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Effects of Broadcasting and of Drilling Methiocarb Molluscicide Pellets on Field Populations of Wood Mice, *Apodemus sylvaticus*

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The agricultural use of methiocarb, a carbamate molluscicide, is widespread in the UK. The molluscicide pellets have a cereal base to attract slugs and this is potentially attractive to small rodents. The wood mouse (Apodemus sylvaticus) is usually the commonest small mammal found in arable fields (Green, 1979) and the only one consistently present throughout the year. Laboratory studies on wild caught animals have shown that wood mice are susceptible to poisoning by methiocarb pellets (Tarrant and Westlake, 1988).

This paper describes work, carried out as part of 'The Boxworth Project' (a seven year, multidisciplinary project organised by the Ministry of Agriculture, Fisheries and Food (Hardy, 1986; Greig-Smith, 1987 a, b; Jarvis, 1988)) to investigate the effects of drilled and broadcast methiocarb applications on field populations of wood mice.

MATERIALS AND METHODS

Wood mouse populations on the fields of a farm at Boxworth, Cambridge, U.K. were studied using Capture-Mark-Recapture techniques (Flowerdew, 1976). Mice were caught in Longworth live traps (Chitty and Kempson, 1949) baited with wheat; marking was by toe clipping (up to 1986) or fur clipping (1987 and 1988). Traps were set for two to four nights and checked daily.

Commercially available molluscicide pellets ('Draza') containing 4% methiocarb were applied to fields of winter wheat during the autumn. Some study fields had an 'insurance' application of molluscicide every autumn from 1982 - 1987, regardless of whether slugs (chiefly Deroceras reticulatum) were likely to be a problem, while others had applications only when needed for slug control.

Molluscicide pellets were applied either by broadcasting, using a DPM Nodet granular spreader, or by mixing with the seed and drilling at a depth of approximately 4 cm using a 6 m Accord

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drill. Both methods of application are commonly used by farmers in the U.K., and both methods use molluscicide pellets at the same rate of 5.5 kg/ha.

Trapping results were analysed using non-parametric statistics to compare either trapping success or the proportion of animals recaptured from earlier sessions. 'Trapping success' was defined as the proportion of available trap-nights which caught new mice (i.e. previously uncaptured in that session). Traps were unavailable when occupied by other species or by wood mice captured earlier in that trapping session, or when left in a non-functioning state following disturbance, usually by carrion crows (Corvus corone).

Three experiments were carried out to investigate the short-term impact of methiocarb applications on field populations of wood mice. During autumn 1983 five fields were each trapped for three sessions. All five fields received methiocarb applications during this period, and, since the molluscicide was not applied simultaneously to all fields, it was possible to compare population changes between trapping sessions on as yet untreated fields with changes that occurred following broadcasting of methiocarb. The numbers of mice captured on each field were low and results were combined to compare treated with untreated fields. In addition a sixth field, which did not receive a methiocarb application, was utilised as a further control, being trapped during the second and third trapping sessions.

A further experiment on the effects of broadcasting methiocarb was carried out in autumn 1988. Two adjacent fields were trapped for two sessions, one field being broadcast with methiocarb between trapping sessions and the other being utilised as a control.

In 1987 three pairs of fields were each trapped for two sessions to investigate the effects of drilled applications of methiocarb. One field in each pair had methiocarb drilled with seed between the two trapping sessions, while the other field in each pair received no molluscicide.

In addition to these experiments, annual monitoring of wood mouse populations was carried out to study the long-term effects of methiocarb applications. Three fields at Boxworth were trapped for four nights during July or August of each year from 1983 to 1988. One field was broadcast with methiocarb every autumn from 1982 to 1987 while the other two fields had applications of methiocarb only in the autumns of 1982 and 1983 or 1983 and 1987.

RESULTS AND DISCUSSION

Trapping results for autumn 1983 are shown in Table 1. Traps were set in lines of ten points 20 m apart with two traps per point. Traplines were randomly assigned to tractor wheelings, with the number of traplines set being proportional to the field area (approximately one per 2 ha). Five fields were trapped for three

Table 1. Trapping success (mice caught/trap-nights) 1983

Trapping session	Methiocarb application: A) Between sessions 1 and 2	B) Between sessions 2 and 3	C) None
1	7/157 (4.5%)	21/478 (4.4%)	-
2	0/160 (0%)	20/473 (4.2%)	6/120 (5.0%)
3	12/159 (7.5%)	17/474 (3.6%)	7/115 (6.1%)

sessions, each session consisting of two nights trapping. Two fields (Group A) had methiocarb broadcast 2 - 4 days before the second trapping session, while the other three fields (Group B) had methiocarb broadcast 7- 17 days before the third session. A further field (C), which did not receive a methiocarb application, was trapped for the final two sessions only.

Trapping success was initially very similar for Group A and Group B fields. Following application of methiocarb to the two Group A fields, no mice were captured on these fields in the second trapping session, although numbers on the, as yet, untreated fields were practically unchanged from the first trapping session. At this stage trapping success was significantly lower on treated than on untreated fields ($\chi^2 = 5.6$, 1 d.f., $p<0.02$). Trapping success on the control field (C) was similar to that on the untreated fields.

By the third trapping session, 17 - 27 days after methiocarb was applied to the Group A fields, trapping success on these fields had increased significantly ($\chi^2 = 10.5$, 1 d.f., $p<0.01$). However, the Group B fields (trapped 7 - 17 days after methiocarb application) showed no significant change in trapping success from the earlier sessions. Trapping success on the control field was also similar to that recorded earlier.

The failure to catch any wood mice on the Group A fields 2 - 4 days after the broadcasting of methiocarb indicates that there was a rapid and significant impact on wood mice in the treated area. However, the subsequent increase in trapping success in the third session suggests that there was a rapid recovery from this effect.

Results from the Group B fields also suggest a decline and rapid recovery following methiocarb application. Although trapping success on these fields did not vary significantly between sessions, the final trapping session covered the period 7 - 17

days after methiocarb was applied. Analysis of the pattern of recaptures from earlier sessions suggests that there was a major change in the population following the molluscicide application. Of the 21 mice captured in trapping session 1 on these fields, 10 were recaptured in session 2, but of the total of 20 mice captured in session 2 none were recaptured in session 3 (χ^2= 10.3, 1 d.f., $p<0.01$). In contrast to this, on the control field 5 of the 6 mice trapped in session 2 were recaptured in session 3 (Fisher Exact Test, $p<0.001$).

Although similar total numbers of mice were trapped on Group A and B fields in the 1st and 3rd sessions (28 and 29 mice respectively), the age structure of the wood mouse population had changed considerably in the intervening 28 day (mean) period (Table 2), with a highly significant increase in the proportion of juveniles (taken as those mice weighing 15 g or less and therefore likely to be less than three months old (Flowerdew, 1972)). The mouse population in the control field (C) was still largely composed of adults at the time of the 3rd trapping session, although total numbers were small.

Table 2. Wood mouse population structure, pre- and post-methiocarb (1983)

Trapping session	Adults (>15g)	Juveniles (<15g)	Total weighed
1 (Pre-methiocarb)	23	4	27*
3 (Post-methiocarb)	11	18	29
	χ^2= 11.1, 1 d.f., $p<0.001$		

(*1 additional mouse not weighed)

These results suggest a major reduction occurred in the numbers of wood mice in cereal fields very shortly after the surface application of methiocarb pellets. Mouse populations recovered rapidly, apparently due to immigration from surrounding habitats, with the immigrants including a high proportion of juveniles.

Further evidence that broadcast methiocarb has a detrimental effect on wood mice was obtained in 1988. Two adjacent fields were trapped on two occasions in autumn 1988, one field receiving a broadcast application of methiocarb between trapping sessions, the other acting as a control. Both fields had been ploughed prior to trapping and the treated field had also been cultivated and drilled. Two 8 x 8 grids of traps (with points 20 m apart and with one trap per point) were set on each field and trapped for a session of three nights, 8 - 10 October. Methiocarb

was broadcast on the treatment field on 19 - 21 October. The control field received no methiocarb application. The grids were then reset and trapped for four nights, 25 - 28 October.

Significantly fewer wood mice were captured on the treatment than on the control field in the first (pre-treatment) trapping session (68 compared with 29 mice respectively, $\chi^2 = 22.2$, 1 d.f., $p<0.001$). This difference can probably be attributed to the treatment field having been cultivated and drilled with seed. This procedure removes much cover for mice, compared with a ploughed field, and may be detrimental to resident mouse populations (Hare, unpublished).

Trapping success was lower on both fields in the second trapping session. Only nine mice were captured on the treatment field after molluscicide application, but this decline was not significantly greater than that which occurred over the same period on the control field, where 47 mice were captured in the second session ($\chi^2= 2.92$, 1 d.f., $p<0.10$). However, results from 1983 (see above) indicated that recolonisation of fields by wood mice can occur very rapidly. To allow for possible effects of immigration, the proportions of mice from the first trapping session which were subsequently recaptured were compared for the treated and the control field. By the end of the second trapping session, 17% (5/29) of the mice caught in the first trapping session had been recaptured on the treated field, significantly less than the 43% (29/68) recaptured on the control field. This result, therefore, supports the findings of the earlier work, indicating that wood mouse survival is reduced following the broadcast application of methiocarb.

An alternative to the broadcast surface application of methiocarb is to drill the pellets with the seed when sowing the next season's crop. In 1987 work was carried out to investigate the effect of drilled methiocarb on field populations of wood mice.

Methiocarb was drilled with wheat in three fields in autumn 1987. Each field was trapped three to five days before methiocarb was applied and again four or five days after drilling. In each case a control field, receiving no methiocarb application, was trapped on approximately the same dates. Trapping was for two nights, with traps set in lines of ten points with two traps per point, and the number of lines in proportion to the area of the field, with approximately one line per 2 ha.

Of the mice caught before molluscicide was applied to the treatment fields, 29% (15/52) were recaptured after drilling. Over approximately the same period 18% of animals (8/45) were recaptured on the control fields ($\chi^2= 1.1$, 1 d.f., N.S.). For one matched pair of fields the interval between trapping was fourteen days for the control, compared with seven days for the treated field. Excluding the results from this pair, there was still no significant difference in recapture rates on treatment and control

fields (χ^2 = 1.75, 1 d.f., N.S.). Neither the total number of mice captured, nor the proportions of juveniles in the populations changed significantly on the drilled or control fields.

Unfortunately it did not prove possible to make a direct comparison of the effects of drilled and broadcast methiocarb applications. However the results obtained indicate that drilled methiocarb does not significantly affect wood mouse survival or the composition of the population in the short term.

In July or August of each year 1983 - 1988 wood mouse numbers were monitored on three fields at Boxworth by trapping for four nights on a fixed position grid consisting of 8 x 8 points, 20 m apart, with two traps per point. Field 1 received an 'insurance' broadcast application of methiocarb in the autumn preceding each of the annual trapping sessions. Field 2 received broadcast methiocarb in the autumns of 1982 and 1983 and field 3 had molluscicide broadcast in autumn 1983 and drilled in autumn 1987. The results of this long-term monitoring are shown in Fig. 1.

Results of the trials carried out in 1983 and 1988 clearly showed that broadcast methiocarb can drastically reduce wood mouse survival on treated fields. However, Fig. 1 shows that annual changes in wood mouse numbers, while often very marked, followed similar trends in each of the long-term study fields, indicating that there was no long-term effect on field populations of wood mice from autumn applications of methiocarb. Populations generally declined from 1983-1986, with a sudden population increase occurring in 1987. Numbers declined again somewhat in 1988, but were still much higher than in the years 1984-1986. Changes between years are likely to be caused by a range of factors such as the severity of the winter weather and the overwinter food supply.

The results of these trials suggest that surface applications of methiocarb are poisoning a large proportion of the mice resident in the treated fields. Results of one trial suggested that the impact of methiocarb applications on mice is greatly reduced when the molluscicide pellets are drilled rather than applied to the field surface. In view of this, it is recommended that to reduce the likelihood of adverse effects on non-target species, grain-based carbamate pellets should be drilled rather than broadcast. Further work is required to determine whether wood mice are affected directly through the ingestion of methiocarb pellets, or indirectly, through the ingestion of large numbers of contaminated invertebrates.

Despite the short-term declines in wood mouse numbers which rapidly followed the broadcasting of methiocarb, applications in six consecutive autumns failed to produce any apparent long-term depression of mouse numbers on treated fields. This may to some extent be a consequence of the nature of the farm at Boxworth. The fields had an average size of 12 ha, had hedgerows on at least one boundary, and were near small blocks of woodland, both of the

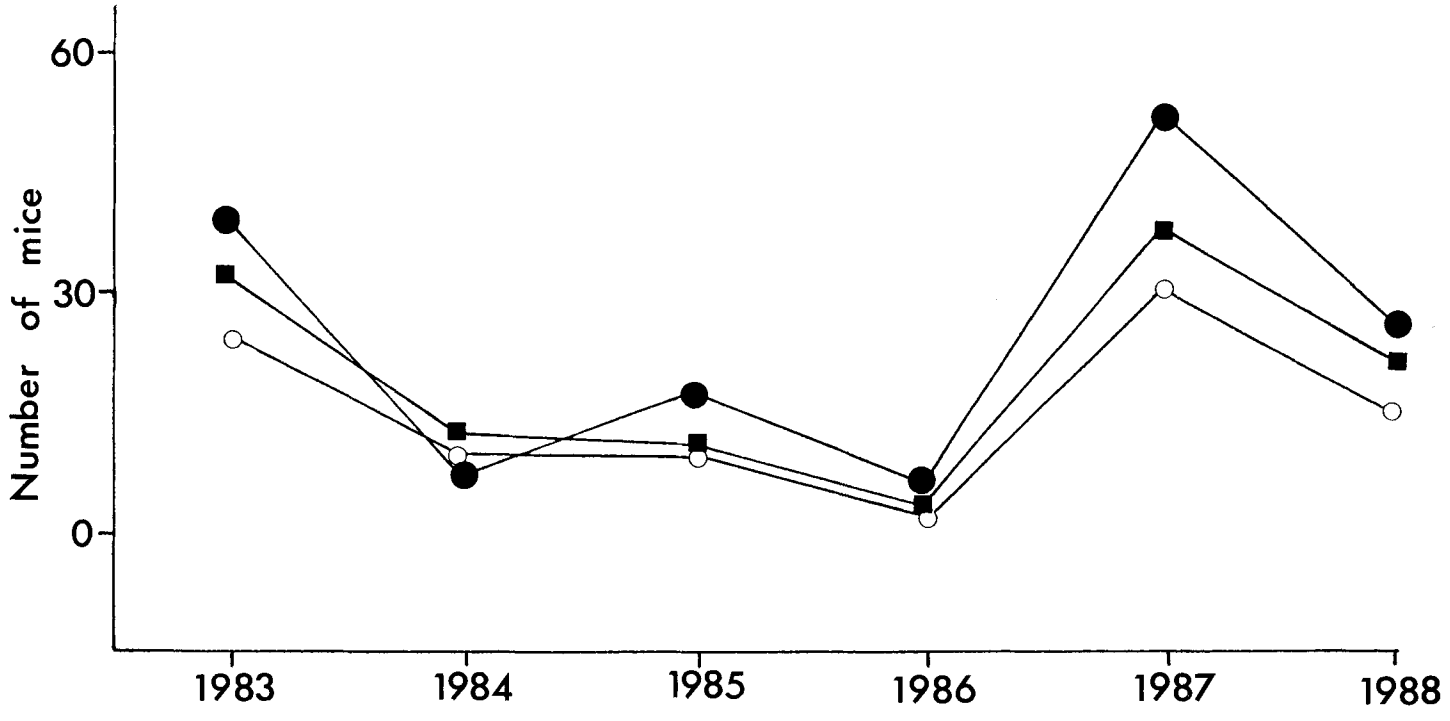

Figure 1. Total numbers of wood mice caught on fixed trapping grids in July/August 1983-88. Key: ■ field 1, methiocarb broadcast autumn 1982-87; ● field 2, methiocarb broadcast autumn 1982-1983; ○ field 3, methiocarb broadcast autumn 1983 and drilled autumn 1987.

latter habitats probably acting as 'reservoirs' of wood mice ready to invade depleted fields in the autumn. It may be that in larger fields, or in areas lacking alternative, untreated habitats, the impact of methiocarb on field populations of mice could be of greater long-term significance than at Boxworth.

Another factor which might affect the impact of methiocarb is the timing and frequency of application. In this study methiocarb was applied in the autumn, when the annual cycle of mouse numbers is reaching its peak and many juvenile mice are likely to be dispersing (Green, 1979; Flowerdew, 1985). Thus any depletion of the population is likely to be shortlived. Summer applications, for example to potato crops, may have a longer-lasting impact on populations of mice, because of the lack of dispersing animals and the lower densities of mice encountered at this time of year. This study has shown that methiocarb does have an impact on field populations of wood mice, but further study is needed to reveal how serious is this impact in differing circumstances.

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