Physicists Show that Correlated Environmental Variations Can Quicken Extinctions

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The passenger pigeon, once the most common bird in North America, was hunted to extinction during the late 1800s and early 1900s. Image: Orthogenetic Evolution in the Pigeons (1920).

(PhysOrg.com) -- In general, population extinction is a natural process. For one reason or another, an estimated 99.9% of all species that have lived on Earth are now extinct. However, the reasons for a species going extinct are complex, varied, and changing. Ever since the human population began dispersing throughout the Earth 100,000 years ago, the extinction rate has increased dramatically - as much as 1,000 times, by some estimates - putting us in the midst of a modern extinction called the Holocene extinction event.

Why populations go extinct is relatively unknown. Ecologists, biologists, physicists, and other experts have investigated the dynamics of extinctions in an effort to understand the factors involved, which is essential for optimizing conservation management.

Recently, a team of physicists has studied how random environmental noise (from a wide variety of factors such as climate and resources) affects how quickly a population goes extinct, which the scientists call the "mean time to extinction" (MTE). Physicists Alex Kamenev and Boris Shklovskii of the University of Minnesota, along with Baruch Meerson of the Hebrew University of Jerusalem, have published their study in a recent issue of *Physical Review Letters*.

As the scientists explained, environmental noise is known to affect a population's birth and death rates, occasionally decreasing the population size and accelerating its extinction. Earlier theoretical work had assumed that the environmental noise is "white" - that is, random variations of the environment are uncorrelated. But more recently, researchers have found that the real environmental variations are correlated, or "colored" rather than white.

"In a broad sense, environmental noise includes irregular variations of environment which are relevant for population dynamics," Meerson told *PhysOrg.com*. "For example, temperature variations, droughts, floods, diseases, predators. Were random variations of the environment uncorrelated, they would be describable by the white noise model. The real environmental variations, however, are often correlated. For instance, there is a certain duration of diseases, predators may be present for a certain time, and so on. More often than not, the white noise model should give way to the colored noise model."

Meerson and his coauthors addressed the question of how the color of the environmental noise affects the extinction rate of a population, which has eluded understanding for many years. They found that even relatively weak environmental noise can cause extinctions to occur more rapidly. Generally, the larger a population's size, the longer it takes a population to become extinct. However, the researchers show that noise color changes this relationship, depending on how long the noise is correlated.

"The most significant result of this work is that the color of environmental noise may dramatically enhance the population extinction risk," said Meerson. "Among other surprises was the prediction of the most probable realizations of environmental variations (as reflected in the time-dependence of the birth and death rates) which lead to extinction. It turns out that these vary quite a lot with the noise color."

For a long correlation time of the environmental noise, the population size has almost no effect on the MTE, for a strong enough noise. In this scenario, the population size decreases gradually. The noise color doesn't directly cause extinction, but it makes a large population fluctuation more probable. In turn, large negative population fluctuations make species more vulnerable to extinction (for instance, because of a temporary drop in fertility), potentially wiping out the population.

On the other hand, for a short correlation time of the environmental noise, the MTE changes from scaling exponentially with population size to scaling as a power law. Such short-correlated noise can cause a sudden "catastrophe" in the population, such as by reducing its birth rate to a value that cannot sustain a steady population.

Overall, the physicists hope that understanding how correlated environmental variations affect extinction rates will help them understand consequences for ecosystem fragility and species conservation. In the midst of the modern extinction era, understanding the dynamics of extinctions may help humans better realize how we influence natural population changes.

More information: Kamenev, Alex; Meerson, Baruch; and Shklovskii, Boris. "How Colored Environmental Noise Affects Population Extinction." *Physical Review Letters* 101, 268103 (2008).

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