The Invisible
Jellyfish blooms in disturbed oceans

Galloping along Malibu Beach in 1980, my horse's hooves crunched purplish blue beings with every stride. Young, impressionable, utterly fascinated with the massive armada of By-the-Wind Sailors, as far as the eye could see in both directions, perhaps I was long-destined to study jellyfish blooms.

I came to Australia in 1998 on a Fulbright Fellowship, to study the effect of jellyfish on commercial fisheries. I became lured by the taxonomy of the world's deadliest species, the Box Jellyfish and their demure but 'evil' cousins the Irukandjis. Now, 167 new species later, I am returning to my early interest, jellyfish blooms.

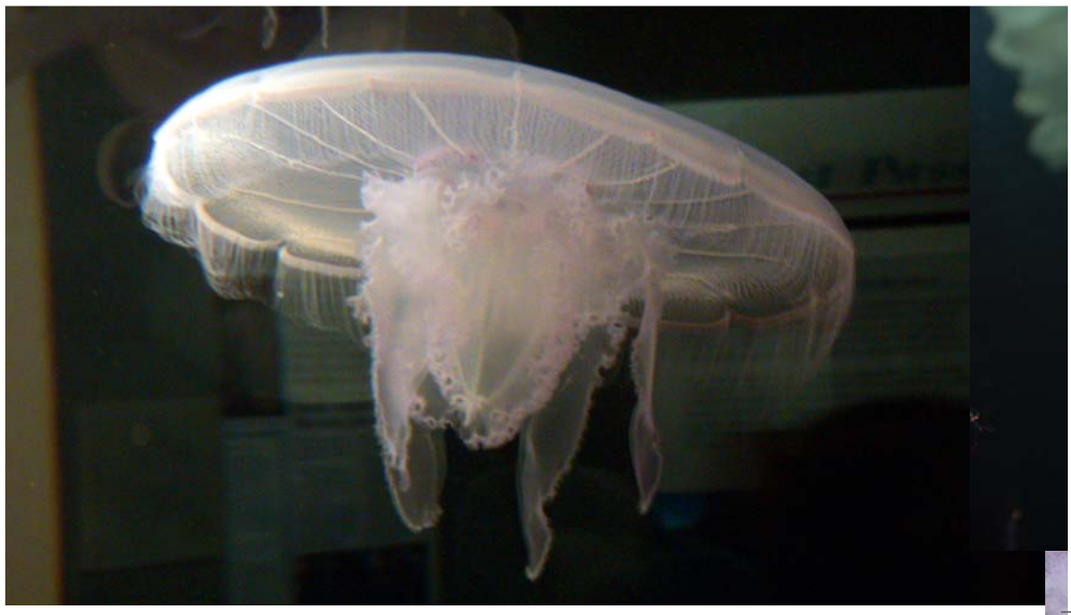
Jellyfish Behaving Badly

It was September, 1981, the Diablo Canyon Nuclear Power Plant was built on the picturesque coast at Avila Beach, central California. The plant was to begin low power testing, triggering a massive public demonstration – the largest act of civil disobedience in US anti-nuclear history.

Skip ahead. On 21 October 2008, a story hit the world headlines that a species of jellyfish – none other than *Aurelia labiata*, one of my earliest taxonomic subjects – had been sucked into the cooling water intakes of the Diablo Canyon plant, in such huge numbers as to trigger a complete shutdown of one reactor and reduction to the other... for THREE days! The jellyfish were able to do what even decades of activists could not accomplish!

If this were an isolated incident, it might be an amusing historical anecdote, but it's not. Jellyfish blooms have been causing a lot of havoc.

On 27 July 2006 in Brisbane, Australia, the world's most modern aircraft carrier, the USS *Ronald Reagan*, with a crew of 6000 and capable of taking on an entire nation's armed forces, met its match. Thousands of jellyfish were sucked into the condensers used to cool down the ship's engines. All the might of the US Navy couldn't stop the jellyfish from disabling the 100,000 ton, 333 metre long, 77 metre high, $4.5 billion nuclear-powered aircraft super-carrier.



***Aurelia labiata*, the eastern Pacific Moon Jellyfish, from California and Oregon, USA**

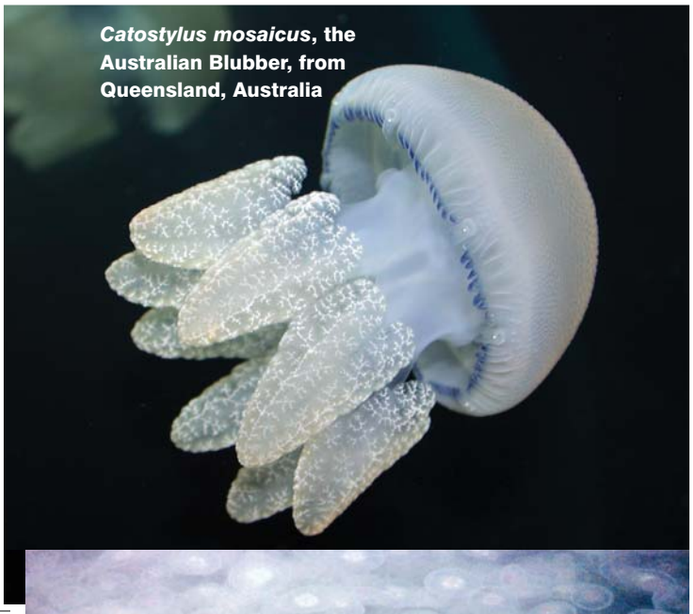
When on the night of 10 December 1999, some 40 million people across the northern half of the Philippines were suddenly plunged into darkness with a power outage many, including the international media, thought a coup d'état was underway. It was not, President Joseph Estrada was meeting with senators at the time of the incident, and remained in the dark for ten minutes power was restored. The public, however, remained in the dark until the following day! It was fifty truck-loads of jellyfish that had been sucked into the seawater cooling system of the coal-fired Sual power station which caused the cascading black-out.

Many salmon farms throughout the world have been plagued by jellyfish. Their mucus rapidly suffocates the fish, and it is not uncommon to get many thousands of dead fish in mere minutes: 56,000 in New Zealand; 25,000 in Tasmania; 250,000 in Ireland in two incidents in two weeks; and over two million in Scotland in multiple incidents over four years.

There is something that goes well beyond the "ick factor" to the "wow factor" with a jellyfish that grows to two metres in diameter and over 200 kilos. In the case of Nemopilema nomurai, it's more like "WOW FACTOR". It's pink, it's slimy, it's lethal and it is HUGE; and the females carry up to one billion eggs. Enormous blooms of this enormous species appear to be triggered in Chinese waters, then drift into the Sea of Japan, at a rate of up to 500 million jellyfish per day. The impact on Japanese fishing operations has been devastating, including the capsizing of a 10-ton trawler in November 2009.

Hundreds of thousands of stings each year are reported on Florida and Mediterranean beaches, many people each year in Australia, Thailand, and the Philippines receive deadly or life-threatening stings. Perhaps, the most

Variable:



***Catostylus mosaicus*, the Australian Blubber, from Queensland, Australia**

Swarm of *Aurelia*, the sort that often suffocate farmed salmon

Mesmerising... otherworldly... pestilent – call them what you will. A combination of weedy biological and ecological traits, allow jellyfish to essentially build an empire from disturbed ecosystems. Lisa-ann Gershwin, Director of the Australian Marine Stinger Advisory Services asks us to think of them as middlemen of opportunity... or perhaps the angels of death

bizarre sting would have to be that of a Filipino ship worker who was stung on the face while fishing off the deck of a bulk carrier in Queensland, Australia, 25 metres above the water! It seems that the tiny Irukandji jellyfish, no more than one centimetre in size, was in seawater as it splashed up.

Perturbations – bad news for most, good news for jellies?

Anthropogenic changes such as overfishing, climate change, pollution, introduced species, and ocean acidification can have far reaching impacts upon marine life but they can open niche gaps that jellyfish can and do exploit through a double whammy of predation and competition. Remedial predictions based on pollution reductions or fishing bans fail to consider the invisible variable - the jellyfish effect, which drives damaged ecosystems to further destruction.

The impacts of overfishing and how it imbalances ecosystem stability is well documented. Removal of prey means upstream starvation, whereas removal of predator allows unchecked abundance of prey, leading to over-predation on its food-source, exactly what happens with jellyfish.

Oscillating changes such as El Niño / La Niña differ from 'global warming' in that the latter is a directional shift over time, rather than flipping back and forth between states. Jellyfish are favoured by increasing temperatures. Colder water holds more dissolved oxygen than warmer water, but jellyfish are low oxygen users, so will be last affected. Warmer waters generally increase jellyfish reproduction rates as well. Furthermore, salinity changes caused by flooding or drought can be disastrous to other species, while many types of jellyfish have broad salinity tolerances, again they are 'winners'.

Many types of pollution are deleterious to marine life however eutrophication, or an excess of nutrients, which causes 'Dead Zones' in coastal marine habitats triggers phytoplankton blooms, which stimulate zooplankton. Rapid jellyfish life cycles respond in bloom proportions with a near-zero time lag, preying on herbivorous copepods. Jellyfish continue to live in the highly productive region over the dead zone, creating an exclusion area of stinging tentacles and viscous, slimy water, where fish dare not enter.

High-Energy and Low-Energy Ecosystems

Perturbations, especially eutrophication, can cause fundamental changes to the phytoplankton community structure. Diatom-based ecosystems support krill as well as anchovies and sardines, which in turn support high-energy predators, e.g., whales, sharks, seals, penguins, and large fish. Conditions which favour small flagellates over large diatoms, and therefore small zooplankton over large zooplankton, in turn favour tactile predators like jellyfish over visual predators that cannot see smaller prey. So, because jellyfish are essentially a 'trophic dead end', i.e., energy is not transferred up the food chain, the flagellate-based ecosystems are considered low-energy systems. Some disturbed ecosystems have not only shifted to jellyfish, but also to flagellates and small copepods. It is thought that these whole-of-system shifts are likely to be long term.

Invaders

The capacity to take advantage of new situations is very well illustrated by one of the most notorious cases of a non-indigenous species *Mnemiopsis*, a comb

The world's deadliest animal, *Chironex fleckeri*, and its tiny but 'evil' cousin, an Irukandji, *Carukia barnesi*, both from Queensland, Australia

jellyfish, in the seas throughout Europe. *Mnemiopsis* is believed to have been transported from the Chesapeake Bay to the Black Sea in 1982, in ballast water in a grain ship. By the late 1980s, it had invaded throughout, completely crashed the fisheries, and comprised up to 90% of the biomass. It wreaked great havoc on the Azov Sea and went on to invade the Caspian... the Sea of Marmara... the Aegean... Mersin Bay... Mediterranean coast of Israel... the Baltic... the North Sea... the Ionian Sea... by 2009, *Mnemiopsis* had reached the Western Mediterranean. The world now waits to see what happens next.

Ocean acidification, which shifts ocean chemistry towards acidity, is predicted to have negative impacts upon many calcifying organisms. Some scientists suggest that non-calcifiers, like jellies are likely to benefit from exploiting the gaps in the ecosystem as ocean acidification proceeds.

The Jellyfish Double Whammy

We are accustomed to thinking of the traditional food chain with the following rules: big things eat little things; faster things eat slower things; 'smarter' things with bigger brains eat 'dumber' things with smaller brains. In other words, the higher something is on the phylogenetic tree, the higher it should be on the food chain. Most of the time, this generalisation is more or less true, but not with jellyfish. Few organisms prey on jellyfish: turtles, sunfish, swimming crabs. But jellyfish prey on many species higher on the food chain than themselves: fish, crustaceans, molluscs, echinoderms, tunicates, any species with part of its lifecycle spent as a small, planktonic form is likely to be easy prey.

Jellyfish take over damaged ecosystems through a devastating combination of predation and competition. By eating eggs and larvae of species higher on the food chain, as well as the plankton that those larvae would eat, the jellyfish are able to deliver a one-two punch that not only whittles down other species, but keeps them down.

It is a myth to think that stopping overfishing or stopping polluting will lead back to a normal state. Jellyfish inherit a disturbed ecosystem and drive it to a much worse state. Like a ratchet, click by click, jellyfish drive ecosystems to a 'new normal', one dominated by jellyfish.

I hope you like jellyfish risotto!◎

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For further information: www.stingeradvisor.com.
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***Mnemiopsis*, a comb jellyfish, from the Chesapeake Bay, USA**

***Physalia utriculus*, the Pacific Blue Bottle, a relative of the Portuguese Man-o-war**