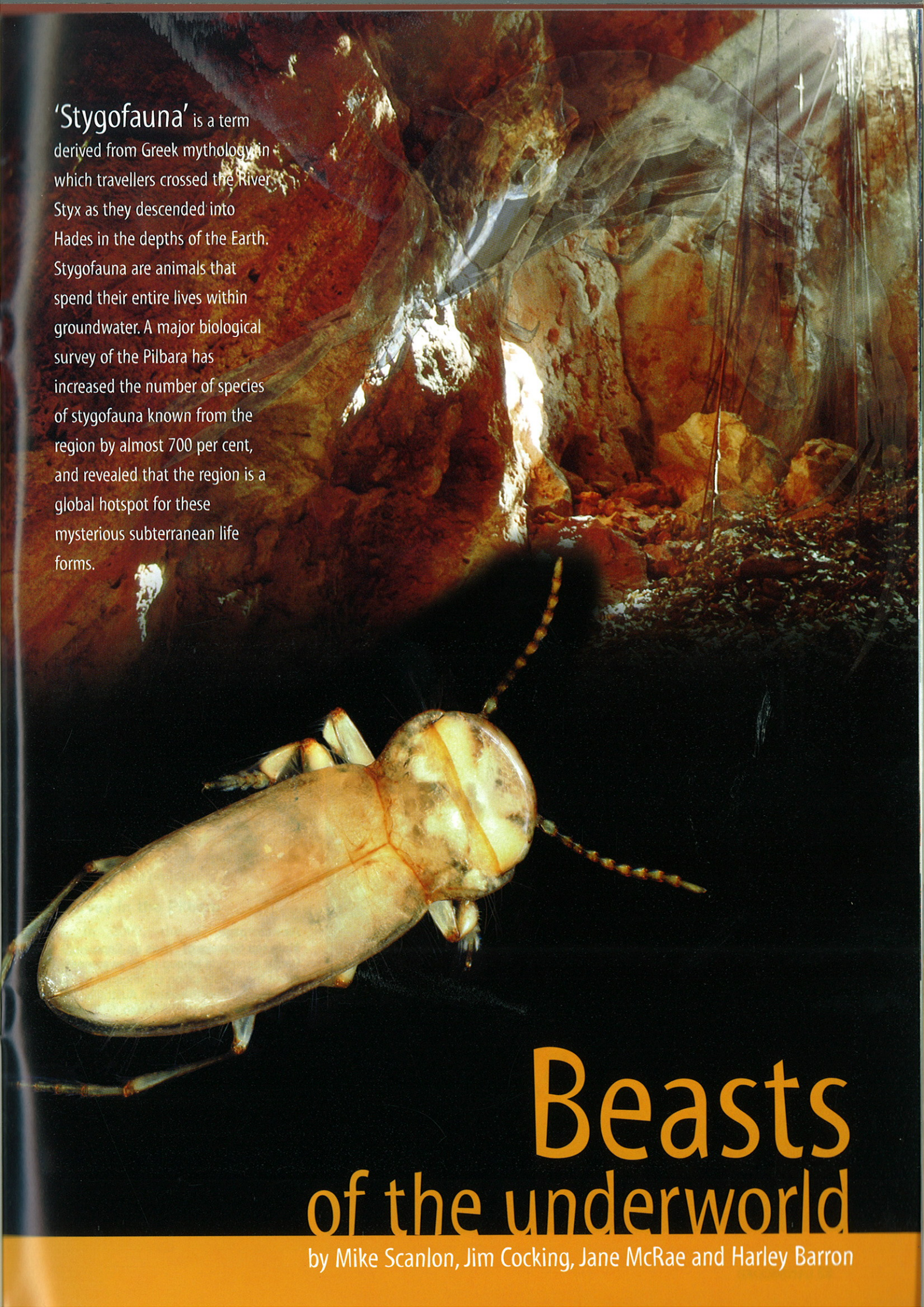


'Stygofauna' is a term derived from Greek mythology in which travellers crossed the River Styx as they descended into Hades in the depths of the Earth. Stygofauna are animals that spend their entire lives within groundwater. A major biological survey of the Pilbara has increased the number of species of stygofauna known from the region by almost 700 per cent, and revealed that the region is a global hotspot for these mysterious subterranean life forms.

Beasts of the underworld

by Mike Scanlon, Jim Cocking, Jane McRae and Harley Barron

Stygofauna are animals living permanently underground in water. They occur in all sorts of groundwater habitats, from the tiny spaces between sand grains to large subterranean caves that have been formed over thousands of years as more soluble rocks have dissolved. Because stygofauna live in the dark, they lack eyes and pigmentation, and they also tend to be fragile and elongated in shape. Although some species are fish—including two threatened species found at Cape Range near Exmouth, the blind cave eel (*Ophisternon candidum*) and the blind gudgeon (*Milyeringa veritas*)—most are small crustaceans that vary from about 0.3 to 10 millimetres in length.

Stygofauna have great scientific and conservation significance. They have a significant role in maintaining water quality, which is likely to be increasingly important as Western Australia relies more heavily on groundwater for domestic and industrial water supply. As nutrients and organic matter percolate down from the surface, grazing stygofauna reduce concentrations of this matter. Stygofauna also keep spaces between soil particles open, to maintain groundwater flow, which is a critical factor in determining the amount of water that can be abstracted from an aquifer. Although stygofauna do a lot of engineering to maintain stable groundwater conditions, they can be overwhelmed by pollution events, such as major petroleum and sewage spills. Groundwater abstraction and dewatering of aquifers, usually to enable mining below the water table, are other important threats.

First discoveries

Scientific interest in stygofauna first gathered momentum in WA when Bill Humphreys and Brenton Knott, from the WA Museum and The University of Western Australia, undertook systematic collecting in pools of subterranean caves at Cape Range in the late 1980s. Subsequently, Bill Humphreys collected many new species on Barrow Island and in the Pilbara, and suggested that north-western Australia had particular scientific and conservation significance for stygofauna. The Environmental Protection Authority supported this view and began to consider likely impacts on stygofauna when assessing resource development projects in the Pilbara.

As soon as stygofauna were included in impact assessments, it became apparent how little was known about the distribution of individual species. One of the problems was that nearly all assessments appeared to collect new, restricted species that were potentially at risk of extinction if developments proceeded. Was this pattern real or the result of so little information on distributions of stygofauna species being available? Was the same species being identified as different (and restricted) in each impact assessment because of an uncoordinated identification process?

Previous page
Main top Surveys of caves on Cape Range peninsula helped raise awareness about the conservation significance of stygofauna in north-western Australia. *Photo – Geoff Taylor/Lochman Transparencies*
Below A stygofaunal beetle (*Liodessus harleyi*) from just east of the Pilbara.
Inset top A new genus of melitid amphipod is one of several being studied by DNA analysis to determine its origins.

Above left A copepod belonging to a new family from the mainland Pilbara and Barrow Island.

Left A new species of syncarid, one of 18 found during the survey.
Photos – Jane McRae/CALM

Above CALM technical officer Jim Cocking measures water chemistry at Nimingarra Well on Muccan Station.
Photo – Mike Scanlon/CALM

Right Berringarra Claypan in August 2004, several weeks after receiving run-off from local rainfall.
Photo – Adrian Pinder/CALM

Published taxonomic descriptions and keys to all known species would overcome this problem.

Survey in the Pilbara

In 2002, the Department of Conservation and Land Management (CALM) began a biological survey of the Pilbara as part of an ongoing inventory of Western Australian plants and animals, designed to provide information on species distributions and their conservation status. It will also enable efficient identification of areas suitable for nature reserves to conserve as much of the plants and animals as possible in a given area of land. Most survey effort is being directed towards terrestrial species, and the aquatic wildlife of river pools and other surface water bodies, but for the first time stygofauna have been included.

Including stygofauna will enable development of a framework for proper assessment of impacts of groundwater extraction and mining below the water table, and allow scientists to identify areas of particularly high stygofaunal richness, where special measures to protect groundwater habitat may be necessary. Describing new species of stygofauna is a major focus of the work, because until species are named and illustrated there is no basis for consistent identifications or accumulating information about them.

Collecting stygofauna is difficult because there is limited access to the groundwater where they occur. Although some species occur near the surface in springs (which represent groundwater discharge at the surface), such areas are usually awkward to sample because they are associated with bedrock. Pastoral wells, which are

Left CALM technical officers Jim Cocking and Harley Barron video down a bore.
Photo – supplied by Harley Barron/CALM

usually more than a metre in diameter and not much more than 12 metres deep, offer easier access to groundwater. However, wells are limited in number, and narrow, deep bores are much more common (50 to 400 millimetres in diameter, with average depths of 40 metres, and the deepest bore sampled being 160 metres). Most bores are cased in PVC or steel. Slots in the casing allow water exchange, so that the groundwater level inside the bore reflects outside conditions. Stygofauna move into bores through the slots.

Sampling consists of dropping a small net, with a brass weight attached, to the bottom of the bore and then hauling it back up through the water column to catch stygofauna. This is repeated several times. To date, 378 bores and 122 wells have each been sampled twice during the survey. Sampling is a blind process and the operator has no idea whether there are animals in the bore escaping the net. Preliminary work suggests that only a third of the species in the bore and its immediate surrounds are collected each time a bore is sampled. About two thirds of bores yield stygofauna on first sampling, with an average of 5.4 species.

Staggering results

Before the survey, about 40 species of stygofauna were known from the Pilbara, but now it is clear that at least 275 species exist. The most common stygofauna are copepod and ostracod crustaceans. Forty-four species of copepods have been collected, including one that belongs to a new family so far known only from Barrow Island and the Pilbara.

About 73 new species of ostracod have been discovered. Ostracods are small seed-like animals with a calcified bivalved carapace that is sometimes highly ornamented. The different shapes and patterns on the valves of each species mean that, even after death, these animals can often be identified from a preserved valve of their carapace.

Another important group of crustaceans are the amphipods. These rather shrimp-like animals have traditionally been regarded as having very localised distributions and being difficult to distinguish at species level. One of the major challenges of the survey will be improving taxonomic knowledge of this group.

The survey has found at least four new species of isopod crustaceans, which are closely related to the slaters found in domestic gardens. Pilbara isopods belonging to the genus *Pilbarophreatoicus* are Gondwanan relicts. Their closest relatives are in India, reflecting the joining of Western Australia and India 80 million years ago.

Other interesting crustaceans include syncarids. This species-rich group of rather tubular animals with poorly differentiated legs has representatives throughout the world and they are common in groundwater in Australia. Despite their ubiquity in Australia, few have been described, and the 18 species found during the survey are all undescribed.

Not all stygofaunal invertebrates are crustaceans, however, and 15 species of water mites have been collected during the survey. Various worm species have been collected, including an undescribed marine polychaete 400 kilometres inland south of Paraburdoo. Two new species of snail have been found, including one in which the shell is shaped like a small cow's horn to enable the snails to move between sand grains. Stygofaunal beetles, which are common in the Goldfields, appear not to occur in the Pilbara, although they have been found immediately to the east.

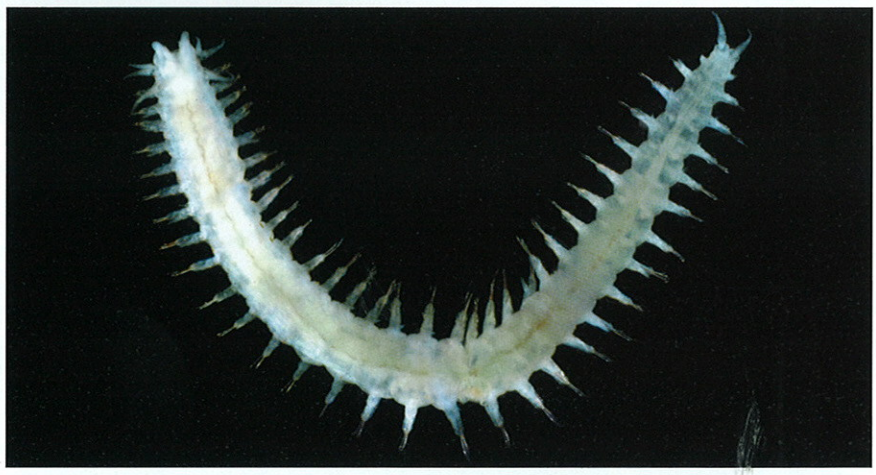
Global hotspot

There is clear evidence that the Pilbara is a global hotspot for stygofauna. South-western Australia has long been renowned for plant diversity, and is now being recognised as a hotspot for crustacean diversity in surface waters. Thus, the stygofaunal

Right The bed of Palm Creek, Millstream, has yielded several stygofauna species.
Photo – Stuart Halse/CALM

Below right A never-before-collected marine polychaete worm was found 400 kilometres inland.

Bottom right A completely new species of snail, with a shell shaped like a small horn, was located during the Pilbara survey.
Photos – Jane McRae/CALM



story is adding to an already established pattern of internationally important biological values in WA.

The full explanation for this biological richness is still being researched. One likely reason for high richness and scientific interest of Pilbara stygofauna is related to the region's geological history. The central Pilbara has remained above sea level for more than 550 million years, while the Australian continent has joined and separated from other landmasses (Pangea and Gondwana) because of tectonic movement. As a result, it shares species lineages with many other parts of the world and these lineages appear to have radiated in the Pilbara over time, without the waves of extinction that have characterised most parts of the world with less stable land surfaces.

Now that we recognise the antiquity of much of the Pilbara stygofauna, the challenge is to ensure the survival of these animals into the future. The current survey is only the first step in planning a conservation strategy. Habitat protection, which in this case is the maintenance of groundwater quantity and quality, is an essential component of conservation. Understanding the ecology of individual species is also important, as to formulate a comprehensive conservation plan we need information about their lifespans, the number of young produced, the distances that individual animals are able to travel, and their ability to withstand periods of low water tables as a result of drought or periods of dewatering by industry. Hopefully, ecological studies will continue once the survey is completed.

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