Forensics ferret out fire beetle secret

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Black fire beetles of the genus Melanophila possess unusual infrared sensors. Researchers from the University of Bonn and from the Forschungszentrum Julich have concluded that the beetles' sensors might even be more sensitive that uncooled infrared sensors designed by humans. Having this natural model opens up new perspectives, such as for early warning systems for forest fires. The results have been published in PLoS ONE.

Criminal cases can often only be solved using forensics to piece together physical evidence and reconstruct what happened. Prof. Dr. Helmut Schmitz from the Institute of Zoology at the University of Bonn and Dr. Herbert Bousack from the Peter Grünberg Institut at the Forschungzentrum Jülich went through the same experience. Prof.

Schmitz has been researching fire beetles of the genus *Melanophila* and their sophisticated IR sensors, which these pyrophilous insects use to detect forest fires, for many years. This is a very special ecological niche. "It allows the beetle larvae to freely eat their way through the wood because the trees, which have been killed by great heat, can no longer fight back, and there are hardly any predators that would eat them in freshly burned forests," the Bonn zoologist reported.

Meanwhile, with the help of the Forschungszentrum caesar in Bonn and the Technische Universität Dresden, the researchers have unraveled the functional principle of this so-called photo-mechanical beetle infrared sensor, and they have started to work on a technical reconstruction of this natural prototype. Tiny cuticula spheres of the beetles' IR receptors – at 0.02 mm, smaller than the diameter of a fine hair – are filled with water and absorb IR radiation very well. Due to the fact that they heat up, the water in particular expands suddenly, and the resulting change in pressure is immediately detected by highly sensitive mechano-sensitive sensory cells. "However, an important question had remained unanswered – how sensitive is the sensor?" asked Prof. Schmitz. This question could be best answered by equipping *Melanophila* beetles with mini transmitters on their search for forest fires. "Then we would be able to log the distance flown to the burnt area and, based on this distance, calculate the minimum required heat radiation the beetles are attracted by," explained the zoologist. But at a length of about 1 cm, the beetles are too small to carry a transmitter for long distances.

The resourceful scientists turned to a past event, which proved helpful. In August 1925, a large oil depot in Coalinga, California, went up in flames. "Reports from that era mentioned that the huge blaze attracted masses of charcoal beetles (*Melanophila consputa*)," explained Prof. Schmitz. Since the fire location was in the forest-less Central Valley of California, the beetles must have flown in from a great distance. Most likely, they came from large forests on the western foothills of the Sierra

Nevada about 130 kilometers away, where there had been large forest fires in the two preceding years. "On such burnt areas, beetles multiply en masse, and after they emerged, they went to look for forest fires in the subsequent summers," said Prof. Schmitz. A forested area about 28 kilo–meters from the burning oil tanks in the San Benito Mountain Natural Area north of Coalinga seems rather unlikely as the source of the beetles since forest fires had not been reported in this area prior to 1925.

Dr. Herbert Bousack, an engineer from the Peter Grünberg Institut at the Forschungszentrum Jülich performed the calculations for modeling the sensitivity of the sensor. "The Coalinga fire is a good match for this simulation," Dr. Bousack reported. First however, many parameters had to be researched painstakingly, such as the size of the fire, or the weather conditions. "More than 85 years after the event, such data was hard to obtain." The engineer based his mathematical simulation on various fire models such as are used in assessing of fire risks for storage tank facilities. "We adapted these technical guidelines for our purposes, which allowed us to fall back on proven experiences," said the engineer.

The result was amazing. "According to our calculations, the infrared sensors of *Melanophila* beetles should be able to sense signals even if they are below the level of thermal noise," reported Dr. Bousack. Obviously, the beetles rely on stochastic resonance. "This method enables them to detect weak periodic signals that are normally superimposed by the noise," explained the engineer. According to the results of the calculations, the sensors can detect the tiniest amounts of heat - roughly comparable to the energy resolution of radio telescopes. "Our simulations and calculations make it seem quite probable that the IF sensors of pyrophilous *Melanophila* beetles are more sensitive than uncooled infra¬red sensors currently available in the market," Prof. Schmitz summarized the outcome. "Additional efforts to implement this natural prototype technologically will be required." So, they might be

able to revolutionize early-warning systems for forest fires.

More information: Modelling a historic oil-tank fire allows an estimation of the sensitivity of the infrared receptors in pyrophilous Melanophila beetles, Online-Journal PLoS ONE, DOI: 10.1371/journal.pone.0037627

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