fallen Twin Towers. Each is produced by 44 xenon bulbs with 7,000-watt intensities. Their light can be seen from 60 miles away. From closer up, onlookers often notice small flecks, dancing amid the beams like gentle flurries of snow. Those flecks are birds. Thousands of them.

This annual ritual unfortunately occurs during the autumn migratory season, when billions of small songbirds undertake long flights through North American skies. Navigating under cover of darkness, they fly in such large numbers that they show up on radar. By analyzing meteorological radar images, Benjamin Van Doren showed that *Tribute in Light*, across seven nights of operation, waylaid about 1.1 million birds. The beams reach so high that even at altitudes of several miles, passing birds are drawn into them. Warblers and other small species congregate within the light at up to 150 times their normal density levels. They circle slowly, as if trapped in an incorporeal cage. They call frequently and intensely. They occasionally crash into nearby buildings.

Migrations are grueling affairs that push small birds to their physiological limit. Even a night-long detour can sap their energy reserves to fatal effect. So whenever 1,000 or more birds are caught within *Tribute in Light*, the bulbs are turned off for 20 minutes to let the birds regain their bearing. But that's just one source of light among many, and though intense and vertical, it shines only once a year. At other times, light pours out of sports stadiums and tourist attractions, oil rigs and office buildings. It pushes back the dark and pulls in migrating birds.

In 1886, shortly after Thomas Edison commercialized the electric light bulb, about 1,000 birds died after colliding with illuminated towers in Decatur, Illinois. More than a century later, the environmental scientist Travis Longcore and his colleagues calculated that almost 7 million birds die each year in the United States and Canada after flying into communication towers. The lights of those towers are meant to warn aircraft pilots, but they also disrupt the orientation of nocturnal avian fliers, which then veer into wires or each other. Many of these deaths could be avoided simply by replacing steady lights with blinking ones.

"We too quickly forget that we don't perceive the world in the same way as other species, and consequently, we ignore impacts that we shouldn't," Longcore tells me in his Los Angeles office. Our eyes are among the sharpest in the animal kingdom, but their high resolution comes with the cost of low sensitivity. Unlike most other mammals, our vision fails us at night, so we crave more nocturnal illumination, not less.

Read: The dark side of light

The idea of light as a pollutant is jarring to us, but it becomes one when it creeps into places where it doesn't belong. Widespread light at night is a uniquely anthropogenic force. The daily and seasonal rhythms of bright and dark remained largely inviolate throughout all of evolutionary time—a 4-billion-year streak that began to falter in the 19th century.

When sea-turtle hatchlings emerge from their nests, they crawl away from the dark shapes of dune vegetation toward the brighter oceanic horizon. But lit roads and beach resorts can steer them in the wrong direction, where they are easily picked off by predators or squashed by vehicles. In Florida alone, artificial lights kill baby turtles in the thousands every year. They've wandered into a baseball game and, more horrifying, abandoned beach fires. The caretaker of one property in Melbourne Beach found hundreds of dead hatchlings piled beneath a single mercury-vapor lamp.

Female crickets struggle to find the best mates when noise pollution masks the males' songs. (Shayan Asgharnia for *The Atlantic*)

Artificial lights can also fatally attract insects, contributing to their alarming global declines. A single streetlamp can lure moths from 25 yards away, and a well-lit road might as well be a prison. Many of the insects that gather around streetlamps will likely be eaten or dead from exhaustion by sunrise. Those that zoom toward vehicle headlights will probably be gone even sooner. The consequences of these losses can ripple across ecosystems. In 2014, as part of an experiment, the ecologist Eva Knop installed streetlamps in seven Swiss meadows. After sunset, she prowled these fields with night-vision goggles, peering into flowers to search for moths and other pollinators. By comparing these sites to others that had been kept dark, Knop showed that the illuminated flowers received 62 percent fewer visits from pollinating insects. One plant produced 13 percent less fruit even though it was visited by a day shift of bees and butterflies.

The presence of light isn't the only factor that matters; so does its nature. Insects with aquatic larvae, such as mayflies and dragonflies, will fruitlessly lay their eggs on wet roads, windows, and car roofs, because these reflect horizontally polarized light in the same way bodies of water do. Rapidly flickering light bulbs can cause headaches and other neurological problems in humans, even though our eyes are usually too slow to detect these changes; what, then, do they do to animals with faster vision, like insects and small birds?

Colors matter, too. Red is better for bats and insects but can waylay migrating birds. Yellow doesn't bother turtles or most insects but can disrupt salamanders. No wavelength is perfect, Longcore says, but blue and white are worst of all. Blue light interferes with body clocks and strongly attracts insects. It is also easily scattered, increasing the spread of light pollution. It is, however, cheap and efficient to produce. The new generation of energy-efficient white LEDs contain a lot of blue light, and the world might switch to them from traditional yellow-orange sodium lights. In energy terms, that would be an environmental win. But it would also increase the amount of global light pollution by two or three times.

From the April 2020 issue: Ed Yong on how we can save giraffes from extinction

After talking with Longcore, I head home to Washington, D.C., on a red-eye flight. As the plane takes off, I peer out the window at Los Angeles. The twinkling grid of lights stirs the same primordial awe that comes from watching a starry sky or a moonlit sea. But as the illuminated city recedes beneath my window, that amazement is tinged with unease. Light pollution is no longer just an urban problem. Light travels, encroaching even into places that are otherwise untouched by human influence. The light from Los Angeles reaches Death Valley, one of the largest national parks in the United States, more than 150 miles away. True darkness is hard to find.

SO IS TRUE SILENCE.

It's a sunny April morning in Boulder, Colorado, and I've hiked up to a rocky hillside, about 6,000 feet above sea level. The world feels wider here, not just because of the panoramic view over conifer forests but also because it is blissfully quiet. Away from urban ruckus, quieter sounds become audible over greater distances. On the hillside, a chipmunk is rustling. Grasshoppers snap their wings together as they fly. A woodpecker pounds its beak against a nearby trunk. Wind rushes past. The longer I sit, the more I seem to hear.

Two men puncture the tranquility. I can't see them, but they're somewhere on the trail below, intent on broadcasting their opinions to all of Colorado. Then I realize I can also hear faraway vehicles zooming along a highway beyond the trees. Denver hums in the distance, an ambient backdrop that I had all but blocked out. I notice the roaring engines of a plane flying overhead. After my hike, I meet up with Kurt Fristrup, who says he's been backpacking since the mid-1960s. In that time, aircraft emissions have increased nearly sevenfold. "One of my favorite parlor tricks when friends visit is to ask, at the end of the hike, if they heard any aircraft," he tells me. "People will say they remember one or two. And I'll say there were 23 jets and two helicopters."

Before he retired, Fristrup was a scientist at the National Park Service's Natural Sounds and Night Skies Division, a group that works to safeguard (among other things) the United States' natural soundscapes. To protect them, the team first had to map them, and sound, unlike light, can't be detected by satellites. Fristrup and his colleagues spent years lugging recording equipment to almost 500 sites around the country, capturing nearly 1.5 million audio samples. They found that human activity doubles the background-noise levels in 63 percent of protected spaces like national parks, and increases them tenfold in 21 percent. In the latter places, "if you could have heard something 100 feet away, now you can only hear it 10 feet away," Rachel Buxton, a former National Park Service research fellow, told me. Aircraft and roads are the main culprits, but so are industries like oil and gas extraction, mining, and forestry, which fill the air with drilling, explosions, engine noises, and the thud of heavy tires. Even the most heavily protected areas are under acoustic siege.

Busy roads may drown out the alarm calls of songbirds like the tufted titmouse. (Shayan Asgharnia for *The Atlantic*)

In towns and cities, the problem is worse, and not just in the United States. In 2005, two-thirds of Europeans were immersed in ambient noise equivalent to perpetual rainfall. Such conditions are difficult for the many animals that communicate through calls and songs. Scientists have found that noisy neighborhoods in Leiden, in the Netherlands, compel great tits to sing at higher frequencies so that their notes don't get masked by the city's low-pitched hubbub. Nightingales in Berlin are forced to belt out their tunes more loudly to be heard over the surrounding din. Urban and industrial noise can also change the timing of birds' songs, suppress the complexity of their calls, and prevent them from finding mates. Noise pollution masks not only the sounds that animals deliberately make but also the "web of unintended sounds that ties communities together," Fristrup says. He means the gentle rustles that tell owls where their prey is, or the faint flaps that warn mice about impending doom.

In 2012, Jesse Barber and his colleagues Heidi Ware Carlisle and Christopher McClure built a phantom road. On a ridge in Idaho that acts as a stopover for migrating birds, the team set up a half-mile corridor of speakers that played looped recordings of passing cars. A third of the usual birds stayed away. Many of those that didn't paid a price for persisting. With tires and horns drowning out the sounds of predators, the birds spent more time looking for danger and less time looking for food. They put on less weight and were weaker during their arduous migrations. The phantom-road experiment was pivotal in showing that wildlife could be deterred by noise and noise alone, detached from the sight of vehicles or the stench of exhaust. Hundreds of studies have come to similar conclusions. In noisy conditions, prairie dogs spend more time underground. Owls flub their attacks. Parasitic *Ormia* flies struggle to find their cricket hosts.

Sounds can travel over long distances, at all times of day, and through solid obstacles. These qualities make them excellent stimuli for animals but also pollutants par excellence. Noise can degrade habitats that look idyllic and make otherwise livable places unlivable. And where will animals go? In 2003, 83 percent of the contiguous United States lay within about a kilometer of a road.

Even the seas can't offer silence. Although Jacques Cousteau once described the ocean as a silent world, it is anything but. It teems with the sounds of breaking waves and blowing winds, bubbling hydrothermal vents and calving icebergs, all of which carry farther and travel faster underwater than in air. Marine animals are noisy, too. Whales sing, toadfish hum, cod grunt, and bearded seals trill. Thousands of snapping shrimp, which stun passing fish with the shock waves produced by their large claws, fill coral reefs with sounds similar to sizzling bacon or Rice Krispies popping in milk. Some of this soundscape has been muted as humans have netted, hooked, and harpooned the oceans' residents. Other natural noises have been drowned out by the ones we added: the scrapes of nets that trawl the seafloor; the staccato beats of seismic charges used to scout for oil and gas; the pings of military sonar; and, as a ubiquitous backing track for all this commotion, the sounds of ships.

Read: These animals are feasting on the ruins of an extinct world

"Think about where your shoes come from," the marine-mammal expert John Hildebrand tells me. I look; unsurprisingly, the answer is China. Some tanker carried my shoes across the Pacific, leaving behind a wake of sound that radiated for miles. From 1945 to 2008, the global shipping fleet more than tripled, and began moving 10 times more cargo at higher speeds. And in the past 50 years, shipping vessels have multiplied the levels of low-frequency noise in the oceans 32-fold—a 15-decibel increase over levels that Hildebrand suspects were already 10 to 15 decibels louder than in pre-propeller seas. Because giant whales can live for a century or more, there are likely whales alive today that have personally experienced this growing underwater racket and now can hear only a small fraction of their former range. As ships pass in the night, humpback whales stop singing, orcas stop foraging, and right whales become stressed. Crabs stop feeding, cuttlefish change colors, damselfish are more easily caught. "If I said that I'm going to increase the noise level in your office by 30 decibels, OSHA would come in and say you'd need to wear earplugs," Hildebrand tells me. "We're conducting an experiment on marine animals by exposing them to these high levels of noise, and it's not an experiment we'd allow to be conducted on ourselves."

Because of the way we have upended the worlds of other animals, senses that have served their owners well for millions of years are now liabilities. Smooth vertical surfaces, which don't exist in nature, return echoes that sound like open air; perhaps that's why bats so often crash into windows. Dimethyl sulfide, the seaweedy-smelling chemical that once reliably guided seabirds to food, now also guides them to the millions of tons of plastic waste that humans have dumped into the oceans; perhaps that's one reason an estimated 90 percent of seabirds eventually swallow plastic. Manatees can detect the currents produced by objects moving in the water with whiskerlike hairs found all over their body, but not with enough notice to avoid a loud, fast-moving speedboat; boat collisions are responsible for at least a fifth of deaths among Florida's manatees. Odorants in river water can guide salmon back to their stream of birth, but not if pesticides in that same water blunt their sense of smell. Weak electric fields at the bottom of the sea can guide sharks to buried prey, but also to high-voltage cables.

Manatee whiskers can detect currents in the water, but not quickly enough to dodge loud, fast boats. (Shayan Asgharnia for *The Atlantic*)

Some animals have come to tolerate the sights and sounds of modernity. Others even flourish among them. Some urban moths have evolved to become less attracted to light. Some urban spiders have gone in the opposite direction, spinning webs beneath streetlights and feasting on the attracted insects. In some Panama towns, nighttime lights drive frog-eating bats away, allowing male túngara frogs to load their songs with sexy flourishes that would normally attract predators as well as mates. Animals can adapt, by changing their behavior over an individual lifetime and by evolving new behaviors over many generations.

Read: Why some moths are evolving to avoid artificial light

But adaptation is not always possible. Species that mature and breed slowly can't evolve quickly enough to keep pace with levels of light and noise pollution that double every few decades. Creatures that have already been confined to narrow corners of shrinking habitats can't just up and leave. Those that rely on specialized senses can't just retune their entire Umwelt.

With every creature that vanishes, we lose a way of interpreting the world.

Our influence is not inherently destructive, but it is often homogenizing. In pushing out species that cannot abide our sensory onslaughts, we leave behind smaller and less diverse communities. And beyond polluting the world with unwanted sensory stimuli, we're also removing natural stimuli that animals have come to depend on, flattening the undulating sensescapes that have generated the wondrous variety of animal Umwelten.

Consider Lake Victoria, in East Africa. It is home to more than 500 species of cichlid fish that are found nowhere else. That extraordinary diversity arose partly because of light. In deeper parts of the lake, light tends to be yellow or orange, while blue is more plentiful in shallower waters. These differences affected the eyes of the local cichlids and, in turn, their mating choices. The evolutionary biologist Ole Seehausen found that female cichlids from deeper waters prefer redder males, while those in the shallows are drawn to bluer ones. These diverging penchants acted like physical barriers, splitting the cichlids into differently colored forms. Diversity in light helped create diversity in vision, in color, and in species. But over the past century, runoff from farms, mines, and sewage filled the lake with nutrients that spurred the growth of clouding, choking algae. The old light gradients flattened in some places, the cichlids' colors and visual proclivities no longer mattered, and the number of species collapsed. By turning off the light in the lake, humans also switched off the sensory engine of diversity, contributing to what Seehausen has called "the fastest large-scale extinction event ever observed."

As those species go extinct, so too do their Umwelten. With every creature that vanishes, we lose a way of interpreting the world. Our sensory bubbles shield us from the knowledge of those losses. But they don't protect us from the consequences. In the woodlands of New Mexico, the ecologists Clinton Francis and Catherine Ortega found that the Woodhouse's scrub-jay avoids the noise of compressors used in extracting natural gas. The scrub-jay spreads the seeds of piñon pine trees, and a single bird can bury thousands of pine seeds a year. They are so important to the forests that, in quiet areas where they still thrive, pine seedlings are four times more common than in noisy areas they have abandoned, Francis and colleagues found in a later study.

Left: As babies, clown fish use sounds to find their way to the safety of a coral reef. *Right*: To avoid excessive noise, prairie dogs spend more time underground. (Shayan Asgharnia for *The Atlantic*)

Piñon pines are the foundation of the ecosystem around them—a single species that provides food and shelter for hundreds of others, including Indigenous Americans. To lose three-quarters of them would be disastrous. And because they grow slowly, "noise might have hundred-plus-year consequences for the entire ecosystem," Francis tells me.

A better understanding of other creatures' senses can show us how we're defiling the natural world—and can also point to ways of saving it. In 2016, the marine biologist Tim Lamont (formerly Tim Gordon) traveled to Australia's Great Barrier Reef to begin work for his doctorate. Lamont should have spent months swimming amid the corals' vivid splendor. Instead, a heat wave had forced the corals to expel the symbiotic algae that give them nutrients and colors. Without these partners, the corals starved and whitened in the worst bleaching event on record, and the first of several to come. Snorkeling through the rubble, Lamont found that the reefs had been not only bleached but also silenced. Snapping shrimp no longer snapped. Parrotfish no longer crunched. Those sounds normally help guide baby fish back to the reef after their first vulnerable months out at sea. Soundless reefs were much less attractive.

Lamont feared that if fish avoided the degraded reefs, the seaweed they normally eat would run amok, overgrowing the bleached corals and preventing them from rebounding. He and his colleagues set up loudspeakers that continuously played recordings of healthy reefs over patches of coral rubble. The team would dive every few days to survey the local animals. After 40 days, he ran the numbers and saw that the acoustically enriched reefs had twice as many young fish as silent ones and 50 percent more species. They had not only been attracted by the sounds but stayed and formed a community. "It was a lovely experiment to do," Lamont says. It showed what conservationists can accomplish by "seeing the world through the perceptions of the animals you're trying to protect."

From the July 2019 issue: The last of its kind

Lamont's experiment was possible only because the team managed to record the sounds of the healthy reefs before they were bleached. Natural sensescapes still exist. There is still time to preserve and restore them before the last echo of the last reef fades into memory. And in most cases, the work ahead of us is considerably simpler. Instead of adding stimuli that we have removed, we can simply remove those that we added. Radioactive waste can take millennia to degrade. Persistent chemicals like the pesticide DDT can thread through the bodies of animals long after they are banned. Plastics will continue to despoil the oceans even if all plastic production halts tomorrow. But light pollution ceases as soon as lights are turned off. Noise pollution abates once engines and propellers wind down. Sensory pollution is an ecological gimme—a rare example of a planetary problem that can be immediately and effectively addressed. And in the spring of 2020, the world did unknowingly address it.

The body clock of the barred tiger salamander is disrupted by artificial light at night. (Shayan Asgharnia for *The Atlantic*)

As the coronavirus spread, public spaces closed. Flights were grounded. Cars stayed parked. Cruise ships stayed docked. About 4.5 billion people—almost three-fifths of the world's population—were told or encouraged to stay home. As a result, many places became substantially darker and quieter. With fewer planes and cars on the move, the night skies around Berlin were half as bright as normal. Alaska's Glacier Bay, a sanctuary for humpback whales, was half as loud as the previous year, as were cities and rural areas throughout California, New York, Florida, and Texas. Sounds that would normally be muffled became clearer. City dwellers around the world suddenly noticed singing birds.

Read: Artificial lights tell the story of the pandemic

In a multitude of ways, the pandemic showed that sensory pollution can be reduced if people are sufficiently motivated—and such reductions are possible without the debilitating consequences of a global lockdown. In the summer of 2007, Kurt Fristrup and his National Park Service colleagues did a simple experiment at Muir Woods National Monument, in California. On a random schedule, they stuck up signs that declared one of the most popular parts of the park a quiet zone and encouraged visitors to silence their phones and lower their voices. These simple steps, with no accompanying enforcement, reduced the noise levels in the park by three decibels, equivalent to 1,200 fewer visitors.

> To perceive the world through others' senses is to find splendor in familiarity, and the sacred in the mundane.

To truly make a dent in sensory pollution, bigger steps are needed. Lights can be dimmed or switched off when buildings and streets are not in use. They can be shielded so that they stop shining above the horizon. LEDs can be changed from blue or white to red. Quiet pavements with porous surfaces can absorb the noise from passing vehicles. Sound-absorbing barriers, including berms on land and air-bubble curtains in the water, can soften the din of traffic and industry. Vehicles can be diverted from important areas of wilderness, or they can be forced to slow down: In 2007, when commercial ships in the Mediterranean began slowing down by just 12 percent, which saves fuel and reduces emissions, they produced half as much noise. Such vessels can also be fitted with quieter hulls and propellers, which are already used to muffle military ships (and would make commercial ones more fuel-efficient).

We could regulate industries causing sensory pollution, but there's not enough societal will. "Plastic pollution in the sea looks hideous and everyone is worried, but noise pollution in the sea is something we don't experience so directly, so no one's up in arms about it," Lamont says. And as we desecrate sensory environments, we grow accustomed to the results. Our blinding, blaring world becomes normal, and pristine wilderness feels more distant.

But the majesty of nature is not restricted to canyons and mountains. It can be found in the wilds of perception—the sensory spaces that lie outside our Umwelt and within those of other animals. To perceive the world through others' senses is to find splendor in familiarity, and the sacred in the mundane. Wonders exist in a backyard garden, where bees take the measure of a flower's electric fields, leafhoppers send vibrational melodies through the stems of plants, and birds behold the hidden palettes of ultraviolet colors on their flock-mates' feathers. Wilderness is not distant. We are continually immersed in it. It is there for us to imagine, to savor, and to protect.

Barn owls track prey using stiff facial feathers that funnel sound toward their ears. (Shayan Asgharnia for *The Atlantic*)

In 1934, after considering the senses of ticks, dogs, jackdaws, and wasps, Jakob von Uexküll wrote about the Umwelt of the astronomer. "Through gigantic optical aids," he wrote, this unique creature has eyes that "are capable of penetrating outer space as far as the most distant stars. In its Umwelt, suns and planets circle at a solemn pace." The tools of astronomy can capture stimuli that no animal can naturally sense—X-rays, radio waves, gravitational waves from colliding black holes. They extend the human Umwelt across the universe and back to its very beginning. The tools of biologists are more modest in scale, but they, too, offer a glimpse into the infinite. Scientists have used night-vision goggles to show that nocturnal bees can see in extreme darkness, clip-on microphones to eavesdrop on the vibrational songs of leafhoppers, and electrodes to listen in on the pulses of electric fish. With microscopes, cameras, speakers, satellites, and recorders, people have explored other sensory worlds. We have used technology to make the invisible visible and the inaudible audible.

No creature could possibly sense everything, and no creature needs to. Evolving according to their owner's needs, the senses sort through an infinity of stimuli, allowing through only what is relevant. To learn about the rest is a choice. The ability to dip into other Umwelten is our greatest sensory skill. A moth will never know what a zebra finch hears in its song, a zebra finch will never feel the electric buzz of a black ghost knifefish, a knifefish will never see through the eyes of a mantis shrimp, a mantis shrimp will never smell the way a dog can, and a dog will never understand what it is like to be a bat. We will never fully do any of these things either, but we are the only animal that can try. Through patient observation, through the technologies at our disposal, through the scientific method, and, above all else, through our curiosity and imagination, we can try to step into perspectives outside our own. This is a profound gift, which comes with a heavy responsibility. As the only species that can come close to understanding other Umwelten, but also the species most responsible for destroying those sensory realms, it falls on us to marshal all of our empathy and ingenuity to protect other creatures, and their unique ways of experiencing our shared world.

This article has been adapted from Ed Yong's latest book, An Immense World: How Animal Senses Reveal the Hidden Realms Around Us. *It appears in the July/August 2022 print edition with the headline "Our Blinding, Blaring World."*

An Immense World: How Animal Senses Reveal The Hidden Realms Around Us

ED YONG, RANDOM HOUSE

BUY BOOK