A MECHANICAL INSECT TRAP.

By C. B. Williams, Sc.D., & P. S. Milne, B.Sc.
Entomology Department, Rothamsted Experimental Station.

(Plate XXI.)

Introduction.

In the course of some work at Rothamsted on the activity and abundance of insects, in which a light trap was used as a method of estimating the numbers of insects in a state of activity, it appeared advisable to have a further trapping method which did not depend on phototropic response for its efficiency. A rough design for a mechanical trap was therefore drawn up by the senior author.

In October 1934 the junior author came to work at Rothamsted and took up the problem of the construction of the trap with such alterations and improvements as appeared necessary as the work proceeded.

As the trap has now reached a stage when its efficiency has been tested and found to be higher than we expected, and as it may be useful to other workers on the problem of insect populations, it is described below, with one or two examples of typical catches. The full discussion of the results obtained by its use at Rothamsted will form the subject of a later paper by the junior author.

The trap (Plate XXI) consists essentially of two long conical muslin nets fastened to the ends of a light framework about 12 ft. in diameter which is free to rotate and which can be raised and lowered so that the distance of the nets from the ground can be altered.

In the mouth of each net is an electric fan which drives a rapid current of air into the net and at the same time pulls the net forward so that the whole framework rotates horizontally round the central axis.

In the model constructed the nets are 22 in. in diameter at the mouth and 4 ft. 6 in. long. The fans are 16 in. in diameter, and the revolution of the fans is sufficient to cause the whole frame to rotate once in about 12 seconds or five times a minute. This means that the nets advance at a speed of about 3 ft. a second. The insects are drawn into the net chiefly by the inrush of air caused by the fan, but also to a lesser extent by the forward movement of the net.

The following is a description of the mechanical construction of the trap from which it is hoped that anyone who wishes to make one can do so without difficulty.

Mechanical Construction.

The fixed central axis of the trap is a straight tube of drawn steel 12 ft. high and $\frac{3}{4}$ in. in external diameter. It stands vertically on the cast-iron base of a standard G.E.C. electric fan, the connection between the two consisting of a peg of mild steel turned in the lathe to fit the inside of the tube and the socket in the base. A staggered series of holes is drilled diametrically through the tube at intervals of six inches starting from a point 2 ft. from the lower end.

The rotation of the horizontal framework carrying the fans and nets is achieved in the manner of a bicycle steering column. The framework, together with the electrical arrangements to be described later, is made as a complete unit which can be moved up or down the central axis and fixed by means of the pin (fig. 1, Pn) passing through one of the holes; the choice of the hole determines the height of the nets above the ground.

Downloaded from https://www.cambridge.org/core. BBSRC, on 24 Oct 2018 at 10:53:14, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S0007485300036889

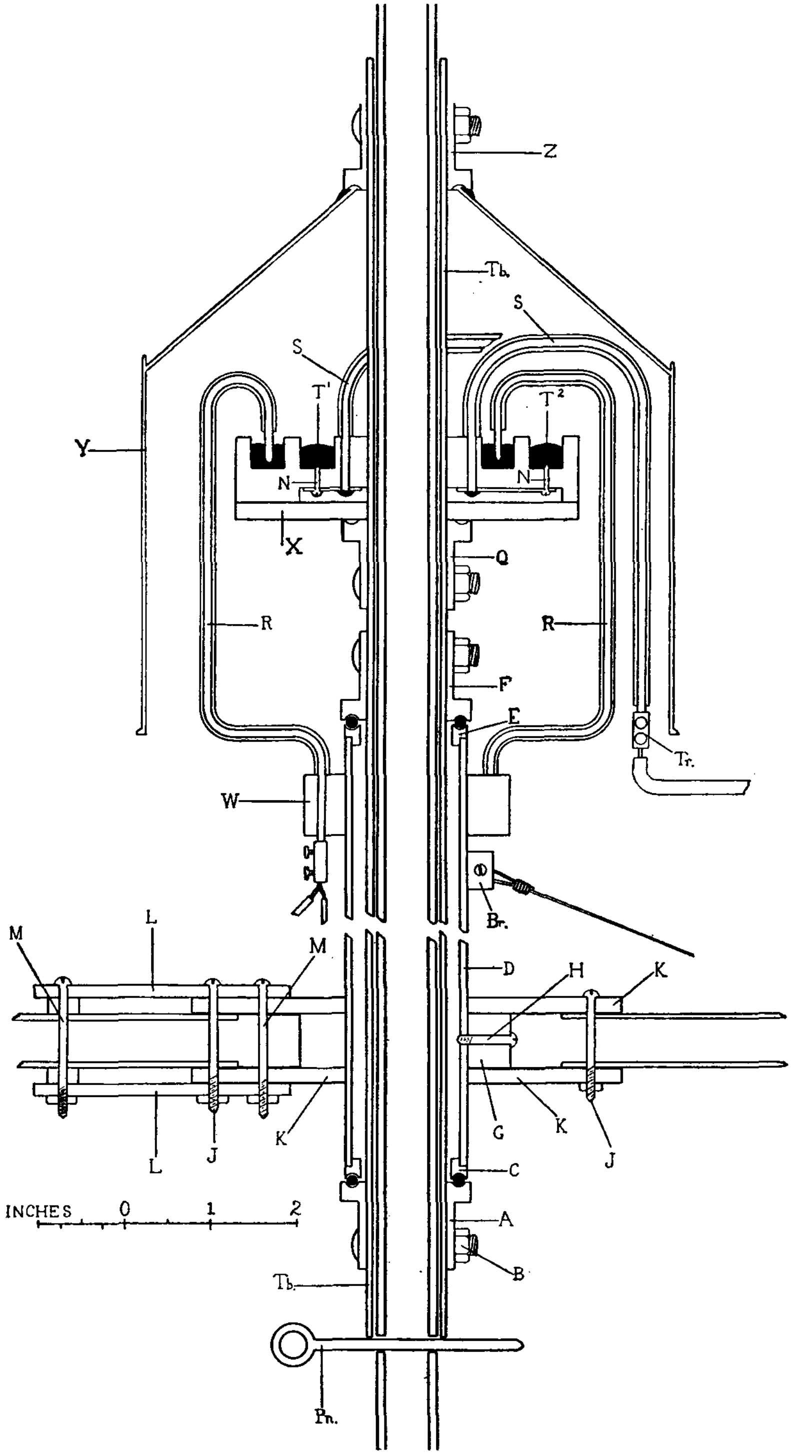

Fig. 1. Diagrammatic section through the central axis of the trap, showing the rotating column, the attachment of the radial arms and the electrical connections.

Downloaded from https://www.cambridge.org/core. BBSRC, on 24 Oct 2018 at 10:53:14, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S0007485300036889

The inner non-rotating member of the column is a steel tube (Tb) 4 ft. 6 in. long, $\frac{15}{16}$ in.* in external diameter, and with walls $\frac{1}{16}$ in. thick. A standard bicycle steering-head clip (A) is slipped over this tube with the ball-race uppermost and filled with $\frac{1}{8}$ in. steel balls. The clamping nut (B) is tightened so that the clip grips the tube about 5 ins. from the lower end. A loose steering-head ball-race (C) is then placed in position on top of the balls and above this again is a 2 ft. 6 in. length of stout tubing (D) with an internal diameter of $1\frac{1}{4}$ in. This tube fits closely over the shoulder on the loose ball-race and is therefore centred about the tube (Tb). It forms the rotating member of the column. To complete the column another ball-race and clip (E and F), with the necessary number of balls, are slipped over the tube in an inverted position and the whole is brought into alignment by tightening the clamping nut on the upper clip.

Six arms of steel tubing radiate out from the lower end of the rotating tube and the four longer of these are supported at or near their extremities by guy wires fixed to the top end of the rotating tube. The relative positions of the arms in the horizontal plane are maintained by a further system of guys connecting each arm to its neighbour.

The attachment of the arms to the tube is shown in section in fig. 1 and in plan in fig. 2. A 6-sided block of hard wood (G) of a thickness equal to the external diameter of the radial arms, and with a central hole slightly wider than the diameter of the column, is fixed round the latter at a point 1 in. from its lower end by means of three horizontally placed set-screws (H) engaging in tapped holes in the metal. Two circular plates of stout brass (K) are bolted one on each face of the wood to form a large bush. The ends of the radial arms are pushed into the space between the two plates and are secured by bolts (J) passing vertically through clearance holes in the four thicknesses of metal.

In order to prevent the arms from taking up positions tangential to the centre bush when the horizontal guy wires are tightened, the attachment of the two short arms (fig. 2, C) is made completely rigid by means of the strip iron supports (L) shown in the left-hand side of fig. 1. These lie above and below the arm and are fastened by two additional bolts (M), one through the bush and the other, with spacing washers, through the arm alone. This arrangement gives good rigidity when the guys are tightened and allows of a partial folding of the arms when the apparatus is to be moved in a confined space.

The lengths of the three pairs of arms (A, B, C, fig. 2) are 5 ft. 6 in., 8 ft., and 2 ft. 6 in. respectively ; the tubing has walls $\frac{1}{16}$ in. thick and an internal diameter of $\frac{1}{2}$ in.

The fan motors are mounted on the end of the first pair, the longest arms (B) support the tail ends of the nets and the short rigid third pair are used as fixed points to which the guy wires are attached. The two longer pairs of arms are braced in the vertical plane by inclined guys fixed to brackets (Br, fig. 1) near the top end of the rotating tube.

Saddle-pieces and lugs of strip brass fixed by bolts passing through the arms are used to anchor the ends of the guy wires, which are of 16-gauge galvanised iron wire ; each wire contains a small steel and brass strainer having a range of movement of about 2 ins. on which the final adjustments of tension are made.

The fans are the standard 16-in. induction pattern table model made by the General Electric Company. The motor and trunnion with its $\frac{1}{2}$ in. diameter peg are removed from the socket in the fan base and the peg is pushed into the end of the $\frac{1}{2}$ in. tube forming one of the arms (A) on the rotating beam ; a bolt passing through the arm and the peg retains the motor with the fan in a vertical plane and

* This diameter was chosen as it exactly fits the standard bicycle steering-column ball-bearings and steering-head clips.

Downloaded from https://www.cambridge.org/core. BBSRC, on 24 Oct 2018 at 10:53:14, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S0007485300036889

at the same time fixes the lug for the guy wire supporting the weight of the motor. When the second motor is similarly fitted to the opposite arm the whole beam is balanced and will rotate smoothly and without wobble on the small stand provided by the original base of one of the fans.

The fan blades face the long arms provided for the support of the tail ends of the nets so that when the current is switched on, air is drawn over the motors and the latter are pushed forward by the reaction of the flow.

A wooden hoop (fig. 2, D) 22 in. in diameter is placed concentrically round each motor and is fixed at three points provided by the horizontal arm and two brass rods which are screwed into the tapped holes in the motor casing; these holes are already present and are made available by removing the small lifting handle fitted by the makers.

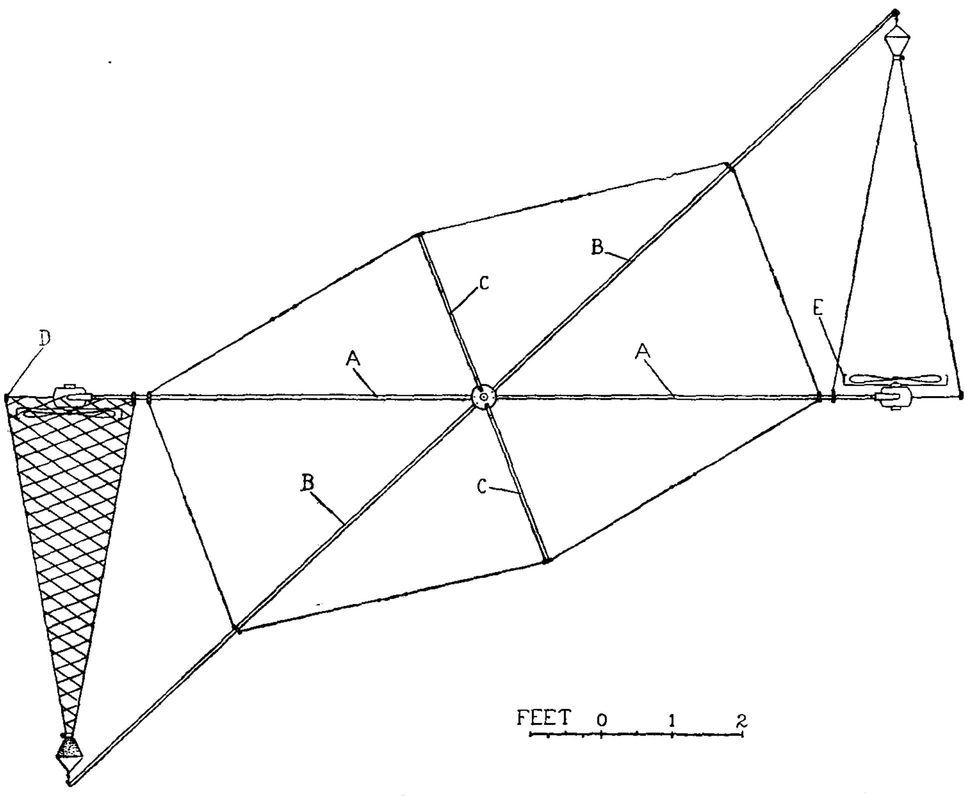

Fig. 2. Diagrammatic plan view of the trap showing the arrangement of the radial arms, fan motors and nets.

The mouth of the net is made of a hoop of similar size which is clipped on to the fixed hoop by three springy brass catches on the circumference. Three small bearing plates of sheet brass are screwed on to the edge of the net hoop so as to register with the catches and prevent the fabric of the net from being worn away at these points.

The stiff wire guard (E) supplied with the fan is retained to keep the net free from the edges of the fan blades in windy weather, but that portion of the guard which faces the blades is cut away to minimise losses due to eddy currents.

Downloaded from https://www.cambridge.org/core. BBSRC, on 24 Oct 2018 at 10:53:14, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S0007485300036889

The motors are totally enclosed except for the small hole through which the flexible leads emerge, and were thought to be weatherproof. In wet weather, however, water was found to be entering through the spindle bearings and steps had to be taken to avoid this. The front and back inspection covers were loosened and turned round so that all the grease cups were inclined downwards. The end of the spindle carrying the fan blades was surrounded by a closely fitting hood of sheet brass with an opening below giving access to the greaser. Holes in the side of the hood allow the guard struts to pass through and these were packed round with rubber washers and insulating tape to prevent water draining in from above. The other end of the spindle was protected by a similar hood of simpler construction. Both hoods were fitted with lugs fastened down to the inspection covers by the bolts holding the latter to the body of the motor.

Current is supplied to the motors by means of contacts dipping into two concentric troughs of mercury fixed round the main axis just above the rotating column (fig. 1).

A thick teak board is turned in the lathe to give a circular block 4 in. in diameter with a $\frac{31}{32}$ in. hole in the centre. Two concentric troughs (T_1 and T_2) each $\frac{3}{8}$ in. wide and $\frac{3}{8}$ in. deep are then cut out of one face of the block at suitable distances from the edges and from each other ; small channels in the wood leading to the side of the block communicate with the troughs and serve as drains when the mercury is to be removed, but are normally closed by short plugs. Two recesses leading radially from the centre are cut out of the lower face of the block and terminate respectively below the inner and outer troughs. Each recess contains a strip of brass connected electrically with the bottom of its trough by a brass bolt (N) ; the inner ends of the strips are fixed to two insulated bus-bars (S) passing vertically through the block and then bent round clear of the dipping contacts described below to form the terminals (Tr) for the power supply from the mains.

The channels in the lower face of the block are protected by the circular piece of wood (X). The lower side of this carries a steering-head clip (Q) by which the whole unit can be adjusted and clamped at the appropriate height on the tube Tb.

A wooden collar (W) is pushed tightly over the top end of the column and it carries two stiff brass rods (R) placed diametrically opposite each other and covered with rubber sleeving except for a small portion at each end ; these pass upwards and outwards round the side of the teak block and are then bent through two right angles so that the tip of one rod dips into the mercury in the outer trough and the tip of the other into the mercury in the inner trough.

The leads from the two fan motors are fastened by insulating tape to the radial arms and pass up the side of the rotating column to be connected to the lower ends of the brass contact rods.

As the column rotates the brass rods rotate with it, their tips describing circular paths in the mercury and providing a continuous circuit for the current.

An ordinary 1-gallon paraffin can (Y) with a conical top is modified as a protecting cover for the troughs and contents. The bottom of the can is cut out neatly with a rolling type can-opener, the handle and spout are melted off and in place of the latter is sweated a bicycle steering-head clip (Z). This cover is then lowered over the troughs as far as possible without fouling the contact rods and is tightened on to the tube (Tb) by the clamping nut on the clip.

The Nets.

The nets are made of book-muslin and are 4 ft. 6 in. long and 22 in. in diameter at the mouth. The apex is fitted with a short zinc cone leading to a glass container whose open end is covered with muslin or net ; a convenient form of container is

Downloaded from https://www.cambridge.org/core. BBSRC, on 24 Oct 2018 at 10:53:14, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S0007485300036889

a glass funnel with a short wide stem which can be joined to the zinc cone by a contracting band of strip brass controlled by a wing nut.

A three-point yoke of cord is slipped over the glass funnel and hooked on to a small coil spring of piano wire fixed to the long arm of the rotating beam. The net is thus supported horizontally under a slight tension and at right angles to the fan blades.

The quality of the muslin used in the making of the nets has a great effect on the speed of the rotation of the trap and it is essential to use a fabric of regular mesh with the interstices free from stray fibres if a reasonable angular velocity is to be attained : if the resistance of the fabric is too high it may not be able to cope with the air delivered by the fans and some part of the air will be forced to escape forwards round the edge of the net, with a consequent reduction in the forward thrust and the speed of rotation. Two samples of muslin of approximately equal mesh but of widely differing texture gave speeds of $1\frac{1}{2}$ and $4\frac{1}{2}$ revolutions a minute respectively ; tests with a delicate anemometer showed that in the former case air was escaping forward in an annular zone 1–2 in. wide round the mouth of the net, while in the latter case air was entering across the whole of the mouth and for a distance of about 15 in. down towards the narrow end.

The speed of $4\frac{1}{2}$ revolutions a minute was considered to be suitable for practical field work and a set of nets was made up using the second type of muslin. It has 45 meshes to the inch and is fine enough to retain all the smaller flying insects.

Installation in the Field.

In the field the top of the central axis must be supported by guys fixed in the ground to prevent the whole trap being blown over by the wind ; four ropes or wires are taken out almost horizontally to pulleys on iron posts set obliquely outside the sweep of the nets and then descend to pegs driven into the ground. The guys should include strainers for setting the axis truly vertical.

The base should be placed on a level slab and packed round with sand-bags to prevent creeping. (More recently the fan base has been removed and the central tube dropped directly into a hole chiselled out of the slab.)

The height of the nets above the ground or vegetation can be adjusted within the limits set by the height of the central axis and the arrangement of the guy ropes. If the trap is set over a growing crop the nets can be raised at intervals by lifting the rotating framework and inserting the pin through the next higher hole in the axis.

Nets at different Levels.

In the original design the two nets were at the same level, but it was thought desirable to be able to use them at different levels if required. The motor of one side was removed from the end of the arm and an extension piece was substituted consisting of a $\frac{1}{2}$-in. iron rod bent down through a right angle and attached to a short length of tubing. The motor and hoop were then re-fitted as before but in a completely inverted position. The length of the extension arm is such that the nets sweep through contiguous layers of air.

The tail end of the net is supported by a light wooden rod attached at right angles to the end of the long arm. The rod extends above the latter and is guyed forwards from its top end to the motor arm, so that the forward pull of the tail end of the net on the bottom end of the rod is balanced by an equal and opposite pull on the top end. A lead weight of appropriate size is fastened to the opposite motor arm to counterbalance the additional weight of the parts comprising the extension arm.

Downloaded from https://www.cambridge.org/core. BBSRC, on 24 Oct 2018 at 10:53:14, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S0007485300036889

Effect of Wind.

The trap has been used for the most part in its modified form with the nets at different levels and the lower one just above the ground. The speed of rotation is but little affected by light winds, although small variations are produced by gusts. The effect of strong gusty winds is more marked; the upper net is more exposed than the lower one and is frequently brought to a standstill facing the wind for periods of 10 to 30 seconds during peaks in the wind velocity. On the other hand the rotation may be considerably accelerated if the peak comes when the upper net is travelling for the moment in the direction of the wind. The final effect of the wind is a definite decrease in the average number of revolutions per minute and a partial loss of the regularity of motion upon which the value of the trap depends.

Passage of Insects through the Fan Blades.

Early tests with the trap showed that its efficiency was much higher than was anticipated. Only a very small percentage of the insects caught are damaged in their passage through the fans. (The speed of the fans is given by the makers as 1,200 r.p.m.) Honey-bees, large Tipulids, moths, and even small tortoiseshell butterflies have been found in the glass funnels in perfect condition and apparently none the worse for their experience. Those few insects which are stunned by contact with the blades are caught by the mouth of the net and either remain sticking to the muslin or are eventually blown back towards the apex.

Examination of Catch.

The short zinc cone leading to the wider glass funnel at the end of the net has the effect of concentrating the air flow at this point and most of the insects are swept through and confined, but each individual is not necessarily swept through immediately; therefore, when the catch is large and insects are arriving in a constant stream, a number are found congregated in front of the entrance to the funnel.

It has not been found possible to overcome this difficulty at present and the original intention of incorporating a mechanism which would automatically change the container at intervals has not been carried out. Consequently, when the catch has to be examined at regular intervals, the nets are removed and replaced by another pair; any insects remaining near the mouth are shaken down and the fabric is folded over the hoop to prevent any escape until the greater part of the net is placed in a killing chamber. After death the contents are emptied down a funnel into a pill box.

Cost of Materials.

The total cost of the materials for the trap, excluding the nets, was approximately £12. The construction was carried out by the authors in the workshop at Rothamsted. Each pair of the nets requires two 22 in. hoops and 5 yards of the fabric known as "book-muslin no. 86." The cost per net is approximately a half-crown.

Examples of Catches made by the Trap.

This paper is intended as a description of a new weapon for the study of insect activity rather than as an account of the results obtained with it, but some of the catches are given here as an indication of the kind of material which is collected.

The trap in its present form, but with the nets at the same level, was set up on 1st February 1935 on a plot of rough grass at Rothamsted lying close by the experimental orchard and surrounded by grass land on the other sides. The centre of each net was 2 ft. above the ground.

Downloaded from https://www.cambridge.org/core. BBSRC, on 24 Oct 2018 at 10:53:14, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S0007485300036889

The current was switched on at 16·30 G.M.T. on 2nd February and was left on until 10·00 on 3rd February, when the nets were removed and the catch examined. Thirty insects were found, as set out in Table I. A further run during the daylight hours of 3rd February produced a catch of 369 insects: 362 small Diptera, 5 Coleoptera and 2 Psyllids. The catch during the night of February 3rd–4th (16·30 to 10·00) was rather higher, with 54 insects, than that of the previous night. The maximum temperature during the days, minimum temperature during the nights, together with the relative humidity and a general description of the weather conditions are given in the table.

TABLE I.

Analysis of catches during a period of three nights and two days.

FEBRUARY 1935.

Date	2nd–3rd	3rd	3rd–4th	4th	4th–5th
Time	16·30–10·00	11·00–15·30	16·30–10·00	11·00–15·30	16·30–10·00
HOMOPTERA					
Psyllidae	—	2	—	—	—
COLEOPTERA	—	5	—	48	—
DIPTERA					
Chironomidae ...	21	239	34	2,344	29
Trichoceridae ...	1	5	14	7	33
Cecidomyidae ...	1	22	—	168	—
Mycetophilidae ...	3	17	1	211	65
Psychodidae	—	5	5	32	3
Acalypterae	4	74	—	163	1
	30	369	54	2,973	131
Max. day temperature ...		50·2°F.		47·3°F.	
Min. night temperature	41·4°F		37·6°F.		43·1°F.
Relative humidity (at 9·00 hrs.)		81%		92%	
General weather conditions	Cloudy, moderate N.W. wind	Overcast, showers, light wind	Overcast, slight rain light wind	Fair, periods of sunshine	Fair, sky variable, light N. wind

The next day was fair, and very humid, with periods of sunshine, and the catch went up to 2,973 insects, of which 2,344 were small Chironomids of the genus *Smithia*. The insect activity fell during the following night, but was still greater than on the two previous nights.

On 14th February one net was placed 22 in. lower than the other, as described above, the height of the centres of the nets being 15 in. and 37 in. respectively from the ground. For the next fortnight bad weather prevailed and the catches were very small. Then at the beginning of March, water got into the lower fan motor and caused the windings to be burnt out. While repairs were being made, the brass cowls for the protection of the spindles were designed and fitted, and they have proved entirely successful in preventing a recurrence of the trouble.

Trapping was resumed on 13th March; each 24 hours was divided into three periods of 3 hours and one of 15 and the nets were changed at the beginning of each period. The times were 9·15 to 12·15, 12·15 to 15·15, 15·15 to 18·15, and 18·15 to 9·15, the beginning of the last period being approximately sunset at that season.

Downloaded from https://www.cambridge.org/core. BBSRC, on 24 Oct 2018 at 10:53:14, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S0007485300036889

An example of a complete day's catch, from 9·15 on 20th March to 9·15 on 21st March is given in Table II. The day was remarkable for the sudden increase in the numbers of small Staphylinid beetles and for the fact that 78 per cent. of these were found in the upper net. A similar increase in the number of STAPHYLINIDAE with height above the ground was very evident during the days preceding and succeeding 20th March, though the numbers involved were smaller.

TABLE II.

Analysis of catches during a period of 24 *hours continuous running.*

20th–21st MARCH, 1935.

Time	9·15–12·15		12·15–15·15		15·15–18·15		18·15–9·15	
	U.	L.	U.	L.	U.	L.	U.	L.
HOMOPTERA								
Psyllidae	1	—	—	3	—	—	—	—
COLEOPTERA								
Staphylinidae	105	38	129	39	290	73	11	—
Other Coleoptera	15	17	46	45	48	51	2	5
MICROLEPIDOPTERA	—	—	—	—	—	—	1	—
DIPTERA								
Chironomidae	14	31	19	27	38	58	54	61
Trichoceridae	1	—	—	—	—	1	2	5
Cecidomyidae	8	10	5	13	5	13	—	3
Mycetophilidae	28	19	61	33	70	43	4	4
Psychodidae	—	—	—	—	31	124	20	44
Lonchopteridae	—	—	—	1	—	—	—	1
Acalypterae	11	16	17	23	9	8	2	3
HYMENOPTERA								
Chalcidoidea	—	4	7	14	3	3	—	—
Ichneumonoidea	2	2	1	2	—	—	—	—
SPIDERS	2	—	—	—	—	—	—	—
	186	137	285	200	494	374	96	126
				1,898				

Maximum day temperature 63·2°F.
Minimum night temperature 34·5°F.
Relative humidity (at 9·00 hrs. on 20th) 85 per cent.
Relative humidity (at 9·00 hrs. on 21st) 79 per cent.
Slight mist early morning followed by bright sunshine during day ; clear sky at night ; calm.
U=upper net. L=lower net.

Apart from these insects, and considering the latter part of March as a whole, there appears to have been a progressive increase in the catch of the upper net, relative to that of the lower one, during the daylight hours, and a sharp decrease during the hours of darkness.

These two series of catches show how the mechanical trap can be used as a means of sampling the flying insect population of a given area and how, by changing the nets at intervals, the variation in numbers with time and season can be investigated.

Downloaded from https://www.cambridge.org/core. BBSRC, on 24 Oct 2018 at 10:53:14, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S0007485300036889