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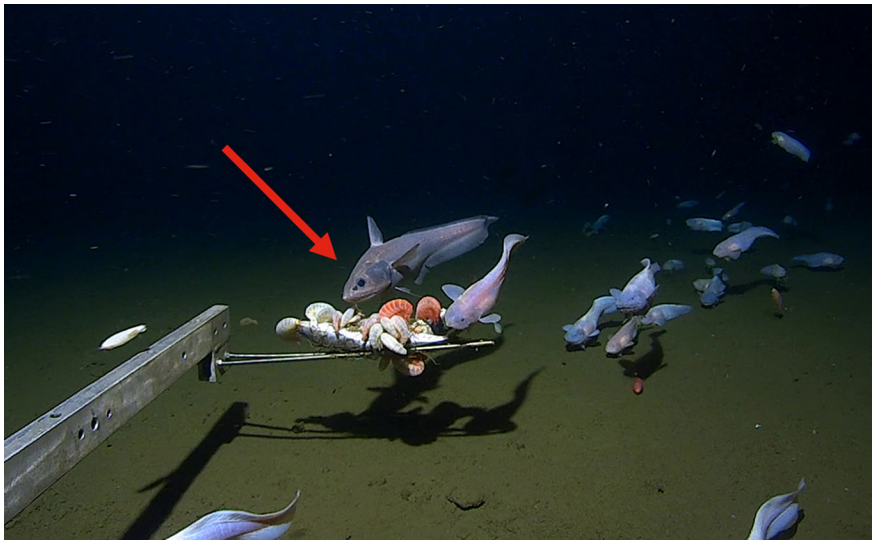
INSIDE JEB

How a macrourid fish remains buoyant at depths it should be unable to reach



The macrourid fish *Coryphaenoides armatus* (arrow) visits the lander to feed at 7259 m.

Descending 6000 m to the bottom of the ocean is a long and extraordinary experience, but a select band of adventurers and scientists have voyaged even further, into the ocean's deepest trenches. 'The so-called hadal habitat and the biodiversity of deep trenches… have been little studied', says Hiroshi Kitazato, from Tokyo University of Marine Science and Technology, Japan, so a team of researchers led by Alan Jamieson [The University of Western Australia (UWA), Australia] visited the Japan Trench in 2022 to investigate the impact of the 9.1-magnitude Tōhoku earthquake and tsunami on the seabed. Before embarking on their descent, Jamieson and colleagues deployed unmanned landers to the bottom of the trench, complete with bait and camera, to film the creatures in the vicinity. However, it was only months later, while scrutinising the movie at UWA, that Jamieson and Todd Bond (UWA) spotted a macrourid fish, known as the abyssal grenadier (*Coryphaenoides armatus*), visiting the lander at the astonishing depth of 7259 m, which was unexpected, because fish with swimbladders, such as macrourids, were thought to be unable to remain buoyant below 7200 m. How could the miraculous fish have descended so far?

Jamieson contacted his old boss, Imants Priede (University of Aberdeen, UK), an expert in deep-sea buoyancy, to see whether he could figure out what was going on. Priede explains that deep-sea fish with swimbladders are able to develop stronger, heavier bones and better muscles than fish without swimbladders, thanks to their buoyancy, which offsets the additional weight. Knowing that fish fill their swimbladders with oxygen, Priede decided to calculate how much buoyancy a swim bladder comprising 5% of a 1 kg fish's body would produce at 7259 m depth and discovered that the resulting 0.16 N force was sufficient to counteract the weight of the fish's heavy bones and muscles, allowing it to remain neutrally buoyant. Provided that the macrourid could fill its swimbladder with sufficient oxygen, the fish could remain comfortably at 7259 m and they should remain buoyant even if they descend further, as the gas becomes incompressible at these enormous depths.

But how long would it take a macrourid to fill its swimbladder to prevent it from collapsing at these extreme pressures? 'It can be quite hard work pumping up your car or bike tyres to 2.5 atmospheres by hand or foot, so imagine how much harder it is for the fish to achieve 600 atmospheres!' Priede exclaims. Calculating that the fish's swimbladder could hold 37.9 g of oxygen at these depths, Priede then evaluated how much energy would be required to compress the oxygen and worked out that it would take the fish 16 days if it did nothing except pump oxygen. However, when he redid the calculation, factoring in the amount of energy required to run the gland that produces the buoyant gas, he came up with a value of 221–440 days. 'This is plausible,' he says, explaining that it can take a decade or more for a growing macrourid fish to descend to these depths; 'There is no need for young fish to quickly pump up the swimbladder to 60 MPa', he adds.

In addition, Priede calculated whether the swimbladder might store oxygen for the fish's consumption, realising that the fully inflated swimbladder could carry sufficient oxygen to keep the fish fuelled for 1.1 years. However, he suspects that it is unlikely that the fish turn to their swimbladders to supplement their oxygen supply, as the cold waters in the Japan Trench are well oxygenated and the fish are more likely to lose the oxygen into the water through their gills than use it for their own consumption.

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Priede, I. G., Jamieson, A. J., Bond, T. and Kitazato, H. (2024). *In situ* observation of a macrourid fish at 7259 m in the Japan Trench: swimbladder buoyancy at extreme depth. *J. Exp. Biol.* **227**, jeb246522. doi:10.1242/jeb.246522

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