Australian fire-beetles

by Helmut and Anke Schmitz

When a large bushfire is raging, two little-known species of beetle—dubbed fire-beetles—approach the fire, sometimes in unbelievable numbers. Two German researchers are investigating this phenomenon.

In Australia, organisms have been exposed to fires for millions of years. This long-lasting evolutionary pressure has caused many endemic plants to evolve special adaptations to cope with fires. The capsules of fire-adapted banksias, for example, can only release their seeds when exposed to the high temperatures of a fire. This allows sprouting after the first rain. The new banksia generation, therefore, has a considerable advantage over other new plant settlers. Adaptation of the balga, or grasstree (see 'Believing the Balga' in *LANDSCOPE*, Special Fire Issue, 2000), to fires is so perfect that the tree itself can survive fires. A fire also initiates flowering of the grasstree in the following year. Thus, an important aspect of fire adaptation seems to be that reproduction and dispersal is linked to fires.

Although they are not as well known, some insects have adapted to fires and can be found more frequently on burnt than on unburnt land. These insects are called pyrophilous. Interestingly, some of them are attracted to open flames, hot ash or smoke. One reason for this unusual behaviour is that insects or their offspring are highly dependent on food resources that are made available by fire. Such food includes the wood of the freshly burnt trees or fungi, which start to grow on the freshly burnt soil or wood as soon as the flames have subsided (see 'Fruits of fire', *LANDSCOPE*, Winter 2001). When removing the black, charcoaled bark of a tree that was killed by the high temperatures of a fire, it is astonishing to see that the wood itself is intact, whereas the water content is considerably reduced. As insects are able to gain water by metabolic processes, a variety of wood-boring larvae are known to develop in dry wood, so the burnt wood can be a valuable food source for some specialised insect species.

In February 2002, we had the chance to investigate the behaviour of two species of 'fire-beetles' on freshly burnt areas in the Perth region. During our stay, we gained new insights into the fascinating behaviour and sensory physiology of these highly-specialised insects.

THE BIG AUSTRALIAN FIRE-BEETLE

Members of the Family Buprestidae—more commonly known as jewel beetles—are mostly brightly coloured and highly attractive. At first glance, the Australian jewel beetle *Merimna atrata* is no credit to its family; it is a monotonous black colour. This is one reason why it is nearly impossible to discover a *Merimna* beetle in the field. In contrast to its inconspicuous appearance, *Merimna atrata* shows a highly interesting behaviour: the beetle is attracted by forest fires.

When a large bushfire is raging, *Merimna atrata* approaches the fire in sometimes unbelievable numbers. The reason for its unusual behaviour is because the reproductive cycle of *Merimna* is totally dependent on bushfires. First, the fire serves as a meeting place for males and females. Second, the wood-boring larvae of this species can only develop in the wood of freshly burnt trees. The beetles invade the still-steaming burnt area, as soon as the flames of the running fire have passed over the vegetation. Most beetles can be found sitting on or running over the charred bark of the burnt trees. Now it becomes obvious why *Merimna* is black: it is perfectly camouflaged against the predominant surface colour of its special habitat. Males look for females, and copulations can be frequently observed. Finally, females deposit their eggs under the bark of the burnt trees. We have also observed that the beetles inspect crevices in the bark or in the burnt soil in search of food. As well as scorched insects, they will consume edible plant material, such as fruits and seeds, that has not burnt to ash.

Because reproduction is only possible when a fire takes place, the beetles have to be able to detect a fire from great distances. But while fire is an essential component in the reproductive cycle, a freshly burnt area bears many risks. There are a lot of 'hot spots' where high temperatures can be encountered, and it is often not possible to determine visually whether the surface of a tree or the ground has a dangerously high temperature. However, *Merimna atrata* manages to

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Main: The large Australian fire-beetle *Merimna atrata*.
Photo – Helmut Schmitz

Left: Balga grasstree on fire.
Photo – Len Stewart/Lochman Transparencies

evade such hot spots safely, and we have never yet found a beetle that was injured or killed by hot surfaces.

One possible explanation of how the beetles are able to detect fires and hot spots is that they are able to sense infrared radiation. And, not surprisingly, we have discovered that *Merimna atrata* does indeed have infrared receptors, but not where we would have expected them.

INFRARED RECEPTORS

Interestingly, the infrared organs of *Merimna* are not on the antennae, where most sensory receptors can be found in insects. Instead, we found two pairs of infrared receptors on the underside of the posterior part of the body, which is called the abdomen in insects. The two pairs of receptors are situated on both sides of the second and the third abdominal segments. Because the lower part of an abdominal segment is bent upward laterally, the receptor 'looks' both towards the ground and to the side.

An infrared receptor consists of two main components: an infrared absorbing area and a sensory nerve cell. The infrared absorbing area can be seen with the naked eye. It consists of a more or less circular region (about 0.3 millimetres in diameter) where the outer shell of the beetle, which is made of cuticle, is a yellowish colour. The area is also slightly concave, like a satellite dish, and, under a microscope, the surface has a honeycomb-like structure. The thickness of the cuticle of the absorbing area is only slightly reduced compared with that of the remaining abdominal segment.

Directly beneath the absorbing area we found a large sensory nerve cell. It quickly became clear that this cell was sensitive to changes in temperature. Because it is in direct contact with the cuticle, it can monitor any increases in the temperature of the absorbing area due to the absorption of infrared radiation. Sensitivity is remarkably high: an increase of less than a tenth of a degree in temperature can be perceived by the receptor. This type of infrared sensor is known as a bolometer (a device that measures minute amounts of radiated energy). Until now, biological infrared receptors based on the bolometer principle were only known in infrared-sensitive snakes such as pythons. So it was exciting to see that the infrared receptors of the big Australian fire-beetle showed a high degree of similarity to infrared receptors found in certain snakes. In the lip scales of a python (particularly the lower scales beneath the eye) one can also find specialised regions where the surface is somewhat lowered. Under these concave areas, highly thermosensitive nerve fibres measure increases in temperature due to infrared absorption. The night-hunting snakes use their infrared organs to detect warm-blooded prey, even in complete darkness.

The infrared receptors of *Merimna atrata* obviously serve two purposes. Firstly, the receptors enable the beetles

Top: **Infrared receptor of *A. nigricans*.**
Photo – Eva Kreiss

Top left: **Most jewel beetles are brightly coloured and highly attractive.**
Photo – Jiri Lochman

Above: **The large Australian fire-beetle *Merimna atrata* mating on a burnt tree.**
Photo – Helmut Schmitz

Left: Close-up of the small Australian fire-beetle *Acanthocnemus nigricans.* The infrared receptors are located on both sides of the first thoracic segment, which also bears the first pair of legs.

Below left: The small Australian fire-beetle is just four millimetres long and is almost impossible to see on the bark of a burnt tree.
Photos – Helmut Schmitz

to detect a forest fire from a distance. Secondly, after arriving on the freshly burnt area, the beetles use their receptors to scan the surface temperatures in flight in order to prevent them from landing on a dangerously hot surface.

THE SMALL AUSTRALIAN 'FIRE-BEETLE'

When inspecting a freshly burnt area some hours or even a few days after the fire, we concentrated on localities where hot ash or glowing remnants of trees could be encountered. Near these 'hot spots' we looked closely at the ground or on the black bark of trees. As well as observing many *Merimna atrata*, we also saw a much smaller, rather inconspicuous beetle measuring only three to five millimetres in length. This was *Acanthocnemus nigricans*. In contrast to *Merimna atrata*, this insect has very cryptic behaviour. It quickly runs over the burnt ground or bark of trees for a short time and then seeks shelter in little crevices for many minutes. We speculate that this behaviour has evolved because *Acanthocnemus* is a potential prey of *Merimna.*

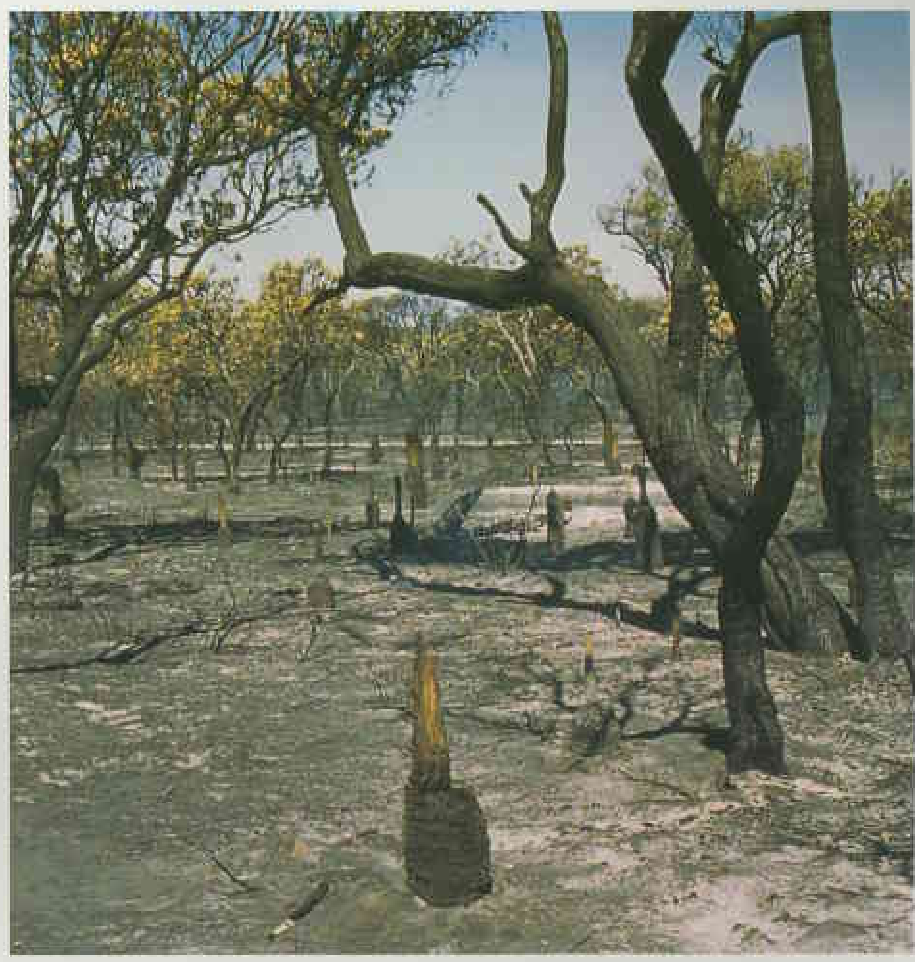
The reason for the presence of *Acanthocnemus* on a freshly burnt area is not yet clear. There is some evidence that the fire attracts males and females, and that the area around hot spots serves as a meeting place for the sexes. We have observed a single copulation on a little stem close to a glowing tree trunk. No information is available about the food resources of the beetles and their larvae, but it can be speculated that the larvae of this species also feed on freshly burnt wood or depend on fungi that quickly emerge and grow on burnt soil or wood.

Despite *Acanthocnemus* being much smaller than *Merimna,* we found a highly sophisticated infrared sensory organ in this beetle too. While it was known that *Acanthocnemus* had some unusual structures on its first thoracic segment (the part of the body bearing the first pair of legs), nothing was known about their possible function. The structures were described as a pair of partly covered cavities in front of the coxae (that is, the hips) of the forelegs. The scanning electron microscope revealed that a little round disc made from cuticle was held at its side by a little stalk over a cavity. We found about 30 thermosensory neurones within the disc that showed nearly the same ultrastructure as those under the absorbing area in *Merimna atrata.*

It became clear that the little disc had a thermosensory function. Infrared radiation is absorbed by the outer surface of the sensory disc, which can therefore be regarded as a tiny bolometer (a microbolometer). Because the disc is arranged over an air-filled cavity, its thermal mass is considerably reduced, which points to an enhanced sensitivity. So it turns out that this infrared receptor is even more complex than the one found in *Merimna.*

Right: The freshly burnt area, a day after the fire. Smoke indicates a hot spot.
Photo – Helmut Schmitz

Below right : The Australian fire-beetles have infrared receptors similar to those found in the lower lip scales (particularly beneath the eye) in snakes such as pythons.
Photo – Marie Lochman



The special construction of the *Acanthocnemus* infrared receptor can also be compared with those of the infrared-sensitive snakes. The most powerful infrared organs hitherto known in the animal kingdom were those of pit vipers, such as the rattlesnakes. The *Acanthocnemus* system is amazingly similar to these sensitive vertebrate infrared receptors. Pit vipers have a pair of infrared organs, one on each side of the head. From the outside, the organs are visible as little openings between the nostrils and the eyes. The openings widen to pit-like pockets within the snake's skull. Infrared radiation enters through the opening and is absorbed by a thin membrane that is suspended in the middle of the pit. The membrane, which corresponds to the sensory disc in *Acanthocnemus*, is richly endowed with highly thermosensitive nerve fibres. The inner air-filled half of the pit below the membrane corresponds to the inner chamber under the sensory disc in *Acanthocnemus*. Therefore, the infrared organ of pit vipers can also be regarded as microbolometers with reduced thermal mass.

MORE QUESTIONS

It was impressive to see how perfectly the two species of fire-beetles were adapted to their hot environment. We have never seen a beetle that had become a victim of the heat.

Although we are beginning to understand some basic features of the sensory physiology of the fire-beetles, many questions remain. For instance, why are the infrared receptors of the two beetles so different? Are other senses, such as vision or smell, also used to detect fires or to recognise hot spots on a burnt area? Research into these fascinating insects continues and we hope to be able to give some answers in the near future.

Helmut and Anke Schmitz are working at the Zoology Department at Bonn University in Germany. Besides her interest in the biology and morphology of fire-adapted beetles, Anke is also working on the respiratory biology of spiders and insects. Helmut works on thermo- and infrared reception in insects, and has a broad interest in morphology, sensory physiology and behaviour.

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Discover some amazing lifestyles of the little-known fungi of our south-west forests. See 'Forest fungi' on page 10.

Two wildlife rescuers recently received Queen's birthday honours. See 'Kanyana to the rescue' on page 42.

Winner of the Alex Harris Medal for excellence in science and environment reporting.

LANDSCOPE

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One of WA's longest serving wildlife researchers looks at changes to nature conservation in the State. See 'For the times they are a-changin' on page 20.

Two unusual beetles are attracted to large bushfires. But why, and how do they find the fires and avoid getting burnt? See 'Australian fire-beetles' on page 36.

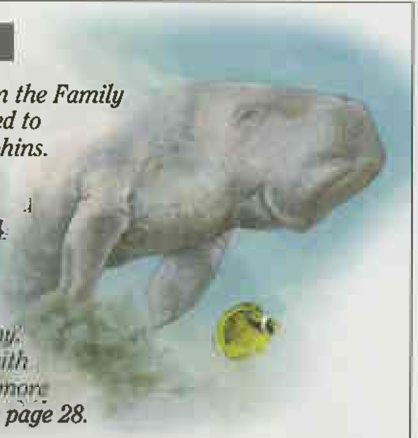
What do wildlife officers do when a large whale weighing up to 80 tonnes becomes entangled? Turn to 'When nature calls...for help' on page 42.

F E A T U R E S

R E G U L A R S

C O V E R

The dugong is the only living species in the Family Dugongidae, and is more closely related to elephants than it is to whales and dolphins. One of the largest and most secure populations of dugong grazes on the extensive beds of seagrass in the shallow marine environment of Shark Bay. An estimated 10,000 dugongs, representing 10 per cent of the world's population, live in the bay. A new study, involving collaboration with local Aboriginal people, is discovering more about their movements in the bay. *See page 28.*



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