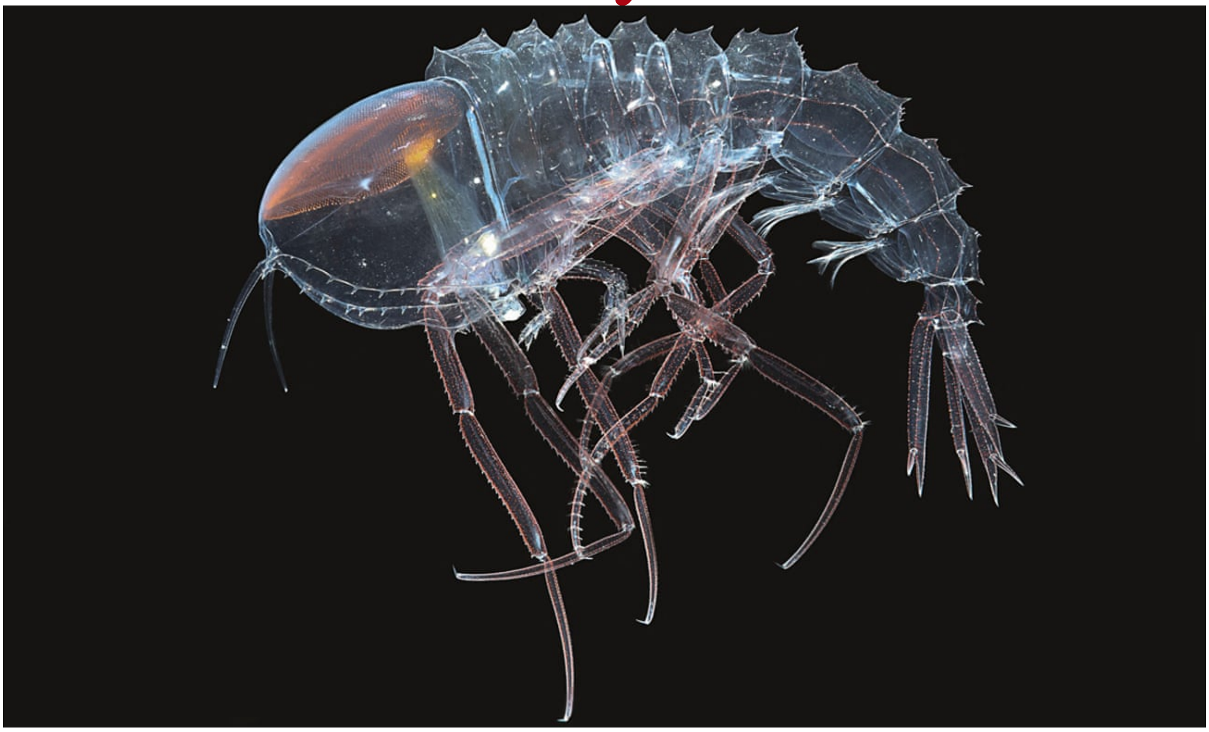
Discovered in the deep: the crustacean with eyes for a head



Cystisomas, tiny shrimp-like crustaceans that live in the ocean's twilight zone, are 'masters of transparent camouflage'. Photograph: KJ Osborn/Smithsonian

Shrimp-like Cystisoma are protected from predators by being virtually invisible – thanks to unique retina and a body that casts almost no shadow

Helen Scales

Wed 14 Sep 2022 06.30 BST

The inky depths of the ocean's twilight zone are home to fist-sized shrimp-like crustaceans with ridiculously big eyes. Most of *Cystisoma*'s head is taken up by its eyes – all the better for seeing in the dark. "The bigger you make your eye, the more likely you are to catch any photons that are out there," says Karen Osborn, research scientist at the Smithsonian Institution in Washington DC.

A big challenge for animals living in deep midwater, in *Cystisoma*'s case between 200 and 900 metres down, is to see while not being seen by predators. "It's basically like playing hide and seek on a football field," says Osborn. "There's nothing to duck behind."

Eyes are especially hard to hide because retinas always have to contain dark, photon-absorbing pigments, which predators can either make out in the dim twilight zone illumination, or in the beams of their own bioluminescent searchlights. *Cystisoma* disguises its huge eyes in a unique way. Instead of concentrating the pigments in a small area, Osborn says, they spread their retina into a thin sheet of tiny reddish dots that are too small for most animals to see.

Cystisoma hides most of the rest of its body by being completely transparent. When scientists catch them in trawl nets and empty them into a bucket of seawater, they appear as empty, palm-sized gaps between other animals. "You really cannot see these things until you pick them out of the water," says Osborn.

Most of *Cystisoma*'s internal organs appear crystal-clear thanks to the very orderly, structured way their tissues are arranged, Osborn explains. "The only thing they can't seem to do it very well with is their gut," she says. The golden structure visible beneath the eyes is the digestive organ. Even this is stacked tall and straight to cast as small a shadow as possible while *Cystisoma* hangs in its usual horizontal position.

Most of Cystisoma's head is taken up by its enormous eyes. Photograph: KJ Osborn/ Smithsonian

These crustaceans make themselves even harder to spot underwater by reducing the light that reflects off their transparent bodies, Osborn and colleagues discovered in 2016. Seen under an electron microscope, parts of *Cystisoma*'s exoskeleton are covered in tiny protuberances, which Osborn likens to a shag-pile carpet. Other parts are covered in a single layer of spherical shapes, which the scientists think could be colonies of an unknown form of bacteria.

The nanoscopic shag-pile carpet and spheres make light 100 times more likely to pass straight through C*ystisoma*, rather than reflect into the eye of a passing predator. "It works in exactly the same way as an anti-reflective coating on a camera lens," says Osborn.

Cystisoma's legs in particular benefit from the anti-reflection shag-pile covering and sphere-covered joints, because otherwise they would easily catch the light as they flick and wriggle about. "These guys are absolute masters of transparent camouflage out in the midwater."

But what happens when the near-invisible *Cystisoma* actually wants to be found? These crustaceans need to pair up to reproduce. A clue as to how mates find each other is in the male *Cystisoma*'s large antennae covered in structures that detect chemicals in the surrounding water. "They're actually smelling each other," says Osborn.

Discovered in the deep: the 'Elvis worms' that sparkle in the darkness

A close-up of *Peinaleopolynoe orphanae*, one of the species of hungry scale-worms that scientists named in 2020. Photograph: Greg Rouse and Avery Hiley

In 2020, scientists found sparkling *Peinaleopolynoe* on hydothermal vents in the eastern Pacific – and were irresistibly reminded of the king of rock'n'roll

Helen Scales

Wed 7 Sep 2022 06.00 BST

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early 4,000 metres (13,000 feet) underwater in the Pescadero basin in the Gulf of California lie some of the Pacific's deepest hydrothermal vents – and they're covered in small iridescent worms. "You'll see little pink sparkly worms, blue ones, red ones, black ones and white ones," says Avery Hiley, a graduate researcher at the Scripps Institution of Oceanography in San Diego.

These are hungry scale-worms, or *Peinaleopolynoe* – *peinaléos* meaning "hungry" or "famished" in Greek – named as such because they were first found clustered around a pile of food that scientists had left experimentally on the deep-sea floor. For years they have been nicknamed "Elvis worms" for their sparkling scales, reminiscent of the sequined jumpsuits worn by Elvis Presley.

There are six known species of hungry scale-worms, all roughly thumb-sized and living in the deep sea, including four named in 2020. One of these, which boasts a coat of shimmering pink scales, is specifically named after the king of rock'n'roll – Hiley and her colleagues named it *Peinaleopolynoe elvisi*.

Q&A
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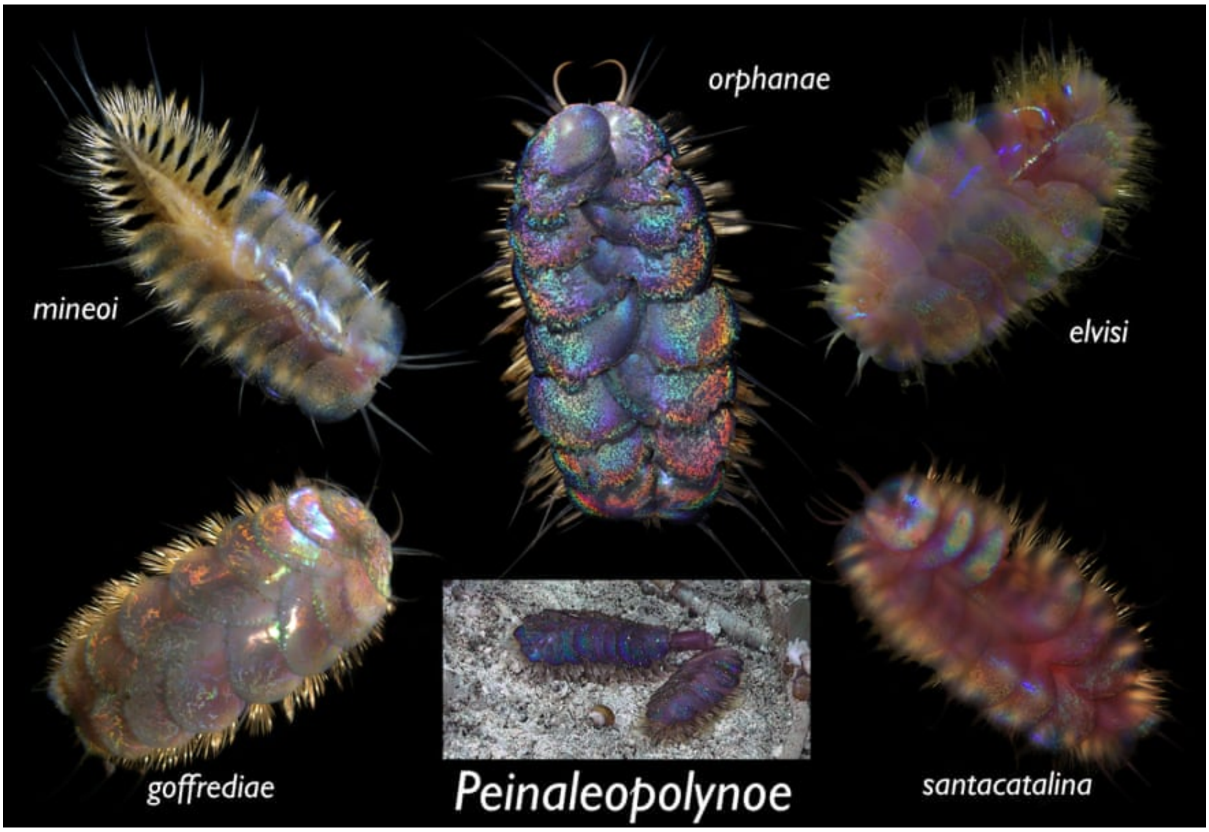
Hungry scale-worms have been found on the carcasses of dead whales, and on volcanic seamounts, hydrothermal vents, and cold seeps, where methane trickles up through the seabed like champagne bubbles.

It is likely the worms are feeding on chemical-harnessing bacteria that grow on all these habitats. “They have jaws which we suspect they use to graze bacteria,” says Hiley. “So, we do think they’re bacteriovores.”

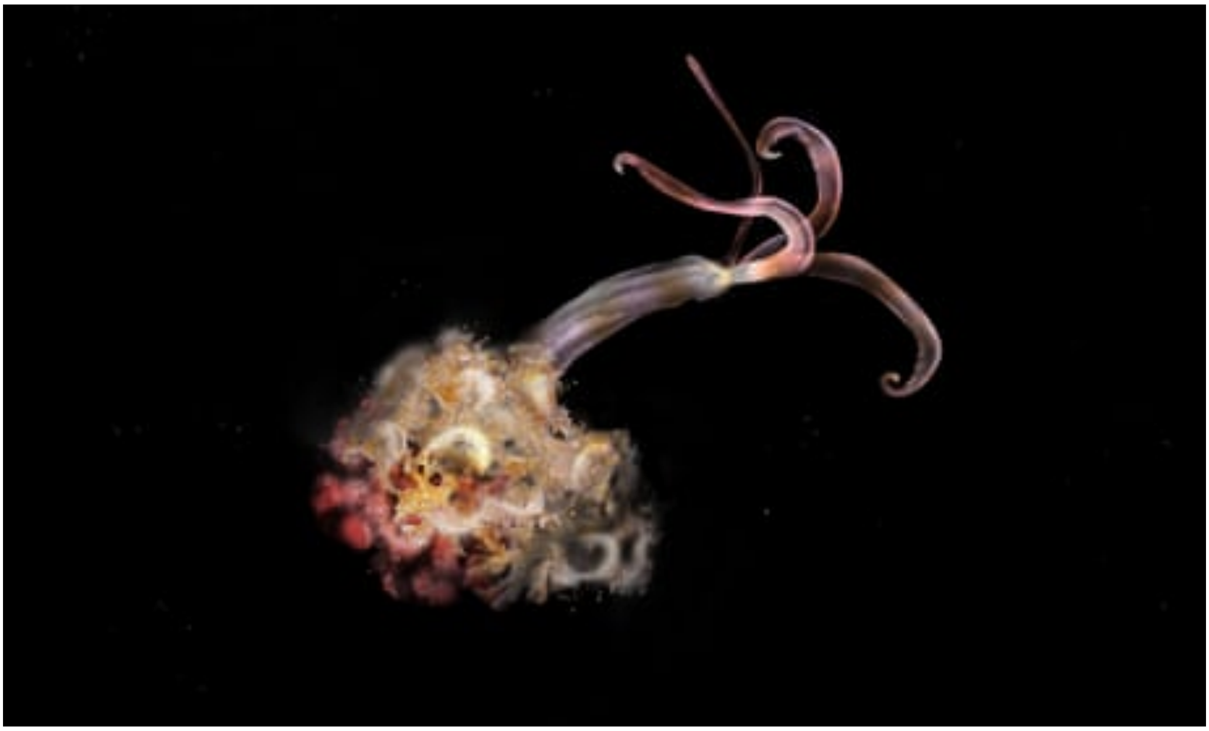
When Hiley and colleagues carried out genetic tests of the hungry scale-worms from the Pescadero basin, what they assumed were multiple species, each with its own colour, turned out to be a single species. “We realised that with age it seems that [the] species changes in colour, as it develops from a juvenile to an adult form.”



The four species of hungry scale-worm named in 2020 – *P mineoi, P elvisi*, *P orphanae* and *P goffrediae* – as well as the previously named *P santacatalina*. Photograph: Greg Rouse

The worms’ colours are created not by pigments but by light reflecting and refracting within the internal structure of the scales, in the same way as with shining blue butterfly wings. The only light available in the deep sea to make them sparkle is the bioluminescence of other animals, but they gleam brilliantly in the headlights of deep-diving robots and submersibles.

It's possible that as worms get older their colour changes because their scales grow thicker, altering how light passes through them. The thickest scales are blue. Slightly thinner are pink. "The littlest worms tend to always be white and the scales are very flimsy," says Hiley.



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Previously, when scientists collected specimens of hungry scale-worms, many had chips in their thick scales; they assumed their scales were damaged while being picked up by a deep-diving robot and transferred to the surface. Then, in 2017 at the Pescadero basin, a rare scene was caught on camera. "It turns out, actually, this species does this fighting ritual," says Hiley.

Hungry scale-worms bounce on the spot and throw punches at each other, inverting their snout and biting chunks out of each other with their powerful jaws. "It was a piece of the puzzle that we didn't know for a long time," says Hiley.

It is still not clear why the worms fight each other. "We have more observation to do, definitely," she says.

One more puzzle that Hiley wants to solve is how hungry scale-worms evolved from ancestors living in shallow seas to be able to survive in the low-oxygen, hyper-pressurised environment of the deep sea. She is looking for clues in their genes.

“We are starting to see some weird things on a genetic level with these deep-sea worms,” says Hiley. The 29 species of deep-sea scale-worms, including the hungry species, have a huge variation in their gene order compared with species of worms that live in shallow seas. Hiley is investigating whether this may somehow help explain how the worms have adapted to the rigours of the deep ocean.