

## Invasive species

### Go forth and multiply

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#### **Invasive plant species have different chemistry from their neighbours**

WHAT makes for a successful invasion? Often, the answer is to have better weapons than the enemy. And, as it is with people, so it is with plants—at least, that is the conclusion of a paper published in *Biology Letters* by Naomi Cappuccino, of Carleton University, and Thor Arnason, of the University of Ottawa, both in Canada.

The phenomenon of alien species popping up in unexpected parts of the world has grown over the past few decades as people and goods become more mobile and plant seeds and animal larvae have hitched along for the ride. Most such aliens blend into the ecosystem in which they arrive without too much fuss. (Indeed, many probably fail to establish themselves at all—but those failures, of course, are never noticed.) Occasionally, though, something goes bananas and starts trying to take the place over, and an invasive species is born. Dr Cappuccino and Dr Arnason asked themselves why.

One hypothesis is that aliens leave their predators behind. Since the predators in their new homelands are not adapted to exploit them, they are able to reproduce unchecked. That is a nice idea, but it does not explain why only certain aliens become invasive. Dr Cappuccino and Dr Arnason suspected this might be because native predators are sometimes “pre-adapted” to the aliens' defences, but in other cases they are not.

To test this, they had first to establish a reliable list of invaders. That is not as easy as it sounds. As they observe, “although there are many lists of invasive species published by governmental agencies, inclusion of a given species in the lists may not be entirely free of political motivation”. Instead, they polled established researchers in the field of alien species, asking each to list ten invasive species and, for comparison, ten aliens that just rubbed along quietly with their neighbours. The result was a list of 21 species widely agreed to be invasive and, for comparison, 18 non-invasive aliens.

Having established these lists, they went to the library to find out what was known about the plants' chemistry. Their aim was to find the most prominent chemical weapon in each plant, whether that weapon was directed against insects that might want to eat the plant, bacteria and fungi that might want to infect it, or other plants that might compete for space, water, nutrients and light. Botanists know a lot about which sorts of compounds have what roles, so classifying constituent chemicals in this way was not too hard.

The researchers then compared the chemical arsenals of their aliens with those of native North American plants, to see if superior (or, at least, unusual) weaponry was the explanation for the invaders' success. Their hypothesis was that highly invasive species would have chemical weapons not found in native plants, and which pests, parasites and other plants would therefore not have evolved any resistance to. The more benign aliens, by contrast, were predicted to have arsenals also found in at least some native species. And so it proved. More than 40% of the invasive species had a chemical unknown to native plants; just over 10% of the non-invasive aliens had such a chemical. Moreover, when they looked at past studies on alien plants that had examined how much such plants suffer from the depredations of herbivorous insects, they found that the extent of the damage reported was significantly correlated with the number of native species with which that alien shared its principal chemical weapon.

For alien plants, then, the real secret of success—also as in human warfare—is surprise. It is not that the chemicals concerned are more toxic in any general sense (indeed, successful invaders are often rare in their own native habitats). Rather, it is that the locals just don't see them coming.

## Alien species

### New flora and fauna for old

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**Animals, plants and microbes can now migrate across the planet to new homes with unprecedented ease. Ought they to be stopped? Some, no doubt. But the arrival of new species is no novelty, and many have been harmless, some highly beneficial**

FAR off in the South Atlantic, 2,500 kilometres (1,550 miles) from the nearest landmass, Africa, a war is being waged on a lonely spot called Gough Island. One side has suffered heavy casualties: over 1,000 dead this year, 63 alone on one particularly bloody night. The outcome of this interspecies warfare is a foregone conclusion, however: battered but unbowed, the mice are defeating the humans.

Out in its isolation, Gough is home to animals found nowhere else. The mice, however, arrived quite recently on sealing vessels. They now over-run the island, the base camp and the food store of the other newly arrived species: the currently ten intrepid scientists and meteorologists who live there for year-long stretches. The humans face long evenings, with limited scope for entertainment. In some ways, here is a microcosm of human attitudes towards new alien species. It's a grudge match.



### New species, an old story

Whether by choice or chance, when humans have gone to new places, other species new to those lands have always journeyed with them. Australia's dingos were brought in by its aborigines. Polynesians sailed from island to island with pigs, yams and around 30 different plants. Later, whether as stowaways on ships, planes and trains, or deliberately carried for utility, vanity or idiocy, newly arrived species have delighted and intrigued. Only recently has humankind realised the harm its species-spreading habits might be doing; and, nowadays, gone on, often, to forget the benefits.

Benefits there are. The histories of farming, horticulture, forestry and aquaculture are thick with new, exotic species joining or replacing old. In many places, introduced species are the main source of food. The potato that by the early 19th century fed (and later reduced to famine) most of Ireland hailed from the Andes; likewise the tomato, now cultivated across Europe and round the Mediterranean. Soya probably reached the Americas from China.

There are less happy histories, of course, like that of the Black Death—a mixture, probably, of bubonic and pneumonic plague, though even now no one is quite sure—which in the 14th century dispatched around 30% of Europe's human population. It came from Asia, arriving the way most new species still do, along trade routes; and it was carried by rats, which carried fleas, which carried the bacillus concerned.

For hundreds of years botanical gardens, zoos, arboreta, estate owners and random well-off or merely curious individuals have collected, maintained and distributed exotic plants

and animals from around the globe. To this day, during very cold winters, red-necked wallabies—a smallish kangaroo-like animal from Australia—bounce across the frozen waters of Loch Lomond, in Scotland, from a colony on a private island estate. The muntjac deer now common in southern England arrived and spread, early in the late century, in the same way.

NHPA, Ardea



**Off to Gough Island... To Europe from the Andes... The Epping Forest ninja**

In Epping Forest, just outside London, you can find the real Teenage Mutant Ninja Turtles. During the 1980s craze for these cartoon characters, many children bought cute baby red-eared terrapins, two centimetres long, as pets. But as the babies grew, and fashions changed, the terrapins were abandoned in rivers and lakes across Britain. Like their cartoon cousins, they are now hefty teenagers, voracious predators of native fish and other water creatures.

Introducing new plants and animals used to be positively fashionable. When Europeans migrated overseas, they took many along for food and transport: wheat, barley, rye, cattle, pigs, horses, sheep, and goats. But they took some just to make themselves feel at home. Acclimatisation societies sprang up, dedicated to introducing familiar species to unfamiliar places. One took European fish for angling to Australia. Another set out to introduce all the birds mentioned in Shakespeare into the United States. For this purpose, a hundred pairs of starlings (*Hotspur: I'll have a starling shall be taught to speak—“Henry IV, Part 1”*) were freed in New York's Central Park. The starling is now one of America's commonest birds.

## **Out with the new**

All such transfers can, like the rabbit in Australia, go wrong. The Japanese knotweed came to Britain as an ornamental plant; spreading it is now against the law in Wales, such is its ability to burst through walls and road surfaces. Much more recently, good intentions took the Nile perch to Lake Victoria, as prey for local fishermen; this large predator simply ate up all the other fish they used to catch. Not that that is the fishermen's only trouble: a worse one is the water hyacinth, another, if unintended, import.

These days, even the accidental arrival of alien species is cause for great alarm. Airliners and their passengers are fumigated, ships and cargoes scrutinised, fruits, seeds, meats and other edible goods banned, impounded and destroyed. Customs officers crawl through dimly lit aircraft cavities, arrests, prosecutions and fines are made. The United States Department of Agriculture alone employs 1,300 inspectors at 90 ports (some with dogs to sniff out "prohibited agricultural produce", and they don't mean the end-products of poppies or the coca bush). There are journals, newsletters, government committees, inter-agency groups and a global conservation hit list of the 100 most wanted (dead)

new species. In the Grand Canyon, the park's habitat restoration team feels species-elimination might even be an attraction. It wants to offer the public "the joy of eradicating non-native species". In Britain, zealots go out "rhodie-bashing" to slash away that "invasive" native of Asia, the rhododendron, that now beautifies the woods of Surrey and Scottish lochsides.

What has changed, to make the aliens so unwelcome? For one thing, though humans have helped species move beyond natural biogeographical boundaries for millennia, today this is happening with far greater speed. From 1965 to 1990, says the World Resources Institute, global imports of agricultural products and industrial raw materials went from \$55 billion to \$480 billion. Crazy ants reached Christmas Island, south of Indonesia, inside a bag of rice. They are now annihilating the native red crabs. Who ever heard of a parrot with a wasp problem? Yet the kaka, a forest-dwelling parrot in New Zealand, is competing with (and losing to) introduced wasps for honeydew and nesting holes.

Alien species often arrive with unprocessed wood. In the past 15 years, the US Department of Agriculture has found insects in wooden packing materials 5,300 times, in shipments from 90 countries. The Asian longhorned beetle, a pest of hardwood trees, evaded the bug-catchers' net four years ago; already it is alarming American foresters. At sea, meanwhile, on any day it is estimated that around 3,000 species of aquatic animals and plants are being carried around the world in ballast. The waters of the United States alone receive some 80m tonnes a year of ballast water. This is how the zebra mussel that now infests American waterways was brought in.



**Shakespeare's starling... The concrete-loving knotweed... The wasp-worried kaka**

Individual enterprise also plays a role. Piranhas, red fire ants and emperor scorpions have been intercepted in mail parcels to Hawaii. Gardeners seeking rare and/or prohibited plants can buy them by mail order, or over the Internet. And though plants do not move fast, scientists say that alien species of plant pose the biggest ecological threat, because they can disrupt entire ecosystems from the ground up.

As this globe-girdling traffic increases, so will the number of accidental introductions. In Hawaii, some new alien invertebrate is reckoned to establish itself roughly every 18 days; left to nature, these isolated oceanic islands might expect that once every 25,000-100,000 years. And more new arrivals means a greater risk of a dangerous invasion.

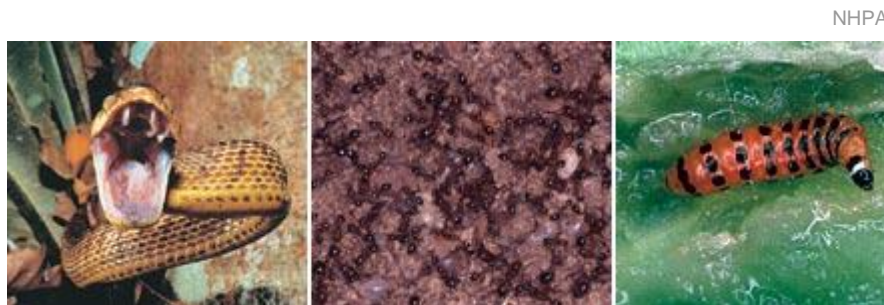
Not every alien will manage to break out of its beachhead. Army ants, tree frogs, spiders, even snakes, often arrive with fruit, vegetables and other plants from their tropical homes to startle consumers in temperate zones. But any new arrival faces a succession of hurdles. It must turn up at a favourable season, in a climate it can tolerate. And it must be capable, like the roving hands of John Donne, of some ecological match to its new-found land.

But if all the conditions are right, bingo. If an alien species no longer faces the predators and diseases that it evolved alongside, once established it may breed without restraint. Biologists call the process "ecological release". And, if the new species takes a fancy to a plant or animal that is widely farmed, or widely distributed, in its new colony, the resultant population explosion can have an extraordinary impact on agriculture and natural habitats.

## Nasty things are rare

Yet only a tiny proportion of alien species do in fact establish populations. And of those only about one in ten becomes a pest. Oceanic islands are most at risk. But South Africa and North America have had plenty of trouble. One in five of the United States' 4,500 exotic species has caused serious economic or ecological harm. Most came by chance, like the Asian tiger mosquito, shipped in with imports of old tyres. Of the United States' threatened native species, 40% can blame their decline partly on the newcomers.

The costs are hard to quantify. Since 1900, says one government estimate, a selection of 79 harmful species has cost the United States a cumulative total of \$96 billion. A recent article in *Bioscience* put the damage done by new species, plus the costs of control, at \$136 billion a year. That's not all pure loss, of course: one man's pest is another man's sale of pesticide or job applying it. But whatever the effects and the figures, they will grow, as world trade does.



**Guam's new bird-basher... Fire ants mock insecticide... An Oz feast for cactus-moth larvae**

Isolation is the reason why ocean islands face the worst trouble. In millions of years, they have evolved many species all of their own, often ill-equipped to deal with new aliens. The resulting wave of species extinctions on ocean islands has led scientists to argue that diversity at a global level is threatened.

During post-1945 reconstruction on Guam, one female, brown tree snake is thought to have arrived in a shipment of timber from New Guinea. Guam today has over a million of them. Since the 1960s, they have all but wiped out its native forest birds, bats and reptiles. Five species of lizard, nine of birds, many unique to Guam, have vanished. The numbers of the Guam rail fell from 80,000 to 50 in two decades; the bird has no answer to a voracious snake which, facing few predators of its own, can reach densities of 5,000 per square kilometre. Hawaii, its own species already hard-hit by alien ones, is watching Guam nervously. There is a lot of military traffic between the two islands, and dead snakes have already been found among the wiring of aircraft from Guam.

## Fighting the fight

Once a species is established, it is almost impossible to get rid of. Britain's dreaded Japanese knotweed, says Mark Williamson, a York University expert on invasive species, "pushes up pavements in Swansea and gets people very excited, and they spray it with glyphosate. They might as well water it."

Yet New Zealand is trying hard. With reason: of its once 120 endemic birds, 40% are now extinct. Nearly all its land mammals are aliens, and two-fifths of its flora. First to go, when Polynesian islanders arrived maybe 1,000 years ago, were the giant flightless birds, easily caught and eaten by the humans. Birds of other sizes were polished off by the arrival of rats, dogs, cats, ferrets and stoats. The kiwi survives, but only just. So far, New Zealand has managed to eliminate rats from 60 small coastal islands, mainly by spreading poisoned bait from helicopters. As recently as 1978 such a task was considered futile. Now, in the spring after an island has been cleared, seedlings flourish in greater abundance, lizard species are noticeable, insect numbers increase, chicks survive in abundance and trees bear seed.

Some attempts to remove new species, though, have done more harm than good. On Ascension Island, in the South Atlantic, cats were deliberately introduced to eat the accidentally introduced rats. But rats are hard to catch; the cats turned on the island's birds and their nests. Plans to eliminate the cats, probably by trapping and shooting, are now being hatched—to the dismay of animal rights groups. That reaction may rule out a method said to have been employed earlier to cut the numbers of the (also alien) goats: during the second world war, they were used for target practice.

The alien fire ant once faced a campaign of extirpation in the United States. A Harvard ecologist, E.O. Wilson, labelled this "the Vietnam of entomology". The \$200m carpet-bombing with insecticides was a total failure. Natural enemies of the ant were killed, the ants reinvaded treated areas faster than native species, and at higher densities than before.

The use of natural enemies to control a pest species is growing in popularity. When it works, it can fix a problem at little cost. The invasive prickly pear cactus in Australia was controlled by bringing in an Argentinean cactus moth. A wasp was brought from South America to combat Africa's cassava mealybug. But there is always the risk that the new species—like Ascension's cats—may shun the pest it was brought in to deal with, and munch its way through native flora or fauna instead. So researchers are hard at work on new methods, for instance looking for specific strains of virus that might attack a pest species; Guam's brown tree snake is one intended victim. But the best, and far the cheapest, remedy is prevention. Control agencies are now proliferating almost as fast as new exotic species.

The economics of the issue are poorly developed. What is it worth paying to bar or control the spread of some species? The answer, if it is a deadly disease like Ebola, might seem obvious: any price. More generally, ecologists think that, as more cost-benefit analyses are done, the true costs imposed by new exotic species will make the benefits of control or prevention manifest. With the main geographic barriers—oceans, mountains, large rivers and deserts—no longer effective, they argue, we risk the homogenisation of the planet's flora and fauna; a real disbenefit, because countries place a strong aesthetic value on their special plants and animals.

One can be cynical about cost-benefit sums; often they remarkably reflect the views of the analyst. But if enough people believe—as increasingly they do—that the arrival of

alien species means economic costs, the more will be spent to prevent it. That is what is happening—and the good guys are getting zapped with the bad. Maybe we should think another way. New species have often been essential, useful or at least harmless. Albeit a few have turned out to be a pain in the neck (or skin, or pocket), let us be grateful. The most lethal migrant species of all, remember, has been the human one.