The secret lives of JELLYFISH

Long regarded as minor players in ocean ecology, jellyfish are actually important parts of the marine food web.

BY GARRY HAMILTON

Jennifer Purcell watches intently as the boom of the research ship *Skookum* slowly eases a 3-metre-long plankton net out of Puget Sound near Olympia, Washington. The marine biologist sports a rain suit, which seems odd for a sunny day in August until the bottom of the net is manoeuvred in her direction, its mesh straining from a load of moon jellyfish (*Aurelia aurita*). Slime drips from the bulging net, and long tentacles dangle like a scene from an alien horror film. But it does not bother Purcell, a researcher at Western Washington University's marine centre in Anacortes. Pushing up her sleeves, she plunges in her hands and begins to count and measure the messy haul with an assuredness borne from nearly 40 years studying these animals.

Moon jellyfish (*Aurelia aurita*) contain more calories than some other jellyfish.

JEFF WILDERMUTH/NATL GEOGR. CREATIVE

Most marine scientists do not share her enthusiasm for the creatures. Purcell has spent much of her career locked in a battle to find funding and to convince ocean researchers that jellyfish deserve attention. But she hasn't had much luck. One problem is the challenges that come with trying to study organisms that are more than 95% water and get ripped apart in the nets typically used to collect other marine animals. On top of that, outside the small community of jellyfish researchers, many biologists regard the creatures as a dead end in the food web — sacs of salty water that provide almost no nutrients for predators except specialized ones such as leatherback sea turtles (*Dermochelys coriacea*), which are adapted to consume jellies in large quantities.

"It's been very, very hard to convince fisheries scientists that jellies are important," says Purcell.

But that's starting to change. Among the crew today are two fish biologists from the US National Oceanic and Atmospheric Administration (NOAA) whose research had previously focused on the region's rich salmon stocks. A few years ago, they discovered that salmon prey such as herring and smelt tend to congregate in different areas of the sound from jellyfish[1] and they are now trying to understand the ecological factors at work and how they might be affecting stocks of valuable fish species. But first, the researchers need to know how many jellyfish are out there. For this, the team is taking a multipronged approach. They use a seaplane to record the number and location of jellyfish aggregations, or 'smacks', scattered about the sound. And on the research ship, a plankton net has been fitted with an underwater camera to reveal how deep the smacks reach.

Correigh Greene, one of the NOAA scientists on board, says that if salmon populations are affected in some way by jellyfish, "then we need to be tracking them".

From the fjords of Norway to the vast open ocean waters of the South Pacific, researchers are taking advantage of new tools and growing concern about marine health to probe more deeply into the roles that jellyfish and other soft-bodied creatures have in the oceans. Initially this was driven by reports of unusually large jellyfish blooms wreaking havoc in Asia, Europe and elsewhere, which triggered fears that jellyfish were taking over the oceans. But mounting evidence is starting to convince some marine ecologists that gelatinous organisms are not as irrelevant as previously presumed.

Some studies show that the animals are important consumers of everything from microscopic zooplankton to small fish, others suggest that jellies have value as prey for a wide range of species, including penguins, lobsters and bluefin tuna. There's also evidence that they might enhance the flow of nutrients and energy between the species that live in the sunlit surface waters and those in the impoverished darkness below.

"We're all busy looking up at the top of the food chain," says Andrew Jeffs, a marine biologist at the University of Auckland in New Zealand. "But it's the stuff that fills the bucket and looks like jelly snot that is actually really important in terms of the planet and the way food chains operate."

A MASS OF MUSH

The animals in question are descendants of some of Earth's oldest multicellular life forms. The earliest known jellyfish fossil dates to more than 550 million years ago, but some researchers estimate that they may have been around for 700 million years, appearing long before fish.

They're also surprisingly diverse. Some are tiny filter feeders that can prey on the zooplankton that few other animals can exploit. Others are giant predators with bells up to two metres in diameter and tentacles long enough to wrap around a school bus — three times. Jellyfish belong to the phylum Cnidaria and have stinging cells that are potent enough in some species to kill a human. Some researchers use the term jellyfish, or 'jellies' for short, to refer to all of the squishy forms in the ocean. But others prefer the designation of 'gelatinous zooplankton' because it reflects the amazing diversity among these animals that sit in many different phyla: some species are closer on the tree of life to humans than they are to other jellies. Either way, the common classification exists mainly for one dominant shared feature — a body plan that is based largely on water.

This structure can make gelatinous organisms hard to see. Many are also inaccessible, living far out at sea or deep below the light zone. They often live in scattered aggregations that are prone to dramatic population swings, making them difficult to census. Lacking hard parts, they're extremely fragile.

"It's hard to find jellyfish in the guts of predators," says Purcell. "They're digested very fast and they turn to mush soon after they're eaten."

For most marine biologists, running into a mass of jellyfish is nothing but trouble because their collection nets get choked with slime. "It's not just that we overlooked them," says Jonathan Houghton at Queen's University Belfast, UK. "We actively avoided them."

> "IT'S NOT JUST THAT WE OVERLOOKED THEM. WE ACTIVELY AVOIDED THEM."

But over the past decade and a half, jellyfish have become increasingly difficult to ignore. Enormous blooms along the Mediterranean coast, a frequent summer occurrence since 2003, have forced beaches to close and left thousands of bathers nursing painful stings. In 2007, venomous jellyfish drifted into a salmon farm in Northern Ireland, killing its entire stock of 100,000 fish. On several occasions, nuclear power plants have temporarily shut down operations owing to jelly-clogged intake pipes.

JELLIES ON THE RAMPAGE

The news spurred scientists to take a closer look at the creatures. Marine biologist Luis Cardona at the University of Barcelona in Spain had been studying mostly sea turtles and sea lions. But around 2006, he shifted some of his attention to jellyfish after large summer blooms of mauve stingers (*Pelagia noctiluca*) had become a recurring problem for Spain's beach-goers. Cardona was particularly concerned by speculation that the jellyfish were on the rampage because overfishing had reduced the number of predators. "That idea didn't have very good scientific support," he says. "But it was what people and politicians were basing their decisions on, so I decided to look into it."

For this he turned to stable-isotope analysis, a technique that uses the chemical fingerprint of carbon and nitrogen in the tissue of animals to tell what they have eaten. When Cardona's team analysed 20 species of predator and 13 potential prey, it was surprised to find that jellies had a major role in the diets of bluefin tuna (*Thunnus thynnus*), little tunny (*Euthynnus alletteratus*) and spearfish (*Tetrapturus belone*)[2]. In the case of juvenile bluefins, jellyfish and other gelatinous animals represented up to 80% of the total food intake. "According to our models they are probably one of the most important prey for juvenile bluefin tuna," says Cardona.

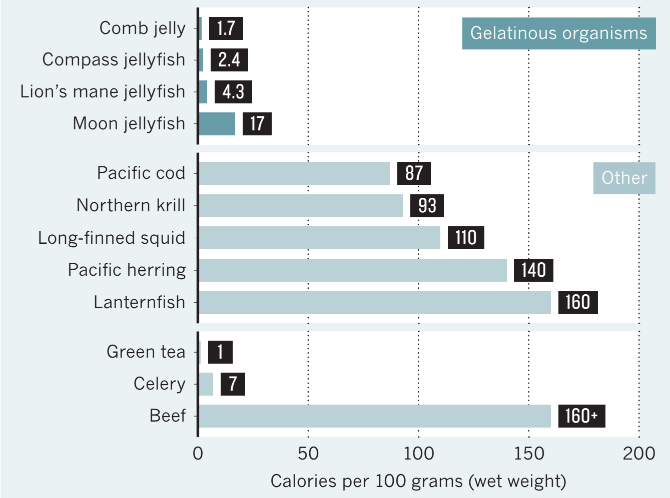
Some researchers have challenged the findings, arguing that stable-isotope results can't always distinguish between prey that have similar diets — jellyfish and krill both eat phytoplankton, for instance. "I'm sure it's not true," Purcell says of the diet analysis. Fast-moving fish, she says, "have the highest energy requirements of anything that's out there. They need fish to eat — something high quality, high calorie."

But Cardona stands by the results, pointing out that stomach-content analyses on fish such as tuna have found jellyfish, but not krill. What's more, he conducted a different diet study[3] that used fatty acids as a signature, which supported his earlier results on jellyfish, he says. "They're probably playing a more relevant role in the pelagic ecosystem of the western Mediterranean than we originally thought."

Researchers are reaching the same conclusion elsewhere in the world. On an expedition to Antarctica in 2010–11, molecular ecologist Simon Jarman gathered nearly 400 scat samples to get a better picture of the diet of Adélie penguins (*Pygoscelis adeliae*), a species thought to be threatened by global warming. Jarman, who works at the Australian Antarctic Division in Kingston, reported in 2013 that DNA analysis of the samples revealed that jellyfish are a common part of the penguin's diet[4]. Work

LEAN CUISINE

Compared with other marine prey, jellyfish and other gelatinous creatures provide relatively few calories by weight. They are like the green tea of the sea.



SOURCES: J. SPITZ *ET AL. J. MAR. SCI.* **67,** 909–915 (2010); T. K. DOYLE *ET AL. J. EXP. MAR. BIOL. ECOL.* **343,** 239–252 (2007)

"IT'S OVERTURNING THE PARADIGM THAT JELLYFISH ARE DEAD ENDS IN THE FOOD WEB."

that has yet to be published suggests the same is true for other Southern Ocean seabirds.

"Albatrosses, gentoo penguins, king penguins, macaroni and rockhopper penguins — all of them eat jellyfish to some extent," says Jarman (see 'Lean cuisine'). "Even though jellyfish may not be the most calorifically important food source in any area, they're everywhere in the ocean and they're contributing something to many top-level predators."

And some parts of jellyfish hold more calories than others. Fish have been observed eating only the gonads of reproductive-stage jellyfish, suggesting a knack for zeroing in on the most energy-rich tissues.

Through DNA analyses, researchers are also discovering more about how jellyfish function as refuges in the open ocean. Scientists have long known that small fish, crustaceans and a wide range of other animals latch on to jellyfish to get free rides. But in the past few years, it has become clear that the hitchhikers also dine on their transport.

In the deep waters of the South Pacific and Indian oceans, Jeffs has been studying the elusive early life stages of the spiny lobster (*Panulirus cygnus*). During a 2011 plankton-collecting expedition 350 kilometres off the coast of Western Australia, he and his fellow researchers hauled in a large salp (*Thetys vagina*), a common barrel-shaped gelatinous animal. The catch also included dozens of lobster larvae, including six that were embedded in the salp itself. DNA analysis of the lobsters' stomach glands revealed that the larvae had been feeding on their hosts[5].

Jeffs now suspects that these crustaceans, which support a global fishery worth around US$2 billion a year, depend heavily on this relationship. "What makes the larvae so successful in the open ocean," he says, "is that they can cling to what is basically a big piece of floating meat, like a jellyfish or a big salp, and feed on it for a couple of weeks without exerting any energy at all."

WHERE DID THEY GO?

Researchers are starting to recognize that jellyfish are important for other reasons, such as transferring nutrients from one part of the ocean to another. Biological oceanographer Andrew Sweetman at the International Research Institute of Stavanger in Norway has seen this in his studies of 'jelly falls', a term coined to describe what happens when blooms crash and a large number of dead jellies sink rapidly to the sea floor.

In November 2010, Sweetman began to periodically lower a camera rig 400 metres to the bottom of Lurefjorden in southwestern Norway to track the fate of this fjord's dense population of jellyfish[6]. Previous observations from elsewhere had suggested that dead jellies pile up and rot, lowering oxygen levels and creating toxic conditions. But Sweetman was surprised to find almost no dead jellies on the sea floor. "It didn't make sense."

He worked out what was happening in 2012, when he returned to the fjord and lowered traps baited with dead jellyfish and rigged with video cameras. The footage from the bottom of the fjord showed scavengers rapidly consuming the jellies. "We had just assumed that nothing was going to be eating them," he says.

Back on land, Sweetman calculated[7] that jelly falls increased the amount of nitrogen reaching the bottom by as much as 160%. That energy is going back into the food web instead of getting lost through decay, as researchers had thought. He's since found similar results using remotely operated vehicles at much greater depths in remote parts of the Pacific Ocean. "It's overturning the paradigm that jellyfish are dead ends in the food web," says Sweetman.

Such discoveries have elicited mixed responses. For Richard Brodeur, a NOAA fisheries biologist based in Newport, Oregon, the latest findings do not change the fact that fish and tiny crustaceans such as krill are the main nutrient source for most of the species that are valued by humans. If jellyfish are important, he argues, it is in the impact they can have as competitors and predators when their numbers get out of control. In one of his current studies, he's found that commercially valuable salmon species such as coho (*Oncorhynchus kisutch*)and Chinook (*Oncorhynchus tshawytscha*) that are caught where jellyfish are abundant have less food in their stomachs compared with those taken from where jellies are rare, suggesting that jellyfish may have negative impacts on key fish species. "If you want fish resources," he says, "having a lot of jellyfish is probably not going to help."

But other researchers see the latest findings as reason to temper the growing vilification of jellyfish. In a 2013 book chapter[8], Houghton and his three co-authors emphasized the positive side of jellies in response to what they saw as "the flippant manner in which wholesale removal of jellyfish from marine systems is discussed". As scientists gather more data, they hope to get a better sense of exactly what role jellyfish have in various ocean regions. If jellies turn out to be as important as some data now suggest, the population spikes that have made the headlines in the past decade could have much wider repercussions than previously imagined.

Back in Puget Sound, Greene is using a camera installed on a net to gather census data on a jellyfish smack. He watches video from the netcam as it slowly descends through a dense mass of creamy white spheres. At a depth of around 10 metres, the jelly curtain finally begins to thin out. Later, Greene makes a crude estimate. "Two point five to three million," he says, before adding after a brief pause, "that's a lot of jellyfish."

A more careful count will come later. Right now there's plenty of slime to be hosed off the back deck. Once that's taken care of, the ship's engines come to life. The next jellyfish patch awaits. ■

Garry Hamilton *is a freelance writer in Seattle, Washington.*

1. Rice, C. A., Duda, J. J., Greene, C. M. & Karr, J. R. *Mar. Coast. Fish.* **4,** 117–128 (2012).
2. Cardona, L., Álvarez de Quevedo, I., Borrell, A. & Aguilar, A. *PLoS ONE* **7,** e31329 (2012).
3. Cardona, L., Martínez-Iñigo, L., Mateo, R. & González-Solís, J. *Mar. Ecol. Prog. Ser.* **531,** 1–14 (2015).
4. Jarman, S. N. *et al. PLoS ONE* **8,** e82227 (2013).
5. O'Rorke, R. *et al. ICES J. Mar. Sci.* **72** (Suppl. 1), i124–i127 (2014).
6. Sweetman, A. K., Smith, C. R., Dale, T. & Jones, D. O. B. *Proc. R. Soc. B* **281,** 20142210 (2014).
7. Sweetman, A. K. & Chapman, A. *Front. Mar. Sci.* **2,** 47 (2015).
8. Doyle, T. K., Hays, G. C., Harrod, C. & Houghton, J. D. R. in *Jellyfish Blooms* 105–127 (Springer, 2013).