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They're Taking Over!

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Issue

Stung! On Jellyfish Blooms and the Future of the Ocean
by Lisa-ann Gershwin, with a foreword by Sylvia Earle
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David Hall

A moon jellyfish and cross jellyfish floating in a remote channel near Vancouver Island, British Columbia; photograph by David Hall from Beneath Cold Seas: The Underwater Wilderness of the Pacific Northwest*, which collects his images of marine life in that region. It is published by University of Washington Press.*

It's become fashionable to keep jellyfish in aquariums. Behind glass they can be hypnotically beautiful and immensely relaxing to watch. Unless we are enjoying them in this way, we usually give little thought to the creatures until we are stung by one. Jellyfish stings are often not much more than a painful interlude in a seaside holiday—unless you happen to live in northern Australia. There, you might be stung by the most venomous creature on Earth: the box jellyfish, *Chironex fleckeri*.

Box jellyfish have bells (the disc-shaped "head") around a foot across, behind which trail up to 550 feet of tentacles. It's the tentacles that contain the stinging cells, and if just six yards of tentacle contact your skin, you have, on average, four minutes to live—though

you might die in just two. Seventy-six fatalities have been recorded in Australia since 1884, and many more may have gone misdiagnosed or unreported.

In 2000 a somewhat less venomous species of box jellyfish, which lives further south, threatened the Sydney Olympics. It began swarming at the exact location scheduled for the aquatic leg of the triathlon events. The Olympic Committee considered many options, including literally sweeping the course free of the menace, but all were deemed impractical. Then, around a week before the opening ceremony, the jellyfish vanished as mysteriously as they had appeared.

Most jellyfish are little more than gelatinous bags containing digestive organs and gonads, drifting at the whim of the current. But box jellyfish are different. They are active hunters of medium-sized fish and crustaceans, and can move at up to twenty-one feet per minute. They are also the only jellyfish with eyes that are quite sophisticated, containing retinas, corneas, and lenses. And they have brains, which are capable of learning, memory, and guiding complex behaviors.

The Irukandjis are diminutive relatives of the box jellies. First described in 1967, most of the dozen known species are peanut- to thumb-sized. The name comes from a North Queensland Aboriginal language, the speakers of which have known for millennia how deadly these minuscule beings can be. Europeans first learned of them in 1964 when Dr. Jack Barnes, who was trying to track down the origin of symptoms suffered by swimmers in Queensland, allowed himself to be stung by one. With nobody attending but a lifeguard and his fourteen-year-old son, he was lucky to survive.

It's now known that the brush of a single tentacle is enough to induce "Irukandji syndrome." It sets in twenty to thirty minutes after a sting so minor it leaves no mark, and is often not even felt. Pain is initially focused in the lower back. Soon the entire lumbar region is gripped by debilitating cramps and pounding pain—as if someone is taking a baseball bat to your kidneys. Then comes the nausea and vomiting, which continues every minute or so for around twelve hours. Shooting spasms grip the arms and legs, blood pressure escalates, breathing becomes difficult, and the skin begins to creep, as if worms are burrowing through it. Victims are often gripped with a sense of "impending doom" and in their despair beg their doctors to put them out of their misery.

It's difficult to know how many victims the Irukandji have claimed. The extreme high blood pressure that often kills is hardly diagnostic. Many deaths have doubtless been put down to stroke, heart attack, or drowning. There is some evidence that the problem is growing: Irukandji have recently been detected in coastal waters from Cape Town to Florida.

The box jellies and Irukandjis are merely the most exotic of a group of organisms that have existed for as long as complex life itself. In *Stung! On Jellyfish Blooms and the Future of the Ocean*, biologist Lisa-ann Gershwin argues that after half a billion years of quiescence, they're on the move:

> If I offered evidence that jellyfish are displacing penguins in Antarctica—not someday, but now, today—what would you think? If I suggested that jellyfish could crash the world's fisheries, outcompete the tuna and swordfish, and starve the whales to extinction, would you believe me?

Jellyfish are among the oldest animal fossils ever found. Prior to around 550 million years ago, when a great diversity of marine life sprang into existence, jellyfish may have had the open oceans pretty much to themselves. Today they must share the briny deep with myriad creatures, and with machines. It's not just the wildlife they're worrying. In November 2009 a net full of gigantic jellyfish, the largest of which weighed over 450 pounds, capsized a Japanese trawler, throwing the three-man crew into the ocean. But even mightier vessels have been vanquished by jellyfish.

On July 27, 2006, the USS *Ronald Reagan*, then the most modern aircraft carrier in existence, was docked in the port of Brisbane, Australia. New Zealand had earlier banned the entry of nuclear-powered ships, and many Australians felt it might be prudent to follow their lead. So when the commander of US Naval Air Forces announced that an "acute case of fouling" had afflicted the giant vessel, people took notice. Thousands of jellyfish had been sucked into the cooling system of the ship's nuclear power plant, forcing the closure of full onboard capabilities. Newspapers ran the headline "Jellyfish Take on US Warship." Local fire crews were placed on standby, and the citizens of Brisbane held their collective breaths as the battle between the navy and the jellyfish raged. In the end, they proved too formidable, and the ship was forced out of port.

Even nations can be affected by the power of the jellies. On the night of December 10, 1999, 40 million Filipinos suffered a sudden power blackout. President Joseph Estrada was unpopular, and many assumed that a coup was underway. Indeed, news reports around the world carried stories of Estrada's fall. It was twenty-four hours before the real enemy was recognized: jellyfish. Fifty truckloads of the creatures had been sucked into the cooling system of a major coal-fired power plant, forcing an abrupt shutdown.

Japan's nuclear power plants have been under attack by jellyfish since the 1960s, with up to 150 tons per day having to be removed from the cooling system of just one power plant. Nor has India been immune. At a nuclear power plant near Madras, workers removed and individually counted over four million jellyfish that had become trapped on screens placed over the entrances to cooling pipes between February and April 1989. That's around eighty tons of jellyfish.

As Gershwin says, "Jellyfish have an uncanny knack for getting stuck…. Imagine a piece of thin, flexible plastic wrapper in a pool, where it can drift almost forever without sinking, until it gets sucked against the outflow mesh." Chemical repellents don't work, nor do electric shocks, or bubble curtains, or acoustic deterrents. In fact even killing the jellyfish won't work as, dead or alive, they still tend to be sucked in. And everyone from concerned admirals to the owners of power plants that lose millions of dollars with each shutdown have tried very hard to deter them.

Salmon swimming in pens can create a vortex that sucks jellyfish in. Tens of thousands of salmon can be stung to death in minutes, and repeated attacks can kill hundreds of thousands of the valuable fish. But those losses are small compared with the financial devastation jellyfish have inflicted elsewhere. Would you believe, Gershwin asks, that "a mucosy little jellyfish, barely bigger than a chicken egg, with no brain, no backbone, and no eyes, could cripple three national economies and wipe out an entire ecosystem"? That's just what happened when the *Mnemiopsis* jellyfish (a kind of comb jelly) invaded the Black Sea. The creatures arrived from the east coast of the US in seawater ballast (seawater a ship takes into its hold once it has discharged its cargo to retain its stability), and by the 1980s they were taking over. Prior to their arrival, Bulgaria, Romania, and Georgia had robust fisheries, with anchovies and sturgeon being important resources. As the jellyfish increased, the anchovies and other valuable fish vanished, and along with them went the sturgeon, the long-beloved source of blini toppings.

By 2002 the total weight of *Mnemiopsis* in the Black Sea had grown so prodigiously that it was estimated to be ten times greater than the weight of all fish caught throughout the entire world in a year. The Black Sea had become effectively jellified. Nobody knows precisely how or why the jellyfish replaced the valuable fish species, but four hypotheses have been put forward.

The first is that stocks of anchovy, which compete with the jellyfish, collapsed because the jellyfish ate their eggs and young. A second is that jellyfish ate the same food as the anchovies, and starved them. A third is that overfishing left more food for the jellyfish, and the fourth is that climate change caused a decline in plankton or promoted a jellyfish bloom. There may be a little truth in all four of these ideas. But one thing is clear. In the end, *Mnemiopsis* was controlled, and then only partially, by the accidental introduction of another comb jelly. *Beroe* has tooth-like structures that allow it to eat *Mnemiopsis*. Only a jellyfish, it seems, can halt a jellyfish invasion.

Jellyfish continue to pop up in unusual places, and more often than not trouble is not far behind. Around 2000, the Australian spotted jellyfish was noticed in the Gulf of Mexico. It had presumably arrived in ballast water. These jellyfish can weigh up to fifteen pounds, and by August 2000 a plague of them covered around sixty square miles. Their consumption of fish eggs, fish larvae, and other plankton was far greater than could be sustained. They ate ten times more fish eggs than was typical for the area. And they had a sneaky way of catching plankton. They jellified the surrounding waters with a kind of foam that slowed the plankton down, making them easier to catch.

Then the Gulf experienced Hurricane Katrina and the oil spill of 2010. Fish and prawn numbers plummeted, but the Australian spotted jellyfish kept going from strength to strength. By 2011 it had shown up in the western Mediterranean, and more than ten people a day were being stung, forcing the closure of tourist beaches at the height of the season. It's recently been spotted off Israel and Brazil.

From the Arctic to the equator and on to the Antarctic, jellyfish plagues (or blooms, as they're technically known) are on the increase. Even sober scientists are now talking of the jellification of the oceans. And the term is more than a mere turn of phrase. Off southern Africa, jellyfish have become so abundant that they have formed a sort of curtain of death, "a stingy-slimy killing field," as Gershwin puts it, that covers over 30,000 square miles. The curtain is formed of jelly extruded by the creatures, and it includes stinging cells. The region once supported a fabulously rich fishery yielding a million tons annually of fish, mainly anchovies. In 2006 the total fish

biomass was estimated at just 3.9 million tons, while the jellyfish biomass was 13 million tons. So great is their density that jellyfish are now blocking vacuum pumps used by local diamond miners to suck up sediments from the sea floor.

David Hall

A fried egg jellyfish, Nigei Island, British Columbia; from David Hall's Beneath Cold Seas

Jellyfish are very diverse. They range in size from a millimeter long to giants with bells over a meter across that can weigh almost half a ton. Common names give some idea of the diversity and appearance: moon jellies, lion's manes, sea walnuts, snotties, agua vivas, agua mala, blubbers, Portuguese men-o-war, and long stingy stringy thingies. These last two types are not, strictly speaking, organisms at all. Instead they are made up of collections of jellyfish species, the individuals of which are referred to as "persons" (as in food-catching persons, digestive persons, defensive persons, etc.) that function collectively like, and indeed appear to be, a single individual. And they can be enormous—up to 150 feet long. If you're confused by this you're in good company. As Gershwin explains, such entities are "not quite an individual. Not quite a colony…. For over 150 years, many of the greatest minds in evolutionary biology have debated [their] proper status."

To understand why jellyfish are taking over, we need to understand where they live and how they breed, feed, and die. Jellyfish are almost ubiquitous in the oceans. As survivors of an earlier, less hospitable world, they can flourish where few other species can venture. Their low metabolic rate, and thus low oxygen requirement, allows them to thrive in waters that would suffocate other marine creatures. Some jellyfish can even absorb oxygen into their bells, allowing them to "dive" into oxygen-less waters like a diver with scuba gear and forage there for up to two hours.

Jellyfish reproduction is astonishing, and no small part of their evolutionary success: "Hermaphroditism. Cloning. External fertilization. Self fertilization. Courtship and copulation. Fission. Fusion. Cannibalism. You name it, jellyfish [are] 'doing it.'" But perhaps the most unusual thing is that their eggs do not develop immediately into jellyfish. Instead they hatch into polyps, which are small creatures resembling sea anemones. The polyps attach to hard surfaces on the sea floor, and are particularly fond of man-made

structures, on which they can form a continuous jelly coating. As they grow, the polyps develop into a stack of small jellyfish growing atop each other that look rather like a stack of coins. When conditions are right, each "coin" or small jellyfish detaches and swims free. In a few days or weeks, a jellyfish bloom is observed.

One of the fastest breeders of all is *Mnemiopsis*. Biologists characterize it as a "self-fertilizing simultaneous hermaphrodite," which means that it doesn't need a partner to reproduce, nor does it need to switch from one sex to the other, but can be both sexes at once. It begins laying eggs when just thirteen days old, and is soon laying 10,000 per day. Even cutting these prolific breeders into pieces doesn't slow them down. If quartered, the bits will regenerate and resume normal life as whole adults in two to three days.

Jellyfish are voracious feeders. *Mnemiopsis* is able to eat over ten times its own body weight in food, and to double in size, each day. They can do this because they are, metabolically speaking, tremendously efficient, being able to put more of the energy they ingest toward growth than the more complex creatures they compete with. And they can be wasteful. *Mnemiopsis* acts like a fox in a henhouse. After they gorge themselves, they continue to collect and kill prey. As far as the ecosystem goes, the result is the same whether the jellyfish digest the food or not: they go on killing until there is nothing left. That can happen quickly. One study showed that *Mnemiopsis* removed over 30 percent of the copepod (small marine crustaceans) population available to it each day.

Jellyfish "can eat anything, and often do," Gershwin says. Some don't even need to eat, in the usual sense of the word. They simply absorb dissolved organic matter through their epidermis. Others have algae living in their cells that provide food through photosynthesis.

The question of jellyfish death is vexing. If jellyfish fall on hard times, they can simply "de-grow." That is, they reduce in size, but their bodies remain in proportion. That's a very different outcome from what is seen in starving fish, or people. And when food becomes available again, jellyfish simply recommence growing. Some individual jellyfish live for a decade. But the polyp stage survives pretty much indefinitely by cloning. One polyp colony started in 1935 and studied ever since is still alive and well in a laboratory in Virginia.

One kind of jellyfish, which might be termed the zombie jelly, is quite literally immortal. When *Turritopsis dohrnii* "dies" it begins to disintegrate, which is pretty much what you expect from a corpse. But then something strange happens. A number of cells escape the rotting body. These cells somehow find each other, and reaggregate to form a polyp. All of this happens within five days of the jellyfish's "death," and weirdly, it's the norm for the species. Well may we ask of this astonishing creature, "Sting, where is thy death?"

Despite their marvelous biology, jellyfish populations have been held in check ever since complex life evolved half a billion years ago. So why are they expanding now? In Part 2 of *Stung!*, titled "*Jellyfish, Planetary Doom, and Other Trivia*," Gershwin attempts to answer this, and to tell us what it means for the oceans.

It's clear from Gershwin's book that it has taken a mighty effort by other living creatures to hold jellyfish down. An important part of that effort has involved the maintenance of complex ecosystems, with their abundant predators and competitors of jellyfish. It's no accident that prodigious jellyfish blooms have occurred in areas like the Black Sea and off South Africa, where anchovies once swarmed. Overfishing anchovies, which compete with jellyfish for food, has doubtless helped them take over. That alone might not have been enough to allow the jellyfish to gain the march on us, but we've overfished virtually every resource in the oceans, causing the outright collapse of many ecosystems, thus opening vast new resources to the jellyfish.

Our waste, such as plastic bags, and fishing methods like drift nets and long lines are busy destroying the few jellyfish predators, such as sea turtles. We are also creating the most splendid jellyfish nurseries. From piers to boat hulls, oil and gas platforms and industrial waste and other floating rubbish, we're littering the oceans with the kind of artificial hard surfaces that jellyfish polyps love.

Then there is the amount of oxygen dissolved in seawater. Oxygen is created by plants using photosynthesis, and high oxygen levels allow fish and other complex creatures to compete successfully with jellyfish. But the oxygen in water can be depleted far more quickly that it can be replaced. Where humans add nutrients to seawater (such as fertilizer runoff from farms), areas with depleted oxygen, known as eutrophied zones, form. They can occur naturally, but are spreading quickly as the oceans become filled with excess phosphorus and nitrogen derived from a variety of agriculture and industrial human activities. In river estuaries, and in confined waters

such as the Baltic, the Black Sea, and the Gulf of Mexico, eutrophied zones have spread to a frightening extent, and they appear to be permanent. Nothing that needs even moderate amounts of oxygen, including fish, shellfish, prawns, and crabs, can survive in them. But the jellyfish thrive.

Our changing climate is also having many impacts on jellyfish. As the oceans warm, the tropical box jellyfish and the Irukandjis are likely to extend their ranges, while other species will benefit from the lowered oxygen levels that warmer waters contain. Remarkably, jellyfish may have the capacity to accelerate climate change. This can happen in two ways. Jellyfish release carbon-rich feces and mucus (poo and goo) that bacteria prefer to use for respiration. As Gershwin puts it, "jellyfish blooms turn these bacteria into carbon dioxide factories." But jellyfish also consume vast numbers of copepods and other plankton. These creatures migrate vertically through the water column, taking in carbon-rich food at the surface and releasing it as fecal pellets, which fall to the sea floor and are buried. The plankton are thus a major means of taking carbon dioxide out of the atmosphere and oceans. If their loss occurs on a large enough scale, it will hasten climate change.

There is one final impact that must be considered: acidification of the oceans. This results from carbon dioxide being absorbed into seawater. Already our oceans are 30 percent more acidic than they were thirty years ago, and creatures with shells are suffering. In recent years, there has been mass failure of oyster spawning off the American Northwest, and tiny snails in the Arctic and Antarctic oceans are having their shells eaten away by the acid. Jellyfish lack hard parts: they, it seems, will pull through the acidification crisis admirably.

How could jellyfish take over the ocean? "One bite at a time" Gershwin says. And there may be no way back. A new balance may be struck, one in which jellyfish rule:

> We are creating a world more like the late Precambrian than the late 1800s—a world where jellyfish ruled the seas and organisms with shells didn't exist. We are creating a world where we humans may soon be unable to survive, or want to.

At the same time that Gershwin asserts that jellyfish are taking over the oceans "one bite at a time," she offers a slender hope that we might eat our own way through the problem. Ancient Chinese texts show that jellyfish have been part of the human diet for over 1,700 years. Recently, the global jellyfish harvest has risen to 321,000 tons, most of which is consumed in China and Japan. But unless we all develop an Asiatic zeal for the gelatinous creatures it's hard to imagine we humans making much of a dent in the jellyfish multitudes.

As I came toward the end of this astonishing, if dismaying, book my spirits were lifted briefly when I discovered that Congress seems to be aware of the jellyfish menace. On November 2, 1966, it passed the Jellyfish Control Act (16 U.S.C. §§ 1201–1205; 1966, amended 1970 and 1972). This seemingly prescient legislation authorized the secretary of commerce to "conduct studies, research and investigations to determine the abundance and distribution of jellyfish and other pests and their effects on fish, shellfish and water-based recreation." Up to $1 million annually was spent in the 1970s. Regrettably, today Gershwin and the handful of jellyfish experts in the world struggle for access to what is clearly pitifully inadequate funding.

Gershwin leaves us with a disturbing final rumination:

> When I began writing this book,… I had a naive gut feeling that all was still salvageable…. But I think I underestimated how severely we have damaged our oceans and their inhabitants. I now think that we have pushed them too far, past some mysterious tipping point that came and went without fanfare, with no red circle on the calendar and without us knowing the precise moment it all became irreversible. I now sincerely believe that it is only a matter of time before the oceans as we know them and need them to be become very different places indeed. No coral reefs teeming with life. No more mighty whales or wobbling penguins. No lobsters or oysters. Sushi without fish.

Her final word to her readers: "Adapt."

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