Report prepared for the
British Potato Council

Wireworms: end-user evaluation of click beetle pheromone traps as an aid to risk assessment

Final Report 2002 -2003

By

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Summary

This project was designed to evaluate the use of click beetle (*Agriotes* spp.) sex pheromone traps as an aid to risk assessment for wireworms. The objectives of the work, done between April 2002 and October 2003 were:

1. To evaluate the use of click beetle pheromone traps at commercial field sites using the participation of the potato industry.
2. To establish the relationship between click beetle pheromone trap catches and subsequent wireworm damage to potato crops planted in infested fields.
3. To identify the number of traps required to estimate accurately the wireworm population in a field.
4. To assess the distribution of beetles within fields in relation to possible population movement into fields from neighbouring field margins.

Pheromone trap sets, instructions and field history record sheets were sent to 45 growers or their consultants, representing 85 fields potentially available for trapping. Data were returned for 37 fields from a total of 26 participants. Of these, 21 fields provided an acceptable, season-long run of data. All three species of click beetles (*Agriotes obscurus*, *A. sputator* and *A. lineatus*) were trapped at virtually all sites. *A. obscurus* was usually the dominant species at western sites, whereas *A. sputator* was often dominant at eastern sites. 70% of fields sampled did not have a history of grass in the rotation despite the presence of beetles, indicating that ‘arable wireworm’ may be much more widespread that hitherto thought.

Follow-up wireworm sampling was done in 18 fields potentially available for commercial potato cropping in the spring of 2003. However, potatoes were actually planted in only eight of these fields. Damage assessments were successfully completed at seven of these sites. Although the number of sites was limited, the results provided some tentative evidence that total click beetle trap catches of <100 did not result in measurable wireworm damage to the potato crop. Analysis of data from this and earlier projects also strongly suggested that total click beetle trap catches of <50 indicated that although wireworms were present, they could not be detected by standard sampling techniques and represented a low risk of damage to potatoes.

Fully replicated studies work at two sites (Buckfastleigh, Devon and Borth, Ceredigion) investigated the number of traps required to consistently estimate click beetle populations, and the degree of inter-field movement which may occur. Wireworm populations were estimated in ‘Target’ and ‘Neighbouring’ fields as well as the field margin between the two. Overall, pheromone trap catches were lower in the ‘Neighbouring’ field compared with the ‘Target’ field at both sites. The pattern and number of beetle catch was consistent between replicated blocks of nine traps (three per species) in the ‘Target’ field, but data for sets of three traps were much more variable. There was evidence of a discontinuity in beetle trap catches between the ‘Target’ and ‘Neighbouring’ fields, especially for *A. sputator*, suggesting that at least for this species, inter-field movement may have been limited by the field boundary. The work provided good evidence that more than one trap set per field should be used, and that traps should be placed at least 20 m into the field. Trap placement on the field margin should be avoided.

General introduction

Wireworms, the larvae of click beetles (Coleoptera: Elateridae), are recognised worldwide 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. In 2000 and 2001, BPC-funded work (Project 807-192) investigated the use of sex pheromone traps designed to capture male click beetles (adult wireworms) as an alternative method of risk assessment. This work, done in association with other European countries (Toth *et al*., 1998; Furlan *et al*., 2001), showed that the pheromone traps were effective in trapping beetles, usually highly specific (few non-*Agriotes* beetles caught), and were potentially capable of identifying the presence of *Agriotes* populations in fields where detecting wireworms by soil sampling was difficult. However, pheromone trap work has only been done so far at five sites known to be infested with wireworms, and the data set on the relationship between the numbers of wireworms remaining in fields and click beetle pheromone traps is consequently too small to be of practical value. No work has yet been done on making a connection between adult beetle trap catches and subsequent crop damage, or evaluating how many traps are required to make an acceptable estimation of the click beetle population in an individual field.

The objectives of the current work were therefore:

1. To evaluate the use of click beetle pheromone traps at commercial field sites using the participation of the potato industry.
2. To establish the relationship between click beetle pheromone trap catches and subsequent wireworm damage to potato crops planted in infested fields.
3. To identify the number of traps required to estimate the wireworm population in a field.
4. To assess the distribution of beetles within fields in relation to possible population movement into fields from neighbouring field margins.

Materials and methods

Evaluation of pheromone traps at commercial field sites

Through direct contact and publicity in the agricultural press, growers and consultants were invited to register their interest in taking part in evaluating click pheromone traps. Site requirements were that traps should be evaluated in fields likely to be going into potatoes in 2003 and where there was a possibility that a wireworm infestation may exist – prior knowledge of wireworm infestation was not required. Forty-five (45) growers and consultants representing 85 fields were identified who wished to take part in the evaluation exercise, ranging in location from Scotland (Fife) to Cornwall.

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 monitoring sites. The traps (known as 'YATLORfunnel' traps) were designed and manufactured in Italy. Although not available commercially, traps can be obtained from Dr Lorenzo Furlan (email lorenzo.furlan@inwind.it). Pheromone capsules were produced and supplied by Dr Miklos Toth, Hungarian Plant Protection Institute, Budapest, and are commercially available (these can also be obtained via Dr Furlan).

Trapping & reporting procedures

Detailed instructions and record sheets were provided to all participants (see Appendix 1). These included record sheets for cropping and insecticide treatment histories for all fields used for click beetle monitoring.

Relationship between click beetle trap catches and damage to potato crops

Analysis of the data returned form the grower sites in 2002 indicated that 18 (out of a target number of 20) sites had data of sufficient quality (traps out in May and checked most weeks until the end of July) to merit follow-up sampling for wireworm. The location and overall beetle trap catches of these sites is given in Table 1. ADAS personnel sampled these sites for wireworms in March 2003 using the standard soil core method (20 x 10 cm diameter soil cores taken in a 1 ha area adjacent to the pheromone trap locations). Of these sites, only eight were planted with potatoes in 2003. Growers at the remaining 10 sites often decided not to plant potatoes on the basis of the trap catches found in 2002, particularly at those sites where season-long catches of beetles were high (see Table 1).

Damage assessment procedure

For those sites where potatoes were to be grown in 2003, growers were sent instructions as to how to proceed to enable damage assessments to be made. In summary, these were:

1. Crop not treated for wireworms (i.e. no application of Nemathorin or Mocap): no grower action required at planting.

2. Crop treated at planting with either Nemathorin or Mocap: growers were asked to leave 10 small untreated plots, each approximately 1 bed (2 rows) by approx. 10 m in length, in the area of the field where pheromone trapping had been done in 2002. Growers were asked to space these plots out at least 10 m apart (see Figure 1 for an example).

Sampling for wireworm damage at harvest

At or near harvest, ADAS staff visited the sites and sampled tubers from untreated areas and (where appropriate) adjacent treated areas using one of the following options:

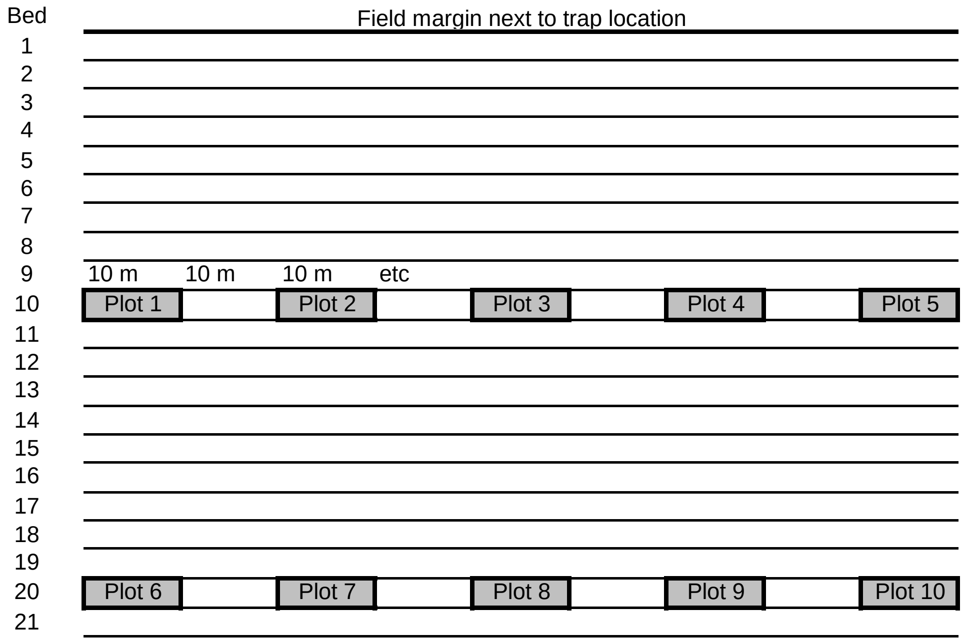
Option 1 – field treated, untreated plots left and identifiable

A random selection of 10 tubers was taken from the centre of each of the 10 untreated plots with a further 10 samples of 10 tubers each taken from a treated area of the field approximately 10 m to one side of each untreated plots. This resulted in a sample of 100 tubers from untreated plots, and 100 tubers from adjacent treated areas.

Option 2 – field treated, no untreated plots OR no treatment applied

A random selection of 20 tubers was taken from each of 10 different locations spaced at 20 m intervals running into the field (a sample size of 200 tubers) adjacent to where pheromone traps were located in 2002.

Figure 1. Example suggested layout of untreated plots in a treated field for damage assessment.



Option 3 – part of field treated, part untreated

A random selection of 20 tubers was taken from each of 10 different locations spaced at 20 m intervals running into the field (a sample size of 200 tubers) adjacent to where pheromone traps were located in 2002. This was repeated for both treated and untreated areas of the field.

Damage assessments

Samples of tubers were returned to the laboratory, washed, dried and inspected for wireworm damage (percentage of tubers damaged and number of holes per tuber).

Table 1. Grower sites running pheromone traps in 2002 selected for follow-up wireworm sampling and potato damage assessment in 2003.

Location	**Treatment**	**Planted**	**Harvested**	**Variety**	**Total beetle catch 2002**
a) Potatoes grown in 2003					
Bourne, Lincs	Nemathorin	20/04/2003	15/10/2003	Maris Piper	404
Baldock, Herts	Mocap	15/03/2003	15/09/2003	K Edward/Estima	150
Bridgwater, Somerset	Nemathorin	25/04/2003	10/09/2003	Sante	110
Woodbridge, Suffolk (S)	None	01/07/2003	01/10/2003	Maris Piper 2nd crop	96
Bradwell, Gt Yarmouth	Mocap	03/04/2003	20/08/2003	Estima or Marfona	58
Nacton, Suffolk	Yes	*No data*	15/08/03	Carlingford	40
Carlton, N Yorks	Nemathorin	15/04/2003	01/10/2003	Pentland Dell, Russett Burbank	39
Woodbridge, Suffolk (B)	Nemathorin	25/03/2003	01/07/2003	Maris Peer	5
b) Potatoes not grown in 2003					
Cressage, Shropshire	No				412
Babraham, Cambridge	No				227
Petersfield, Hants	No				195
Dereham, Norfolk	No				183
Ditton Priors, Shropshire (A)	No				176
Ditton Priors, Shropshire (B)	No				127
Raglan, Gwent	No				78
Crediton, Devon	No				70
St Ishmaels, Dyfed	No				62
Camborne, Cornwall	No				7

Evaluation of number of traps require/field, trap positioning and inter-field movement (Objectives 3 and 4).

Site Locations

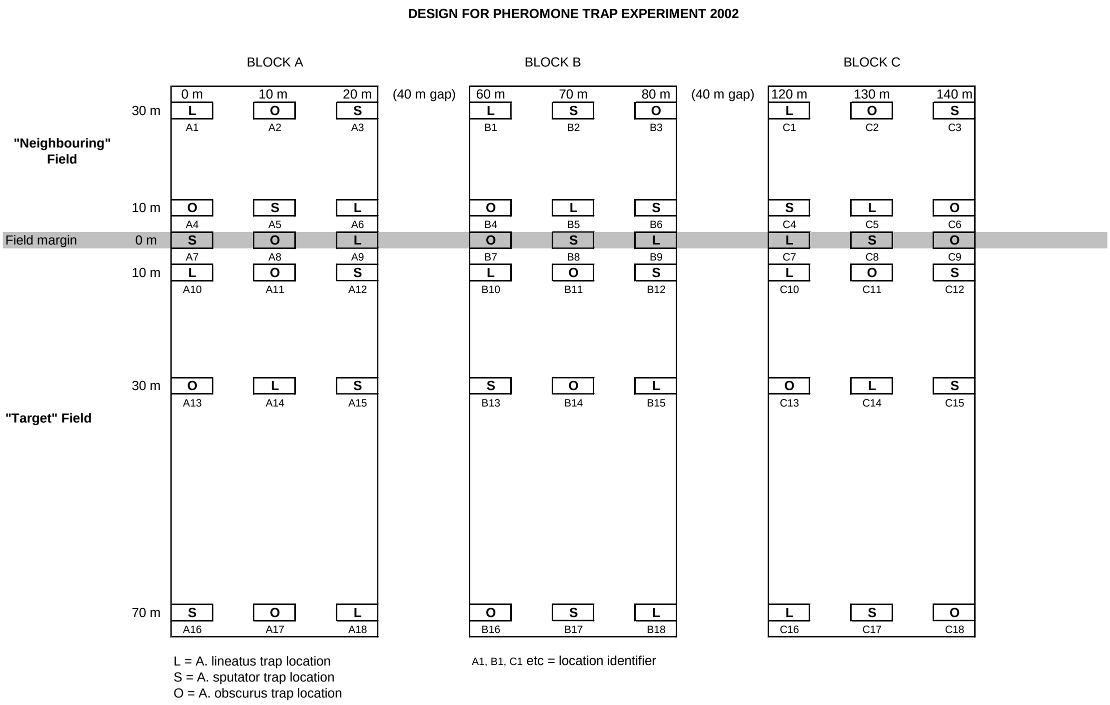
Work was done at Buckfastleigh, Devon and Borth, Ceredigion. Fields at the Buckfastleigh site were in set-aside and those at the Borth site were in grass. Both sites were known to be infested with wireworms.

Experimental design & methodology

Traps were placed both in the 'Target' field (i.e. the field known to contain the wireworm population) and in a field immediately adjacent to the target field (the 'neighbouring' field). Three 'blocks' of pheromone traps were set out (18 traps per block representing six traps each for *A. lineatus*, *A. sputator* and *A. obscurus*) using the design given in Figure 2. The traps were placed at soil level and were inspected once a week for beetle catches from early May until mid-August. Pheromone capsules were replaced at 30 day intervals. All beetles trapped were retained for identification. At both sites, the boundary between the 'Target' and 'Neighbouring' fields consisted of a ditch (containing reeds at Borth) without any hedge-line.

Larval population estimations were done in May 2002 and October/November 2002 by taking one 10 cm diameter soil core to a depth of at least 20 cm at the location of each pheromone trap. On the second sampling occasion, the core at each sampling point was taken 20 cm to one side of the original (May 2002) core location. The soil cores were individually bagged. Wireworms from each core were extracted using Tulgren funnels. Each soil core was placed in a funnel and left in place under the extraction lights for a minimum of 48 h, or until the soil was completely dry. Wireworms were collected under the funnels in pots containing moist soil. The number of wireworms recovered from each sample was recorded. All wireworms were retained for identification.

Figure 2. Experimental layout for field experiments at Buckfastleigh and Borth.



Results

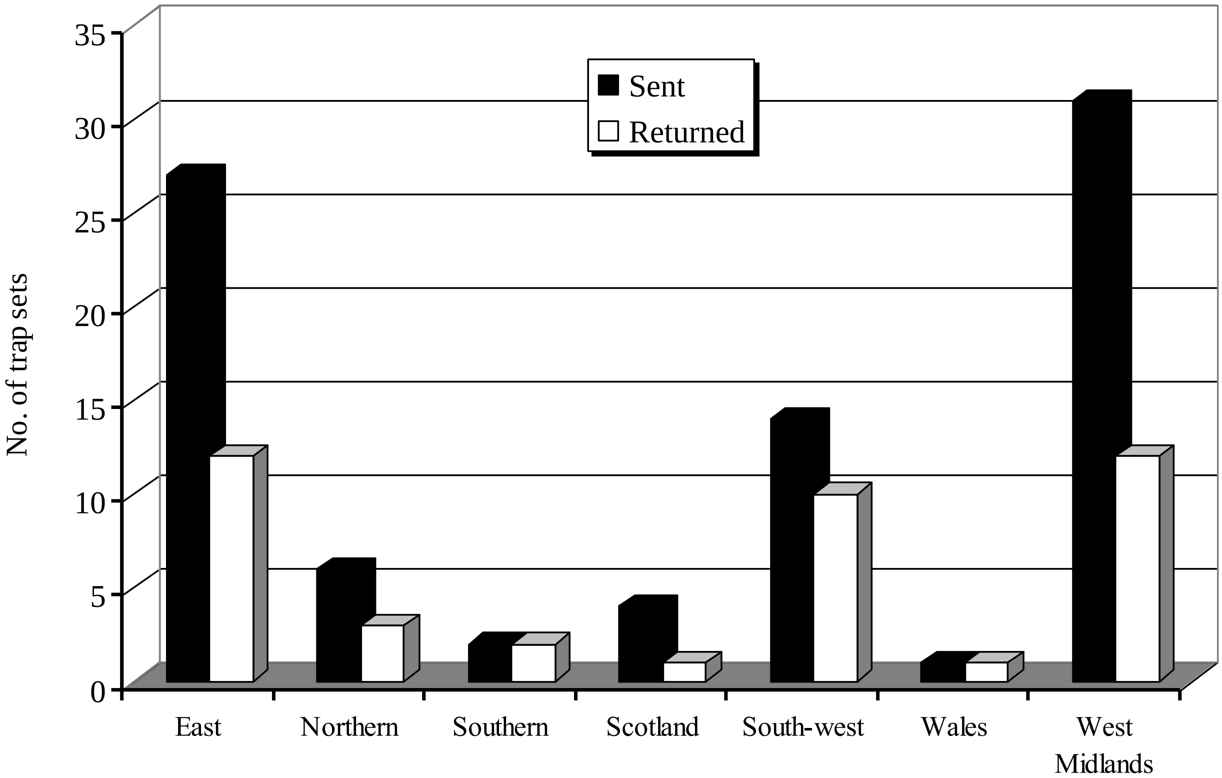
Grower evaluation of pheromone traps

Results from grower sites

Data sets were returned for 37 fields (44% of those originally sent out) from 26 participants (58% of those initially requesting traps). This level of response for a grower-based trial is in fact better than might have been expected. At least 16 trap sets sent to 8 participants were not set out at all. The geographical distribution of the trap returns can be used to indicate areas where wireworms are of particular concern (Figure 3). The majority of trap data (83%) were returned from eastern England, the West Midlands and the south-west, mirroring both the major potato production area (eastern England) and the areas traditionally at more risk from wireworm attack (western and south-western counties).

Due to the late delivery of pheromone traps from Italy and then subsequent delays in recipients actually setting traps, only 21 sites consistently trapped beetles from May (some starting in late May) through until August. The majority of these sites will be followed up for detailed sampling by ADAS in February/March 2004 to evaluate residual wireworm populations.

Figure 3. Distribution of trap sets sent and returned by geographical area



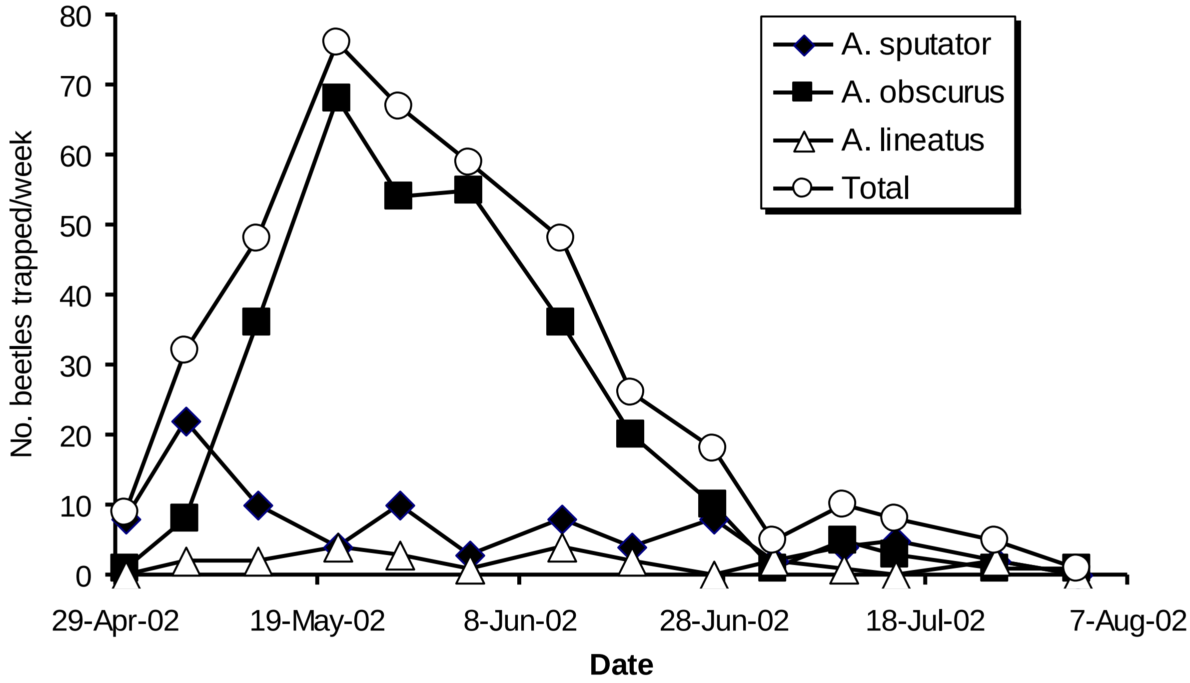
Despite the late start and intermittent data at some sites, click beetles were caught at every site, with the vast majority of sites recording catches of all three species. Using the 21 sites returning the best quality data sets, season-long total catches ranged from just five beetles up to 412. Typical activity patterns at individual sites and a range of sites with different population levels is shown in Figure 4 and 5 respectively. It was also apparent that *A. obscurus* tended to be the most dominant species in western counties (6/8 sites), whereas *A. sputator* tended to be the dominant species at the eastern sites (5/7 sites). *A. lineatus* was dominant at only one site. Broadly equal numbers of the three species were recorded at the remaining sites.

Cropping records from the 37 fields (going back to 1997) indicated that only 11 (30%) of fields had any recent history of grass in the rotation. The majority of fields had been in arable production for at least the last five years, and yet still harboured significant numbers of click beetles. This is the first indication of the extent to which *Agriotes* species are apparently widespread in all-arable fields.

There were some unexpected problems with the management of the traps. Some growers inadvertently opened the pheromone capsules. This allows the pheromone to disperse very quickly, and would have reduced the overall trap catch. More explicit instructions would solve this problem. Some traps placed in cereal fields also caught relatively high number of different ground beetle species. However, these can be easily distinguished from click beetles as they are often fast-moving and brightly coloured, whereas click beetles tend to 'play dead' when disturbed, and do not have bright colouration.

Figure 4. Examples of activity patterns of click beetles caught in traps at growers' sites.

a) Cressage, Shropshire



b) Babraham, Cambridgeshire

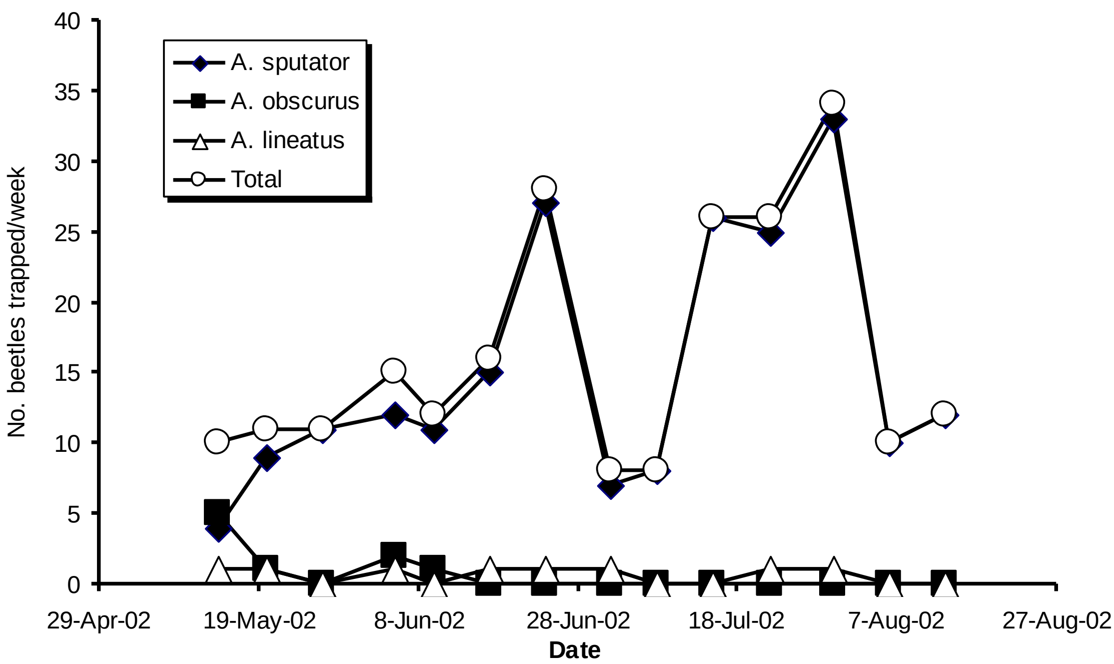
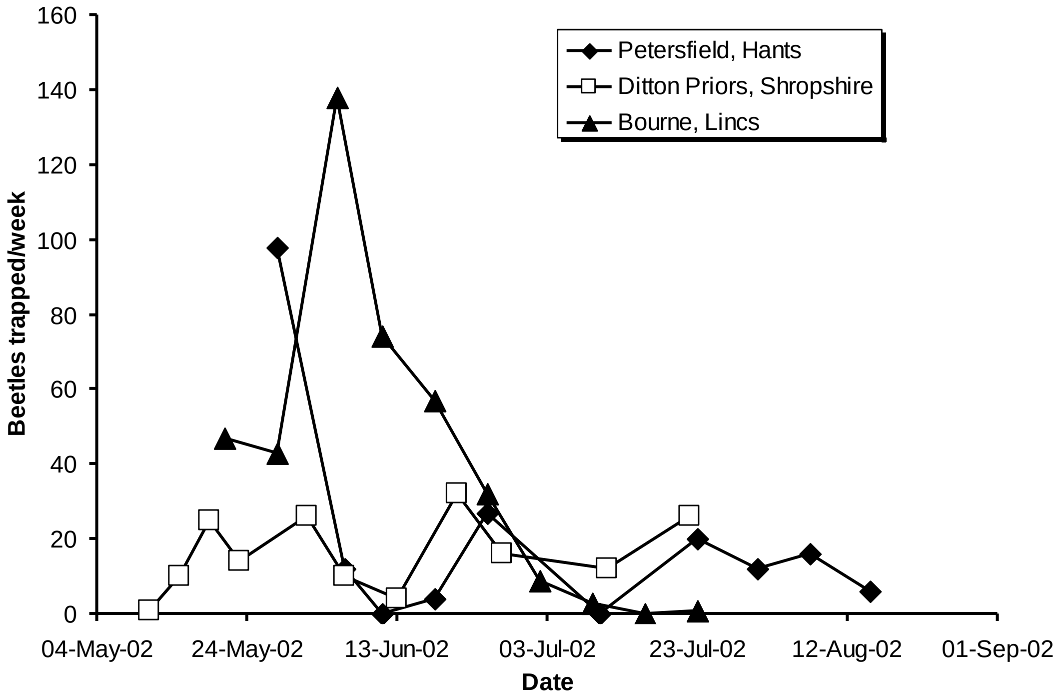
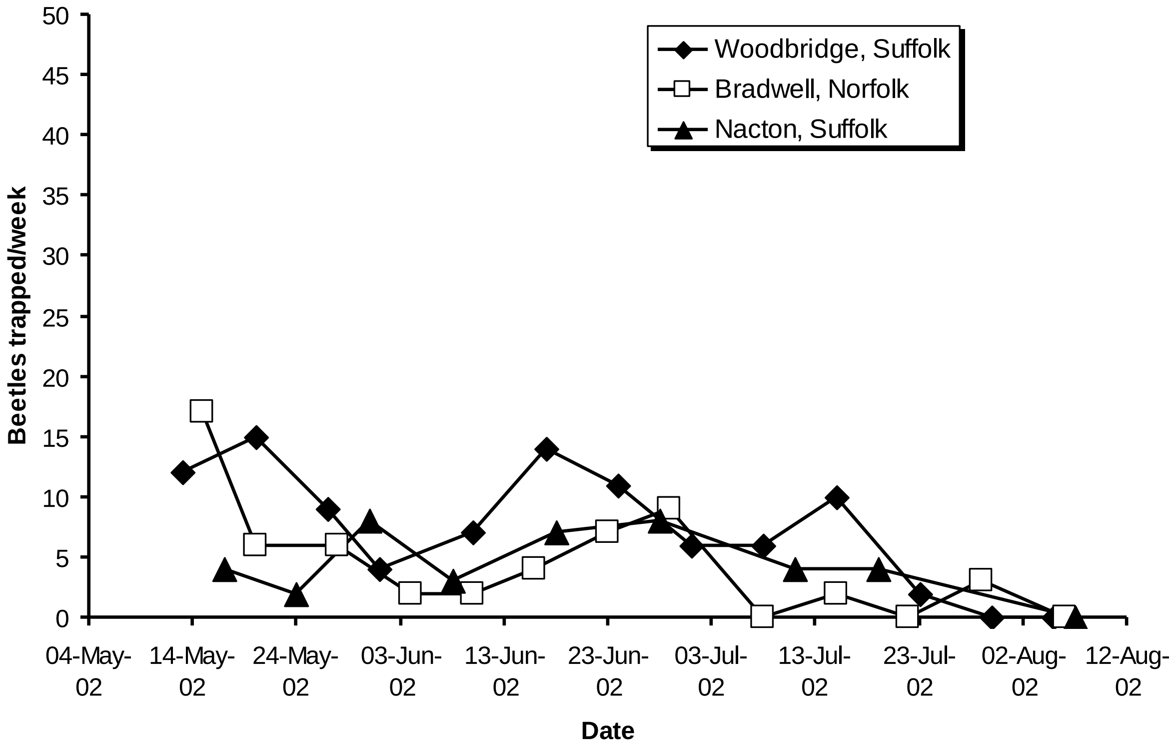


Figure 5. Examples of high and low click beetle catches at growers' sites.

a) High incidence sites



b) Low incidence sites



Relationship between beetle trap catches and residual wireworm populations

The results of the wireworm sampling done at the 18 grower sites selected for further study (see Table 1) are given in Table 2.

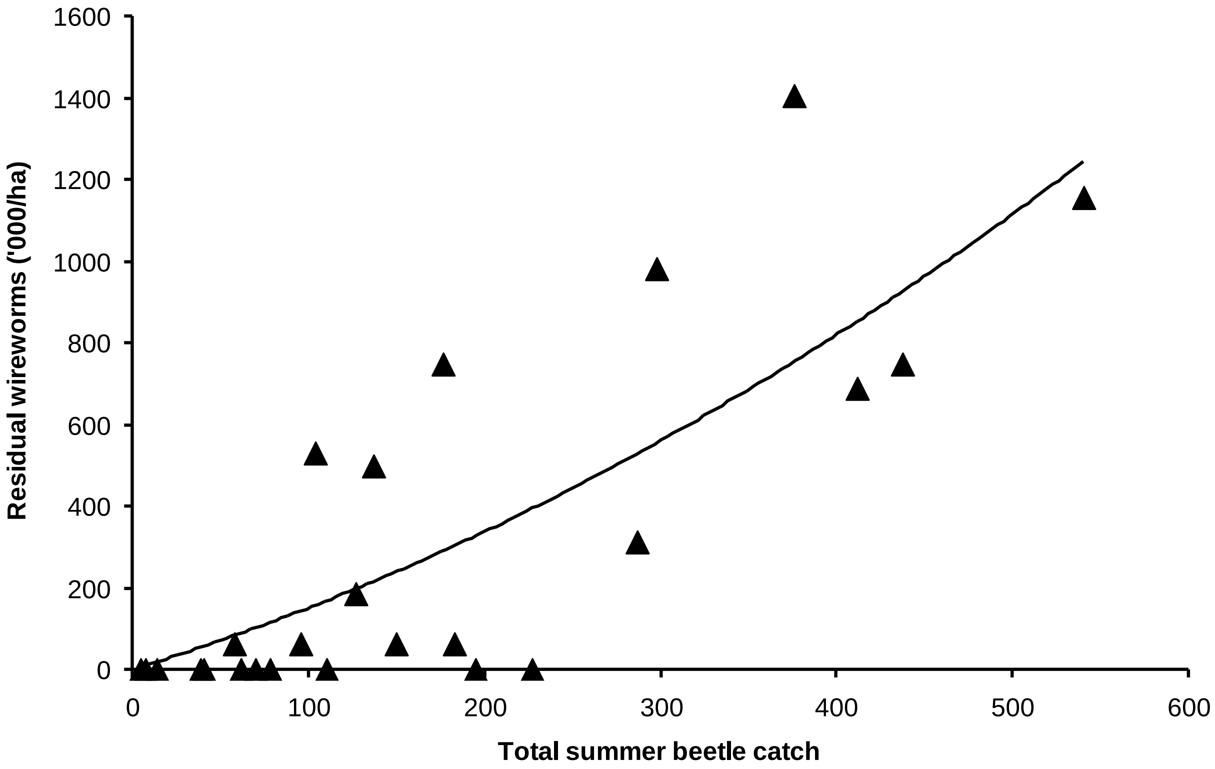
Table 2. Result of wireworm assessments (by soil core sampling) made at 18 sites in March 2003.

Location	**Wireworms in 20 cores**	**Wireworm population (000/ha)**	**Total beetle catch 2002**
Cressage, Shropshire	11	687,500	412
Bourne, Lincs	2	125,000	404
Babraham, Cambridge	0	0	227
Petersfield, Hants	0	0	195
Dereham, Norfolk	1	62,500	183
Ditton Priors, Shropshire (A)	12	750,000	176
Baldock, Herts	1	62,500	150
Ditton Priors, Shropshire (B)	3	187,500	127
Bridgwater, Somerset	0	0	110
Woodbridge, Suffolk (S)	1	62,500	96
Raglan, Gwent	0	0	78
Crediton, Devon	0	0	70
St Ishmaels, Dyfed	0	0	62
Bradwell, Gt Yarmouth	1	62,500	58
Nacton, Suffolk	0	0	40
Carlton, N Yorks	0	0	39
Camborne, Cornwall	0	0	7
Woodbridge, Suffolk (B)	0	0	5

There was a considerable variation in the number of wireworms found relative to the numbers of beetles caught. One site (Bourne) was an obvious outlier where 404 beetles were caught but only two wireworms were found. Previous work (BPC Project 807-192) has also found occasional sites that do not fit the general pattern of the data. However, wireworms were detected at the majority (6/9) of sites where >100 beetles were caught during the season, whereas wireworms were detected at only 2/9 sites where <100 beetles were caught. This difference was nearly statistically significant ($\chi^2 = 3.6$, 1 d.f. $P = 0.058$). No wireworms were found at sites where the total beetle catch was <50.

Compared with work done in BPC Project 807-192 where highly infested sites were deliberately chosen, the beetle catches at the grower sites were relatively low. Combining the data from this study and from Project 807-192 (excluding the obvious outliers, 3/28 sites) gave a much clearer indication of the relationship between beetle trap catches and residual wireworm populations than has hitherto been possible (Figure 6). The equation for the curve fitted to the data in Figure 6 (2nd order polynomial) is $y = 0.0018x^2 + 1.3231x$, where y = the residual wireworm population and x = total click beetle trap catch. The % variance accounted for (R^2) was 63.3%.

Figure 6. Relationship between summer beetle catch and residual wireworm population at individual sites (data covering period 1999-2003).



The data in Figure 6 can also be used to produce generalised risk categories to aid growers in interpreting click beetle trap catches in terms of likely residual wireworm population levels. This was done by selecting a range of click beetle catch categories, allocating each of the data points in Figure 6 to one of the categories, and averaging the actual beetle catch and wireworm infestation level for all sites within a category. The results are presented in Table 3, and graphically in Appendix 2.

Table 3. Categorisation of beetle catches and wireworm populations (data ex Figure 6, n = number of data points (sites) in each category).

Category (beetle trap catch)	Mean no. beetles (range)	Mean no wireworms (range)	Mean no. wireworms/ha	n
<50	21 (5 - 40)	0 (0)	0	5
50-100	72.8 (58 - 96)	0.4 (0 -1)	25,000	5
101-150	125.6 (104 - 150)	4.1 (1 - 9)	256,250	5
151-300	227.7 (176 - 298)	5.6 (0 - 16)	351,000	6
>301	441.3 (376 – 540)	16.0 (11 - 19)	1,000,000	4

Relationship between click beetle pheromone trap catches and subsequent wireworm damage to potato

Data on damage to potatoes was obtained from seven of the eight sites that were planted with potatoes in 2003 (see Table 1 for site locations). The site at Baldock, Herts was harvested before a damage assessment in the field could be made. The results for the remaining sites are given in Table 4.

Table 4. Wireworm damage assessments made at sites growing potatoes in 2003 where pheromone trapping had been done in 2002.

Location	Treated	Untreated	Total beetle catch 2002
Bourne, Lincs	7	4	404
Bridgwater, Somerset	0.5	0	110
Woodbridge, Suffolk (S)	0	0	96
Bradwell, Gt Yarmouth	11	3	58
Nacton, Suffolk	0	0	40
Carlton, N Yorks	7	5	39
Woodbridge, Suffolk (B)	0	No data	5

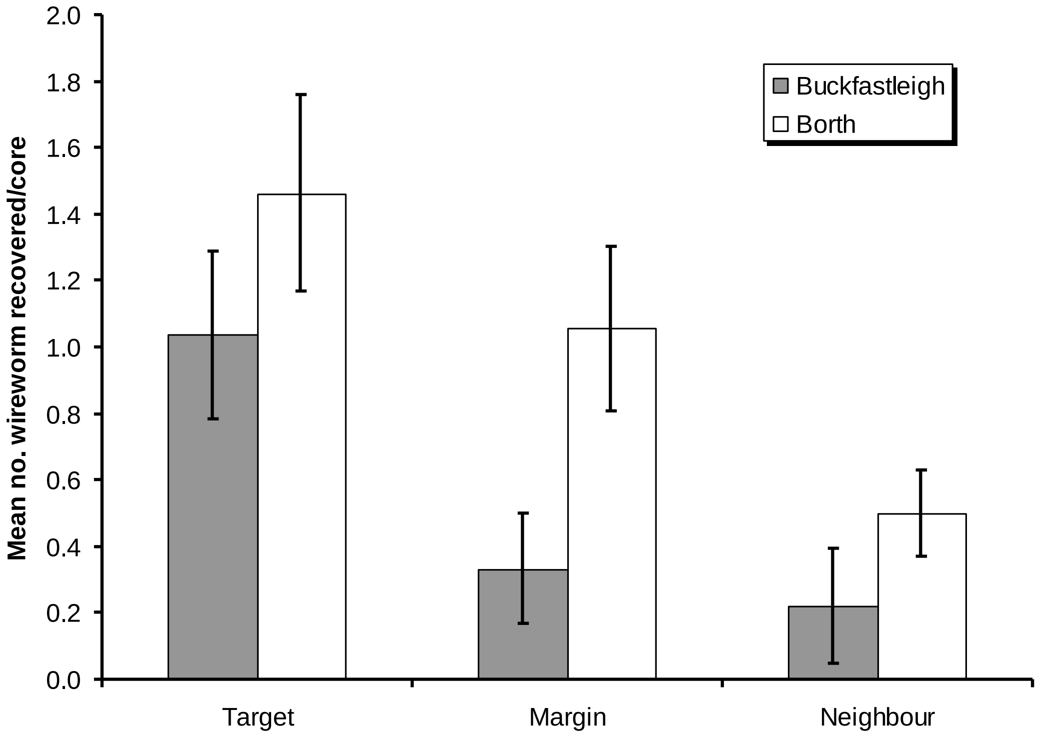
These data are limited and insufficient for detailed statistical analysis. A tentative conclusion is that wireworm damage was generally <10% of tubers attacked at those sites where total click beetle catches were <100 in the previous summer, and that treatment with either Mocap or Nemathorin was probably not worthwhile at this level of infestation. The damage at Bourne, Lincs appeared low relative to the numbers of beetles caught. However, an atypically low number of wireworms were found at this site (Table 2).

Evaluation of number of traps require/field , trap positioning and inter-field movement

Wireworm populations

The wireworm populations from the target field, margin and neighbouring fields from the sites at Borth and Buckfastleigh are shown in Figure 7. At Buckfastleigh, a total of 35 wireworms were recovered (May sampling only). Analysis of variance (ANOVA) using the General Linear Model (GLM) indicated that significantly fewer wireworms were found in the ‘neighbouring’ field compared with the populations in the ‘target’ field ($F_{2,49}$=5.05, P=0.01, data $\log_{10}$ (n+1) transformed prior to analysis).

Figure 7. Mean number of wireworms/core (± standard error of the mean) in the 'target' field, field margin and 'neighbouring' field at Buckfastleigh and Borth.

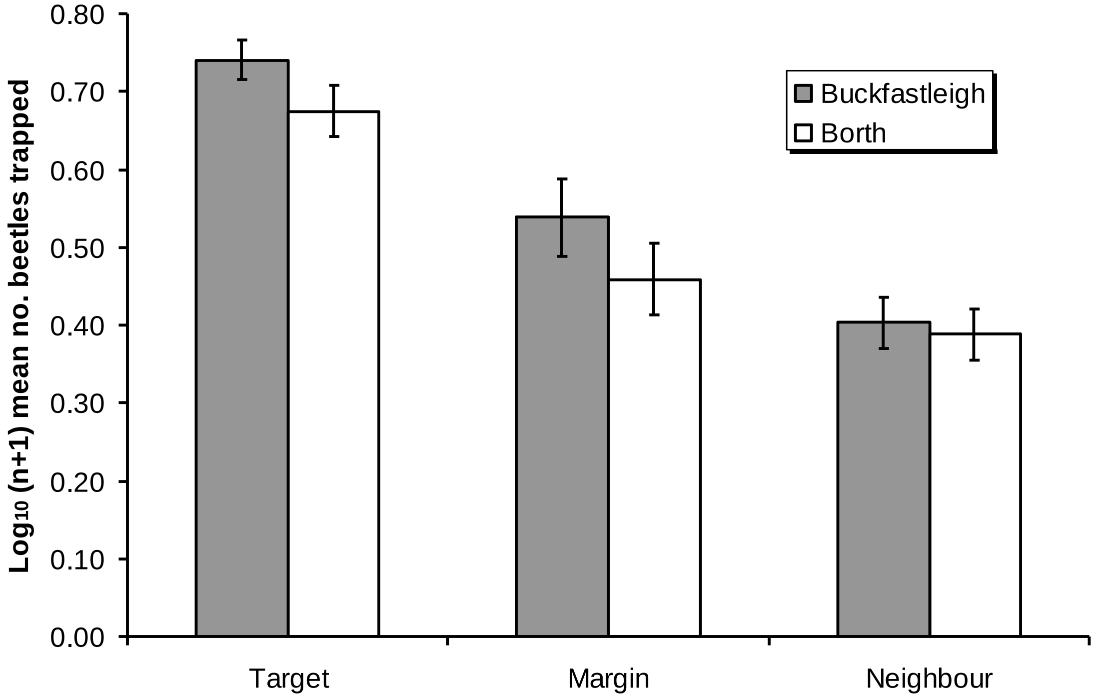


At Borth, data from both the spring and autumn samples were available (a total of 116 wireworm recovered) at the time of writing. There was no significant difference in the total number of wireworms recovered on the two sampling occasions ($F_{1,102}$=1.14, *P*=0.29, data $\log_{10}$ (n+1) transformed prior to analysis). As at the Buckfastleigh site, significantly fewer wireworms were recovered from the 'neighbouring' field compared with the populations in the 'target' field ($F_{2,102}$=3.50, *P*=0.03). There were no differences in the mean number of wireworms recovered between the three replicate blocks at either site (Buckfastleigh, $F_{2, 49}$=2.47, *P*=0.095; Borth, $F_{2, 102}$=0.74, *P*=0.48; all data $\log_{10}$ (n+1) transformed prior to analysis).

Pheromone trap catches

Overall, significantly more beetles were caught in the 'Target' field than the 'Neighbouring' field (Figure 8) at both Buckfastleigh ($F_{2, 693}$=33.52, *P*<0.001) and Borth ($F_{2, 746}$=20.10, *P*<0.001), reflecting the lower wireworm populations recorded in the 'Neighbouring' fields at both sites (Figure 7). Beetle trap catches in the field margin were intermediate.

Figure 8. Mean number of beetles trapped (quoted as $\log_{10}$ (n+1) transformed data ± standard error of the mean) in the 'Target' field, field margin and 'Neighbouring' field at Buckfastleigh and Borth.



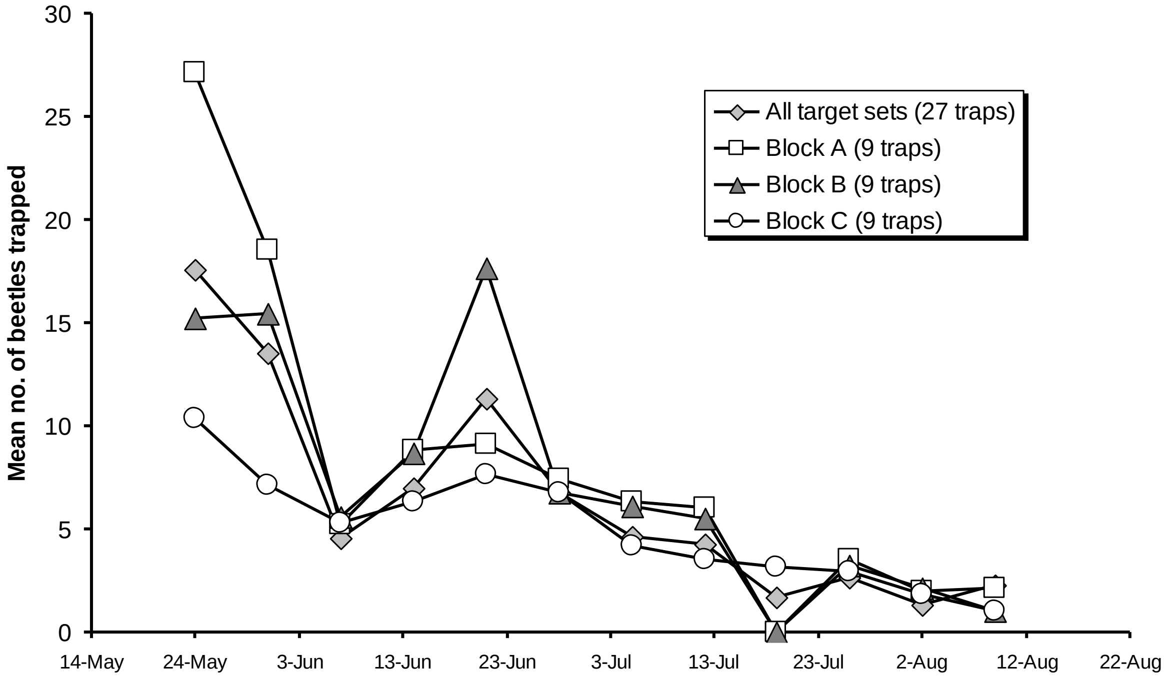
Effect of trap number on overall beetle catch

At Buckfastleigh and Borth, the pattern of activity in all traps in the 'Target' field was similar whether a total of 27 traps were used (all traps in the 'Target' field) or whether only the traps from one block (9 traps/block) in the 'Target' field were used (Figure 10). In terms of the mean total trap catch for the season in the 'Target' field only, there was no significant difference between the 27 trap total of the three individual nine-trap catch totals (Buckfastleigh, $F_{2,\ 462}$=2.35, *P*=0.096; Borth, $F_{2,\ 498}$=1.26, *P*=0.286.

The season-long total trap catches from the sets of three traps (one each for *A. sputator*, *A. obscurus* and *A. lineatus*) placed at different locations are shown in Figure 10. Analysis of variance of the data from Buckfastleigh (Figure 10a) indicated a significant difference between blocks ($F_{2,\ 684}$=4.99, *P*=0.007), between trap location in the 'Target' field, field margin or 'Neighbouring' field ($F_{5,\ 684}$=14.44, *P*<0.001), and a significant block x position interaction ($F_{10,\ 684}$=2.69, *P*=0.003).

Figure 9. Mean number of beetles trapped per sample period in the 'Target' field across all blocks (n=27 on each occasion) and in individual blocks (n=9 on each occasion).

a) Buckfastleigh



b) Borth

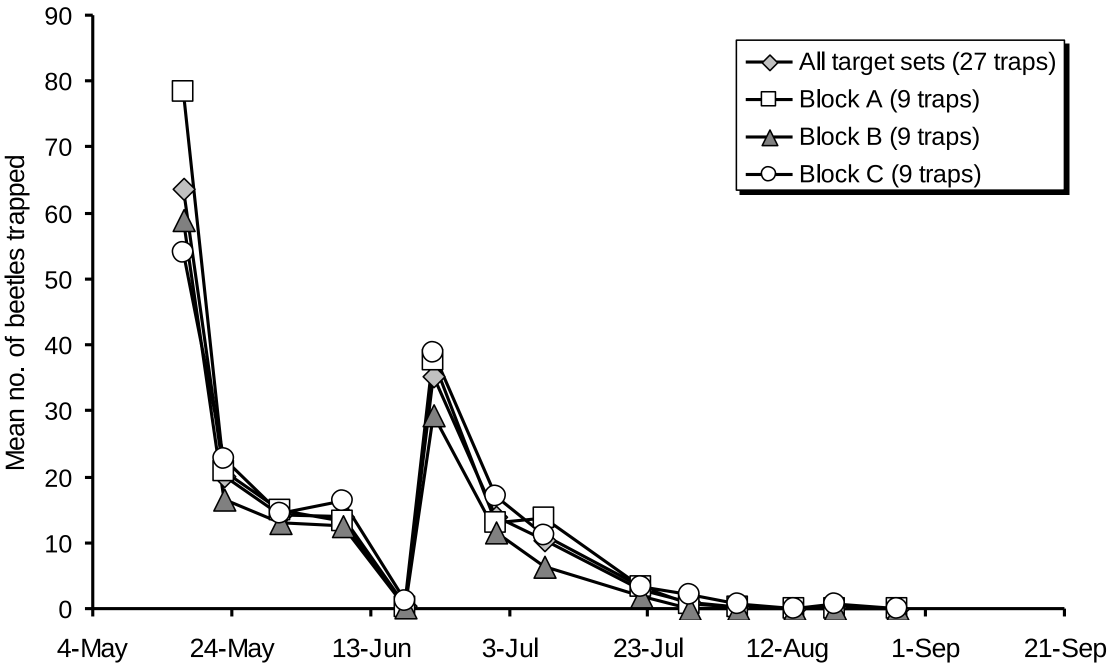
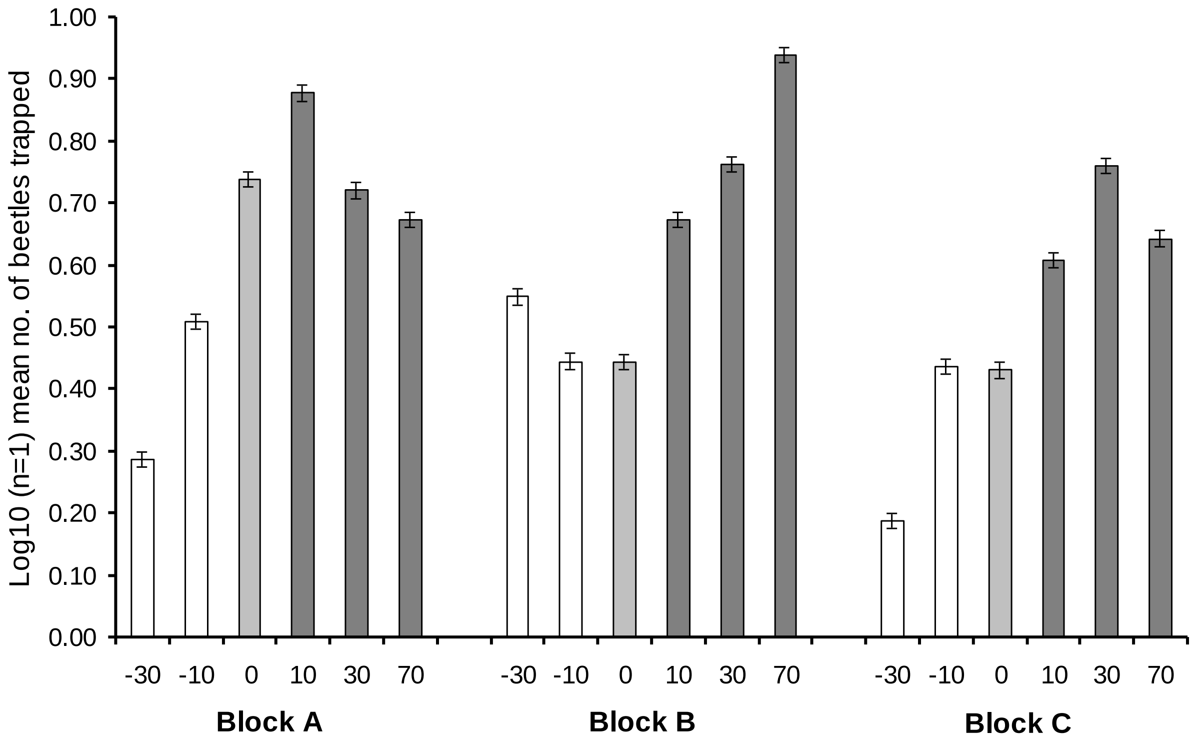
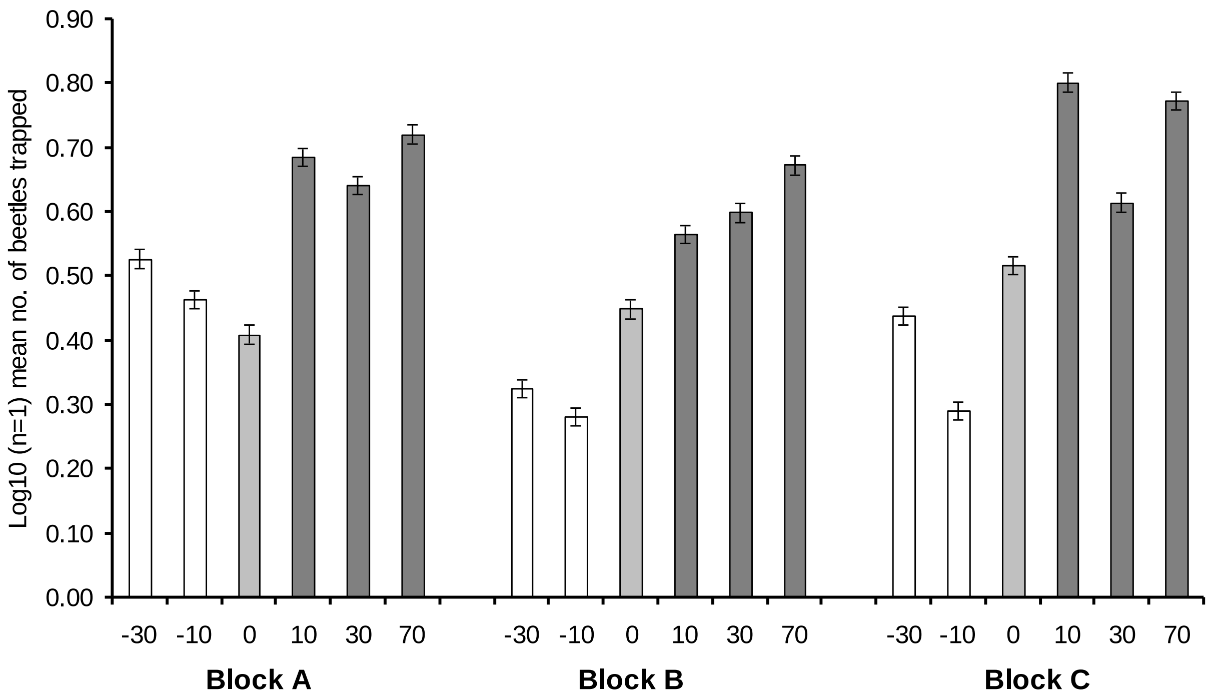


Figure 10. Log_{10} mean number of beetles trapped (season's total $\pm$ standard error of the mean)) in the 'Target' field (10, 30 & 70 m into the field), in the field margin (0 m) and in the 'Neighbouring' field (-10 & -30 m) in different blocks. Each bar represents the season-long catch of 3 traps.

a) Buckfastleigh



b) Borth



At the Borth site, a significant effect of trap location on trap catch was observed ($F_{5, 737}$=8.68, *P*<0.001), but not between blocks ($F_{2, 737}$=2.07, *P*=0.127). No significant block x position interaction was found ($F_{10,737}$=0.59, *P*=0.821). At both sites, trap catches were generally lower in the 'Neighbouring' fields (and to some extent in the field margins) than in the 'Target' field.

Possible inter-field movement of beetles

The experimental layout was designed to assess whether marked discontinuities in pheromone trap catches of beetles occurred at or around the field margin of adjacent fields. Figure 11 shows the mean season total trap catch for all traps at different distances from the field margin in both the 'Target' and 'Neighbouring' fields at both sites. At Buckfastleigh (Figure 11a), total beetle trap catches varied significantly ($F_{5, 684}$=14.44, *P*<0.001) with trap location. Catches were highest 10 m or more away from the field margin but declined at the field margin and were lower still in the 'Neighbouring' field. Analysis of the trap catches for individual species showed that this decline was largely due to significantly lower *A. sputator* catches (effect of trap position, $F_{5, 684}$=9.78, *P*<0.001) in the 'Neighbouring' field.

Broadly similar results were also recorded at Borth (Figure 11b – total beetle catches are a mean of all three species) where total beetle trap catches also varied significantly with trap position ($F_{5, 737}$=8.68, *P*<0.001). Analysis of the trap catches for individual species showed that this decline was again largely due to significantly lower *A. sputator* catches (effect of trap position, $F_{5, 234}$=17.11, *P*<0.001) in the 'Neighbouring' field.

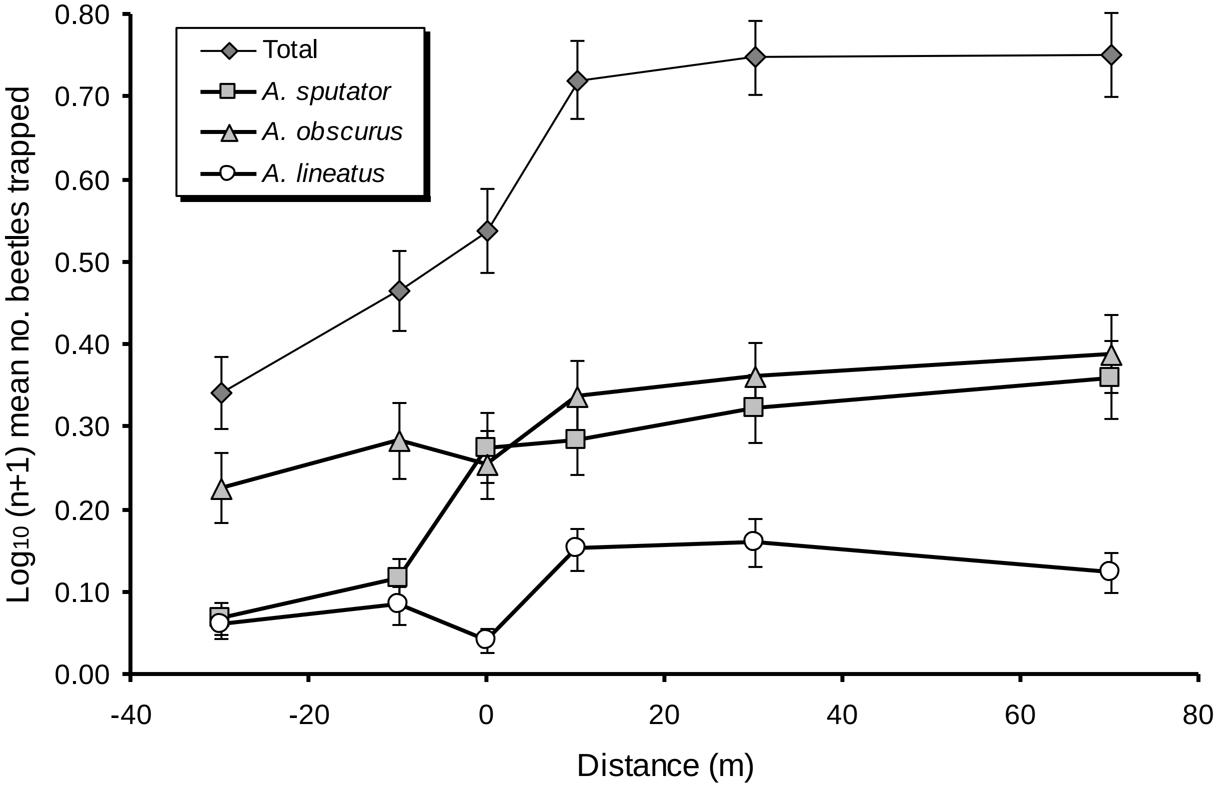
Discussion

Pheromone trapping at commercial sites

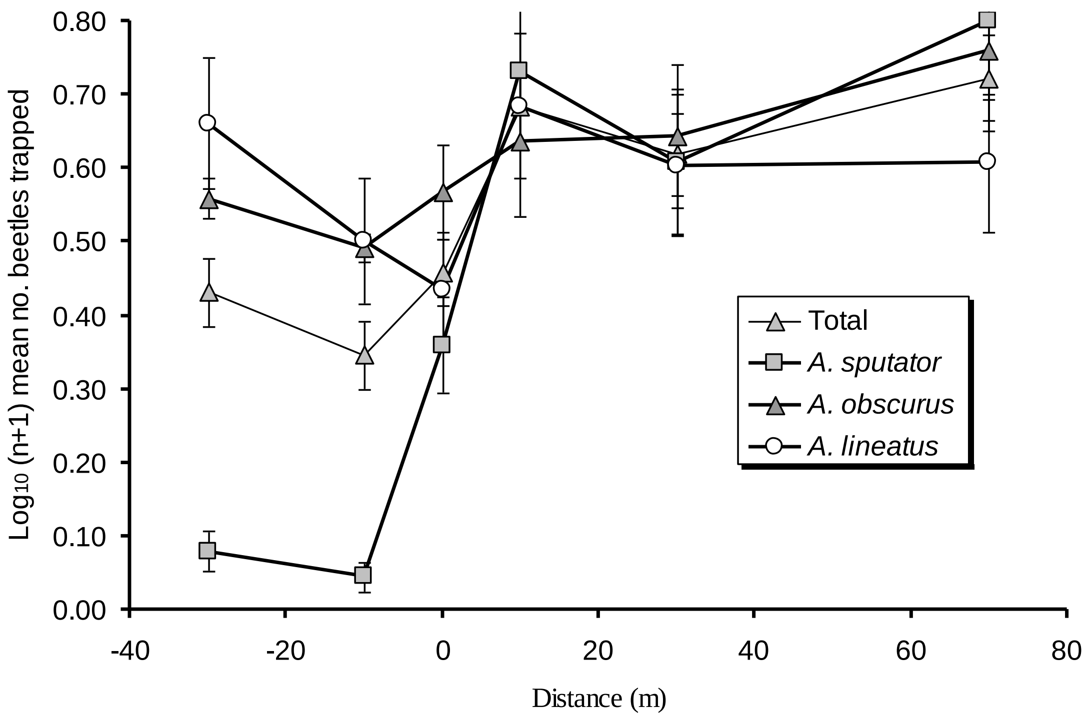
The available data from this exercise showed that the pheromone traps consistently caught all three species of click beetles at a wide range of sites in a range of crop types. The importance of ensuring traps were out in time to catch the peak of beetle activity in mid to late May was particularly highlighted. Those data sets that only included trapping records form the beginning of June are of limited value in determining any relationship between beetle trap catches, residual wireworm populations, and subsequent crop damage, although they did of course indicate that a wireworm population was present in the field.

One of the most striking overall features of the data set obtained from growers was that click beetles were caught at every site, even though the majority of sites (70%) had no history of grass in the rotation at least as far back as 1997. This clearly indicates the wireworms are much more widespread in all-arable fields than hitherto suspected, possibly persisting at levels normally too low to cause obvious damage to crops such as cereals.

Figure 11. Mean total number of beetles (quoted as $\log_{10}$ (n+1) transformed data $\pm$ standard error of the mean) trapped a different locations in the 'Target' field (10, 30 & 70 m), field margin (0 m) and 'Neighbouring' (-10 & -30 m).



b) Borth



The observation that *A. sputator* was often dominant in eastern sites, whereas *A. obscurus* was dominant at western sites is only broadly comparable to the results of surveys done in the 1940s (Anon., 1948). These showed that *A. obscurus* was the dominant species in northern England and mid- and North Wales, whereas in the midlands and eastern and southern England, all three species occurred, although *A. sputator* and *A. lineatus* were locally dominant.

Relationship between click beetle trap catches, residual wireworm populations, and crop damage

The large data set created by the grower evaluation of pheromone traps and the subsequent follow-up wireworm sampling has proved to be entirely complimentary to data on pheromone trap efficacy collected in previous work in the UK. Combining these data have allowed a robust relationship (Figure 6) to be derived that links total (season-long) click beetle trap catches with residual wireworm populations. This and further examination of the data (Table 3) suggests that click beetle catches of <50 during the season indicates the presence of wireworm populations that are below the detection limit of standard soil sampling techniques.

Although only limited work relating actual wireworm damage to potato click beetle trap catches was possible, a tentative conclusion would be that beetle catches of <100 (residual wireworm populations at or below the detection limit) indicate a very low risk of crop damage. However, *c*. 5-10% of field sites throw up ‘outlying’ results (very high beetle populations with low wireworm populations or *vice versa*). Growers should therefore try to use as many risk assessment methods as possible (site factor analysis, pheromone trapping, soil sampling, bait trapping) to gauge fully the wireworm risk in any particular field.

Evaluation of number of traps require/field, trap positioning and inter-field movement

The detailed pheromone trapping work at Buckfastleigh (Devon) and Borth (Ceredigion) provided statistically sound evidence of the level of variability that can occur in trap catches at different locations in the same field. The results from the two sites were generally consistent, indicating that general conclusions may be drawn with reasonable confidence about them, although the wider applicability of the results to other sites with different characteristics is speculative at the moment.

The pattern of beetle trap catches and the number trapped through the season was consistent at both sites regardless of whether data were taken for the full trap complement in the ‘Target’ field (27 traps), or from sub-sets of nine traps placed in different blocks in the same field (Figure 6). However, using data from sets of three traps at different locations in the ‘Target’ and ‘Neighbouring’ fields (Figure 7) clearly resulted in more variability in total trap catch. A single set of three traps is almost certainly too small a number to give an acceptably consistent indication of click beetle populations in any particular field. With the exception of Block A at Buckfastleigh (Figure 7a), more beetles tended to be caught 10 m or more away from the field margin in the 'Target' field , indicating that the field margin is probably not the ideal location for the traps.

Evidence of the degree of inter-field movement derived from the experiments at Buckfastleigh and Borth is only circumstantial, but nonetheless provides some useful indications. Wireworm populations were lower in the 'Neighbouring' field than the 'Target' field and both sites (Figure 4), and overall mean beetle trap catches were also lower in the 'Neighbouring' field at both sites (Figure 5). This infers that any inter-field movement was limited. The mean total catches of the three species at different locations (Figure 8) also suggest that a marked discontinuity in beetle trap catches can occur around the field boundary. At both sites, this was most marked for *A. sputator*. This is the smallest of the three species, and it is possible that the 'ditch' barrier between the 'Target' and 'Neighbouring' fields at both sites presented more of a barrier to this species (all of which probably mainly disperse by walking) than the other two. However, this may also reflect a difference in species composition between the two fields. Identification to species of the wireworms recovered from the two fields (currently in hand) would help to resolve this question.

Conclusions

1. The pheromone traps were effective in trapping click beetles at a range of sites throughout the UK. Placing traps out in late April/early May is critical if a full picture of the level of beetle populations at individual sites is to be identified.
2. Click beetles were easily found in many fields with all-arable rotations, suggesting that so-called 'arable' wireworms are much more widespread than hitherto suspected.
3. A single set of three traps (one trap per species) was not enough to give a consistent estimation of the click beetle population in a given field. Nine traps (three traps per species) gave a much more robust estimate. However, in practice, a *minimum* of two trap sets (six traps in total) could be used.
4. Trap location can influence the level of trap catch. Traps placement in the field margin should be avoided as this could underestimate the beetle population.
5. Some inter-field movement may occur, but the current indications are that this is likely to be limited. The recommendation used in 2002 to place traps 20 m from the field margin and at least 30 m apart should ensure that inter-field movement does not significantly influence the overall trap catch.
6. A sound relationship exists between the total (season-long) catch of adult click beetles and the residual wireworm population remaining in the soil. This can be exploited to guide growers on the interpretation of trap catches
7. Only limited work relating actual wireworm damage to potato click beetle trap catches was possible. However, this did indicate the possibility that very low (<50) catches of beetles indicated the presence of wireworm populations below the detection limit of standard soil sampling techniques. Any damage caused by such low populations was also commercially undetectable, although it should be noted that wireworm distribution and hence damage in the field can be patchy.

Acknowledgements

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Appendix 1: Grower instructions for pheromone trapping

EVALUATION OF CLICK BEETLE (WIREWORM) PHEROMONE TRAPS

Thank you for agreeing to take part in this evaluation of click beetle traps. This is part of a research project sponsored by the British Potato Council (BPC). The work is being co-ordinated by ADAS.

BACKGROUND TO THE PROJECT

Current risk assessment methods for identifying wireworm-infested fields (principally soil sampling and bait trapping) are not foolproof and are often used too close to planting to allow alternative, uninfested sites to be found. Wireworm risk assessment methodologies therefore need to be improved. BPC-funded work over the last two years has evaluated the use of pheromone traps for click beetles (adult wireworms) as an alternative approach to risk assessment. This work, done in association with other European countries, has shown that pheromone traps can provide a quick and sensitive method of detecting the presence of wireworm populations in individual fields.

As there is currently tremendous interest in the potential use of the click beetle pheromone traps in the potato growing industry, we are running a wider-scale evaluation of the pheromone traps is done. This allows users to assess for themselves the use of the traps, and will also vastly increase the data set on pheromone trap effectiveness in a wide range of commercial situations.

In addition to the monitoring done by growers, more detailed, targeted scientific work associated with this wide-scale test will ensure that additional data on the key relationship between click beetle trap catches, wireworms present in the soil, and subsequent damage to the potato crop can also be done efficiently.

The overall project objectives are listed below.

Objectives

1. To evaluate the use of click beetle pheromone traps at commercial field sites.
2. To establish the relationship between click beetle pheromone trap catches and subsequent wireworm damage to potato crops planted in infested fields.
3. To identify the number of traps required to estimate accurately the wireworm population in a field.
4. To assess the distribution of beetles within fields in relation to possible population movement into fields from neighbouring field margins.

If you have any queries, please contact the project leader:

Dr Bill Parker, ADAS, Woodthorne, Wolverhampton, WV6 8TQ *Office tel*. 01902 693271; *fax*: 01902 693166; *home business line*: 01746 712815 (from 15 May); *mobile*: 07785 351955; *email*: bill.parker@adas.co.uk

TRAPPING INSTRUCTIONS

To ensure that consistent results are obtained, it is important to follow the instructions as closely as possible.

Setting up the traps

1. You need three traps per field, on trap for each of the three main click beetle species (*Agriotes sputator, Agriotes lineatus, Agriotes obscurus*). Assemble the traps using the instructions enclosed in the box. Mark each trap (e.g. using a permanent marker or a sticky label) with either an 'S', 'O' or 'L' (for **S**putator, **O**bscurus, or **L**ineatus) so you can identify which trap contains the pheromone for each click beetle species.
2. Insert the pheromone capsule – again refer to the instructions for the where in the trap system to locate the pheromone capsule. The pheromone capsules come in the foil packets with the name of the relevant beetle species on a small label on the outside. Cut open the foil packet and lift out the pheromone dispenser using the plastic tape attached to it. **IT IS VERY IMPORTANT NOT TO TOUCH THE PLASTIC OF THE DISPENSER OR THE RELEASE OF PHEROMONE WILL BE IMPAIRED!** Ensure that you put the Sputator pheromone in the trap marked 'S', the Obscurus pheromone in the trap marked 'O', and the Lineatus pheromone in the trap marked 'L'.
3. Note that you will need to put a fresh pheromone capsule in each trap every 30 days (see below) – **please keep the spare pheromone capsules in the 'fridge** (not the freezer).

Where to put the traps

1. The traps should be set up in fields that are likely to be going into potatoes in 2003 and where you think you either have or might have a wireworm infestation. The traps should be located about 20 m into the field, with each trap separated by about 30 m.
2. The traps should be placed on the ground – the plastic spike on the base of the trap should be pushed into the soil to prevent it being blown away. If the field has a standing crop in it which is high enough to shelter the trap (e.g. cereals), you will need to cut down a small area of crop around the trap location: 0.5 m^2 around each trap is sufficient. Mark the location of each trap with a tall cane.

Trapping Period & frequency of checking

The main beetle activity period is April to August, so traps need to go out as soon as possible, and should be checked at least **weekly** until mid-August.

Checking the traps and keeping records

1. Beetles are caught in the traps by walking up the sides of the base cone and falling into the inside of the cone via the hole at the top. To check the trap, the easiest was is to lift it up and shake it gently to see if you can hear anything rattling inside. If there is a rattle, open the trap by removing the plastic base-plate and tip

the beetles out to count them. The trap is best opened over a tray or in a large plastic bag to prevent the beetles just dropping onto the ground.

2. Count the number of beetles in the trap, record the catch (including zero catches) on the sheet provided – don't forget to fill in the date.
3. Replace the base plate and put the trap back in position.
4. Don't forget to change the pheromone capsule every 30 days, and ensure you replace the pheromone with the type (Sputator, Obscurus or Lineatus) that was in the trap before.

Field Information

For each field where you are doing trapping, please fill out one of the enclosed field history and information sheets.

Additional sampling for wireworms

The value of the results will be greatly increased if you can sample the fields used for trapping for wireworms in the autumn. This will enable us to analyse the relationship between pheromone trap catches of beetles and wireworms remaining in the soil. Wireworm sampling can be done either by soil sampling or bait trapping - further instructions on how to do this will be issued in the autumn. As a back up, ADAS will select 20 fields based on the pheromone trap catch data and sample these to ensure that some data on wireworm populations is obtained.

Damage assessment in potatoes in 2003

We would also like actual levels of wireworm damage to be assessed in fields that eventually go into potatoes in 2003 – again, further details on this will be issued later.

Review meetings

We intend to hold a meeting late in 2002 to review the findings of the work to date which you will be invited to attend. Further details will follow in due course.

CLICK BEETLE PHEROMONE TRAPPING – TRAP CATCH RECORD SHEET

Field name:	
Name & Farm address:	

Date traps out:	

Date	**No. beetles caught**					**Date**	**No. beetles caught**			
	sputator	**obscurus**	**lineatus**	**Total**			**Sputator**	**obscurus**	**lineatus**	**Total**

CLICK BEETLE PHEROMONE TRAP EVALUATION

Field Information Questionnaire

Please complete the form as fully as possible.

1. Field Details

Field Location

Field name:	
OS grid reference:	
Field OS no:	

Name:	
Farm:	
Village:	
Town:	
County:	
Post code:	

Form filled by:	
Organisation:	
Contact tel:	

Field environment

Field aspect (if sloping):		N, NE, E, SE, S, SW, W, NW, Flat
Main field boundary type:		Fence, high hedge, low hedge, bank, ditch, wood
Drought-prone (yes/no)?:		
Next to watercourse (yes/no):		

Soil type - please tick relevant box

S	LS	SL	SZL	ZL	SCL	CL	ZCL	PL	LP	SP	P

S = sand, LS = loamy sand, SL = sandy loam, SZL = sandy silt loam, ZL = Silt loam, SCL = sandy clay loam, CL = clay loam, ZCL = silty clay loam, PL = peaty loam, LP = loamy peat, SP = sandy peat, P = peat.

PLEASE TURN OVER TO FILL IN CROPPING HISTORY DETAILS

2. CROPPING HISTORY

A. Cropping, cultivation & straw disposal history - GIVE CROP NAME, then tick relevant boxes

		Pre-crop cultivation								Straw disposal		
Harvest year	**Crop**	**Plough**	**Press**	**Disc**	**Rotavate**	**Minimal**	**Bed form**	**Destone**		**Burn**	**Bale & cart**	**Incorporate**
1997												
1998												
1999												
2000												
2001												

B. Insecticide Use - give product name if known

Harvest year	Pre-drilling	Seed treatment	Foliar 1	Foliar 2	Foliar 3
1997					
1998					
1999					
2000					
2001					

C. Field pH - give value if known

Harvest year	pH
1997	
1998	
1999	
2000	
2001	

D. Weed control - tick relevant boxes

E. Irrigation - tick relevant box

Harvest year	Broad-leaved weeds Good	Fair	Poor		Grass weeds Good	Fair	Poor
1997							
1998							
1999							
2000							
2001							

Harvest year	**Yes**	**No**
1997		
1998		
1999		
2000		
2001		

Appendix 2: Graphical interpretation of click beetle trap catches.

Graphical representation of suggested 'Risk Categories' for estimating residual wireworm populations based on season-long click beetle catches in pheromone traps.