spotlight

Locusts

God's wrath or revelation?

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'…When morning came, the east wind had brought the locusts.…They devoured all the vegetation and all the fruit of the trees…'
The Bible, Exodus (10:13–15)

Locusts have been known since antiquity to be extremely destructive to agriculture. When conditions are favourable, a vast migrating swarm of locusts can appear as a cloud that darkens the sky, and rapidly devour all plant material on their way, from field crops to the foliage on trees. So great is their apocalyptic quality in human minds that, since the time of the Pharaohs, locusts have been seen as a symbol of destruction — the wrath of God or a sign of cosmic disorder. Why are they such pests, and why have we not managed to control them?

What are locusts?

Locusts are large to medium-sized insects belonging to the order Orthoptera. This group also includes crickets and grasshoppers, with more than 20 000 species worldwide. Locusts and grasshoppers are fairly unspecialised feeders. Having selected their food using taste receptors on their mouthparts, their hardened mandibles can chew most kinds of vegetation. There are only about ten species of locust (see Table 1). At first glance they look like large, short-horned grasshoppers, but their behaviour is different. Unlike grasshoppers, when locusts are present in large numbers they tend to crowd together. They form vast cohesive groups of **nymphs** or 'hoppers' known as bands, or swarms of winged adult insects (see Figure 1). Also unlike grasshoppers, locusts are capable of migrating long distances in swarms containing many millions of individuals. As a result, locusts cause occasional but catastrophic 'plagues', followed by subsequent quiet periods called recessions (see Figure 2).

The intention of this column is to throw a *spotlight* on individual organisms — not to blind you with science but to reveal important and fascinating aspects of specific plants, animals and microorganisms.

Locust phases

Locusts are not always found in swarms. They exist in two main forms — solitary (isolated) and gregarious (crowded) — with a series of intermediates. The gregarious and solitary forms of locusts have different 'phase characteristics', including shape, coloration, reproduction, behaviour and physiology. Solitary nymphs of both the desert and the migratory locusts are green or straw-coloured, whereas gregarious ones have a striking pattern of black markings on a yellow/orange background (see Figure 3 on p. 8). Adults of both forms have similar coloration but differ in other ways. Gregarious females produce larger offspring, which can survive longer without food, while solitary females lay more eggs than crowded ones.

At any stage in development, locusts can transform from a solitary, sedentary form into a gregarious, migrating form — a process called **gregarisation** — or vice versa. If a batch of eggs laid by one female is split into two and one group is reared individually while the other group is reared in crowded conditions, the isolated locusts develop as solitary forms, the crowded individuals as gregarious forms. This biological phenomenon was discovered and first explained by the Russian entomologist Boris Uvarov, in 1921.

An understanding of how phase changes are controlled is central to any attempt to monitor and manage a locust problem. What turns the solitary phase into the ravaging swarms of flying locusts in the gregarious phase? Is it possible to 'switch off' a swarm by reverting them back to the solitary phase?

We know that physical contacts between individuals are crucial for triggering gregarious behaviour, and

Table 1 **The three most infamous species of locusts**

Scientific name	Common name	Area over which control is needed/ million hectares	Most recent plague: Locality and date	Most recent plague: Cost of control/US$
Schistocerca gregaria	Desert locust	25	Middle East and North Africa, 1986–89	Over 300 million
Locusta migratoria	Migratory locust	4	Madagascar, 1996–2000	Over 50 million
Calliptamus italicus	Italian locust	10	Central Asia (Kazakhstan and Russia), 1999–2000	Over 23 million

visual contacts combined with odour stimuli are then responsible for maintaining it. Painstaking research, involving stroking various parts of the hoppers' bodies, has shown that tactile stimulation of the hind femurs provides the major stimulus. The change in behaviour allows other processes to be brought into play, mainly regulated by hormones and **pheromones**.

Juvenile hormone, which is present in all insects except at the pre-adult stage, prevents the juveniles turning into adults when they moult, and promotes egg development in adults. If present in sufficient concentration, it also prevents a locust transforming to the gregarious phase. Yet this is not the main physiological factor involved in gregarisation. Both hoppers and adults produce several hormones, and some of these act both as 'primer' pheromones, altering development, and as 'releaser' pheromones, altering behaviour. Physical contacts between nymphs may transfer a 'cuticular contact pheromone', which plays a major role in the behavioural transformation of hoppers from the solitary to the gregarious phase. The faeces of hoppers also contain a pheromone that makes the hoppers aggregate, and gregarious phase females secrete a pheromone in the foam surrounding their eggs that causes the hoppers to develop as the gregarious form. The population density of the parents also seems to determine whether the offspring are biased towards developing as the solitary or gregarious form. Despite considerable progress in understanding the physiology of locust phase **polymorphism**, the basic mechanisms underlying it remain to be discovered.

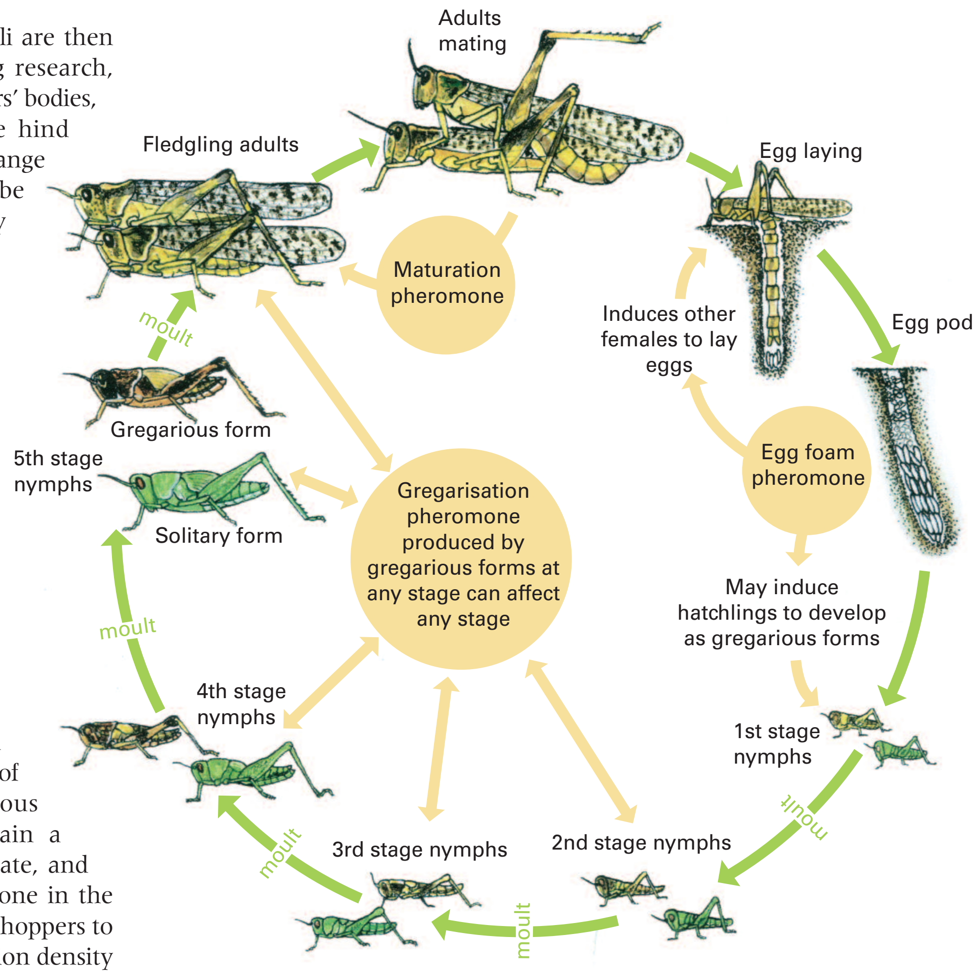

Figure 1 **Life cycle of a locust. Locusts can switch to gregarious phase or solitary phase individuals at any stage in development. Some of the stages at which pheromones act are also shown. (Modified from Hassanali and Torto, 1999)**

In the desert, it is probably rainfall that underlies the switch from solitary to gregarious form. Rainfall speeds the development of the eggs in the ground and the growth of fresh vegetation. But the desert vegetation will be patchy, so the hoppers will become concentrated in these patches. Having once been forced into a group, the locusts behave gregariously. The change in behaviour brought about by crowding then induces the physiological mechanisms that lead towards the gregarious form in preparation for migration. Some pheromones accelerate maturation so that the swarm builds rapidly. However, the transformation of phases is not necessarily continuous or direct. If conditions change, the transformation can reverse, or the insects may remain in an intermediate stage for generations.

Outbreak areas and migrations

The phase transformations of locusts take place in regions known as 'outbreak areas'. These areas are characterised by particularly favourable ecological conditions for locusts. For the migratory locust, a single region in Africa, the Middle Niger flood plain, has been the origin of all upsurges and plagues in the last 50 years. For other species, such as the desert locust, gregarisation can take place in many parts of the range, provided local environmental conditions are suitable (see Figure 4 on p. 8). Under the right conditions, typically good rains, up to four locust generations are born each year, and at least four generations are needed for the locusts to reach swarming density.

Migration in locusts occurs when a swarm starts flying away from the immediate 'outbreak area' to much wider territories called the 'invasion area'. This swarming behaviour is a survival strategy — the locusts need to move to new areas to find fresh food supplies, and a locust in a swarm has a better chance of survival

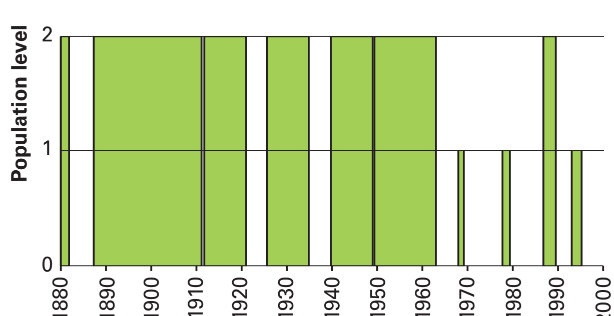

Figure 2 **Plague and recession periods of the desert locust, 1880–2000. Population level: 0, recession; 1 upsurge; 2 invasion. (Modified from Lecoq, 2001)**

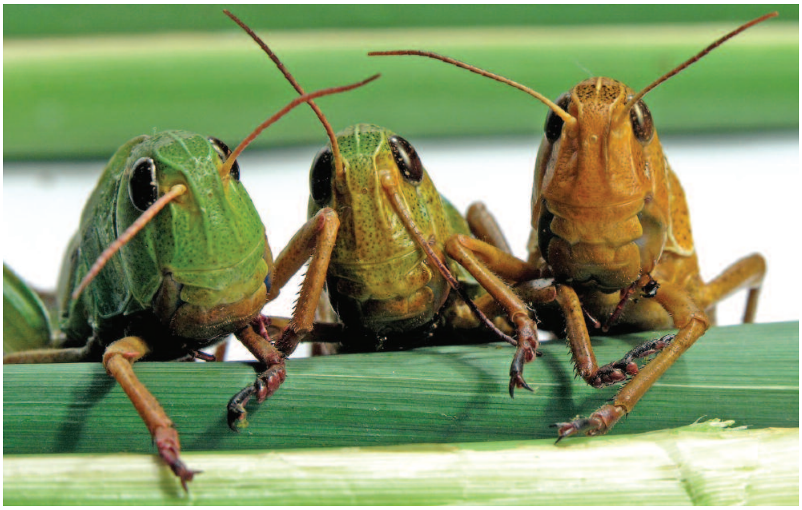

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Figure 3 **Hoppers of the migratory locust from central Asia (northeast Kazakhstan). Left, solitary nymph; middle, intermediate nymph; right, gregarious nymph. This picture demonstrates distinct differences in colour between the different forms of the same species.**

against predatory birds than an isolated individual. Following seasonal changes of climate, locusts migrate back and forth between successive breeding regions and seek new or better ecological conditions. Swarms can lead to an invasion of an area of Africa and Asia that extends across 57 countries and covers more than 20% of the land surface of the Earth. Individual swarms can move over 3000 miles from their place of origin. The direction of the swarm's movement is largely determined by the wind and takes place only during the daytime at temperatures of 30–40°C. Swarms move in a downwind direction and can sustain speeds of 9–12 miles per hour. As the direction of swarm displacement depends on the wind, it produces a fairly regular and therefore predictable pattern of migratory movements. This predictability is of utmost importance for monitoring and preventing locust plagues.

Adult swarms may extend over tens of square kilometres, with the average, 'preferred' distance between locusts being 2–4 metres. Thus, a single swarm may contain many million individuals, with an overall mass of several tonnes. Since these insects eat approximately their own mass of vegetation daily, they cause immense destruction of crops and pastures. For instance, 2.5 square kilometre's worth of locusts — 100 to 200 million individuals — can consume 220–270 tons of food, which is enough to feed 200 000 people. In a single day, an average swarm can eat the same quantity of food as 2500 people.

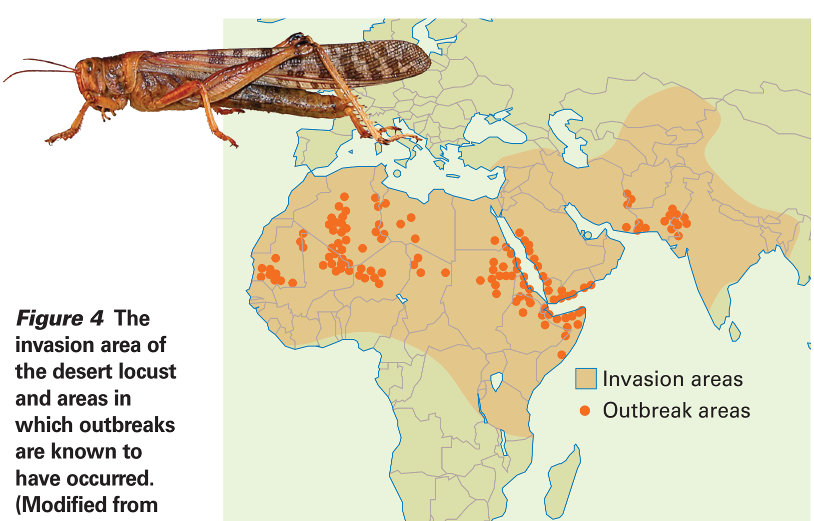

Figure 4 **The invasion area of the desert locust and areas in which outbreaks are known to have occurred. (Modified from Popov, 1997)**

Monitoring and control

Once started, a locust plague is just about impossible to stop. Although the first known system for forecasting locust plagues was established in China in AD 720, the first scientifically based control campaigns took place in Algeria in the late nineteenth century. Nowadays, there are two approaches to locust control: plague suppression and plague prevention. The first is an 'emergency strategy' when large-scale locust infestations have developed. Depending on the seriousness of the situation, this approach includes either control operations, i.e. full coverage by chemical sprays, or simply takes appropriate measures to protect threatened croplands. The second strategy is to use preventive measures that nip an outbreak in the bud by trying to eliminate the appearance of the first gregarious population.

Both approaches rely upon natural or synthetic insecticides used as sprays, baits, or slow-release products. The agents currently used against locusts, particularly in emergency situations, comprise broad-spectrum insecticides such as organophosphates, carbamates and pyrethroids. The term 'broad spectrum' means that these insecticides act on a wide variety of insects, including useful pollinating insects. The new generation of control agents includes insect growth regulators, such as diflubenzuron. Diflubenzuron inhibits the synthesis of chitin, which is a major component of the cuticle. It is therefore fatal to hoppers when they try to **moult**, and to the nymphs developing inside eggs. Despite the efficacy of chemical control, the agents used can be hazardous to humans and wildlife. Therefore, there is a high demand for alternative, environmentally inoffensive solutions.

Chemicals released into ecosystems can cause short-term disturbances to the ecosystem equal in scale to massive fires or storms. To reduce the environmental risk of locust control, biological control agents such as the 'locust fungus' (*Metarhizium anisopliae*) are being developed for use. Fungus-based products (mycopesticides)

TERMS explained

Gregarisation The process of developing the behavioural, morphological and physiological characteristics of the gregarious form.

Moulting The process where an insect sheds its outer (exo-) skeleton in order to grow.

Nymph (or **hopper**) A locust in its early wingless stages.

Pheromones Volatile chemical signals used by insects as a means of communication.

Polymorphism The occurrence of many different forms (phenotypes).

BOX 1 Why not eat locusts?

Locusts, which migrate in swarms of millions of individuals, constitute a major source of proteins and vitamins in many countries of Asia, Africa and South America. People collect locusts for food, particularly during outbreaks. Locusts are rich in protein and can be stir-fried, roasted or boiled.

are applied as fungal spores. Fungal hyphae emerge from the spores, penetrate the joints in the insect's cuticle, and grow throughout the insect's body. They can permanently suppress a locust population by up to 90% and have no side effects on non-target organisms, so they are environmentally safer than other pesticides. Unfortunately, mycopesticides act slowly and are inappropriate for emergency situations, for which conventional chemicals still offer the only available option.

According to a rather extreme viewpoint, no attempt to control locusts or bring down the swarm has ever succeeded — in each case the plague disappeared only when 'nature had run its course'. Whether this is true or not, from 1986 to 1989 the world faced a severe desert locust plague, which affected many countries from northwest Africa to the Caribbean. Globally, the costs of combating this plague were colossal — over US$300 million. It is believed that the 1986–89 plague occurred mainly due to the decline of cooperation between neighbouring countries. Survey and control operations often have to be carried out in important breeding areas in which access is severely restricted due to civil conflicts and general insecurity (some regions of Algeria, Somalia, Yemen, Sudan and others). Thus, the key issues of locust control now are not the lack of scientific knowledge or technical means, but a problem of socio-political organisation (which cannot be controlled by scientists!) Unless this basic issue is resolved, alas, humans will always be at the mercy of nature when it comes to dealing with locust plagues.

Further reading

Chapman, R. F. (1976) *A Biology of Locusts, Studies in Biology No. 71*, Edward Arnold.

Marshall, J. A. and Haes, E. C. M. (1988) *Grasshoppers and Allied Insects of Great Britain and Ireland*, Harley Books.

Biotechnology and Biological Science Research Council (2001) *One of the Crowd: The Amazing Biology of the Desert Locust*. This is an illustrated 12-page booklet that can be downloaded free from:

www. bbsrc.ac.uk/life/crowd/booklet/one_of_the_crowd.pdf

ISPI databases of literature on locusts and grasshoppers (Acrididae), online at:

www.pestinfo.org/Literature/lit185.htm

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