Leaf-mining insects destroyed with the dinosaurs, others quickly appeared

July 24 2014

This is a *Platanus raynoldski*, or sycamore, with two mines at the leaf base produced by wasp larvae. Credit: Michael Donovan, Penn State

After the asteroid impact at the end of the Cretaceous period that triggered the dinosaurs' extinction and ushered in the Paleocene, leaf-mining insects in the western United States completely disappeared. Only a million years later, at Mexican Hat, in southeastern Montana, fossil leaves show diverse leaf-mining traces from new insects that were

not present during the Cretaceous, according to paleontologists.

"Our results indicate both that leaf-mining diversity at Mexican Hat is even higher than previously recognized, and equally importantly, that none of the Mexican Hat mines can be linked back to the local Cretaceous mining fauna," said Michael Donovan, graduate student in geosciences, Penn State.

Insects that eat leaves produce very specific types of damage. One type is from leaf miners—insect larvae that live in the leaves and tunnel for food, leaving distinctive feeding paths and patterns of droppings.

Donovan, Peter Wilf, professor of geosciences, Penn State, and colleagues looked at 1,073 leaf fossils from Mexican Hat for mines. They compared these with more than 9,000 leaves from the end of the Cretaceous, 65 million years ago, from the Hell Creek Formation in southwestern North Dakota, and with more than 9,000 Paleocene leaves from the Fort Union Formation in North Dakota, Montana and Wyoming. The researchers present their results in today's (July 24) issue of *PLOS ONE*.

"We decided to focus on leaf miners because they are typically host specific, feeding on only a few plant species each," said Donovan. "Each miner also leaves an identifiable mining pattern."

This is a mine produced by a micromoth larva on *Platanus raynoldski*, a sycamore. Credit: Michael Donovan, Penn State

The researchers found nine different mine-damage types at Mexican Hat attributable to the larvae of moths, wasps and flies, and six of these damage types were unique to the site.

The researchers were unsure whether the high diversity of leaf miners at Mexican Hat compared to other early Paleocene sites, where there is little or no leaf mining, was caused by insects that survived the extinction event in refugia—areas where organisms persist during adverse conditions—or were due to range expansions of insects from somewhere else during the early Paleocene.

However, with further study, the researchers found no evidence of the survival of any leaf miners over the Cretaceous-Paleocene boundary,

suggesting an even more total collapse of terrestrial food webs than has been recognized previously.

"These results show that the high insect damage diversity at Mexican Hat represents an influx of novel insect herbivores during the early Paleocene and not a refugium for Cretaceous leaf miners," said Wilf. "The new herbivores included a startling diversity for any time period, and especially for the classic post-extinction disaster interval."

Insect extinction across the Cretaceous-Paleocene boundary may have been directly caused by catastrophic conditions after the asteroid impact and by the disappearance of host plant species. While insect herbivores constantly need leaves to survive, plants can remain dormant as seeds in the ground until more auspicious circumstances occur.

This is a micromoth larva mine on *Juglandiphyllites glabra*, the earliest known member of the walnut family. Credit: Michael Donovan, Penn State

The low-diversity flora at Mexican Hat is typical for the area in the early Paleocene, so what caused the high insect damage diversity?

Insect outbreaks are associated with a rapid population increase of a single insect species, so the high diversity of mining damage seen in the Mexican Hat fossils makes the possibility of an outbreak improbable.

The researchers hypothesized that the leaf miners that are seen in the Mexican Hat fossils appeared in that area because of a transient warming event, a number of which occurred during the early Paleocene.

"Previous studies have shown a correlation between temperature and insect damage diversity in the fossil record, possibly caused by evolutionary radiations or range shifts in response to a warmer climate," said Donovan. "Current evidence suggests that insect herbivore extinction decreased with increasing distance from the asteroid impact site in Mexico, so pools of surviving insects would have existed elsewhere that could have provided a source for the insect influx that we observed at Mexican Hat."

Provided by Pennsylvania State University