Movement and arousal decisions by healthy and diseased cave-dwelling bats during hibernation.

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Motivation: Several cave-dwelling bat species in the northeastern US, including the Little Brown Myotis and the federally endangered Indiana Bat, are at risk of regional extirpation by the fungal disease known as white-nose syndrome. Since appearing in New York in 2006, this disease has swept southwestward via bat migration and has now reached Kentucky, with mortality rates apparently reaching 100% in infected caves. Currently, the most plausible explanation for the mortality is that the disease causes bats to dehydrate more rapidly during hibernation, and the resulting frequent arousals to replace the lost water use fat reserves too quickly for the bats to survive the entire winter. Little is known about how hibernation physiology might influence the decisions bats make concerning their location—and thus their temperature- and humidity-dependent fat utilization rates—within the cave.

Research Questions: Since the temperature and its variability within the cave hinges in part on distance from the entrance, where should healthy or diseased bats locate within the cave? How often should they arouse during the winter to drink and relocate? What mortality rates and timing will result from these behaviors?

Methods: We assumed that a cave can be represented as a temperature (and humidity) gradient from a single entrance to a point deep enough to reach the constant deep-cave temperature characteristic of latitiude. In agreement with existing data, we constructed a computer simulation model in the MATLAB programming language based on the premise that bats arouse from hibernation after using a constant increment of fat reserves since the last arousal. To this we added a water-loss component that arouses the bats sooner if they become dehydrated. We assumed that the bats relocate at each arousal to the location that minimizes their arousal frequency, and we tracked their resulting movements within the cave over the winter.

Results: Bats in the model relocate through the winter in characteristic, latitude-dependent ways that differ when healthy vs diseased. Diseased bats arouse more frequently and are likely to exhaust their fat reserves during the winter under a wide range of plausible conditions.

Discussion: To date, behavior during hibernation is poorly known, and only the frequency of arousal has been reasonably well documented for mammals. Our model generates both arousal and movement patterns, based on optimal decisions, that can be tested in the field. If bat populations are able to evolve at least partial immunity to the disease, these behavioral decisions may enable interventions like supplementary food and water to facilitate population survival. Note that the decisions here will respond in the short term to environmental and physiological condition but in the longer term to global and evolutionary change.