Farming in the ant colony

Human foibles seem to be a natural trend gone astray

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Much of our current climate crisis is blamed on using too much chemical fertiliser to promote farm productivity. A study shows that the tendency is also found in the natural world.

Jonathan Z Shik, Pepijn W Kooij, David A Donoso, Juan C Santos, Ernesto B Gomez, Mariana Franco, Antonin JJ Crumière, Xavier Arnan, Jack Howe, William T Wcislo and Jacobus J Boomsma, from the University of Copenhagen, the Smithsonian Tropical Research Institute, Panama City, the Royal Botanic Gardens, Kew, London, Universidad Tecnológica Indoamérica, Quito, St John's University, New York, Centre de Recerca Ecològica i Aplicacions Forestals, Cerdanyola del Vallès, Spain, describe in the journal, *Nature Ecology and Evolution*, a study of farming methods of colonies of ants, and find trends that could "shed light on nutritional trade-offs that shaped the course of culturally evolved human farming."

Striving to strengthen the source of food has been a driver of evolution in the natural world and has given rise to forms of farming and social organisation among bacteria and insects, just as it has, by a cultural driver, among humans. While one should tread with care when "drawning analogies between domains," the paper says, it is reasonable to take it that both forms of farming have grown in sophistication over time. The plants that we grow today, for instance, are quite different from their ancestors in the wild -- with cultivated varieties showing more nutritious or enlarged leaves, roots or seeds. And domestication of the wild varieties has called for trade-offs, sacrificing resilience and needing special conditions, of sun or shade, water or nutrients.

These are the choices that the impetus to secure the food source forces the farmer to make. And human farmers, the paper says, "managed to push these trade-offs to extremes." A few high yielding varieties of crops have been widely farmed, "even though the vulnerability of the plants to herbivores and pathogens has often increased." This has called for the manufacture and use of pesticides. And then technological solutions, like synthetic fertilisers, have shrunk the size of the niche where the crop can flourish.

A parallel world of farmers is that of some ants, termites and bees, which, over millions of years, much longer than the time that humans have been farming, have evolved to depend on and support different sources of nutrition. The study has considered a particular group of ants, the attine ants, found in the Americas, which live on fungi that the ants cultivate with nutrition, including grasses and leaves that the ants bring to the nest. Unlike human farmers, who grow a variety of crops, however, fungus growing ants specialise in promoting in the nest basically only a single form of fungus. A disadvantage in this specialisation, or lack of diversity, is that the strain of fungus is sensitive to changes in nutrition and susceptible to infection. The ants, accordingly, have evolved ways to recycle fungal enzymes, to improve productivity, and powerful antibiotic defences to control disease, the paper says. And it is the specialisation, in the strain of fungus, and the attendant measures, that have led to the 19 different groups of these ants, with more than 240 distinct species to arise, from Argentina to north-eastern United States.

The interplay of the extent of specialisation of the fungi and the sources of nutrition was studied, first by identifying the specific nutrition that different fungi required – by growing the fungi in the laboratory, in glass dishes, with controlled supply of protein and carbohydrates -- to reveal the different Fundamental – al Niches (FNN); into which the fungi had painted themselves. To cater to these nutritional needs, the ants harvest what they can from the available debris, even freshly cut bits of leaf, and convert the harvest to a form suitable for fungi. This form, of the main nutrients that the ants offer to the fungi they cultivate, was determined by field surveys, where the material was extracted from the ants' jawbones, when they were returning to the nest, and analysed. The comparison of what the ants harvest, and what the fungi need, brings out the "provisioning strategy" the ants employ – for analysis in terms of how far the nutritional niche of the fungi has narrowed and the stage of evolution of the species of ant.

A first result of the investigation was that the earliest species, closest to the ancestral line, supported fungal varieties that showed broad FNN – viz, they were the least specialised in their nutritional requirements, and growing well even with a wide range of the mix of protein and carbohydrate as nutrition. The colonies were also of modest productivity and size. The fungi, however, could be far more productive with richer nutrition, in the lab, than what their natural caterers, the ants, could provide.

The fungi cultivated by the next evolutionary group of ants was the domestication of a specialised line of fungi, which sprouted nutrient-rich swellings for the ants to feed on.

Leafcutter ants

Although the ant colonies as well as the extent of cultivation stayed modest, the specialisation led to shrinking of the nutritional niche. That this was happening became apparent because fungus cultures in the laboratory were not able to survive if they were not provided their narrower range of nutrients.

And further along the timeline were the ants with large colonies and complex social organisation, the leafcutter ants, which bring to the nest freshly cut vegetation from hundreds of plant species. The fungal variety which the leafcutter cultivates is a specific species and it can grow only with the nutrition the ants bring. The fungi support huge colonies, of millions of ants, but cannot survive a blend of nutrition outside their FNN. The leafcutters, with this fine-tuned appetite of the fungus they cultivate, have hence evolved different measures to manage even with changes in the kind of leaf or grass that is available.

The study reveals the trend, over the millions of years of evolution, of increasing specialisation of the fungi cultivated by the ants, which supports greater productivity and colony size, matched by increasing capacity of the ants to cater to the nutritional needs of the fungi. The parallel with the development in human farming is striking – we now cultivate far more crops and get more yield per hectare than our ancestors. But our methods, energy and the use of fertilisers and insecticides, threaten our very existence. The great increase in human agriculture has been only since the last century. But the attine ants had millions of years to adapt and provide for the insecurity that dependence on a narrow band of resources must bring with it. Getting to understand how the ants do it could show us the way to deal with our own problems!

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PLUS POINTS

Nature's soothsayers

Bats are extraordinary animals – they are the only truly flying mammal species, and they are so adept at it that they can outmanoeuvre birds. They also pollinate plants, use echolocation like sonar to navigate through the darkest nights, are known to trade food for sex, and even know to self-isolate when they get ill.

But the latest scientific research into bats reveals these matchless mammals are such highly evolved creatures, they can accurately "predict the future", when it comes to tracking their prey.

So, while their oracular abilities may not be much use in a casino, bats are very skilled at predicting one thing – where to find dinner. Bats calculate exactly where their prey is going by building on-the-fly predictive models from echoes.

Researchers from John Hopkins University in Maryland, US, said the bats' predictive models are so robust, they can continue to track their airborne prey even when it temporarily vanishes behind echo-blocking obstacles like trees. The researchers said that while the prediction of possible paths based on visual information has been extensively studied, their project is the first to do so using auditory information.

The team said their work could help scientists gain greater insights into auditory-guided behaviours among humans and other animals, including sight-impaired people who use sounds to track objects around them. "Just the way a tennis player needs to find out when and where they will hit the ball, a bat needs to anticipate when and where it will make contact with the insect it's hunting," said senior author Cynthia Moss, a neuroscientist and professor of psychological and brain sciences at John Hopkins University, "The insect is flying. The bat is also flying. In this very rapidly changing environment, if the bat were to just rely on the information it got from the most recent echo, it would miss the insect."

Bats use the time delays between each echolocation call and the resulting echoes to determine how far away prey

is. The researchers said the bats tilt their heads to catch the changing intensity of echoes to figure out where the prey is in the horizontal plane. They then must put together echo information about object distance and its direction to successfully track an erratic moving insect. But because the bats are so adept at this, the research team wondered whether in addition, the bats could also be somehow using this information to predict where their prey is going.

To test this in the lab, they designed an experiment that closely mirrored the situation of a bat hunting in the wild. They trained bats to stay on a perch and track insects. The team recorded each bat's echolocation calls and head movements as they changed where the insects moved and how quickly. They also added obstacles to interrupt the echoes.

If the bats were not predicting where the insects were going, then their head movements would always lag behind the target. But the scientists found that wasn't the case. And if the bat kept his head in a fixed position, which sometimes reflected where the insect ended up, that would eliminate the prediction theory. But that wasn't happening either. And if the bat was only using information from the echoes to estimate velocity, that wouldn't be enough to explain the extent of the bat's precision.

"We found that bats use both the velocity information from the timing of the echoes and further adjust their head aim," said co-first author Angeles Salles, a postdoctoral fellow.

The findings upend the previously accepted notion that bats do not predict an insect's future position – a conclusion largely drawn from a 1980s study done before high-speed video was widely available. The research is published in the journal Proceedings of the *National Academy of Sciences*.

– THE INDEPENDENT

TURNING TWENTY

The International Space Station offers hope and a template for future cooperation

WENDY WHITMAN COBB

The first female space tourist, Anousheh Ansari in the ISS in 2006

On 2 November this year, the International Space Station celebrated its 20th anniversary of continuous human occupation. With astronauts and cosmonauts from around the world working together, the ISS has demonstrated humankind's ability to not only live and work in space but cooperate with one another. This remarkable achievement is significant as countries and companies around the world look to expand space exploration beyond Earth orbit.

The path to this anniversary was not easy; like most things done in space, the cost and the difficulty were high. Supported by the Reagan administration as part of the Cold War competition with the Soviet Union, the ISS began its life in the 1980s. Following the Challenger disaster in 1986, planning fell by the wayside as costs increased. Facing delays and cost overruns, the space station -- then known as Freedom -- was nearly cancelled by the House of Representatives in the early 1990s. While already bringing international partners aboard to lower costs, the Clinton administration invited Russia to participate, leveraging the station as a tool of foreign policy between former adversaries.

What began as competition has turned into fruitful cooperation not just between Russia and the US but Canada, Japan, Italy, the European Space Agency and over 100 other countries. As a space policy expert, I argue that the achievements of the ISS to date are indeed significant, but they also point the way ahead for cooperation and commercialisation in space.

Accomplishments and significance

By the numbers, the ISS is indeed impressive. At 357 feet in length, it is just one yard shy of an American football field. More than 241 individuals from 19 countries have visited, and at least 3,000 research projects have taken place on the ISS. The ISS is the third brightest object in the night sky and can often be spotted worldwide. Even Lego has immortalised the station with its own building set!

The ISS has proven that humans can live and work in space. These experiences are key as countries look to longer term exploration. The ISS has led to advances in understanding how the human body reacts to sustained microgravity and increased exposure to radiation. Other experiments have allowed researchers to study materials and chemicals in a microgravity environment. Astronauts have also learned how to grow food on the station, leading to insights on how plants grow on Earth.

These accomplishments have not come without criticism. It cost more than US$100 billion to construct; some have questioned the amount and value of the science that has been conducted. More recently, limits on the number of crew residing on the station have reduced the amount of time available for scientific experiments.

However, perhaps one of the most significant legacies of the ISS is the long-term cooperation that has enabled it. While the US and Russia are the countries most closely identified with the programme, Canada, Japan and the European Space Agency also take part. While not always easy, sustained cooperation in a place where operations are difficult and costly is impressive.

For the US and Russia in particular, this achievement is unique. While there was some cooperation between the two during the Cold War, the ISS is the first major space programme in which the two have worked together. Even as relations between Russia and the US have deteriorated over the last several years, the partnership on the ISS has continued. While scientific and space cooperation does not solve all terrestrial issues, it can strengthen other diplomatic relationships.

The future of the ISS

Though turning 20 may not seem like a milestone, for a complicated piece of machinery operating in the dangerous environment of space, the ISS is approaching old age. In recent years, it has suffered several problems, most recently an air leak in the Russian module, Zvezda. However, recent assessments support continued operation of the ISS for at least another 10 years.

In that time, the ISS will likely see an increase in commercial activity. Recently, cosmetics company Estee Lauder launched one of its products to the station to be featured in a commercial filmed there. SpaceX is looking to make the ISS a tourist destination following Nasa's 2019 decision making it easier for space tourists to visit. Another space company, Axiom, recently received a contract to build a commercial module to be added to the ISS in 2024. The module would give additional living and working space to astronauts aboard the station as well as serve as the starting point for a future commercial space station.

Thinking beyond Earth orbit, international cooperation in the ISS provides a solid example for future cooperation in space. As Nasa seeks to return to the Moon, international cooperation will be a way of reducing costs, normalising behaviour in space and increasing national prestige. Nasa has made efforts in these areas through the Artemis Accords, an agreement outlining norms and behaviours for lunar exploration. Additionally, Nasa is partnering with the European Space Agency and others on its plans for the Gateway, a mini-space station in lunar orbit.

Expedition 1 crew members (from left to right) Commander Bill Shepherd, and Flight Engineers Yuri Gidzenko and Sergei Krikalev pose with a model of their home away from home

The ISS experience has been fundamental to all these developments as it continues to launch the next generation of space endeavours.

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