

Delving into rainforest history

What's the first thing that springs to mind when you think of a tropical rainforest? For most of us it's probably their dazzling diversity of plants and animals. But if you ever wondered how they came to acquire such a rich array of species, you're in good company. It's a question that continues to puzzle evolutionary biologists, who can't agree on how – or even when and where – tropical rainforests began to diversify into the treasure house of species they are today.

In a bid to answer some of these fundamental questions, Thomas Couvreur of the New York Botanical Garden and Kew scientists Bill Baker and Félix Forest have delved deep into the history of one plant family – the palms. 'Palms are the quintessential rainforest family,' says Baker, head of palm research in Kew's Herbarium. 'We thought that if we could understand the history of the palm family, then maybe we would find out something of the history of the rainforest as well.'

Palms are ideal for such an investigation. They're ancient and almost entirely restricted to tropical rainforests, where they're one of the most important groups of plants. Above all, there is an enormous amount of data on palms.

'We have a phylogeny – a family tree based on DNA – that spans all the genera, a checklist of where all palm species occur, and lots of data about the conditions they grow in,' says Baker.

With the help of molecular dating methods and fossils of known age as calibration points, the team put a date on each branch of the palm family tree. They also used the tree to model the earliest distributions of each palm lineage and the types of vegetation they grew in. For the first time, a picture emerged of how and where this remarkable family evolved over time (published online by BMC Biology at www.biomedcentral.com/1741-7007/9/44/abstract).

The research suggests that the earliest palms began to diversify in a rainforest-like biome some 100 million years ago, during the mid-Cretaceous period.

How did tropical rainforests become so diverse? The palm family provides a clue

'Our evidence suggests that rainforests existed 100 million years ago in the northern hemisphere'

This date is significantly earlier than the oldest known fossils of palms. 'And because palms are structurally constrained to grow in warm temperatures, they have probably always been rainforest plants – so if there were palms at that time, there were probably rainforests,' says Baker.

Today, tropical rainforests grow only in the equatorial regions of America, Africa and the Indo-Pacific, but when the team modelled the ancient distribution of palms, the picture was very different. 'Our results suggest that they seem to have spanned the continents of North America and Eurasia,' says Baker. 'Taken together, our evidence suggests that rainforests existed 100 million years ago in the northern hemisphere. This is really exciting, because convincing fossil evidence for rainforests does not appear until after the end of the Cretaceous.'

That still leaves the question of how the rainforest acquired its astonishing diversity. Traditionally, rainforests have been regarded as 'museums' of diversity, because they were thought of as an ancient and stable type of vegetation, steadily adding to their tally of species over many millions of years. Alternatively, some studies have shown erratic bursts of speciation in rainforest plants, sometimes early in their history, in other cases very recently. 'One of the cool things you can do with a dated family tree is visualise how species accumulate over time,' says Baker. 'At a big picture level, we find a rather constant accumulation of species over time and that fits the "museum" model.'

That poses yet another question, however. 'We now know that rainforests haven't been enduringly stable but subject to the vicissitudes of climate change, like other biomes,' says Baker. During the past 100 million years, tropical rainforests have expanded and contracted. 'You would expect that to affect their diversity. You'd expect to see extinctions and bursts of speciation, rather than steady change.'

So how to explain the steady pattern seen among the palms? 'We suspect that even though rainforests went through bad times, they never entirely disappeared. Old lineages didn't go extinct, but survived and continued to accumulate in remnants of forest. At finer levels, such as within a genus, we might well see bursts of speciation, but overall the museum model applies to palms.'

Crossing off the ticks?



Kew is helping to establish how well an African shrub can protect cattle from ticks

For farmers in southern Africa, ticks are a constant threat to their livestock. Ticks transmit blood parasites that cause serious diseases, while the wounds irritate the animals and make them vulnerable to infections. To control ticks, cattle must be dipped frequently, usually with a treatment based on the broad-spectrum pesticide Amitraz. During the rainy season, cattle need to be dipped as often as once a week, which for poor farmers and smallholders who own just a few animals is impractical and unaffordable.

Unsurprisingly, some farmers have returned to traditional treatments based on plants with pesticidal properties. One of those plants, the woody shrub *Lippia javanica*, shows great promise as a cheap, easily prepared treatment against ticks, says Phil Stevenson at Kew's Jodrell Laboratory.

Many plants defend themselves with toxic or repellent chemicals, some of which work equally well against agricultural pests. In 2008, a survey of smallholders in Zimbabwe found that some managed ticks effectively with extracts prepared from the leaves of *Lippia javanica*. This shrub is used across much of Africa as a medicine for a range of ailments and is even traded in South Africa as a herbal tea, because of its anti-oxidant properties.

But while there is some evidence that the plant is a deterrent against some insects, there was nothing to confirm the farmers' claims that it helped against ticks. Stevenson and Steve Belmain of the

University of Greenwich and colleagues at the University of Zimbabwe decided to investigate. Did it work? And, if so, how did it compare with commercial pesticides?

At Zimbabwe's Henderson Research Station, the team pulped and soaked *Lippia javanica* leaves in cold water to produce a leaf extract that could be sprayed on to cattle in the way farmers reported they used it (*Tropical Animal Health and Production*, vol 43, p481).

The results indicate that *Lippia javanica* has enormous potential, says Stevenson. 'It's almost as good as the industrial pesticide based on Amitraz, when used in the right dose – which our tests suggest is a 10 per cent solution.'

As an alternative to cattle dip, *Lippia javanica* has much to recommend it: it's a perennial species that is abundant across southern Africa and is easily grown from seed. 'Current work is looking at ways to optimise its use, for instance by focusing on the parts where ticks usually attach, such as the belly, legs and ears,' says Stevenson.

Once the active ingredients are identified, it will be possible to improve the efficiency of the extraction. 'It might be as simple as using hot water instead of cold or adding liquid soap to optimise extraction,' Stevenson suggests.

In Zimbabwe, the Southern Alliance for Indigenous Resources, a local non-governmental organisation, has begun to endorse the use of *Lippia* against ticks, says Stevenson. 'They're taking up the work and promoting it as a practical tool.'



Zoë Lindo climbs an ancient Sitka spruce to gather moss samples

The benefits of old age

It's not only cheese and wine that improve with age. When it comes to providing forest plants with the vital nutrient nitrogen, the most ancient trees are the best source. In Canada's coastal temperate rainforests, big old trees support a luxuriant growth of mosses, which in turn play host to micro-organisms that extract nitrogen from the air and turn it into a form plants can use. 'These trees provide a habitat for something that in turn provides a habitat for something else that's fertilising the forest,' says ecologist Zoë Lindo of McGill University in Montreal.

The old-growth forests of the Pacific coast of North America are thought to suffer a shortage of nitrogen, yet are surprisingly productive. The explanation may lie in the partnership between nitrogen-fixing cyanobacteria and mosses. Past studies have shown that cyanobacteria are more efficient at extracting nitrogen from the air when they live with mosses, and that in boreal forests those living among mosses on the forest floor contribute a significant amount of the nitrogen cycling through the forest. Lindo, an expert on the ecology of the forest canopy, wondered if the same were true among the branches of forest trees.

Working in the Clayoquot Sound UNESCO Biosphere Reserve on the west

coast of Vancouver Island, Lindo picked out 18 of the oldest, most moss-festooned Sitka spruces – each some 50 m tall and more than 500 years old. She then climbed into the canopy of each tree, stopping to gather moss at heights of 15 m and 30 m. Back in the lab, Lindo's colleague Jonathan Whiteley, an expert on nitrogen-fixing micro-organisms, measured the densities of cyanobacteria in each sample and the rate at which they fixed nitrogen (*Plant and Soil*, vol 342, p141). 'We expected to find nitrogen-fixation in the canopy, but were surprised to find increased rates of fixation at greater heights,' Whiteley admits. At 30 m, the rate was twice that on the forest floor. That makes the canopy-dwelling microbes major contributors to the forest's supply of nitrogen.

But, as Lindo points out, the ancient trees are a vital part of the supply chain. 'You need trees that are large enough and old enough to start accumulating mosses before you can have the cyanobacteria that are associated with the mosses, and many trees don't start to accumulate mosses until they're more than 100 years old.' And that, she argues, is yet another compelling reason to preserve the remaining ancient temperate forests, with their venerable old trees.

Climbing leads to falls

Careless climbers can do more damage to cliff-dwelling plants than simply reduce their numbers. German researchers studying the effects of climbing on one rare species found that frequent ascents are altering populations in a way that will eventually lead to a loss of genetic variation, leaving the species vulnerable to change.

Concerned by the growing popularity of mountain climbing and the potential threat to previously undisturbed alpine floras, Frank Vogler and Christoph Reisch of the University of Regensburg looked at the effect of climbing on one representative alpine plant. They chose yellow whitlow grass (*Draba aizoides*), a yellow-flowered plant that forms rock-hugging cushions on limestone cliffs and crags. The species is native in the UK, where it's restricted to sea cliffs and old walls on the Gower Peninsula in Wales. In Europe, its stronghold is on rock faces in the limestone mountains of southern Germany, an area long popular with climbers.

Vogler and Reisch compared populations of yellow whitlow grass on eight pristine cliffs and eight cliffs that have been climbed for 50 years or more. Climbed cliffs had fewer and smaller plants. 'Climbing affects these

plants in a direct way. Abrasion by ropes and using cracks, holes and ledges as hand- and footholds obviously lead to a decline in the species' abundance,' says Reisch. There was another marked difference: there were more plants growing on rocky scree at the base of climbed cliffs than on the rock faces. These were probably plants dislodged from higher up or had grown from seeds scattered by climbers' hands or boots (*Journal of Applied Ecology*, vol 48, p899). The population, once distributed up the cliff, had largely shifted to the bottom.

DNA fingerprinting revealed another difference – one that could lead to future problems for the species. On rock faces that were undisturbed, plants near the top are genetically distinct from those nearer the bottom. But when climbers knock plants or their seeds from one level to another, they promote a mixing of genes and increasing homogenisation of the population. 'Enhanced dispersal increases gene flow, which in turn reduces the levels of genetic differentiation,' says Reisch.

Cliff plants are protected under EU regulations, and climbing organisations, including the British Mountaineering Council, have codes of conduct that specifically ask climbers not to disturb vegetation. Some damage is inescapable, however, and Vogel and Reisch argue that areas popular with climbers should be managed carefully, with some cliffs being completely off limits.



The distribution and genetic diversity of *Draba aizoides* is being altered by rock climbing

Don't turf out seagrass



Dredging, fishing and coastal development all do serious damage to seagrass meadows

Almost a quarter of the world's seagrasses are at risk of extinction. The first global survey of all 72 species found that 15 are under threat and many more are in decline.

Seagrasses may be unfamiliar and overlooked, but they're some of the most important plants on the planet. Seagrasses are flowering plants that grow rooted in coastal sediments at depths of between 1 m and 70 m, where they often form vast underwater meadows. They provide habitats for fish, and food and shelter for iconic animals such as dugongs, manatees and sea turtles. They also clarify the water, stabilise sediments, protect coastlines from wave erosion and contribute to the livelihoods of millions of people.

An international team of researchers spent four years compiling data on the status and distribution of each seagrass species for the International Union for Conservation of Nature, then estimated the probability of extinction for each one (*Biological Conservation*, vol 144, p1,961). They found that 15 species are threatened or near threatened; ten of these face a significant risk of extinction and three are listed as endangered. 'Many other seagrass species are declining globally,' says Suzanne Livingstone of the Biodiversity Consultancy, in Cambridge. 'Although these species don't trigger the thresholds for a threatened category at the moment, they're heading in that direction.'

The biggest danger comes from human activities. 'Coastal pollution and development are major threats for seagrasses – and this is only going to increase,' Livingstone stresses. 'Other major threats are climate change and dredging.' The highest concentration of declining species is around China, Korea and Japan, which have heavily developed coasts and extensive land reclamation along their shorelines. All three of the endangered species are from this part of the Pacific. Closer to home, the species we are probably most familiar with – the UK's eelgrasses (*Zostera*), which provide a habitat for rare seahorses, and *Posidonia oceanica* in the Mediterranean – have long been in decline.

While species with small ranges are at greatest danger from coastal development, the team is most worried by the overall global decline and the impact their loss will have on ecosystems and human livelihoods. 'People don't realise that seagrass beds are an essential component of coastal ecosystems and a reduction in seagrass habitat will increase the loss of other coastal habitats, such as mangroves and coral reefs,' says Livingstone. 'Seagrasses provide services that people round the world depend on.'

Urgent action is needed, says Livingstone. 'Habitat protection and reduced exploitation is required, along with programmes to improve water quality.'