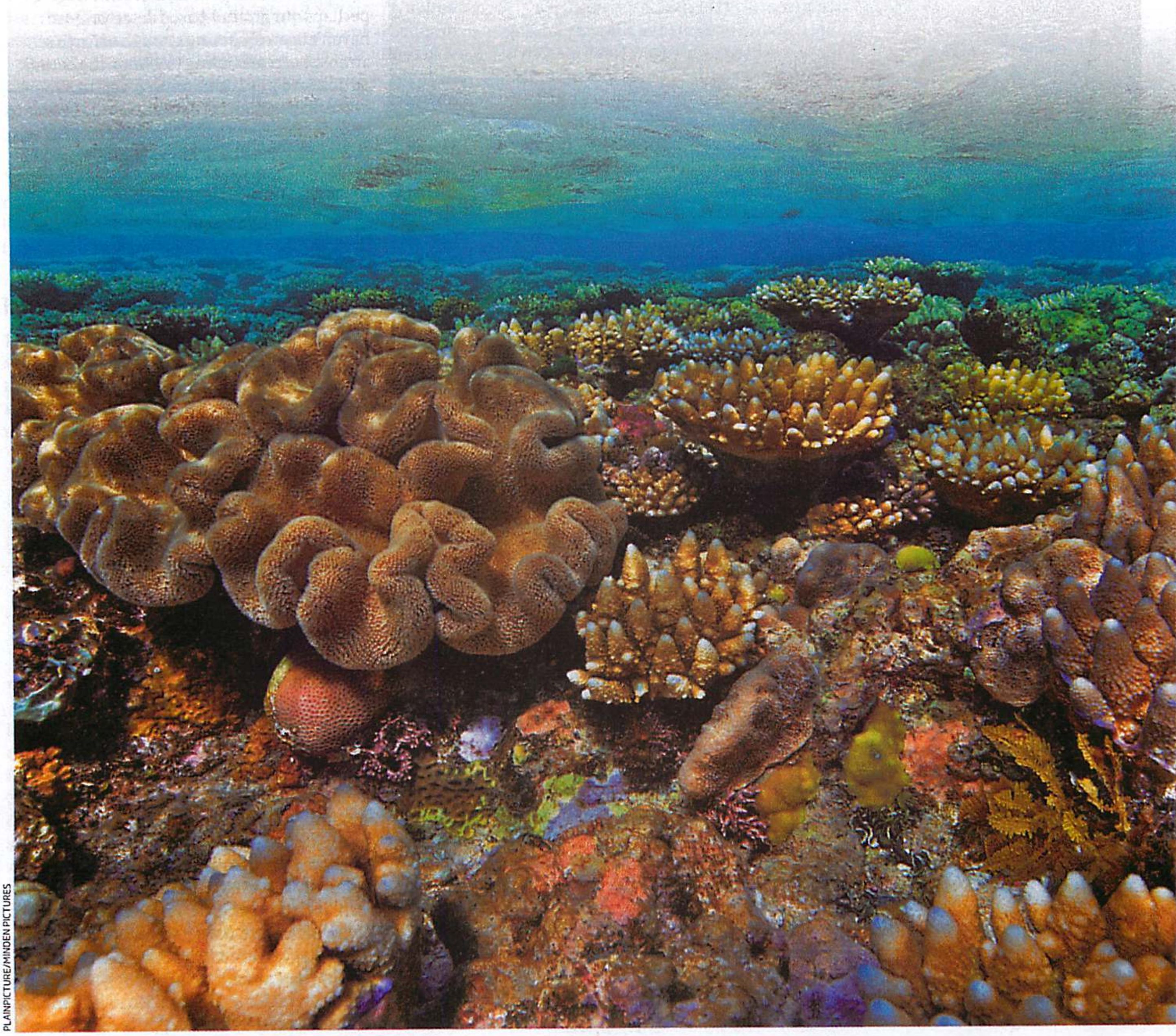
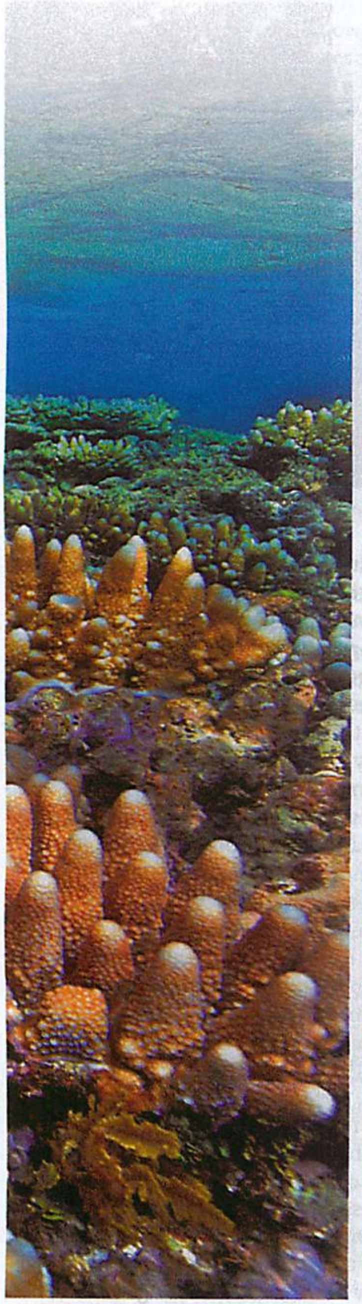
In the battle against climate change, corals have a few tricks up their sleeve, finds Michael Slezak

Not just a pretty face



PLAINPICTURE/MINDEN PICTURES



THE bleaching began in May. By September nearly one-sixth of the world's corals had turned white and were on the brink of death. Vast marine havens, once populated by schools of vibrant fish, were replaced by ghost towns of white, broken coral skeletons.

The 1998 mass-bleaching was the greatest in recorded history. Although it was triggered by a natural event – a strong El Niño that temporarily warmed the oceans – bleached corals have come to symbolise the ultimate consequence of our thirst for fossil fuels: a barren landscape where once there were lush ecosystems.

While greater bleaching is undoubtedly on the list of things that are threatening coral reefs (see "Reefs at risk", page 39), this is a rare instance of where the climate pudding may have been over-egged. New research is painting a very different portrait of corals, one that casts them in the light of plucky little fighters with more oomph in the face of climate change than previously thought.

That's not to say coral reefs are safe. From the Caribbean to the Indian Ocean, human activities are taking their toll. But if we take the right steps now, they might just see out the end of the century.

According to the standard story, climate change will hammer corals in two ways: by warming the oceans beyond what they can cope with, and by tweaking the chemistry of the oceans, thereby stealing away the chemicals they need to build reefs. As a result, corals were front-and-centre in the most recent Intergovernmental Panel on Climate Change report, which said that tropical corals seem unable to adapt to rapidly changing oceans and would suffer greatly. "It looks like by the middle of this century we won't have coral-based ecosystems anymore," says Ove Hoegh-Guldberg of Australia's University of Queensland, a lead author on the IPCC report.

He and his colleagues have grown tiny coral reefs in tanks and simulated possible future climates by varying water acidity, average temperatures, and daily and seasonal temperature variations. According to their tank experiments, none of the future scenarios look great, not even the ones where emissions are reduced immediately.

The results are alarming. Coral reefs are one of the world's most productive ecosystems. They are frequently compared to tropical forests for the sheer mass of marine biodiversity that they harbour, and nick-named the ocean's nurseries for the number of species that seek them out to reproduce.

But there is disquiet among coral reef biologists. "[The IPCC's statements] rely on a limited or outdated reading of the literature," says John Pandolfi, also at the University of Queensland. He believes published papers exaggerate our ability to predict the types of catastrophe that are facing the oceans.

Take ocean acidification. As carbon dioxide is pushed into the oceans, it forms an acid. This causes a subtle change in chemistry that lowers the water's saturation in aragonite, a form of calcium carbonate that corals use to grow and build reefs. Above a saturation state of 1, aragonite begins to precipitate out of the water and can be used to form shells. For years, coral biologists have used this measure as a proxy for estimating reef growth rates. Oceans are currently at an aragonite saturation state of around 3.8. Early experiments suggested corals would stop building reefs when the saturation state dropped below 2.5.

Recently, that crucial level has been put in doubt by people looking more closely at how corals build reefs. "All those alarming predictions were based on just the chemistry," says Adina Paytan at the University of California, Santa Cruz.

One misleading assumption in early studies was that corals built reefs from a fluid that was similar to the seawater they lived in. Instead, Malcolm McCulloch of the University

"EACH INDIVIDUAL CORAL POLYP ISOLATES A DROP OF WATER INSIDE ITS BODY AND DE-ACIDIFIES IT"

of Western Australia has found that each of the individual polyps that make up corals isolates a drop of water inside its body, and de-acidifies it by removing hydrogen ions. This allows corals to build their reefs about 100 times faster than they could in ordinary seawater.

According to Paytan, coral biologists are now leaning towards saying that the 2.5 aragonite saturation point is when corals start to suffer, not a point of no-return beyond which they collapse.

To find out how tropical corals might cope with acidifying oceans, McCulloch and his colleagues grew different species in tanks, varied the pH of the seawater, and measured the pH of each coral's internal fluid. Overall, the team found that acidification had about half the impact on coral reef building than previously thought. They calculate that under the worst climate change scenario, with a rampant rise of greenhouse gas emissions, reef-building will slow by between 15 and 35 per cent by 2100, depending on the coral ›

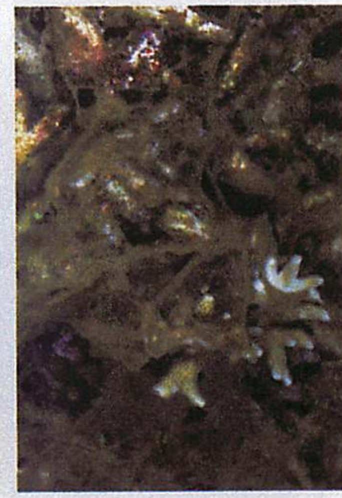
WHAT'S RUINING OUR REEFS?

Climate change might not be as disastrous for corals as assumed (see main story), but humanity still has a lot to answer for.

Unsustainable fishing practices are the biggest killer of coral, affecting over half of the world's reefs. Using dynamite (bottom left) and cyanide (top right) to stun fish, which then float to the surface for easy collection, is bad for corals too. It's often illegal, but still widely practised in South-East Asia.

Overfishing can destabilise the entire ecosystem. Removing plant-eating fish means seaweed can take over (bottom right), and if there are fewer carnivorous fish and crustaceans, coral-munching starfish often thrive.

More than a quarter of reefs are threatened by onshore activities. Deforestation chucks sediment into rivers, and fertilisers and pesticides leach in from farms. All this plus pollutants and sewage eventually gets dumped into the oceans and on any nearby reefs. Sediment literally smothers coral (top left), and fertilisers and sewage boost algae. These factors also make reef-killing diseases more likely to take hold, and make it harder for corals to cope with climate change.



CLOCKWISE FROM BOTTOM LEFT: WILDLIFE GMBH/ALAMY; DANIEL PIRAINO/EYEEM/GETTY; NATURE PICTURE LIBRARY/ALAMY; WOLCOTT HENRY

"OCEAN ACIDIFICATION DOESN'T HELP CORALS BUT IT'S NOT BY ITSELF A MAJOR PROBLEM"

species. Studies by Alexander Venn at the Scientific Centre of Monaco came to similar conclusions. "Ocean acidification doesn't help, but it's not by itself a major problem," says McCulloch.

In an ironic twist, when McCulloch plugged in the added effect of ocean warming, the story got even better. "Corals in warmer temperatures tend to calcify faster," he says. "Warming helps the process if it's not stressful." His conclusion: coral reef building rates won't change as CO_2 emissions rise this century. Not one bit.

There are subtleties, of course. For one thing, McCulloch's study and others show that different coral species react differently to acidification, producing winners and losers. And there's still the other impact of climate change. When things get too hot, the algae that live in symbiosis with corals – lending them their vibrant colours and a ready supply of energy-rich sugars – move out, leaving the reefs looking pale and ghostly. Low-level coral bleaching isn't uncommon or irreversible. But when temperatures rise rapidly, these algal battery packs move out for too long and the corals die.

This can lead to the sort of mass-bleaching that caught the world's attention in 1998. Air and water temperatures soared because of a strong El Niño – a natural weather pattern that triggers extreme weather around the world. Reefs across the globe turned white. The event killed vast amounts of coral, especially in the Caribbean and on Australia's Great Barrier Reef.

Forecasts that climate change will bring more bleachings are concerning, but corals may be more resistant to heat than we have given them credit for. Preliminary experiments suggest that their huge genetic diversity means they can evolve rapidly and may be able to quickly adapt to their changing environment.

In the Florida Keys, Carly Kenkel of the University of Texas at Austin compared off-shore reefs with in-shore ones, because in-shore reefs have to cope with higher temperatures each summer. She found that in-shore corals survived six-weeks of imposed heat stress in large tanks with less bleaching, suggesting they have evolved to survive in their warmer conditions.

All this talk of corals standing fast in the face of climate change is making some conservation biologists uneasy. Hoegh-Guldberg is adamant that climate change will ring a death knell for the ocean's nurseries and tropical forests, and points to 1998 as a taste of what the doomsday future might be like.

The key to who is right may lie in how quickly corals can bounce back from bleaching. We are only just beginning to glean insights into this, thanks to the very same event that gave coral biologists cause for concern.

Coral bounceback

Of all the world's reefs, those in the Seychelles were worst affected by the 1998 bleaching, says Nicholas Graham at James Cook University in Townsville, Australia. He and his colleagues gathered data from 21 coral reefs around the Seychelles during the 17 years following the El Niño. At first it was near-total destruction. More than 90 per cent of the coral was gone, a state of affairs that was largely unchanged for a full decade. Nine of the 21 reefs were taken over by seaweed and, in Graham's words, are as good as lost. In 2006, his team published a gloomy report on the reef's outlook whose pessimistic conclusions have often been cited in reports about corals and climate change.

But between 2005 and 2011, something remarkable happened: coral cover returned almost completely on every other reef. Hard coral had covered 28 per cent of the area before the bleaching; by 2011 it was back up to 23 per cent. Graham says the reefs are on a clear path to a full recovery. Similar findings have been coming in from reefs all over the world.

The Seychelles study is providing crucial tips for how to maximise corals' chances of survival. By comparing reefs that did and didn't recover from the 1998 event, Graham identified five crucial factors. Reefs that were most likely to recover were deeper, had a lot of nooks and crannies, lived in less polluted waters, had lots of young coral and a lot of plant-eating fish.

Pandolfi is impressed. "That was the first time to my knowledge that you could identify manageable factors that might aid reefs in responding to coral bleaching, and by inference climate change," he says. "When you think of the design of a marine reserve you can make sure you encompass the deeper water areas. If the shallow and less complex reefs get hammered these deeper reefs will be able to seed the other ones."

The study also shows the importance of controlling algal growth on reefs. Fertiliser from on-shore farms gives the seaweed a boost, allowing them to smother corals. It also aids animals that feast on coral, like crown-of-thorns starfish. Setting fishing quotas to keep the number of herbivorous fish up helps: like herds of marine goats, they eat seaweed for breakfast, lunch and dinner.

Ultimately, like most things, corals are most vulnerable when they are battling on multiple fronts. Graham points out that this was the case for all the reefs that didn't recover after 1998. And that leads to what may be the most important lesson from all this. Giving corals a break from things that are easier to control, like fishing and pollution, will mean they have a fighting chance of coping with the very real threat of more frequent severe El Niños.

Fertilisers, chemicals, garbage and dynamite are just some of the ills that humans have thrown – sometimes literally – at corals (see "What's ruining our reefs?", left). Jessica Carilli at the University of Massachusetts Boston has found that sites in the Caribbean that were being hammered by such local stresses stayed bleached for eight years, while those that were better managed recovered in as little as two.

Climate events haven't been seen destroying healthy reefs on their own, says Graham. "If we can get on top of those local disturbances which are often chronic – like fishing and water quality – then reefs will have a better chance of bouncing back," he says. "They'll still get knocked over by cyclones and bleaching events but they'll have a better chance."

Pandolfi is on the same page. "As we all got excited about climate change and the future of reefs, we forgot that these other stressors are more important here and now," he says. For that reason, he believes doomsday predictions of the impacts of short-term climate change are dangerous: they give people an easy way out, an excuse to say "Oh well there's nothing we can do about it because climate change is going to wipe them out anyway". That line is starting to look like it's on shaky ground. Corals aren't just a pretty face, they have fight in them too. ■

Michael Slezak is *New Scientist*'s Australasia reporter

TURN OVER A NEW REEF

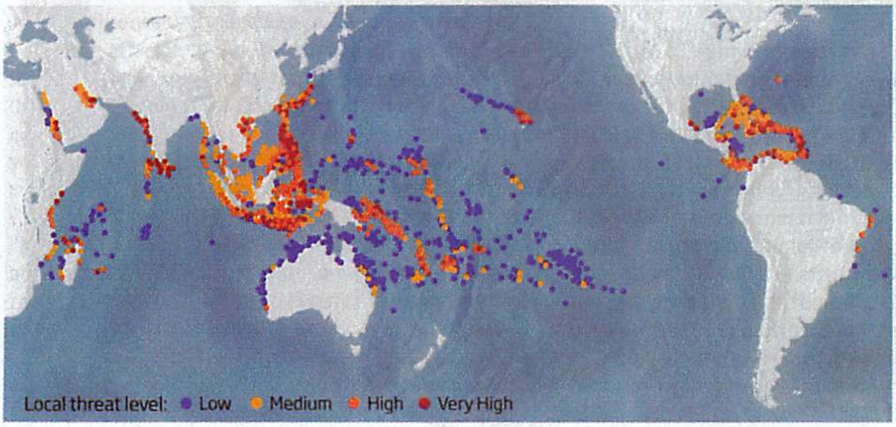
Lying just below the world's largest coral reef – Australia's Great Barrier Reef – is another, dead reef. And below that another. And below that... another. Sandwiched between these layers are the fossils of soils and rainforests that grew over the former reefs when sea level dropped during ice ages. "There are probably five, six or seven reefs," says Jody Webster at Australia's University of Sydney. "It's like a sponge cake. What we have is just the top layer."

By drilling cores through the present and past reefs, Webster has mapped movement through various climate shifts. "You have this system that is quite robust," says Webster. "It's seemingly able to migrate vast distances in response to habitat changes." Remarkably, he has found that when corals later re-emerge, they show striking similarities to their predecessors. Where the corals go to hide in the intervening years is something of a mystery.

It all adds to the picture of corals as peculiarly resilient creatures (see main story). But Webster doesn't see any of this as cause for comfort as far as humans are concerned. "Ultimately, these reefs do die." Ove Hoegh-Guldberg of Australia's University of Queensland agrees. "Try telling a tour operator who depends on a healthy reef for their business, 'They'll be back in 10 million years so don't worry'. I'm sure we'll have wonderful coral reefs again at some point – they might be appreciated by squid or whatever organism has taken over from humans."

Reefs at risk

More than 60 per cent of coral reefs are at risk from local stress. The worst off are in South-East Asia, where overfishing and using dynamite or cyanide to catch fish is common



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