Changes in plant and arthropod biodiversity on lowland farmland: an overview

NICOLAS W. SOTHERTON[1] & MATTHEW J. SELF[2]
[1]*The Game Conservancy Trust, Fordingbridge, Hampshire, SP6 1EF, UK*
[2]*Royal Society for the Protection of Birds, Sandy, Bedfordshire, SG19 2DL,UK*

To match the data collected elsewhere to quantify the declines in farmland birds, other data sets were examined to illustrate the changes in the biodiversity of plants and arthropod groups on lowland farmland. The findings from several sources of data collected in the UK regarding vascular plants, bryophytes and arthropods are summarised. It is concluded that apart from some species of grass weeds, common broad-leaved weeds and most aphid species, many species occupying farmland, for which information is available, are in decline.

Many species of the UK's farmland wildlife have come into recent sharp focus because of their decreasing national distribution and abundance. This is particularly true of farmland bird species following the publication of atlas data and population trends from the British Trust for Ornithology censuses (Sharrock l976, Gibbons *et al.* 1993, Tucker & Heath l994). The status of many of these declining species has prompted the Government to list many of them as Species of Conservation Concern (Anon. 1995), placed them on endangered lists and made them the subject of Biodiversity Action Plans (Anon. 1995). As early as l970, Potts (1970a, 1970b, l970c) expressed concern about the status of the Grey Partridge *Perdix perdix* on farmland, but it was to take another 24 years before these concerns were taken seriously. In this paper we review the data on non-avian species of the farmland flora and fauna and suggest reasons for changes in their distribution and abundance.

REVIEW OF FARMLAND PLANTS

Changes in the abundance and distribution of plants

Farmland vascular plants in the UK have suffered huge declines in range and abundance during this century. Farmland habitats now support a large number of scarce (present in between 16-100 10-km squares) and rare (less than 16 10-km squares) species (Perring & Farrell 1983, Perring & Walters 1990, Stewart *et al.* 1994; Table 1). Farmland is also important for 51 species of lower plants (10 liverworts and 41 mosses), of which 15 species are present in less than 100 10-km squares (Hill *et al.* 1994, R. Porley pers. comm.). Lowland farmland may support more scarce or threatened plant species than any other comparable habitat (Wilson 1990, 1992, Rich & Woodruff 1996).

Table 1. Summary of the status of scarce, rare and selected declining vascular plants on farmland habitats in the UK (Scarce Plants Project - Stewart *et al.* 1994). Totals for all habitats and for individual habitats are not equal owing to presence in more than one habitat.

Lowland farmland habitat	No. species declining but not scarce, but included in Scarce Plants Project	No. scarce species (16-100 10-km squares)	No. rare species (< 16 10-km squares)
All lowland farmland habitats	11	55	27
Arable (all)	9	14	7
Acid grassland	0	4	3
Neutral grassland	1	3	2
Calcareous grassland	1	20	15
Wet/marshy grassland	0	0	7
Hedges	0	5	1
Ditches	1	6	1
Water margins e.g. ruts	0	5	2

Declines have been documented by the Atlas of the British Flora (Perring & Walters 1990), the British Red Data Book (Vascular Plants) (Perring & Farrell 1983), Scarce Plants in Britain (Stewart *et al.* 1994), and monitoring schemes of the Botanical Society of the British Isles (BSBI) (Rich & Woodruff 1996), which resurveyed a sample of squares originally covered in the 1950s. More specific studies have been carried out, such as BSBI's Arable Weed Survey (Smith 1989), which targeted rare species, and The Game Conservancy Trust (GCT) Wildflower Project (Wilson 1993).

All the vascular plant species for which farmland is important listed in the BSBI Atlas (Perring & Walters 1990), the later Scarce Plants Atlas (Stewart *et al*. 1994), or the Red Data Book where appropriate (Perring & Farrell 1983), have suffered range contractions in the latter part of this century (Table 2). Of the 15 bryophyte species present in less than 100 10-km squares, the ranges of 13 have decreased, and 20 of the 23 more widespread species dependent on farmland have also declined (Table 3).

The Game Conservancy Trust's Wildflower Project indicated declines in almost all nationally scarce species, and in many formerly widespread species (Wilson 1993). Once-abundant species have become extremely rare, such as Shepherd's Needle *Scandix pecten-veneris*, Corn Buttercup *Ranunculus arvensis* and Cornflower *Centaurea cyanus*, and scarcer species have similarly declined, including Tower Mustard *Arabis glabra*, Slender Tare *Vicia parviflora* and Ground Pine *Ajuga chamaepitys*. Several species are now extinct, or nearly so, such as Corncockle *Agrostemma githago*, Lamb's Succory *Arnoseris minima*, Thorow-wax *Bupleurum rotundifolium*, Small Bur-parsley *Caucalis platycarpos* and Corn Cleavers *Galium tricornutum*.

Sixteen vascular plants of arable fields have become scarce or rare in lowland England and are listed as Species of Conservation Concern, i.e. included in the Biodiversity Steering Group's 'long' list (Anon. 1995). Some such as Corn Buttercup were once the scourge of arable farmers (Stewart *et al.* 1994) but are now restricted to a few hundred 10-km squares, and their abundance has declined dramatically. Scarce species are often associated with a rich community of commoner species, including Scarlet Pimpernel *Anagallis arvensis*, Venus's Looking Glass *Legousia hybrida*, Field Forget-me-not *Myosotis arvensis*, Field Madder *Sherardia arvensis* and Field Pansy *Viola arvensis*.

Several studies have monitored local changes in plant abundance over extended periods. The GCT set up a study on 62 km^2 of the Sussex Downs in 1970 to monitor changes in Grey Partridge distribution, abundance and productivity in relation to invertebrate availability (Potts 1986, Aebischer 1991). As part of this work, the abundance of plants was assessed annually at each sampling point. Thirty years of data revealed no significant changes in the overall abundance of grasses or broad-leaved weeds. However, there were changes in the abundance of individual genera. Genera, such as stitchworts and chickweeds *Stellaria* significantly decreased over the period (Fig. 1), bedstraws *Galium,* docks *Polygonum,* fat-hens *Chenopodium* and speedwells *Veronica* either remained constant or increased (Ewald & Aebischer 1999). Chancellor (1976a, 1976b, 1985) monitored changes in single arable fields over a period of 20 years. Changes in management practices were considered to be more important than herbicide applications, which he considered to be quite limited in their effect. Other studies on changes in weed floras over time were carried out by Fryer & Chancellor (1970a, 1970b), Way & Chancellor (1976), Stanley & Bunyan (1979), Bunyan & Stanley (1983) and Wilson (1990, 1992), all of whom emphasized the importance of past management on weed floras. There were general indications that plant communities had changed, more species had declined than increased, and general species diversity had declined (Table 4). Special care needs to be used when drawing conclusions from such datasets presented in Table 4, given the different methodologies employed in measuring weed abundance or occurrence and the timing of the surveys in relation to herbicide use. Contradictions can clearly be seen or even some declines have been very recent.

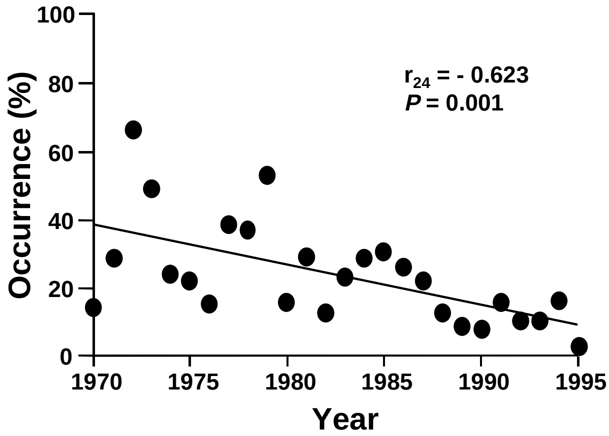

Figure 1. Percentage occurrence of Chickweed *Stellaria media* in cereal fields on The Game Conservancy Trust's Sussex Study area, 1970-1995. From Ewald & Aebischer (1999).

Causes of changes in plant abundance and distribution on UK farmland

Timing of farming operations

Most species found in arable crops are annuals able to complete their life-cycles between crop sowing and post-harvest cultivation. Most produce seeds that can tolerate prolonged dormancy in the soil, for example five years or more in the case of Corn Buttercup, and can survive grassland as part of a rotation. Germination occurs

Table 2. Status of rare, scarce and selected declining vascular plant species for which farmland habitats are of primary importance. Species in **bold** are currently scarce (16-100 10-km squares), **bold underlined** are currently rare (< 16 10-km squares). Data from Perring & Farrell (1983), Perring & Walters (1990), Stewart *et al.* (1994).

Habitat	Species	
Arable		
Less than 50% range contraction	***Apera interrupta***	**Dense Silky-bent**
	Apera spica-venti	**Loose Silky-bent**
	Euphorbia platyphyllos	Broad-leaved Spurge
	Fumaria densiflora	**Dense-flowered Fumitory**
	Polygonum rurivagum	Cornfield Knotgrass
50-70% range contraction	***Ajuga chamaepitys***	**Ground Pine**
	Fumaria bastardii	Tall Ramping Fumitory
	Fumaria parviflora	**Fine-leaved Fumitory**
	Fumaria purpurea	**Purple Ramping Fumitory**
	Fumaria vaillantii	**Few-flowered Fumitory**
	Papaver argemone	Prickly Poppy
	Papaver hybridum	Rough Poppy
	Petroselinum segetum	Corn Parsley
	Ranunculus arvensis	Corn Buttercup
	Silene noctiflora	Night-flowering Catchfly
	Teucrium botrys	**Cut-leaved Germander**
	Valerianella dentata	Narrow-fruited Corn Salad
	Vicia parviflora	**Slender Tare**
Greater than 70% range contraction	***Arabis glabra***	**Tower Mustard**
	Centaurea cyanus	**Cornflower**
	Galeopsis angustifolia	**Red Hemp-nettle**
	Melampyrum arvense	**Field Cow-wheat**
	Rhinanthus serotinus	**Greater Yellow-rattle**
	Scandix pecten-veneris	**Shepherd's Needle**
	Silene gallica	**Small-flowered Catchfly**
	Torilis arvensis	**Spreading Hedge-parsley**
No change data, but highly localised	***Althaea hirsuta***	**Rough Marsh-mallow**
	Filago lutescens	**Red-tipped Cudweed**
	Fumaria reuterii	**Martin's Ramping Fumitory**
	Lythrum hyssopifolia	**Grass-poly**
Grassland - acidic		
Less than 50% range contraction	***Hypericum undulata***	**Wavy St.John's-wort**
50-70% range contraction	***Chamaemelum nobile***	**Wild Chamomile**
	Festuca longifolia	**Blue Fescue**
	Phleum phleoides	**Purple Stem Cat's-tail**
Greater than 70% range contraction	***Dianthus armeria***	**Deptford Pink**
	Hypochaeris glabra	**Smooth Cat's-ear**
	Pulicaria vulgaris	**Small Fleabane**
Grassland - calcareous		
Less than 50% range contraction	***Carex humilis***	**Dwarf Sedge**
	Gentianella anglica	**Early Gentian**
	Gentianella germanica	**Chiltern Gentian**
	Orchis morio	Green-winged Orchid
	Phyteuma orbiculare	**Round-headed Rampion**
	Silene nutans	**Nottingham Catchfly**
	Tephroseris integrifolia	**Field Fleawort**
	Thesium humifusum	**Bastard Toadflax**
	Trifolium ochroleucon	**Sulphur Clover**
50-70% range contraction	***Aceras anthropophorum***	**Man Orchid**
	Ajuga chamaepitys	**Ground Pine**
	Cirsium tuberosum	**Tuberous Thistle**
	Eryngium campestre	**Field Eryngo**
	Euphrasia pseudokeneri	
	Herminium monorchis	**Musk Orchid**

	Hypochoeris maculata	**Spotted Cat's-ear**
	Iberis amara	**Wild Candytuft**
	Lathyrus aphaca	**Yellow Vetchling**
	Linum perenne	**Perennial Flax**
	Ophrys fuciflora	**Late Spider Orchid**
	Orobanche reticulata	**Thistle Broomrape**
	Salvia pratensis	**Meadow Clary**
	Teucrium botrys	**Cut-leaved Germander**
	Trinia glauca	**Honewort**
Greater than 70% range contraction	***Fritillaria meleagris***	**Snake's Head Fritillary**
	Galium pumilum	**Slender Bedstraw**
	Himantoglossum hircinum	**Lizard Orchid**
	Lotus angustissimus	**Slender Bird's-foot Trefoil**
	Ophrys sphegodes	**Early Spider Orchid**
	Orchis ustulata	**Burnt-tip Orchid**
	Pulsatilla vulgaris	**Pasqueflower**
	Rhinanthus serotinus	**Greater Yellow-rattle**
No change data, but highly localised	***Althaea hirsuta***	**Rough Marsh-mallow**
	Filago lutescens	**Red-tipped Cudweed**
	Orchis simia	**Monkey Orchid**
Grassland - neutral		
Less than 50% range contraction	***Euphrasia rostkoviana***	
	Oenanthe silaifolia	**Narrow-leaved Water-starwort**
	Orchis morio	Green-winged Orchid
50-70% range contraction	***Orobanche reticulata***	**Thistle Broomrape**
Greater than 70% range contraction	***Fritillaria meleagris***	**Snake's Head Fritillary**
No change data, but highly localised	***Fumaria occidentalis***	**Western Ramping Fumitory**
Grassland - wet		
50-70% range contraction	***Cyperus fuscus***	**Brown Galingale**
	Lobelia urens	**Heath Lobelia**
	Scorzonera humilis	**Viper's Grass**
Greater than 70% range contraction	***Lythrum hyssopifolia***	**Grass-poly**
No change data, but highly localised	***Apium repens***	**Creeping Marshwort**
	Bupleurum falcatum	**Sickly-leaved Hare's Ear**
	Fumaria occidentalis	**Western Ramping Fumitory**
Ditches		
Less than 50% range contraction	***Callitriche truncata***	**Short-leaved Water-starwort**
	Potamogeton trichoides	**Hairlike Pondweed**
	Wolffia arrhiza	**Rootless Duckweed**
50-70% range contraction	*Hydrocharis morsus-ranae*	Frogbit
	Myriphyllum verticillatum	**Whorled Water-milfoil**
	Sium latifolium	**Greater Water-parsnip**
Greater than 70% range contraction	***Stratiotes aloides***	**Water-soldier**
No change data, but highly localised	***Apium repens***	**Creeping Marshwort**
Water margins		
50-70% range contraction	***Cyperus fuscus***	**Brown Galingale**
	Persicaria laxiflora	**Tasteless Water-pepper**
	Pilularia globulifera	**Pillwort**
Greater than 70% range contraction	***Limosella aquatica***	**Mudwort**
	Mentha pulegium	**Pennyroyal**
	Pulicaria vulgaris	**Small Fleabane**
	Ranunculus tripartitus	**Three-lobed Crowfoot**
Hedges		
Less than 50% range contraction	***Fallopia dumetorum***	**Copse Bindweed**
	Sorbus devoniensis	
50-70% range contraction	***Campanula patula***	**Spreading Bellflower**
	Lobelia urens	**Heath Lobelia**
	Melampyrum cristatum	**Crested Cow-wheat**
Greater than 70% range contraction	***Ulmus plotii***	**Plot's Elm**

Table 3. Status of bryophytes found on lowland farmland habitats, including species present on > 100 10-km squares if farmland is of primary importance. Data from Hill *et al.* 1994.

Species	No. 10-km squares post-1950	% decline pre-1950 to post-1950	Species	No. 10-km squares post-1950	% decline pre-1950 to post-1950
Liverworts			Mosses (continued)		
Anthoceros agrestis	92	25.8	*Dicranella staphylina*	623	0.0
Anthoceros punctatus	92	21.4	*Dicranella varia*	1128	8.1
Fossombronia pusilla	475	13.5	*Ditrichum cylindricum*	748	6.4
Fossombronia wondraczekii	306	8.9	*Ditrichum pusillum*	24	29.4
Phaeoceros laevis ssp. carolinianus	4	42.9	*Ephemerum recurvifolium*	48	21.3
Phaeoceros laevis ssp. laevis	158	18.6	*Fissidens bryoides*	1513	5.2
Riccia glauca	378	11.5	*Funaria fascicularis*	144	35.7
Sphaerocarpus michelii	26	60.6	*Phascum floerkeaum*	62	25.3
Sphaerocarpus texanus	14	33.3	*Phascus cuspidatum*	938	7.4
			Physcomitrium pyriforme	499	16.7
Mosses			*Pleuridium acuminatum*	659	13.6
Barbula convoluta	1763	4.4	*Pohlia lescuriana*	70	0.0
Barbula fallax	1323	6.6	*Pottia commutata*	22	21.4
Barbula tomaculosa	6	0.0	*Pottia davalliana*	354	29.2
Bryum gemmilucens	10	9.1	*Pottia recta*	205	17.3
Bryum klinggraeffii	395	0.3	*Pottia starkeana*	59	33.7
Bryum microerythrocarpum	438	0.9	*Pseudephemerum nitidum*	640	10.6
Bryum rubens	1071	0.4	*Weissia multicapsularis*	13	38.1
Bryum sauteri	192	0.0	*Weissia rutilans*	102	27.7
Bryum violaceum	242	0.4	*Weissia squarrosa*	10	79.6

Table 4. Summary of trends for annual plants in UK farmland since 1960 (adapted from Campbell *et al.* 1997).

Family	Species	Change since 1970	Source
Ranunculaceae	*Ranunculus* spp.	decrease	Fryer & Chancellor (1970b)
	*Ranunculus arvensis**	decrease	Wilson (1994)
Papaveraceae	*Papaver* spp.	decrease	Fryer & Chancellor (1970b)
Fumariaceae	*Fumaria* spp.	decrease	Boatman (1989)
Cruciferae	*Sinapis* spp.	decrease	Fryer & Chancellor (1970b)
Caryophyllaceae	*Agrostemma githago**	decrease	Firbank (1988)
	Stellaria media	increase	Whitehead & Wright (1989)
Chenopodiaceae	*Chenopodium* spp.	stable/increase	Chancellor (1979, 1985)
Papilionaceae	*Trifolium* spp.	decrease	Marshall & Birnie (1985)
	Vicia spp.	decrease	Chancellor (1979, 1985)
Umbelliferae	*Scandix pecten-veneris**	decrease	Wilson (1994)
Polygonaceae	*Polygonum aviculare*	decrease	Potts (1986)
	Rumex spp.	decrease	Smith (1989)
	Polygonum spp.	stable/increase	Aebischer (1991)
Scrophulariaceae	*Veronica* spp.	stable/increasing	Fryer & Chancellor (1970b)
	Veronica persica	increasing	Whitehead & Wright (1989)
Rubiaceae	*Galium* spp.	stable/increasing	Aebischer (1991)
Compositae	*Matricaria* spp.	increasing	Whitehead & Wright (1989)
	*Centaurea cyanus**	decreasing	Smith (1989)
Gramineae	*Poa annua*	increasing	Chancellor (1976a, 1976b)
	Bromus sterilis	increasing	Aebischer (1991)
	Alopecurus myosuroides	increasing	Wilson (1992)

* indicates scarce or RDB species, listed in Perring & Farrell (1983) or Stewart *et al.* (1994).

primarily in autumn or spring for a particular species.

The differing fates of arable weed species have been attributed to variations in seed longevity when buried in the soil following ploughing (Firbank 1989, Wilson 1990). Species with long-lived seeds such as Common Poppy *Papaver rhoeas* have persisted, whereas others with shorter-lived seeds, such as Shepherd's Needle, have declined. Corncockle probably declined as a result of its lack of persistence in the seed bank, and the introduction of effective seed-cleaning techniques (Wilson 1990, Stewart *et al.* 1994). The practice of minimal tillage and direct drilling has increased the abundance of Black-grass *Alopecurus myosuroides* and Barren Brome *Bromus sterilis* (Critchley 1994, Clarke & Davies 1995), both common weeds of arable areas. Failure to bury seed during non-inversion cultivation is thought to have increased their abundance.

The timing of cultivation may also affect weeds of crops. The widespread switch to autumn cultivation may have been partly responsible for the decline of spring-germinating species such as Cornflower and Red Hemp-nettle *Galeopsis angustifolia* (Stewart *et al.* 1994). However, a number of declining weed species are autumn-germinating, such as Shepherd's Needle, Corn Buttercup and Spreading Hedge-parsley *Torilis arvensis,* but some of these, such as Shepherd's Needle, may not set seed before post-harvest cultivation begins. Seed-cleaning technology has improved considerably, and weed seeds are now rarely drilled with the crop (Shrubb 1997).

Timing of cultivation, sowing and harvesting also affect habitat availability, so species germinating in autumn, such as Shepherd's Needle and Corn Buttercup, tend to be restricted to autumn-sown crops. Conversely, predominantly spring-germinating species, such as Narrow-fruited Corn-salad *Valerianella dentata*, are dependent on spring-sown crops. Fast-growing crop varieties are harvested as early as July, and the next crop in the rotation sown without a fallow period, which may prevent many vascular plants completing their life cycles. Changes in timing of cultivation will restrict species that only germinate in the spring following soil disturbance, prevent species that set seed only late in the autumn (usually on the stubbles) from producing seed and increase competition from early-sown vigorous, established, crops to less competitive weed species.

Fertiliser application

Inorganic fertiliser application is incompatible with maintenance of botanical diversity, both in arable crops and grassland. Modern fertilisers promote rapid growth of a dense, even crop with few niches for other species, such as Cornflower (Stewart *et al.* 1994). The addition of fertiliser may change the light levels within crops and therefore the environment and competitive conditions (Kleijn & Van der Voort 1997). Crop breeding has resulted in plants that respond readily to fertiliser inputs.

Applications of artificial fertiliser rapidly reduce the plant species diversity of semi-natural species-rich grasslands (Mountford *et al.* 1994a, 1994b, Smith 1994). In grasslands, the effects of inorganic fertiliser may remain for years. In hay meadows in Somerset, soil nutrients (especially phosphorus) remained high three years after cessation of fertiliser input (Tallowin & Smith 1994), with no recovery of plant diversity. Slurry, a mixture of animal wastes produced by housed animals with little or no bedding can cause the same declines in plant species as inorganic fertiliser when applied to species-rich grassland (Crofts & Jefferson 1994).

Manure has lower concentrations of nutrients, which are released more slowly than inorganic products. However, even well-rotted manure can be damaging to unimproved, species-rich grasslands: applications of 20 t/ha every 3-5 years may be too high to maintain species diversity and abundance (Mountford *et al.* 1994a, 1994b). Within organic regimes, reduced nitrogen inputs are positively related to plant species diversity (Frieben & Kopke 1996). The use of light dressings of well-rotted manure does not affect botanical diversity on grasslands mown for hay on neutral soils (NVC communities MG3, 4, 5, 11 and 13). Manures from pig and poultry units are high in available nutrients and are unsuitable for use on grasslands with conservation value (Crofts & Jefferson 1994).

Grassland-dependent species of conservation concern tend to be grazing-tolerant perennials. Those for which information is available have declined greatly (plus one extinction), reflecting the great decline in unimproved pasture. Ploughing, reseeding and inorganic fertiliser application have been implicated in declines of species such as Monkey Orchid *Orchis simia* and Burnt-tip Orchid *Orchis ustulata.* A 'suitable' grazing regime is necessary to maintain a short sward, possibly with gaps for colonisation by species such as Dwarf Sedge *Carex humilis,* Late Spider Orchid *Ophrys fuciflora* and Pasqueflower *Pulsatilla vulgaris*. However, species such as Heath Lobelia *Lobelia urens* are susceptible to overgrazing.

Crop protection

For decades, agronomists have applied themselves to the control of weeds in agricultural crops, and now many of the weed species that were once widespread have become rare or extinct on farmland (Wilson 1990, Potts 1991, Wilson, 1992). The proportion of the total crop area treated with herbicides has increased, particularly in the 1950s and 1960s. However, the amount of active ingredient applied per unit area has been declining since the early 1980s as new products have been introduced, and others have become obsolete. Early hormonal herbicides such as

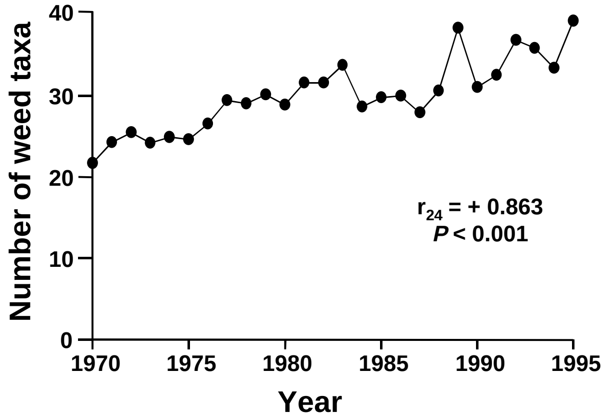

Figure 2. Number of weed taxa classed as "susceptible" on the labels of herbicides used in The Game Conservancy Trust's Sussex Study Area, 1970 – 1995. From Ewald & Aebischer (1999).

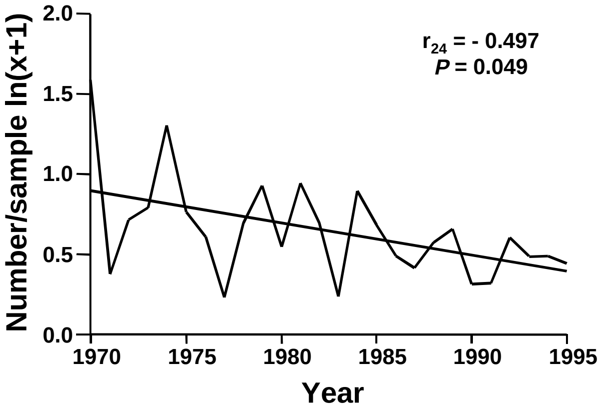

Figure 3. Numbers of caterpillar–like larvae collected from cereal fields in June from l970 to l995. From Ewald & Aebischer (1999).

2, 4-D and 2, 4, 5-T were applied at rates of 1-4 kg/ha. Imidazolinone herbicides introduced in the 1980s were applied at 100 g/ha. Recent sulphonylurea compounds are applied at rates of as little as 10-25 g/ha (Campbell *et al.* 1997). Tonnage used has indeed fallen, but area treated and the activity of active ingredients against plant species has increased (Fig. 2).

REVIEW OF FARMLAND ARTHROPODS

Changes in abundance and distribution of arthropods

There is less information regarding the status of arthropods on farmland although three long-term data sets are available. Two of these sampling networks have become known collectively as the Rothamsted Insect Survey (RIS) (Woiwod & Harrington l994). Aphids (Hemiptera: Aphididae) and other groups are collected on the wing, 12 m off the ground from a national network of aerial suction traps, and Lepidoptera are collected from a national network of light traps operating on the ground.

At a regional level, The Game Conservancy Trust's Sussex Study has collected arthropods from cereal fields from 12 farms on a 62-km² study area on the South Downs since l970. At a field level, diversity of ground beetles (Coleoptera: Carabidae) has been assessed in a weedy arable plot in the Tyne Valley since l981 (Luff l990). No comparable databases could be found for grassland arthropods.

The Rothamsted Insect Survey

The first suction trap was put into operation in l964 and soon a network of 23 was running throughout Britain. Over this time no change has been detected in the numbers of aphids over the long term and two species were shown to increase (Woiwod & Harrington l994).

Whereas biodiversity was maintained and no change in abundance was recorded for macro-Lepidoptera in light traps located in woodland sites since the l960s at the Rothamsted Experimental Station, on the farmland sites moth diversity and numbers decreased from a geometric mean catch per annum of 3910 individuals between 1933 and 1950 to 1280 between 1960 and 1989. Woiwod & Thomas (1993) were able to assess the impact of land use on the biodiversity of the moths caught from 26 light traps set up on the Rothamsted Estate in l990. Areas of non-cropped habitat such as woodland and hedgerows were important in promoting diversity and high moth abundance on the farm, whereas they concluded that arable and grassland areas now provide very poor habitats for non-pest species (Woiwod & Thomas l993).

The Sussex Study

In Sussex invertebrate samples collected since l970 from over 100 cereal fields per year have shown varying fortunes for different groups. No change in abundance of ground beetles, aphid-specific predators such as ladybirds (Coleoptera: Coccinellidae) and predatory Diptera was detected in the dataset. However, numbers of cereal aphids, their parasitoid wasps (Hymenoptera: Parasitica), leaf beetles (Coleoptera: Chrysomelidae), rove beetles (Coleoptera: Staphylinidae), spiders (Araneae) and sawfly larvae (Hymenoptera: Symphyta) all decreased (Aebischer l991). Many of these non-pest groups are key insect foods of farmland bird chicks (Campbell *et al*. 1997) (Fig. 3).

The Tyne Valley Study

In the weedy arable plot in the Tyne Valley, there has been a decreasing trend in species of ground beetles with associated changes in a measure of diversity since l981 (Luff & Woiwod l995). However no obvious changes in land use took place to account for these differences.

Causes of changes in invertebrate abundance and distribution on UK farmland

The Game Conservancy Trust's Sussex Study provides the best attempt to attribute causes to the observed declines in invertebrate numbers, and these are related to the intensification of agricultural production via the increased impact of pesticides (Ewald & Aebischer 1999).

Significant negative relationships were found between several invertebrate groups and the use of insecticides, the timing of their use (summer applications were more damaging than autumn ones), their spectrum of activity (organophosphate compounds were associated with the largest reduction compared to products containing pirimicarb) and with their use in the previous year (Ewald & Aebischer 1999).

Many of these declining insect species are weed-feeding and may have declined as a result of the indirect effect of herbicide use, in other words the removal of their host plants. Whilst the Sussex data do not conclusively demonstrate such an impact, other autecological entomological studies have shown the potential of such a mechanism, especially on species with relatively poor powers of dispersal. One such key chick-food insect is the Knotgrass Beetle *Gastrophysa polygoni* (Coleoptera: Chrysomelidae), a species that is restricted to feeding upon Knotgrass *Polygonum aviculare* and Black Bindweed *Fallopia convolvulus* only, spring-germinating broad-leaved weeds of the Polygonaceae (Sotherton 1982a). The distribution and abundance of Knotgrass Beetle was very closely linked to that of its host plant (Sotherton 1982b) and local extinction was observed following herbicide use. In subsequent years, despite the reappearance of host plants, populations of beetles took years to recover.

In experiments to increase levels of weeds in cereal crops to increase densities of non-target beneficial herbivorous insects, between two- and three-fold increases have been observed (Rands *et al.*1985, Chiverton 1999, Moreby & Southway 1999).

Other changes to farmland practice may also have influenced the distribution and abundance of arthropods. For example, the practice of establishing ley grassland in the rotation by undersowing a mixture of grass and legumes into the previous spring cereal has declined on the Sussex Study area over the last 30 years. Once practised on all farms, it is now part of the rotation of only one farm (Ewald & Aebischer 1999). It is believed that undersowing encourages beneficial insects, particularly sawflies (Potts 1986, Aebischer 1990), and its demise could also be responsible for insect declines (Fig. 3).

Other changes to the management of arable fields such as depth and timing of cultivation could also have caused changes, especially to edaphic species.

CONCLUSION

What little information there is available to show the changing status of plant and anthropod species on farmland illustrates increases and declines over the last 30 years and more. Some weeds have become rare, some even have become extinct. Others have attained pest status and are subjected to eradication campaigns by farmers. Invertebrates have also declined, probably as a result of the use of insecticides but also following herbicide use and consequent eradication of their host plants. All too few of these declines have experimental evidence to show the cause and little is known about the impacts of habitat loss and fragmentation. Certainly the pattern of the farmed landscape has changed as well as the management intensity of fields and farms. More work is needed to link declines to actual practices so that remedial measures can be recommended to halt declines and restore populations.

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