Long-term effects of pesticides on Carabidae in U.K. farmland: some initial results from the "SCARAB" Project

G.K. FRAMPTON & T. ÇILGI

Department of Biology, School of Biological Sciences, University of Southampton, SO9 3TU, U.K.

Summary

The U.K. Ministry of Agriculture, Fisheries and Food (M.A.F.F.) "SCARAB" Project was set up in 1989 to extend information obtained during the 1980s from a long-term, large-scale study of the consequences for farmland wildlife of intensive pesticide use.

Seven fields and a variety of arable crops are used in the project, situated on three M.A.F.F. Experimental Husbandry Farms in England. Carabidae populations have been monitored in the fields continuously since the summer of 1990. Current Farm Practice (CFP) and reduced-input pesticide regimes were introduced into each field at the start of the 1990–1991 crop year and will continue until 1996.

Up to the autumn of 1991, all fields had received at least one insecticide spray as part of their CFP pesticide input regime. Two of the insecticides, chlorpyrifos and deltamethrin, showed adverse effects on Carabidae, particularly species of *Bembidion*.

Some of these effects were persistent, with no substantial population recovery six months after the spray, despite plot sizes of 4 ha.

Introduction

During the 1980s the Ministry of Agriculture, Fisheries and Food "Boxworth Project" examined the consequences for wildlife of intensive pesticide use on a cereal farm in eastern England (Greig-Smith *et al.* 1992). A wide range of wildlife was monitored in groups of wheat fields which received different intensities of pesticide inputs over a 5–year period. Early in the Boxworth Project there was evidence that intensive pesticide use was detrimental to some groups of invertebrates, including Carabidae (Burn 1992; Vickerman 1992). For some species, such as *Bembidion obtusum* Serville, the effects were severe and persisted even after the intensive pesticide treatment reverted to a normal regime.

The M.A.F.F. SCARAB Project (Seeking Confirmation About Results At Boxworth) aims to investigate whether such adverse effects could occur elsewhere in England in different arable crops, and with pesticide inputs more typical of those in use in the 1990s.

Material and methods

This account summarises important aspects of the SCARAB Project. Further details of its background, design and layout were given by Cooper (1990) and Perks & Lane (1990).

Sites

The seven fields involved in the project range in size from 8 to 34 ha and are situated on Experimental Husbandry Farms at Drayton (Warwickshire), Gleadthorpe (Nottinghamshire) and High Mowthorpe (North Yorkshire). There are two SCARAB fields at each farm, except for Gleadthorpe which has three.

Crops

At each farm the crops grown in the SCARAB fields follow a six-year rotation which is specific to the farm and typical of the region (Table 1). Fields on the same farm entered the appropriate rotation at different points at the start of the

K. Desender et al. (eds.), Carabid Beetles: Ecology and Evolution, 433–438.

Table 1. Cropping in SCARAB fields, 1989–1992 (the period covered in this paper). w: winter-sown crop; s: spring-sown crop.

Farm	SCARAB field (size, ha)	Cropping		
		1989–1990	1990–1991	1991–1992
Drayton	Field 1 (11)	5th grass ley[a]	w. wheat	w. wheat
	Field 5 (8)	4th grass ley[a]	5th grass ley[a]	w. wheat
Gleadthorpe	Balk (12)	w. barley	sugar beet	s. wheat
	Near Kingston (8)	sugar beet	s. barley	w. barley
	South (12)	w. barley	potatoes	s. wheat
High Mowthorpe	Bugdale (19)	w. barley	w. oilseed rape	w. wheat
	Old Type (34)	w. barley	s. beans	w. wheat

[a] Part of a 5-year ley supporting sheep, cattle and silage.

Project and will have each completed one course of the rotation when the Project ends in 1996.

Pesticides

Two pesticide regimes are compared in the Project: for each crop, "Current Farm Practice" (CFP) represents an 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. Both regimes will keep pace with current farming practice by responding to any changes indicated in the pesticide usage surveys.

Pesticide applications

During the period June 1990–December 1991 (the results presented in this paper), seven fields received herbicides and insecticides and five received fungicides. A total of nine insecticides was applied to SCARAB fields as part of their CFP treatment (Table 2); no insecticide applications were made to the RIA half of any field.

Table 2. Insecticide applications to the "Current Farm Practice" half of SCARAB fields, 1990–1991.

Field	Insecticide	Date	Application rate[a]
Field 1	deltamethrin	8–11–90	5.0 g.a.i./ha
	deltamethrin	27–11–91	5.0 g.a.i./ha
Field 5	chlorpyrifos	28–1–91	720 g.a.i./ha
Balk	aldicarb (drilled)	4–4–91	2.6 g.a.i./ 100 m row
	pirimicarb	17–7–91	140 g.a.i./ha
Near Kingston	chlorpyrifos	25–2–91	720 g.a.i./ha
South	pirimicarb	17–7–91	140 g.a.i./ha
Bugdale	triazophos	24–6–91	420 g.a.i./ha
Old Type	pirimicarb	24–7–91	140 g.a.i./ha

[a] g.a.i.: grammes of active ingredient.

Comparison of regimes

The Project commenced in autumn 1989. During 1989–1990, all fields received only the CFP pesticide input appropriate to the particular crop. This was to allow "baseline" monitoring of invertebrate populations. 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 (field sizes are given in Table 1). These contrasting pesticide regimes in each field will continue until 1996. There is no physical barrier between the CFP and RIA halves of any field. Cultivations affect whole fields and do not differ between CFP and RIA areas.

Carabid sampling

Carabidae and other invertebrates 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. The minimum distance between any CFP trap and another in the RIA area was 84 m. The distance between the closest D-vac samples was ca. 110 m.

Results

In comparison with RIA catches, CFP pitfall-trap catches of some Carabidae were considerably lower at Drayton following two insecticide applications. The insecticides were chlorpyrifos sprayed on the CFP half of Field 5 in January 1991 to control leatherjackets in a 5th-year grass ley (Fig. 1) and deltamethrin sprayed on the CFP half of Field 1 in November 1990 and 1991 to control aphids in winter wheat (Fig. 2).

Following the chlorpyrifos spray, CFP catches of adult *Bembidion aeneum* Germar, *B. lunulatum* (Fourcroy), *B. obtusum* and *Trechus quadristriatus* (Schrank) were considerably lower than RIA catches. These differences between CFP and RIA catches were also reflected in the Carabidae as a group (Fig. 1). There was also evidence that larvae, but not adults, of *Nebria brevicollis* (F.) were adversely affected by the chlorpyrifos spray, with lower CFP than RIA catches after the application (Frampton & Çilgi 1992a).

Catches of *Bembidion lunulatum* in CFP traps were considerably lower than RIA catches after the deltamethrin spray but there was no apparent effect of this insecticide on other species of Carabidae and no evidence of an effect on Carabidae as a group (Fig. 2).

The effects of chlorpyrifos on *Bembidion* spp. were persistent, with lower CFP than RIA catches of *B. aeneum* and *B. lunulatum* lasting up to six months after the spray, although overall catches of these species in both CFP and RIA traps were low after May (Fig. 1). Catches of *B. obtusum* were low in June and July but higher in December. Eleven months after the spray, in the following crop (wheat), there were still higher numbers of this species captured in RIA than in CFP traps (Fig. 1).

Discussion

SCARAB was set up to investigate the long-term consequences for invertebrates of average pesticide use over six years, so the results presented here are preliminary. The Project provides repetitions of the CFP and RIA regimes over six years (Cooper 1990) but the pesticide regimes are not replicated within individual years (as fields entered the rotation at each farm in different crops). Orthodox statistical methods cannot, therefore, identify pesticide effects early in the Project. The assertion that the changes in carabid catches reported here were influenced by chlorpyrifos and deltamethrin is justified because the changes coincided in time with the insecticide sprays and consistent differences between CFP and RIA catches subsequently persisted over several months. For pitfall-trap catches, the long persistence of such differences gives confidence that the catches reflect population changes rather than differences in carabids' activity. Suction samples are less likely to be biased by activity, but D-vac sampling trapped too few carabids in the six months following the chlorpyrifos spray to permit a detailed analysis of CFP and RIA catches. D-vac sampling did, however, reveal major declines in CFP catches of Collembola, a prey item for many Carabidae, which coincided with the chlorpyrifos spray. Several other beneficial taxa appear also to have been adversely affected both by chlorpyrifos and deltamethrin (Frampton & Çilgi 1992a).

Effects of chlorpyrifos and deltamethrin

Adverse effects of chlorpyrifos on Carabidae including *Nebria brevicollis*, *Trechus quadristriatus*, *Bembidion lampros* (Herbst), *Loricera pilicornis* (F.) and *Notiophilus biguttatus* (F.) were shown in newly-sown grass by Asteraki *et al.* (1992). The latter three species, which are predators of Collembola (e.g. Bauer 1981; Forsythe 1982), were too rare in SCARAB traps to show any knock-on effects of the major depletion in Collembola which coincided with the use of chlorpyrifos in Field 5 (Frampton & Çilgi 1992a). Asteraki *et al.* (1992) did not detect effects of chlorpyrifos on the three species of *Bembidion* which were adversely affected by the SCARAB chlorpyrifos spray, namely *B. aeneum*, *B. lunulatum* and *B. obtusum*, but these species occurred infrequently in their study (E. Asteraki, unpublished data). In addition to the species described above, some other Carabidae, such as *Pterostichus* spp., were trapped in small numbers in Field 5 but did not display obvious effects of the SCARAB chlorpyrifos spray; for a full list of the species trapped in SCARAB see Frampton & Çilgi (1992b).

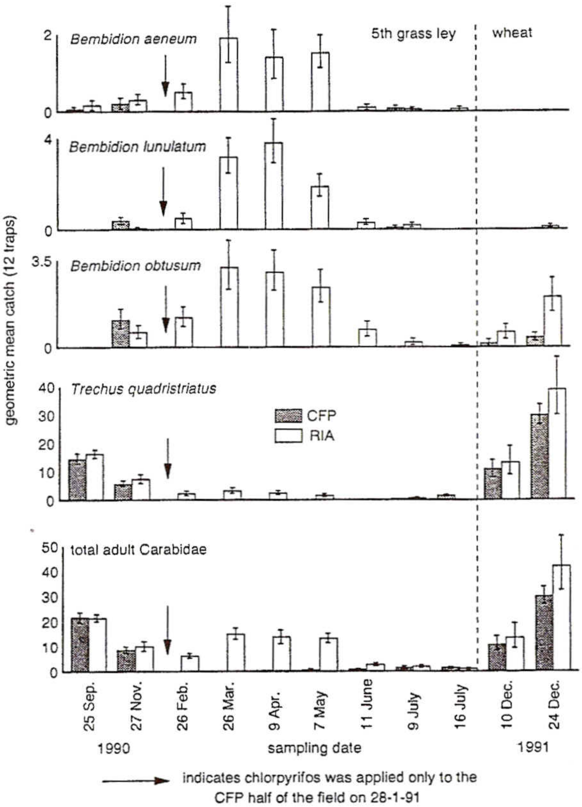

Fig. 1. Mean (±S.E.) catches of Caradibae in Field 5 CFP and RIA pitfall traps on 11 sampling occasions, 1990–1991. Geometric means and S.E.s are each derived from 12 [log (x + 1)-transformed] catches.

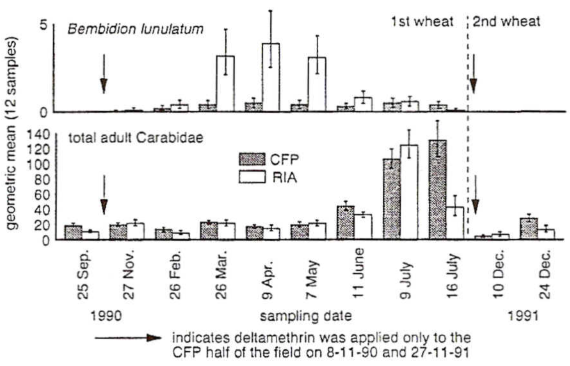

Fig. 2. Mean (±S.E.) catches of Caradibae in Field 1 CFP and RIA pitfall traps on 11 sampling occasions, 1990–1991. Geometric means and S.E.s are each derived from 12 [log (x + 1)-transformed] catches.

Results from the Boxworth Project showed that the life cycle and dispersal ability of carabids on farmland are important determinants of their response to pesticides (Burn 1992). *Bembidion obtusum* has a poor dispersal ability which might explain its inability to recover following pesticide-induced population perturbations such as those seen at Boxworth (Vickerman 1992; Burn 1992) and in SCARAB. The less severe effects of chlorpyrifos on *Trechus quadristriatus* (Fig. 1) could be explained by the fact that a large proportion of the overwintering population consists of subterranean larvae (Mitchell 1963a) which are not directly exposed to winter pesticide sprays. The transient over-winter decline in CFP catches of *T. quadristriatus* (Fig. 1) reflects the effects of chlorpyrifos on those individuals which overwintered as epigeal adults. Macropterous forms of *T. quadristriatus* are known to be capable of dispersal by flight (Mitchell 1963b) and such behaviour could, if sufficiently frequent or widespread, also explain the lack of long-term effects of chlorpyrifos on this species, via rapid recolonisation. At present the responses of *B. obtusum* and *T. quadristriatus* to chlorpyrifos seem to mirror their responses to the intensive pesticide regime at Boxworth, with more severe and prolonged effects on *Bembidion* than on *Trechus*. *Bembidion aeneum* and *B. lunulatum* were rare at Boxworth but their initial responses to chlorpyrifos mimic that of *B. obtusum*, with poor recovery.

The protracted effect of deltamethrin on *B. lunulatum* (Fig. 2) was unexpected because other European studies have shown this insecticide to have transient effects on Carabidae (Matcham & Hawkes 1985; Chambon *et al.* 1987; Fischer & Chambon 1987; Vickerman *et al.* 1987; Purvis *et al.* 1988) or no apparent effects (Basedow *et al.* 1985). It is, however, possible that the relatively small spatial (sub-field) and temporal (within-season) scales of many of these studies have resulted in underestimates of the effects of deltamethrin on Carabidae (Purvis *et al.* 1988). Persistent effects of the deltamethrin spray were also evident in catches of Hydrophilidae (Frampton & Çilgi 1992a). Whereas effects of chlorpyrifos on individual species were reflected in the total Carabidae as a group (Fig. 1), those of deltamethrin on *B. lunulatum* were not (Fig. 2). This underlines the importance of studying individual species of carabids when investigating effects of pesticides on carabid assemblages, particularly if the catch is dominated by large, active species which are able to rapidly recolonise a sprayed area. Current evidence suggests that several *Bembidion* species may be good indicators of the use of broad-spectrum insecticides on farmland.

Other insecticides

It is not surprising that only two of the nine insecticides applied in SCARAB fields showed adverse effects on Carabidae. Three of the applications made to SCARAB fields were of pirimicarb (Table 2) which is widely regarded, with some exceptions (e.g. Vickerman *et al.* 1987), as a selective aphicide. Aldicarb was used on one occasion in a SCARAB field (Table 2) but, although having broad-spectrum properties, this insecticide was drilled into the soil as granules and probably posed less of a hazard to epigeal carabids than a surface treatment would have done. Deltamethrin was applied on two occasions (Table 2) and it is not known at present if the application in November 1991 was as harmful to *Bembidion lunulatum* as the application in November 1990 (Fig. 2). The remaining three insecticide applications to SCARAB fields were of broad-spectrum organophosphorus compounds. These included two applications of chlorpyrifos and one of triazophos (Table 2). One of the chlorpyrifos applications occurred at Gleadthorpe on 25 February 1991 in a spring barley crop with an already impoverished carabid fauna; species susceptible to the effects of the chlorpyrifos spray at Drayton (*Bembidion* spp., *Nebria brevicollis* and *Trechus quadristriatus*) were entirely absent both before and after the Gleadthorpe spray. Too little information is currently available to determine whether or not the triazophos spray used at High Mowthorpe to control cabbage seed weevils *Ceutorhynchus assimilis* (Paykull) in rape (Table 2) had any effect on Carabidae catches.

Up to autumn 1991 there was no evidence for any effects on carabids of different CFP and RIA applications of fungicides or herbicides in SCARAB fields.

Additional monitoring

The fields used in SCARAB are small (8–34 ha) so there are two potential limitations of the study: (1) Dispersal of carabids could obscure some pesticide effects. To investigate this, transects of pitfall traps across the interface between CFP and RIA areas have been used to monitor carabid dispersal and aid interpretation of the scale of pesticide effects. (2) Drift of pesticide spray could occur from sprayed CFP to unsprayed RIA areas in fields. This has been monitored in SCARAB fields by mixing fluorescent tracers with insecticide sprays. So far there has been negligible drift of insecticide into RIA areas. Bioassays with Carabidae are planned to investigate the biological significance of this and any other insecticide drift which occurs in future.

Acknowledgements

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