TWENTY YEARS OF MOTH MONITORING AT BROOM'S BARN

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As part of a long term project to monitor aerial insect populations the Rothamsted Insect Survey, which is based at Harpenden in Hertfordshire, currently operates a network of 95 light traps over Great Britain. One of these is situated at Broom's Barn Experimental Station, an agricultural research station specialising in sugar beet, at Barrow, near Bury St. Edmunds (Site No. 88, O.S. grid ref. TL 752 656) and it has been in operation since 1968. All traps are of the standard Rothamsted design which stand 4 ft. above the ground and have a 200 Watt clear tungsten bulb, covered by an opaque roof. They are operated every night of the year and the samples are collected each morning. These can then be sent elsewhere for identification or checking. The macrolepidoptera (larger moths) are identified from all catches and recorded daily. Although the catches have to be killed for consistency and accuracy of identification, the samples are small enough not to affect local populations but are of sufficient size to be scientifically valid as a measure of the local moth communities.

The data collected by the Survey have been used extensively in fundamental studies of large scale distribution (Taylor, 1986). The light traps can also be used to compare the composition of moth communities in various habitat types such as at moorland, woodland or urban sites throughout the country, and consequently monitor trends caused by environmental or climatic change (Taylor, French & Woiwod, 1978; Woiwod, 1981; Taylor, 1986). With a growing awareness of environmental issues, one of the current aims of the light trap survey is to monitor the responses of Lepidoptera to such habitat changes as those resulting from agricultural practices. For such monitoring to be most useful, long runs of consistent trapping such as that provided by the Broom's barn trap are necessary.

In a previous article in this journal, Ian Woiwod (1981) discussed some of the results from the Broom's Barn light trap for the period 1968–1979. As the trap has now been in continuous operation for 20 years it is opportune to re-examine long term trends in moth populations at this site and to compare current results with those found in the previous study.

Three important parameters for measuring the moth community sampled by Rothamsted light traps are the total number of individual moths caught per year, the total number of species caught per year, and log-series α, which is a statistical measure of the diversity of the moth population and is independent of sample size. Numbers are converted to logarithms in order to compare very large and very small numbers. It also emphasizes differences between very small values, which may be important, and decreases the differences between very large numbers, which are generally less important. Figure 1 shows the annual changes in these three parameters for the period 1968–1987 inclusive.

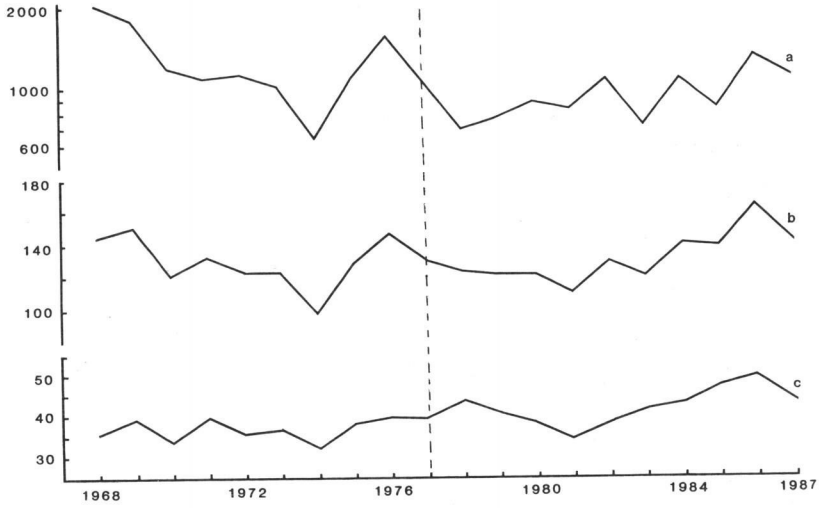


Fig. 1 Population parameters of the macrolepidoptera from the Broom's Barn light trap 1968–1987.
(a) Total number of moths per year (N) Logarithmic scale.
(b) Total number of moth species per year (S).
(c) Diversity of moth population per year (α).

Number of individuals (Fig. 1a & Table 1)

The geometric mean (mean of the log totals) of individuals per year for all the Rothamsted light traps in Great Britain over the 20-year period is 1,825. Therefore Broom's Barn with a geometric mean of 1,098 is well below average. This seems typical of samples collected in areas of intense arable cultivation, such as parts of East Anglia. There was an overall decline in numbers from 1965 to 1987, with a slight upward trend during the latter half of this period, but Fig. 1a is difficult to interpret because there were two years (1968 and 1976) during which much larger than average numbers of moths were caught. The long hot summer of 1976 caused a dramatic increase in moth numbers, following a year in which the weather was also favourable. However, it may be useful to compare the data from the first and second halves of the 20-year period (Table 1).

Number of species (Fig. 1b & Table 1)

The number of species per year tends to follow fluctuations in the number of individuals (Fig. 1b). This is why the number alone is a poor indicator of diversity. The average number of species caught per year by all the Rothamsted light traps during the 20-year period was 129 and, despite the mean number of individuals caught per year being below the national average, the

Table 1

Moths caught during the first and second halves of the trapping period 1968–1987

	1968–77		1978–87	
i) *Numbers of individuals*				
Geometric mean of individuals per year	1,199		919	
Largest yearly total	2,036	(1968)	1,323	(1986)
Smallest yearly total	648	(1974)	722	(1983)
ii) *Numbers of species*				
Average number of species per year	130		132	
Largest yearly total	151	(1969)	165	(1986)
Smallest yearly total	98	(1974)	111	(1981)
iii) *Diversity (a)* - approximate	37		42	

Broom's Barn trap caught an average of 131 species, i.e. more than the national average.

Woiwod (1981) stated that the total number of species caught up to 1979 was 296 and, although 57 of these have not been recorded since, this is offset by the addition of a further 43 species in the subsequent eight years, taking the total for the whole 20 years to 339. However, it should be noted that this includes six species of the genus *Eupithecia* – a group which were not routinely identified to species level before 1984. Of the 57 species not recorded since 1979 and the 43 additional species caught since that date, 34 of the former and 20 of the latter have only been caught on one occasion – indicating a high turnover of species. This may be explained by movement of individuals from diverse surrounding habitats such as the Brecklands. A number of species normally associated with the Brecklands are, or have been, represented in the trap catches (e.g. *Heliothis viriplaca* Hufn. (marbled clover), *Agrotis vestigialis* Hufn. (Archer's dart), and *Lithostege griseata* D. & S. (grey carpet).

Whereas the average number of individuals per year and the maximum number recorded for any one year was higher in the first half of the trapping period than in the second at Broom's Barn, the reverse was true for the number of species (Table 1).

Diversity (α) (Fig. 1 & Table 1)

This parameter (α) expresses the statistical relationship between the number of species and the number of individuals within a given sample. It is independent of sample size and therefore is a better indicator of species richness in an area than the number of species recorded. For a more detailed explanation of 'α' and its calculation the reader is referred to Lewis and

Taylor (1967). It is not directly equivalent to species richness – rather it is a measure of the species structure of a community at a given time (Woiwod, 1981). At a stable site 'α' is known to remain constant. Therefore changes in this measurement indicate a changing or unstable environment.

The mean 'α' at Broom's Barn for the whole trapping period was approximately 41 considerably larger than the approximate national average of 32. This may partly reflect the trap's proximity to the Breckland with its highly diverse moth fauna. The Rothamsted light trap at Santon Downham (Site No. 259, O.S. grid. ref. TL 816 876) is situated about 23km from the Broom's Barn trap on the Brecklands, and it has a mean 'α' of approximately 52, a very high value.

From Fig. 1c it can be seen that there has been an increase in the diversity of the moth populations at Broom's Barn since trapping began in 1968. Although the mean figure for the latter half of the 20-year period was higher than the ealier half (Table 1) the overall rise in diversity is not statistically significant because of the variability between years. Even so, the general upward trend suggests an environmental change, which will be discussed later.

Management of the area surrounding the trap

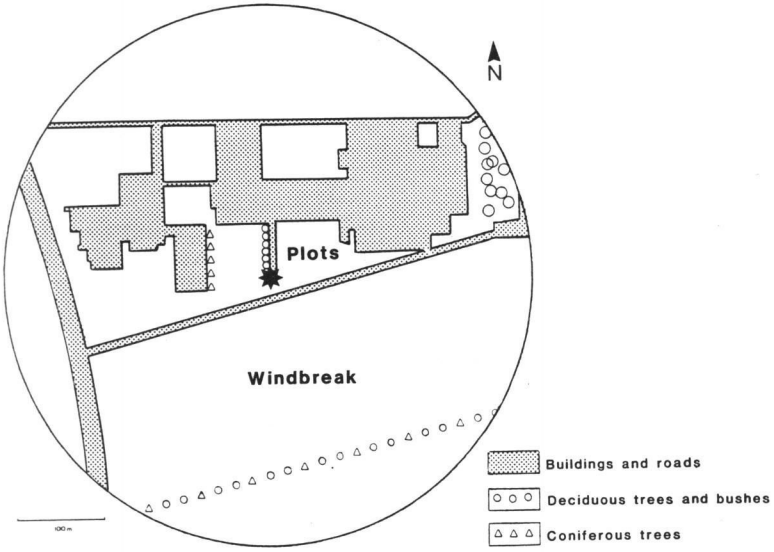
As Broom's Barn is an experimental farm detailed records have been kept and Mr John Webb has been able to provide useful information on management practices in the trap area since 1968. These are briefly outlined below. Fig. 2 shows a plan of the area surrounding the trap including those areas which are cited in the text.

Windbreak Field

Since 1968 this area has been in continuous cultivation, the main crops being wheat, sugar beet, barley, maize and grass. Herbicides were used on these crops throughout the trapping period – usually once a year but more intensively since 1981. Insecticides were used more sparingly and were restricted mainly to the periods 1969–1973 and 1984–1987. Between 1968 and 1970 plots of grass were grown on Windbreak but they were not on the same plot each year. However, from 1980 onwards, a single plot of grass for hay was maintained at the eastern end of the field. No herbicide or pesticide was used on the grass plots between 1968 and 1970 and apart from 1984, when herbicide was applied, neither was used on the single grass plot between 1980 and 1987.

Plots Area

This area was kept in constant cultivation between 1968 and 1979 as small plots of barley, sugar beet, potato and maize (with the exception of 1975 when it was ploughed and kept fallow). Between 1968 and 1979 there were regular applications of insecticides and herbicides. In 1980 the whole area was sown with grass and has subsequently been maintained as lawn.



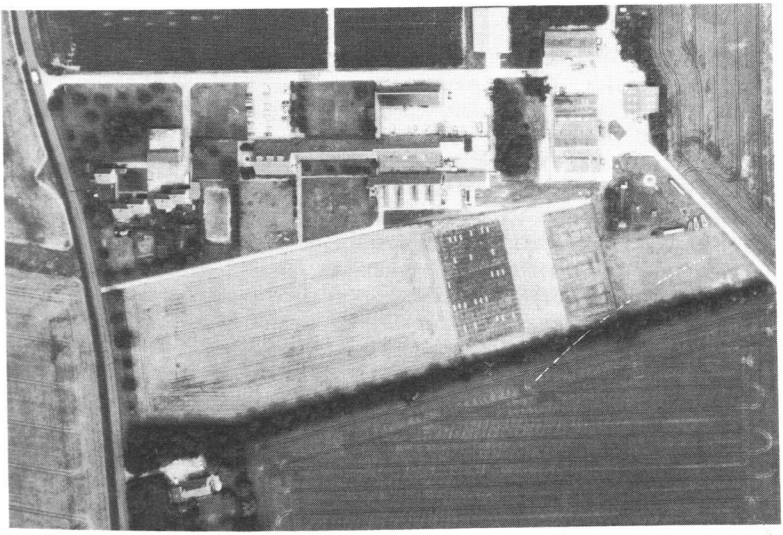


Fig. 2 Position of light trap, main land usage and field names referred to in the text. From a photograph by MAFF, ADAS Aerial Photography Unit, Cambridge, for Broom's Barn Experimental Station.

The area immediately to the west of the trap has been lawn for the whole of the trapping period. One other constant feature is an ornamental shrub hedge which runs from the laboratories to the trap itself. This has been subjected to occasional, though sometimes vigorous, pruning and clipping. Precise records of the hedge trimming are not available.

Overall Trends

The trend in the number of species and individuals was markedly downwards during the period 1968 to 1974. Although less marked, there is also a downward trend in the diversity over this period. These trends coincide with a period of continuous insecticide and herbicide application to the Plots area immediately adjacent to the trap. There was also intensive application of insecticides to Windbreak during 1972 and 1973 and this may have had a detrimental effect on the numbers of certain species in the general area of the trap. Although herbicide was applied to Windbreak over the whole trapping period no general insecticides were applied to either Windbreak or Plots during 1974. The dramatic fall in numbers of individuals and species of moths as well as the diversity during this year may be due to the effects of spraying in 1972 and 1973 and/or weather conditions. During 1975 all values recovered to their previous levels. The lack of cultivation on Plots and the consequent absence of insecticides and herbicides there would have contributed to this recovery. The weather in 1975 was also favourable and would have been a further contributing factor.

The long hot summer of 1976 led to a dramatic increase in the number of individuals and species but the diversity was not significantly affected.

In 1980 Plots was sown with grass and has since been maintained as lawn. Also a permanent area of grass for hay was established in the eastern end of Windbreak. No herbicides or insecticides have been used on the lawns since that time and there has been one application of herbicide (1984) to the grass plot on Windbreak. This significant reduction in the use of pesticides and the creation of areas which are no longer subject to the constant upheaval of ploughing and the subsequent destruction of larval foodplants will benefit resident moth populations. Although totals for individuals, species and diversity fell in 1981, the steady general increase in all values since then appears to support this view. The drop in values in 1981 may have been caused by the very thorough preparation of the ground (digging, sieving and removal of undesirable vegetation) which was needed prior to laying the lawn in 1980. Hence this area was probably devoid of Lepidopterous foodplants for a period in 1980 which could have accounted for the decrease in the total catch in 1981.

Although there has been an overall increase in all values since 1981, it is noticeable from Fig. 1 that the numbers of species and individuals have fluctuated during this period. Although this coincides with an intensification in the use of herbicides and a resumption of insecticide application on Windbreak, the diversity rose during this time, thus indicating an increasing complexity in the structure of the moth populations in the immediate vicinity on the trap. Further study would be required to evaluate the importance

of the undisturbed areas of grass in maintaining the diversity of moth populations.

Trends in individual species

Of the 339 species recorded at Broom's barn, a few have been chosen to illustrate trends, some of which have been chosen to illustrate trends, some of which have resulted from the various management practices already outlined. Those species cited by Woiwod (1981) are examined further and trends which have only become noticeable due to the lengthy period of monitoring can now be discussed.

Luperina testacea D. & S. (flounced rustic)
This moth increased its numbers markedly until it reached a peak of 271 in 1977. In 1978 the total fell to only 63 and Fig. 3a shows how it has subsequently remained at about that level. The period of greatest increase in numbers was from 1969 to 1971 which coincides with large scale cultivation of winter wheat on Windbreak; the dramatic decline in numbers in 1978 was associated with the growth of spring-sown barley on both Windbreak and Plots. The larvae of *L. testacea* feed from September to June on the roots of various grasses including cereal crops and this larval period coincides with the cultivation of winter wheat but not with that of spring barley.

The annual numbers recorded since 1978 may indicate a background level for this species at Broom's Barn. The results from 1969–1971 and 1978 show how quickly and dramatically this level can change for *L. testacea* according to prevailing situations and opportunities such as the intensity of cropping with winter-sown hosts. The establishment of a permanent grass plot on Windbreak will benefit this species whilst the existence of lawned areas will maintain a resident population in the immediate area of the trap.

Eilema lurideola Zinck. (common footman)
Woiwod (1981) observed that the abundance of *E. lurideola* fluctuated around a constant mean value. Its numbers have remained generally stable, but there is evidence of a slight upward trend (Fig. 3b) which has only become noticeable because of the long run of data available from this site. The larvae of this species feed on various lichens growing on trees, fences, etc. (Skinner, 1984). Most of the fences, walls and shrubs in the immediate vicinity of the trap do not appear suitable and one must assume that *E. lurideola* is mainly established in hedgerows to the south and west of the trap which contain mature trees such as hawthorn on which such lichens are found.

The fluctuations in numbers of adults reaching the trap each year may reflect changes in population size or weather conditions during the flight period which either encourage or inhibit movement of individuals from their breeding sites. Lichens are very sensitive to air pollution and the presence of other lichen-feeding moths in the catches, such as *Thumatha senex* Walk. (round-winged muslin), *Cybosia mesomella* Linn. (four-dotted Footman), *Eilema griseola* Hb. (dingy footman), *Cryphia domestica* Hufn. (marbled

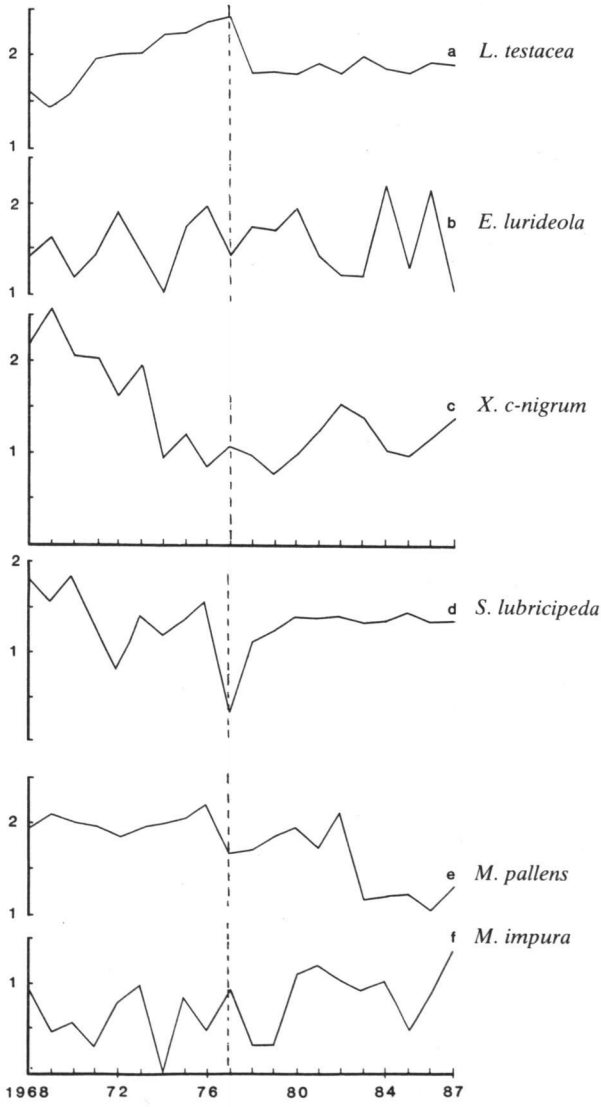


Fig. 3 Log_{10} annual totals for six species from the Broom's Barn light trap 1968–1987.

beauty) and *Laspeyria flexula* D. & S. (beautiful hook-tip), suggests that the environment at Broom's Barn is fairly free from air pollution.

Xestia c-nigrum Linn. (setaceous Hebrew character)
This species was in decline in 1979 but, although it is now caught in generally smaller numbers than previously, it appears to have stabilised and even increased slightly (Fig. 3c). The larvae of this species feed on a variety of herbaceous plants and its decline between 1968 and 1979 was probably due to the constant use of herbicides on Plots during this period. The cessation of herbicide use after this area was laid to lawn would have allowed the possible establishment of larval foodplants such as dandelion both in the various shrub borders and within the lawn itself. (R. Eley (Pers. comm.) states that this species had declined generally in this area over the last few years).

Spilosoma lubricipeda Linn. (white ermine)
S. lubricipeda shows a simultaneous decline and recovery with *X. c-nigrum* over the same period (Fig. 1d). This species also feeds on various herbaceous and annual plants and the reasons for its decline and recovery are probably similar to those outlined for *X. c-nigrum*. Allan (1949) suggests a wider range of foodplants for *S. lubricipeda* and this may explain its faster recovery and greater stability since cultivation ceased on Plots in 1979.

Lacanobia suasa D. & S. (dog's tooth)
This is another herbaceous plant feeder which followed the same trend of decline and recovery, but this species disappeared completely between 1974 and 1981. Having re-appeared it now maintains roughly its previous level. This shows that although a species may become rare or even apparently absent in an area, the presence of a Rothamsted type trap does not inhibit the species' recovery should the resident population begin to strengthen once more – an important conservation consideration in areas such as nature reserves where sensitive species are present.

Mythimna pallens Linn. (common wainscot)
M. pallens has declined whereas its close relative *M. impura* (smoky wainscot) has generally maintained its numbers (Fig. 3e & f). The reasons for the decline in *M. pallens* are unclear and specific investigation would be required to discover the environmental changes taking place which appear to discriminate between these two closely allied species.

Species of local and national interest

Of the notable species mentioned by Woiwod (1981) *Epirrita autumnata* Bork. (autumnal moth), *Aporophyla nigra* Haw. (black rustic), *Dichonia aprilina* Linn. (merveille du jour), *Heliothis viriplaca* Hufn. (marbled clover), *Autographa pulchrina* Haw. (beautiful golden Y), *Tyta luctuosa* D. & S. (four-spotted) and *Bomochla crassalis* Fabr. (beautiful snout) have not subsequently been caught; *Agrotis vestigialis* Hufn. (Archer's dart) and

Paradiarsia glareosa Esp. (autumnal rustic) have been recorded on only one occasion (in 1987 and 1986 respectively) and *Ennomos autumnaria* Werneb. (large thorn) and *Lithophane ornitopus* Hufn. (grey shoulder-knot) continue to be caught regularly in small numbers. *Lithostege griseata* D. & S. (grey carpet), a Breckland speciality which had only been caught once prior to the previous study, has since been caught in small numbers most years. This suggests that there may be a small resident population in the vicinity of the trap and that it is not merely represented in the catches as a vagrant from its usual Breckland habitat.

Other species of interest, because they are only infrequently caught in Rothamsted light traps, are the immigrant geometrid *Rhodometra sacraria* Linn. (vestal) (recorded in 1982 and 1984); *Chesias rufata* Fabr. (broom-tip) (1983); *Rhyacia simulans* Hufn. (dotted rustic) (1985 and 1986), a species which has increased its numbers nationally in recent years (Skinner, 1984); *Lithophane leautieri* Boisd. (Blair's shoulder-knot) (1985 and 1986), a species which has spread rapidly over southern England since 1960 (Heath & Emmet, 1983); *Xanthia ocellaris* Borkh. (pale-lemon sallow), a Breckland species caught once in 1980; *Ipimorpha subtusa* D. & S. (the olive) (1980 and 1982) and *Hoplodrina ambigua* D. & S. (Vine's rustic) (1986).

Summary

We have seen that data from the Rothamsted light trap at Broom's Barn show how moths at this site have responded to various agricultural and management practices over the last twenty years. Some species, such as *L. testacea*, react very quickly to certain environmental changes and their responses are clearly reflected in the trap catches. This allows us to assess the stability of the environment in the vicinity of the trap over short periods of time. The data also illustrate the value of long term monitoring as a means of discerning trends which are sometimes not obvious over short periods. Just as some of these trends could not be seen after only ten years of monitoring, others may not emerge unless operation of the trap continues, perhaps for many years to come. Such monitoring will also help us to understand the ecological requirements of sensitive species, or at least to identify management practices which are detrimental to them. As arable crop cultivation is so intensive in East Anglia, such an exercise in this region is particularly important – not only with direct respect to agricultural crop production but, in the present period of agricultural surplaces, in enabling quantitative observation of the effect of removing land from cultivation.

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