Climate change is breaking Earth's beat

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Abstract

Forests, deserts, rivers, and oceans are filled with animal vocalizations and geological sounds. We postulate that climate change is changing the Earth’s natural acoustic fabric. In particular, we identify shifts in acoustic structure that all sound-sensitive organisms, marine and terrestrial, may experience. Only upstream solutions might mitigate these acoustic changes.

Text

From pole to pole, numerous animal species transmit sounds for communication, foraging, and navigation, in particular. Sound is a major element of animal behavior that is used, for example, in territory defense, mate attraction, parent–offspring identification, orientation, prey localization, predator escape. Natural sounds may also come, in part, from plants, initiated both internally and as a consequence of external abiotic forces such as rain, wind, and moving water. Here, we emphasize that climate change is transforming two components of the global soundscapes (Figure 1): biophony which includes biotic sounds; and geophony that groups abiotic, but natural, sounds coming, for example, from running water, wind, and earth movements.

Weather properties play a role in the propagation of animal sound in the surrounding environment as sound speed depends on a range of parameters including ambient temperature, relative humidity, wind, and rain intensity. Variations in these parameters can drastically change the range of communication between individuals [1] unusual weather conditions might prevent sound propagation, for example, the temperature might be too high or the air too dry. In addition, there are abundant examples that demonstrate how temperature directly governs the acoustic behavior of terrestrial, aquatic, and marine animals through chemical and physiological regulation, in particular neuron activity and muscle contraction. It is well known that the ambient temperature controls the vocalization repetition rate, pitch, volume, and the auditory processes of ectothermic species, such as amphibians, fish, and arthropods [2]. The dependence of animal vocalization on climate is actually so strong that it is apparent in past and present popular culture: animals are thought to be able to predict weather as the thermometer crickets, the forecasting frogs, and the summer cicadas.

Individual sensitivity to meteorological conditions induces cascading effects at larger ecological scales. There is growing evidence that climate change is affecting the phenology of plant and animal populations [3], a property that has a major role in both ecology and evolution. Acoustic phenology can be viewed as the seasonal acoustic activity of animals, a well-known and popular phenomenon for bird and whale songs for instance. Climate change can induce shifts in acoustic phenology either directly through a change in the phenology of signal-producing organisms or indirectly through a change in their resources (e.g., food plants). Similarly, the population spatial distribution can be modified by a change in climatic conditions with movements toward higher latitudes or altitudes [4], remodeling locally the population acoustics and soundscapes. Changes in population phenology and biogeography may then have relevant consequences in terms of nature acoustics.

The signal-producing capacity and distribution of a significant number of species may be then altered by climate change. Novel weather characteristics and dynamics might reduce, or increase, vocal emissions of soniferous species with consequences for other energy demanding activities. Some populations face the risk of extinction leading to silencing of the biophony. Alternatively, other populations may benefit from climate change, extend their distribution, and dominate the acoustic space. The loss and gain of soniferous species could thus strongly rearrange the natural soundscapes of large areas. This reorganization could lead to a loss of acoustic diversity among sites and across time and an acoustic homogenization with ubiquitous species dominating the soundscapes. This would be a reduction of beta diversity, a crucial component of biodiversity. Acoustic changes might be even more pronounced for the species living in both cold and tropical areas that have a low thermal tolerance and a limited acclimation capacity [5].

The acoustic niche hypothesis, derived from the ecological niche concept, stipulates that at a given location each species would occupy non-overlapping specific acoustic space to avoid interference. This partitioning observation is often noted in pristine environments but might not hold in perturbed environments, and may not prove to be viable with climate change due to the rearrangement of community composition, shifts in acoustic phenology, and to modifications of signal parameters as time pattern or frequency range. These changes would then lead to asynchrony and niche partition obfuscation.

Extreme climate events are already occurring and are predicted to increase in frequency and severity over time. These will not only damage the habitats of soniferous species [6] but also deeply affect natural soundscapes, in particular, geophony. Cyclones, heat waves, droughts, floods, and wildfires generate soundscapes that will be more frequent than before.

For humans, changes in biophonic patterns can be a factor of anxiety and stress as natural soundscapes have been proven to be a source of tranquility and serenity, an acoustic refuge where the human mind can recover, and an important factor for green tourism and local economies [7]. Humans should be prepared for a change in acoustic environments, from remote wilderness to urban areas, and efforts in education should alert citizens to these future changes. The seasonal acoustic signatures will shift with noticeable changes in species density, and diversity. In particular, the populations of birds may show different song dynamics [8], the populations of frogs may call earlier or less [9], and the populations of nocturnal insects may decrease inducing a reduction of stridulations [10].

While solutions may exist to control anthropogenic sound by reducing the sound pressure level of sound sources or by protecting the receiver, there are unfortunately no straightforward solutions to reduce the effects of climate change on natural sound. The only upstream solutions are those advocated for climate mitigation. Nonetheless, current research in ecoacoustics can help in monitoring the changes affecting natural sounds. Noninvasive, long-term, and large-scale techniques are able to record and analyze natural soundscapes for ecological research, introduced in Box 1.

If animal sounds are the material of several research programs in ecology and biological conservation, they have been also a source of inspiration for artists since the origin of music, in all styles. Sound travels across oceans and passes over country boundaries; as the acoustic medium of the natural world, it knows no boundaries. Such cultural importance and universality make natural soundscapes a fundamental means of increasing popular awareness about climate change.

Anthropogenic noise and land use have been identified so far as major threats to animal acoustics [11]. Nonetheless, climate change also acts as a major risk for changing Earth's natural soundscapes through direct, indirect, and combined effects. If singing animals are proto-musicians interacting in a proto-orchestra, we can then predict that changing the thermal and moisture conditions of the concert hall will detune the ensemble and affect the performance capacities of the players. Furthermore, it will likely introduce a perceived dissonance in the music. The same is happening for Earth's orchestra: new atmospheric conditions are detuning natural sounds and only major mitigation actions will help preserve Earth's beat.

Box 1. **The challenges of monitoring soundscapes over the long-term**

For those researchers attuned to habitat-defining ecoacoustic indicators, there are many scattered reports of shifts in the density and diversity of organism voices due to climate change [12]. However, these fluctuations are difficult to quantify, in part, because this subject is so new resulting in a paucity of quality data sets and analytic tools. But also, the older institutional sound libraries have primarily focused on individual species' acoustic samples rather than the collective expressions inherent in a more holistic biophonic approach; this last method is one that has evolved independently over the last half century. These biophonic collections must be mined for their baseline potential, especially where they have been recorded under strict protocols. In addition, ecoacousticians now have access to recording technologies that store layers of long-term metadata not previously possible with earlier systems. Because of their inherent value, we have reached a critical preservation turning point for such data acquisition and research.

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Figure 1. Climate change and soundscape change. Changes in the soundscape of a natural environment over time. Top is a spectrogram revealing sound intensity in color according to time (year) and frequency. Bottom is an oscillogram showing sound amplitude according to time (year). This time-lapse is a series of 10-s samples extracted from recordings conducted from 2005 to 2019 with the exception of the year 2012. The recordings were obtained at the same location (Sugarloaf State Park, CA, USA, 38°26′23.00″N/122°29′53.44″W), at the same date (15 April), at the same time (06.35 h), with the same calibrated equipment. In red is overlaid the trend of the average temperature of April recorded at the same hour. This trend and 95% confidence intervals (broken lines) were obtained with a polynomial regression fitted over 30 years (1989–2019). Located about 50 m from a year-round stream, the site is an ecotone between riparian and oak savannah which did not suffer main land use changes. The lower half of the spectrogram shows the signature of the nearby stream with different flow regimes under different precipitation patterns. Weather-related changes reduced bird diversity from 2011. Recordings by Bernie Krause; temperature data from weatherspark.com.