Nature's recycling squad

'Not everyone welcomes having "creepy-crawlies" around but we should be grateful for what they do.'

M. Telfer (2004)

Waste disposal is a growing problem for all industrialised nations. The UK generates about 100 million tonnes of waste each year, the majority of which is disposed of in landfill. But what happens to organic waste, such as the carcasses of dead animals, dung and plant detritus, in the wild? Waste collection authorities do not operate there — but there are numerous groups of insects that live on decaying organic matter. By recycling the nutrients locked up in dead organic materials, insects make these nutrients available to new life. Yet the recycling of waste is just one of numerous ecological services provided by insects (see Table 1).

Sanitary officers of the fields

Eighteen of the 32 orders of insects contain members that are **carrion** feeders. Most of them are beetles and flies. Because carrion is a limited but valuable food resource, and quite unpredictable in distribution, insects, vertebrates and microorganisms compete for it. A key characteristic of carrion feeders is the ability to find and secure a suitable carcass quickly and to make efficient use of it.

Key words
Recycling
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Succession
Insects
Ecology

In the northern hemisphere, the dead bodies of small mammals and birds are used primarily by burying beetles, which compete very effectively with carrion-eating mammals. For example, at the Biological Station of Michigan University in the USA, scientists laid 780 fresh bodies of dead house mice on the ground in a hardwood forest. Within 24 hours, 95% of the bodies had been discovered. Burying beetles had found 94% of these and scavenging mammals only 6%.

Table 1 Major ecological services provided by insects

Insects as...	Comment
Recyclers	See the main text
Pollinators	About 80% of the world's flowering plants depend on insects for pollination; pollinators include bees, moths, beetles and flies
A food source	The main source of protein diet of many birds, particularly of growing chicks, reptiles and fishes is insects; some insects are also a food source for humans in some parts of the world
Biological control agents	Leaf, wood and seed-feeding insects suppress weeds; other insects, particularly the parasitic wasps, control alien insect pests that attack our crops
Dispersal agents	Insects disperse seeds, transmit pathogenic agents, and even transport other invertebrates from place to place; ants are important seed dispersers

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Figure 1 A parental pair of burying beetles (*Necrophorus vespilloides*) taking care of their larvae; beetles and larvae are sitting on the meat ball prepared by the beetles.

Male and female burying beetles form parental pairs, concealing and maintaining carrion while also taking care of their offspring (see Figure 1). After the carcass has been buried, the beetles prepare a meatball from it. The meatball is prevented from rotting by anal secretions from the beetles, which kill bacteria. The female lays up to 30 eggs. The parents feed the young larvae that hatch from these eggs by regurgitating the partially digested food directly to the larvae mouthparts. After 1–2 weeks the larvae pupate in the soil and a few weeks later new adult beetles emerge.

In terrestrial ecosystems, 25–65% of dead bodies larger than mice are consumed by scavenging mammals and birds. The dominant group of insects that feed on large carcasses is the maggots of blowflies and flesh flies. They often occur in large numbers, as each female can lay about 300 eggs, and hatched maggots complete their development in less than 2 weeks. Fly maggots do not have mandibles so cannot gnaw carrion. Instead they release protein-digesting enzymes secreted in their intestines and then ingest the pre-digested liquefied flesh. If fly maggots are present, about 90% of the available soft tissue on the carcass is gone in around 6 days.

A **succession** of different carrion-feeding species of insects appears until the carcass is little more than a skeleton covered by hair. Caterpillars of certain moths (e.g. clothes moths) and larder beetles, which can digest keratin, then consume hairs and the dry remains of tissues (see Figure 2). Under similar conditions, the succession of species in a decomposing body is rather precise and predictable. This is why forensic entomologists use knowledge

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Figure 2 A museum specimen of the larder beetle *Dermestes maculatus*. In natural history museums, larder beetles are used to clean small and fragile skeletons. The beetles feed on the tissue remains, leaving the bones and collagen intact.

of insect succession associated with body decomposition during murder investigations to assist in determining the time of death (see BIOLOGICAL SCIENCES REVIEW, Vol. 15, No. 4, pp. 15–17).

During the decomposition of carrion, organic fluids of various sorts and faecal matter from the resident insects seep into the earth beneath. Many different soil-dwelling organisms such as soil mites and springtails use these fluids and faecal matter. Eventually, nothing remains except sweet, rich soil. Carrion-feeding insects play a key role in nutrient recycling and in the sanitation of the environment.

Processing dung

On average, about 40% of the food intake of mammals is either excreted as urine or passed out of the body as faeces. The solid waste is decomposed and returned to the soil by insects that use dung as food for themselves and for their larvae, thereby preventing it from building up. How this is accomplished is best known for cattle dung.

A cow's fresh dung pat is colonised by a succession of dung-breeding insects, numbering several dozen species and often exceeding 1000 individual insects. A total of 275 species have been reported in cattle dung in Britain. The majority of dung beetles are **scarabs** that feed directly on dung.

There are three main ecological groups of dung beetles. First, small-sized beetles usually feed in the main dung mass. Others, like the horned dung beetle, dig burrows beneath the dung pat and pack pieces of dung into the burrow for feeding their larvae (see Figure 3). The third group includes beetles that make spherical dung balls, roll them away and bury them intact in shallow burrows. The sacred scarab is the most famous of the rollers (see Figure 4 on p. 24).

Cow dung pats are also colonised by dung-feeding fly maggots, predatory beetles that feed on eggs and larvae of other insects, small parasitic wasps, fungus-eating insects and mites. At the last stage of degradation, soil invertebrates, including earthworms (see BIOLOGICAL SCIENCES REVIEW, Vol. 18, No. 3, pp. 14–17), begin to move into the dung pat. The natural rate of dung degradation depends on temperature, humidity, habitat and season of deposition. All these factors affect the composition and number of insect colonists. In Britain, the complete natural disappearance of a cow dung pat is achieved in 2–3 months.

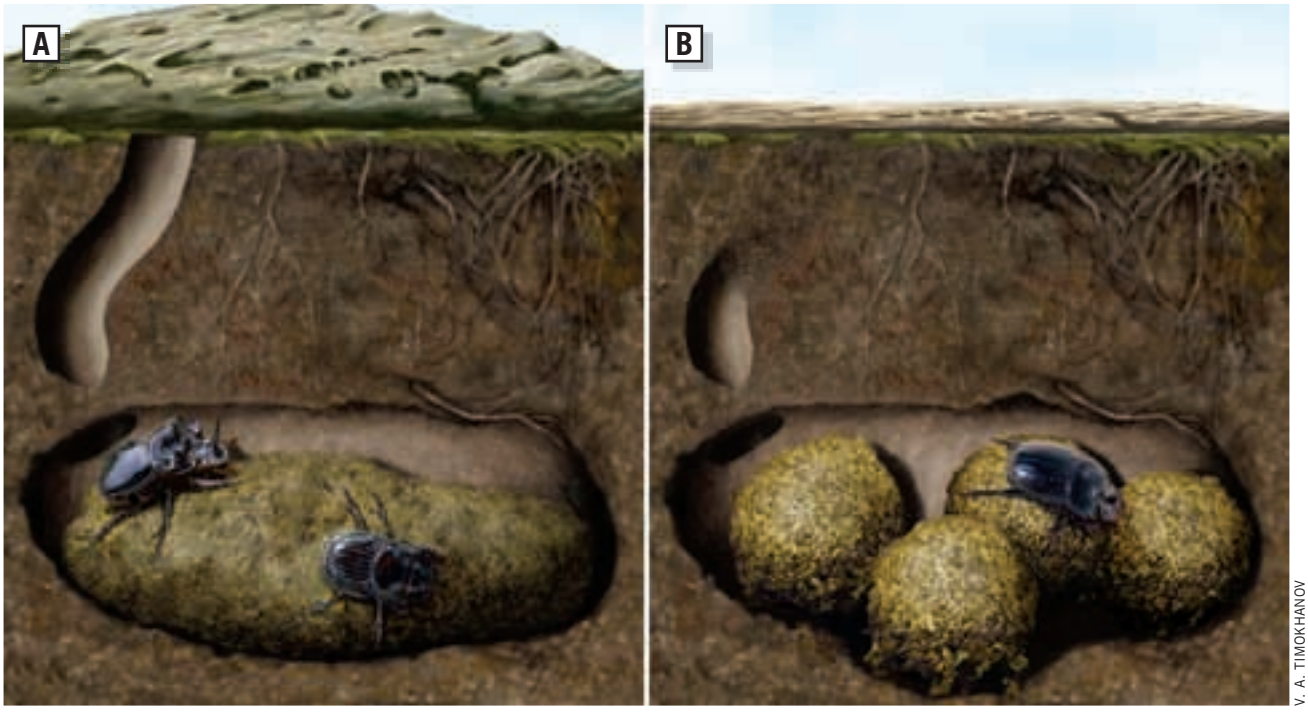
It is known that each cow produces an average of 12 dung pats per day, or over 9000 kg of solid waste per year. It is estimated that livestock produce approximately 200 million tonnes

TERMS explained

Carrion Dead and rotting animal flesh.

Scarabs A group of beetles belonging to the family Scarabaeidae.

Succession The progressive and gradual change of plant and animal communities over time.



V. A. TIMOKHANOV

Figure 3 Nesting by the horned dung beetle (*Copris lunaris*). (A) Initial stage, male (left) and female (right) working the 'dung cake'; (B) female alone, making brood-balls of the 'cake' for laying eggs.

Table 2 Examples of pathogens found in livestock wastes

Pathogenic microorganism	Disease
Salmonella (bacterium) (Monera)	Salmonellosis or typhoid fever, causing diarrhoea, fever, vomiting and abdominal cramps
Yersinia enterocolitica (bacterium)	Acute enteritis, causing diarrhoea and/or vomiting, mainly in children
Cryptosporidium (Protoctista)	Cryptosporidiosis, the illness causing diarrhoea; pathogen is resistant to chlorine disinfection
Giardia lamblia (Protoctista)	Giargiasis, causing diarrhoea, fatigue, nausea and abdominal cramps

Figure 4 A pair of sacred scarabs (*Scarabeus sacer*) rolling a dung ball.

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of waste each year in England and Wales, and about 900 million tonnes in the USA. Dung beetles recycle about a third of this. In the USA alone, the annual economic value of this service is at least $380 million. Unfortunately, the activity of dung beetles is severely disrupted by current agricultural practices, such as the treatment of livestock with drugs to kill parasitic worms. Residues of these drugs persist in the dung and are lethal to the beetles. As a result, the dung pats of treated animals remain biologically undegraded for months, fouling available grazing area. If left unprocessed, livestock wastes may present a health risk to humans, because they can contain pathogenic microorganisms (see Table 2).

The best example of the economic and ecological value of dung beetles comes from Australia. Most of their 500 native dung beetles cannot use cattle dung. Since the eighteenth century, when English colonists brought cattle to Australia, dung contamination has been a growing environmental problem, causing the loss of about 6 million acres of pastures each year. Only in the late twentieth century has the problem of dung accumulation been largely solved by the introduction of European and African dung beetles accustomed to cattle dung.

Decomposing dead plant material

It is estimated that approximately 99% of the organic resources that undergo decomposition in terrestrial ecosystems are from plants (leaf litter, root exudates, stems etc.) or faecal matter. Dead plant material is usually called

Further reading

Berenbaum, M. R. (1995) *Bugs in the system. Insects and their impact on human affairs*, Helix Books.

Waldbauer, G. (2003) *What good are bugs?* Harvard University Press.

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Figure 5 A termite mound in the Gambia (west Africa).

detritus. It is low in protein but relatively rich in indigestible polymers such as cellulose. Any detritus-feeding insect is therefore dealing with quite a poor diet. By chewing detritus into tiny pieces, digesting it and then passing it out as faeces and other waste, insects stimulate and accelerate its further breakdown by such organisms as soil mites, pot-worms, fungi and bacteria.

Probably the most important decomposers of dead plants are the termites. There are over 2000 known species of termites, most of which are tropical. All termites live in colonies comprising several thousand to several million individuals. Termite communities are famous for the high degree of their social organisation, which includes three principal castes: reproductives (the queen and king), soldiers and workers (sterile males/females). Termite nests vary from single galleries in the wood to the sophisticated and elaborate nests known as mounds. The mounds of savanna termites are typically 2–3 m high (see Figure 5). In some parts of Africa, there are over 800 mounds per hectare.

In tropical regions, termites outnumber all other insects and play a major role in litter removal and the carbon

cycle of terrestrial ecosystems. They consume 80–90% of the dead wood produced annually, so the nutrients and minerals in the plants are returned to the soil. Termites also act as ecosystem engineers by modifying the soil's properties. By mixing up organic and inorganic material, they improve soil fertility. Their complex underground gallery systems increase soil porosity, aeration and water-holding capacity, and serve as an environment for other organisms. As you might guess, termites can be very destructive if they invade the wood of buildings (see Box 1).

Most termites have intestinal microorganisms that assist in the breaking down of otherwise indigestible cellulose. The interactions between termites and microorganisms are mutually beneficial — called mutualism. 'Higher termites' produce their own digestive enzymes and can split cellulose apart. Some termites cultivate cellulose-digesting fungi, which aid in the consumption of cellulose, converting it to nutrients required by termites. Termites produce large quantities of methane, a powerful greenhouse gas, resulting from the fermentation processes in their guts. Their contribution to atmospheric methane is comparable to that made by human industries.

As recyclers, insects do an indispensable job for our planet. Without organisms breaking down dead organic materials and recycling nutrients in the wild, as well as in gardens and on farms, the planet would soon be piled deep with the waste products of its inhabitants, and the spread of diseases would be unavoidable. Whether we like it or not, our own existence depends on insects and their ecological services.

BOX 1 Large Transcaspian termite

This wood-destroying pest found in Central Asia attacks all kinds of wood, any materials containing cellulose, many stored products, paper, cloth, and some living plants. Even soft plastic materials can be damaged and used by termites for construction of nests.

Winged adult (left), soldier with large mouthparts (middle), worker (right), and a section of surface-soil-covered termite runways.

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