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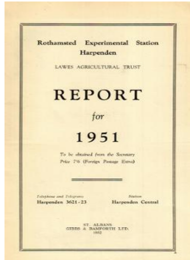
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HOW FAR DO INSECTS TRAVEL?

By C. B. Williams

A knowledge of the distances that either injurious or beneficial insects can move is of major importance to economic entomologists all over the world in planning either direct control, or measures for the prevention of outbreaks of insect pests or of insect-borne diseases.

Apart from accidental transport in cars, trains, ships and aeroplanes, which is a major problem in itself, movements of insects over longer or shorter distances can take place actively—by the action of the insects themselves, or passively—when they are carried away by the wind. The active movements may be just the normal flight of the insects wandering round their habitat, or may be definite flights over a long distance in a fixed direction. For the latter type of movement we use the term " migration ".

As the study of insect migration and insect drift has been one of the major investigations of the Department of Entomology at Rothamsted for many years, it may be of interest to summarize some of the results obtained, and to show how they have altered the outlook of the applied entomologists.

There is no doubt that 50 years ago, or less, there was little knowledge and much misunderstanding, particularly among the general public, about how long insects lived in their adult winged stage and how far they could move during that period.

To clear up the former point we may say that an adult life of less than a week is probably unusual in flying insects; that most live two or three weeks; that quite a number live several months; and that a small number of species (including bees and ants) are known to live several years. In a life of even only a few weeks there are possibilities of movement much greater than that of the hypothetical May-fly which hatches in the evening and is dead before daybreak, and we now know that even in 24 hours the distances covered could be measured in miles rather than in yards.

In lectures on Agriculture at the University of Cambridge in 1910, one of the major reasons given for the rotation of crops was its value in preventing outbreaks of insect pests. There are undoubtedly some pests, particularly those in the soil, which have little power of movement; and there are others, such as wireworms, with a larval stage lasting several years, in which a sudden break in continuity of food supply might possibly be injurious to the insect. But to imagine that the average insect pest would be seriously incommoded by having to move from one side of the hedge to another in order to find its next year's food supply is quite unjustified.

There are many good reasons for a rotation of crops in farming practice, but the value of the process as a method of avoiding insect pests has been greatly exaggerated.

It is perhaps interesting to note at this stage that Broadbalk field has, in the first 100 years of wheat growing, not yet suffered from any major disaster. So that the absence of rotation does not appear to be—by itself—a necessarily dangerous proceeding in the development of insect attack.

In a light trap that was worked by the Entomology Department on one of the fields at Rothamsted for four consecutive years 1933-1936, 240 different species of moths were captured. The total number of known species in the families of insects concerned is about 750 for the whole of the British Isles, so that in four years almost one-third of all the British species of moths had visited one spot in one field. Some of these may have bred within a few yards of the trap—some others, on the contrary (such as the Silver-Y Moth, *Plusia gamma*), may have migrated to the field from hundreds of miles away—but the majority had undoubtedly wandered accidentally to within the very limited sphere of danger round the traps from their natural habitats within perhaps a few miles of the trap.

Had the trap been a plant newly introduced to the area, then we must realize that in about four years perhaps one-third of the British moths would have come near enough to see whether or not it was suitable for food; and there is little doubt that most other groups of winged insects are capable of similar wanderings.

When we come to study the problem of movement in insects known to migrate, the distances covered rise from yards and miles, to tens or hundreds of miles, and occasionally even to a thousand or more.

Nearly every year our British population of Large Cabbage-White Butterflies (*Pieris brassicae* L.) is reinforced by considerable immigration from the Continent across the southern North Sea and the eastern half of the English Channel. Millions of butterflies cross without difficulty the 30 to 300 miles that separate us from France, Belgium, the Netherlands and Denmark. We have good reason to believe that before setting out to cross the North Sea, the butterflies had already in many cases flown from north Germany, from southern Scandinavia, or from islands in the Baltic (Williams, 1939).

An entomologist who studied the biology of this butterfly in England some years ago expressed an opinion that its death rate from parasites was so high that it was doubtful if it could long survive in Britain if it were not for the regular reinforcements which arrive from the Continent.

The Silver-Y Moth (*Plusia gamma* L.)—an irregular pest of peas, beans and many other field crops in England and Central Europe—does not survive the winter in any stage in these latitudes, but flies in from the Mediterranean area each spring in varying numbers. A big migration usually means a big outbreak and widespread damage—but the real source of the trouble is 400 miles or more from the area of damage if they have come from the northern shores of the Mediterranean, and more than twice that distance if their origin has been in North Africa.

In Egypt I have had experience with a case of an opposite kind. The Greasy Cutworm (*Agrotis ipsilon* L.) is a serious pest of grain in the autumn and winter months and occasionally attacks young cotton in the early spring. Money was at one time spent on a "control" measure which consisted of trapping, by means of a poison bait, large numbers of the adult moths particularly about April and May. It was then discovered that the insect was a

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migrant and only a winter visitor to Egypt. Every spring all the moths left the country and, almost certainly, flew to Europe—hundreds of miles away. A failure to understand this aspect of their behaviour resulted in much wasted effort and expenditure.

In North America one of the major pests of cotton during the nineteenth century was the "Cotton Leaf Worm" (*Alabama argillacea* Hbn.). It appeared each summer in the cotton belt of North America, and several generations in rapid succession often did enormous damage. During the winter the insect could not be found in any stage of development in any part of the cotton belt, nor could any alternative foodplant to cotton be discovered. Just a hundred years ago it was first suggested that the moths were coming in each spring as immigrants from South or Central America. This is now known to be the correct interpretation, although the exact area of origin is still uncertain, but for at least 50 years the suggestion was thought to be a wild improbability owing to the great distance of movement required.

The Painted Lady butterfly (*Pyrameis cardui* L.), which is occasionally a serious pest of artichokes in France, but is mildly beneficial in the U.S.A. where it feeds chiefly on thistles, breeds during our winter in the arid areas on the edges of the Great North African Desert. From there it moves north each spring, first to the north coast of Africa, then across the Mediterranean and northwards across Europe. It reaches the latitude of the British Isles almost every year about June, and not infrequently wanders on still further to Iceland in the west and to beyond the Arctic Circle in Finland. The total distance covered may be nearly 2,000 miles.

The same butterfly in North America appears to have its winter quarters in Western Mexico (where there are arid conditions somewhat similar to North Africa) and to spread out each spring towards the north and north-east. In some years thousands of millions of insects are concerned in the flights, and they may spread over the greater part of the United States and southern Canada, even as far as the mouth of the St. Lawrence River and to Newfoundland. Altogether they may move nearly 3,000 miles from their starting point in Mexico.

There is no evidence of winter survival of Painted Lady butterflies anywhere in northern Europe or in the United States.

There is no need to stress the great distance that can be traversed by swarms of locusts. Some of the few individuals that have occasionally been captured in Britain have been shown (by statistical measurements) to have almost certainly come from populations in south-eastern Europe—a distance of well over a thousand miles. Locusts and Painted Lady butterflies have on several occasions been captured on board ships more than a thousand miles from land.

An unusual adaptation to migration came to my notice in East Africa, where a burrowing wasp (*Sphex aegyptiacus*), which is predaceous on locusts, was found to have developed a habit of migrating along with the swarms of its host—so that both pest and predator were moving over many miles of country deliberately and simultaneously.

Many species of dragonflies are capable also of flights to be measured in hundreds of miles. I have seen them myself more than a hundred miles from water in the Egyptian desert, and—like the locusts and butterflies mentioned above—they have been recorded on ships at sea hundreds of miles from the nearest land, and hence from the nearest fresh water which is necessary to them for breeding.

Ladybirds in California are known to move from the coastal plains to the hills about 50 miles away every autumn for the purposes of hibernation, and to return back to the coast in the spring; and a somewhat similar habit is found in the American Bean Beetle (*Epilachna*), a relative of the ladybird which however lives on a vegetarian diet.

Turning now to the question of passive drifting of insects, this chiefly affects the smaller species with poor powers of flight which are easily carried away from the ground by winds and by convection currents. The insects mostly concerned are Aphidae (greenflies), small Diptera, small Hymenoptera, small beetles, with occasional Lacewings and other groups. They include many pests and transmitters of disease.

Small insects are often carried short distances of a hundred yards to a mile or so by winds quite near to the ground, but once they get away from the ground into the upper air they may be carried tens or even hundreds of miles before they come back to earth.

As early as 1913 entomologists in America had shown that the just hatched caterpillars of the Gipsy Moth (*Porthesia dispar*), which are covered with long hairs, are so buoyant in the air that they could be carried at least a mile by air currents near the ground. Two years later Collins (1915) showed that they could be carried up to at least 13 miles.

Experimental work with traps attached to 'aeroplanes was carried out between 1926 and 1931 in Louisiana, U.S.A., and the results (Glick, 1939) showed a total of nearly 25,000 insects caught at heights from 200-16,000 feet in a trap 1 foot square, in about 900 hours of flying during day hours. This is an average of about 30 insects per hour.

In about 100 hours flying at night time up to 5,000 feet, about 4,000 insects were caught.

The insects that were identified included about 700 different species belonging to 198 families and 18 different orders. There were also over 1,000 spiders and a small number of mites.

Included among the insects were over 50 wingless Thysanura and Collembola (one of the latter at 11,000 feet) and many wingless immature stages of Heteroptera, Homoptera, Orthoptera, Coleoptera, Lepidoptera and Diptera—also numbers of wingless ants.

In Britain Hardy, Milne and Freeman carried out upper air trapping by nets hung first from kites and later from tall radio masts (Hardy, Milne and Freeman). Hardy also had nets attached to the masts of ships crossing the North Sea, which were only opened when the ships were more than 50 miles from land. Their results agreed completely with the then unpublished results from the United States, and showed the unexpectedly large numbers of drifting insects that may be present in the upper air. Hardy calculated that on many fine summer days in the area over the North Sea more than 50 miles from land, there were millions of insects drifting above the sea, the majority of which were Aphidae.

There is no doubt that with an easterly wind most of these would arrive alive in Britain.

In 1946 an investigation was started at Rothamsted under the immediate direction of Dr. C. G. Johnson and he was fortunate in being able to establish an excellent co-operation with the Research and Development Establishment of the Ministry of Supply, at their station for Barrage Balloons at Cardington, about 15 miles from Rothamsted. For the first time in this work it became possible to get continuous records, both by day and by night, simultaneously at several definite heights and almost independent of weather conditions.

In the first two years nets were attached to the cables of the balloons at different levels up to 2,000, and occasionally up to 4,000 feet, and the insects were thus filtered out of the air as the wind blew through the nets. Once again all previous results were confirmed with a great increase in reliability of interpretation. On a fine summer day in a net about 3 feet in diameter, at a height of 2,000 feet it was not unusual to get 10 or even 20 living aphids in a single hour. When one considers the microscopic proportion of the air that is being filtered by the net (which is practically invisible at 2,000 feet) it is possible to realize the enormous total population of insects that are being drifted across any mile front of land in any warm summer day.

More recently Johnson has put the work on a still sounder numerical basis by using suction traps which draw a fixed amount of air through the net, almost independent of the wind velocity. This technique enables quantitative results to be obtained even in dead calm weather—as for example may occur at night. A further refinement also enables him to separate the insects caught in each successive hour, so that the times of capture and the relative density for each hour of the day and night can be determined.

The majority of the insects captured in the traps are Aphidae and of these already over 60 species have been identified, of which about 20 species have been found at 1,500 feet or above. In addition to these, species of the following groups have also been observed :—Heteroptera, Homoptera, Diptera, Hymenoptera, Thysanoptera, Neuroptera, Coleoptera, Lepidoptera and Psocoptera.

Johnson's recent results indicate that although the density of insects (i.e., number in a given volume of air) is greater near the ground, the space above is so vast that on an average about 70 per cent of all the insects in the air are above 100 feet from the ground.

Turning away from experimental evidence to field observation we may quote the case recorded by Elton in 1924. He and his colleagues on an expedition to Spitzbergen found living Aphidae on the snow, up to several per square yard in places. The Aphidae were later identified as a species feeding on conifers and the nearest possible food supply was over 800 miles away in the mainland of Europe. At the same time that the Aphidae were found there were also seen a small number of hoverflies (Syrphidae) which are known to be predators on Aphids.

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Even in Britain there are many records of the air being full of Aphidae drifting on the wind and also cases when they have been washed up along the tide line of our shores in millions. These swarms are not infrequently accompanied by hover flies and lady-birds, both of which feed on Aphidae.

It is not easy in many of these records to distinguish between migration and drift—and indeed from the purely economic point of view it does not matter so much—but quite recently apparently true migration has been established in the hover flies, by the observations of Lack and others, of Syrphidae passing in very large numbers through passes in the Pyrenees from France to Spain in the autumn in two successive years.

For many years we have had the co-operation of the Masters of many of the Lightships off our coasts, and they have sent in many records and specimens of insects which have come aboard. Between 1933 and 1939 (Gibbs, 1942) ten Lightships, situated from 1 to 30 miles off our south-east and east coasts, sent in about 390 records, and included among these were 120 different species of Lepidoptera, of which about 20 were previously known or suspected to be true migrants As the majority of the species which could be identified belonged to the so-called " Macrolepidoptera "—the figures indicate that at least 10 per cent of our native moths are capable of flying or drifting over the water a minimum of 1 mile and frequently at least 30 miles. Fifty of the 120 species identified were seen on the Outer Dowsing light vessel, which is 30 miles east of Spurn Head in Yorkshire.

Palmèn (1948) records that he examined large numbers of beetles washed ashore in windrows on the coast of Finland. In nine such aggregations over 1,000 species of beetles were represented, some in countless thousands of individuals, and the vast majority were alive. These beetles had probably flown or been carried out to sea by winds, and then brought down to the surface of the sea perhaps by rain, and finally carried back to the shore by surface winds and waves. It is, of course, also possible that they might have been carried out to sea by some flooded river. In either case millions of individuals of hundreds of species have been distributed over quite large distances by wind or water currents and were still alive at the end.

Some years ago I visited the south-western corner of a large lake in Minnesota, U.S.A., just after a strong north-easterly gale. The water line and the shore line was alive with insects, several hundred per square yard, and among these were hundreds of Colorado beetles. These had undoubtedly been blown from the opposite shore which was about 30 miles away. There is little doubt that many of the occasional outbreaks of this insect in Britain are due to adults being blown over from the Continent.

Records and facts of this nature could be quoted almost without end, but enough has been said to show that most of our ideas on the distances that insects can travel—either on their own wings or on the wings of the wind—have altered very considerably in the last few decades, and may have to be altered still more as our knowledge of the extent of the movements increases.

We have to face the fact that every year millions of millions of insects are distributed by natural causes—migration or drift—over distances to be measured in miles, and not infrequently in hundreds of miles. Among these are some of the major pests of the world—and perhaps to compensate, a small sprinkling of beneficial insects and parasites.

There must follow from this a re-orientation of many old ideas linked up with the prevention and control of outbreaks of insects and of insect-borne diseases.

Firstly, in the case of rotation crops, already mentioned above, it is doubtful if moving a crop from one area to another within any distance less than a few miles, is of any value in the control of the majority of insect pests.

Secondly, the possibility of really exterminating an insect pest becomes untenable, unless it can be done over the whole area of distribution. If an injurious aphid—for example *Aphis fabae*—could be got rid of momentarily in England—say by eliminating its winter food supply—there would be still a constant source of re-infection each summer from the Continent.

Thirdly, the problem of keeping an area free from virus infection takes on new difficulties when we realize that millions of living Aphidae are regularly distributed over distances reaching hundreds of miles; and not to recognize this fact is only to live in a fool's paradise.

Fourthly, some of the activities of quarantine and port inspection of plant imports must be viewed in a new light when we realize that millions of insects per square mile are drifting across the man-made national frontiers, and even over the heads of the inspectors. Inspection is often of great value in preventing the introduction of entirely new pests by artificial means from distant countries, but can do little to reduce the total movement between adjacent areas.

Finally, the knowledge forces us to recognize the international responsibility and the need for co-operation in the control of migrant pests, and of those liable to extensive drift. In the locusts this has already been done to some extent, and with benefit to all: also to a smaller extent with the Colorado beetle situation in western Europe. But more co-operation is needed and Governments must recognize that they have a responsibility to see that insect pests do not leave their country as well as that they do not arrive in it from abroad.

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