Complex networks

Competition: intra- and inter-specific

Competition between and within species

Most animals interact with other animals or plants directly because they depend on them for food. They also compete with animals of their own species, or with other animal populations, for the same food sources, especially when these are scarce.

Some species interact for mutual benefit – like the birds that feed on the mites that pester buffalo – and some, like viruses and parasites, only interact to help themselves.

Human populations are involved in more interactions with other species than it seems possible to count – from our domestication of animals for food and companionship, to the destruction of natural ecosystems, to the communities of bacteria in our guts that help us digest our food. Of course, human populations also interact with one another. Like all animals, we fight over territory and resources, even as we try to cooperate for the greater good.

Within all ecosystems there is competition for precious resources, such as light, water or space. When competition is between members of the same species, it is intraspecific; when it is between different species, it is interspecific.

Scientists have spent many years studying interspecific competition between crayfish species across Europe and North America. In many areas of the UK native white-clawed crayfish are being replaced by invasive North American signal crayfish, which originally escaped from British crayfish farms. The larger invaders oust the native crayfish from the limited refuges under rocks in streams and rivers and compete for food. They also carry a fungal plague, to which the UK species has no defence.

Their battle over niche is an example of the competitive exclusion principle, which states that two species in the same ecosystem cannot coexist if they are competing for the same resources.

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Cooperation between species

Some species are natural partners, or even bedfellows

Snapping shrimps build their homes by burrowing into the seafloor, but they don't sleep alone. At night a shrimp will share its burrow with a goby fish. In return, the fish guards the entrance to the burrow, alerting the shrimp with a waggle of its tail when it spies danger.

This kind of close cooperation between species is known as symbiosis, or mutualism. Other symbionts include Rhizobia, the soil bacteria that live in the roots of bean and pea plants, where they "fix" nitrogen from the air using specialised nitrogenase enzymes. In return for nitrogen, which the plants need to grow, the bacteria receive essential nutrients from the plant.

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Conservation

What efforts are humans making to preserve biodiversity?

Humans have changed the world. Our appearance on Earth is associated with the dawn of a new age, informally known as the Anthropocene epoch or era.

Although the Anthropocene has only been brief compared to, say, the Mesozoic era, which saw the reign of the dinosaurs, our impact has been dramatic enough to trigger what is now considered to be our planet's sixth mass extinction.

In 2017, researchers reported that around a third of the 27,600 vertebrate species (animals with backbones) they surveyed had suffered population declines and reductions in their range since 1900. They called it a "biological annihilation". Two years earlier, some of the same researchers had suggested that vertebrates' rates of extinction were higher than in all of the previous five mass extinctions. For comparison, the mass extinction at the end of the Mesozoic era killed off 70 per cent of all plant and animal species by its end. Today, species are going extinct at least 100 times faster. Most recently, researchers have highlighted the plight of insects – 40% of the world's insect species may die out just in the next few decades.

What's different about this mass extinction is that humans are in the unique position of being able to do something about it. We are conscious of our effects on the planet, and through conservation efforts we are trying to reduce our impact on ecosystems and biodiversity. It is worth remembering that there are selfish reasons for doing this: the natural world provides important benefits, referred to as ecosystem goods and services, that we all enjoy. These include food, medicines, carbon storage and the purification by plants of the air we breathe.

Global agreements

Currently 196 nations around the world are working towards goals set out under the Convention on Biological Diversity, which opened for signature at the Rio Earth Summit in 1992. But not for much longer. Under the Convention, 20 conservation goals for 2020 were set out in 2010. They were called the Aichi Biodiversity Targets and included halving (at least) the rate at which natural habitats are being lost, ensuring that fish stocks are being used sustainably and reducing pollution to levels that are not damaging to biodiversity. However, by 2016, it was reported that a fifth of nations had made no progress or were in a worse situation than before, while only 5 per cent were on track to achieve their goals. Nations are now preparing a new biodiversity framework to guide progress to 2050.

International agreements to cut the greenhouse gas emissions that cause climate change, such as the Kyoto Protocol and Paris agreement, are also relevant to conservation goals. Climate change is expected to shift the habitat range of many species towards the poles or to higher elevations. It has been estimated that most species will have to shift their range by more than a kilometre every year in order to survive. Inevitably, many will not be able to keep up and species with small populations may be the most vulnerable to extinction.

Under the Kyoto Protocol, 38 countries agreed to reduce their greenhouse gas emissions by 5% on average, or 1 gigatonne of carbon per year collectively, by 2012, as compared to 1990 levels. It is widely considered a failure, with much of the reduction that was achieved coming from Russia before the deal was sealed or as a result of the global financial crisis. The US and Canada both abandoned it.

Whilst the Kyoto Protocol was extended to 2020, world leaders hammered out the Paris agreement to cover the following ten years, with the aim of keeping the global temperature rise below two degrees Celsius – a limit that, if it is exceeded, opens the door to the most catastrophic effects of climate change. It is now accepted that we will probably exceed this limit. However, under the agreement, countries are required to submit "nationally determined contributions" to reducing greenhouse gas emissions and to adapting to the impacts of climate change.

Conservation choices
Conservation approaches that focus on protecting habitats and ecosystems, rather than individual populations or species, may be more useful for saving a greater number of species. Focusing on single species may also neglect the important relationships they share with others. For instance, a project to reintroduce red kites to England's Lake District has been criticised for its impact on songbird populations.

Conservation can also take place outside a species' natural habitat, for example in zoos or by establishing populations elsewhere. Some projects attempt to preserve biodiversity in banks that store eggs, sperm or seeds of threatened species. The Kew Millennium Seed Bank Partnership, for example, aims to conserve 25 per cent of the world's plant species by 2020, and has already banked over half – seeds from more than 40,000 species, representing the largest collection of wild plant species in the world. Due to the difficulty of achieving its ambitious goal, it is currently focusing on the at least 60,000 species considered under threat.

Dependence on crop plants
The human population depends on crop plants for food. Supermarket shelves are stocked with a wide selection of fruit, vegetable and grain varieties. But relative to the diversity present within nature, our options are limited. So what does this mean for those plants that have made it onto the menu?

Plant crops are very different to their wild ancestors. Over thousands of years we have domesticated them to produce hardier species that are easier to grow. The ancestor of the modern-day apple is a wild Asian species known as Niedzwetzky's apple that is today considered to be on the verge of extinction. Its native habitat is the Tian-Shan mountain range in Central Asia, where in 2019, one researcher counted only 149 surviving apple trees.

Agriculture creates an unnatural environment for food crops. One problem with the systems of intensive agriculture that keep the growing human population fed is that they rely on monoculture – the cultivation of a single crop over very large areas. Monoculture is risky because it leaves plant populations susceptible to pests and diseases that can wipe out entire crops.

In the most extreme cases we face the possibility of losing important food crops entirely. Of over 1,000 banana varieties, for example, only one, the Cavendish banana, accounts for 99 per cent of exports globally, and it is currently under threat from a deadly fungus known as Panama disease. If we want to save our supermarket bananas, we may have to consider genetic modification – using genes from wild bananas - to provide disease-resistance. Or start eating other types of bananas.

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Bacteria communicate with each other using quorum sensing

Humans talk to one another. Other animals, like birds and whales, also use sound to communicate. But in the bacterial world, conversation is chemical. This chemical communication, or 'quorum sensing', is what allows bacteria to synchronise the type of coordinated attack that will leave you feeling sick.

Since the discovery of quorum sensing several decades ago, scientists have realised that all bacteria use it to communicate all the time – within their own population and with other populations of bacteria within the same community.

Quorum sensing is based on population density. Bacteria release communication molecules that float away when the population is small. But when the population is large and the bacteria are all squashed together, the communication chemicals build up to a level that signals to the bacteria that they are surrounded. One universal molecule is used by all types of bacteria to provide information about a community as a whole, whereas more specialised molecules are used by individuals of the same species – each has its own chemical language.

A curious light-producing bacterium called *Vibrio fischeri* uses quorum sensing molecules to sense when its population has grown to a certain size, at which point all the bacteria in the population switch on their lights. The bacteria are symbiotic, living in an organ of the Hawaiian bobtail squid. The bacteria's luminescence prevents these squid from casting shadows on moonlit nights, which in turn helps them avoid predators.

Other bacteria use quorum sensing to coordinate production of enzymes needed for growth or of toxins needed to fight off invaders, or to control conjugation – transfer of genes between bacterial cells.

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Understanding host–pathogen interactions

An infection occurs when a population of pathogens (the disease-causing agents) grow in or on an organism (the host), affecting its function. The host population might be made up of people, animals, plants or even bacteria. Some pathogens infect more than one host – like the flu viruses that infect birds as well as humans, and the tuberculosis-causing bacteria that infect cows and badgers.

At the individual level of the host, an infection is a battle between its defences – its immune system – and the strategies that the pathogen population deploys to bypass these defences. A healthy human immune system will fight off the pathogen and develop antibodies that can recognise it in the future. At the population level, this creates an arms race between the pathogen population and the host population, in which the pathogen evolves new strategies to overcome the hosts' defences. In human populations these defences involve drugs and vaccines as well as naturally developed immunity.

Viruses can only live and reproduce inside their hosts' cells. Any flu virus that leaves your body via a sneeze will only survive on a door handle or a kitchen surface for a matter of hours. This is why viral epidemics can only sustain themselves if enough new, susceptible members of the population are available to spread the infection. The success of measles and cervical cancer vaccines depends on critical thresholds of vaccination being reached within a population, thereby preventing the viruses that cause these diseases from moving easily between one host and another. This concept is known as 'herd immunity'.