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In mosquito, a small tale of climate change

Andy Cord (above), an undergraduate research assistant, worked in the University of Oregon lab of Christina M. Holzapfel (rear, right photo), who with her husband, William E. Bradshaw, has documented genetic changes in hundreds of thousands of mosquitoes. Scientists say species with short life cycles can evolve quickly and keep up with changing environmental conditions. (DINA RUDICK/GLOBE STAFF)

By Beth Daley
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UNORGANIZED TERRITORIES, Maine - In a woodsy bog on the road between Millinocket and Baxter State Park, a mosquito that can barely fly is emerging as one of climate change's early winners.

The insect, which lives in the carnivorous purple pitcher plant, is genetically adapting to a warming world. By entering hibernation more than a week later than it did 30 years ago, the Wyeomyia smithii mosquito is evolving to keep pace with the later arrival of New England winters.

Along with Canadian red squirrels and European blackcap birds, the mosquito - a nonbiting variety found from Florida to Canada - is one of only five known species that scientists say have already evolved because of global warming.

The unobtrusive mosquito's story illustrates a sobering consequence of climate change: The species best suited to adapting may not be the ones people want to survive. Scientists say species with short life cycles - Wyeomyia smithii lives about eight weeks - can evolve quickly and keep up with changing environmental conditions as a result. Rodents, insects, and birds, some carrying diseases deadly to humans, are genetically programmed to win. Polar bears and whales, which take years to reproduce, are not.

Scientists have demonstrated that genetic change is taking place in four species besides the purple pitcher plant mosquito.

Canadian red squirrels
Reproducing earlier in the spring. The change allows the squirrels to take advantage of greater spruce cone production that is driven by warming temperatures and drier conditions.

European blackcaps
Overwintering in warmer Britain instead of Iberia. The change allows the birds to arrive earlier at nesting sites to get the best territories and mates.

European great tits
Individuals are laying eggs earlier. The change helps newly-hatched chicks feed on caterpillars that are maturing earlier in the spring because of climate change. It is not clear yet if the population can keep pace with global warming.

Fruit flies *(European, Australian, North American)*
A chromosomal mutation typical of fruit flies in warmer climates is becoming more common in northern species. The mutation appears to help the fruit fly, but scientists don't yet know how.

SOURCES: University of Alberta; Bradshaw-Holzapfel lab, University of Oregon

PHOTOS: DINA RUDICK, GRAPHIC: DAVID BUTLER/GLOBE STAFF

"Rapid climate change is actually now driving the evolution of animals - that is a dramatic event," said Christina M. Holzapfel, who, with her husband, William E. Bradshaw, has documented genetic changes in hundreds of thousands of mosquitoes at their University of Oregon lab in Eugene. The couple, both evolutionary geneticists, began collecting the mosquitoes at the bog here and in other New England locations more than 30 years ago while at Harvard University.

Until now, the effects of climate warming had been most noticeable in the Arctic, as glaciers melt. But dramatic changes are also being seen in northern temperate zones such as New England, where the average winter temperature has risen 4.4 degrees Fahrenheit over the last 30 years. Growing seasons have lengthened, winter is arriving later, and the weather has become more erratic.

Scientists are worried that climate change, caused largely by the release of heat-trapping gases from power plants and cars, will drive evolution in unpredictable and unwelcome ways in these regions, where millions of people live. Researchers are trying to determine in more detail how species will adapt to a projected 3.2- to 7.2-degree rise in the world's average annual temperature by the end of the century. Their answers could help predict outbreaks of diseases spread by insects and rodents, and how ecosystems will change as species react at different rates to the warming.

"The world is going to be a very different-looking place," said Loren Rieseberg, an evolutionary biologist at the University of British Columbia in Vancouver. He has done rough calculations suggesting that species that take longer than two years to reproduce will not be able to keep up with

the current pace of climate change. Some of the laggards will probably become extinct, he said, while others will migrate to new places.

"We are going to have very different sets of organisms living together," he said.

Hibernation in a lab

In a cramped, steamy room at the University of Oregon in Eugene, dozens of mosquitoes feebly flit above rows of red-veined purple pitcher plants. Oversized Petri dishes, each with dozens of mosquito larvae, are stacked nearby.

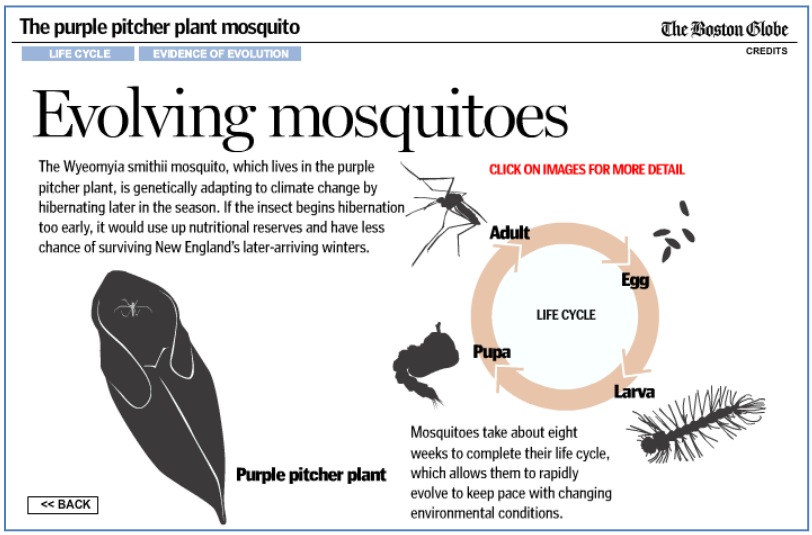
The windowless room is part of a five-year experiment by Bradshaw and Holzapfel that simulates global warming in Northern Maine. Using sophisticated computers that constantly monitor and adjust the room's temperature and humidity, the couple is replicating the climate of New Jersey - which northern Maine is expected to experience in 180 years if the current rate of warming continues.

VIDEO: http://www.boston.com/news/specials/climate_change/wyeomia_video/

The room's fluorescent lights are programmed to mimic the number of hours of light per day in northern Maine because day length signals mosquitoes to begin hibernating.

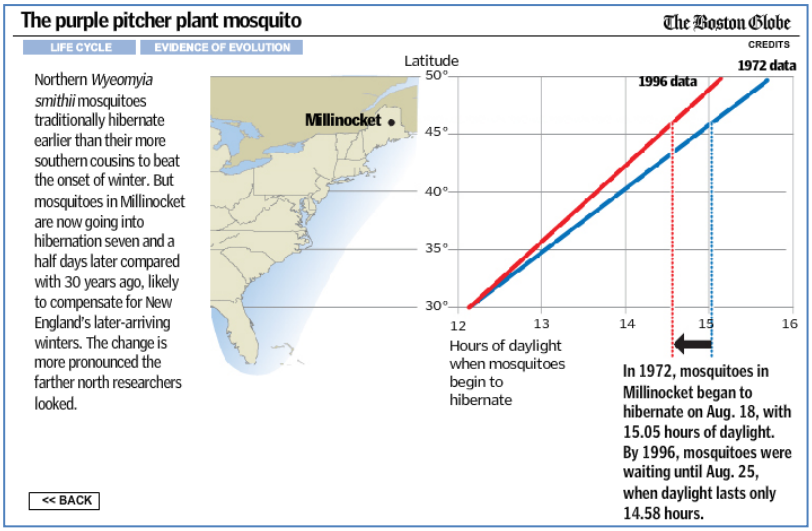
In Maine, the mosquitoes mostly begin hibernation on Aug. 25, when there is a little less than 15 hours of daylight. But to survive in New Jersey, they must begin hibernating later in the season, when day length is less than 14 hours, to compensate for the later onset of winter.

Timing of hibernation is a life or death decision for the mosquito: If it begins hibernating too early, it will use up limited nutritional reserves when it doesn't need to and reduce its chance of surviving the winter. If it starts too late, it will freeze to death.



The experiment favors individual mosquitoes in each generation that, because of genetic variation, start hibernating later than the rest of the population. More of these late-hibernating mosquitoes survive the winter and then pass on that later-hibernation genetic trait to the next generation. The process continues until most of the population is hibernating at the best time to ensure they survive the winter.

The experiment, now in its third year, is similar to what is happening in a warming New England, where the growing season is getting longer and winters are arriving later "but the day length stays the same," Holzapfel said.



Survival in a bog

Bradshaw and Holzapfel never set out to study global warming with the fragile Wyeomyia smithii mosquito. As post-graduate students at Harvard in the early 1970s, they became interested in species' biological clocks and settled on the pitcher plant mosquito as a good case study.

The two would pull on hip boots and wade into bogs around Boston and in Northern Maine searching for the stubby plants and their signature tall summer purple blooms.

The plant, which can live 100 years, feeds on ants, moths, and other insects that drown in its water-filled leaves. The mosquito spends much of its life in water and doesn't succumb in the plant's watery trap. The mosquito larvae also feed on the decaying bugs and the adults rarely stray far from the plant: They are so weak-flying, a strong wind will send them crashing to their deaths.

Over the years, Holzapfel and Bradshaw gathered insects and purple pitcher plants from more than 100 sites from Florida to Canada. Back at their lab in Oregon, they would place the mosquitoes in a constant environment and meticulously record at what day length they began hibernating.

As global warming became a pressing scientific issue, the couple pored over their exhaustive records. Their data showed that Millinocket mosquitoes and others at the same latitude (46 degrees north) were starting hibernation 7.5 days later in 1996 than they had in 1972. Bradshaw and Holzapfel demonstrated that this was a genetic response to climate change because the further north they

looked, the more mosquito hibernation dates shifted. In Florida, for example, the mosquito hibernation dates didn't change at all.

These observations fit with other scientific evidence that global warming becomes more pronounced closer to the poles.

"No one set out 30 years ago to ask questions about climate warming and evolution," said Bradshaw. "It was a nonissue."

`Things are changing'

Nearly every species reacts to changes in the weather. Lilacs bloom earlier if a spring is particularly warm. Mice populations boom in years when winter temperatures are warm enough for them to reproduce.

Yet these responses aren't necessarily genetic: Most species, including humans, have a built-in flexibility - scientists call it phenotypic plasticity - that allows them to adjust to temporary environmental conditions. It is partly why we can withstand Boston's frigid winters and steamy summers.

But when the changes are all in the same direction and continue for a long time - such as the warming taking place in New England - Charles Darwin's natural selection can take over: Individuals with certain characteristics better suited to the changed environment survive in greater numbers than others in the population. Those individuals then pass on those favorable genetic characteristics to their offspring, eventually leading to evolutionary change in the entire population.

Now that Bradshaw and Holzapfel have demonstrated this shift in the wild among mosquitoes from Maine and elsewhere, they are trying to better understand the exact mechanisms. Their current experiment with Maine day length and New Jersey climate is designed to further illuminate the critical role day length plays in mosquitoes' survival in a warming world.

In the May issue of Genetics, the scientists report that they have identified regions on three chromosomes containing genes involved in controlling mosquitoes' response to day length.

Scientists say that global warming is almost certainly driving evolution of other, less-studied species. And while they know that short-lived species that reproduce rapidly have a better chance of adapting, they cannot yet predict exactly which species will ultimately win and which will face the threat of extinction. Some long-lived species may be able to adjust without genetic changes; humans, for example, can move from flood-prone areas as sea levels rise. Some short-lived species may die because their environment changes too greatly for them to survive.

"The moral of the story is that things are going to be different," said Kevin Emerson, a graduate student in the Bradshaw-Holzapfel lab. "Whether we know exactly what is going to be different ... I don't think we can say. But people have to accept that things are changing."

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