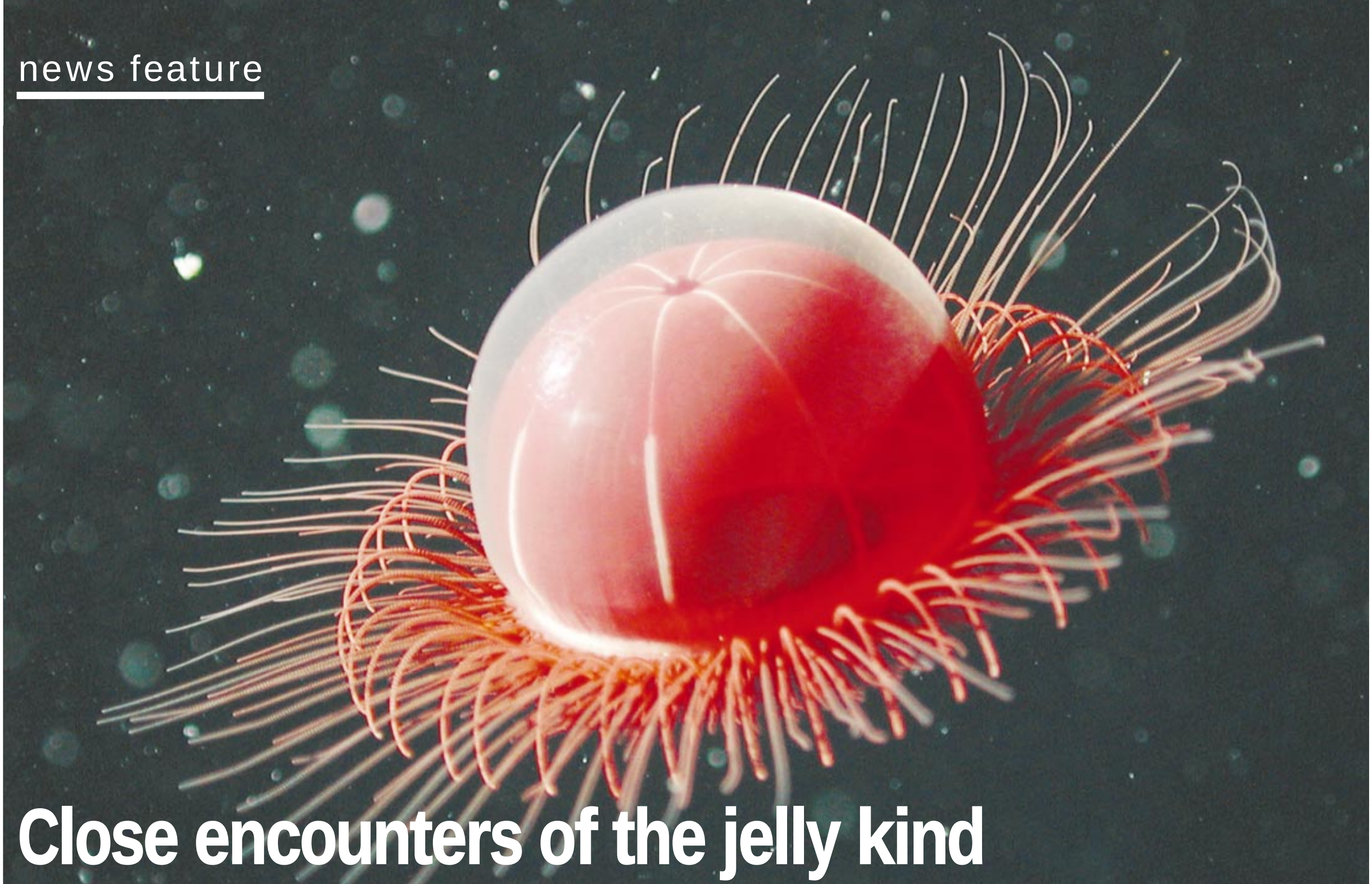

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Close encounters of the jelly kind

Deep-diving submarines have opened a new window onto the ocean's gelatinous inhabitants. And biologists are discovering that these denizens of the deep have a few surprises in store. Carina Dennis dives in.

Spending hours in a damp, cold and cramped space, peering through a tiny window into murky darkness, doesn't sound like a recipe for job satisfaction. But for Dhugal Lindsay, a biologist at the Japan Marine Science and Technology Center in Yokosuka, this is the best part of his job.

The reason Lindsay subjects himself to long hours in such conditions, crammed into a three-person submarine thousands of metres below the ocean waves, is because it's the best way to spy on jellyfish and other gelatinous creatures — collectively known as jellies. The ocean is awash with these diaphanous creatures, from the familiar jellyfish — properly referred to as cnidarians — to ctenophore comb jellyfish with waving cilia that propel them along, to a mass of other creatures including gelatinous snails, worms and larvaceans — tiny tadpole-like filter-feeders that spin mucous webs to catch their food. But before the advent of submersible vehicles, researchers were in the dark about this marine menagerie, and what its members get up to in the murky depths.

Only now are researchers such as Lindsay, with their undersea craft, starting to fill in the gaps. And they are startled by what they have found. Jellies, it seems, have a much bigger role in the ocean system than we thought, and could even provide the missing piece in a long-standing puzzle about how carbon cycles from the ocean's upper layers to its floor. "We greatly underestimated their ecological significance," says Bruce Robison, who dives for jellies in waters near the Monterey Bay Aquarium Research Institute in Moss Landing, California.

Sting in the tail

For most of us, jellyfish are either simple curiosities to be admired at the aquarium, or pests that keep us from bathing in the sea. To others, they pose more of a problem. Mass blooms of jellyfish, which appear when the creatures reproduce in the spring or summer, are a perennial nuisance to fishermen and coastal dwellers. They decimate fisheries by munching on fish larvae and eating all of the shrimp and plankton — the same food that fish rely on. They stow away in ships' ballast waters and take over ecosystems in foreign seas. They can even close down coastal nuclear power plants by clogging up the pipes that bring cooling water from the sea.

Despite all this, jellies have tended to slide off the radar of most oceanographers, whose perception of mid-ocean biology has largely been based on what they haul up in nets. That hasn't included many jellies, as they are often chopped into pieces of gelatinous gunk by the netting. With no easy way to collect them, jellies have literally fallen through the gaps of oceanographic study.

Only with the widespread introduction of research submarines in the 1980s did researchers begin to spy on the world of jellies — and scientists have still barely scratched the surface of this gelatinous underworld. Most research subs are limited to depths shallower than 1,000 metres, leaving the vast world below unexplored — the average ocean depth is about 4,000 metres and the Pacific Ocean's Mariana Trench extends down to 11,000 metres. Even the jellies above 1,000 metres have been largely neglected by submersibles. "Researchers are usually in a rush to get the subs down to the bottom as fast as possible and in the dark to save battery life, so they miss the show," says Claudia Mills, a jelly biologist at the University of Washington's marine laboratory in Friday Harbor. Mills knows her stuff when it comes to jellies — she just had a new species of deep-sea jellyfish, *Crossota millsae*, named after her[1].

Lindsay is among the few lucky biologists to have access to one of the world's deepest-diving subs — the *Shinkai 6500*, which can dive to 6,500 metres. It's a strange kind of luck, though — few people would covet the conditions Lindsay faces in this craft. A dive lasts roughly eight hours, during which the scientist, pilot and co-pilot are crammed into a space of just 4.5 cubic metres. "It's cold and clammy, the temperature is freezing and you can't stretch out your legs," says Lindsay. Temperatures drop to less than 2 °C below 2,000 metres, so the voyagers have to wear special suits to stave off hypothermia. The vessel is not heated, both to save on battery power and to prevent the risk to its flammable gas tanks. Even looking out of the window isn't easy. There are three viewing ports, but each is smaller than a grapefruit — any larger and they would collapse under the pressure.

Juggling act

As if that isn't enough, Lindsay goes to rather extreme measures to squeeze as much useful time into his dives as possible — he counts himself lucky if he is aboard more than one of the 60 dives that the *Shinkai 6500* makes each year, such is the competition for the vessel's time. Lindsay's time-saving measures include tricks to avoid the call of nature. "Everyone has their own strategy, but I self-medicate with vodka the night before to make sure I'm dehydrated," says Lindsay. Coffee is kept to a minimum — just enough to keep the pilot alert. And Lindsay usually finds it too time-consuming and awkward to eat a proper lunch, so he sucks candy to keep his blood sugar up. He sits for hour after dehydrated hour with his forehead pressed against a window, calling directions to the pilot, manoeuvring the robotic arms that collect specimens, and trying to capture the most interesting creatures on video. "It's a juggling act," he says. Steering a 26,000-kilogram vehicle around a fragile jelly is not easy — often, jellies splatter against the sides of the craft or hurtle into oblivion when the submersible uses its thrusters. "It's always the one you really want that you can never get," Lindsay laments.

After catching the jellies, there is still the challenge of getting them out of the deep and into the light of day. "We manage to trap them in containers at these great depths, but we

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Depth charge: *Shinkai 6500* gives researchers a rare glimpse of the deep ocean's delicate jellies.

S. HADDOCK

rarely get anything back intact — they tend to completely disintegrate," says Richard Harbison, who studies jellies at the Woods Hole Oceanographic Institution in Massachusetts. The fragile jellies rarely survive the temperature changes and physical buffeting they experience during the trip to the surface. There are other problems too. Many jellies eat prey that glow, and to avoid becoming a beacon to their own predators, they camouflage their guts with red or black pigment. Lindsay thinks that these pigments can become lethally toxic on

D. LINDSAY

Back home: some crustaceans, such as this amphipod, settle down and raise their young atop a jelly.

exposure to light — including the headlamps on submersibles. "I had been trying to catch a particular red jellyfish for four years," he recounts. "Finally, I caught one. I brought it to the surface in a protective case and was just about to start filming when the light on the video camera inadvertently switched on at full strength. The jellyfish spat out its gut and disintegrated within minutes before my eyes."

There has to be a big pay-off for this kind of suffering and frustration, and for Lindsay it is the joy of discovery. "I see a new species almost every time I dive," he says. Discoveries can also be made after the dives — Lindsay's videos, along with footage taken by colleagues who were persuaded to turn on the sub's lights during their descent, have revealed yet more creatures of the deep. So far the tally stands at about 2,000 species of jelly — doubtless, many more lurk undiscovered in the deep.

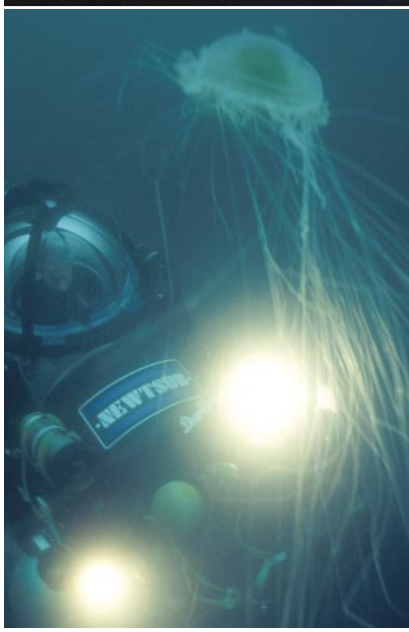
Aside from the new species, the sheer number of jellies has caught researchers by surprise. "There are no published records on how much of the midwater biomass is gelatinous. Studies with nets suggested that it might be 1 or 2% but now, with submersible dives, it seems like it's more than 50%," says Lindsay.

Jelly fishing

Richard Brodeur, from the National Marine Fisheries Service in Newport, Oregon, was originally interested in studying fish, but ended up studying jellyfish by default. "We couldn't complete our research surveys of fish because there were so many jellyfish in the water. They'd fill our nets before we could catch the fish we were after," he says. Together with his postdoc Cynthia Suchman, Brodeur has calculated the proportion of total biomass in waters off the coast of Oregon that is accounted for by the huge jellyfish *Chrysaora fuscescens*. It turns out to be comparable to that of copepods — crustaceans that are the most ubiquitous sea animals and are thought to represent a large chunk of the ocean's carbon. "Jellies are major players in the ocean's carbon biomass," concludes Robison.

Just as revealing have been the insights that such dives bring into jellies' behaviour. Jellies have been perceived as carnivores that drift passively around, snaring prey when they chance upon it. But we now know that some jellies come up from the deep under the cover of night to gorge on plankton and krill in surface waters, before sinking back down to digest their meal at depth. Other jellies have evolved specific features to prey on their gelatinous cousins — some jellies of the genus *Beroe*, for example, are made of nothing more than a mouth-like sac with tooth-like macrocilia that chomp exclusively on other jellies. "A substantial percentage of the oceanic biomass is tied up in the bodies of jellies that are feeding on each other," says Robison, who is trying to work out who is eating whom in this tangle. "We haven't yet worked out how it ties back

With the advent of diving missions, researchers such as Bruce Robison (below) are uncovering the secret watery world of jellies — some, for instance (below right), dine on jelly themselves.



LEFT, S. HADDOCK; ABOVE, D. LINDSAY

K. EVANS/NATL GEOG. SOC.

into the mainstream food web," he adds.

A more fundamental complication is that jellies seem to be involved in the direct uptake of nutrients at the bottom of the food chain. Some studies suggest that jellies can suck nutrients floating loose in the water straight through their 'skin' as a nutritious snack[2,3]. Lindsay and his postdoc Hiroshi Miyake are currently looking at how these carbon sources affect the growth of different jellies.

Jellies' diverse roles in the food web, coupled with their immense numbers, could answer some outstanding questions about how carbon cycles through marine ecosystems. Oceanographers have long struggled to understand how organisms living on the sea floor get enough organic material to support their growth. The most obvious source is 'marine snow' — a constant deluge of tiny plankton, fish faeces, moulted exoskeletons and dead organisms that drifts down onto the sea bed. But add it up and you wind up short — there doesn't seem to be enough snow to feed all the creatures that live down there. Some estimates have pegged this shortfall at around 55%, although it is thought to vary widely[4].

Feeding the masses

"Jellies may be an overlooked part of the equation," says Steve Haddock, an oceanographer at the Monterey Bay Aquarium Research Institute. The sheer mass of jellies, along with their ability to suck up carbon, means that dead jellies should contribute a large amount of carbon to the sea floor. Living jellies also lose globs of mucus from their exteriors from time to time, just as a human sheds dead skin. And larvacean jellies contribute to this rain of gelatinous gunk by discarding their mucous webs, which they use to catch food, when they become clogged. As these globs fall through the water column they are compressed by the increasing pressure and accelerate downwards. "These become great big, carbon-rich, fast-moving particles the size of your fist that shoot to the deep sea floor," says Robison. "The carbon content of these particles is a major percentage of what gets down there."

A final surprise has been the close relationship that jellies seem to have with other organisms. From net hauls, it was known that some crustaceans are frequently found in close proximity to each other, but it was a mystery how they manage to stay together — until observations during dives showed that they perch together on top of jellies.

It makes sense. Jellies can provide shelter and food for a huge range of creatures, who hide in the jellies' folds or even nibble on the jellies themselves. On a recent voyage to the Gulf of California, Haddock and his colleague Rebeca Gasca at ECOSUR, a marine-research college in Chetumal, Mexico, discovered that a crustacean called *Oxycephalus* nurses her young atop a comb jellyfish. And many deep-sea explorers have observed that *Deepstaria enigmatica*, one of the largest midwater jellyfish, which looks like a thin sac of white jelly, almost always has one or two crustaceans called *Anuropus* living with it. "We have no idea why they have this relationship or how they manage to find each other in the vast ocean," says Haddock. "There is a lot of weird stuff going on down there that we're only beginning to figure out."

To solve the remaining mysteries, jelly researchers will need more and better subs optimized for studies at intermediate depths. "Most submersibles are designed for work on the sea floor," says Lindsay. Their viewing ports often face downwards, and many of the vehicles cannot neutralize their buoyancy, meaning that they have to use their thrusters to follow an animal.

The US National Academies in Washington DC is currently assessing the future needs of deep-sea science and the role of vehicles in future ocean exploration[5]. The report is expected to be published shortly and, although committee members have declined to comment on its contents, it is likely to include recommendations for new vehicles, or modifications to old ones, that will better suit the midwater realm. "We're poised for a golden age in studying gelatinous animals. All of the techniques are coming together and now we can start to give jellies the attention they deserve," enthuses Haddock.

In the future, much of this work will probably be done through video cameras attached to robotic submersibles. These are cheaper to build, simpler, smaller and can dive for longer, so they can collect more data than crewed missions[6]. But researchers are reluctant to stop using crewed submersibles altogether. "There is no substitute for the human eye," says Lindsay. Cameras cannot always convey a sense of depth of field, or focus on several objects at once, he points out. Despite the cramped legs, the late-night vodka sessions and the freezing cold, Lindsay would rather keep going down there himself. ■

Carina Dennis is *Nature*'s Australasian correspondent.

1. Thuesen, E. V. *Zootaxa* **309,** 1–12 (2003).
2. Shick, J. M. *Biol. Bull.* **148,** 117–140 (1975).
3. Haddock, S. H. D., Rivers, T. J. & Robison, B. H. *Proc. Natl Acad. Sci. USA* **98,** 11148–11151 (2001).
4. Smith, K. L. & Kaufmann, R. S. *Science* **284,** 1174–1177 (1999).
5. http://dels.nas.edu/deepsubmergence
6. Clarke, T. *Nature* **421,** 468–470 (2003).