

OUTSIDE JEB

Blue whales not bothered by quake sounds



Our understanding of the prevalence of noise in our oceans has changed dramatically in recent years. We now know that the submarine environment is anything but Cousteau's 'silent deep'. Shipping traffic, naval sonar and exploration for subsea resources, for example, all add to the underwater hubbub, leading to adverse impacts on the ability of marine animals to communicate, altered access to feeding grounds and elevated stress levels. And the largest animal in the world, the blue whale (*Balaenoptera musculus*), is not exempt from the effects of noise. When exposed to military sonar, they may swim faster, stop feeding and call less frequently; they are known to call louder when they hear shipping. And when airguns are discharged while probing for undersea oil, whales appear to call more frequently. Yet, humans are not responsible for all undersea noise. The waters around New Zealand are alive with deep rumbling of earthquakes as the tectonic plates shift and jar. So, what impact do these thunderous natural sounds have on the sensitive behemoths within earshot?

Dawn Barlow at Oregon State University, USA, and colleagues from her home university and Cornell University, USA, listened to the blue whale undersea chorus recorded by five listening stations in the South Taranaki Bight, New Zealand. They used geological databases to identify individual earthquakes with Richter magnitudes greater than 3

originating within the study area and matched up blue whale calls at hourly intervals in the run up to and following each earthquake. The team kept track of two specific kinds of calls – the 'D-call', which is produced by both sexes when feeding and 'song', which is produced only by males – measuring how often and estimating how loud the D-calls were and measuring the intensity of song. In addition, the researchers examined the whales' calls during periods when the earth's crust was silent, to capture seasonal variation in both soundscape and whale behaviour.

To the surprise of Barlow and her colleagues, they found that the whales appeared to be unperturbed by seismic activity. The whales continued producing calls in the periods before and after earthquakes, and there was no difference in the animals' calling rates. Specifically, no earthquake metrics (magnitude, depth, distance to the epicentre and relative received level) were useful predictors for estimating changes in blue whale calling rate. While the acoustic signature of an earthquake typically lasted less than a minute, these loud and natural occurrences did not seem to bother the blue whales. While the recording set-up did not allow the researchers to calculate the sound level that the whales would have heard, they were able to describe how loud the earthquakes were at the recorders and suspect that they all fell below the noise thresholds thought to disturb the whales' behaviour.

Scientists are chipping away at understanding how wild animals respond to disturbances by quantifying the responses of many species to specific acoustic disturbances, as individual intrusions can accumulate to impact the health and survival of a population. They are finding increasingly that the existing backdrop of both the animals' behavioural state and its surrounding environment in which noises are heard matters a lot when it comes to predicting how they react. To contextualise whale responses to anthropogenic sounds, we also need to understand how they respond to natural noises. While the findings in Barlow's

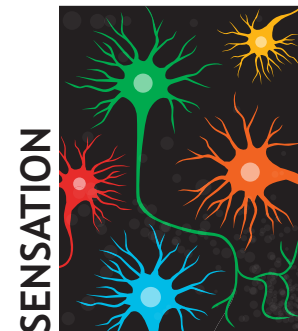
study are for a specific baleen whale in a specific region of the world, understanding how other whales respond to simultaneously occurring natural and anthropogenic noises can help to add context to their responses.

doi:10.1242/jeb.243517

Barlow, D. R., Estrada Jorge, M., Klinck, H. and Torres, L. G. (2022). Shaken, not stirred: blue whales show no acoustic response to earthquake events. *R. Soc. Open Science* 9, 220242. doi:10.1098/rsos.220242

Chloe Malinka (0000-0003-0138-8388)
University of St Andrews
chloe.e.malinka@gmail.com

Cavefish focus on which way the water flows



People tend to rely on their eyes to understand the world, but some fish don't have eyes or even light for illumination. A population of *Astyanax mexicanus*, or 'cavefish', thrive deep in caves where they navigate and find food in total darkness. A team of researchers based at the University of Florida, USA, led by James Liao, looked beyond this obvious difference to understand the hidden mechanisms behind the cavefish's success in exploring the world without eyes. They wanted to know if the cavefish nervous system adjusted to the lack of eyes by amplifying other senses, specifically the fish sense of 'touch', which detects water flow through structures called neuromasts distributed across the fish's body. The researchers compared how the neuromasts differ

between the blind cavefish and another sighted population of *A. mexicanus*, which live in streams on the surface of the planet and use their eyes to explore.

Instead of comparing how the adult fish responded to flowing water, the team compared larval fish from each species to rule out the possibility that any differences between the sighted and blind fish were due to learning as they developed. They found that the distribution of neuromasts along the sides of the fish larvae differs between the two populations: the blind cavefish have more neuromasts closer to their heads than the fish from a river at the surface. However, each neuromast was made up of a similar number of the flow-sensitive hairs that get tugged as the water moves past them – similar to the hair cells in our inner ears, which sense air pressure changes and allow us to perceive sound.

To determine whether the nervous system of the blind cavefish also adapted to the dark environment, the researchers measured the electrical signals produced by a single sensory neuromast when the larvae were still. When not swimming, the electrical signals produced by the blind cavefish neuromasts were stronger than those produced by their sighted relatives, indicating that the baseline of communication between the neuromast and the brain is higher. In addition, when the team vibrated the hairs of a neuromast to mimic the water flowing past, the response was again stronger in the cavefish than the surface fish.

The researchers then determined how the nervous system of the blind cavefish communicated while the larvae simulated swimming. By recording electrical signals from neuromasts, they found that when the surface fish are swimming, their neuromasts relay even fewer signals than when they are still, which allows the larval fish to ignore water flow across their body when generating their own movement. However, the blind cavefish's neuromasts continued to relay signals when swimming.

Next, the team tested whether the surface fish's lack of sensitivity as they swim is dictated by the brain. They located neurons in the brain that send signals to the neuromast flow sensors and experimentally silenced the neurons. Without signals from the brain, the neuromasts of the surface-dwelling fish

relayed signals similarly to the cavefish: they continued to be active when the fish were swimming. Suppressing the sensory signals produced by neuromasts during swimming can lead to more efficient swimming for the surface dwellers, but for the blind cavefish, more sensitive neuromasts are likely to be beneficial. And, when the researchers tested two other populations of blind cavefish that live in other cave systems, they found that the nervous systems of both populations adopted a similar strategy to increase their sensitivity to flowing water while swimming.

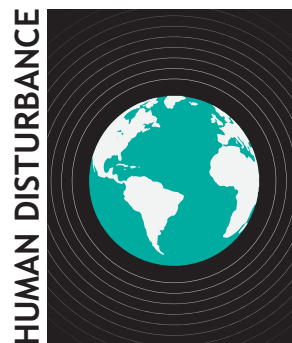
Fish with eyes rely on their sight to navigate while swimming. Without eyes, cavefish feel their way through the water by continuing to signal waterflow even when the fish are swimming. This extra attention likely requires more energy, but it's worth the cost in the darkness.

doi:10.1242/jeb.243518

Lunsford, E., Paz, A., Keene, A. and Liao, J. (2022). Evolutionary convergence of a neural mechanism in the cavefish lateral line system. *eLife* 11, 77387. doi:10.7554/eLife.77387

Ellen Lesser (0000-0001-7929-0503)
University of Washington
eless@uw.edu

Bearing bad news: human presence influences bear diet



As human populations get larger, we occupy more space in the world, which leads to increasing contact with wild animals. However, the effect of human presence on wild animals is not well understood. American black bears (*Ursus americanus*) are abundant and widespread across North America, yet little is known about the influence of

humans on their consumption of salmon. Thomas Shardlow and colleagues from the University of British Columbia Okanagan and Ministry of Forests, Canada, set out to determine how salmon stocks and the presence of humans influences the number of salmon in the diet of American black bears in British Columbia, Canada.

Between 2008 and 2011, Shardlow and colleagues surveyed the salmon stocks in various streams and rivers – from Vancouver Island and Princess Royal Island to Gill Island – by foot and snorkel during the fish's migration and spawning periods. The researchers also collected berry and leaf samples from bear trails parallel to the study streams along with other food that the animals might consume, such as shore crabs, prickleback, woodlice and ants. In addition, the team collected bear hair samples to test and see what type of food the bears were eating. To do so, the researchers set up barbed wire hair snag sites above a scent lure 5–30 m from the waterways, retrieving the hair samples every 21 days during the summer and every 10 days during the autumn. Lastly, to measure the effects of humans on the bears' diet, the team classified human presence in two separate ways; on a scale of 0–4 (0 being no human presence, and 4 as frequent human activity and bear hunting) and categorized the human presence as either 'high' or 'low' based on the range of human activities.

Back in the lab, after following the bears and their prey in the wilderness, the researchers measured the carbon and nitrogen levels in the hair and food samples. Additionally, they obtained previously published values for the carbon and nitrogen content of black-tailed deer, before comparing the values to identify whether the bears were consuming plants, salmon, other forms of meat from the ocean (such as fish or crustaceans) or land-based meat such as ants and deer. The team also sent the bears' hair samples to Wildlife Genetics International to determine the sex of the bears.

The researchers found salmon populations ranging from 800 to 13,800 fish in the study waterways. Yet, despite the availability of salmon, the bears' diet mainly consisted of leaves and berries; and all bears consumed less salmon in areas with high levels of human presence.

However, the team was also surprised that the bears shunned a salmon diet even when they rarely saw humans. They suggest that even a small amount of human presence may have a considerable impact on the foraging behaviour of bears. In addition, the researchers found that female bears ate less salmon than males. As female bears need to fatten before heading to dens during winter where they give birth, a decrease in the number of salmon in their diet may reduce their ability to build-up sufficient fat stores for winter to support their growing cubs. The diet of all bears contained greater quantities of ants and deer than salmon or crustaceans, which led the researchers to suspect that bears eat more land animals to obtain sufficient protein from their diet.

Shardlow and colleagues have provided evidence that the presence of humans in the wild – no matter how minimal – can lead to a dietary shift in bears. As humans encroach more on wild spaces, disturbing the residents, the need to understand the dynamics of ecosystems is vital. Importantly, wildlife and ecosystem management need to consider the roles that humans play, no matter how insignificant.

doi:10.1242/jeb.243515

Shardlow, T., Van Elslander, J. and Mowat, G. (2022). The influence of human disturbance on Pacific salmon (*Oncorhynchus* spp.) in the diet of American black bears (*Ursus americanus*) in two areas of coastal British Columbia, Canada. *Can. J. Zool.* **100**, 401-417. doi:10.1139/cjz-2021-0198

Kristina A. Muise (0000-0002-0497-4086)
Royal Veterinary College
kristinamuise@gmail.com

How rivalries shape the ranges of tropical birds



Tropical mountains host some of our planet's hottest biodiversity hotspots.

Ascending just a few hundred metres up an equatorial slope can reveal canopies teeming with distinct bird populations, such as hummingbirds, toucans and owls at each narrow slice of mountain side you cover. These differences yield stunning biodiversity, but we don't yet fully understand why tropical birds seem confined to such slim slivers of elevation.

Historically, people have pinned climate as the culprit. Tropical lowlands are typically hot while the highlands run much cooler and temperatures tend to remain seasonally stable, which creates narrow and distinct climatic niches along a mountain's slope. It's reasonable to predict that birds would prefer to live at temperatures that are just right for them – their 'Goldilocks' zone. Competition between different species of birds, however, can also constrain elevational ranges. For example, research has documented narrow elevation ranges of animals that live on mountain regions rich in species but broader ranges on mountains with fewer species. Benjamin Freeman and colleagues from University of British Columbia, Canada, and the Cornell Lab of Ornithology, USA, set out to measure the relative importance of these two hypotheses – climate and competition – for elevational range breadth using a global comparative approach of tropical bird species across 31 montane regions, from the Northern Rockies in the USA to the Southern Alps in New Zealand.

The researchers, taking advantage of the arsenal of data available on eBird – a global citizen science project that logs avian sightings – accessed 4.4 million detailed records to define the elevation range within which each species lives. They found that the number of species present in a region (that is the species richness or range overlap with other species) is a stronger predictor of elevational range than is temperature seasonality (or stability throughout the year). For example, consider two regions on opposite slopes of the Andes at the equator: the west and the east. These regions host similar temperature seasonality and mountain heights. The eastern slope, however, hosts 120 more species of birds but each species is spread over a significantly narrower elevational

range, which is consistent with the competition hypothesis.

Next, the authors examined the specific mechanisms by which competition could lead to the birds' narrower elevational ranges in more biodiverse locations. To do this, they analysed the territorial push and pull within pairs of closely related species that inhabit different elevational zones. They found in nearly half the cases (23 of 52) – and mostly in cases where birds show territorial behaviours – that related but competing species limit each other's ranges. For example, when two closely related species of *Campephilus* woodpeckers inhabit the same range, they avoid each other, and *Campephilus haematogaster* pass up the opportunity to inhabit elevations they would normally occupy if residing there alone. Clearly, rivalries between tropical bird species have a major impact on where they choose to live.

Despite over a century of investigation, the role of biological factors versus nonbiological factors in setting species ranges remains contentious, but competition certainly plays a role. This study also provides insights into how and why tropical birds (and possibly other tropical animals, from mammals to reptiles and amphibians) are responding to climate change. As a consequence of global warming, we've witnessed many dramatic species-wide shifts upslope to higher and cooler elevations. Most mountains, however, are shaped like pyramids with less and less suitable land at higher elevations, leading to increased competition. Thus, upslope range shifts generally lead to progressive declines in population size – a so-called 'escalator to extinction'. The degree to which the prevailing predictions of widespread extirpations of tropical species will come to pass depends on our ability to understand both biological and nonbiological influences on community structure, such as climate and competition.

doi:10.1242/jeb.243519

Freeman, B. G., Strimas-Mackey, M. and Miller, E. T. (2022). Interspecific competition limits bird species' ranges in tropical mountains. *Science* **377**, 416-420. doi:10.1126/science.abl7242.

Julie Jung (0000-0001-8319-3984)
University of Utah
julie.jung@utah.edu

Shark noses know how water flows



Hammerhead sharks are known for their unique head shape and researchers are fascinated by the potential advantages that their wide heads may give them. While all shark species have a knack for detecting the scent of prey with their powerful noses, some researchers have wondered whether the shape of the hammerhead could mean that picking up scent is easier for these species, since the space between the nares (shark nostrils) could help them to figure out where a scent is located. Hammerhead species also have specialized grooves in front of the nares which could help them to detect faint scents in larger volumes of water. While previous work has suggested that hammerheads are no more sensitive to scent than other sharks, there is still much to learn about how the sense of smell is shaped in this extraordinary species.

Lauren Simonitis and Christopher Marshall from Texas A&M University, USA, investigated the olfactory organs of bonnethead sharks, a hammerhead species with a slightly narrower head than the typical hammerhead, to understand better how this system picks up scents when water flows over it.

The researchers collected four bonnethead sharks from local fishers for testing. They took detailed photos using a scanning electron microscope of the tiny ribbings, called lamellae, which cover the scent detecting olfactory bulbs and interact with the water to allow a shark to sense a scent. They also studied the internal structure of the olfactory bulbs using a light microscope to view thin slices of the olfactory bulb. They measured how much of the olfactory bulb was made up of tissues that can sense scent and compared the shape of the lamellae across different areas of the olfactory bulb, since previous studies had revealed that water flow rates vary across the bulb.

The research duo found that the bonnethead shark's olfactory bulb is similar to that of other shark species, but they lack structures known as true olfactory knobs (swollen structures on scent reception cells) that occur in other non-hammerhead sharks, such as spiny dogfish. They also found that bonnethead sharks have larger lamellae in areas where

the water flow over the olfactory bulb is highest and smaller lamellae in areas where the water flow is slower. The areas with high water flow tend to be the most scent-sensitive tissues, with more folds in the lamellae, which could help the lamellae to physically withstand powerful water flows while picking up fainter scents from the fast-flowing fluid.

These results tell us that while many of the structures in the shark olfactory systems are similar across different species, there are important variations that can affect their sense of smell. Looking within the olfactory bulb, we know that water flow rates can vary in different areas and see that the shape of the lamellae and the area of sensory tissue are correlated with these differences. The increased sensitivity in these areas is essential for the sharks to detect dilute scents carried in fast-flowing water, just like it is harder for us humans to smell something outside when it is windy compared to the stagnant odours in an unaired room.

doi:10.1242/jeb.243516

Simonitis, L. E. and Marshall, C. D. (2022). Microstructure of the bonnethead shark (*Sphyrna tiburo*) olfactory rosette. *Integr. Org. Biol.* **4**, obac027. doi:10.1093/iob/obac027.

Amanda Palecek (0000-0002-9908-3103)
Clemson University
 apalece@g.clemson.edu