Report prepared for the
British Potato Council

WIREWORM BIOLOGY,
RISK ASSESSMENT & CONTROL

Annual Report 2001

By

Dr William E Parker

ADAS
Woodthorne
Wolverhampton
WV6 8TQ

Tel.: 01902 754190
Fax: 01902 693166
Email: bill.parker@adas.co.uk

TABLE OF CONTENTS

Summary

In 2001, work aimed at improving wireworm risk assessment systems by evaluating adult trapping systems was done at Buckfastleigh (Devon), Llanafan (Ceredigion) and Unstone (Yorkshire). The efficacy and specificity of novel click beetle (adult wireworm) pheromone traps were assessed and compared with beetle catches obtained using simple ‘grass’ traps. Soil sampling and bait trapping for wireworms in the soil was done in the spring and autumn to allow the relationship between pheromone trap catches and soil populations of wireworms to be investigated.

The pheromone traps were effective and specific in trapping adults of all three main species of wireworms of agricultural importance (*Agriotes obscurus*, *A. lineatus* and *A. sputator*). The numbers of beetles caught throughout the key adult flight period (which varied between May and July in 2001) were usually one and occasionally two orders of magnitude higher than the numbers of wireworms found in the soil. This confirmed the results obtained in 2000 at the same field sites in the UK, and was consistent with work done with the same pheromone traps on a range of *Agriotes* species throughout Europe. Pheromone traps are likely to be considerably more sensitive at detecting wireworm-infested fields than traditional soil sampling or bait trapping techniques, which are very dependent on soil conditions at the time of sampling.

There was a significant relationship between catches of beetles in pheromone traps and wireworm populations found in the previous autumn or spring. No significant relationship was found between pheromone trap catches of beetles and subsequent wireworm populations. However, the data set was limited, and further investigation is required to evaluate this latter relationship more fully.

Simple ‘grass’ traps were also an effective means of capturing adults at some sites, but the efficacy of these traps was much more variable as they are particularly prone to poor performance in wet weather. The association (in terms of coincidence of peaks of beetle activity) between beetle catches in pheromone traps and ‘grass’ traps was variable but usually poor. No significant relationship between the number of beetles caught in grass trap catches and those caught in pheromone traps was found

General introduction

Wireworms, the larvae of click beetles (Coleoptera: Elateridae), are recognised world-wide as pests of potato. Up to 39 species from 12 genera have been recorded as attacking potato, although the number of important species in any one global region is constant and relatively low (Jansson & Seal, 1994). The species that most commonly attack potato in the UK are *Agriotes lineatus*, *A. sputator* and *A. obscurus*. Other species (e.g. *Athous haemorrhoidalis*) have also been recorded as attacking potato, but these are generally much less common in agricultural land and are usually found in mixed populations with *Agriotes* species.

Potato crops are particularly susceptible to attack as wireworm damage to tubers reduces crop quality rather than yield. Even low populations can cause an economic level of damage. Typical crop losses in North America range from 5 to 25% (Jansson & Seal, 1994), a figure comparable to damage levels seen in the United Kingdom when insecticides are used on potato for wireworm control (Hancock *et al*., 1986; Parker *et al*., 1990).

In the United Kingdom, high wireworm populations have traditionally been associated with fields in long-term grassland (Miles, 1942; Anon., 1948) as this undisturbed habitat is generally favourable for wireworm survival. As most potatoes are not grown in rotations that include long-term grass, wireworms were until recently regarded as a minor but locally important pest of potato in mixed arable and livestock farming areas (e.g. western England and Wales) where grassland is still common. However, in the last few years, wireworm damage has become an increasing problem for UK potato growers. Factors contributing to this increase probably include increasingly stringent quality demands from retailers, an increase in the use of old pasture as 'clean' potato land free of soil-borne skin finish diseases, and an apparent increase in wireworm damage in fields in all-arable rotations (Parker & Howard, 2001a). This increase in so-called 'arable wireworm' problems has occurred in all the main potato growing areas in the UK. Both the extent and the reasons for this apparent shift in the pest status of wireworms are not entirely clear, but there is some evidence (Hancock *et al*., 1992; Parker & Howard, 1999) that arable crops following long-term set-aside (one to five years fallow) may provide a suitable habitat for wireworms. Crops such as potato subsequently planted in these fields are prone to wireworm attack.

The general increase in the perception of wireworms as a serious problem for UK potato growers has highlighted the shortcomings in current risk assessment and control techniques. Risk assessment is an essential component of a wireworm management strategy, as the best way of preventing wireworm damage to potato is not to grow potatoes in wireworm-infested fields. However, standard techniques to assess wireworm populations in the soil (soil sampling and bait trapping) are labour-intensive and can be unreliable, particularly where wireworm populations are low or patchily distributed.

This report describes work done in the final year of a four year study on wireworm biology and control. In the first year, work was done in three areas:

1. A literature review on wireworm biology and control aimed at drawing current knowledge together and identifying gaps for further work (Parker & Howard, 2001a).
2. A small experiment on assessing the possible differences between potato cultivars in their susceptibility to wireworm damage (Parker & Howard, 2001b).
3. A small survey of wireworm problems in arable rotations to try and identify common characteristics of these sites which might indicate important factors influencing the survival of wireworms in arable rotations.

This work helped to highlight some key areas:

- Although a great deal of work has been done over the years on chemical control of wireworms (Parker & Howard, 2001a), no scientifically rigorous work had been done to examine the interactions between potato variety, insecticide use and harvest date on the level of wireworm damage.
- Wireworm risk assessment techniques still require improvement. The most promising area of work was in the development of pheromone traps for click beetles (adult wireworms). Work was already under way in Europe (Furlan *et al*., 1996, 1997; Toth *et al*., 1998) and there were excellent opportunities to key into this work.
- Both short- and long-term set-aside appeared to favour the build-up of wireworm populations.

Work in the second (1999), third (2000) and fourth (2001) years of the project addressed the first two of these key areas. The scientific objectives were:

1. To investigate the combined effects of insecticide use, variety and harvest date on wireworm damage.

This work was designed to investigate the interactions between two varieties (Charlotte, Maris Piper), four treatments (untreated, Mocap (ethoprophos), Phorate (phorate), Nemathorin (fosthiazate)) and 3 lifting dates in relation to the incidence and progression of wireworm damage. This was done as a glasshouse study in 1999 and as a semi-field trial in 2000 (see previous project reports for 1999 and 2000). Due to relatively low levels of wireworm damage, it was difficult to draw firm conclusions from this work. However, it was clear that the three main insecticides used for wireworm control in the UK (ethoprophos, phorate and fosthiazate) all gave similar levels of damage reduction. None gave complete control of wireworm damage. Phorate has since been withdrawn from use on potato in the UK.

2. To develop adult click beetle monitoring systems as an aid to risk assessment.

This programme of work was closely co-ordinated with similar work being done in a number of southern and eastern European countries on other wireworm species, and the aims were to:

a) Investigate whether pheromone traps developed in Europe for *Agriotes sputator, A. lineatus* and *A. obscurus* are effective for monitoring UK populations.

b) Compare (number & species range trapped) pheromone trap efficacy with 'grass' traps for monitoring adult beetles.

c) Determine the correlation between adult trap catches and larval populations assessed by soil sampling & bait trapping before and after the main adult flight peak in the summer.

Work done in 1999 identified a range of field sites for conducting this work, and ascertained the level of wireworm infestation and the identity of the principal species present. These sites had varying levels of wireworm infestation ranging from very low to high. In 2000, the efficacy and specificity of pheromone traps for the adult beetles of the three main species of wireworms (*Agriotes lineatus*, *A. sputator* and *A. obscurus*) were assessed at these same sites. The relationship between pre- and post-adult flight pheromone trap catches and wireworm populations in the soil was also investigated. At four sites, comparisons were also made between pheromone traps and a simple 'grass trap' method of capturing adult beetles. This work was continued in 2001 and is the subject of this report.

Materials and methods

Site locations

Work was done at three of the five sites originally identified and sampled in 1999 (Table 1), and which were also used to evaluate pheromone traps in 2000. One site used in 1999 and 2000 could not be used in 2001 due to Foot and Mouth Disease restrictions. Work at the fifth site was discontinued.

Table 1. Locations of field sites for adult monitoring work in 2001

Site no.	**Location**
1	Buckfastleigh, Devon
2	Llanafan, Ceredigion
3	Unstone, Sheffield, South Yorkshire

At the Yorkshire site, the experimental procedures described below for larval sampling and pheromone trap assessments were done twice in different areas of the same field.

Assessment of larval populations

Larval population assessments were done in April/May 2001 and repeated in October/November 2001 at three sites. Larval populations were assessed by soil core sampling only in the spring and by soil core sampling and bait-trapping in the autumn. Procedures were as follows:

Soil core sampling

A 10 x 4 grid of 40 soil samples (20 m x 30 m spacings between sample points) was taken covering the area of the field where the pheromone traps were due to be (spring sampling) or had been (autumn sampling) located. On all sampling occasions, one 10 cm soil core was taken to a depth of at least 20 cm (or plough depth in a freshly cultivated field) at each grid intersection. At the second (October/November) sampling occasion, the core at each sampling point was taken 20 cm to one side of the location of the soil core taken in the spring. Wireworms were extracted from soil cores by soil washing and flotation in magnesium sulphate solution. The number of wireworms found was recorded, and the larvae were retained for identification.

Larval bait trapping

Twenty traps per site were used. The design of the trap was a modified version of the type described by Parker (1996). All bait traps were soaked for at least 24 h in water prior to use, and then set out in the same 1 ha area and as near as possible to the same pattern as that used for the soil core sampling. Traps were placed in the bottom of a hole dug to 20 cm with a 10 cm diameter soil corer. The hole was back-filled with loose field soil. Traps were all placed in position on the same day, and then left for a minimum of 10 days. At the end of the baiting period, traps were removed by digging down to the level of the lid of the trap and pulling the trap out unopened. The collar of soil immediately surrounding the sides of the trap was also removed for examination (and placed in the same bag as the unopened trap) as previous work has shown that wireworms are often just outside the trap (Parker, 1994).

All samples were returned to the laboratory, and thoroughly searched by hand for the presence of wireworms. Any larvae found were counted and retained for identification.

Adult beetle monitoring using pheromone traps

One pheromone trap for each of the three main species (*Agriotes obscurus, A. lineatus* and *A. sputator*) was evaluated at each of the three monitoring sites. The traps (known as 'YATLORfunnel' traps) were designed and manufactured in Italy (Dr Lorenzo Furlan, University of Padova); these traps are not yet commercially available. Pheromone capsules were produced and supplied by Dr Miklos Toth, Hungarian Plant Protection Institute, Budapest, and are commercially available.

The traps were placed out in the field in early May, and were maintained and checked until the middle of August. The traps were placed on the soil (beetles enter the traps by walking) in the middle of the area used for larval assessments by soil sampling and bait trapping. Where the trap was placed in a standing crop, a small area of crop was cut down to allow trap placement. The distance between traps was at least 40 m. The traps were inspected once a week, and all beetles present in the trap were removed, counted and retained for identification. Pheromone capsules were replaced every 30 days.

Adult beetle monitoring using 'grass' traps

This work was done weekly during the period early May to late June/early July at all sites. Five 40 cm x 40 cm plastic sheets were laid out on bare ground at 15 m intervals on a transect running into the 1 ha block. At the start of each trapping period, the sheet was covered with freshly-cut rye grass. These 'traps' were checked after two or three days. Adult click beetles, if present, were collected from under the grass on the plastic. Once beetles had been collected, all forage was removed from the plastic sheet until the start of the next trapping period. Any beetles found were counted and retained for identification.

Adult and larval identifications

Beetles and larvae were sent to Dr Lorenzo Furlan, University of Padova, Italy for definitive identifications.

Results

Larval sampling

The results of the soil core sampling from the three sites indicated that a range of populations were present in the fields chosen for assessment (Table 2). The numbers found at the summer and autumn sampling times were broadly equivalent at Unstone. At Buckfastleigh, much higher numbers were found in the spring compared with the autumn, whereas at Llanafan, more wireworms were found in the autumn.

Table 2. Number of wireworms found at monitoring sites using soil core sampling in April/May and October/November.

	Spring sampling		Autumn sampling	
Site	**Date**	**No. found**	**Date**	**No. found**
Buckfastleigh	2 May 2001	43	10 October 2001	24
Llanafan	18 March 2001	9	11 November 2001	16
Unstone 1	2 May 2001	14	16 November 2001	16
Unstone 2	2 May 2001	11	16 November 2001	17

Work in 2000 indicated that when used in the spring, bait traps caught a similar number and sometimes more wireworms than soil core sampling. However, bait trapping was much less effective in the autumn than soil sampling, and a similar situation was observed in 2001 (Table 3). The low catch in bait traps in the autumn is probably a reflection of wet, cold soil conditions, which limit the attractiveness of the traps.

Table 3. Number of wireworms found at monitoring sites using bait trapping in autumn 2001.

Site	**Traps out**	**Traps checked**	**No. found**
Buckfastleigh	- Traps vandalised – no result -		
Llanafan	11 November 2001	26 November 2001	1
Unstone 1	2 November 2001	16 November 2001	2
Unstone 2	2 November 2001	16 November 2001	2

The results of the specific identifications made on wireworms recovered in 2001 are still awaited. Data from 2000 (Table 4) suggest that *Agriotes obscurus* is the dominant species at all sites except Llanafan, where *A. sputator* was also common.

Table 4. Results of larval identifications on wireworms collected from field sites in 2000.

	Site			
Species	**Buckfastleigh**	**Llanafan**	**Wheaton Aston**	**Unstone**
Agriotes lineatus	0	0	0	0
Agriotes obscurus	36	18	5	6
Agriotes sputator	0	17	0	2
Adrastus spp.	0	0	0	4

Pheromone trapping

All three major species of click beetle were caught at all sites; beetles were active from May right through until August. The full results are shown in Figures 1 (Buckfastleigh), 2 (Llanafan) and 3 (Unstone – data for *A. lineatus* not shown as only two beetles were caught in each replicate). In 2000, all three species showed distinct peaks of activity in mid-May. However in 2001, such obvious peaks of activity, when they occurred, tended to be seen in June or July. *A. obscurus* and *A. sputator* were the most common species at all three sites, accounting for *c*. 40 to 50% of the beetles trapped. *A. lineatus* accounted for 16% and 18% of the beetles trapped at Buckfastleigh and Llanafan respectively, but only 1% at Unstone. , and *c*. 70-80% of beetles at Wheaton Aston and Unstone.

Pheromone efficacy

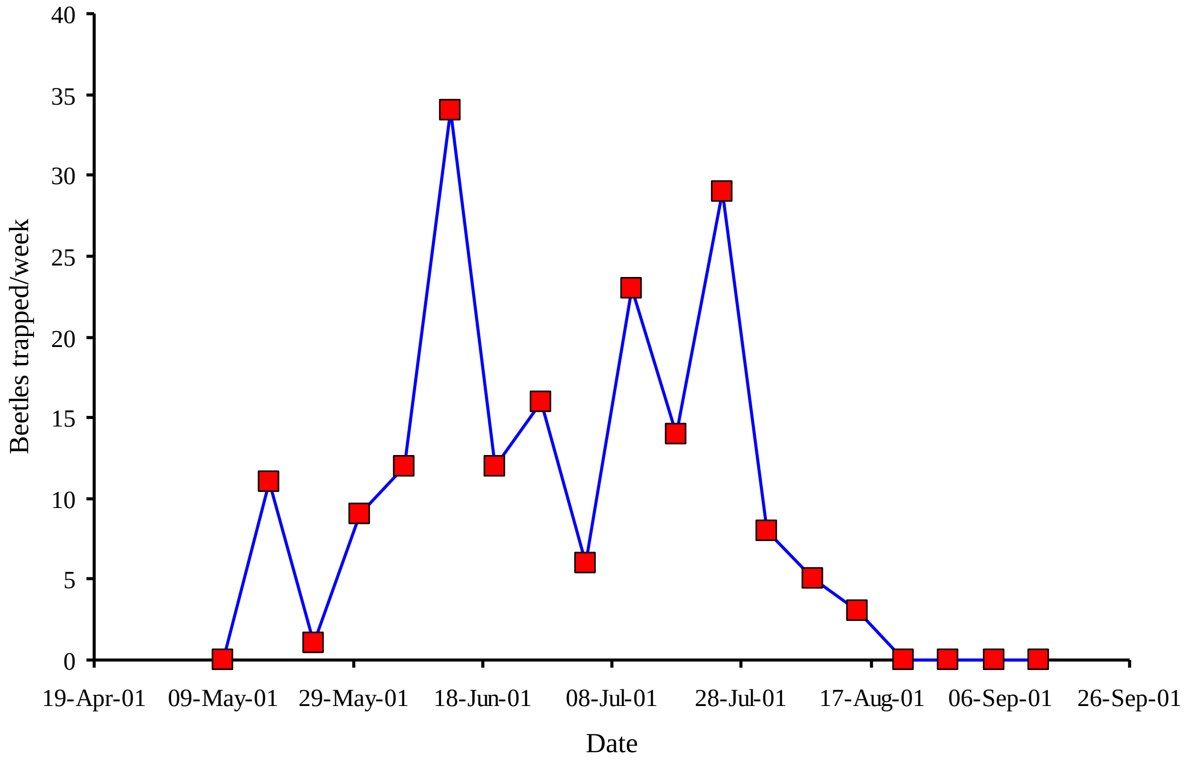
The number of beetles trapped was usually an order of magnitude higher than the number of wireworms found in the soil. This is indication that pheromone traps are potentially a more sensitive tool for identifying wireworm-infested fields than soil sampling or bait trapping. There was some inter-site variation. At Buckfastleigh, where the wireworm population in the soil was very high, and relatively few beetles (437) were trapped in total through the season. However, at Llanfan, wireworm populations in the soil were moderate, but beetle trap catches were very large (a total of 4,844 beetles trapped during the season).

Pheromone specificity

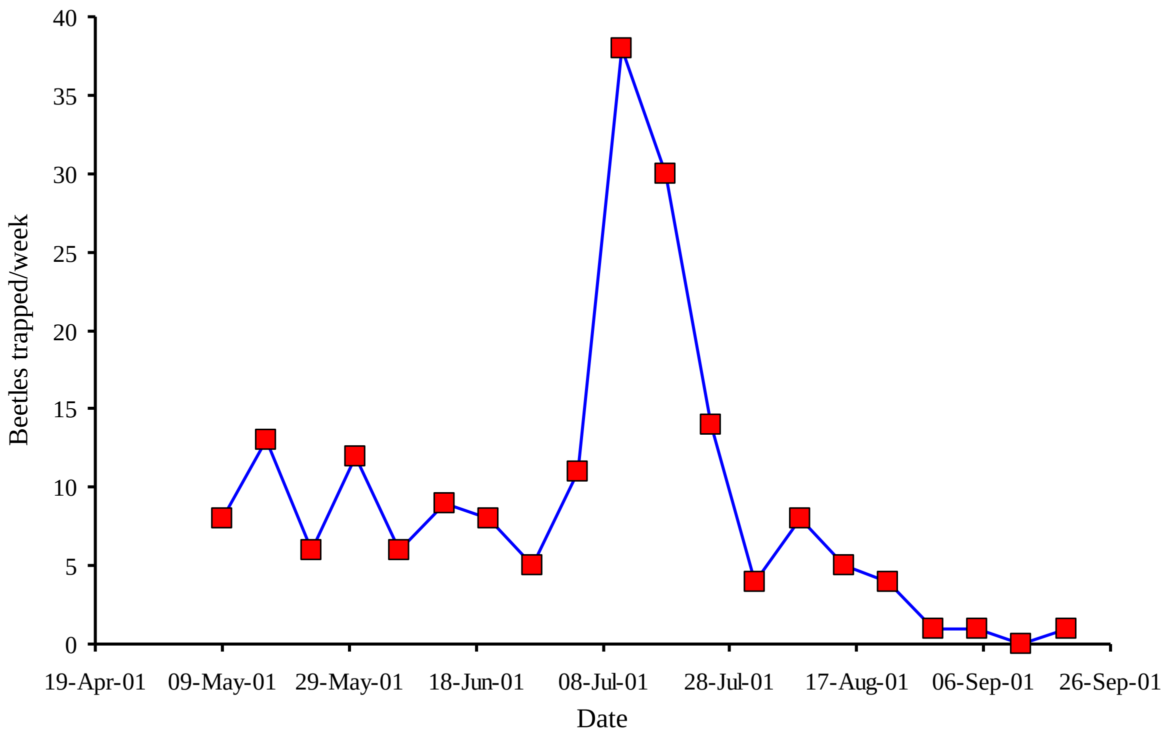
The pheromone traps did catch a few other beetles. These were mainly mainly ground beetles (Carabidae) that had probably entered the trap by chance. Occasionally, the odd *A. obscurus* beetle was found in *A. sputator* traps. Thus, overall, the specificity of the pheromone traps was very high.

Figure 1. Pheromone trap catches of adult click beetles (wireworm adults) at Buckfastleigh, Devon.

a) *Agriotes obscurus* (Buckfastleigh)



b) *Agriotes sputator* (Buckfastleigh)



c) *Agriotes lineatus* (Buckfastleigh)

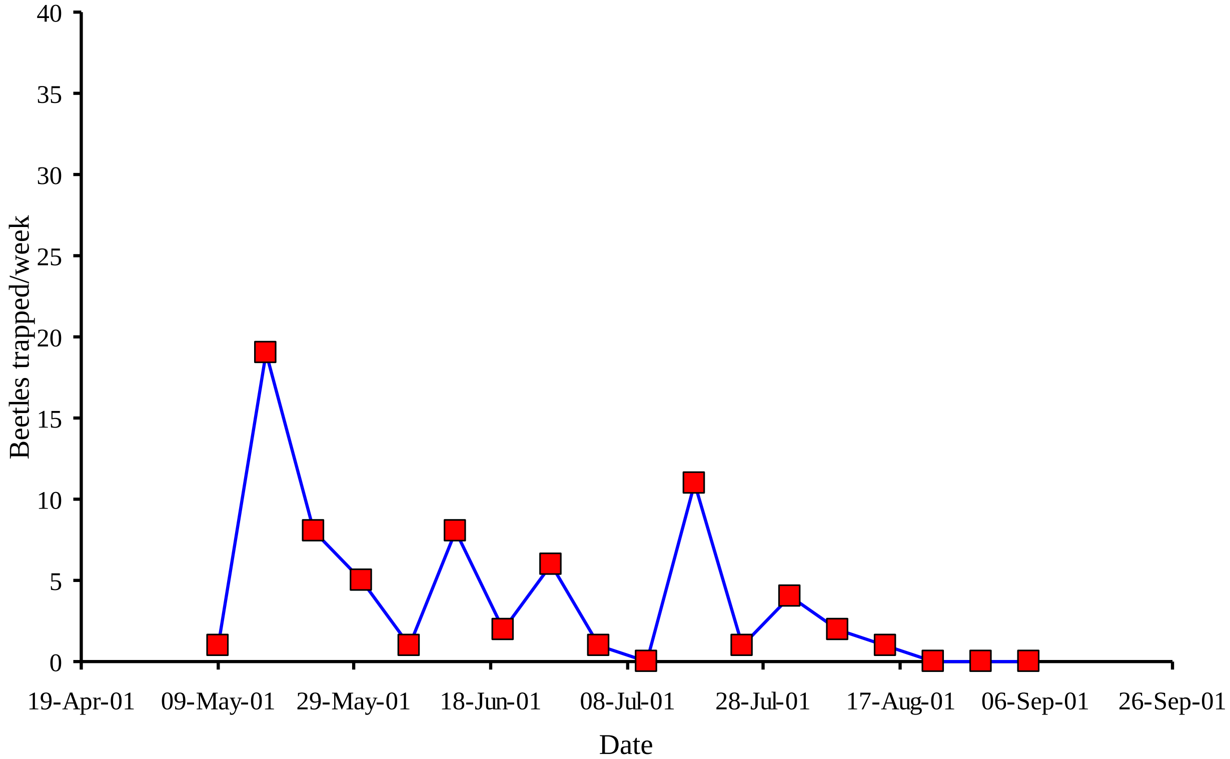
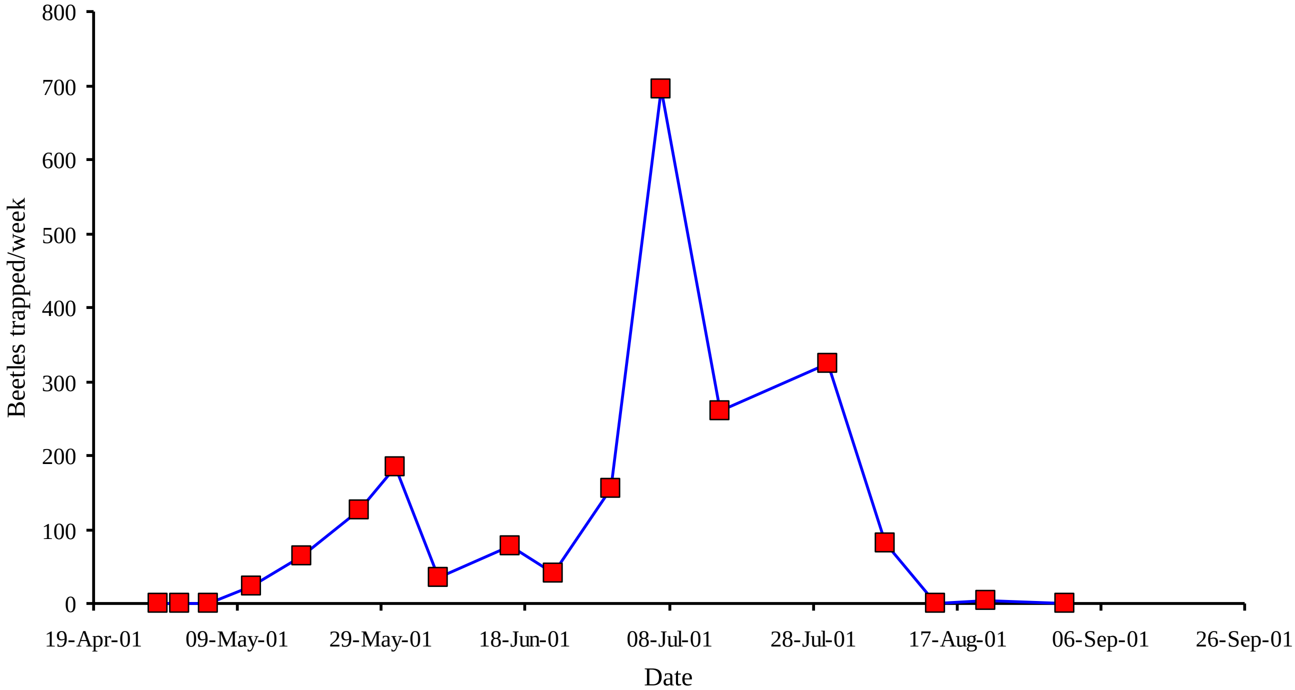
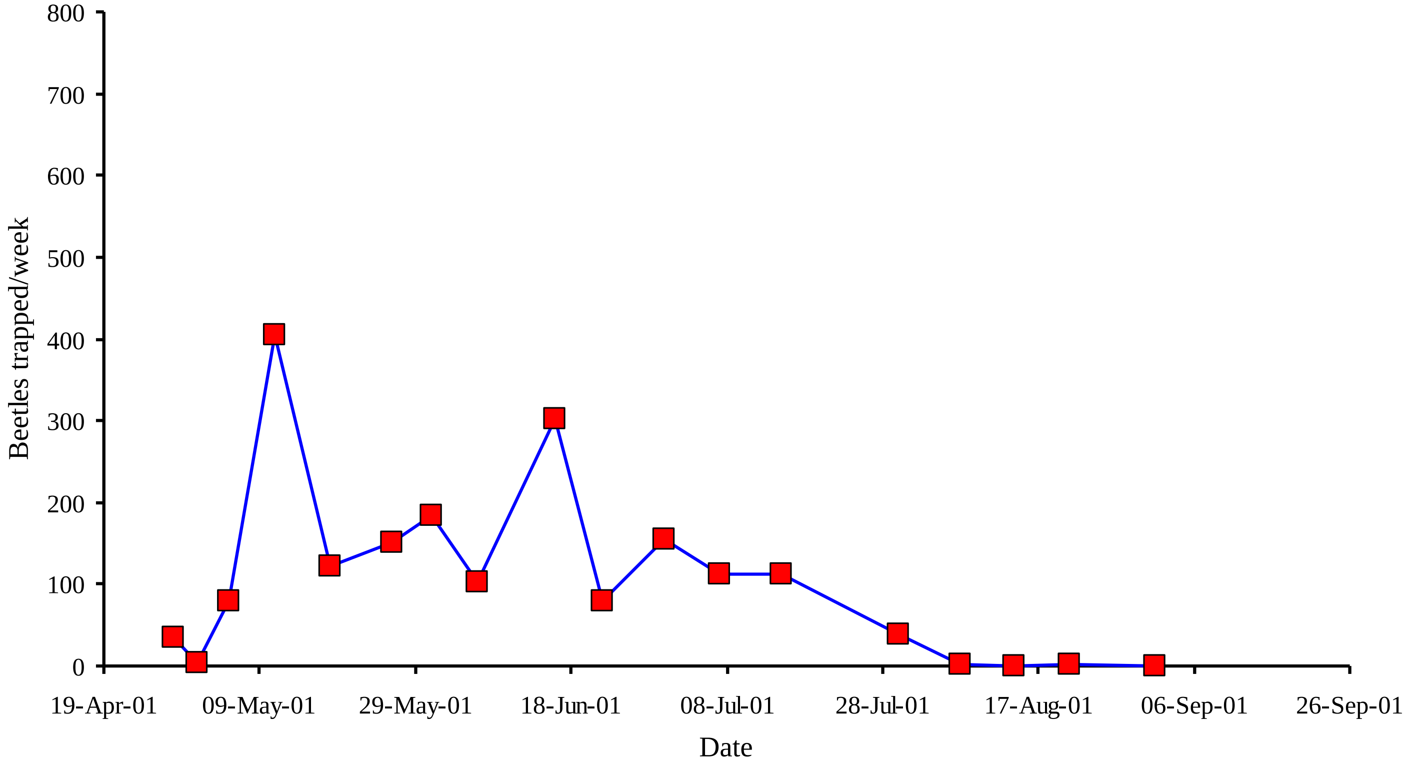


Figure 2. Pheromone trap catches of adult click beetles (wireworm adults) at Llanafan, Ceredigion

a) Agriotes obscurus (Llanafan)





c) *A. lineatus* (Llanafan)

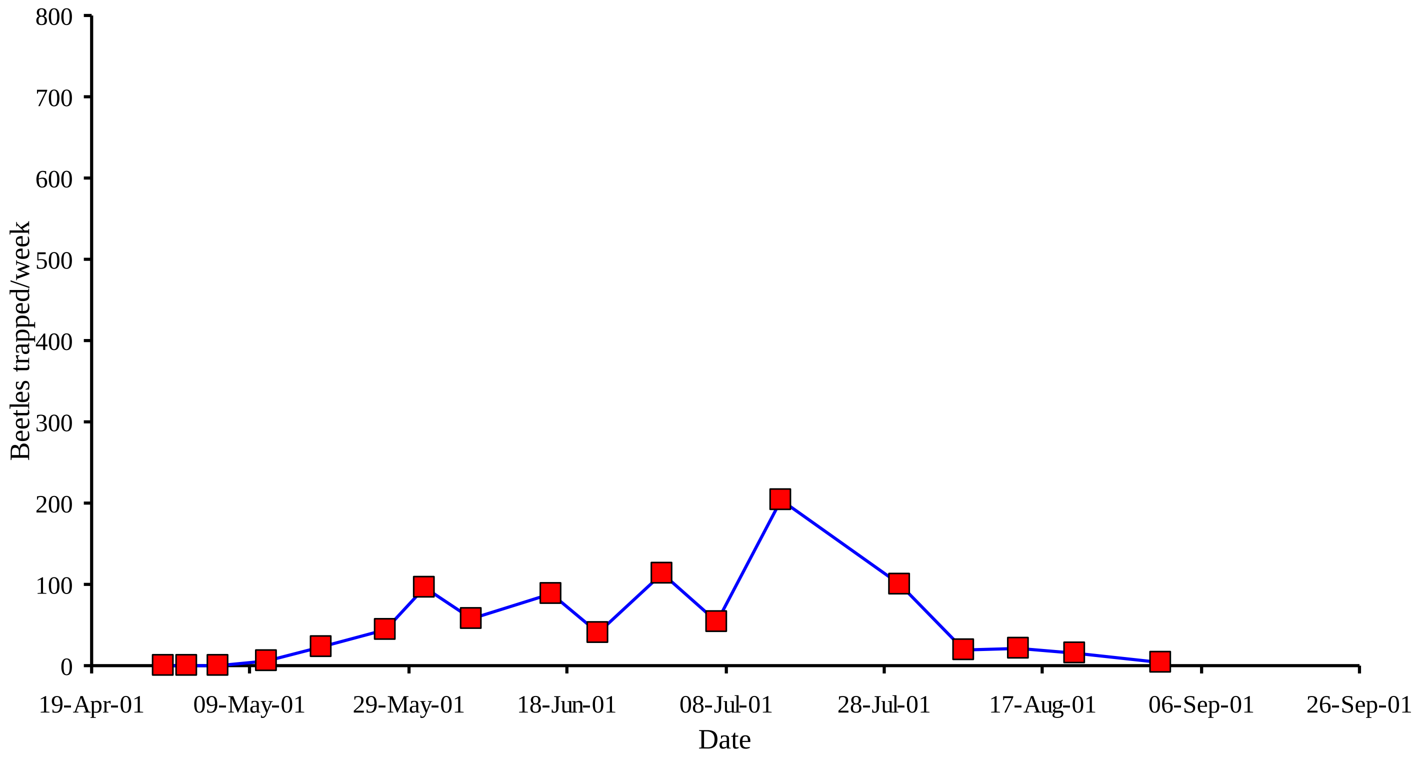
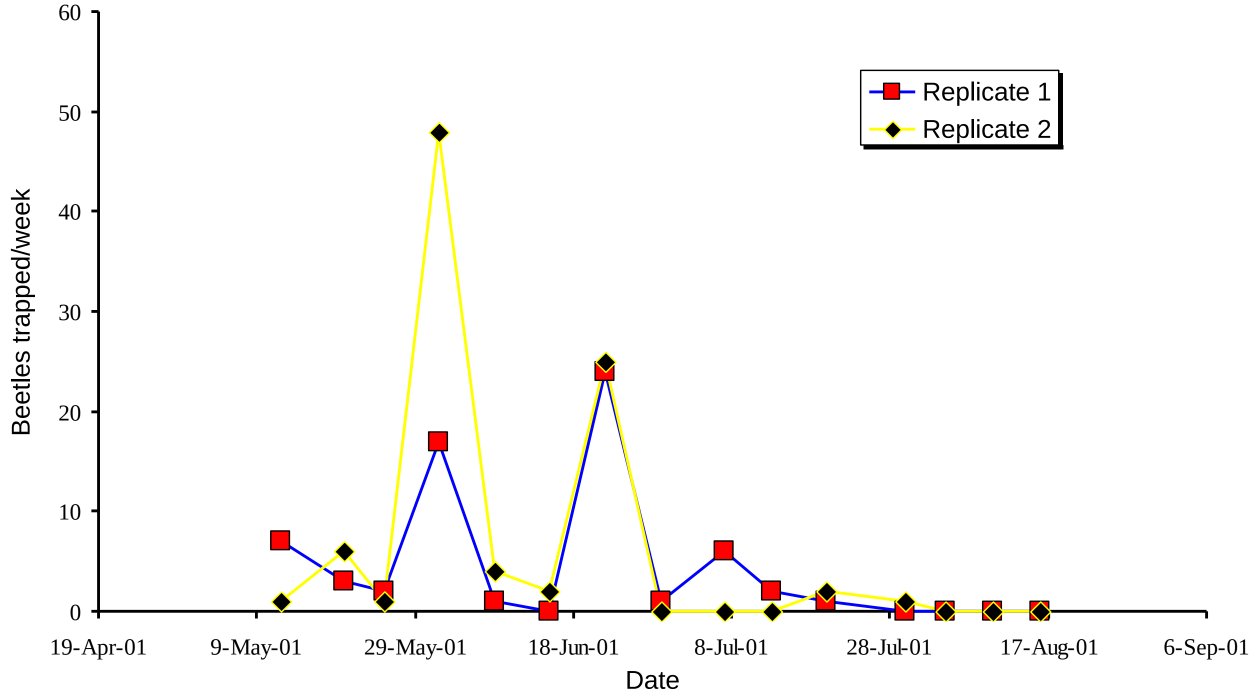
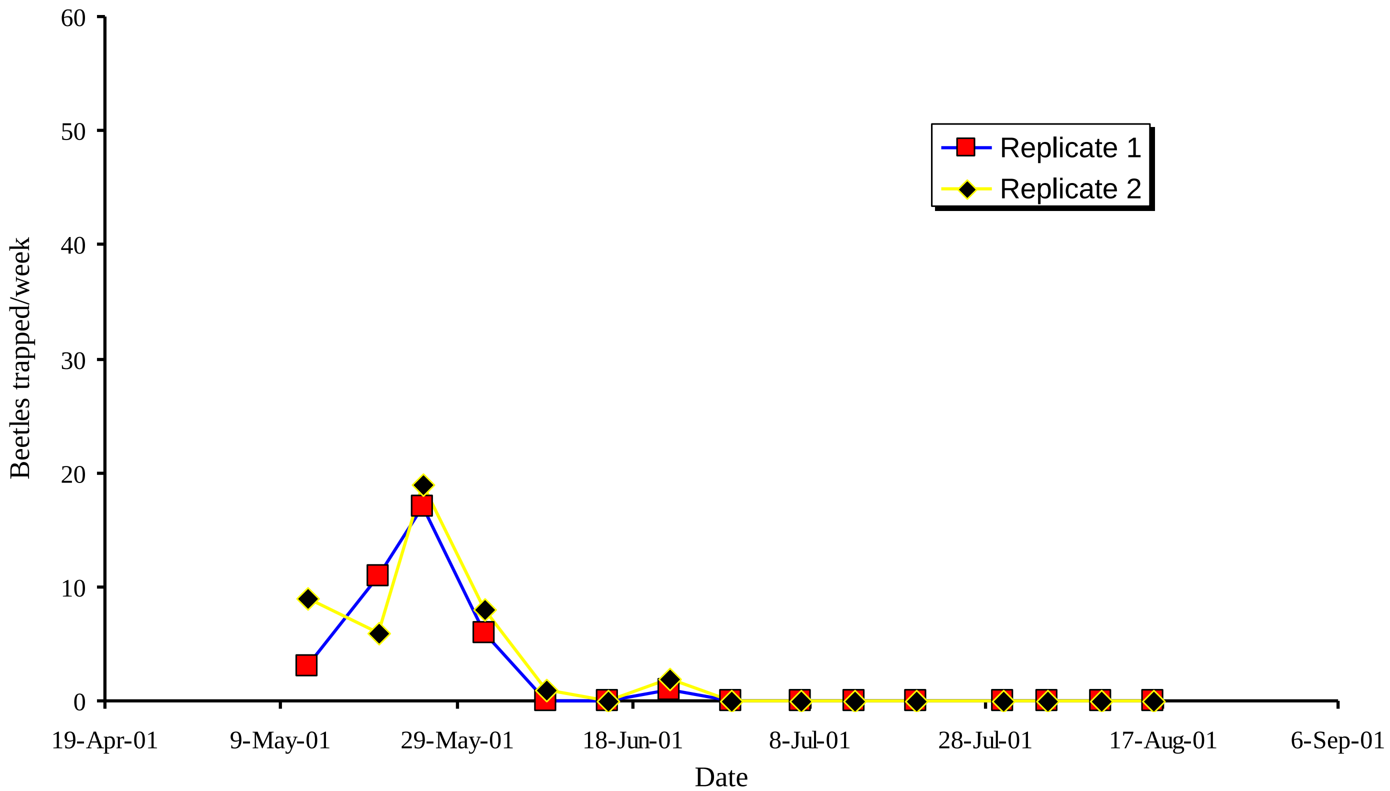


Figure 3. Pheromone trap catches of adult click beetles (wireworm adults) at Unstone, Yorkshire (data from two replicates presented).

a) *A. obscurus* (Unstone)



b) *A. sputator* (Unstone)

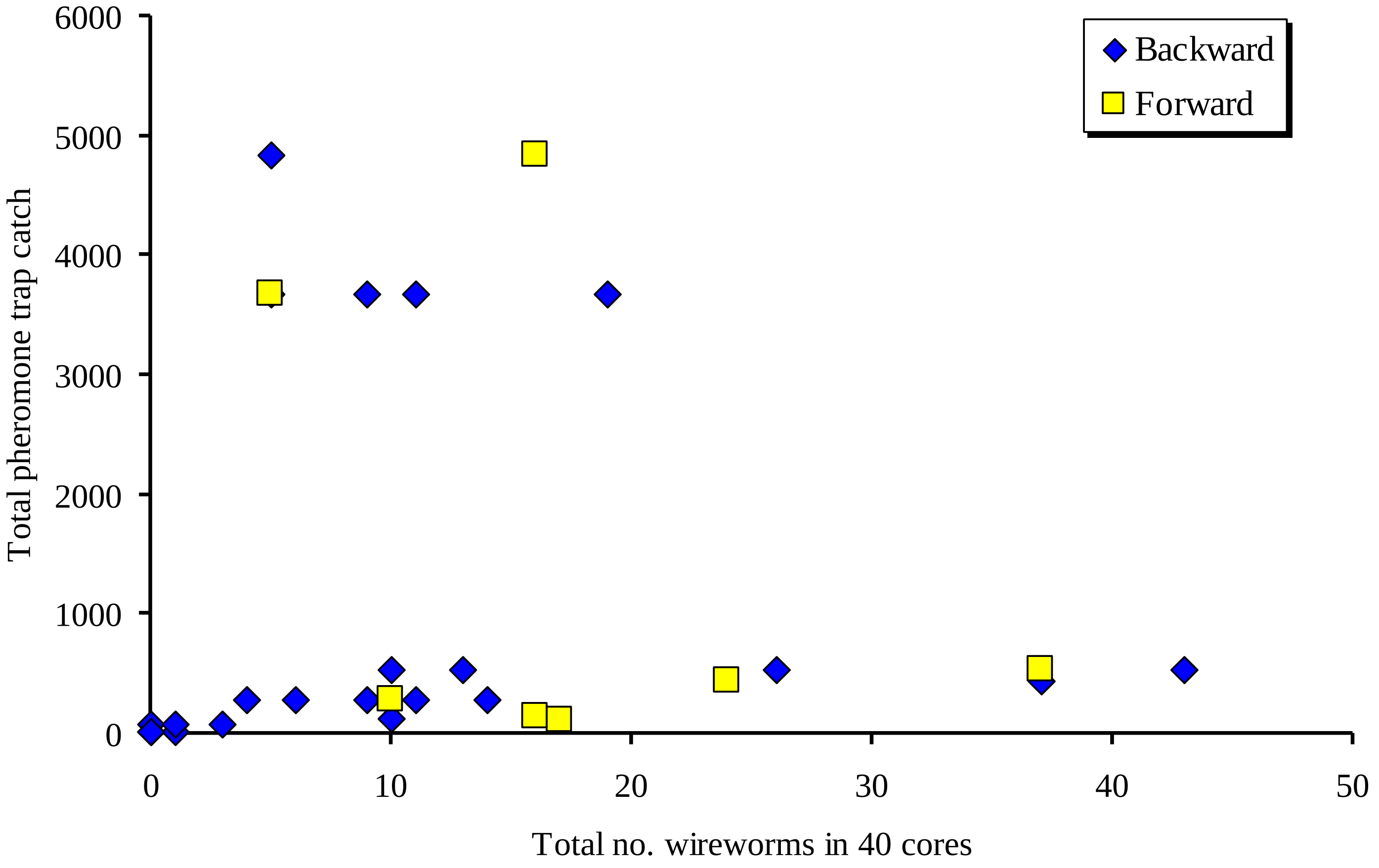


Relationship between pheromone trap catches and wireworm numbers

Beetles caught in pheromone traps during the summer pupated during the late summer/early autumn of the previous year and overwintered as adults in the pupal cell prior to emerging the following summer. Therefore, depending on the age structure of the wireworm population (only final instar larvae will pupate) there should be a relationship between summer pheromone trap catches and wireworm numbers found in the previous year up to the point that pupation occurred. However, although this 'backward' correlation can be used to show a biological link between wireworm populations and adult pheromone trap catches, it has little practical relevance if pheromone traps are to be used to predict the future risk of wireworm attack. In practice, therefore, the important correlation is between pheromone trap catches of beetles in the summer and wireworms remaining in the soil the *following* autumn/winter (the 'forward' prediction).

Initial examination of the available data for the period 1999 to 2001 (Figure 4) showed that the data from the Llanafan site were clearly well outside of the range of the data from the other sites.

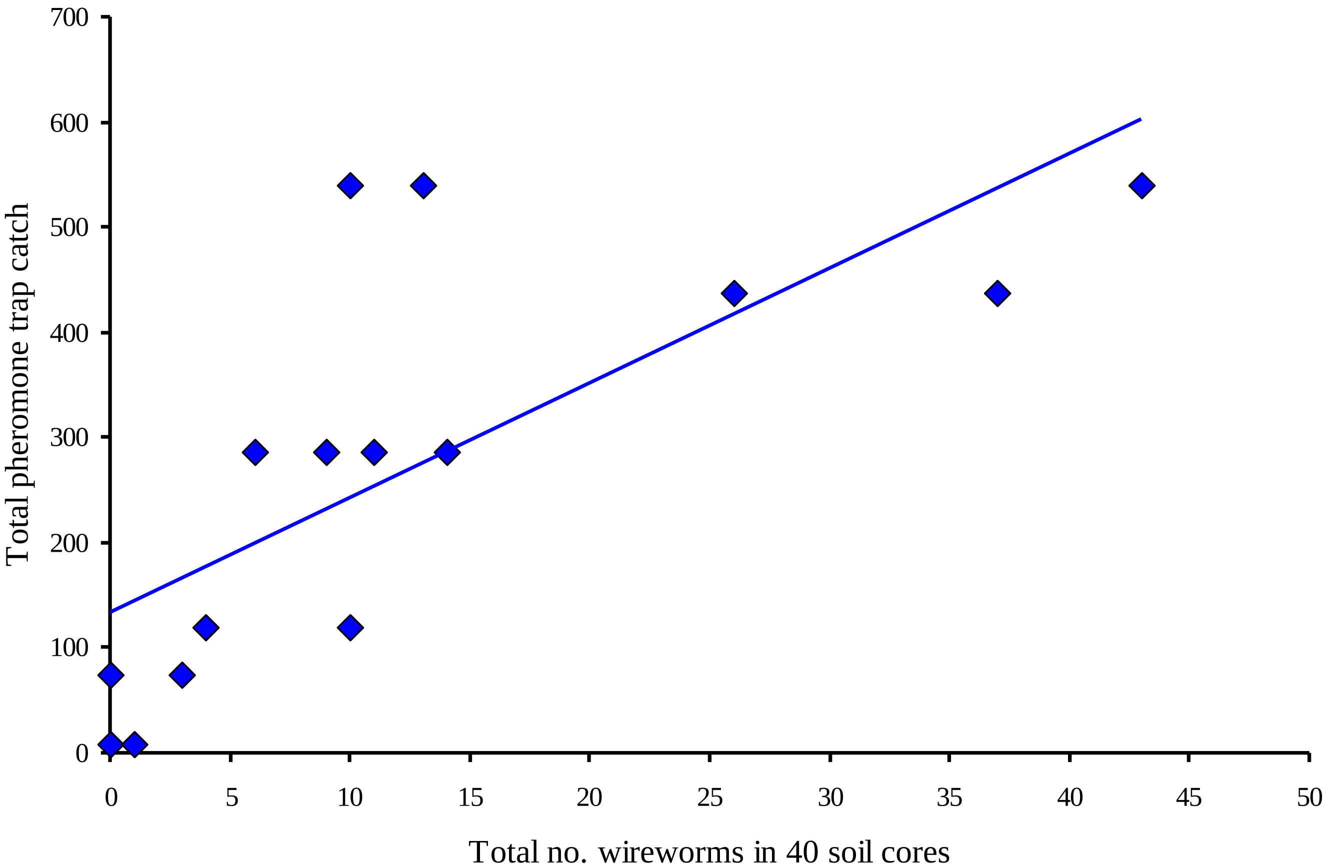
Figure 4. 'Backward' and 'forward' relationship between pheromone trap catches (total catch for the year) and wireworm populations in the soil (total number of wireworms found in 40 soil cores). Data from Llanafan are the cluster of six points above the main scatter of data points.



from further analyses.

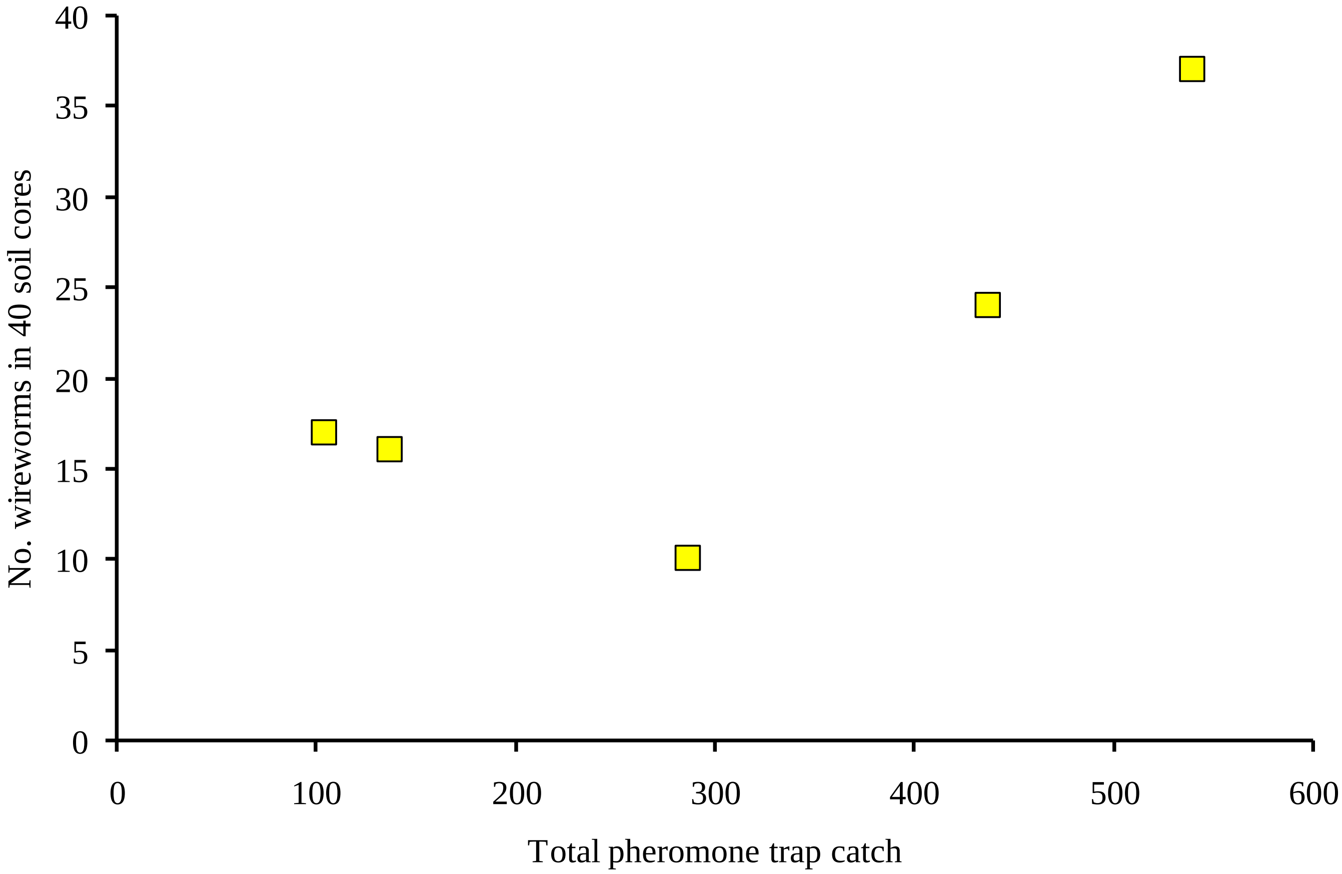
Correlation with previous wireworm populations ('backward' relationship): there was a significant relationship between wireworm populations as assessed by soil core sampling and pheromone trap catches recorded in the subsequent summer (Figure 5). Data from all sampling occasions prior to the summer pheromone trapping were used. The regression equation was y = 134+10.9x, where y = pheromone trap catch and x = wireworms in soil cores (F=14.87, P=0.002, adjusted R^2=49.8%).

Figure 5. Relationship between pheromone trap catches and wireworm populations sampled in the previous autumn and spring.



Correlation with 'subsequent' wireworm populations ('forward relationship'): due to the exceptionally wet autumn in 2000 which limited autumn sampling, and the Foot and Mouth outbreak in the spring 2001 which prevented access to some sites, only limited data are available to investigate this relationship. Based on the available data (Figure 6), there is no significant relationship between pheromone trap catches in the summer and wireworm populations remaining in the soil (y=9.0+14.0x, where y=wireworm population in the soil and x=total pheromone trap catch, F=4.40, P=0.127, adjusted R^2=46.0%). However, this may simply reflect the limited data set.

Figure 6. Relationship between pheromone trap catches and wireworm populations sampled in the following autumn.



Capture of beetles using 'grass' traps compared with pheromone traps

'Grass' traps successfully caught beetles at Buckfastleigh and Unstone, but virtually no beetles were found in grass traps at Llanafan despite very high catches in pheromone traps at this latter site. Regression analysis indicated a very poor statistical relationship between beetle numbers in pheromone traps and 'grass' traps at Unstone and Buckfastleigh (Figure 6).

Despite the inconsistent statistical relationship between 'grass' and pheromone trap catches, the relative patterns of beetle incidence given by the two types of traps were similar (Figure 5), particularly at Buckfastleigh, where pheromone traps caught more beetles than grass traps. At Unstone, the grass traps tended to catch more beetles than pheromone traps, particularly during May.

Figure 6. Correlation between the number of beetles caught on 'grass' traps and the total number of beetles found in pheromone traps at equivalent times.

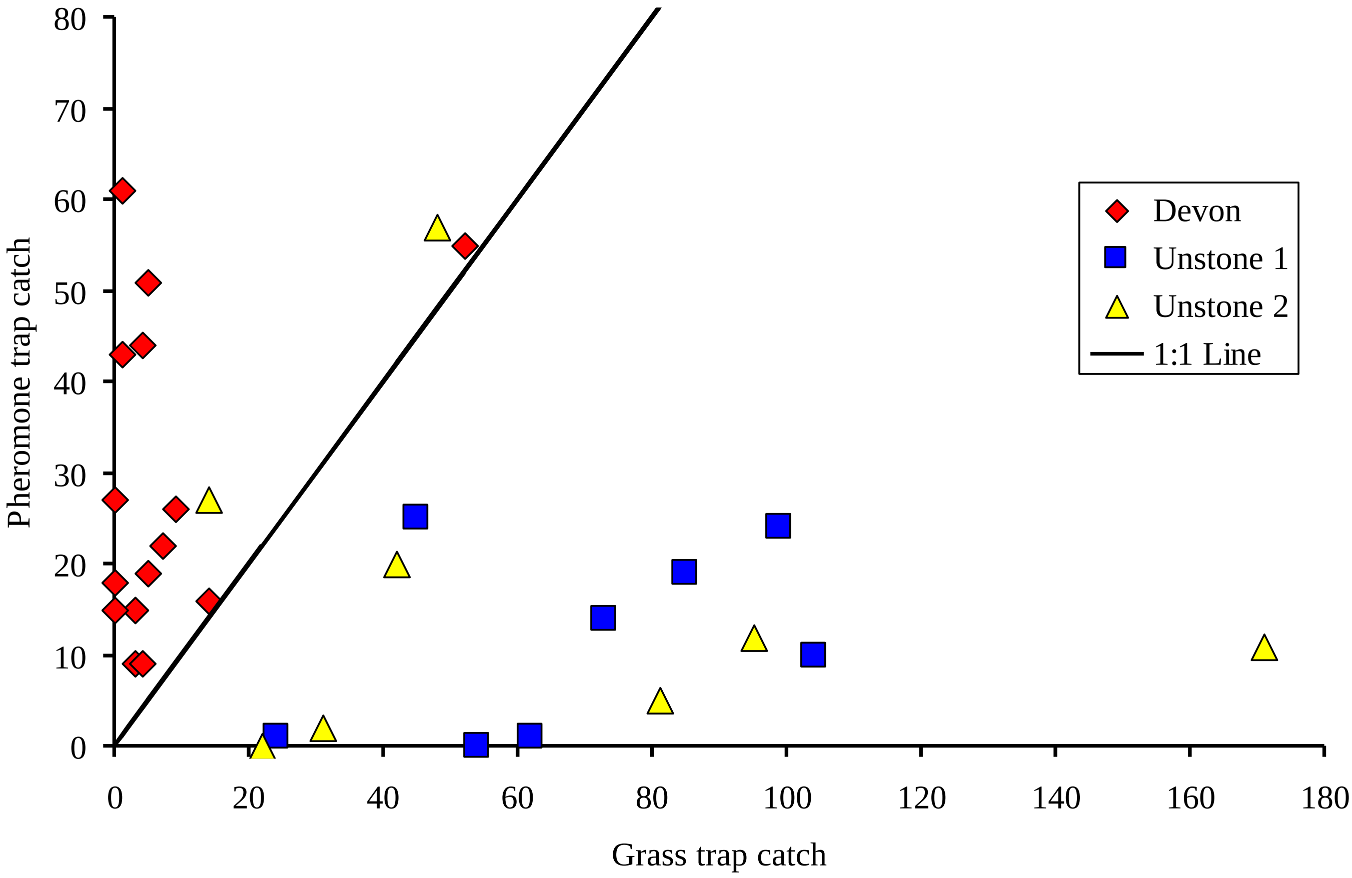
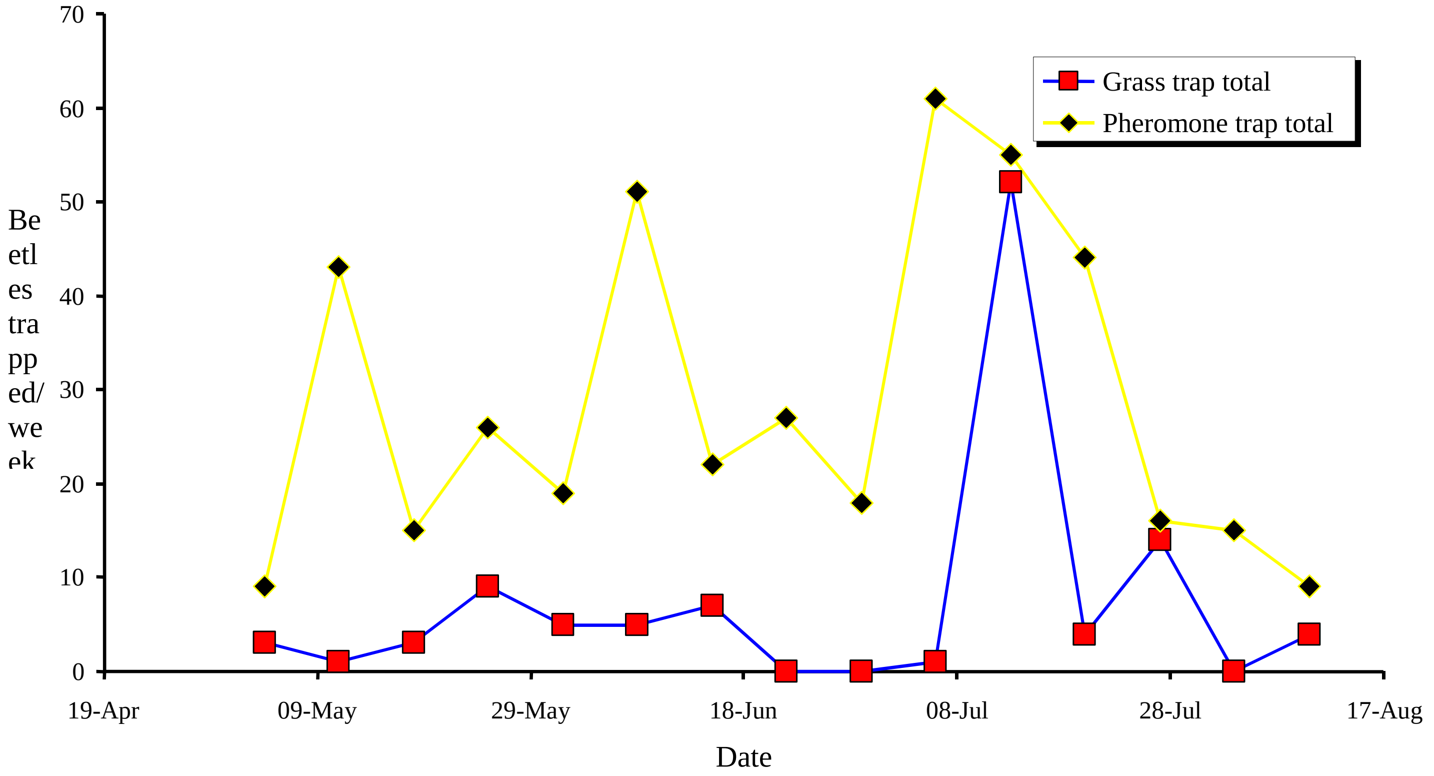


Figure 7. Comparison of beetle numbers trapped using pheromone and 'grass' traps.

a) Buckfastleigh



b) Llanafan

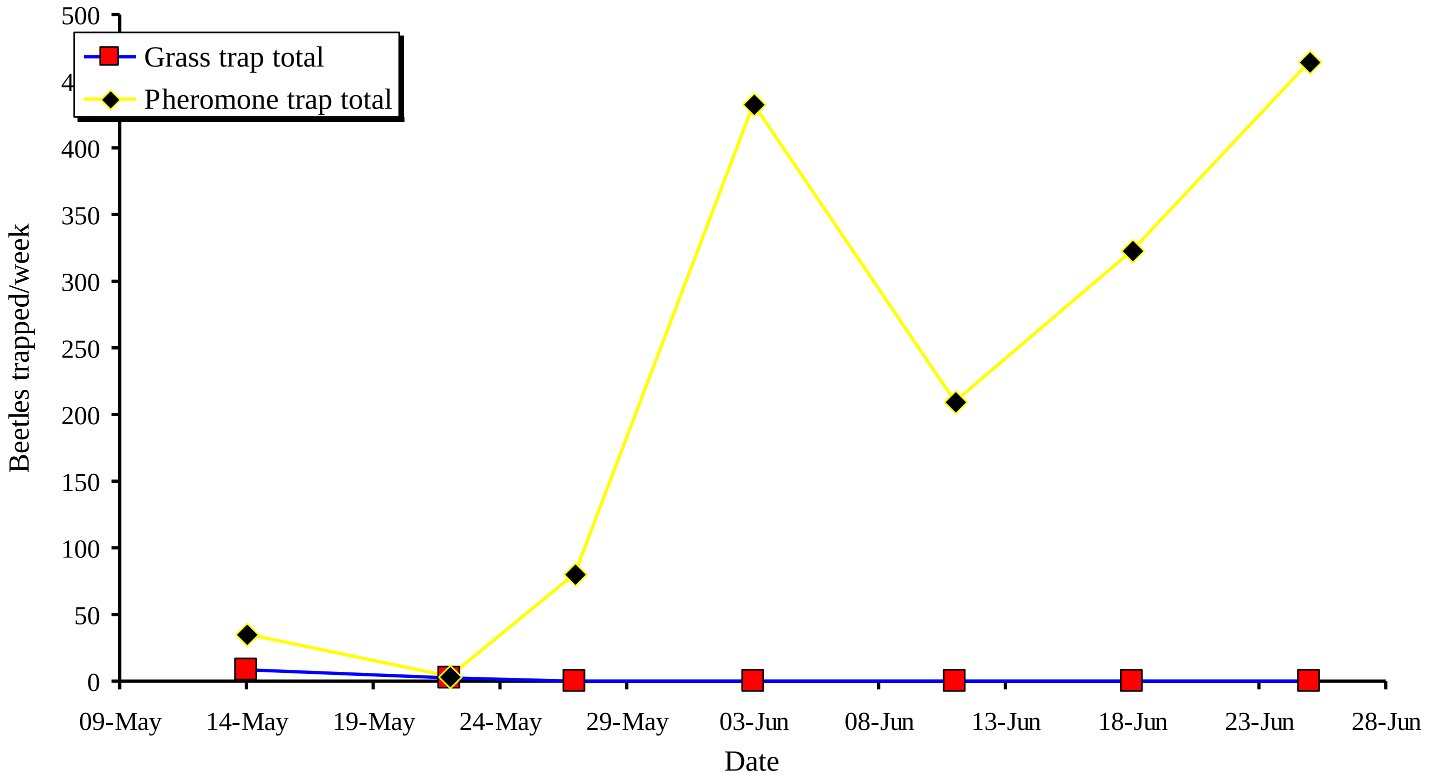
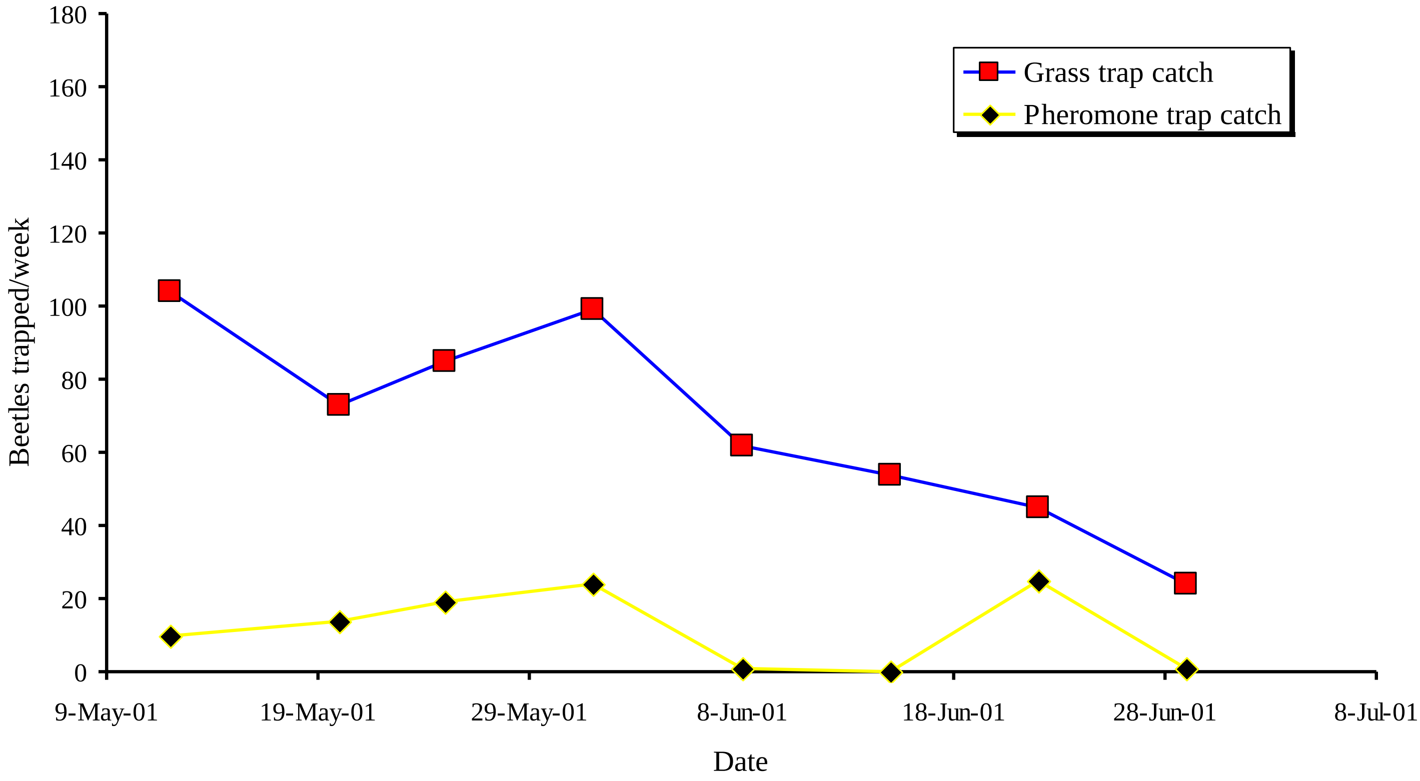
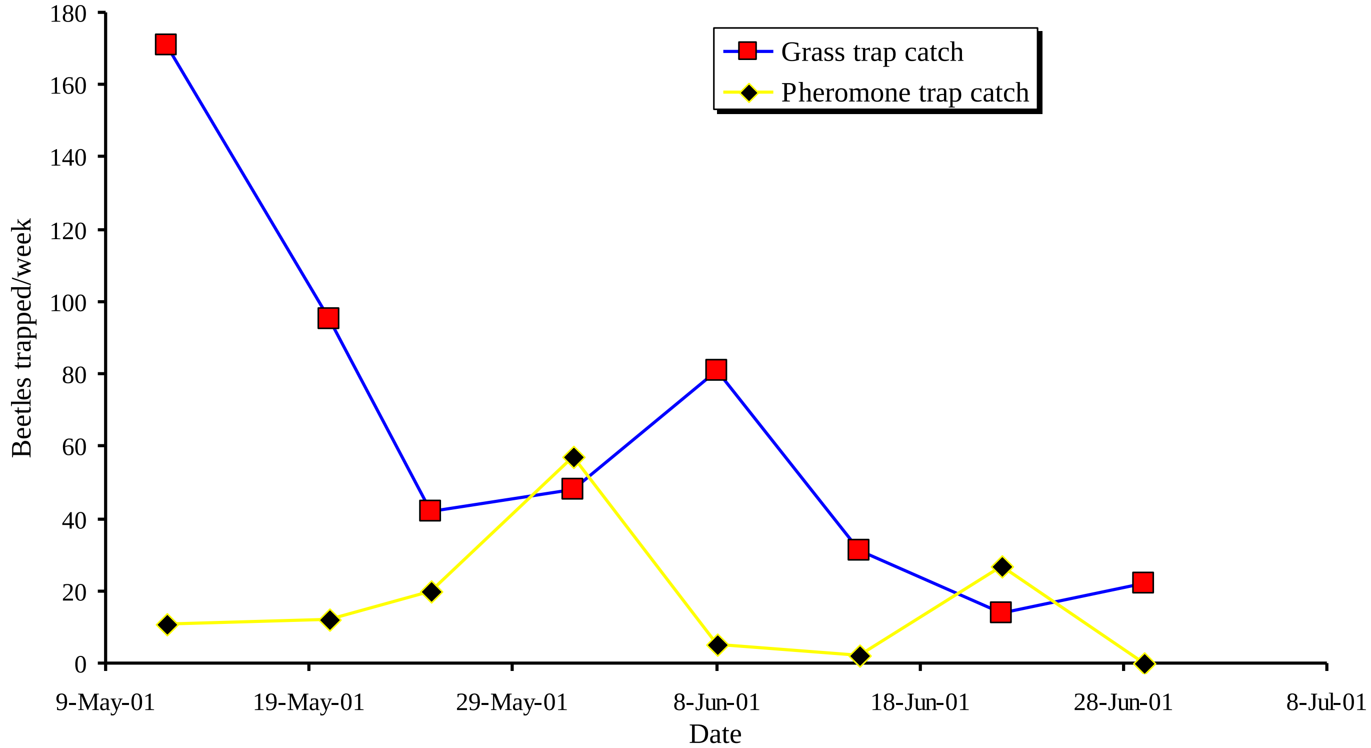


Figure 7 (Contd).

c) Unstone (replicate 1)



d) Unstone (replicate 2)



Discussion

The results of the pheromone trap work done in 2001 largely confirmed the initial findings of the 2001 work. The pheromone traps were effective and specific in trapping all three main species of wireworms of agricultural importance. The current trap design is also easy to use and assess. The numbers of beetles caught throughout the key adult flight period (May) were usually one and occasionally two orders of magnitude higher than the numbers of wireworms found in the soil. This suggests that pheromone traps are likely to be considerably more sensitive at detecting wireworm-infested fields than traditional soil sampling or bait trapping techniques, which are very dependent on soil conditions at the time of sampling. These findings are also consistent with similar work done elsewhere in Europe (Furlan *et al*., 2001).

Given that the traps are an effective means of identifying the presence of *Agriotes*-infested fields, the key issue is the relationship between wireworm populations in the soil and pheromone trap catches. This is an area that merits further study, as only limited data are currently available. It is clear that there is a reasonable relationship between wireworm populations identified by soil core sampling in the previous autumn or spring, and subsequent pheromone trap catches (Figure 5). However, if pheromone trapping is to be used as a risk assessment tool, pheromone trap catches must also relate to wireworm populations remaining in the soil (Figure 6). More data are required to assess the nature of this relationship, which on the available data appears to subject to some variability.

The data from Llanafan clearly indicate that some sites do not readily conform to even a general relationship. Similar discrepancies have been noted at sites elsewhere in Europe (Furlan *et al*., 2001), and are probably related to soil conditions at the time of sampling and/or the age structure of the wireworm population.

The ‘grass’ traps were also an effective means of capturing adults at some sites, but the efficacy of these traps is much more variable as they are particularly prone to poor performance in wet weather conditions which do not affect pheromone traps. This probably explains the inconsistent relationship between ‘grass’ trap catches and pheromone trap catches. Nonetheless, ‘grass ‘ traps could provide a useful ‘stop-gap’ measure for adult monitoring until the work on pheromone traps is completed and/or pheromone traps become commercially available.

The most common species caught in pheromone traps at all sites were *Agriotes obscurus* and *A. sputator*. The latter species formed a higher proportion of the population than in 2001. *A. lineatus* was found at all sites, but only in low numbers. The presence of a non-*Agriotes* species (*Adrastus* spp.) was also observed at the Unstone site. Where such mixed populations occur, the *Agriotes* species usually dominate the population (Parker & Seeney, 1997).

Conclusions

The work in 2000 and 2001 has unequivocally shown that pheromone traps are a potentially valuable aid to wireworm risk assessment. However, their effective use will require growers to make decisions about which fields to monitor up to 12 months ahead of planting a potato crop. This duration of forward planning in field selection is not commonplace in the industry at the moment. In addition, a better understanding of the relationship between pheromone trap catches and subsequent wireworm infestations is essential. The early indications from this work is that useful relationships can be derived.

Acknowledgements

We thank the host farmers at the field monitoring sites for their co-operation in this work, Dr Lorenzo Furlan for provision of pheromone traps and Dr Miklos Toth for provision of pheromones.

References

Anon. (1948). *Wireworms and Food Production; a Wireworm Survey of England and Wales (1939-1942).* Bulletin No. 128, Ministry of Agriculture, Fisheries and Food, H.M.S.O., London. 62 pp.

Furlan, L., Toth, M., Ujvary, I. & Toffanin, F. (1996). The utilisation of sex pheromones to improve wireworm (*Agriotes spp.*) control: first trials in Italy. *ATTI Giornate Fitopatologiche* **1**, 133-140.

Furlan, L., Toth, M. & Ujvary, I.. (1997). The suitability of sex pheromone traps for implementing IPM strategies against *Agriotes* populations (Coleoptera: Elateridae). *Abstracts of the XIX Conference of the International Working Group on* Ostrinia *and other Maize Pests*, 6-7.

Furlan, L., Toth, M., Parker, W. E., Ivezic, M., Dobrinčić, R., Muresan, F., Subchev, M., Molnar, Z., Ditsch, B., Voigt, D. (2001). The efficacy of the new *Agriotes* sex pheromone traps in detecting wireworm population levels in different European countries. Proceedings of the XXIst IWGO Conference, Venice, November 2001 (in press).

Hancock, M., Ellis, S., Green, D. B. & Oakley, J. N. (1992). The effects of short- and long-term set-aside on cereal pests. In Clarke, J (ed.) 'Set-Aside'. *BCPC Monograph No. 50*, 195-200.

Hancock, M., Green, D., Lane, A., Mathias, P.L., Port, C.M. & Tones, S.J. (1986). Evaluation of insecticides to replace aldrin for the control of wireworms on potatoes. *Tests of Agrochemicals and Cultivars No. 7, Annals of Applied Biology*, **108** (Suppl.), 28-29.

Jansson, R. K. & Seal, D. R. (1994). Biology and management of wireworm on potato. *Proceedings of the International Conference on 'Advances in Potato Pest Biology and Management', Jackson Hole, Wyoming, October 1991* 31-53.

Miles, H. W. (1942). Wireworms and Agriculture. *Journal of the Royal Agricultural Society of England* **102**, 1-13.

Parker, W. E. (1994). Evaluation of the use of food baits for detecting wireworms (*Agriotes* spp., Coleoptera: Elateridae) in fields intended for arable crop production. *Crop Protection* **13**, 271-276.

Parker, W. E., Clarke, A., Ellis, S. A. & Oakley, J. N. (1990). Evaluation of insecticides for control of wireworms (*Agriotes* spp.) on potato. *Tests of Agrochemicals and Cultivars No. 11, Annals of Applied Biology* **116** (Suppl.), 28-29.

Parker, W. E. & Howard, J. J. (1999). Wireworm biology, risk assessment and control. *British Potato Council Project Report* 41pp.

Parker, W. E. & Howard, J. J. (2001a). The biology and management of wireworms (*Agriotes* spp.) on potato with particular reference to the United Kingdom. *Agricultural & Forest Entomology* **3** pp 85-98.

Parker, W. E. & Howard, J. J. (2001b). Assessment of the relative susceptibility of potato cultivars to wireworm (*Agriotes* spp.) damage. *Tests of Agrochemicals and Cultivars* **21**.

Parker, W. E. & Seeney, F. M. (1997). An investigation into the use of multiple site characteristics to predict the presence and infestation levels of wireworms (*Agriotes* spp., Coleoptera: Elateridae) in individual grass fields. *Annals of Applied Biology* **130**, 409-425.

Toth, M., Furlan, L., Yatsynin, V.G., Szarukan, I., Ujvary, I., Tolasch, T. & Francke, F. (1998). Development of pheromone traps for European click beetle pests (Coleoptera: Elateridae*). Abstracts of the 2nd International Symposium on Insect Pheromones*, WICC-International Agricultural Centre Wageningen, The Netherlands, 53.