ARTHROPOD POPULATIONS UNDER CURRENT AND REDUCED-INPUT PESTICIDE REGIMES: RESULTS FROM THE FIRST FOUR TREATMENT YEARS OF THE MAFF "SCARAB" PROJECT

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ABSTRACT

The MAFF-funded SCARAB project ("Seeking Confirmation About Results At Boxworth") was initiated in 1990 to answer questions raised by the Boxworth project (1981-1988). Boxworth examined effects of intensive pesticide use on wildlife in winter wheat on a farm in eastern England. Monitoring over five years indicated that non-target arthropods were particularly vulnerable to intensive pesticide use. SCARAB aims to determine whether such side-effects of pesticide use also occur in other crops, at other locations, and with current pesticide inputs. In SCARAB, the arthropod populations are routinely monitored at three farms, on each of which fields were split into "Reduced Input Approach" (RIA) and "Current Farm Practice" (CFP) treatments. Data from the first four treatment years of this long-term project indicated that most damage to populations of non-target arthropods was done by autumn- and winter-applied broad-spectrum insecticides. The overall results and their implications are discussed in relation to the ecological effects of pesticides on non-target invertebrates.

INTRODUCTION

The application of pesticides may cause short-term or long-term effects on non-target arthropod populations. Short-term effects may result from direct or indirect exposure to the chemical and can usually be detected shortly following pesticide applications. On the other hand, long-term effects may be slow to develop and although less obvious initially may become permanent, for example through repeated population perturbations with poor reinvasion from surrounding areas. The short-term (within-season) effects of pesticides on non-target invertebrates have been relatively well-researched in the UK and elsewhere (Çilgi, 1994*a*). A number of field studies have shown adverse effects on arthropod populations following individual pesticide applications (Vickerman & Sunderland, 1977; Powell *et al.*, 1985; Cole *et al.*, 1986; Vickerman *et al.*, 1987; Brown *et al.*, 1988; Smart *et al.*, 1989; Thomas *et al.*, 1990; Pullen *et al.* 1992; Duffield & Aebischer, 1994 *inter alia*). These and other short-term studies examined the effects of single applications of one pesticide whereas in commercial farming practices numerous chemicals may be applied within a season, both as mixtures and repeated applications. For example, according to the UK MAFF 1992 Pesticide Usage Survey Report (Davis *et al.*, 1993), the number of pesticide products applied varied from 3.3 to 13.2 per annum depending on the type of arable crop. Therefore, such studies cannot identify any cumulative effects of repeated exposure to one or a number of chemicals, which may not allow recovery of the exposed populations between treatments.

The MAFF Boxworth project was the first long-term experimental study to investigate non-target effects of pesticides in the UK. Starting in 1981, its main aim was to examine the overall effects of pesticides on birds, small mammals, soil fauna, crop invertebrates and plants in cereal fields at Boxworth Research Centre (Greig-Smith *et al.*, 1992). At the end of the project (i.e. 1988), monitoring had revealed clear effects of the contrasting pesticide inputs indicating that the sustained prophylactic use of a wide range of pesticides was causing harmful effects to some groups of non-target arthropods (Burn, 1992; Vickerman, 1992). Monitoring of birds, small mammals and plants, indicated that there were no obvious long-term effects on these groups under the experimental conditions at Boxworth.

The Boxworth project subsequently led to the setting up of a new long-term project called SCARAB (Seeking Confirmation About Results At Boxworth). The SCARAB project aims to investigate whether such adverse effects occur elsewhere in England in different arable crops, and with pesticide inputs more typical of those in use in the 1990s.

MATERIALS AND METHODS

A summary of important aspects of the SCARAB project is given below. Further details of its background, design and layout were given elsewhere (Cooper, 1990; Çilgi *et al.*, 1993; Frampton & Çilgi, 1992, 1993).

Experimental design

The SCARAB experimental set-up involves comparing two different pesticide regimes in seven fields. The study fields range in size from 8 to 32 ha. Each field was split into two halves to allow comparisons between the two contrasting pesticide regimes which will continue for six years. The study fields are sited at three ADAS Research Centres (Drayton, Gleadthorpe and High Mowthorpe) in central and northern England. The crops grown are part of six-course rotations, each typical of the region in which the farm is situated. They include cereals, grass ley, root crops (sugar beet and potatoes), field beans and oilseed rape.

Pesticide regimes

Two pesticide regimes are compared in the project: "Current Farm Practice" (CFP) represents average pesticide use, based on recent pesticide usage surveys and "Reduced Input Approach" (RIA) represents a managed, lower input of pesticides based on monitoring pests, weeds and diseases in the crop. The RIA regime aims to avoid the use of insecticides if possible. The experimental protocol allows for pesticide treatments to evolve according to changes indicated in the pesticide usage surveys. The only differences between the CFP and RIA halves of the study fields are in pesticide inputs; cropping and husbandry do not differ.

During the baseline year (1989-1990), all fields received only the CFP pesticide input appropriate to the particular crop. This was to allow arthropod populations to be monitored in the study fields prior to the treatment phase of the project. At the start of the 1990-1991 crop year, all fields were split in half. One half of each field retained the CFP regime and the other half was switched to a RIA regime. These contrasting pesticide regimes in each field will continue until harvest in 1996.

Arthropods have been monitored routinely since summer 1990 by pitfall trapping and suction (D-vac) sampling at matched locations in the CFP and RIA areas of each field.

RESULTS AND DISCUSSION

In the first four treatment years, a total of 132 pesticides (28 insecticides) were applied at full label recommended rates to the CFP halves of the seven study fields. During this time no insecticides were applied to the RIA halves of fields and overall the RIA received less than 50% of CFP fungicides and herbicides. Although the project was designed to evaluate the long-term effects of overall pesticide use, the adverse effects observed so far have been attributed to a handful of insecticides. As yet there is no clear evidence that fungicides and herbicides had any substantial effects on beneficial arthropods.

The beginning of the major arthropod population declines coincided in time with the application of some broad-spectrum insecticides, especially those sprayed in autumn and winter rather than in summer. This was also the case in the Boxworth project (Burn, 1992; Vickerman, 1992). A possible explanation is that species which overwinter in the field are very likely to be exposed to autumn and winter applications when there is little vegetation cover, whereas crop cover is more dense in summer. Five different active ingredients were applied in autumn and winter: the organophosphates chlorpyrifos (in "Field 5" and "Near Kingston") and omethoate (in "South" and "Field 1"), the carbamate aldicarb (in "Balk" and "South") and the synthetic pyrethroids cypermethrin (in "Near Kingston") and deltamethrin (in "Field 1"). Of these, harmful effects of chlorpyrifos both in "Field 5" (Drayton Research Centre) and "Near Kingston" (Gleadthorpe Research Centre) fields were obvious on a range of arthropods (Çilgi *et al.*, 1993). Recovery took longer than six months for many arthropods following the first chlorpyrifos spray in "Field 5" (Figs 1 and 2 show examples from one field). Chlorpyrifos has also been shown to be detrimental to beneficial arthropods, including those affected in the current work, in other studies (Luff *et al.*, 1990; Asteraki *et al.*, 1992).

Although no effect of omethoate was detectable, this compound was applied in "South" field (Gleadthorpe Research Centre) on 3 March 1992 when few beneficial arthropods were trapped. Therefore, potential exposure to the spray would have been minimal for most taxa. However, short-term adverse effects were observed following another application of omethoate on 28 May 1993 when there were relatively high numbers of arthropods in "Field 1" at Drayton Research Centre. No adverse effects of aldicarb were detected in this study which is monitoring epigeal arthropods. Although having broad-spectrum properties, this insecticide was drilled into the soil as granules and probably posed less of a hazard to epigeal arthropods than a surface treatment would have done. In addition, this compound was applied on 5 March 1991 and 10 April 1994 when few non-target arthropods were trapped in "Balk" and "South" fields of Gleadthorpe Research Centre.

In the case of cypermethrin and notably deltamethrin, their clear effects were mainly confined to money spiders (Frampton & Çilgi, 1993). Pyrethroids are well known to be particularly detrimental to spiders (Cole *et al.*, 1986; Brown *et al.*, 1988; Thomas *et al.*, 1990; Pullen *et al.*, 1992). However, these studies have also demonstrated that spiders are able to recover from autumn pyrethroid-induced population perturbation by the following summer. This was also the case in the present study fields, despite the additional herbicide and fungicide use which was not examined at the same time in the studies mentioned above.

Except for Collembola (Fig. 2), consistent and long-lasting differences in excess of two months between the CFP and RIA arthropod catches were not observed after summer applications of insecticides. Applications included the carbamate pirimicarb and the organophosphates dimethoate and triazophos and no long-term effects were evident even for those species considered most likely to be vulnerable (Burn, 1992; Çilgi, 1994*b*). The persistence of major differences between RIA and CFP catches of Collembola (Fig. 2) cannot as yet be unequivocally attributed solely to insecticide use because several species are sensitive to fungicide use (Frampton, 1994). Pirimicarb is widely regarded as a selective aphicide and has been demonstrated as harmless to many beneficial arthropod groups in a number of short-term studies (Cole & Wilkinson, 1984; Powell *et al.*, 1985; Smart *et al.*, 1989). On the other hand, dimethoate is widely considered as broad-spectrum and detrimental to most arthropod groups (Vickerman & Sunderland, 1977; Powell *et al.*, 1985; Cole *et al.*, 1986; Vickerman *et al.*, 1987; Duffield & Aebischer, 1994). However, these studies indicated that recovery always occurred after short-term population reductions. Results from the SCARAB project so far are in line with those of the above studies showing short-term declines in arthropod numbers after a dimethoate spray and no tangible effect of pirimicarb.

A second chlorpyrifos spray applied to "Field 5" in summer 1994 to control frit fly (*Oscinella frit*) in grass had detrimental effects on farmland arthropods (Figs 1 and 2). However, it is too early to determine the persistence of these effects because post-spray data have only been available for a month following the spray application at the time of writing.

Although the results of the first four treatment years of the SCARAB project are broadly similar to those found in the above short-term studies and the long-term Boxworth project, two aspects of the SCARAB project distinguish it substantially from other investigations of the effects of pesticides on non-target arthropods. These are (1) most of the results obtained in the previous short- and long-term studies came from cereal ecosystems, whereas the SCARAB project has been gaining information on the potential harmful effects of pesticides in other arable rotations, and (2) SCARAB was set up to compare the ecological effects of overall current and reduced-input pesticide regimes and will provide information on the environmental impact of reducing pesticide inputs. This is a topical issue as most farmers are now moving closer to sustainable farming in Europe and elsewhere for environmental and/or economical reasons (Holland *et al.*, 1994).

In conclusion, it is important to emphasize that the SCARAB project is an ongoing project and was not designed to monitor effects of individual chemicals so it remains to be seen whether future pesticide use, or cumulative effects of previous applications, will affect arthropod populations. Some serious side-effects of pesticide use at Boxworth did not occur until half-way through the treatment phase of the study and declines in some species appear to have been triggered by atypical weather conditions which led to a combination of unusually

Figure 1. Pitfall trap catches of Coleoptera (all families grouped together) in SCARAB project Field 5 (Drayton).

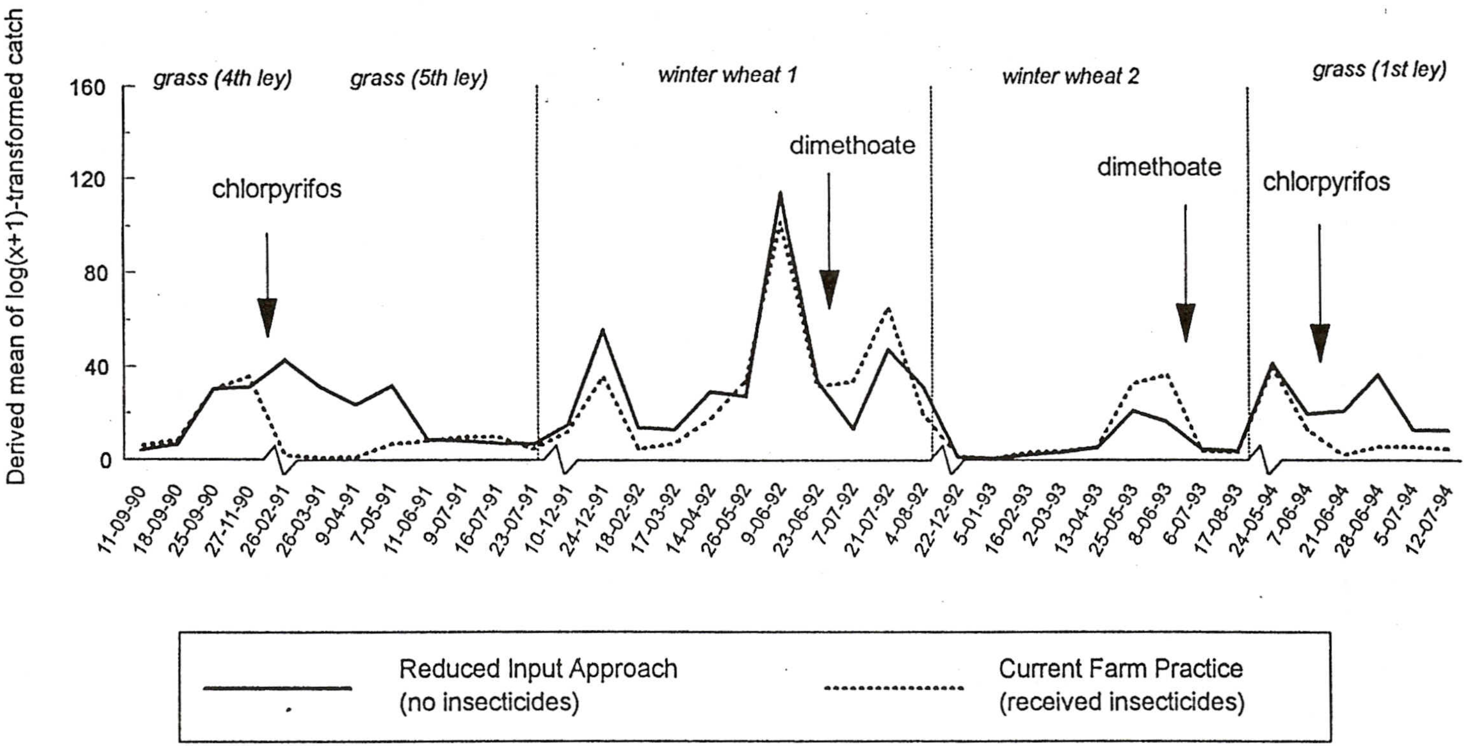
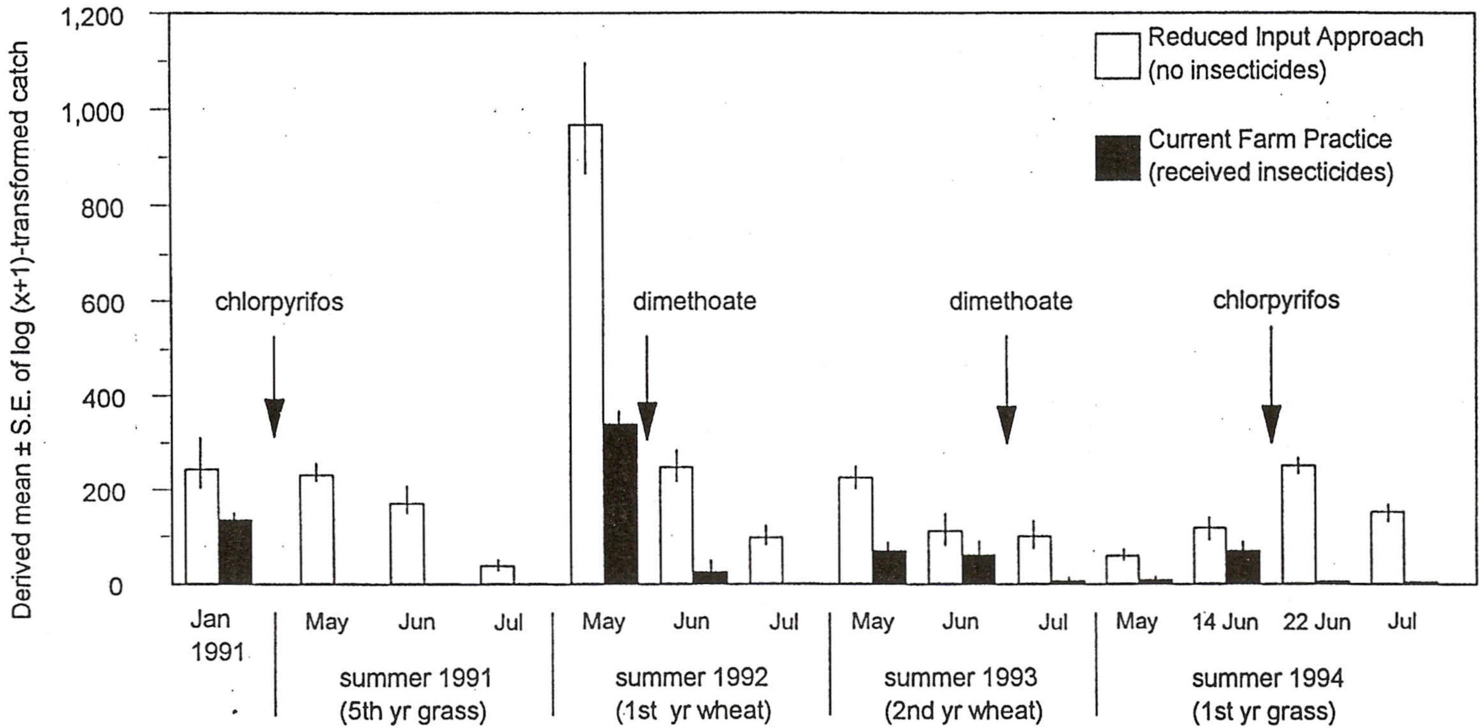


Figure 2. Suction sample catches of Collembola sub-order Arthropleona in SCARAB project Field 5 (Drayton).



late winter pesticide applications and exceptionally poor crop cover in 1986 (Vickerman, 1992). Clearly, the longer the duration of a study, the greater chance it has of including "rare events" which could be ecologically important. Indeed, most ecological studies are short-term (Hassell *et al.*, 1989) and are therefore less likely to detect density dependence and other population mechanisms which operate over long periods. The transient occurrence of species should also be considered, for example the numbers of some species of *Helophorus* (Hydrophilidae) and *Bembidion lunulatum* (Carabidae) were substantially reduced after the chlorpyrifos spray in "Field 5" in January 1991 (Frampton & Çilgi, 1992). However, these beetles have not been trapped in either the RIA or CFP areas of "Field 5" in the subsequent treatment years. This transient occurrence did not enable us to establish a clear relationship between the chlorpyrifos application and the subsequent population reductions, despite intensive monitoring.

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