SHARDS OF SCIENCE

Biodiversity: Species are moving, scientists are perplexed

Climate change is already causing shifts in living things, which will increase. But science is struggling to anticipate them. And the reasons for these migrations of fauna and flora are multiple, according to several recent publications.

Yves Sciama - November 9, 2024 at 2:10 p.m.

It wasIn 1995, a young American ecologist, Camille Parmesan, was studying an elegant butterfly from the West Coast, *Euphydras editha* , Edith's checkerspot. Comparing her observations with those of colleagues from the beginning of the century, she noticed that the distribution area (the area occupied by the animal) of her graceful lepidopteran had changed: it was now found much further north and at higher altitudes. An observation that would revolutionize the hitherto relatively static worldview of scientific ecology.

Because the researcher, intrigued, wondered if global warming, which was just beginning to be discussed, was not the cause. To verify this, she joined forces with a team of colleagues from around ten European countries (those with the best historical data on butterflies), who then reviewed thirty-five species. Their work , published in *Nature* in 1999, was a bolt from the blue: 63% of these species were now found further north than a century ago, from 35 to 240 km, and only 3% further south. The first consequence of global warming on living things had been identified.

Camille Parmesan's work will then be extended , by herself and by others, to thousands of organisms, terrestrial and marine. Showing that the living has started to move, on a very large scale. On all continents, countless microbes, plants, corals, insects, mammals are in the process of modifying their distribution area, in a sort of immense planetary crisscrossing.

The study of these movements has an obvious theoretical scientific interest: they hold the key to what is important for species, how they move, how they assemble. But understanding and predicting the future movements of animals, plants or microbes would, moreover, have a major practical interest.

"There are two important areas that will be impacted by these movements: nature conservation and public health ," says Veronica Frans, a researcher at Stanford University, who published a notable article on these issues in the journal *Nature Ecology and Evolution in June 2024*.

"Indeed, to define the location of protected areas, it is important to know what species will be there!" she comments. A forest can become ecologically essential or, conversely, an island uninhabitable. *"As for health, many diseases, such as malaria, depend on the movements of vector organisms such as mosquitoes. We must therefore know how to model these species movements."*

There are at least two other areas where this prediction would be valuable. Agriculture, because many plants and livestock are always interacting, positively or negatively, with wild organisms, whether pollinating insects, meadow plants or various pests.

And then there is forestry, where there is concern about the speed of global warming. Which trees will survive the future climate, should we let the forests manage to adapt or should we plant them, and in this case which species? To answer these questions, we still need to be able to determine the movements of the distribution areas of the trees...

Predictions still imprecise

But it is precisely in these predictions that the problem lies. Because a quarter of a century after Camille Parmesan's discovery, the understanding and especially the predictability of the movements of each species remains extremely limited.

Certainly, a recent article validates Camille Parmesan's general conclusions. The BioShifts database, covering thousands of species movements, beyond just butterflies, reveals that only 6% of these have remained static over the last few decades. The great crossover has therefore begun.

But, if 59% of them go towards the poles or the altitude, confirming the signature of the warming, no less than 35% go in the opposite direction, without it being necessarily understood why a particular organism makes a particular movement.

The initial theoretical reasoning of ecologists was that species would follow their "thermal optimum", in other words their ideal living temperature, and thus travel towards the poles and higher up at the same rate as warming. They would roughly follow isotherms (the lines joining points of the same temperature, analogous to contour lines).

Climate debt

In practice, and for example, since it is estimated that Paris today has the climate of Bordeaux forty years ago, and will reach that of Toulouse around 2050, species should broadly follow similar trajectories. However, this reasoning has been simply refuted by reality.

What we observed is indeed very different. *"To begin with, we can see a major difference between marine species and continental species: the former migrate almost six times faster towards the poles than the latter; on average, 5.92 kilometers/year, compared to 1.11 kilometers/year!"* explains Jonathan Lenoir, a researcher at the CNRS, who published this discovery in 2020.

The explanation is relatively simple: the ocean environment is more or less continuous, and species manage to follow their isotherms as best they can, while the continents are bristling with barriers, some of which are natural (mountain ranges, large rivers), but above all artificial, built by humans: *"Cities, large infrastructures such as roads and railways, areas of intensive agriculture or deforested areas..."* , lists Jonathan Lenoir.

Continental species are therefore accumulating a *"climate debt"* , the researcher believes, without it being really possible to determine the consequences. In addition, species are more behind in their migration towards the poles than in their migration towards higher ground. To "cool down" by one degree, you have to travel about 180 kilometres north, whereas you only need to move a few kilometres in the mountains, where human activity is generally less. But the altitude "debt" still exists: while the isotherms rose by 165 metres in the 20th century in the Alps, plants only progressed by 66 metres.

First come, first served?

Moreover, there are very significant differences between the groups of species considered: insects, for example, are among the fastest migrants in Europe, moving around 20 kilometres per year towards the north, while plant families have on average... stayed put.

It is tempting to explain these differences by the mobility abilities of individuals, but this does not hold up. Birds, for example, have on average changed their range less than insects, even though they are as mobile as – if not more so.

This is because other factors can hinder the movements of organisms. For example, there is the "priority effect", says Jonathan Lenoir: *"A species can arrive in a habitat that is certainly more favorable in theory, but already occupied by a rival species, which will hinder, or even prevent, its installation for a time."*

A species also needs a procession of allies, because it is "interwoven" with others, according to the expression of the philosopher Baptiste Morizot . If it is a plant, it will need, for example, pollinating insects, seed-dispersing birds, symbiotic fungi, etc. And if it is an animal, it will need prey, possibly other species that provide it with shelter, etc. If one or more of the members of this

procession are unable to move, the organism will struggle, or even fail, to establish itself.

In addition, species have a capacity for evolution and adaptation that ecological models still rarely take into account. *"Trees are genetic mosaics* ," notes forester Francis Martin, emeritus researcher at INRAE in Nancy. Some branches can indeed have a different genome, if mutations occur in their terminal bud, mutations that will be found in the fruits that grow there. *"They could have sufficient evolutionary capacities to disprove the models that predict their disappearance in a given place* ," he believes.

The impact of human activities

Finally, there is another essential aspect to add to all this. Certainly, climate is important for a species. But, in the era of the Anthropocene, it is far from being the only factor influencing the movements of organisms. This is shown by an article by a team led by Pieter Sanczuk of the University of Ghent, in Belgium, published in *Science* in October 2024, which found, from 266 European understory plants, that they had migrated mainly towards the west, and not towards the north, in recent decades.

The explanation, according to the authors, seems to be found in two human parameters. First, the acid rain of the 1970s and 1980s, the effects of which are beginning to fade, following the deindustrialization of Europe, with stricter environmental standards, opening the way to the colonization of new lands.

Second, the intensification of agriculture in the west of the continent: in fact, by fertilizing their fields, farmers spread a certain amount of nitrogen into the environment, which accelerates the reconquest of wild plants. These two factors have so far weighed more heavily than global warming, which is nevertheless very real. *"The impact of human activities on the ground is very important for the movements of species, and it has been underestimated in ecologists' models* ," generalizes Veronica Frans. They, she explains, began by modeling the "natural" parameters that explain the presence of a species in a given place. *"For example, temperature, rainfall, soil type, slope, light, altitude, etc."*

Conversely, human parameters – such as road density, pesticide use, pollution in general, hunting, night lighting, noise, etc. – were only taken into account in 11% of the 12,854 species distribution models she examined! *"While these parameters are often very important* ," notes the researcher.

A need for interdisciplinarity

Veronica Frans, herself an ecologist, sees this as a bias in her discipline as a whole: *"We still tend to think that the presence of an animal depends on the nature that surrounds it, while human systems are now merging with nature, in the era of the Anthropocene."*

To make the immense crisscrossing of species that will take place over the coming century more predictable, ecological models describing the needs of species – which have already made a lot of progress – must now incorporate these human variables, argues the researcher. This will require ecologists to interact with economists, demographers, sociologists, and anthropologists.

An interaction that is certainly developing, but is not always easy, and which will take time, since human sciences and natural sciences often have difficulty talking to each other enough to conduct joint investigations. Suffice to say that if the evolution of the climate, at least on the scale of a few decades, is relatively predictable, that of the biosphere, despite its importance, remains for the moment a black box.

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Le journal MEDIAPART est édité par la Société Editrice de Mediapart - 127 avenue Ledru-Rollin, 75011 Paris.
RCS Paris 500 631 932. Numéro de CPPAP : 1224Y90071 - Directeur de la publication : Carine Fouteau