

March of the Red Devil

A fierce predator from the deep is taking over the eastern Pacific with extraordinary feats of transformation, finds Michael Tennesen

IN 1940, author John Steinbeck and biologist Ed Ricketts took a trip from the Californian city of Monterey, across the Mexican border and into the Gulf of California to survey the intertidal zones around its shores. In 2004, William Gilly of Stanford University and a team of graduate students retraced the voyage to draw attention to a changing world.

Where Steinbeck and Ricketts had found large sea snails, Gilly's crew found only smaller or dead specimens. Where Steinbeck and Ricketts had seen schools of tuna, marlin, sailfish and swordfish, Gilly's expedition sighted few. The Gulf of California, formerly

known as the great Cortez fish trap, has seen a massive decline in fish and shellfish in recent decades. Most fishermen will attest to it.

The thing that fascinates Gilly is what is replacing these dwindling species. Near San Pedro Martir Island he found a little pocket full of life – plankton, fish, squid and sperm whales. As the boat drifted over 1000-metre deep waters, the group was greeted by an incessant stream of Humboldt squid darting toward the boat and flashing their underbellies red and white. "This was a profound and qualitative change," says Gilly, referring to the new and vast squid population.

Adult Humboldt squid (*Dosidicus gigas*) are roughly the size and weight of an adult human, have eight arms, two long tentacles covered with toothed suckers and are notoriously aggressive (see "Humboldt squid facts", p 34). They will fearlessly latch on to divers with their powerful arms.

They aren't the largest squid in the sea, but deserve your attention for another reason. While many ocean dwellers are suffering as climate change makes waters warmer, less alkaline and less oxygenated, these beasts thrive and push into new territories. Recent observations suggest that this is all down to

extraordinary feats of transformation.

You may have heard of Humboldt squid under a different name. Some people call them jumbo flying squid, contrasting with the larger colossal squid and giant squid. Mexican fishermen call them *diablos rojos* – red devils. When pulled from the sea they flash a deep, angry shade of red and flail muscular tentacles. Underwater, they use their two tentacles with barbed suckers to capture passing prey in a flash and pull them to their arms and parrot-like beak.

Until a few decades ago, Humboldt squid were mostly found off the coast of South

America in the Humboldt current, which flows from the southern tip of Chile to northern Peru (see map, p 35). There are scant references to them in the Gulf of California before the 1960s. A thriving fishery for the squid developed in the Gulf during the 1990s, growing from almost nothing in 1993 to upwards of 110,000 tonnes between 1995 and 2009. They first appeared in California's Monterey Bay in 1998, coinciding with a strong El Niño event that swept warm waters across the Pacific. By 2004, they had roamed as far as Canada, before reaching Alaska in 2005. ➤

"When pulled from the sea they flash an angry red and flail muscular tentacles"

HUMBOLDT SQUID FACTS

THEY ARE CANNIBALS

“As soon as a squid gets hooked and others see it is caught or behaving differently, they attack,” says Roger Hanlon of the Marine Biological Laboratory in Woods Hole, Massachusetts. Unai Markaida, at the Colegio de la Frontera Sur in Campeche, Mexico, looked at 533 squid and found that 26 per cent had eaten other Humboldt squid. The bigger the squid, the more frequently it ate its own kind. Females resort to cannibalism more often than males, perhaps even eating their mates.

THEY ARE MASTER MIGRATORS

Scientists have tracked adult squid migrating from Monterey Bay in California to spawning grounds off Baja California in Mexico – a distance of 600 kilometres, which they cover in just 17 days. In addition to horizontal migrations, Humboldt squid migrate vertically every night, from at least 200 metres down to the surface.

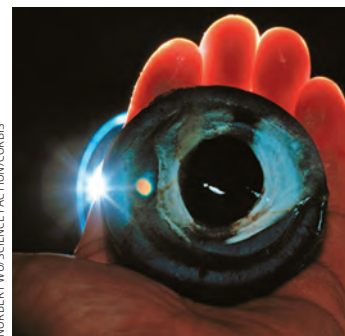
THEY HUNT IN PACKS

Gilly and Kelly Benoit-Bird at Oregon State University have seen groups of up to 40 squid swim in complex ascending spirals during night-time hunts.

THEY FLASH DIFFERENT COLOURS FROM WHITE TO A DEEP RED

One reason may be camouflage. Hannah Rosen at Stanford University says they can make muted waves of red and white scroll across their body like the undulating pattern of sunlight through the water.

They can also pulse like a strobe. According to William Gilly, also at Stanford: “There’s jitter, variation and change in the frequency and timing between two squid. It is highly unlikely this isn’t some kind of communication. It’s a very elaborate behaviour to accomplish nothing.”



NOBERT WU/SCIENCE FACTORY/CORBIS



CARRIE VONDERHAAR/OCEAN FUTURES SOCIETY/GETTY

Red Devils are sometimes aggressive towards divers

One explanation for their frenetic Pacific takeover is that they are seeking prey further and further north as their usual hunting grounds become depleted. But marine biologists also have another theory.

Humboldt squid are masters at surviving in the oxygen minimum zone – vast volumes of deep water, devoid of sunlight but rich in floating microbes. The microbes break down any organic matter that drops from the surface and use up all the oxygen in the process. Unlike other large animals, Humboldt squid can spend hours at a time in these oxygen-starved regions. Recent studies have shown that they survive the low oxygen levels by drastically lowering their metabolism and slowing their pace. They are powerful swimmers capable of outmanoeuvring most fish, says Gilly, but in the oxygen-poor deep, they become far more sluggish – probably to conserve energy.

The red devils’ ability to live in oxygen minimum zones could be an important factor in their recent expansion. Climate models predict that oxygen minimum zones will expand as temperatures rise, and Lothar Stramma of Kiel University in Germany has found evidence that this is already happening in places. Meanwhile, Julia Stewart-Lowndes at the University of California in Santa Barbara has examined Humboldt squid expansion and found that it parallels the expansion of the oxygen minimum zones.

Life in the deep

A turning point for Humboldt squid came in 2009, when another El Niño hit the Gulf of California, causing the squid fishery to collapse. In the aftermath, the same weather patterns that brought California its current drought also reduced upwellings of nutrient-rich deep waters in much of the Gulf, punishing the entire food chain. In response,

the squid moved deeper into the Gulf, to the Salsipuedes basin – a narrow strip of water that remained relatively rich thanks to localised, tidal upwellings. There, they performed a seemingly impossible transformation.

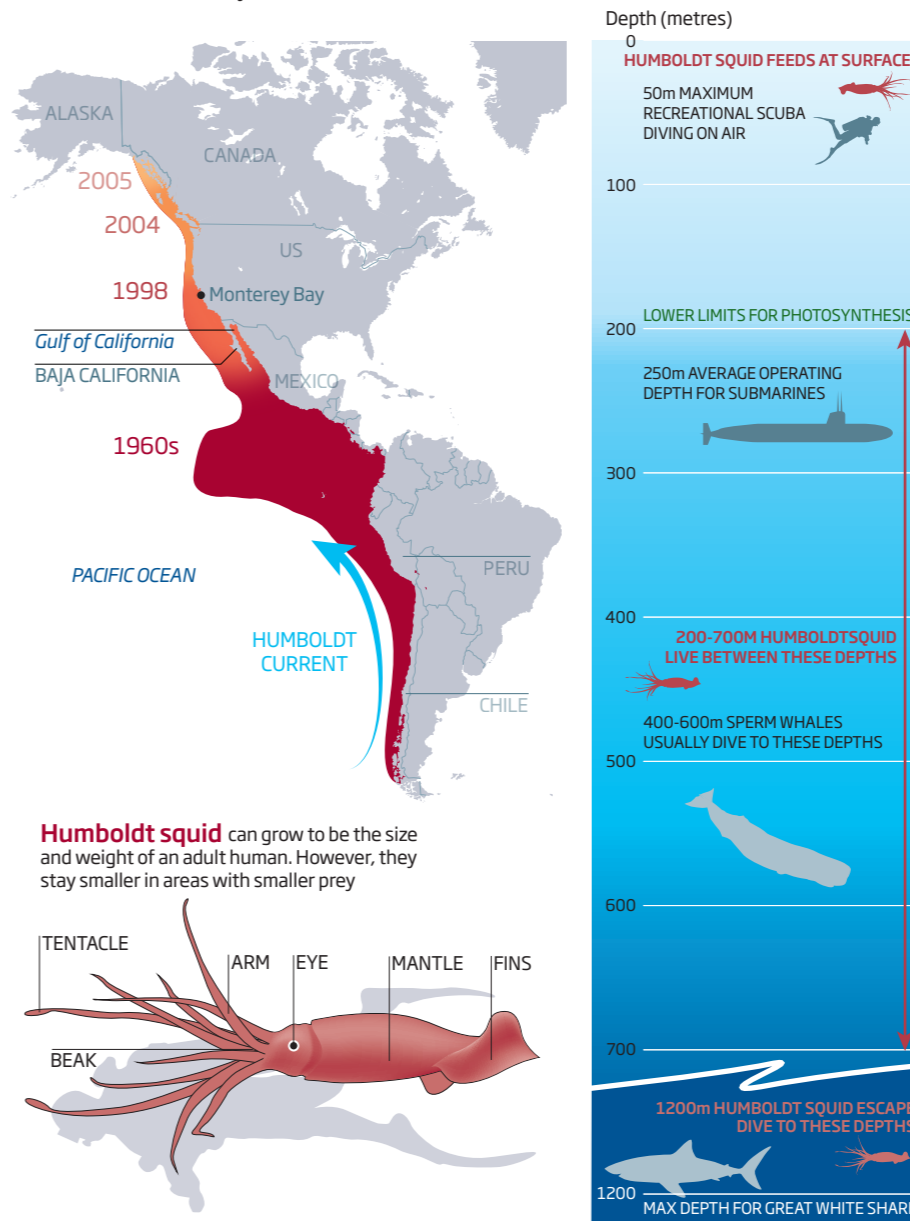
First, they shrank. Instead of catching squid with mantles more than 55 centimetres long, fishermen were now pulling in animals less than 30 centimetres long. That in itself could be explained. Humboldt squid grow with the size of their prey – smaller prey makes for smaller squid and vice versa. For instance, long-term survey cameras positioned underwater in Monterey Bay in the 1990s caught Humboldt squid switching from snacking on small lantern fish to feasts of rockfish, sole, barracuda and salmon. As they did so, their average body size got bigger.

So it’s possible that the Gulf of California population simply adapted to smaller prey when the El Niño culled their usual meals. But that’s not the end of it. Henk-Jan Hoving of the Helmholtz Center for Ocean Research in Kiel, Germany, was one of the first to study the transformation. He found that not only were the squid growing to smaller adult sizes, they were also reaching sexual maturity earlier – much earlier. Instead of maturing in a year and a half, spawning and dying, in the Salsipuedes basin they were reaching sexual maturity at 6 months or less. He says the finding amazed him and his colleagues. Gilly finds it equally surprising. “It’s like a tiger turning into a weasel,” he says.

One of Hoving’s theories is that the eggs and juveniles that were around during the 2009 El Niño were exposed to warmer temperatures, which altered biochemical pathways in their genes. “The environment may have an effect on gene expression during egg development, which leads to changes in growth and sexual maturity that are only visible later in the life of the animals,” he says. Whether such changes

Jumbo expansion

Until a few decades ago, Humboldt squid were mostly found in the Humboldt current off the coast of South America. Now they have reached much further north



CLIMATE ANI-MORPHS

Humboldt squid aren’t the only ones changing in the face of climate change (see main text).

Soay sheep live on the island of Hirta off western Scotland. Over the past 20 years, they have been shrinking. Natural selection has so far favoured bigger sheep able to cope with tough winters, but as global warming has shortened the winters, smaller sheep are now the norm.

When the temperature climbs in the Australian outback, male **bearded dragon lizards** turn into females. Researchers worry climate change could push them toward unisex extinction. That may not come to pass, however: sex-reversed females are

laying more eggs than “normal” females. “One could argue that dad lizards make better mums,” says Clare Holleley of the University of Canberra.

In Alaska’s Auke Creek, **pink salmon** have responded to earlier springs by migrating two weeks earlier than 40 years ago. This turns out to be genetically inherited, demonstrating that pink salmon may be able to evolve to stay ahead of climate change.

Polar and grizzly bears have traditionally been kept apart by ice, snow and different hibernation patterns. No more. As temperatures rise, hybrid “grolar” bears have been confirmed by DNA analysis.

are inheritable isn’t known.

All this should have changed after the El Niño passed, as happened following the 1997 to 1998 event. Instead, the squid have maintained their dwarfed life-cycle.

Studies suggest that weather patterns are once more at play. Winter winds that blow into the Gulf from the US have greatly diminished during the California drought, prolonging the effects of the El Niño. Upwellings are still weak, food is still scarce and the squid are still small.

For the Humboldt squid, being small and reaching maturity earlier may be the better strategy for now. Certainly, there are advantages to gigantism – larger animals have fewer predators, for instance. Larger squid also produce more eggs, but they only do this once in their lifetime, so reaching sexual maturity earlier reduces the chances of being eaten before spawning the next generation. “That may be a suitable strategy when you’re colonising new realms,” says Hoving.

More change ahead?

The squid do indeed appear to be colonising. Measurements suggest that their biomass nearly doubled in the Gulf of California from 2010 to 2011. And Gilly believes we may see them return to jumbo sizes. “It may be that they need two seasonally distinct migration sites in order to grow larger body sizes,” he says. Before 2009, the Gulf squid grew as large as their Peruvian cousins by migrating between a winter feeding ground on the continental side to a summer one on the peninsula. “We’re watching to see if [a new winter site] develops,” says Gilly.

Biologists are also mulling how an approaching El Niño, currently spreading across the Pacific, might affect the squid. “The 1997 to 1998 event is when they first started appearing off California,” says Stewart-Lowndes. “But after the 2009 to 2010 event, they sort of disappeared.” What will happen this time is anyone’s guess.

If one thing seems certain, it’s that this devil is full of surprises. To those who study the Humboldt squid, their incredible ability to survive when times are harsh by adapting at all costs is what sets them aside. It means that when an opportunity presents itself, they can bounce back and fill newly vacant ecological niches. Gilly thinks that if an extinction were to wipe out other animals higher up the food chain – like sharks, tuna or sperm whales – the Humboldt squid could be a contender to fill their shoes. “If someone wanted to design an ocean predator for the future,” he says, “this would sure be it.” ■

Michael Tennesen is a freelance writer based in California. His book, *The Next Species*, is published by Simon & Schuster