# Research shows how carrion beetles turn death into life

June 22 2021

A female burying beetle caring for her brood. Oliver Krueger

It was Halloween and the discussion had inevitably turned to death – and flesh-eating zombies. I had just finished lunch at a "research away day" when I got caught up in a conversation about carrion beetles with a new colleague of mine, Sheena Cotter.

The carrion beetles (also known as burying beetles or sexton beetles), which Sheena researches, are masters of death: they breed in the dead carcass of a mouse or a bird and, together with their larval brood, reduce it to bones and skin in a very short time. Then, a new cohort of beetles disperse. I confess the thought of dead corpses stuffed with creepy crawlies was initially repellent to me (especially just after lunch) but back then I really didn't know much about the incredible biology of these beetles. Over the next few months my feelings changed.

I study soil. Most people, including fellow biologists, basically see soil as a place of death – full of dead plants and animals, which eventually decompose into pieces. But I see soil very differently: as a very thin, breathing skin of the planet, full of myriad different, beautiful forms of invisible life – an ecosystem that enables life to reform from death. Carrion beetles and soil are similar in the way they sit at this interface between the living and the dead. Sheena and I had more in common than I initially thought.

She studies how these beetles use their immune systems to defend themselves against parasites and diseases. Parasites are fascinating. For example, there's the "zombie fungi" that burrow into the brains of ants and manipulate their behavior, or hairworms that make their host leap into water just before the hairworm emerges. Carrion beetles have to contend with nematodes, tiny worms which climb up through the beetle's orifice, delivering a deadly bacteria that turns its insides into a nutritious soup that the nematodes can breed in.

But Sheena is particularly interested in how the beetles defend their babies and the carcass they are feeding on against soil microbes. Soil microbes are microscopic forms of life (mostly bacteria and fungi) that live in soil. She and her team have found that the beetle parents produce antimicrobial substances called lysozymes in their secretions. The production of these substances only starts when parents find a carcass.

This was of great interest to me because people who study soil generally concentrate on how soil microbes interact with plants, rather than animals. In the last two decades we have started to appreciate how important soil and plants are to our life and to the climate. But there is much more going on here. If carrion beetles were having a significant impact on the soil then this would represent a large blind spot in our understanding of it.

Sheena's focus, meanwhile, had always been on the beetles. She hadn't considered how these antimicrobial secretions might have effects beyond the carcass and in the soil itself. It became clear that by looking at the impact of carrion beetles and a dead carcass on the underlying soil, we might reveal a new driver of ecosystem functioning. So we decided to collaborate.

We discovered that the beetle may be playing a vital role in stabilizing soil biology, which is essential if the soil system is to act as a carbon sink and help reduce atmospheric carbon emissions.

## Life, death and soil

These blind spots are important because more than a quarter of all Earth's biodiversity lives in soil. These organisms (bacteria, fungi, protists and tiny invertebrates) are responsible for breaking down dead organisms and controlling the cycling of chemical elements through ecosystems. This is essential to life on this planet. With no life in soil, nutrients would move through the soil very slowly. Plants could not grow well and we would have little food.

The recycling of nutrients into the soil from leaf litter and dung has been well studied. Forensic scientists have also carefully studied the stages of decomposition of larger animals by insects and microbes.

But what happens to small mammals and birds has rarely been considered, despite being vastly more numerous. They are often scavenged or eaten by predators and so removed from the system, to be returned as dung. A recent study in the US found that during spring and summer, up to 75% of all small mammal carcasses are secured by carrion beetles.

We have little knowledge of how carrion beetles change the way nutrients are recycled or the effects they have on the animals and microbes living in the soil. This matters. As we soon discovered, carrion beetles have profound effects on soil and soil is central to how an entire ecosystem works, meaning that the beetle is central to that ecosystem. This is actually very surprising, given the long term focus on the relationship between plants and soil. And it may also have long term consequences on how entire ecosystems work, including the climate.

Sheena and I wanted to focus exactly on the impact that the breeding cycle of carrion beetles has on soil organisms. If carrion beetles find a carcass and start breeding in it, they get rid of it in a few days, rather than the many weeks it would take when they are not breeding. Surely, this must affect what happens in the soil?

## The carrion beetle

Carrion beetles, or *Nicrophorus_spp*, (there are several species) are very particular insects: in order to reproduce they need to find and bury a small mouse or bird carcass. This is a Herculean task. The beetle can smell death from several kilometers away and once a carcass has been located it needs to be secured – it is a rich prize. At just over 1cm in length, a pair of beetles can bury a 30g mouse in matter of hours by excavating the soil underneath it.

Once the carcass has been interred in its crypt, the mother and father strip it of fur or feathers, roll the remaining flesh into a ball and smear it with antimicrobial secretions to prevent bacteria and fungi from attacking it or their brood. The beetles also cover the carcass with their own gut microbes, which help to digest the carcass, prevent decomposition by soil microbes and change the scent of the carcass so that it stops attracting competitors such as flies and other beetles.

Preparing for a new family is a big job but the parents take regular breaks from the carcass to mate. The female will then lay her eggs in the surrounding soil. Two days after carrion beetles secure the carcass, it is ready to host its new family. The parents bite a hole in the skin and on the third day to encourage the newly hatched larvae inside to feed. The beetles are excellent parents. Not only do they prepare and maintain the carcass for their babies, they also regurgitate food for them for the first few days after they hatch.

The mother stays with her brood until they have completely consumed the carcass and the father leaves a few days earlier (unless he has been widowed, in which case he will care for the babies alone). In around a week, the babies reduce a dead mouse to bones and hair. At this point the family parts ways. The remaining parent emerges from the crypt and flies away to feed, and hopefully find a new carcass. The babies burrow into the soil to pupate, emerging as adults three weeks later.


Examples of tiny soil fauna that live in soil.

The carcass of a dead animal is very nutritious, with a much higher proportion of digestible proteins than those found in plants. The decomposition of the carcass, whether by beetles or soil microbes, returns many of these nutrients to the soil.

If there weren't any beetles there, this would happen all the same – bacteria, fungi and other insects would ensure this. But if a burying beetle breeds in the carcass, decomposition occurs underground. The carcass also disappears much more rapidly (one or two weeks versus several weeks with microbial decomposition alone) and so the entire timing and whereabouts of nutrients in the soil is completely altered.

The week-long breeding cycle of the carrion beetles works like a very precise clock, with precise intervals of time at which very specific events happen. We realized that this offered a fantastic opportunity and by studying this process in detail, we would be able to analyze the soil in a fairly unique way.

Soil is very difficult to predict and therefore to study. Two handfuls of soil collected one beside the other can contain very different amounts of organisms, different species and can also differ substantially in terms of basic properties, such as soil water, pH and how much organic matter it contains. And we know very little about how soil changes over time. But these changes are important, especially if we want to know how biodiversity responds to extreme disturbance such as drought and flood.

Carrion beetles produce antibiotics to protect the carcass and their brood at the beginning of the breeding cycle. This means the activity of things like bacteria and fungi in soil are blocked at known points in time. If we could show that the release of the antibiotics correlated with a change in microbes, animals and organic matter, we would have shown that the carrion beetle is a key driver of how matter – and so molecules like $CO_2$ – moves through the ecosystem.

## Light-powered plants and carbon

Soil ecologists like myself have mostly focused on plants because the vast majority of materials in the soil are of plant origin. This material, which we call organic matter, literally fuels soil life.

Consider a huge oak tree. It once was just a little acorn. It then became a seedling, then a tiny sapling, then a young tree, and eventually the majestic oak in front of you. So where did the biomass of this oak tree come from? It all started from that little acorn. The most obvious hypothesis is that it comes from the soil. Already in the 17th century, scientists performed experiments to test this. But it doesn't. It actually comes from the air.

A tree is mostly carbon and water plus a bunch of other vital but much less abundant elements. Photosynthesis powers plants, bringing carbon from the atmosphere to the plant and fixing carbon into the organic materials that make up much of the biomass of plants and, eventually, all other organisms.

Eventually, plants die and their biomass ends up in the soil. Meanwhile, organisms living in the soil eat this biomass in the process known as decomposition. Some of this carbon is re-released back into the air through the process of respiration. But a good portion of it resides in the soil for a long time, thus becoming sequestered. There is debate about whether this carbon is incorporated in a chemically stable form of organic matter, which is the classical theory or, rather, becomes protected from decomposition thanks to various ecological processes, which is the emerging view.

But the key point is that we need soil to be – on balance – a net sink of greenhouse gases such as $CO_2$. Emissions of greenhouse gases from soil should be lower than what is trapped in the soil organic matter. This is a critical component of the climate crisis. And the big problem is that, due to human activities, soils may be becoming a global net source of greenhouse gases to the atmosphere, rather than a sink.

There is very little knowledge of how the input of nutrients and organic matter from animal carcasses may affect soil, and therefore the cycles that connect soil to the global climate. That is why we were particularly excited by the possible results of our experiment. If we could demonstrate that carrion beetles change soil organisms and soil basic properties, the implications for the balance of ecosystems would be very important.

Credit: Oluwatoyin Adedokun from Pexels

## Testing the idea

To test our ideas, first we needed live soil, replete with all of its bacteria, fungi and invertebrates. We collected fresh soil from an oak woodland in

Northern Ireland, in the same habitat that carrion beetles inhabit. We then created three sorts of microcosms in plastic boxes in the lab, with multiple replicates of each type.

The first contained only soil. The second contained a mouse carcass and soil, and the third, a mouse carcass, soil and a pair of beetles. We stored our mini-ecosystems in a cupboard so that the beetles could breed in the dark. At specified times, we took samples of soil so that it could be analyzed. We measured the abundance and type of some of the most important soil animals, the biomass of bacteria and fungi, and the soil organic matter and pH. We took these samples according to the strict timetable of the carrion beetles' breeding pattern, so that we could see how the beetles' activity affected the soil and how it differed from the mouse carcass which didn't have any carrion beetles present.

That was the easy part. Our colleague Marco Ilardi, a PhD candidate also involved in the research, then spent the next year identifying and quantifying all the tiny animals retrieved from the experiment. He focused on what biologists call microarthropods: "micro" because they are a maximum of one or two millimeters long and "arthropods" which denotes that they have jointed legs.

These include springtails (very close relatives of insects) and other arthropods such as mites that feed on fungi and bacteria and predatory mites that feed on other small animals. These animals are very important: their feeding activities affect how nutrients move through the soil. Marco had to count tens of thousands of these microscopic animals.

We needed to measure the fungi and bacteria. In soil, fungi and bacteria are arguably the most important microbes because of their biomass and biological diversity and their ecological links to plants and the decomposition of organic matter. Edith Hammer, a soil ecologist at the University of Lund, helped us with this. She is an expert in quantifying the biomass of microbes in soil. This is not an easy job as there is so much stuff in the soil and it is not easy to separate the various components. But it was vital that we measured how many microbes were present. If beetles produce antibiotics, these must have a negative effect on bacteria and fungi in soil.

We also needed to quantify basic soil properties, especially pH and organic matter, which we did with the help of Gillian Riddell, a senior research technician at Queens's University Belfast.

It took just over two weeks to run the actual experiment but over three years to measure everything we needed to from a few kilograms of soil. Three years of research to understand two weeks of carrion beetle life and its impacts on the soil.

## Soil protectors

Our work paid off. We found that the beetle causes profound changes in the abundance of some important groups of soil animals but also in bacteria and fungi. The beetle also changed the amount of organic matter in the soil over time and caused important changes in pH.

Our initial hunch was correct. All these changes are timed by the key steps of the breeding cycle of the burying beetle. This implies that the beetle temporarily slows down decomposition in the soil while accelerating the dismantling of the carcass, with release of nutrients to soil.

Surprisingly, extra input of fresh organic matter and nutrients to soil can accelerate decomposition of the organic matter already present in the soil, which also depends on the availability of elements like nitrogen. Accelerated decomposition of soil organic matter may increase release of gas to the atmosphere.

We did not measure decomposition rates, but the carrion beetle definitely acted as a damper, slowing down soil biology despite the fresh input from the carcass. And so, it is very likely the beetle also reduced the decomposition of soil organic matter that the carcass alone may cause in the long term. For example, when the beetle produces antibiotics, microbes in the surrounding soil drop, and so microbial decomposition must drop. When the beetle stops producing them, the microbes go up again.

Also, when the beetle was not there, we observed a net average reduction of soil organic matter at the end of the experiment, after an initial increase. With our data we could not calculate a complete carbon balance, and so our conclusions remain speculative in terms of whether the soil became a source or a sink of carbon. But it is a fact that carrion beetles facilitated the decomposition of the carcass and kept the biological composition of the soil very similar to what we observed in fresh soil from the same forest. This did not happen with the carcass alone.

The carrion beetle, *Nicrophorus vespilloides*, burying the mouse carcass. © Sheena Cotter, Author provided

Our interpretation is that the beetle stabilized the soil biology, despite the presence of the carcass. Stability is essential because if the soil system is biologically stable it will most likely act as a carbon sink and certainly will not increase short-term emissions from consumption of soil organic matter, despite the fast decomposition of the carcass.

One carcass and one carrion beetle breeding pair with their brood may seem insignificant. But hundreds or thousands of them scattered across a forest can make an enormous difference in terms of how fast elements like carbon move between soil and the atmosphere. And the beetles we studied, and many others related to it, are very abundant in nature. Our study shows that this beetle is a key driver of soil biology. The implication is that the beetle to some extent controls ecosystem respiration and nutrient cycling by controlling soil biology.

When I am out in the field, collecting soil for my studies, one of my greatest pleasures is the smell. Many would agree: it's that good smell of leaves and rain, the aromatic flavors of a walk in a forest on a sunny spring day. You probably don't associate that nice soil smell with death. But it's only thanks to animals like burying beetles that you don't smell the death.

Biologists think a lot about how we can define life, in general. But we don't really think about the definition of death. Lifeforms like carrion beetles and soil organisms are telling us all the time that death is just a tiny step in the cycle of life. If creepy-crawlies and carrion insects are the ghouls and zombies of the natural world, it's time to listen to what they have to tell us.



Provided by The Conversation

Citation: Research shows how carrion beetles turn death into life (2021, June 22) retrieved 27 April 2024 from https://phys.org/news/2021-06-carrion-beetles-death-life.html