

Plotting insect flight paths

A car-mounted net samples insects near ground level.

How fast do insects disperse? Can we predict which way they'll go? When will they take off, and how far will they get?

These questions have economic as well as academic interest. Although most insects have no effect on man's attempts to make a living from the land, many species do. The 'goodies' devour pest animals and weeds and bury cattle dung; the 'baddies' attack crops or carry disease-causing viruses. We therefore need to know how insects spread from place to place.

Two scientists at the CSIRO Division of Entomology, Dr Roger Farrow and Dr Alistair Drake, use various techniques to study insect migration, ranging in complexity from nets to radar.

Ecos 20 described how Dr Farrow set up radar units on the Northern Territory coast and on an island in the Torres Strait in 1977-78 to scan the sky for insects, including potential pests, crossing the sea from Indonesia and Papua New Guinea. Since then, he and Dr Drake have been using radar to investigate the movements of insects within Australia.

The Division's radar unit transmits signals with a wavelength of 3 cm, and picks up echoes from insects the size of a grasshopper or dragonfly up to 2 km away. The equipment cannot detect very small insects individually, but even aphids, for example, do produce an image on the radar screen if they become sufficiently concentrated.



The Division of Entomology's radar caravan.

The radar picks up echoes from insects the size of a grasshopper or dragonfly up to 2 km away.

From their radar watches, the scientists soon accumulate large amounts of information about insect numbers and densities and about the speed, direction, and times of each flight. Dr Drake analyses all this by computer.

Samples for identification

Although the radar does a good job of detecting migrating insects, it is not so effective for identifying them. By carefully examining the pattern and behaviour of the 'blips' on the screen, and by measuring the radar signals reflected from individual targets, Dr Drake can usually assign insects to broad categories: he can distinguish moths from grasshoppers, for instance.

For the more precise identification essential in entomological studies, the researchers try to catch samples of migrant insects during all radar watches. A light trap makes a convenient sampler.

Many insects migrate by night. Obeying an instinct whose biological causes scientists have not so far identified, fly-by-nights head for bright lights. As we all know, they gather around street lamps and illuminated windows. A light trap exploits this instinct, luring insects to a container of preservative in which specimens collect, to be removed for counting and identification the following day.

This simple apparatus provides valuable information about the kinds and relative numbers of insects flying at night. Light traps that are operated all year round,

like the Division of Entomology's at Trangie, N.S.W., reveal a clear seasonal picture — most insects fly only during the warmer months of the year, and particularly during spells of unsettled weather.

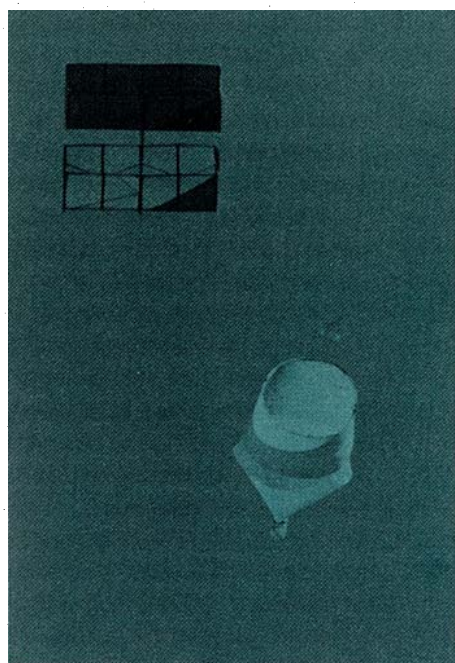
Unfortunately, light traps catch only low-flying insects, many of them probably making local journeys and not migrating at all. Radar has detected some insects flying at altitudes of 2000 or even 3000 m above the ground, and most nocturnal migrants cruise above 100 m. Do the samples collected at light traps satisfactorily represent the high-fliers?

To find out, the CSIRO entomologists use a device invented more than 2000 years ago — a kite. A net slung beneath the kite samples insects at any height up to 300 m above the ground.

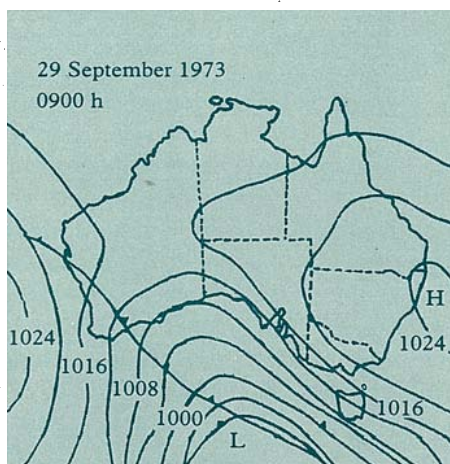
Although the radar screen may display plentiful echoes, catches in the aerial net are generally small even if the kite has been aloft for several hours. The small catches emphasize the extremely low densities at which insects generally occur in the upper air — 'only a few per million cubic metres of air', as Dr Farrow puts it.

Typically, the net filters about 30 cu m of air in the time the radar takes to complete a single scan of 100 million cu m. Even when radar echoes coalesce on the screen into a single large image, the insects may still be much too far apart to constitute a swarm; each individual is apparently making an independent journey, out of contact with its fellows.

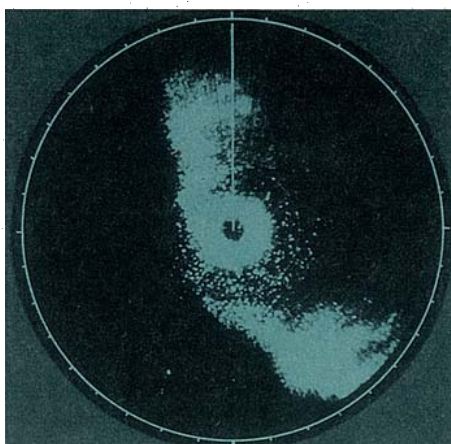
Only exceptionally do insects reach such high densities that the casual observer cannot help noticing them: in a termite flight, for instance, or a locust swarm.



Slung beneath a kite, the net can sample insects up to 300 m above the ground.



A typical weather pattern bringing insects to Tasmania from the mainland in spring.



How the radar 'saw' grasshoppers flying inland on the front of a sea breeze near Canberra.

Enormous numbers of aphids take to the air in spring, covering big distances both by day and by night.

Weather patterns

Dr Farrow and Dr Drake take a particular interest in the influence of weather on insect dispersal. How, for example, do air temperature and wind strength affect the number of insects taking off and the height, speed, and direction of their flight?

Most species, especially tiny ones like aphids, do not behave like those migratory birds that every year beat the same aerial path between, say, a breeding ground and a wintering site. Small insects lack the strength to fly against the wind; their efforts merely keep them in the air while the wind carries them in whichever direction it happens to be blowing.

If an aphid stops beating its wings, it falls about 1 m a second. In still air it cruises at only 1 km an hour, but by simply keeping itself aloft it can cover 500 km in a single night, given a good wind.

Grasshoppers and moths, on the other hand, can reach 10–20 km per hour by their own efforts. Insects of this size can therefore travel downwind faster than the air moves. They also have enough strength for crosswind flights: in Torres Strait the CSIRO radar picked up substantial south-bound traffic across the prevailing south-easterly trade winds and monsoon north-westerlies.

But most insects rely for dispersal on wind, and the scientists always try to relate their catches and radar observations to the weather pattern.

Dr Farrow is compiling a card index of weather maps of the kind you see printed in many newspapers, grouping them into the main categories of recurrent weather patterns. On each card he writes the number of insects trapped that day at the Trangie light trap.

Dr Drake tackles the problem another way: he measures the winds above the radar site by releasing a helium-filled balloon and tracking it by theodolite. He uses his measurements to interpret the insect traces he observes on the radar screen.

Moth invasion

A striking example of the role that weather plays in spreading insects occurred in the spring of 1980. South-eastern Australia was experiencing one of the largest moth invasions on record.

Bogong moths, which normally migrate in late spring from the western plains of New South Wales to spend the summer on the Tablelands, reached the coast in huge numbers; many came down in the ocean and were washed up on beaches.

At Trangie in September of that year, Dr Farrow examined samples of the insects on passage both near the ground, using a net mounted on a car, and at heights of 100–300 m, using the kite-borne net. The aerial net caught eight moth species, including six individuals of one species not previously found during the 3 years of daily trapping at Trangie. Near the ground Dr Farrow caught 23 species of moth at densities about 60 times those at the level of the kite.

At this time (September 17–25) a high-pressure zone moved east across Australia, passing north of Trangie. Well-marked fronts preceded and followed the 'high'. The scientists noticed that moths



Some of the insect migration routes studied with the help of radar.

were more abundant at Traralgon in the westerly air flows following the two fronts than in the warm northerlies ahead of the fronts that might have been expected to carry plenty of insects. From this they inferred that more moths were arriving from the south-west than from other directions.

This fits with another observation: the Riverina district of New South Wales, to the south-west of Traralgon, suffered widespread damage to pastures from huge numbers of caterpillars in early spring, whereas the north of the State experienced a dry spell that must have reduced the moths' breeding success there. The scientists comment that the scale of this

moth invasion and its unusual origin (these moths usually come to Traralgon from the north) emphasize how valuable it could be to know enough about the migratory behaviour of the most important pest species to be able to predict outbreaks and to identify the affected regions.

The kite-net catches at Traralgon during the period of this moth outbreak included large numbers of tiny insects, of which aphids made up two-thirds by night and more than four-fifths by day. The aphid densities averaged 35 000 per million cu m of air in the daytime, falling to 4300 at night. Evidently enormous numbers of aphids take to the air in spring, covering big distances both by day and, to a lesser extent, by night.

Sea breeze

The Southern Tablelands of New South Wales and Australian Capital Territory can also receive insect visitors from the opposite direction — the east. At the end of a hot summer day, a cooling breeze often blows in from the coast. On December 22, 1980, Dr Drake 'saw' this breeze on the screen of his radar unit near Canberra. A clear band of echoes moved across the screen from east to west.

Other radar operators have seen similar echoes from sea-breeze fronts in several countries in the past. These echoes have sometimes been caused by insects, sometimes by birds, and probably sometimes by changes in the refractive index of the air at the boundary between two air masses.

Dr Drake is confident that the echo he saw was caused by insects; the CSIRO radar detects insects especially well, and large numbers of them, especially grass-

hoppers, were in flight at the time. These evening breezes may play an important role in spreading pests that have overwintered in mild conditions on the east coast.

Analysis of radar records also shows that many insects cross Bass Strait to Tasmania on suitable winds, and entomologists believe that annual invasions are essential to maintain Tasmania's populations of certain army-worm moths, whose caterpillars (the 'worms' that give the species its common name) eat pasture foliage.

From different lines of evidence, including weather patterns and the locations of areas suitable for the development of caterpillars, it seems likely that some of the Bass Strait migrants come from as far afield as south-western New South Wales, north-western Victoria, and south-eastern South Australia.

Many important mysteries of migration remain to be solved. The scientists would like to know, for example, how long individual insects remain airborne, and what causes them to land. Why do some individuals climb to a great altitude, while others of the same species travel near the ground? And how do insects reach the densities seen, say, in a sea-breeze front?

Radar shows that night-fliers generally take off more or less *en masse* at dusk, but individuals seem to 'make up their own minds' about when to come down.

The number in flight gradually declines overnight, dropping faster in cold weather. (Low temperatures do not necessarily ground insects altogether. Once airborne, a moth can keep its temperature around the 30°C mark even though the air temperature may have fallen to 10°C. The flight muscles make effective heaters.) From studies of both fat stores and the energy requirements of flight, entomologists know that some species can fly continuously for 12–15 hours.

Understanding the movements of the insect jet-set could prove invaluable in predicting the spread of pests, diseases, and agents of biological control.

John Seymour

More about the topic

Quantitative observation and analysis procedures for a manually operated entomological radar. V. A. Drake. *CSIRO Division of Entomology Technical Paper No. 19* (in press).

Insect migration across Bass Strait during spring: a radar study. V. A. Drake, K. F. Helm, J. L. Readshaw, and D. G. Reid. *Bulletin of Entomological Research*, 1981, 71, 449–66.



Launching an aerial net, which will be kept aloft by a kite.