*Say's reading materials for Group B*

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# The Alarming Case of the Missing Insects

*A pair of researchers found evidence that the insect population in a Puerto Rican rain forest was in free fall. But another team wasn't so sure*

MADDIE STONE

In the biological wonderland of Puerto Rico's Luquillo Mountains, slinky boas and emerald anoles hang out in lowland tabonuco trees, delicate bromeliads decorate the mountaintop cloud forests, and the island's eponymous parrots forage in the canopy. At dawn, the rain forest swells with the mating calls of thousands of coquí frogs. Underpinning this ecological tapestry is a world teeming with arthropods—which is why, when a pair of scientists reported last fall that Luquillo's arthropod populations were crashing due to climate change, the internet reacted with horror.

*The Guardian* called the research "deeply worrying"; one scientist told *The Washington Post* that the collapse was "hyper-alarming." The study, conducted by the biologists Brad Lister of Rensselaer Polytechnic Institute and Andres Garcia of the National Autonomous University of Mexico and published in the *Proceedings of the National Academy of Sciences* (*PNAS*), was picked up all over the web (including by me) and has been cited in more than 75 academic papers since its publication. The work stuck out as a particularly worrying data point in a growing pile of evidence that Earth's insects might be speeding toward some sort of apocalypse.

But the process of scientific knowledge-gathering can be messy, and scientists with Luquillo's Long Term Ecological Research (LTER) Program—which furnished much of the data underpinning Lister and Garcia's conclusions—now believe many of those conclusions are false.

These researchers aren't disputing the fact that climate change is occuring in Puerto Rico, or that insect declines are a serious issue. They just don't see evidence for a simple link between the two in this particular ecosystem. Instead, they see a rain forest experiencing profound boom-and-bust cycles in response to disturbances such as hurricanes. In an effort to set the record straight, the researchers wrote a formal rebuttal letter in the spring and have given presentations at conferences, most recently at the Ecological Society of America meeting this month.

Despite the pushback, Lister and Garcia are standing by their conclusions: Even with imperfect data, they say, what they found is cause for concern.

The seed of their original study came from weather-station data in Luquillo, where Lister had done fieldwork in the 1970s. He became concerned about the rain forest's insects after noticing that temperatures at two sites had risen by about 2 degrees Celsius (3.6 degrees Fahrenheit) in the intervening decades. Some laboratory evidence suggests that tropical insects might be highly sensitive to temperature increases. And so he returned to the same spot where he had studied insects in 1976 and 1977 to see if the forest had changed. On several trips from 2011 to 2013, Lister and Garcia placed sticky traps on the ground and in the canopy, and used sweep nets to collect insects and estimate their total abundance.

Their findings were alarming: Compared with the 1970s, the surveys from 2011 to 2013 turned up 98 percent less insect biomass in ground traps, 83 percent less in sweep nets, and 65 percent less in canopy traps. The scientists also found close to 60 percent less anoles, a diverse family of lizards that eat insects.

To put this worrying data in a broader context, Lister and Garcia looked at the abundance of other animal populations—canopy arthropods, walking-stick insects, frogs, and birds—elsewhere in the forest. In each case, the LTER's long-term data sets, compiled over several decades, seemed to confirm the researchers' fears: Everything was declining. After showing that rising temperatures correlated with declining abundances and, according to Lister, eliminating other factors such as pesticides, the researchers concluded that climate change was the most likely culprit.

When Lister and Garcia published their findings in October, Tim Schowalter, an entomologist at Louisiana State University who has spent decades surveying insects at the Luquillo LTER, thought they looked solid. Other research groups in Europe were documenting long-term insect declines; this seemed like evidence that such declines could be global. Mike Willig, a co–principal investigator for the Luquillo LTER, says his first reaction was: *How did we miss this?*

It wasn't until the LTER researchers assembled to try to answer that question that they began to notice some problems.

One of the first things that looked off to them was Lister and Garcia's report of a 2 degree rise in maximum temperatures at the LTER's El Verde field station. When the LTER scientists examined the data underlying that figure, they found that Lister and Garcia had combined two temperature records, one from 1975 to 1992 and another from 1992 to the present. Those records, they say, shouldn't be combined.

The first came from a station damaged by 1989's Hurricane Hugo; the second a replacement station installed in 1992. As soon as the second station was installed, it began recording temperatures about 2 degrees Celsius higher than the original station, as a result of the instrumentation switch, the LTER says. In the second record, which corresponds with most of the animal-abundance data Lister and Garcia examined, there's actually a long-term cooling trend. The explanation, the LTER team thinks: The forest floor became shadier as the canopy regrew following Hurricanes Hugo and Georges.

Any correlations between animal populations and temperatures that are based on the combined record should be treated as suspect, the LTER researchers say.

There was more. Lister and Garcia had relied on the LTER's long-term data sets without fully considering the data's limitations. For instance, when they analyzed trends in canopy arthropods from 1990 to 2010, they combined data Schowalter had collected across various tree species in his survey plots. But Schowalter had not sampled trees randomly; each year, he had sampled one tree of select species to represent early and late successional trees, as well as understory and overstory trees. Each tree type is home to a unique collection of arthropods, Schowalter says, and combining all the data will overrepresent the arthropods on rarer trees and underrepresent those on more common trees.

The LTER researchers also had caveats about the analysis of the bird-netting surveys, in which Lister and Garcia found a 90 percent decline in insect-eating Puerto Rican tody birds from 1990 to 2005. But the LTER wasn't able to put the same amount of effort into those surveys each year. In some years, scientists spent more time in the field trying to net birds (and therefore caught more), while in other years they expended less energy (and caught fewer). To assess trends over time in this data, variation in effort needs to be corrected for.

Even where the two teams agreed, their interpretation of the underlying cause differed.

Both found that walking-stick insects had declined over time, but the LTER researchers didn't see a connection between that trend and rising temperatures. Instead, they think that walking-stick trends, along with many other population dynamics, can be explained by hurricane impacts and subsequent ecological succession, as food availability and conditions in the forest's understory change.

"Our point isn't that temperature has no effect," Willig says. "Our point is, because of the way data sets were analyzed and interpreted, we felt it was totally premature to say it's a temperature effect and to avoid any disturbance discussion."

The scientists laid out all of their issues in a detailed rebuttal letter, which *PNAS* published in late May alongside a response by Lister and Garcia. Reached by phone, Lister defended his analysis.

To deal with the discrepancies between the El Verde temperature records, Lister used a correction to merge the data sets, he said, and also looked at independent data from the nearby Bisley weather station. (The LTER researchers say Lister's adjustments to the El Verde data were "erroneous" and that the Bisley data are inherently different because the sensor is affixed above the forest canopy rather than near the forest floor.) The cooling trend reflected in the latter half of the El Verde record? Not the result of canopy shading, but part of a global phenomenon in which climate warming stalled around the world.

Lister did agree, after learning that trees were not sampled randomly, that Schowalter's data on canopy arthropods shouldn't be extrapolated to the entire rain forest. He also agreed that the bird data would need to be revisited, as he had assumed that the researchers had conducted similar sampling efforts each year, based on the information he could find online. And there's "no doubt," he said, that hurricanes can influence population dynamics. But he sees them as shorter-duration influences "superimposed on these long-term and ongoing declines."

Finally, Lister emphasized that the arthropod and lizard declines he saw in his own field data—from the 1970s to the 2010s—were very stark. "It's a limited conclusion in a spatially complex forest," he said. "We need more data."

KENT GILBERT / AP

That's a point on which insect researchers are likely to agree. Elsa Youngsteadt, an insect ecologist at North Carolina State University, thinks that the rebuttal raises serious questions, but that the original paper's findings should not be dismissed outright, particularly given the authors' field observations.

The entomologist Jessica Ware of Rutgers University voiced a similar sentiment. "I think it's inevitable to have data reanalyzed—that's what we do in science," Ware says. To her, the most important takeaway from the hullabaloo is that "we're missing a ton of information." And even the best insect data are inherently noisy. "Insect populations bounce up and down like crazy," says Christie Bahlai, an insect ecologist at Kent State University. "You can have orders-of-magnitude differences between years and that's just normal population cycling."

These limitations mean that a single study isn't great evidence for a global insect apocalypse. "It's almost impossible to unequivocally prove global insect decline everywhere," says Manu Saunders, an insect ecologist at the University of New England in Australia. Demonstrating declines for just one ecosystem, she says, requires "continuous data for 10 to 15 years or more across multiple types of habitats and every insect in the system." Many entomologists think we've described only a fraction of the insects that are out there.

None of this is to say that evidence of declines shouldn't be worrying. To the contrary, such evidence should mobilize scientists to try to repeat the studies, or to reinvestigate old data they've been sitting on. And Ware credits Lister and Garcia's paper with doing just that—regardless of how many of their conclusions hold up to further scrutiny.

"The ultimate result of the paper was a call to arms for all of us to reexamine our data and field sites," she says. "As a human, I'm glad that that fire may have been lit under some people."

**MADDIE STONE** is a freelance science journalist based in Philadelphia.