HDC Project FV 163a

ANNUAL REPORT

Brassicas: Refinement and field validation of forecasts for the caterpillar pests of brassicas.

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SCOPE AND OBJECTIVE

The caterpillars of several species of butterfly and moth can damage brassica crops. However, attacks by caterpillars are sporadic and do not occur in every crop each year. Considerable savings can be made in applications of insecticides for caterpillar control by applying sprays only when there are sufficient insects in the crop to warrant treatment. The purpose of this project is to refine and validate forecasts of the timing of activity of the caterpillar pests of brassica crops so that crop walking and subsequent spray applications can be targeted more accurately.

SUMMARY

The pest caterpillars of brassica crops were monitored at 8 sites in 1999. Pheromone traps were used to monitor adult moths and water traps to monitor butterflies. The numbers of immature stages (eggs, caterpillars, pupae) were counted on plants in insecticide free plots of Brussels sprouts. Very few insects were found at any of the sites. The small white butterfly and silver Y moth were the most widespread species, but the numbers of caterpillars of each species never exceeded one/plant. The data were used to validate forecasts of caterpillar phenology developed in LINK Project FV 163. However, because pest numbers were so small that comparisons were limited.

The data from all insecticide free Brussels sprout plots monitored for caterpillar pests in Projects FV 163 (1995-97), FV 163a (1999) and as part of the HRI Pest Monitoring Service (1996-99) were collated. The numbers of adults trapped and eggs, caterpillars and pupae found/plant on each sampling occasion were calculated for each of the 33 sets of data.

Preliminary analyses were made to determine the relationship between the numbers of adults captured in traps and the numbers of caterpillars infesting untreated Brussels sprout plants in the monitoring plots. The first analyses were made using data on the diamond-back moth. The monitoring data were summarised by separating the periods of moth and caterpillar activity into generations. The numbers of moths captured/trap/day and the numbers of caterpillars found/plant at the peak of each generation were determined and then the numbers of caterpillars were plotted against the numbers of moths. A line fitted to the data by regression was statistically significant ($p<0.001$) and accounted for 51% of the variance, although the data were very variable. The capture of approximately 6 moths/trap/day was equivalent to an infestation level of 1 caterpillar/plant.

The caterpillar forecasts, which were developed originally in FORTRAN, were reprogrammed for use in the MORPH decision-support software. These new versions of the forecasts will be validated in the second year of the project using monitoring data collected during 1995-2000.

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ACTION POINTS FOR GROWERS

- The data collected in 1999 confirm that the diamond-back moth and small white butterfly are the most widespread caterpillar pests of brassicas in the UK. The silver Y moth was common also. The cabbage moth and garden pebble moth are localised pests.
- Caterpillar infestations were slight in 1999 and there were no instances where more than one caterpillar of each species/plant was found. This implies that few insecticide treatments would have been required for caterpillar control. This was supported by the results of supervised control experiments at HRI Kirton (FV 194), where few sprays were applied to control caterpillars and even the untreated control plot suffered very slight damage.
- Diamond-back moth caterpillars were present in crops from late June until October. This is a migrant species and the timing of immigration varies from year to year.
- All the small white butterfly caterpillars found on plants were the progeny of either the second or third generations, confirming that the first generation is the least important.
- Silver Y moths were captured at all sites. They are also migrant moths and the timing of immigration varies from year to year. Previous studies suggested that their caterpillars were not important pests of brassicas. Determination of the relationship between numbers of moths trapped and numbers of caterpillars found on plants (second year of project) may support this.
- There was a relationship between the numbers of diamond-back moth caterpillars found at the peak of each generation and the numbers of moths captured in pheromone traps. In future it may be possible to use pheromone trap captures to trigger the start of crop sampling i.e. at the stage when an infestation is likely to become damaging.

BENEFITS

Leafy brassicas are worth more than £160M annually (MAFF Basic Horticultural Statistics for the UK, 1986-96) and cover an area of 41,000 ha. In 1995 (Garthwaite *et al.*, 1995) a total area of 250,000 ha was treated with insecticides, of which about 40% (100,000 ha) were for caterpillar control. The presence of caterpillars or caterpillar damage in produce can lead to supermarket rejections.

MAFF and HDC-funded work has shown that a 25% reduction in the number of sprays applied for caterpillar control might well be feasible. Sprays to brassica crops cost about £200/ha (Nix, 1998) and approximately 25% of these will be for caterpillar control (about £50/ha). Thus even a 5% reduction in the number of treatments applied for caterpillar control to the 41,000 ha brassicas grown in the UK could be worth about £100,000 per year, depending on the costs of insecticide and treatment. This would give a cost-benefit relationship of 1:11 for a period of five years.

Other benefits would accrue from a reduction in insecticide use, which would be favoured highly by consumers. For example, a reduction in the number of pyrethroid sprays applied to crops would benefit non-target species and reduce the rate of development of insecticide resistance in other pests.

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- The project will increase brassica growers' knowledge of caterpillar life cycles and help them anticipate periods of caterpillar infestation. This should lead to better use of crop monitoring resources and improved targeting of insecticide treatments.
- The project will provide the industry with validated forecasts of the timing of caterpillar attacks. These could be made available as regional forecasts or could be generated locally using growers' own weather stations, with the forecast models incorporated into a decision support system such as MORPH.
- Management systems which lead to targeted applications of lower numbers of sprays would be favoured highly by consumers and would have considerable benefits for the environment. The pyrethroids used for caterpillar control are broad-spectrum insecticides which may kill a wide range of non-target species, whilst more specific insecticides such as *Bacillus thuringiensis* are relatively expensive.
- Reduction in the use of pyrethroid sprays for caterpillar control may reduce the rate of development of insecticide resistance in other pests such as the peach-potato aphid (*Myzus persicae*).

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SCIENCE SECTION

INTRODUCTION

Edible brassica crops are sprayed extensively to control foliar pests, particularly caterpillars and aphids (Garthwaite *et al.*, 1995). Crops may be treated routinely with little reference to pest numbers or crop growth stage. The caterpillars of several species of butterfly and moth can damage brassica crops. However, extensive field sampling during a recently completed LINK project (P 132, FV 163) has shown that attacks by caterpillars are sporadic and do not occur in every crop each year.

Previous MAFF-funded research (FO5D, PI0321), and a parallel HDC-funded project (FV 119), have shown that considerable savings can be made in applications of insecticides for caterpillar control by applying sprays only when there are sufficient insects in the crop to warrant treatment. This was done using systems of supervised control to apply sprays only when necessary (Blood Smyth *et al.*, 1992; 1994; Emmett, 1992; Paterson *et al.*, 1994). Pest numbers were assessed by field sampling, and treatment decisions were made using pest tolerance levels (thresholds). However, there was still a need to develop sampling techniques further to make them more appropriate to commercial practice and to reduce the costs of monitoring. One of the main objectives of LINK Project P 132, FV 163 was to develop and validate forecasts that predict the timing of key events in the development of caterpillar pests of brassicas, so that crop monitoring can be targeted more accurately.

Of the six species of caterpillar studied in the LINK project, the diamond-back moth (*Plutella xylostella*) was the most damaging commercially. This was followed by, in decreasing order of importance, the small white butterfly (*Pieris rapae*), cabbage moth (*Mamestra brassicae*), garden pebble moth (*Evergestis forficalis*), large white butterfly (*Pieris brassicae*) and silver Y moth (*Autographa gamma*). Preliminary forecasts of the timing of activity were developed for the diamond-back moth, small white butterfly, cabbage moth and garden pebble moth. These have been validated using monitoring data collected at four sites during 1994-1997. The forecasts now require validation over the geographical range of brassica production in the UK, and further refinement, before they can be used on a commercial scale. The purpose of this project is to refine and validate forecasts of the timing of activity of the caterpillar pests of brassica crops so that these can be made available to growers, thus taking LINK project FV 163 into the field phase.

Apart from caterpillars, brassica crops are attacked by a range of fly, beetle and aphid pests. Forecasts have been developed for the cabbage root fly (*Delia radicum*) and pollen beetle (*Meligethes* spp.) (FV 13a, FV 44, FV 127) and predictions using Meteorological Office weather data are available currently to growers as a fax service from HRI Wellesbourne. These forecasts have also been incorporated into the MORPH decision support software and will be available to growers for use with their own weather data in 1999. A preliminary forecast has been developed for the cabbage aphid (*Brevicoryne brassicae*) (FV 121).

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EXPERIMENTAL

Objective 1. Obtain field-monitoring data for diamond-back moth, small white butterfly, cabbage moth and garden pebble moth from geographically separate areas of brassica production.

1.1 Locate monitoring sites in commercial crops in Devon/Cornwall, Kent, Lancashire, Bedfordshire (3 sites in each year). The aim is to obtain information from regions which are geographically separate from those used to develop the forecasts in FV 163. It should also be possible to use the less detailed information obtained for the HRI Kirton Pest Monitoring Service to validate the forecasts in South Lincolnshire, by combining information from all five monitoring sites. (ADAS, HRI)

The three monitoring plots funded by this project (managed by ADAS) were located on commercial farms in Devon, Kent and Lancashire. The HRI Pest Monitoring Service monitored five sites in Lincolnshire (in commercial fields and at HRI Kirton).

	County	Location	Origin of data
1	Devon	Moreleigh	Current project
2	Kent	Canterbury	
3	Lancashire	Lathom	
4	Lincolnshire	HRI Kirton	Data provided by HRI Pest Monitoring
5		Butterwick	Service
6		Wainfleet	
7		Donington	
8		Moulton	

1.2 Set up plots of Brussels sprouts (minimum 400 plants) to monitor caterpillar pests. The plots should be insecticide-free. (ADAS, HRI)

Insecticide free monitoring plots were established at all the sites.

1.3 Set up pheromone traps and water traps to monitor adult moths and butterflies at each site. (ADAS, HRI)

Pheromone traps to monitor diamond-back moth, cabbage moth, garden pebble moth and silver Y moth were set up at each of the sites. Yellow water traps were used to monitor small white butterflies.

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1.4 Each week from May to October, identify and count all eggs, caterpillars and pupae (where appropriate) of each species of caterpillar pest on 100 plants at each site. Service pheromone and water traps and record numbers of adults of each species captured. (ADAS, HRI)

Pest numbers were recorded each week.

Objective 2. Refine and validate forecasts for diamond-back moth, small white butterfly, cabbage moth and garden pebble moth.

2.1 Refine forecasts of the timing of caterpillar attacks. (HRI)

The caterpillar forecasts, which were developed originally in FORTRAN, were reprogrammed for use in the MORPH decision-support software.

2.2 Collate monitoring data for each species. (HRI)

Data for each of the species sampled in 1999 were tabulated and summarised graphically (Figures 1-5). Numbers of all species, apart from the silver Y moth, were low at all sites.

Diamond-back moth
No moths or caterpillars were found at the monitoring site in Devon. Very few moths were captured at the site in Kent and no caterpillars were found. Moths and caterpillars were found at all other sites, and their numbers were greatest at Butterwick in Lincolnshire (Figure 1). However, there was never more than one caterpillar/plant. Caterpillars were present from July until September.

Small white butterfly
Eggs, caterpillars and/or butterflies were found at most sites, although in very low numbers (Figure 2). The largest numbers of butterflies and caterpillars were found during August and September.

Cabbage moth
Very low numbers of cabbage moth adults and caterpillars were found at two sites, in Kent and at Kirton (Figure 3). Few were found elsewhere.

Garden pebble moth
Again, low numbers of garden pebble moths were found at two sites only (in Kent and Lincolnshire). Most caterpillars were found during September.

Silver Y moth
The silver Y moth was the most numerous lepidopterous pest at all sites. The largest numbers of moths were captured in mid-late July and the largest numbers of caterpillars were often found soon afterwards. Although moth numbers were relatively high, there was never more than one caterpillar/plant.

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2.3 Identify the start and end of each period of infestation for each species at each site. (HRI)

The periods during which caterpillars were found at each site are shown in Table 1. Diamond-back moth caterpillars were present in crops from late June until October. This is a migrant species and the timing of immigration can vary considerably from year to year.

All of the small white butterfly caterpillars found on plants were the progeny of either the second or third generations, confirming that the first generation is the least important.

Silver Y moths were found at all sites. Caterpillars were found generally from late June through to September.

2.4 Validate caterpillar forecasts. (HRI)

Because caterpillar populations were so small in 1999, it was difficult to validate the forecasts in detail. Comparisons between the periods when small white butterfly, cabbage moth and garden pebble moth caterpillars were found and forecasts of 10% egg hatch and 90% pupation (for meteorological stations at Chivenor (Devon), Charing (Kent), Crosby (Lancashire) and Holbeach (Lincolnshire) respectively) are shown in Tables 2-4. In general, caterpillars were found in periods that would be expected using the forecasts. The numbers of diamond-back moths captured were too small to use the forecast effectively.

Monitoring data collected in south Lincolnshire during 1996-98 as part of the HRI Kirton Pest Monitoring Service have been collated and will be compared with appropriate forecasts in the second year of the project.

Objective 3. Determine whether it would be possible to use trap catches of adults to determine the risk of caterpillar damage in particular localities.

3.1 Calculate the numbers of adults captured and the numbers of caterpillars found per plant at each monitoring site. Use data collected during the current project and during the previous LINK project (FV 163). (HRI)

The data from all sites were collated. The numbers of adults captured and eggs, caterpillars and pupae found/plant were calculated for each site.

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The data sets available at present are as follows:

Years	County	Site	No. data sets
1995-1997	Yorkshire	HRI Stockbridge House	3
1995-1999	Lincolnshire	HRI Kirton	5
1995-1997	Cambridgeshire	ADAS Arthur Rickwood	3
1995-1997	Warwickshire	HRI Wellesbourne	3
1996-1999	Lincolnshire	Commercial crops x 4	16
1999	Devon	Commercial crop	1
1999	Kent	Commercial crop	1
1999	Lancashire	Commercial crop	1

Not all species were present at every site.

3.2 Use regression and other statistical techniques to determine the relationship between the number of adults captured and the numbers of caterpillars infesting untreated plants in the monitoring plots. (HRI)

The first analyses were made using data on the diamond-back moth, as this was the most numerous pest caterpillar during 1995-99 and provided the largest data set. The monitoring data were summarised by separating the periods of moth and caterpillar activity into generations. There was an average of 35 days between the dates when peak numbers of first and second generation caterpillars were found and 39 days between the second and third generations.

The numbers of moths captured/trap/day and the numbers of caterpillars found/plant at each peak were determined. Peak numbers of first generation moths were captured between 14 May and 11 August, depending on the year and site. On average, peak numbers of caterpillars were found 16, 15 and 27 days after peak numbers of moths were captured, during the first, second and third generations respectively.

The numbers of caterpillars found at each peak were plotted against the numbers of moths caught in traps. The data are presented in Figure 6. As many as 78 moths/trap/day and 41 caterpillars/plant were found at the peak. The line fitted by regression to the combined data was statistically significant ($p<0.001$), accounting for 51% of the variance, although the data were very variable. The capture of approximately 6 moths/trap/day was equivalent to an infestation level of 1 caterpillar/plant.

The numbers of eggs found at each peak were plotted against the numbers of moths. Egg numbers were not recorded at every site. The data and line fitted by regression are shown in Figure 7. The fitted line accounted for 52% of the variance.

3.3 Determine whether this relationship is consistent between sites and years. (HRI)

When separate lines were fitted for each of the three generations (Figure 6 – no. caterpillars vs no. moths)), they followed a trend, the line for the first generation having the steepest slope and the line for the third generation the shallowest. Further analyses will be made to determine the effects of site and year on this relationship.

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The numbers of moths and caterpillars found at the peaks of the first and second generations were compared. Similar numbers of moths were captured in each generation, but four times as many caterpillars were found at the peak of the first generation. This corresponds to the trend shown in Figure 6. However, once again, the data were very variable.

DISCUSSION

Caterpillar infestations were light during 1999 at all the monitoring sites. This makes forecast validation more difficult because estimates of the timing of each generation are less accurate when insect numbers are small.

As there were no instances where more than one caterpillar/plant was found, this implies that few insecticide treatments would have been required for caterpillar control in 1999. This was supported by the results of supervised control experiments at HRI Kirton (FV 194), where few sprays were applied to control caterpillars and even the untreated control plot suffered very slight damage at harvest.

The information collected in 1999 contributed to another objective of the project, which is to determine the relationship between the numbers of adults captured in pheromone or water traps and the numbers of caterpillars found on untreated plants. There is now a large set of data available for the diamond-back moth, particularly when the generations are considered separately, and there was a relationship between moth and caterpillar numbers (and moth and egg numbers) when they were both plotted on log scales. The analyses will be developed further in the second year of the project.

Because the diamond-back moth is a migrant species, pheromone traps are the most effective way of determining when immigration occurs. The results presented here indicate that not only may trap captures be used to demonstrate the timing of immigration, but they might be used also to indicate the potential size of the infestation, if the crop remains untreated. Captures of approximately 6 moths/trap/day were equivalent to 1 caterpillar/plant.

INTERIM CONCLUSIONS

- The data collected in 1999 confirm that the diamond-back moth and small white butterfly are the most widespread caterpillar pests of brassicas in the UK. The silver Y moth is common also. The cabbage moth and garden pebble moth are localised pests.
- Caterpillar infestations were slight in 1999 and there were no instances where more than one caterpillar of each species/plant was found. This implies that few insecticide treatments would have been required for caterpillar control. This was supported by the results of supervised control experiments at HRI Kirton (FV 194), where few sprays were applied to control caterpillars and even the untreated control plot suffered very slight damage.

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- Diamond-back moth caterpillars were present in crops from late June until October. As this is a migrant species, the timing of immigration varies from year to year.
- All the small white butterfly caterpillars found on plants were the progeny of either the second or third generations, confirming that the first generation is the least important.
- Silver Y moths were captured at all sites. Previous studies suggested that they were not important pests of brassicas. Determination of the relationship between the numbers of moths trapped and the numbers of caterpillars found on untreated plants may support this.
- There was a relationship between the numbers of diamond-back moth caterpillars found at the peak of each generation and the numbers of moths captured in pheromone traps. In future it may be possible to use pheromone trap captures to trigger the start of crop sampling i.e. at the stage when an infestation is likely to become damaging.

ACKNOWLEDGEMENTS

Many thanks to Jennie Blood Smyth and her colleagues in ADAS for monitoring insects at three of the sites and to growers in Lincolnshire for providing plots of insecticide free Brussels sprouts for the HRI Kirton Pest Monitoring Service. We are grateful to the Horticultural Development Council for supporting this project.

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TABLES

Table 1. The periods during which caterpillars of each species were found on plants at the 1999 monitoring sites.

	Diamond-back moth	Small white butterfly	Cabbage moth	Garden pebble moth	Silver Y moth
Devon		11 Aug-8 Sep			30 Jun-8 Sep
Kent		16 Jul-4Oct	6 Sep-4 Oct	21 Sep-4 Oct	8 Jul-21 Sep
Lancashire	2 Jul–3 Sep	6 Aug-21 Sep			16 Jul-3 Sep
Lincolnshire					
Kirton	7 Jul–21 Oct	19 Aug-7 Oct	15 Jul-19 Aug		7 Jul-23 Sep
Butterwick	24 Jun–22 Sep	4 Aug-29 Sep			7 Jul-3 Nov
Donington	24 Jun–14 Oct			9-16 Sep	22 Jul-5 Aug
Moulton	24 Jun–7 Oct	4-11 Aug			1 Jul-23 Sep
Wainfleet	14 Jul–13 Oct	28 Jul – 13 Oct			14 Jul-25 Aug

Table 2. The periods during which small white butterfly caterpillars were found on plants at the 1999 monitoring sites compared with forecast predictions (for meteorological stations at Chivenor (Devon), Charing (Kent), Crosby (Lancashire) and Holbeach (Lincolnshire) respectively).

	Period when caterpillars found	Generation 2 10 % caterpillars	Generation 2 90% pupae	Generation 3 10% caterpillars
Devon	11 Aug-8 Sep	5 Aug	19 Sep	27 Sep
Kent	16 Jul-4 Oct	28 Jul	2 Sep	10 Sep
Lancashire	6 Aug-21 Sep	4 Aug	24 Sep	6 Oct
Lincolnshire		2 Aug	16 Sep	25 Sep
Kirton	19 Aug-7 Oct			
Butterwick	4 Aug-29 Sep			
Donington				
Moulton	4-11 Aug			
Wainfleet	28 Jul – 13 Oct			

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Table 3. The periods during which cabbage moth caterpillars were found on plants at the 1999 monitoring sites compared with forecast predictions (for Charing and Holbeach respectively).

	Period when caterpillars found	Generation 1 10 % caterpillars	Generation 1 90% pupae	Generation 2 10% caterpillars
Kent	6 Sep-4Oct	17 Jun	10 Aug	2 Sep
Lincolnshire *Kirton*	15 Jul-19 Aug	19 Jun	18 Aug	11 Sep

Table 4. The periods during which garden pebble moth caterpillars were found on plants at the 1999 monitoring sites compared with forecast predictions (for Charing and Holbeach respectively).

	Period when caterpillars found	Generation 1 10 % caterpillars	Generation 1 90% pupae	Generation 2 10% caterpillars	Generation 2 90% pupae
Kent	21 Sep-4 Oct	26 May	18 Jul	7 Aug	2 Oct
Lincolnshire *Donington*	9-16 Sep	27 May	21 Jul	13 Aug	18 Oct

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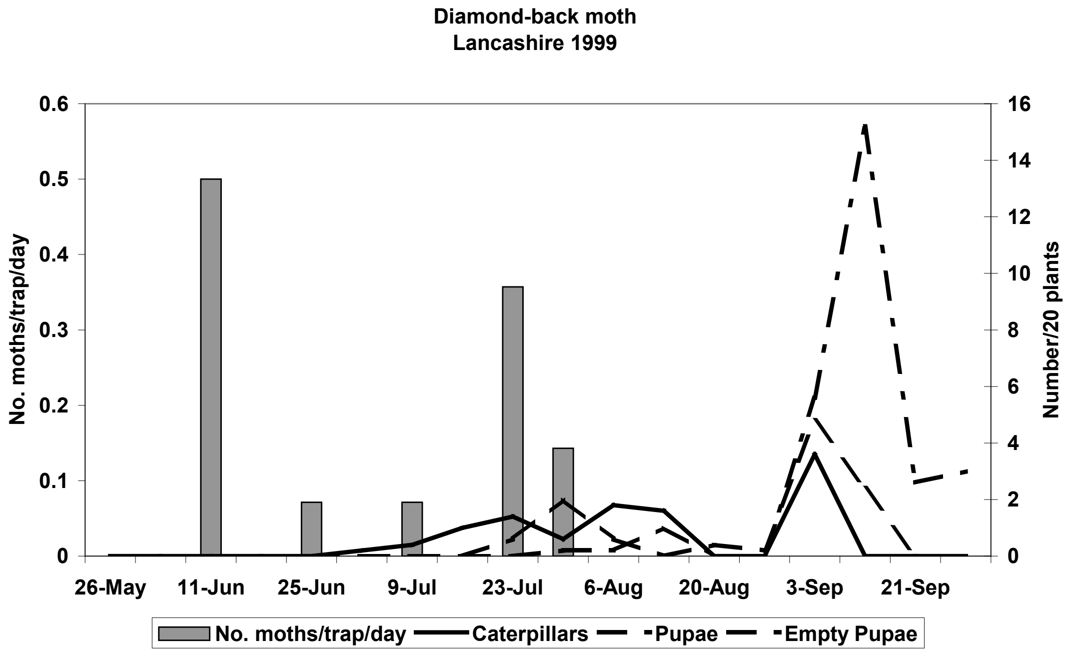
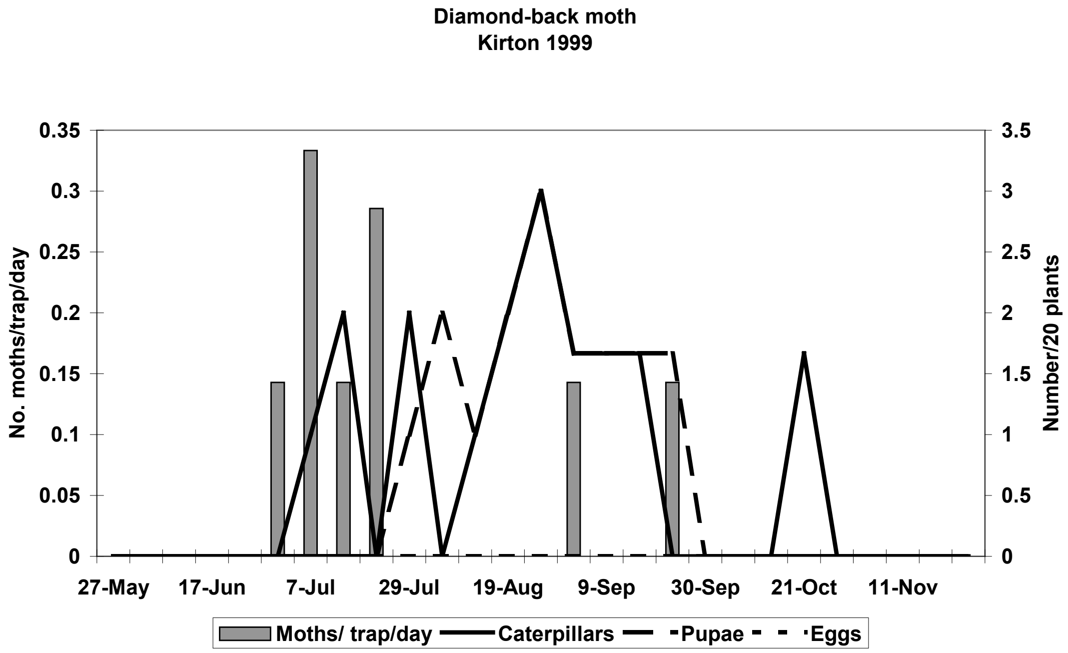
FIGURES

Figure 1. The numbers of diamond-back moths sampled in 1999.





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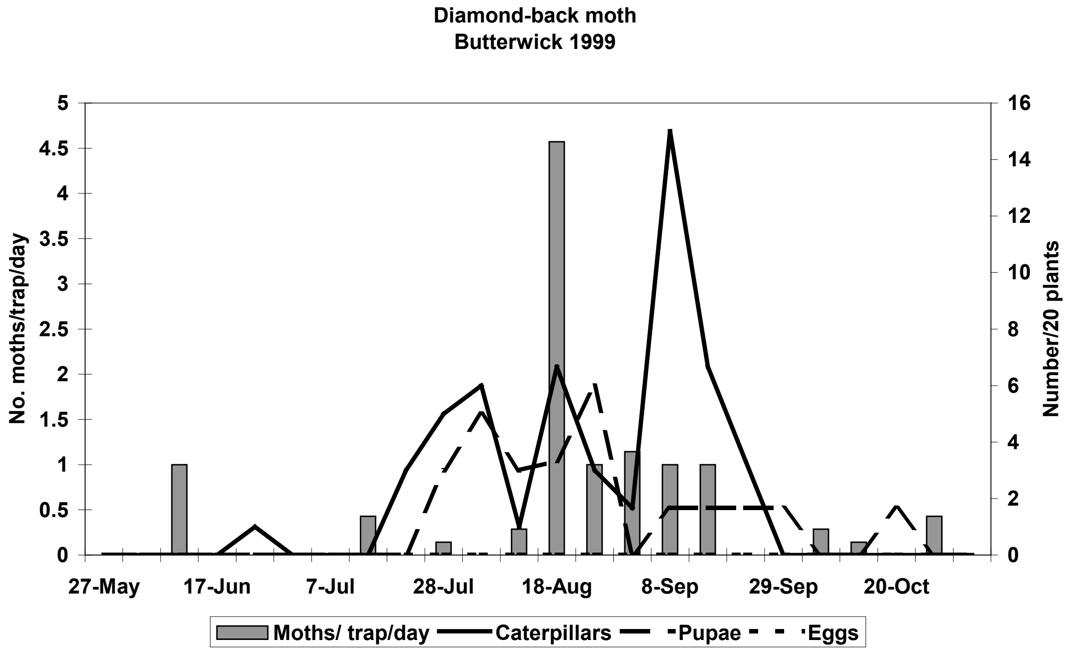

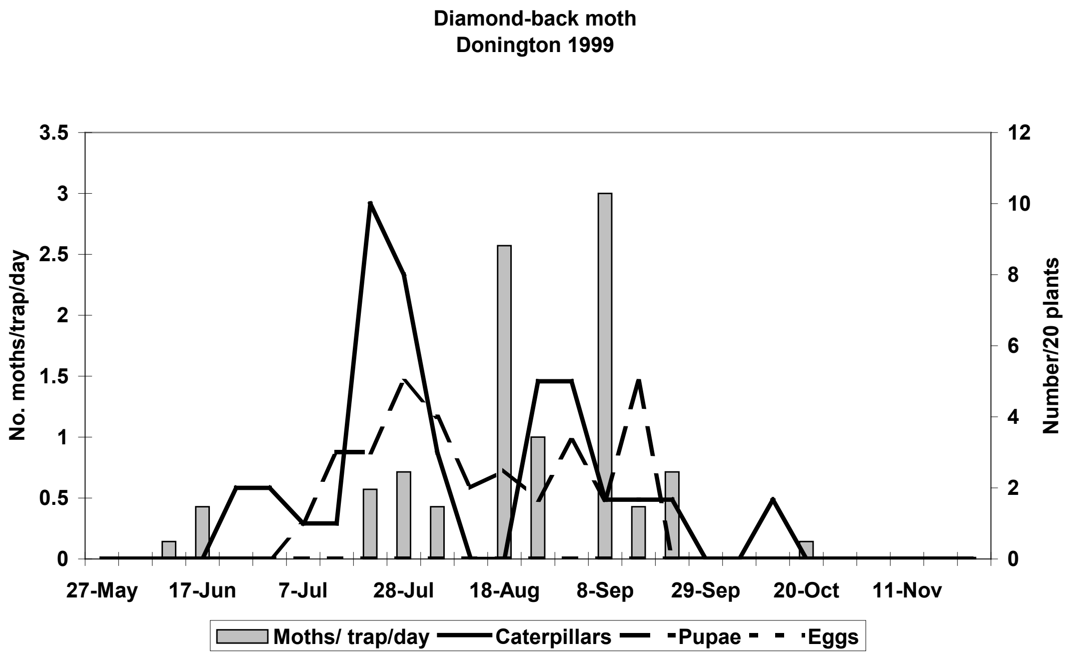

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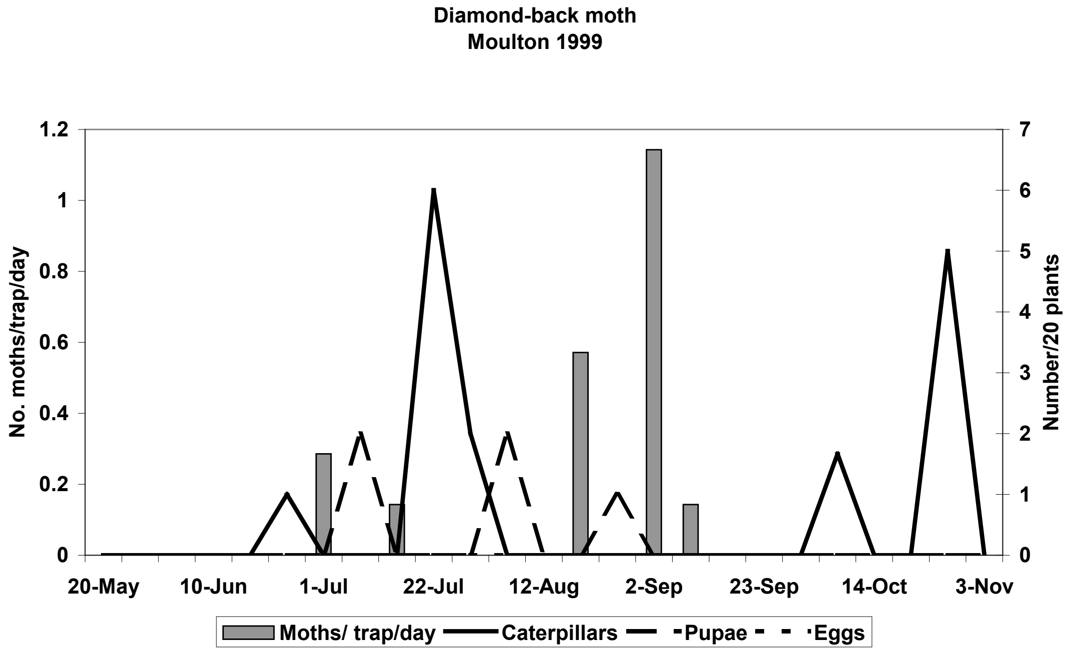
Figure 1. The numbers of diamond-back moths sampled in 1999.



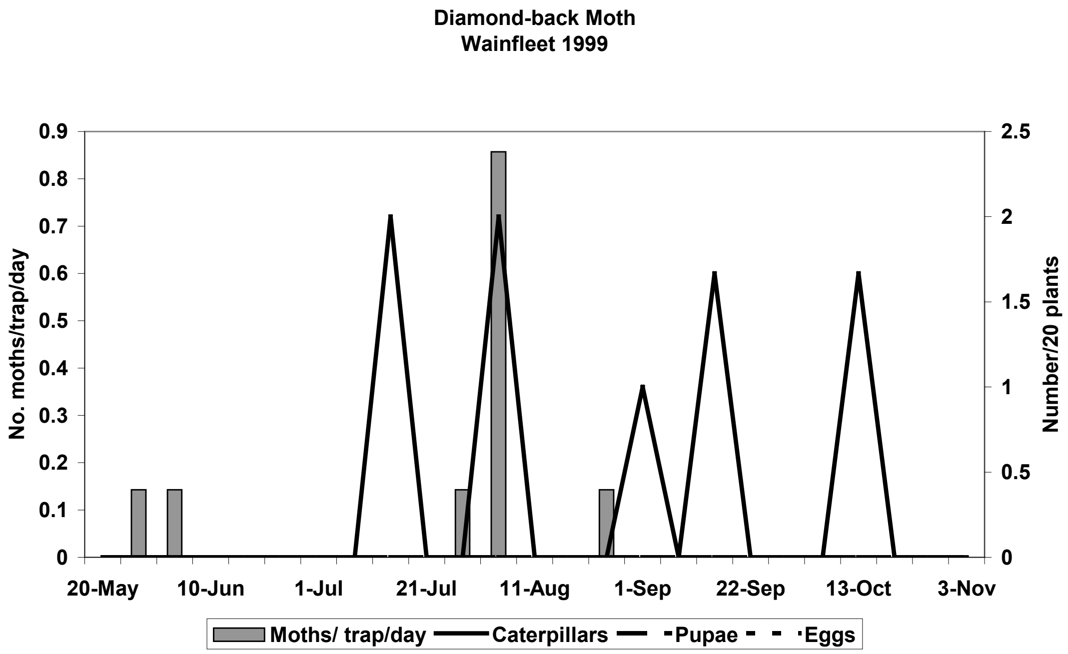


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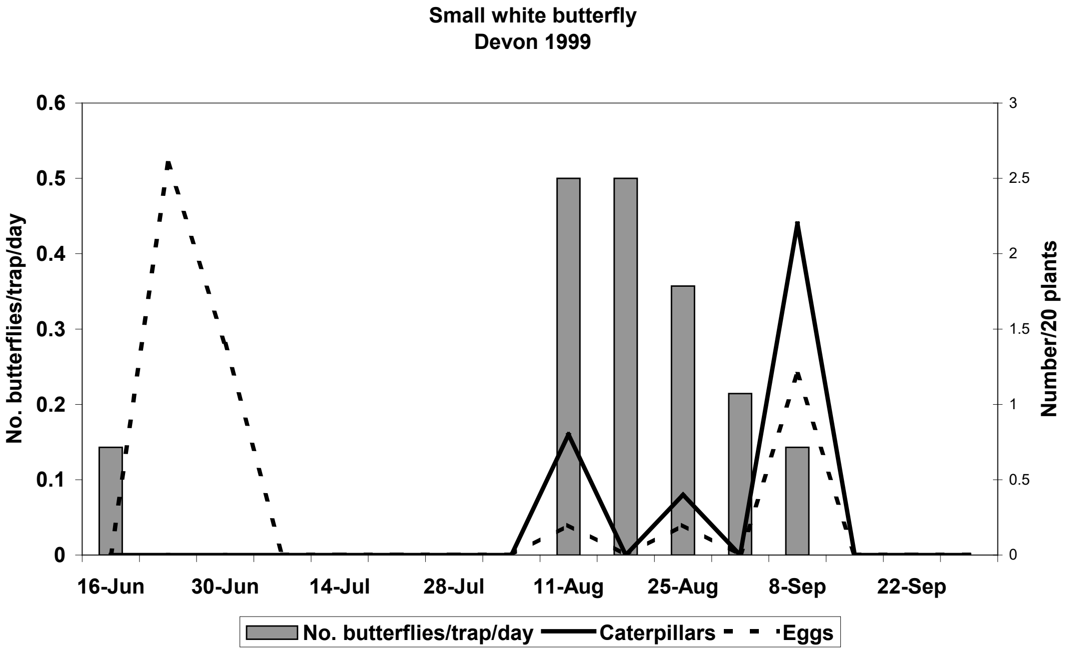
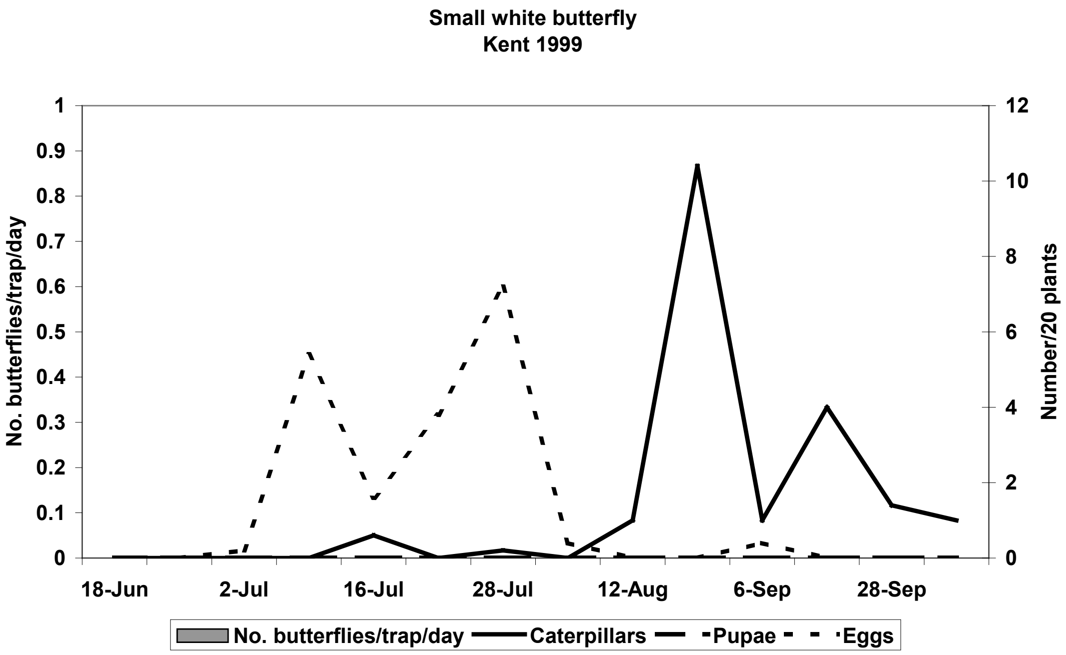
Figure 2. The numbers of small white butterflies sampled in 1999.





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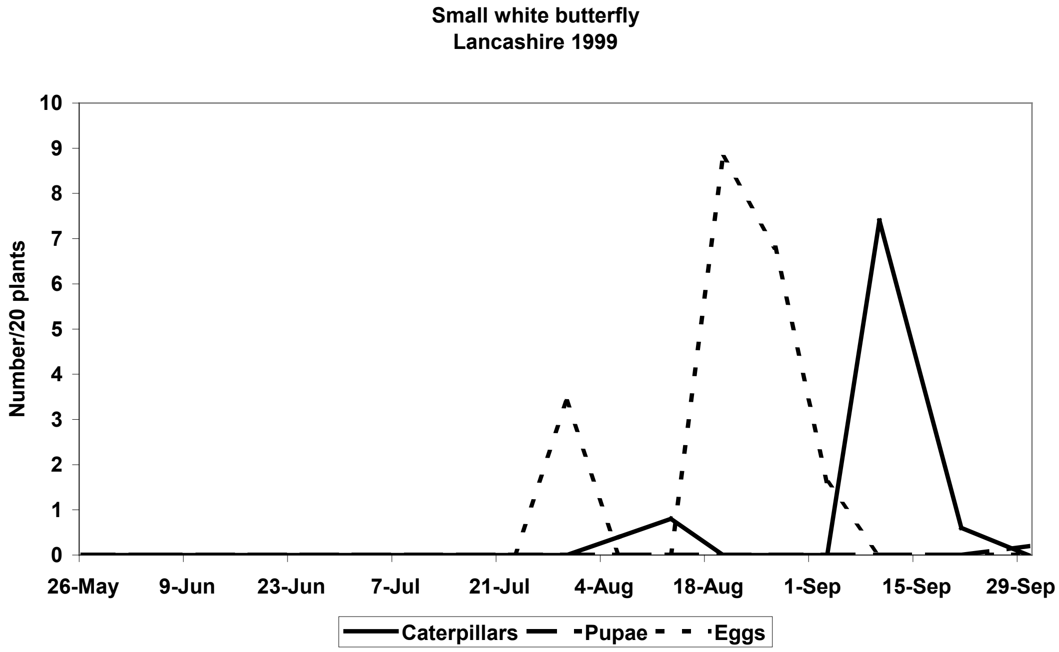

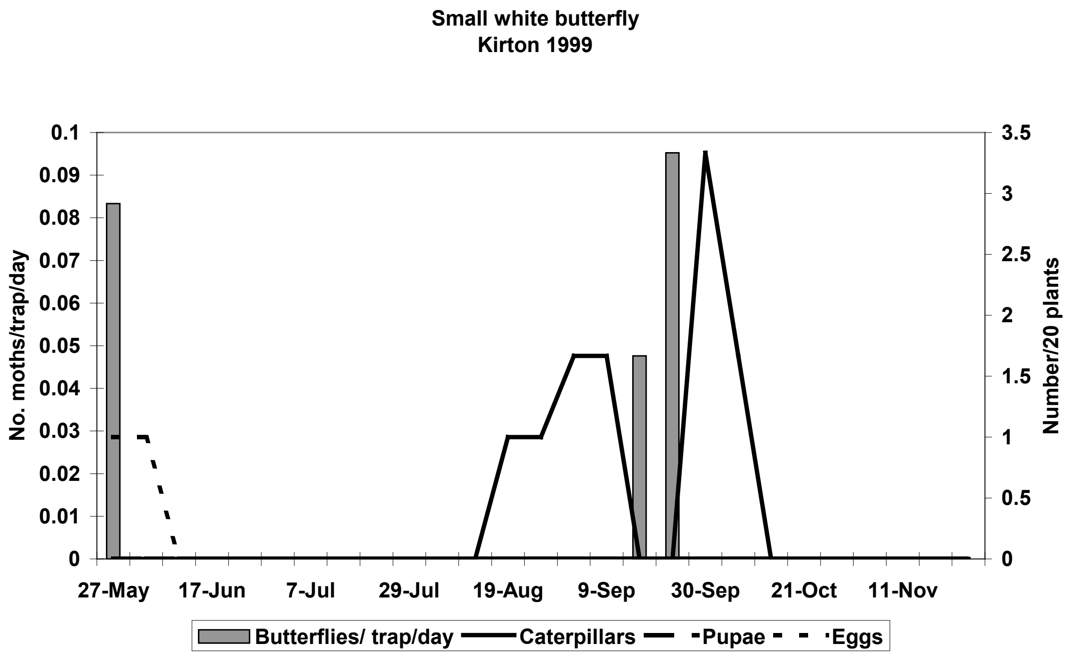

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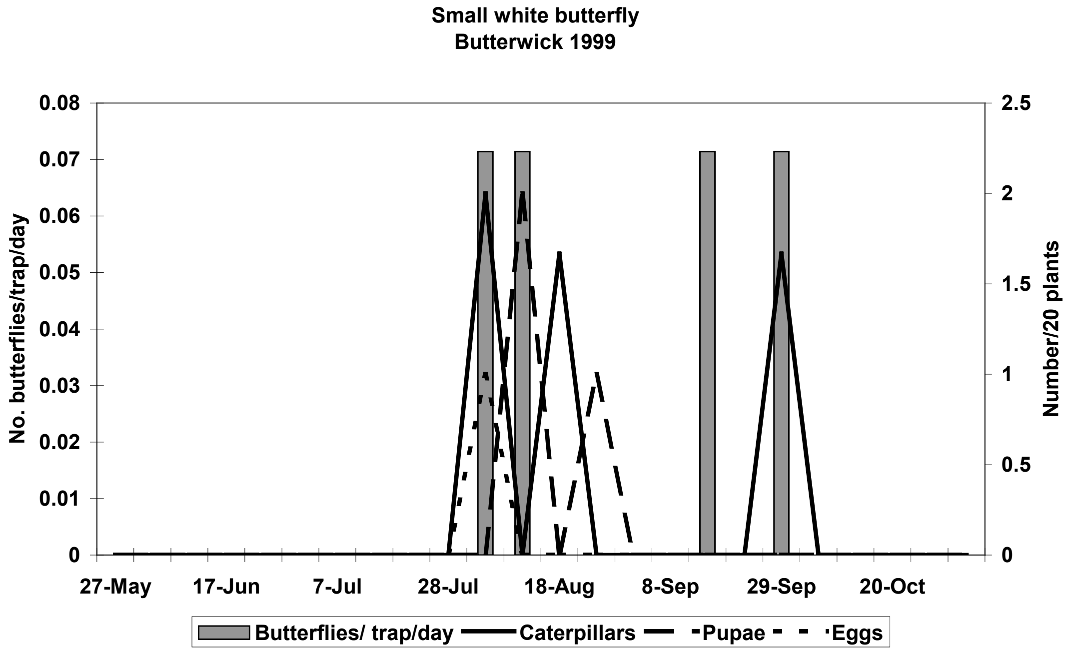

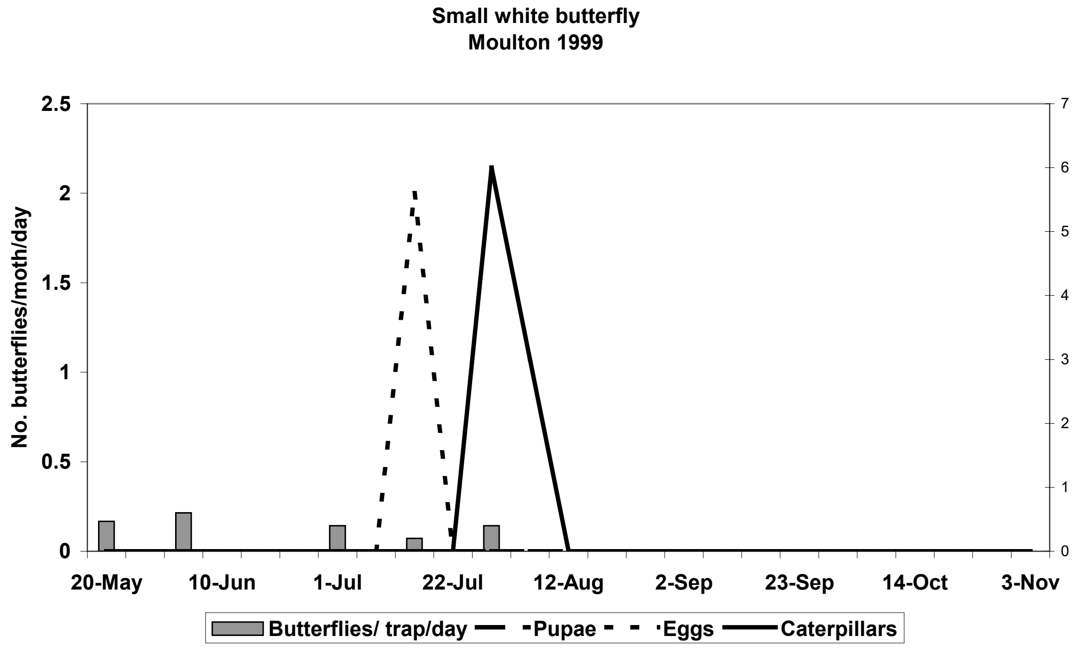

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Figure 2. The numbers of small white butterflies sampled in 1999.

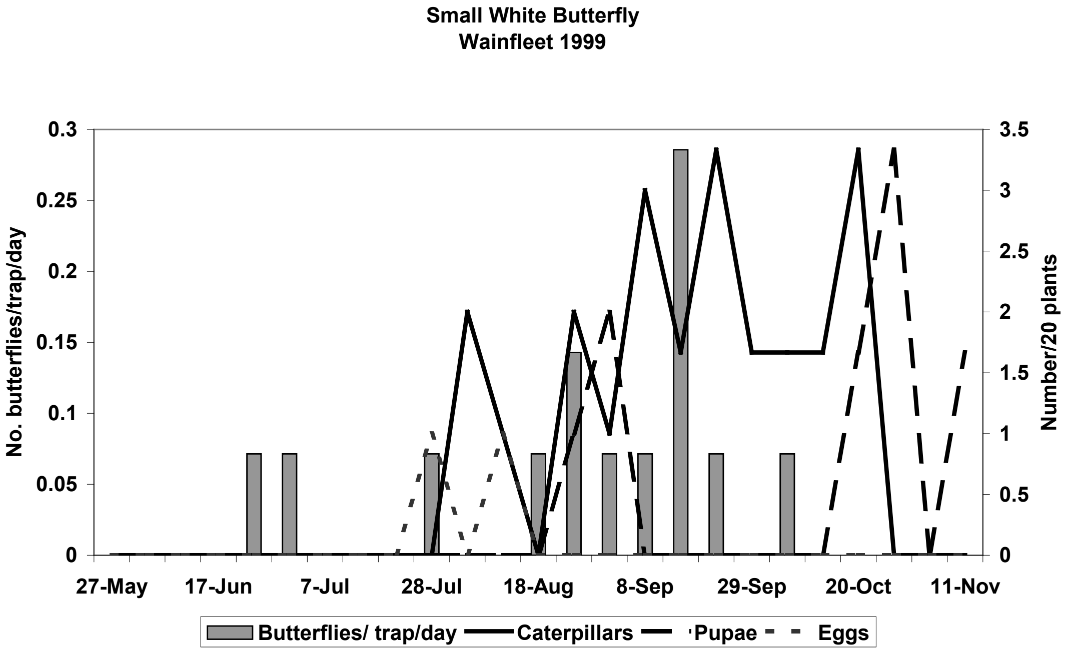

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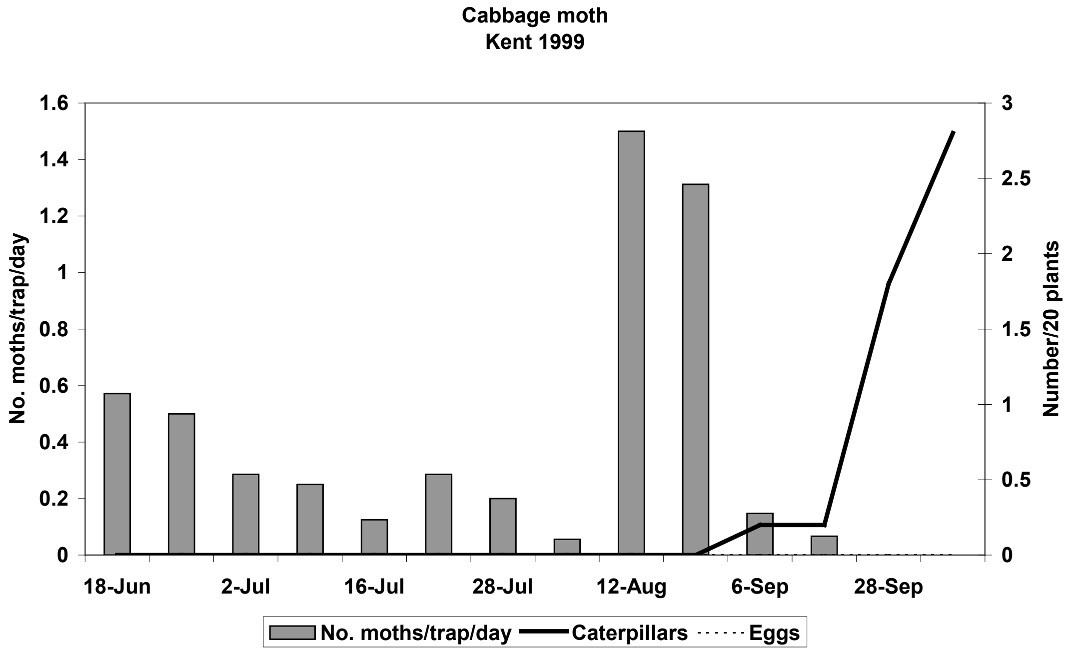
Figure 3. The numbers of cabbage moths sampled in 1999.



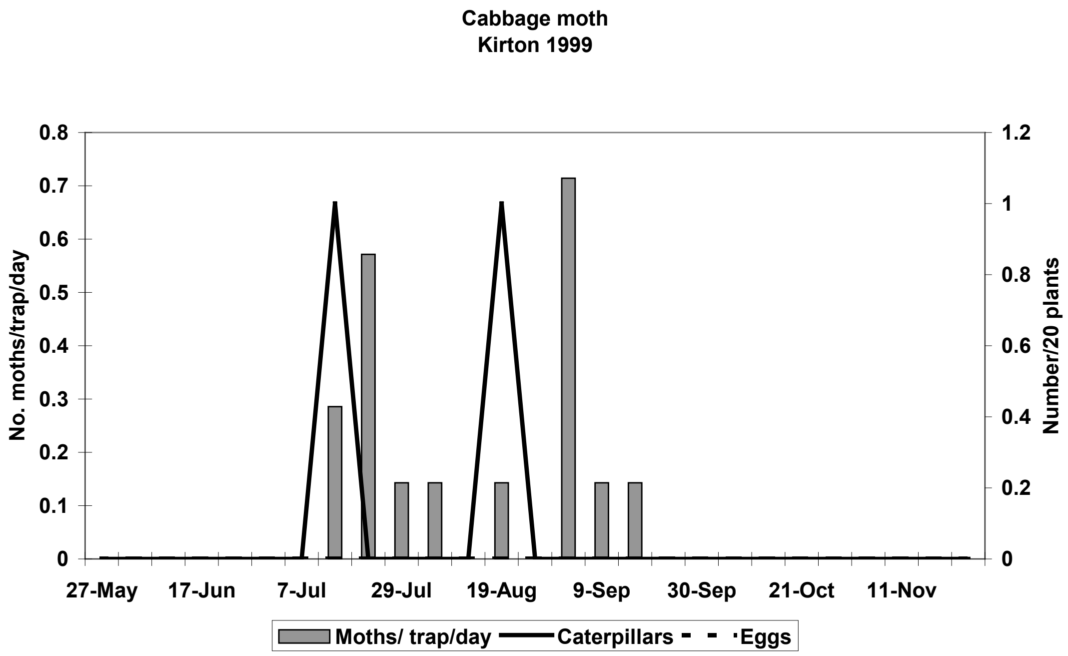


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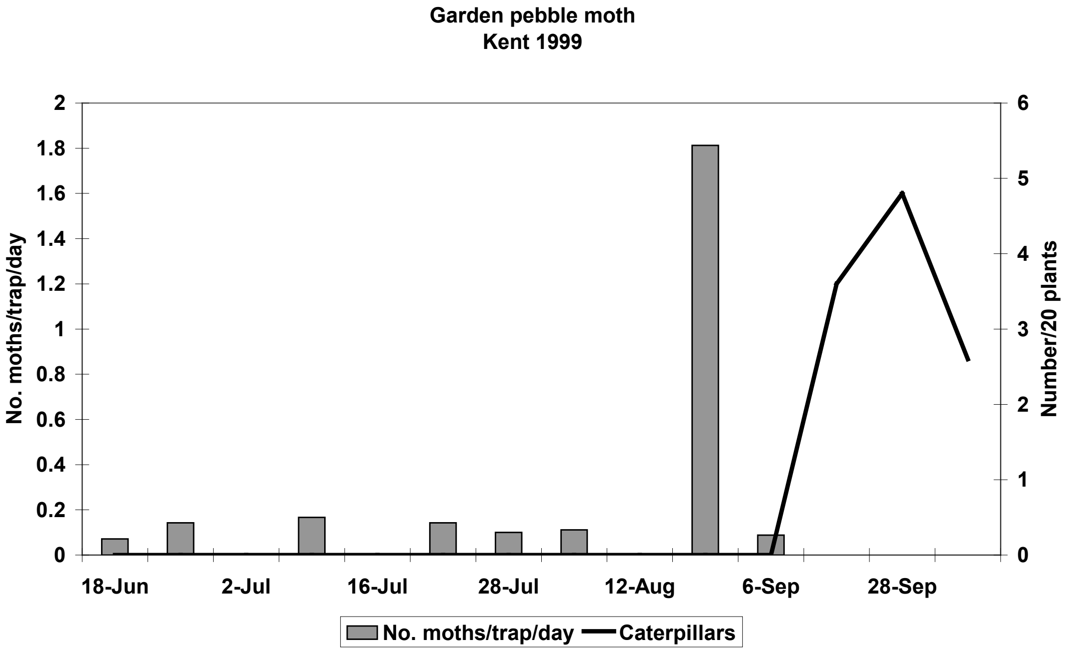
Figure 4. The numbers of garden pebble moths sampled in 1999.



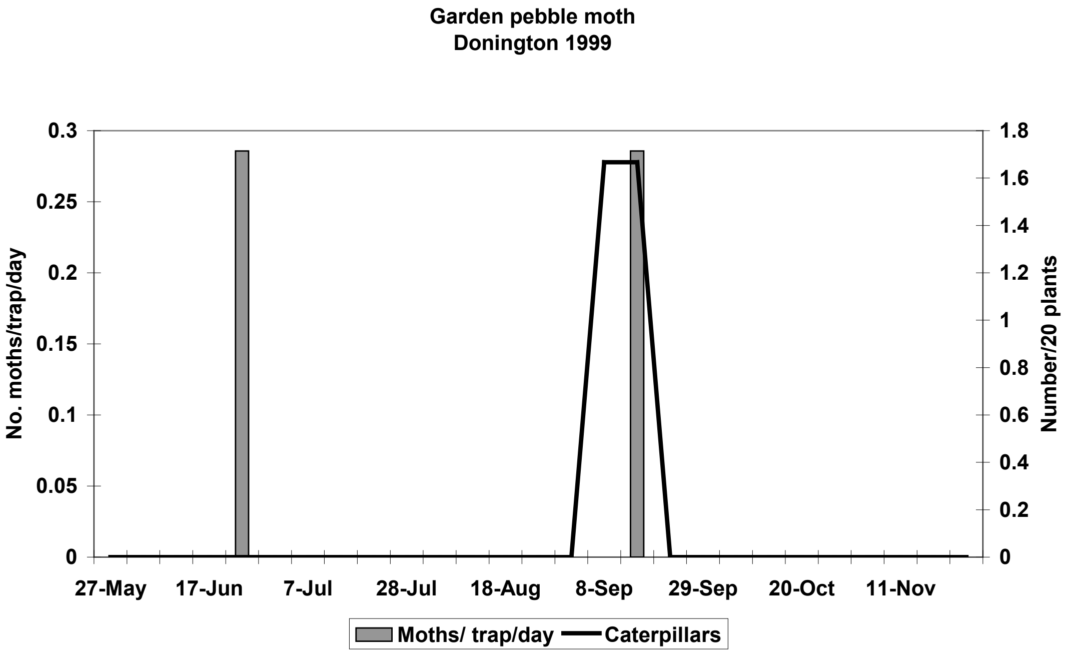


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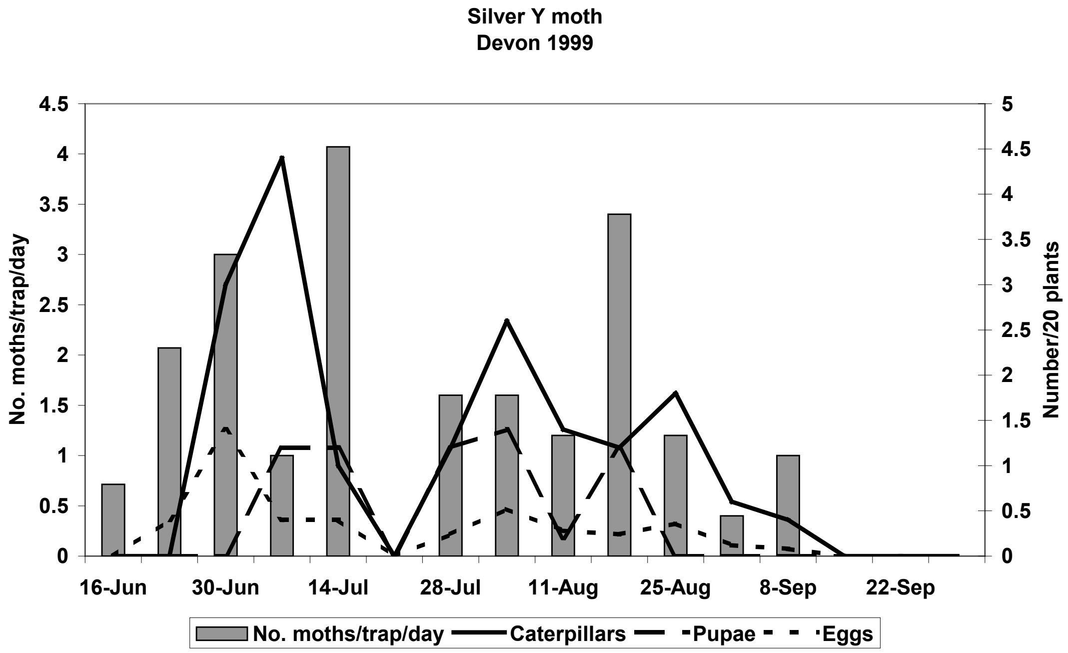
Figure 5. The numbers of silver Y moths sampled in 1999.



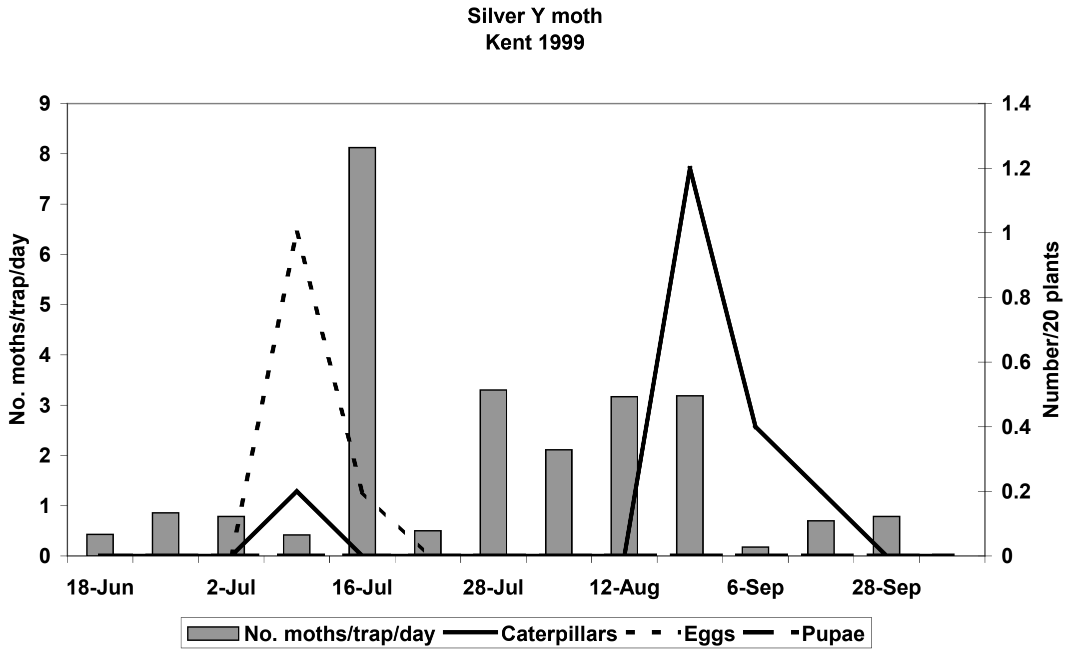


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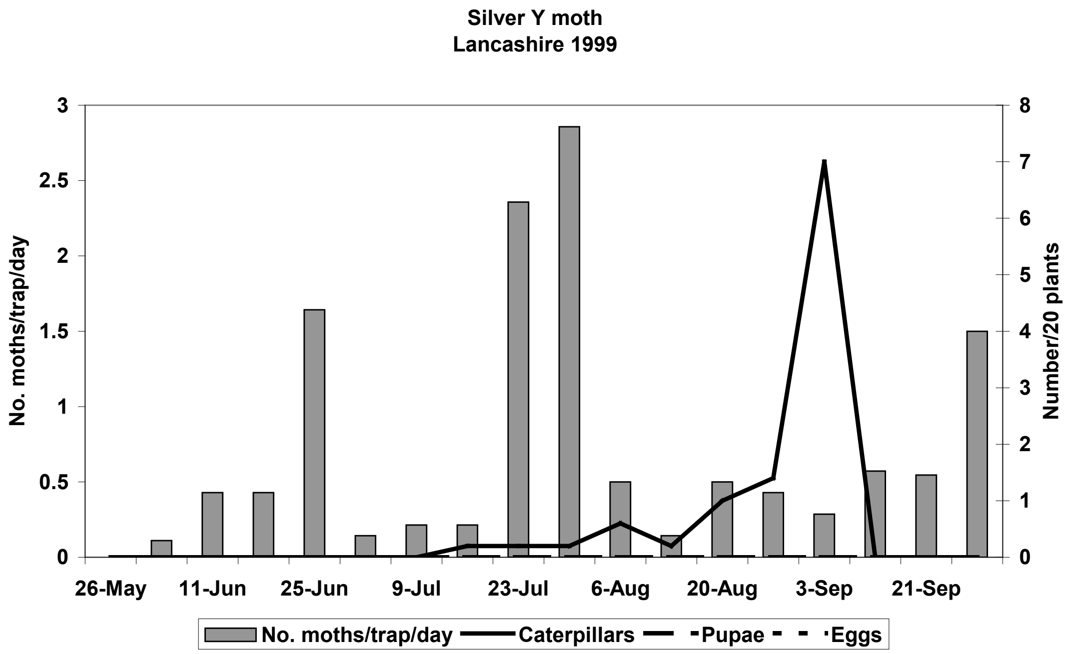
Figure 5. The numbers of silver Y moths sampled in 1999.



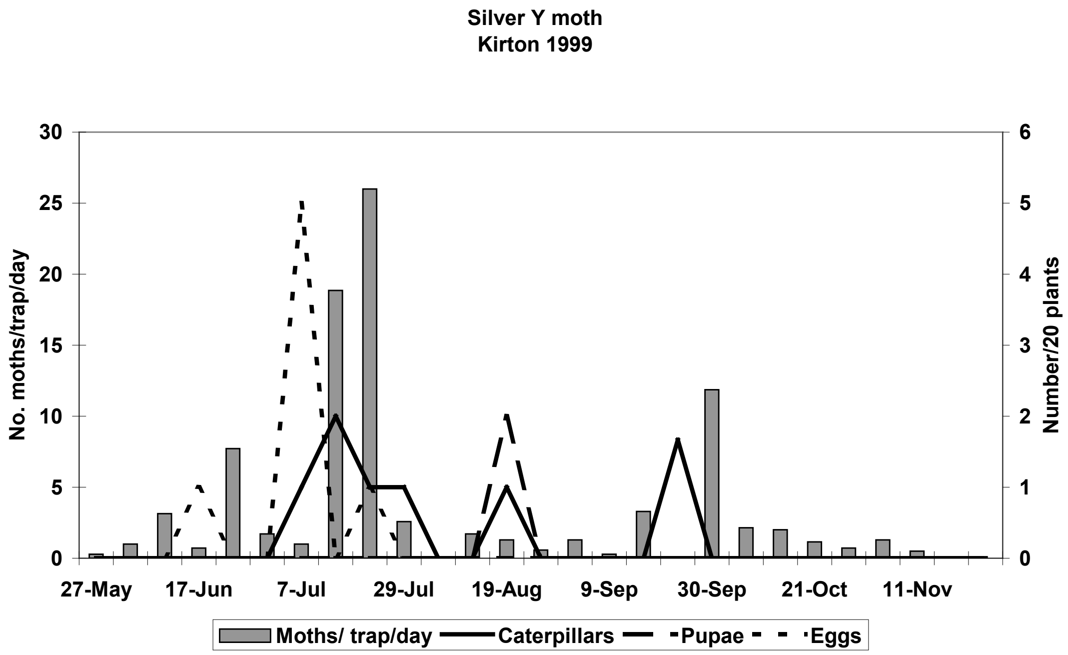


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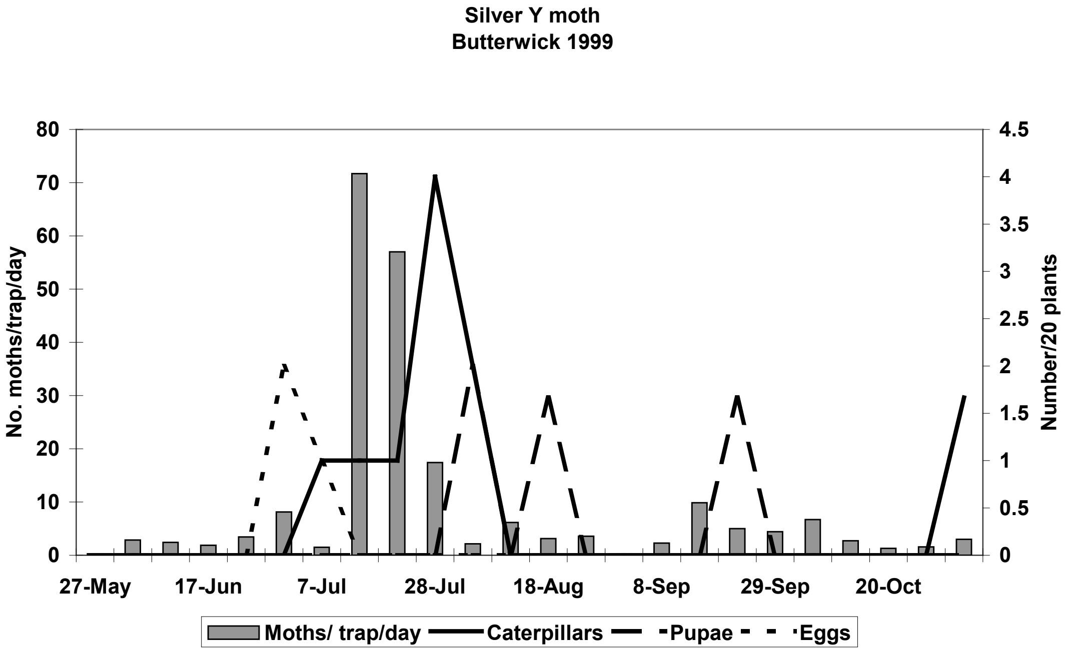
Figure 5. The numbers of silver Y moths sampled in 1999.



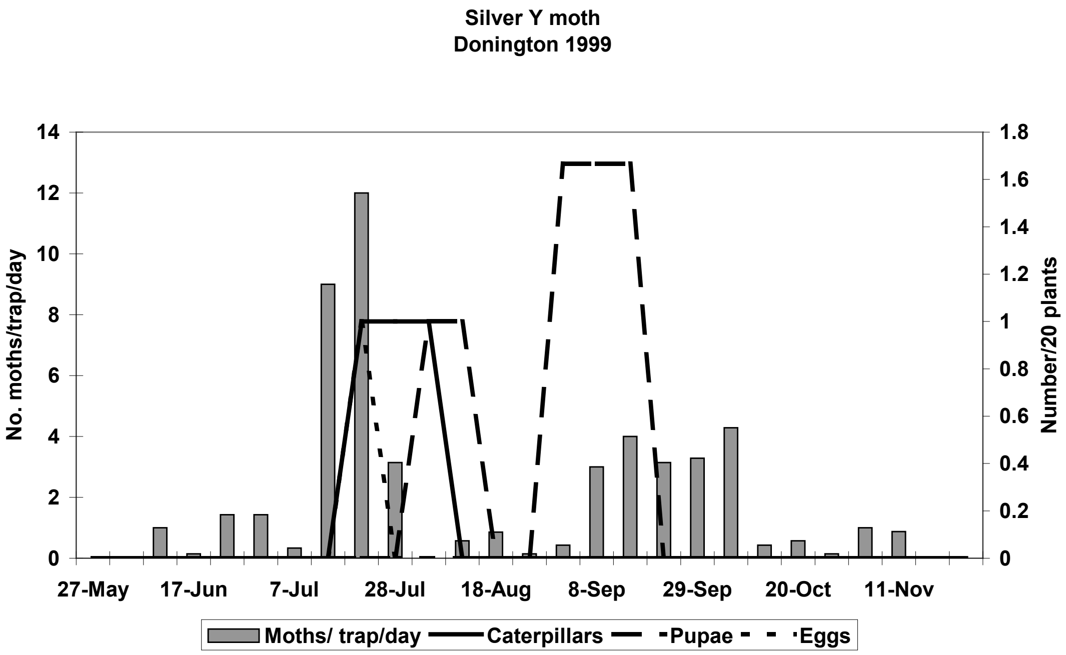


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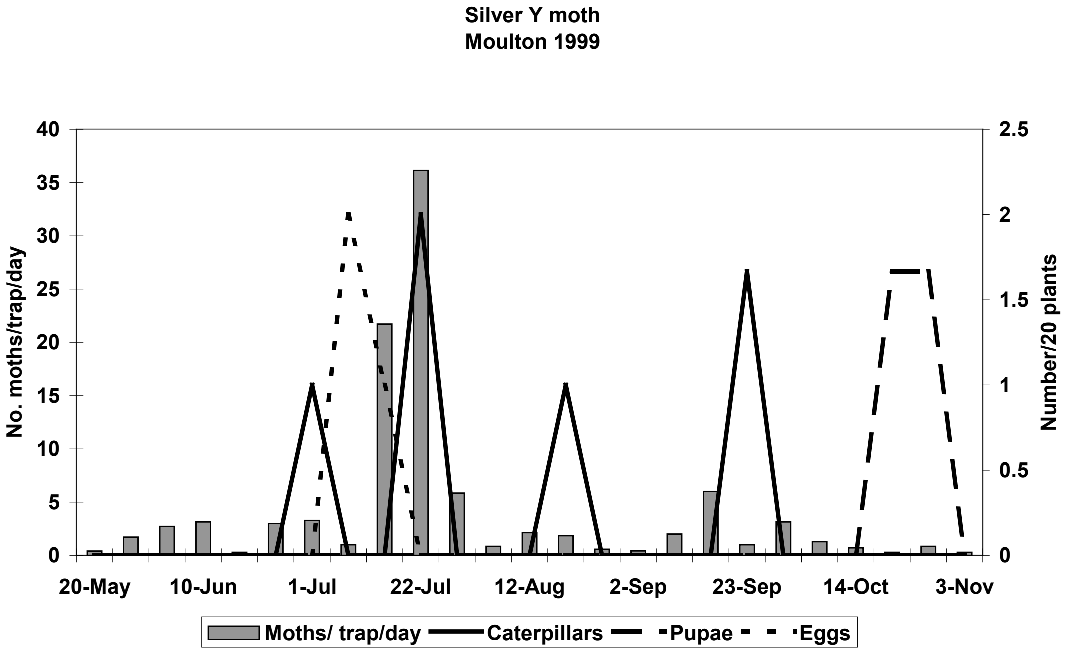
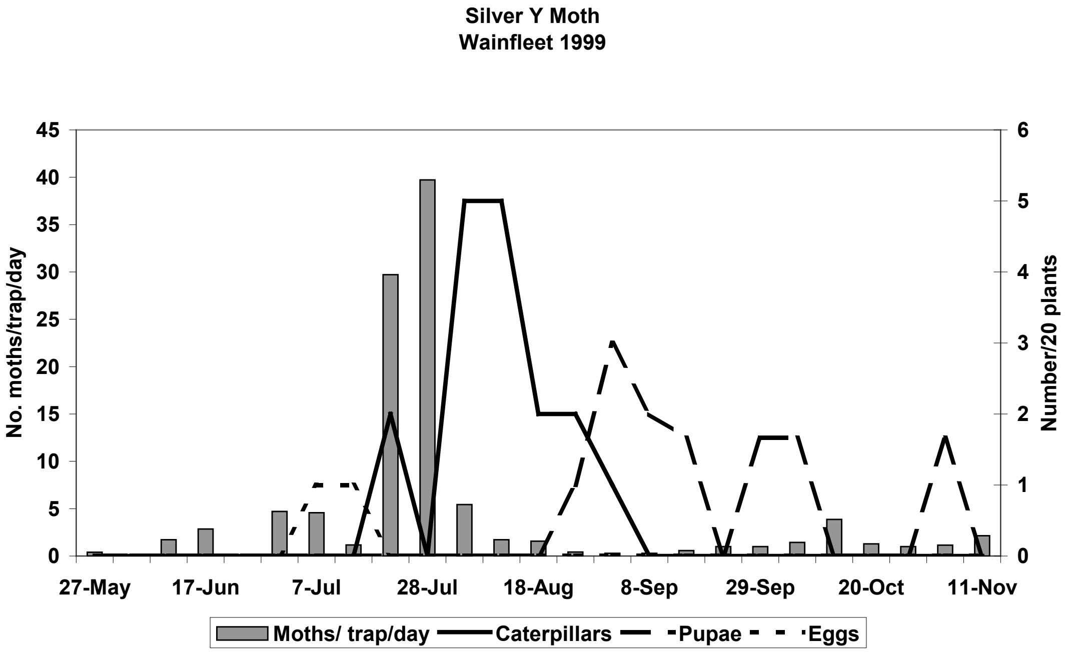
Figure 5. The numbers of silver Y moths sampled in 1999.





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