Pandemics in Roman Empire correlate with sudden climate changes

A new temperature and precipitation proxy record shows that periods of rapid cooling align with the civilization's three worst disease outbreaks.

GERARD VERSTEEGH AND KARIN ZONNEVELD, coauthors of the new study on climate change and pandemics, process a sediment core from the Gulf of Taranto. (Courtesy of Karin Zonneveld.)

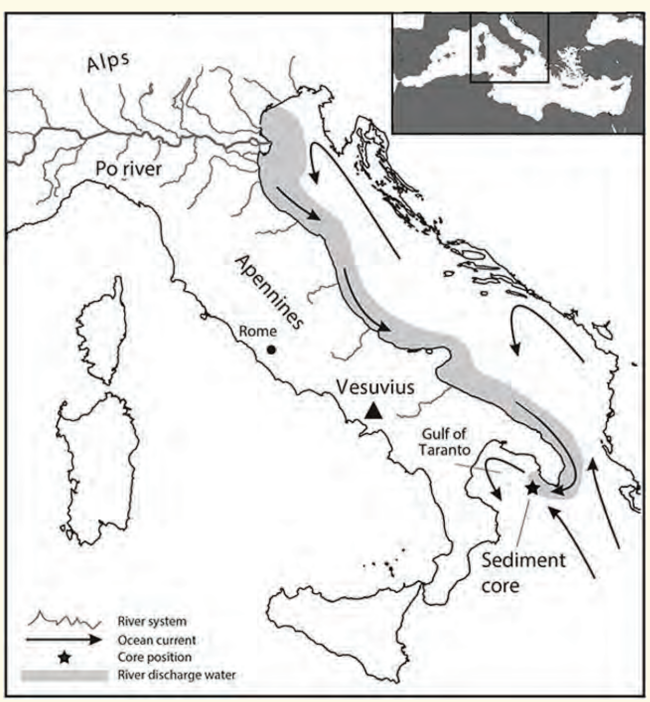
Plankton living in the Mediterranean Sea some 2000 years ago have helped researchers to uncover a correlation between climate change and the spread of disease in ancient Roman Italy and into the early Middle Ages.

Using a sediment core recovered from the Gulf of Taranto, in the arch of Italy's boot, Karin Zonneveld of the University of Bremen in Germany and colleagues reconstructed the regional climate from 200 BCE to 600 CE. The sediment record reveals that periods of rapid cooling and drying in the heart of the Roman Empire align with documented major disease outbreaks, the researchers report in a new study.

The core's plankton fossils are from dinoflagellate cysts, also known as dinocysts. Dinoflagellates bloom in late summer and early fall, with thousands of species that thrive under varying surface temperatures and nutrient levels. By comparing the ratios of dinocyst species that flourish in warmer waters with those that flourish in cooler waters, researchers can precisely estimate historical temperatures. Dinocysts also respond to the water's changing nutrient levels, which are controlled by precipitation. Rain and snowfall over the Italian Peninsula are channeled by rivers into the Adriatic Sea, where currents carry the nutrient-enhanced water southward around Italy's heel and into the gulf.

The core was recovered from a location with a rather high deposition rate, with 1 cm of sediment deposited roughly every 10 years (compared with about 1 cm/1000 yr in the open Mediterranean Sea). That high deposition rate translates into the most detailed record to date of the regional climate at that time—with changes discernible down to a three-year resolution. The new data fill a gap in knowledge that other climate proxies were unable to. Tree-ring records for the area don't go back far enough in time, pollen records are tainted by human agriculture, and cave stalactites don't have a fine-enough temporal resolution. Ash and glass shards from nearby volcanic eruptions, combined with lead and carbon isotope dating, were used to constrain the ages of sediments in the core.

The researchers found that after a few hundred years of a warm, wet, stable climate known as the Roman Climate Optimum, a sharp downward temperature trend began around 130 CE and continued well past the arrival of the Antonine Plague in 165 CE. Temperatures never returned to the warmth or



A MAP OF ITALY shows the site where the sediment core was recovered from the Gulf of Taranto and the direction of offshore currents that carry river discharge southward along the eastern coast and into the gulf. (Adapted from K. A. F. Zonneveld et al., *Sci. Adv.* **10**, eadk1033, 2024.)

stability of the early Roman Empire. The Plague of Cyprian hit around 251 CE amid another rapid temperature decline that lasted half a century. The first plague pandemic arrived in roughly 541 CE, when temperatures were near the lowest measured over the entire record.

"This is a wake-up call," says Zonneveld, who studies marine microfossils. She says climate change affects biodiversity and the migration of species—and of germs. Although the study doesn't attribute a causal relationship between climate change and pandemics, the researchers note that climate impacts on agriculture and regional ecosystems could cause perturbations that trigger or exacerbate disease outbreaks. The results highlight the value of studying the complex relationship between climate change and infectious disease. (K. A. F. Zonneveld et al., *Sci. Adv.* **10**, eadk1033, 2024.)

Laura Fattaruso

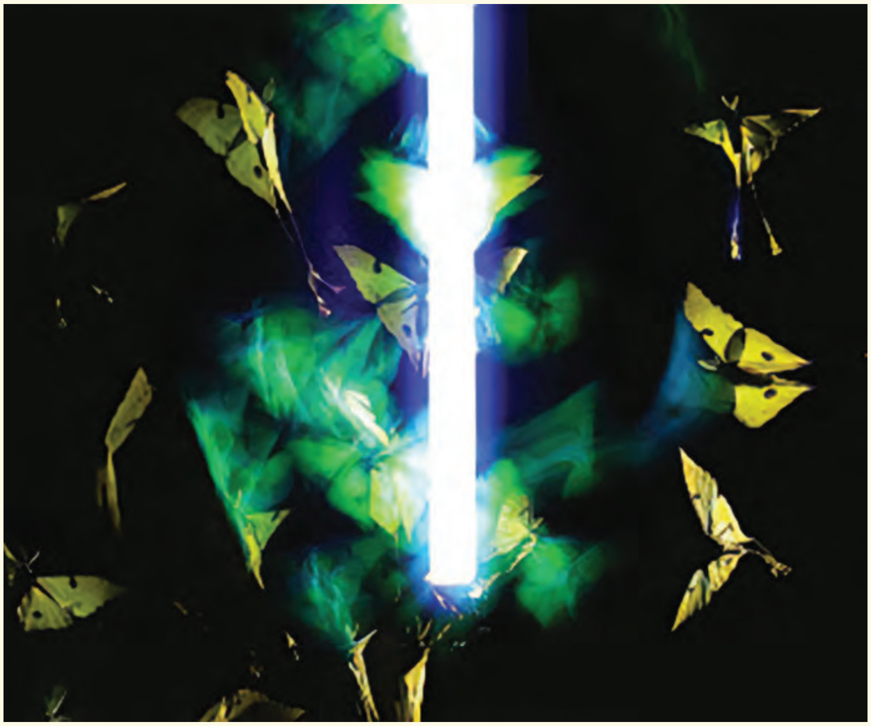
Why insects orbit light at night

Mistaking artificial light for the sky, insects become entrapped while circling it. High-speed camera footage captures the behavior in action.

As soon as human beings started making campfires at night, they noticed that flies, moths, butterflies, and other insects were attracted to the glow. Indeed, records of finding them trapped in the orbit of such artificially produced lights go back to the Roman Empire. Some biologists wondered whether the insects might be confusing the artificial light with the Moon, which some insects use for navigation. Others proposed that insects are instead attracted to its heat. But the kinematic data needed to test predictions are exceedingly rare. Tracking the positions of small, fast-moving insects in low light is technically difficult.

Flying insects need a reliable way to determine their orientation in midair. As the brightest part of the visual field, the sky serves that function—to indicate which way is up. The presence of artificial point light sources can mislead or confuse an insect's sense of orientation. Dragonflies, butterflies, and other large flying insects can leverage their passive stability to stay upright. But the smaller size of most insects makes their lives more turbulent. Their Reynolds number—the ratio of the inertial and viscous forces they experience—is lower. So they must rely on visual cues to remain oriented in a gravitational field.

Two postdoctoral researchers—Sam Fabian from Imperial College London and Yash Sondhi from the University of Florida in Gainesville—and three colleagues have now taken high-resolution video footage of the trajectories of 10 taxonomic orders of insects in the presence of two artificial light sources. A UV LED bulb or tube light first attracted the insects' attention. IR light was then used to photograph their motion without influencing them. That work was done in different locations: first in a controlled laboratory environment in London and subsequently in the wild during trips to Costa Rica.



MULTIPLE EXPOSURES TRACK an African moon moth as it flies around a UV tube light at a laboratory at Imperial College London. (Courtesy of Sam Fabian.)

In the laboratory, the researchers attached reflective markers to the insects' bodies and tracked their positions and orientations using eight motion-capture cameras. That footage and stereo videography taken in the field at rates up to 500 frames per second revealed that the flying insects rarely head directly toward a light source but, rather, fly orthogonal to it. They tilt their backs toward the brightest area they perceive, which can cause an asymmetry in the distribution of the forces on them.

Known as the dorsal-light response, the behavior normally keeps the insects aligned with the horizon. But a point light source disrupts that cue and prompts insects to turn their backs on what they mistake as the sky. The result is a circular orbit in which they're subsequently trapped, as shown in the figure. One of the most concise pieces of evidence revealing that the insects are confused, according to Fabian, is that they flip upside down while flying directly over the light. "That behavior is not explained by any other theory," he says.

Despite the ubiquity of the behavior among insects, there are exceptions. Some species, such as vinegar flies and oleander hawk moths, appear less affected by UV light. Why some species are more sensitive than others remains an open question that the researchers plan to address. (S. T. Fabian et al., *Nat. Commun.* **15**, 689, 2024.)

R. Mark Wilson