ASSESSING PESTICIDE RISKS TO NON-TARGET TERRESTRIAL PLANTS

SECTION THREE: ASSESSING THE IMPORTANCE OF EACH PLANT SPECIES IDENTIFIED AS A FOOD SOURCE/HABITAT FOR VERTEBRATE AND INVERTEBRATE WILDLIFE

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April 1999

3.1 INTRODUCTION

Direct and indirect effects of herbicides on non-plant species are an important consideration in risk assessment procedures but are often difficult to establish comprehensively and cost effectively. This section considers the possible routes of such effects on three major groups, invertebrates, birds and mammals, and highlights the species on the original list of 40 plants which are most important in relation to these groups.

In view of the large quantity of literature and survey data summarised in this section of the report, each group is considered individually (invertebrates in sub-section 3.2, birds in 3.3 and mammals in 3.4), cross referencing to other groups as appropriate. The main conclusions are summarised at the end of the section (3.5). Detailed tables of information and data are included in appendices (3.6), with only summary tables and figures inserted in the text.

3.2 INVERTEBRATES

Herbicide spray drift into field boundaries and other semi-natural habitats may harm invertebrate communities, either through direct toxicity to the animals (e.g. if the chemicals have insecticidal activity) or through indirect effects caused by damage to vegetation which may destroy or modify resources such as food and shelter (Fig. 3.1).

3.2.1 Direct toxicity

It is generally accepted that most herbicides, when used at recommended field-dose rates, have no insecticidal activity and, therefore, pose little or no threat of direct toxicity to invertebrates. The main exceptions to this rule are perhaps the triazine herbicides (e.g. cyanazine, simazine, etc.), which have been reported as moderately toxic to some soil-inhabiting invertebrates (Edwards 1991), and the bipyridyl herbicides (e.g. paraquat), which in laboratory tests have been shown to have contact insecticidal properties against aphids.

In one field experiment (Edwards and Stafford 1979), a single application of the triazine herbicide, cyanazine, in April significantly reduced soil populations of Collembola by about 20-30% over a period of 8-9 months after treatment, compared with populations recorded in untreated, but otherwise similar weed-free control plots.

In another field experiment (Edwards 1988), a single application of the triazine herbicide, simazine, in September significantly decreased the rate at which organic matter was degraded in the soil (45% breakdown after 7 months in the simazine treated plots, compared with 90-100% over the same period in paraquat treated plots and untreated controls). This difference was thought to provide an overall index of the direct toxic effect of simazine on soil fauna.

Laboratory tests have shown that cereal aphids are rapidly killed by contact action when sprayed with paraquat or with paraquat + diquat mixtures, but not when sprayed with glyphosate. In these tests, paraquat and paraquat + diquat were found to have insecticidal activity at concentrations equivalent to 200g a.i./ha (Wright, Kendall, et al. 1985). Field studies, however, suggest that the insecticidal activity of paraquat has relatively little impact on field populations of most invertebrates, at least compared to its indirect effects caused by killing vegetation and weed cover which provide food and shelter for many animals (Kendall, Smith et al. 1989).

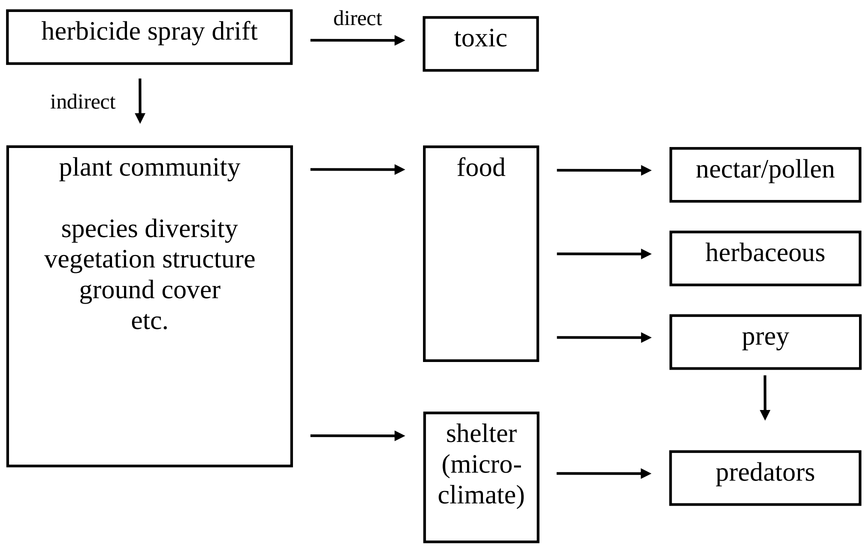

Fig. 3.1 Potential ecological effects of herbicide spray drift on invertebrates

3.2.2 Nectar and pollen plants

All flowering plants are potential food sources for nectar and pollen feeding insects. The majority of insects that feed on nectar and pollen are beneficial and often play an important role in pollination, and hence, the seed production and population dynamics of the plants they visit. Maintaining plants that provide a rich source of nectar and pollen, to attract and encourage nectar and pollen feeding insects, is not only a vital aspect of insect and plant conservation, but also of potential benefit in commercial crop production. Many commercial fruit, vegetable and seed crops (e.g. apples, pears, plums, strawberries, field beans, runner beans, oilseed rape, linseed, etc.) depend on the activities of pollinating insects to ensure adequate seed or fruit set (Free 1993). In addition, some insects whose larval stages are considered important natural enemies of crop pests (e.g. the larvae of syrphid flies and hymenopterous parasitoids) feed as adults on nectar and/or pollen. The local abundance of the predatory and parasitic juvenile stages of these insects in crops and their effectiveness in reducing pest populations, has been shown to depend partly on the proximity of suitable nectar and pollen sources for the adult insects (Harwood, Hickman et al. 1994; Wratten and van Emden 1995).

Although there are some nectar and pollen feeding insects with a generalist approach to foraging, the vast majority of taxa appear to show some degree of floral selectivity or preference (Cowgill, Wratten et al. 1993; Feber, Smith et al. 1994; Fussell and Corbet 1992; Lack 1982). In some cases the co-evolution of flowers and their insect visitors, has lead to extreme specialization in both flower and insect morphology. Consequently, the selection of nectar and pollen sources (and their utilisation when available) tends to differ widely between different insect taxa and species. This emphasises the importance of maintaining floral diversity in the management and conservation of habitats for flower visiting insects, in order to facilitate the partitioning of floral resources, and hence reduce competition, between insect taxa. In turn, this may encourage greater insect diversity and abundance.

Much of the literature on the nectar and pollen sources preferred by different insects is somewhat fragmentary and dispersed. Many observation are rather vague in respect of plant and insect species, whereas more detailed studies have tended to focus on specific habitats and, hence, on a limited range of plant-insect associations. Because of this, the information summarised (appendix 3.1; Fig 3.2) is confined to fairly large insect taxa, in the hope of obtaining a more realistic assessment of the relative importance of different plants as nectar and/or pollen sources. Even so, these data still tend to reflect the plants and insects most intensively studied and probably underestimate the potential value and importance of many of the listed plant species to flower-feeding insects.

Despite this limitation there is little doubt that the Umbelliferae (e.g. *Daucus*, *Heracleum* spp., etc.) and the Asteracea (e.g. *Centaurea*, *Cirsium*, *Carduus*, *Leucanthemum*, *Taraxacum* spp., etc.) attract the greatest diversity of nectar and/or pollen feeding insect, including many species of Coleoptera (beetles), Diptera (flies), Hymenoptera (wasps and bees) and Lepidoptera (butterflies and moths) (Fig. 3.2; Appendix 3.1). Umbelliferae flowers are thought to be one of the main food sources of the adult braconid wasps which parasitise aphids (Wratten and van Emden 1995), as well as being selectively used by many nectar-feeding beetles, including some of our more exotic and colourful species belonging to the families Cantharidae (soldier beetles), Cerambycidae (longhorn beetles) and Pyrochroidae (cardinal beetles) (Joy 1933; Linssen 1959a,b), whilst the Asteracea are important nectar and pollen sources for butterflies, some day-flying moths, solitary bees and bumblebees (Lack 1982; Fussell and Corbet 1992; Free 1993; Feber, Smith et al. 1994). Many adult hoverflies (Syrphidae), including the economically important aphidophagous species of *Syrphus*, *Episyrphus*, *Metasyrphus*, *Melanostoma* and *Platycheirus*, forage primarily on members both these plant families (Lack 1982; Cowgill, Wratten et al. 1993).

Although there is relatively little published information, it seems likely that hawthorn (*Crataegus monogyna*), like other early flowering Rosaceae, is also a valuable nectar and pollen source for many diverse insect groups. For example, over 70 taxa of insects, including hoverflies, beetles, sawflies, wasps, solitary bees and bumblebees, have been recorded from apple blossom (*Malus* spp.) (Kendall and Solomon 1973). Most of these species probably also frequent and utilise hawthorn blossom (e.g. Joy 1933; Lack 1982; Harde and Hammond 1984; Fussell and Corbet 1992).

Other plants of special importance as nectar and pollen sources are the Leguminosae (*Lotus*, *Trifolium* and *Vicia* spp.), Labiatae (*Lamium* spp.) and Scrophulariacea (*Digitalis* spp.). These flowers are selectively foraged by several species of bumblebees, especially those with relatively long tongues such as *Bombus hortorum*, *B. humilis*, *B. lapidarius*, *B. pascuorum*, *B. ruderarius* and *B. ruderatus* (Fussell and Corbet 1992). Also, they are thought to be important forage plants for some of the larger solitary bees such as *Megachile* spp. (leaf-cutter bees) and *Osmia* spp. (mason bees) (Free 1993).

3.2.3. Herbivore plants

Most, if not all, plants probably support their own, somewhat unique, assemblage of phytophagous invertebrates, and in this respect almost every plant species is a potential contributor to the overall diversity of animals likely to occur in any particular habitat. However, whilst bearing this mind and for the purpose of this study, it is assumed that those plants which are hosts to relatively few invertebrate taxa are, in general, likely to prove less important for sustaining biodiversity than plants which support large numbers of herbivore species.

The phytophagous members of five insect taxa (Lepidoptera, Symphyta, Coleoptera, Heteroptera and Diptera), for which specific host-plant data are reasonably well documented, are used here as indicators of the host-plant importance of the various plant species: (1) as larval food-plants of butterflies and larger moths (Lepidoptera), (2) as larval food-plants of sawflies (Hymenoptera, Symphyta), (3) as larval and/or adult food-plants of beetles (Coleoptera), (4) as food-plants of heteropterous plant-bugs (Hemiptera, Heteroptera), and (5) as larval food-plants of flies (Diptera) (Fig 3.3).

The principal larval food-plants of butterflies and larger moths (Lepidoptera) amongst the selected plant species are hazel (*Corylus avellana*), hawthorn (*Crataegus monogyna*), knotgrass (*Polygonum aviculare*), hedge-bedstraw (*Gallium mollugo*), nettle (*Urticae dioica*), eggs and *bacon (Lotus corniculatus*), dandelion (*Taraxacum officinale*), white clover *(Trifolium repens*) and the various species of grasses (Gramineae) (Fig. 3.3). The two tree species, hazel (*Corylus avellana*) and hawthorn (*Crataegus monogyna*), support over 20 species of larger moths belonging to several diverse families, such as the Drepanidae, Geometridae, Lasiocampidae, Lymantriidae, Noctuidae, Notodontidae and Sphingidae. Grouped together, nettle (*Urticae dioica*), eggs and bacon (*Lotus corniculatus*), white clover (*Trifolium repens*) and grasses (Gramineae) are host-plants to 22 species of butterflies and to more than 20 species of larger moths (Appendix 3.2; Allan 1949; Emmet, Goater et al. 1991).

Of the species of sawfly caterpillars (Hymenoptera, Symphyta) associated with the listed plants, over 50 % (21/38 species) feed on either *hawthorn (Crataegus monogyna*) or grasses (Gramineae). Food-plants of the remaining species include hazel (*Corylus avellana*), fat hen (*Chenopodium album*), cleavers (*Gallium aparine*), knotgrass (*Polygonum aviculare*), hedge-*bedstraw (Gallium mollugo*), buttercup (*Ranunculus repens*) and white clover (*Trifolium repens*) (Appendix 3.3; Fig. 3.3; Benson 1951; Benson 1952; Benson 1958).

Several plants on the selected list support extremely diverse assemblages of phytophagous beetles (Coleoptera). In particular, hazel (*Corylus avellana*) and hawthorn (*Crataegus monogyna*) are host-plants to over 40 species of beetles belonging to 9 different families: Anobiidae, Anthribidae, Buprestidae, Cerambycidae, Chrysomelidae, Cleridae, Curculionidae, Melandryidae and Scolytidae. Among the herbaceous plants, particularly rich beetle fauna are associated with the Leguminosae and some Asteraceae. For example, the four legumes, white clover (*Trifolium repens*), eggs and bacon (*Lotus corniculatus*), bush vetch (*Vicia sepium*) and common vetch (*Vicia sativa*), together host about 48 species of Bruchidae, Chrysomelidae, Curculionidae and Nitidulidae; the two thistles (*Carduus acanthoides* and *Cirsium arvense*, Asteraceae) are the food-plants of a further 16 species of Chrysomelidae and Curculionidae, plus 2 species of Mordellidae (Appendix 3.4; Fig. 3.3; Bullock 1992).

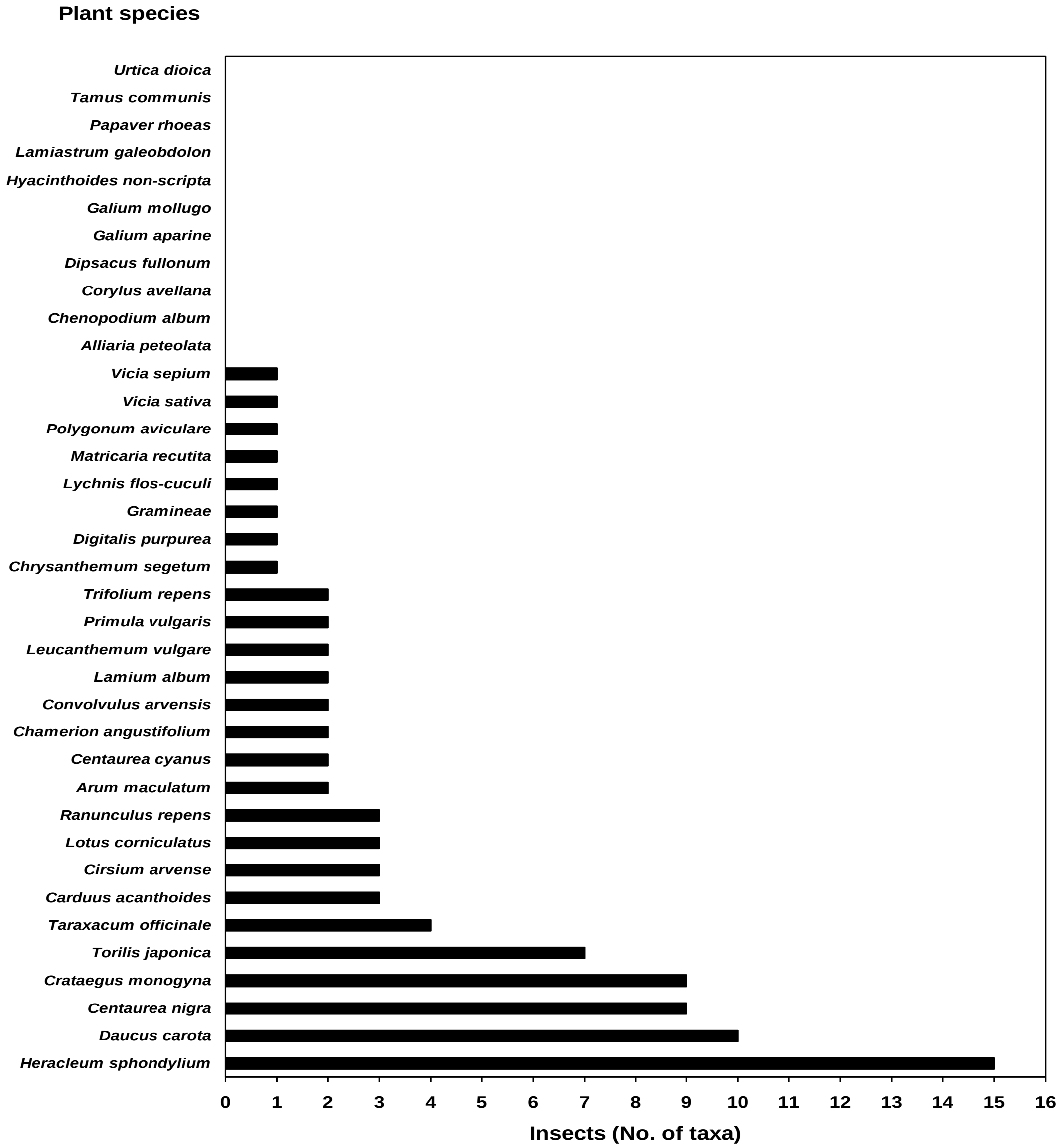

Fig. 3.2 Number of major insect taxa (mainly classed as family groups) utilising the selected flora as a nectar and/or pollen source (data from appendix 3.1, with plants in rank order of insect diversity).

Phytophagous bugs (Hemiptera, Heteroptera), many of which are also opportunistic predators of aphids and other small arthropods, appear to be associated mainly with hazel (*Corylus avellana*) and hawthorn *(Crataegus mongyna*), which together host 14 species; nettle (*Urtica dioica*) and white clover (*Trifolium repens*), which together host over 20 different species; and grasses (Gramineae), which host a further 12 species (Fig. 3.3). Represented in these totals are members of six families: Acanthosomidae and Pentatomidae (shield bugs), Berytidae (stilt bugs), Lygaeidae (ground bugs), Miridae (capsids) and Rhopalidae (Appendix 3.5; Southwood and Leston 1959).

The greatest diversity of phytophagous flies (Diptera) is found on the various grasses (Gramineae), which together host about 30 species of Agromyzidae, Anthomyiidae, Bibionidae, Cecidomyiidae, Chloropidae, Opomyzidae and Tipulidae (Fig. 3.3). All but a few of the listed dicotyledons are food-plants of host-specific, or moderately host-specific, flies belonging to the families Agromyzidae (leaf miner flies), Cecidiomyiidae (gall midges) and Tephritidae (fruit flies and their allies). In total, over 45 different species of these flies are recorded from the Asteraceae alone (i.e. from *Centaurea cyanus*, *C. nigra*, *Carduus acanthoides*, *Cirsium arvense*, *Matricaria recrutita*, *Leucanthemum vulgare* and *Taraxicum officinale*), with a further 80 or more species hosted by the remaining broad-leaf flora, in particular the Leguminosae (with 18 species recorded from *Lotus corniculatus*, *Trifolium repens*, *Vicia sativa and V. sepium*), Umbelliferae (with 13 species recorded from *Heracleum spondylium*, *Torilis japonica* and *Daucus carota*) and Urticaceae (with 8 species recorded from *Urtica dioica*) (Appendix 3.6; Barnes 1946-56; Nijveldt 1969).

Some of the phytophagous insects included in Appendices 3.2-3.6 attack cultivated plants. Hence, their wild hosts could be regarded as potential 'reservoirs' and sources of pest outbreaks. In view of this, the insect species recognised as frequent crop pests, together with their wild and cultivated host-plants, are listed in Appendix 3.7 (Edwards and Heath 1964; Massee 1954; Smith 1931). The main potential sources of crop pests amongst the selected flora seem to be clover (*Trifolium repens*), hawthorn (*Crataegus monogyna*) and the various grasses (Gramineae), followed by fat hen (*Chenopodium album*), nettle *(Urtica dioica*) and the two species of vetch (*Vicia sativa* and *V. sepium*) (Fig. 3.4). However, to varying degrees most of the 'pest' insects identified in Appendices 3.2-3.6 are polyphagous and feed on a wide range of plants in addition to those selected for this study (see Appendix 3.7). Hence, none of the plants considered here, if growing in fairly diverse agroecosystems and plant communities, can really be singled out as potential 'high risk' sources of pest outbreaks.

3.2.4. Vegetation structure and plant cover (shelter)

Field observations and experiments suggest that the overwintering success, abundance and distribution of many beneficial predatory arthropods in farmland is determined by local climate, but the most detrimental effects are mediated by microclimate. Local climate in any winter is determined by a range of factors that are not affected by vegetation structure, such as latitude, altitude, terrain, inversion effects and air mass stagnation (Leather, Walters et al. 1993). The effect of local habitat is governed by such factors as soil type and depth, soil moisture, height above the surface and the vegetation structure (e.g. Luff 1965; Luff 1966a,b; Pollard 1968b; Edgar and Loenen 1974; Bossenbroek, Kessler et al. 1977; Desender 1982; Sotherton 1985; Thomas, Wratten et al. 1991). The interaction of these factors to determine overwintering survival are discussed by Leather, Walters et al. (1993) and will not be repeated here.

The survival of individual insect species is often related to the specific interaction of that species to a particular host plant at the critical stages of its life cycle (eg Walters, Dixon et al 1984). Such cases have to be dealt with on an individual basis and thus it is difficult to generalise on the impact of a reduction of the incidence of a particular plant species by a

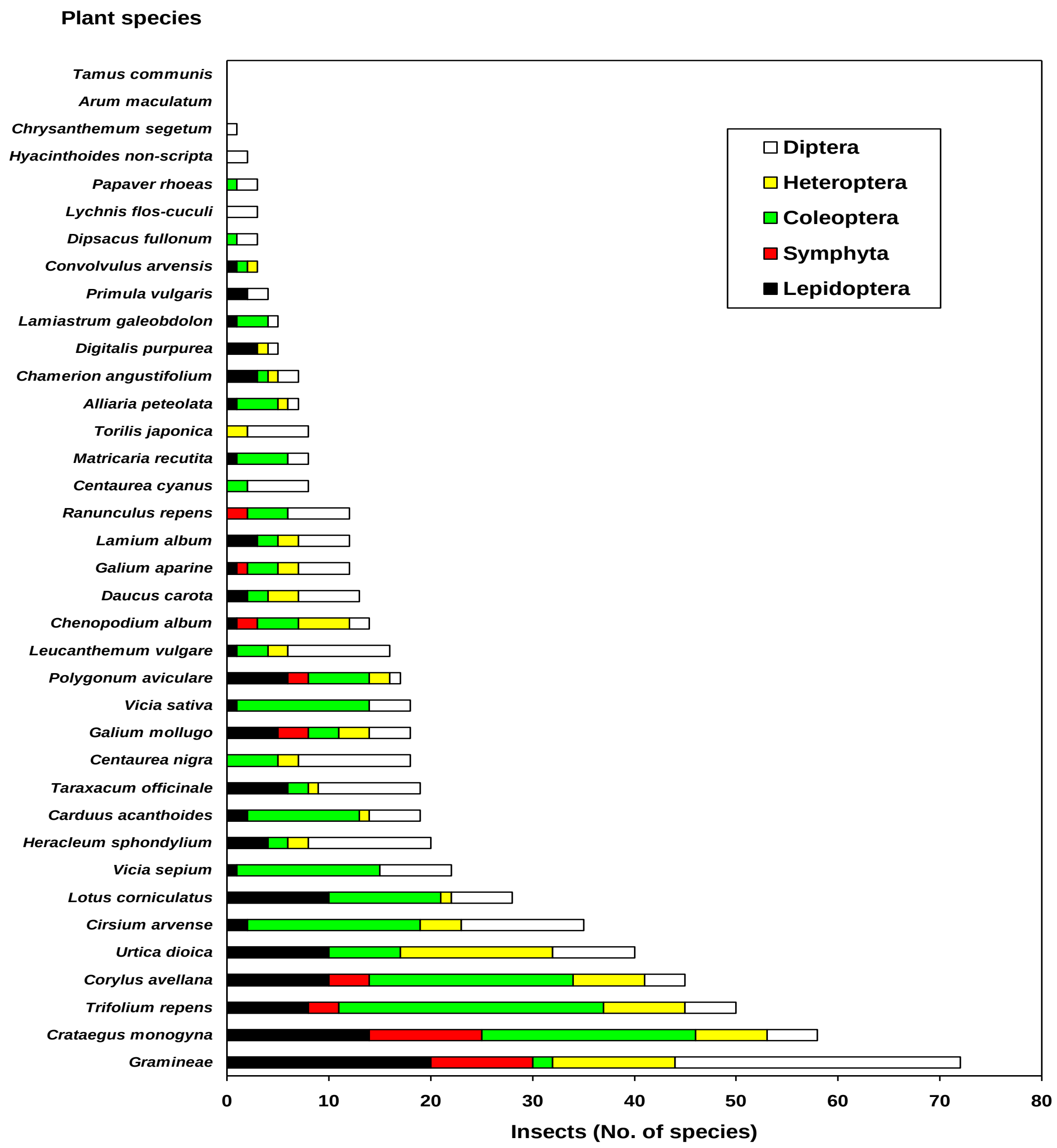

Fig. 3.3 Number of species of Lepidoptera (butterflies and larger moths), Symphyta (sawflies), Coleoptera (beetles), Heteroptera (plant-bugs) and Diptera (flies) utilising the selected flora as larval and/or adult food-plants (data from Appendices 3.2-3.6, with plants arranged in rank order of insect diversity).

herbicide. However, each species of insects will have particular cold hardiness characteristics which govern the range of temperatures at which it can survive (eg McDonald, Bale *et al*,1997, a,b,c,d, 1998). The frequency with which these limiting temperatures are reached arereduced by the selection of protected overwintering sites, and these frequently involve assemblages of particular plants (Leather, Walters et al 1993).

There are numerous studies showing that many species of predatory bugs (e.g. Anthocoridae and Miridae), ground beetles (Carabidae), rove-beetles (Staphylinidae) and spiders (e.g. Linyphiidae) occur in much greater numbers under dense ground vegetation than under sparse or impoverished vegetation (Pollard 1968a,b; Sotherton 1984; Powell, Dean et al. 1985;

Sotherton 1985; Thomas, Wratten et al. 1991; Thomas, Wratten et al. 1992). In addition, the ground vegetation of field boundary habitats seems to be more attractive to some overwintering predatory beetles (Carabidae and Staphylinidae), when associated with hedges or shelterbelts of hawthorn (*Crataegus monogyna*) or other shrub and tree species (Sotherton 1985).

Some graminaceous plants, in particular *Dactylis glomerata* (cocksfoot) and other species of tussock-forming grasses, are known to harbour large numbers of predatory carabid and staphylinid beetles (Luff 1966a). The shelter provided by these grasses is especially important for the winter survival of *Agonum dorsale*, *Demetrias atricapillus* (Carabidae) and *Tachyporus* spp. (Staphylinidae) (Sotherton 1985; Thomas, Wratten et al. 1991; Thomas, Sotherton et al. 1992; Thomas, Wratten et al. 1992; Dennis, Thomas et al. 1994; Wratten and van Emden 1995), all of which are key predators of cereal aphids and probably other aphid pests of arable crops (Sunderland and Vickerman 1980; Sunderland, Crook et al. 1987).

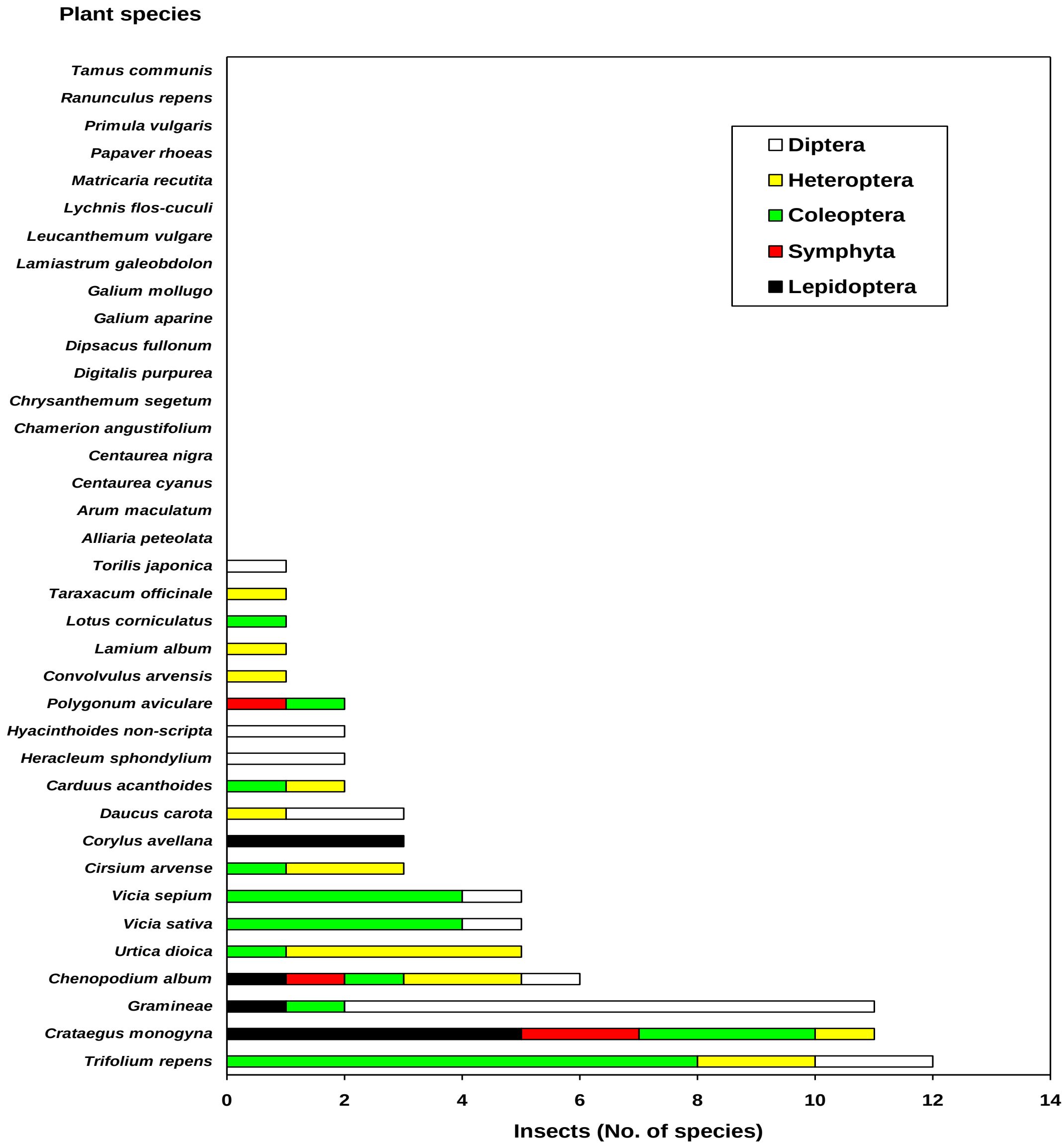

Fig. 3.4. Number of potential pest species of Lepidoptera (butterflies and larger moths), Symphyta (sawflies), Coleoptera (beetles), Heteroptera (plant-bugs) and Diptera (flies) utilising the selected flora as larval and/or adult food-plants (data from Appendices 3.2-3.6, also see Appendix 3.7, with plants arranged in rank order of insect diversity).

3.2.5 Invertebrates in the diet of birds

Loss of plant diversity as a result of herbicide drift into field boundaries and other semi-natural habitats, and its consequential effects on invertebrate diversity and incidence, may also effect populations of birds which prey upon those invertebrates. Wilson, Beatrix et al. (1996) reviewed literature reports of the importance of various insect groups as a food source for 39 species of birds on lowland farms, and classified them as either absent from, present in, or important components of their diets. Their findings are summarised in Appendix 3.8. Of the 109 invertebrate groups featured in this study, only 59 were classified as being important in the diet of one or more bird species. Of the important groups, 12 were insect orders and 32 insect families.

The most important insect orders providing food for birds included (Table 3.1) the Coleoptera, Diptera, Hemiptera, Hymenoptera and Lepidoptera (particularly larvae). Less important orders included the Orthoptera, Collembola, Dermaptera, Ephemeroptera, Odonata and Trichoptera. Specific host plant data are well documented for four of the five important orders (Coleoptera, Diptera, Hemiptera and Lepidoptera - see section 3.2.3), and reliable information is available for a sub-order (the Symphyta) of the fifth. Strong similarities occur between the range of plants which were highlighted as being important in sustaining biodiversity of insects in section 3.2.3 and those reported as being of importance in providing food for birds in this section.

Table 3.1 Utilisation of insect orders in the diets of 37 species of birds commonly found on lowland farms. Compiled from: Wilson, Beatrix et al, 1996. No. of bird species = number of species in which the order is an important dietary component.

Insect order	No. bird species
Coleoptera	32
Diptera	27
Hymenoptera	22
Hemiptera	21
Lepidoptera (larvae)	20
Lepidoptera (non-larvae)	7
Orthoptera	7
Collembola	4
Dermaptera	3
Ephemeroptera	2
Odonata	1
Trichoptera	1

The diverse assemblages of phytophagous Coleoptera which have been recorded on several of the list of selected plants indicate that they may be of importance as sources of bird food. In section 3.2.3 (Appendix 3.4) *Crataegus monogyna* and *Corylus avellana* are listed as a host of over 40 species of beetles from 9 families. Of these 9 families, Wilson, Beatrix et al.. 1996 listed three, Curculionidae, Chrysomelidae and Buprestidae as being important components of the diets of 22, 7 and 1 bird species respectively (Table 3.2). Two others, Scolytidae and Cerambycidae are noted as being present in the diet of some bird species. All the listed annual weed species act as hosts for important bird food families including *Chenopodium album* which has four of these families (Curculionidae, Silphidae, Carabidae and Chrysomelidae), and *Matricaria recutita* with

Table 3.2. Utilisation of insect families in the diets of 37 species of birds commonly found on lowland farms. Compiled from: Wilson, Beatrix et al, 1996. No. of bird species = number of species in which the family is an important dietary component.

Insect family	No. bird species
Curculionidae	22
Arachnida	14
Aphididae	14
Formicidae	14
Tipulidae	12
Silphidae (larvae)	10
Carabidae	9
Staphylinidae	7
Chrysomelidae	7
Acrididae	6
Chironomidae	5
Ichneumonidae	5
Elateridae	5
Bibionidae	4
Tettigoniidae	3
Scatophagidae	3
Muscidae	3
Gryllidae	2
Psyllidae	2
Sphaeroceridae	2
Syrphidae	2
Rhagionidae	2
Coccinellidae	2
Delphacidae	1
Cicadelidae	1
Stratiomyidae	1
Drosophilidae	1
Calliphoridae	1
Brachonidae	1
Tenebrionidae	1
Buprestidae	1
Hydrophilidae	1

three (Curculionidae, Carabidae and Chrysomelidae). Three of the six listed woodland/hedge ground flora acted as hosts for important prey items, 7 of the 8 tall herbs, 8 of the 9 grassland species and all the grasses. Although most of the herbaceous plants act as a host for important Coleopteran species some appear to be of particular importance. For example *Vicia sepium* acts as a host for 11 species from families listed as important as bird food, *Trifolium repens* for 25, and *Vicia sativa* for 10. The thistles *Carduus acanthoides* and *Cirsium arvense* are food plants for 16 species of Chrysomelidae and Curculionidae (Bullock, 1992).

In addition to acting as food plants for phytophagous Coleoptera the effect of vegetation structure and plant cover on a wide range of insects (see section 3.2.4), including predatory Coleoptera, is also important in enhancing potential food sources for birds. The maintenance of dense ground cover may increase the numbers of such insects, although the effect will be mediated by the provision of refuges from predation.

Diptera provide an important component of the diet for at least 27 species of birds on lowland farms (Table 3.1). However, although the literature records many species of dipterans feeding on plants on the list selected for this study, most are from the families Agromyzidae, Anthomyiidae, Bibionidae, Cecidomyiidae, Chloropidae, Opomyzidae and Tipulidae (Fig 3.3). Of these only the Tipulidae and Bibionidae have been recorded as being important in bird diets (Table 3.1). The Tipulidae provides a major food source for least 12 bird species at certain times of the year (Table 3.2) and feed on a wide variety of grasses including those on the selected list. The Bibionidae are also grass feeders and feature prominently in the diet of at least 4 species of birds in appropriate seasons. Syrphid species are known to feed on *Hyacinthoides non-scripta* and *Primula vulgaris* and provide an important food source for at least 2 bird species. The lack of apparent food plants on the selected list for this important order of insects is surprising and may reflect limited information on the full range of their host plants or of the true range of Diptera eaten by birds. Further work is needed to determine the importance of the selected plants in the life histories of these species.

The utilisation of many of the listed plants as sources of nectar rather than as feeding sites may effect their importance as sources of food for birds. For example at least 17 listed species are known to be used by syrphids as nectar sources, thus will attract or arrest adults in the location that they are growing (Appendix 3.1). Insects from five separate families listed as important in bird diets (Table 3.2) are recorded as utilising selected flora as nectar sources (Appendix 3.1). These include the Muscidae (from three plants), Syrphidae (from 17 plants), Stratiomyidae (from 1 plant), Calliphoridae (3 plants), and Brachonidae (3 plants). In addition, various lepidopteran species visit plants for nectar as adults (8 plant species), and other (undefined) Diptera and Coleoptera are known to visit at least one of the listed plants (Appendix 3.1). Individual plants that may be of particular importance as nectar sources include *Heracleum sphondylium* (known to attract 15 insect groups), *Crataegus monogyna*, *Centaurea nigra, Daucus carota* (9 insect groups each) and *Torilis japonica* (7 insect groups). Once again, this may underestimate the importance of some plant species as nectar sources (see comments in section 3.2.2) and further work will be required to confirm this list.

Members of the order Hemiptera, the true bugs, are also a major food source for birds (Table 3.1). Many of the species on the list of selected plants act as a host for a range of phytophagous bugs (Appendix 3.5). Although the insect families represented in Appendix 3.5 do not appear in the list of families utilised in bird diets (Table 3.2), it is likely that they still provide a valuable food source for many birds. Numerous Hemipterans are associated with *Corylus avellana* and *Crataegus monogyna*, *Urtica dioica*, *Trifolium repens* and various grasses (Fig 3.3), and as these plants are known to visited as a source of other insects it is highly likely that such plant-bugs are also taken. As before, further work would be required to confirm the importance of these insects and plants as food sources for birds.

The food plants of Lepidoperans are also well represented on the selected plant list, and reduced incidence of many of these plant species could reduce the availability of prey items. As for earlier insect orders, *Corylus avellana* and *Crataegus monogyna* are known to provide a host for the larvae of many butterflies and moths. *Urtica dioica* is also widely recognised as an important egg laying and larval feeding site for several Lepidopteran species. In addition, *Trifolium repens*, *Lotus corniculatus*, several species of grasses, *Gallium mollugo* and *Taraxacum officinale* feature prominently the list of important hosts.

Detailed information on host plants of the remaining major order listed as being important for bird food (Hymenoptera) is less readily available. However, the sub-order Symphyta is noted by Wilson, Beatrix et al 1996 as being important in the diets of at least 7 birds, and information on food plants for this group was compiled by Benson (1951, 1952 and 1958). A total of 9 plant species from the selected list (Appendix 3.3) are noted as hosts of sawflies (Symphyta) including *Crataegus monogyna* (hosting 11 species), various species of grasses (10 species), *Corylus avellana* (4 species), and *Galium mollugo* and *Trifolium repens* (3 species each).

Potential pest species of cultivated plants which also occur on wild hosts in the selected plant list are also known to feature in bird diets. Many of these species are listed in Appendix 3.7, together with their various host plants. In addition, many species of aphids are known to feed on many of the listed plants and undoubtedly provide additional bird food. The main potential sources of crop pests which can be utilised as bird food mirror plants highlighted in earlier paragraphs and include *Crataegus monogyna*, *Trifolium repens*, *Chenopodium album*, *Urtica dioica*. *Vicia sativa* and various grasses.

As detailed data on the importance of the listed species plants as hosts of prey species for birds is frequently unavailable, it is only possible to draw broad conclusions. However, certain plants from the selected list feature prominently as hosts for several of the most important insect orders that provide bird food. These include *Crataegus monogyna*, *Corylus avellana*, *Trifolium repens*, *Chenopodium album*, *Urtica dioica*, *Vicia sativa*, *Vicia sepium* and several species of grasses. Further work would confirm and extend current knowledge and enable a more robust assessment of the effect of herbicide use on bird food availability.

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3.2 BIRDS

3.2 INTRODUCTION

3.2.1 Farmland bird population declines

Bird populations associated with agricultural land are declining in many areas of Europe and North America (Tucker & Heath 1994, Warner 1994). In Britain long-term population monitoring programmes (e.g. Marchant *et al.* 1990) and periodic national surveys organised by the BTO (e.g. Donald & Evans 1995, Gibbons *et al.* 1993) have provided detailed histories of the time of onset, duration and severity of range contractions and population declines. In a review of these changes Fuller *et al.* (1995) found that 24 out of 28 farmland bird species had undergone range contractions between 1970 and 1990, whilst 15 out of 18 species, for which it was possible to assess population change, had declined in abundance over the same period. Seven of these species had undergone population declines of at least 50%. This preponderance of range contractions and population declines was not found in species guilds characteristic of other broad habitat types such as woodland.

There is now a great deal of evidence to support initial suggestions that changes in agricultural practices are responsible for declines in farmland bird populations. In Britain most declines began in 1970s (Marchant *et al.* 1990, Siriwardena *et al.* 1998) coinciding with the onset of major changes in agriculture including the simplification of crop rotations, more intensive grassland management and a shift from spring to autumn sown cereals (O'Connor & Shrubb 1986, Fuller *et al.* 1995). At the same time there was also a dramatic increase in the use of chemical pesticides to control weed and pest burdens on arable crops (Campbell *et al.* 1997) a trend which is traced by the periodic Pesticide Usage Surveys carried out by the Ministry of Agriculture Fisheries and Food (MAFF) (e.g. Steed *et al.* 1979, Davis *et al.*1993).

Populations of most farmland plants and invertebrates have not been monitored for as long or as consistently as those of birds. In the past there has been some argument about the extent of any reduction in arable weed abundance or range (Whitehead & Wright 1989). However, despite the lack of comprehensive data on overall trends in abundance of these groups, more recent data for a variety of individual species and families give a clear picture of widespread and major declines in many groups (Potts 1991, Donald 1998). There is also evidence that the use of pesticides frequently results in considerable short-term reductions in the abundance of target and non-target species, and that such effects may persist for weeks or months after the date of application (Donald 1998).

Thus the effects of pesticides on non-target plants may harm farmland birds by:

1. Reducing food availability (a) directly, by reducing seeds and fruits of non-crop plant species. These are important food sources for a wide variety of granivorous and frugivorous bird species, some of which depend on there being seeds available all the year round e.g. *Carduelis* finches; (b) indirectly, by reducing the abundance of plants that serve as host species for a range of invertebrates, a number of which are important prey for many farmland birds both as adults and nestlings.

2. Reducing the availability of nesting habitat by reducing the abundance of plants that provide important ground cover or nest sites.

In this section we assess the extent to which the effects of pesticides on non-target plants may affect farmland birds through either a reduction in food or nest sites. We do this by determining, from existing literature, the importance of the non-target plant species listed in Section One in providing food (directly and indirectly) or nesting habitat.

3.2.2 Methods

The ecological importance of the 40 non-target plants listed in Section One is assessed in terms of (a) providing food directly, in the form of fruits, seeds or green material; (b) providing food indirectly, in terms of the invertebrate herbivores they support and (c) providing nesting habitat for 39 bird species characteristic of lowland farmland habitats in Britain. These bird species span a broad range of taxonomic, functional and ecological groups and include passerines e.g. Yellowhammer *Emberiza citrinella* and non-passerines e.g. Red-legged Partridge *Alectoris rufa*, insectivores e.g. Pied Wagtail *Motacilla alba*, granivores e.g. Linnet *Carduelis cannabina*, summer and winter migrants e.g. Turtle Dove *Streptopelia turtur* and Fieldfare *Turdus pilaris* and resident species e.g. Skylark *Alauda arvensis.* The full species list (common and Latin names) is given in Appendix 3.2.1. These farmland bird species also include ten that are listed in the UK Biodiversity Action Plan (Anon 1995, 1998); Grey Partridge, Stone Curlew, Turtle Dove, Skylark, Song Thrush, Tree Sparrow, Linnet, Cirl Bunting, Reed Bunting and Corn Bunting.

The dietary information presented here is derived from two recent reviews, one conducted by the British Trust for Ornithology (BTO); *The Diet of Bird Species of Lowland Farmland* (Wilson *et al.* 1996), and one by Central Science Laboratory (CSL) *Birds and Farming: Information for Risk Assessment* (Buxton & Crocker 1996). The former collates information from published papers and reports. Each food taxon was considered 'present' in the diet of a bird species if it was recorded in any of the studies reviewed, and as 'important' if it comprised a mean of more than 5% of the diet over all quantitative studies reviewed. The latter was assessed either as frequency of occurrence in the diet, percentage of items in the diet, percentage of biomass of the diet or percentage of feeding observations. A food taxon was also considered important if authors of quantitative dietary studies stated that they considered it important at some time in the annual cycle. The 5% value was chosen as the quantitative threshold for this distinction as it marked a major discontinuity in the distribution of the percentage of the diet comprised by food taxa across all studies.

Potential bias may arise as a result of pooling studies using a variety of different methods to quantify diet composition since these methods are not perfectly comparable. For example the apparent importance of large insects, such as grasshoppers (Orthoptera), in the diet of a bird which predominantly eats smaller invertebrates is likely to differ depending upon whether diet composition is measured as a percentage of total food items or percentage of total food biomass. Similarly, individual methods of analysis create different biases in the measurement of overall diet composition. For example, faecal analysis tends to under-record the presence of soft-bodied invertebrates or easily digested seeds, whilst observations of foraging may tend to over-estimate the importance of a food the acquisition of which makes the bird conspicuous to the observer e.g. Goldfinches *Carduelis carduelis* feeding on thistle heads. There is no easy way to correct for these biases but over the large number of studies reviewed it seems unlikely that such biases will alter the coarse categorisation of a food taxon as either 'important' or 'present' using the simple criteria employed.

One important point that should also be considered is the lack of data on food availability. In dietary studies of birds important plant or animal taxa may dominate the diet simply because they are dominant components of the total food resource available. Without data that quantifies food availability it is impossible to make any statements about food preferences or selection. The vast majority of dietary studies of birds do not include any data on food availability and thus the use of the term 'important' should not be interpreted as preferred with respect to availability.

In the initial analyses the BTO review first considered dietary components at broad taxonomic levels. Plant foods were classified to the level of families and animal foods were treated at the phylum/class level with the exception of insects where classification was at the order level. Information at lower and more detailed taxonomic levels (genus level for plants and family level for animal foods) is very limited and was only considered for food found to be important in the diet of several bird species.

CSL's review was intended as an aid to regulatory authorities in calculating likely exposure of birds to agricultural pesticides. Published data on 33 species of lowland birds have been compiled into a data base giving proportions of different foods taken by adults and nestlings at different seasons. The database does not attempt to categorise food items in terms of taxonomic order, but it does include information on which foods are important at what times of year and, where possible, what percentage of the diet they comprise. This enables one to examine whether particular foods account for much more than the nominally important 5% of the diet at certain times of the year.

In the context of this review it is extremely difficult to make very many specific statements about individual plant species listed in Section One. Instead we review the importance of the plant families or genera that contain one or more of the 40 non-target plants as direct sources of food and as nesting habitat. Their importance as indirect sources of food, assessed by considering the extent to which they represent key host plants for invertebrate families known to be present and important in the diet of farmland birds, is considered in detail in Section 3.5.1 and only summarised here.

Information on nesting and habits has been drawn from papers and reports summarised in *The Handbook of the Birds of Europe, the Middle East and North Africa: the Birds of the Western Palaearctic* (Cramp & Simmons 1980, Cramp 1988, 1985, Cramp & Perrins 1993, 1994). These general sources are not cited throughout the text.

3.2.3 Results

3.2.3a Non-target plants as direct food resources for birds

A number of the farmland birds listed in Appendix 3.2.1 have never been recorded as taking plant material (Swallow, House Martin, Sand Martin, Spotted Flycatcher, Pied Wagtail and Yellow Wagtail). Thus, the importance of non-target plant species as direct food sources is considered for 33 species of bird. The 40 non-target plant species listed in Section One derive from a total of 23 plant families. Of these only two families have never been recorded in the diet of any of the farmland bird species considered here - Dioscoraceae (non-target plant: Black Bryony *Tamus communis*) and Araceae (non-target plant: Lords-and-Ladies *Arum maculatum*). The importance of the remaining 21 families, in terms of the number and percent of bird species known to include them in their diet, is summarised in Table 3.2.1. (For details of the bird species that have been recorded as including these plant families in their diet see Appendix 3.2.2a).

Thirteen of the plant families considered are present in the diet of at least ten species (c. 30%) of farmland birds and eight are taken by more than 20 bird species (c. 60%). The most important plant families are; Polygonaceae (bistorts and docks), Chenopodiaceae (goosefoots and oraches), Caryophyllaceae (pinks and allies), Cruciferae (cabbages and allies), Rosaceae (roses and allies), Leguminosae (peas and allies), Compositae (daisies and allies) and Gramineae (wild grasses and cultivated cereals) (Table 3.2.1, Appendix 3.2.2a)

The eight plant families that are important for farmland birds in general are also present in the diet of many of these priority species listed in UK Biodiversity Action Plans (Anon 1995, 1998). Four of these plant families; Polygonaceae, Caryophyllaceae, Compositae and Gramineae, are present in the diet of more than seven of these priority species (70%) and considered important for many of them. (For details of the Biodiversity Action plan Bird Species that have been recorded as including these plant families in their diet see Appendix 3.2.1 and 3.2.2a).

Thus, at the family level, annual weeds (Polygonaceae, Chenopodiaceae, Caryophyllaceae and Compositae) and grassland plants (Caryophyllaceae, Leguminosae, Compositae and Gramineae) seem to be particularly important as direct food sources for farmland birds. Species within these families have been recorded in the diet of a large number of farmland birds and many are considered as important components of the diet of individual species.

However, it is worth noting that even the ‘least important’ families, in terms of the number of birds that include them in the diet (Liliaceae, Umbelliferae and Dipsacaceae) are taken by four or more species of farmland bird although they are not considered as important for any individual bird species.

Information at the lower taxonomic level of plant genera is available for the eight most important plant families (Table 3.2.2). The most important genera, in terms of the number of bird species known to include them in the diet, are *Polygonum* (present in the diet of 20 farmland bird species), *Chenopodium* (17 species), *Trifolium* (14 species) and *Vicia* (11 species) followed by *Centaurea* (nine species), *Cretaegus* and *Taraxacum* (both eight species). (For details of which bird species have been recorded as including these plant genera in their diet see Appendix 3.2.2b).

Most of the plant genera considered have been recorded in the diet of a number of species listed under the UK Biodiversity Action Plans (Anon 1995, 1998), the most important being *Chenopodium* has been recorded as present in the diet of five Biodiversity Action Plan species, important in the diet of four and *Polygonum* which has been recorded as present in the diet of six Biodiversity Action Plan species and important in the diet of five. These findings once again highlight the importance of annual weed and grassland plant species as direct food sources for farmland birds.

The CSL database includes information on which foods are important at what times of year and, where possible, what percentage of the diet they comprise. This enables one to examine whether particular foods account for much more than the nominally important 5% of the diet at certain times of the year. A number of birds have all shown a strong dependence (>40% of diet) on particular foods at particular times including some of the non-target plant species listed in Section One. The following have been recorded as comprising >40% of the diet of one or more species of farmland bird: Hawthorn berries *Cretaegus monogyna* (for Blackbird; Sorensen 1984); Dandelion *Taraxacum officinale* (for Goldfinch, Greenfinch and Linnet; Newton 1967, Sueur 1990, Moorcroft *et al.* 1997), Creeping thistle *Cirsium arvense* (for Goldfinch and Linnet; Newton 1967, Sueur 1990), Teasel *Dipsacus fullonum* (for Goldfinch and Greenfinch; Newton 1967, Sueur 1990, Moorcroft *et al.* 1997) and non-cereal grass seed (for Tree Sparrow; Szlivka 1983).

While there is little evidence that any bird species is wholly dependent on a particular plant species for its survival, it is clear that some plants make up the bulk of some bird diets at certain times of year and this begs the question: if the preferred food is becoming scarce, are there alternative sources of the right quality, available in the right amounts at the right time?

Some insight to this question may be gained from historical studies of diet. In the cases of the Turtle Dove and the Linnet it is possible to compare studies carried out in the 1960s (before agricultural intensification) with recent dietary studies on modern farms in similar areas. Moorcroft *et al.* (1997) note that whereas in 1967 Charlock (*Sinapis arvensis*) was a common arable weed, it is rare today. In 1967 Newton found that Charlock was present in Linnet stomachs for ten months of the year accounting for 45% of the diet. Moorcroft *et al.* (1997) note that Charlock has been replaced in the diet of Linnet nestlings by Oil Seed Rape *Brassica napus* and Dandelion *Taxacarum officinale*. The authors speculate that on intensively managed farms food stocks for Linnets may be severely limited where Oilseed Rape is not grown.

Similarly in 1964 Fumitory seeds *Fumaria officinale* accounted for as much as 60% of Turtle Dove crop contents (Murton *et al*. 1964) , whereas a recent study by Calladine *et al.* (1997) indicates that the majority of birds were dependent on wheat seed found in grain stores and in artificially maintained feeding stations. The only weed seed taken in any quantity was chickweed *Stellaria media*. In a 20 year study of arable weeds, Chancellor (1985) found a significant reduction in the abundance of fumitory.

These two examples suggest that birds may be able to adapt their foraging behaviour to changes in food availability. However, the consequences of these dietary changes are unknown. Populations of both Linnets and Turtle Doves have sustained a steady decline since the mid 1970s (although Linnet seems to be recovering in numbers; Crick *et al.* 1997) but whether changes in diet have contributed to this decline remains unclear.

3.2.3b Non-target plants as indirect food resources for birds.

The importance of non-target plant species listed in Section One as hosts for invertebrate prey for birds has already been considered in detail (see 3.1.5). The presence and importance of various insect groups in the diet of 39 lowland farmland birds is summarised in Table 09 and 10 (Section 3.1.5). The most important insect orders providing food for birds are Coleoptera, Diptera, Hemiptera, Hymenoptera and Lepidoptera. Specific host plant data are well documented for all these orders except Hymenoptera, although in the latter case, information is available for the sub-order Symphyta. Important host plants for phytophagous insect within these orders include two of the three trees, shrub and climber species listed in Section One, all the annual weeds, three of the nine woodland/hedge ground flora, seven of the eight tall herbs and eight of the nine grassland species. Thus, the range of non-target plants that provide indirect food resources is much broader than that of non-target plants providing food directly. Once again, annual weeds and grasses are important but so too are tall herbs and trees, shrubs and climbers.

It is important to note that the absolute abundance of invertebrates on a given plant species does not necessarily equate to availability for birds. Many species do forage in hedgerows and insects present here, for example on Hawthorn, are likely to be available to a large number of them. A number of farmland birds, such as buntings, finches, thrushes and Skylarks forage on or close to the ground. Thus only insects present near the base of grasses or annual weeds will be available to these species. Some species, such as spotted Flycatcher, Pied Wagtail and Swallow will sally over vegetation and will take insects emerging from grasses, annual weeds or tall herbs. However, our current understanding of foraging behaviour and niches of farmland birds is not sufficiently detailed to determine the extent to which this may influence the invertebrate availability on plants. Measures of abundance of invertebrates on plants is, for now, the most appropriate way to assess their importance as indirect food sources.

3.2.3c Non-target plants as nesting habitat for farmland birds

Very few bird species are limited to nesting in one or two plant species only. The importance of different plants as nesting habitat is determined not by species identity but by general structural characteristics. The vast majority of the 36 farmland bird species considered here nest in trees, shrubs or hedges. Only Red-legged and Grey Partridge, Pheasant, Stone Curlew, Lapwing, Skylark, Meadow Pipit, Corn Bunting, Yellowhammer and Yellow Wagtails are regular ground nesters. Red-legged and Grey Partridge and Pheasants nest in thick ground vegetation usually along hedge bottoms or in long grass and crops. Corn Buntings nest in tangled grass or shrubs in arable fields or in pasture in a clump of thick weeds. Yellowhammers almost always nest on, or very close, to the ground, well hidden amongst grass or herbage. They tend to nest in herbaceous vegetation in the field margins rather than in the shrubby vegetation on the hedge itself (Stoate *et al.* 1998). Typically they will nest against the bank or base of a hedge, small tree or bush or well inside Bramble. Yellow Wagtails usually nest in a tussock of vegetation often close to water. Skylark, Meadow Pipit, Lapwing and Stone Curlew tend to nest in more open habitats. Lapwings nesting on grassland prefer fields which have short and tussocky swards and irregular surface topography. However, recent studies on the North Kent Marshes suggest that very few birds actually nest close to or within these tussocks (Peel *et al.* 1997, Milsom & Hart unpubl data) Meadow Pipits also favour thick ground vegetation; Skylarks favour open ground in growing or short vegetation such as grass or growing crops. Lapwing often nest on small hummocks or in grass tussocks whilst Stone Curlew favour open, flat ground with short vegetation.

The remaining 26 farmland bird species nest in woodland, scrub or hedgerows. Not surprisingly the size of tree or shrub required correlates with the body size of the birds and, for the 36 species considered, these fall into three broad categories; doves and pigeons (body size; 31-89 cm), thrushes, Blackbirds and Starlings (21-28 cm) and sparrows, finches and buntings (12-15 cm). Thus, Turtle Dove, Collared Dove and Wood Pigeon tend to nest in relatively large trees, shrubs or hedges, although the latter also nest among thinner twigs of scrub thickets. Stock Doves nest in holes in trees or buildings or in dense clumps of twigs within trees. Song Thrush, Mistle Thrush and Blackbird will nest in smaller trees or shrubs, often against the trunk, but will also use creepers on a wall ledge or bank.

Dunnocks are associated with a wide variety of scrub grown habitats and may be found in coppice woodland with vigorous ground cover, field hedgerows, parks and gardens. The species nests in bushes, hedges or low trees 0.5-3.5 m above the ground. Chaffinches nest at similar heights from the ground (approximately 4 m) often in the fork of a tree on a branch or on several thin twigs. Goldfinches usually nest well hidden in the inaccessible outermost twigs of trees about 6 m from the ground. Greenfinches are associated with tall densely leafed trees and nest usually against the trunk or in a strong fork of a dense bush or small tree often in a hedge. Bullfinches breed mainly in broad leaved woodland but also in thickets and tall dense hedges. Spotted Flycatchers tend to nest on natural or artificial ledges or in shallow crevices in trees or walls.

Linnets and Cirl Buntings both tend to nest in low vegetation, well hidden in dense shrubs and bushes often in thorny trees or in hedges and scrub. Reed Buntings tend to be associated with fens, bogs and marshes as a result of their dependence on particular vegetation types rather than a special need for water. The species usually nests on the ground or in sedge tussocks, heaps of dead rushes *Juncus* or reeds *Phragmites* or up to 4 m from the ground in willow *Salix* or Alder *Alnus*.

Starlings, House Sparrows, Tree Sparrows, Pied Wagtails, Sand Martins, House Martins and Swallows and, to a lesser extent, Robins and Wrens are all hole nesters. Starlings nest in suitable holes in trees, walls and earth banks. House Sparrows usually nest on holes in buildings and other man made structures although they will also nest in trees and creepers on walls. Tree Sparrows have a very patchy distribution within farmland but tend to be associated with free standing trees or small isolated woodlands in open country. They nest predominantly in holes in trees, buildings or earth banks. Pied Wagtails nest in holes or crevices in a wide range of natural or artificial sites and Robins often nest in hollow tree stumps or on banks among tree roots from ground level up to approximately 5 m. Sand Martins nest in holes in river banks, sand quarries or cliffs. Wrens also usually nest in hollows, crevices or holes at ground level or up to 10 m in natural and artificial sites. Swallows and House Martins construct nests of a half cup or cup of mud pellets usually mixed with plant material, positioned on a small ledge against a vertical surface almost always on a building.

The nesting requirements of farmland birds suggest that two plant ‘groups’ are likely to be particularly important in providing nesting habitat; ground cover and hedgerow species. Since most of the farmland birds are tree, shrub or hedgerow nesters perhaps the most important plant species in the list of 40 non-target plants, in terms of providing nest sites, is Hawthorn *Crataegus monogyna*. This is likely to provide nest sites for at least ten of the 36 bird species considered including Song and Mistle Thrush, Blackbird, Dunnock and many of the finches and buntings. In addition many ground nesting species select sites at the base of hedgerows of which Hawthorn is frequently an important part. The other two non-target species listed as ‘trees, shrubs and climbers’ - Hazel *Corylus avellana* and Black Bryony *Tamus communis* -

are also likely to provide suitable nest sites for a number of the bird species, but are much less important than Hawthorn.

Although species such as Hawthorn are frequently cited as key hedgerow species, it is important to note that the structure and management of hedges can have significant effects of their value for birds (Green *et al.* 1994). In general, bird species richness increases with the size and species richness of the hedgerow. This may be related to structural diversity providing a range of nesting habitats for a range of species and supporting a greater diversity and abundance of invertebrate prey (Dowdeswell 1987, Morris & Webb 1987, Dennis & Fry 1992, Parish *et al.* 1994).

The second group of plants that are important in terms of providing suitable nest sites for farmland birds are the grasses Graminea (non target species: Creeping Bent *Agrostis stolonifera*, False Brome *Brachypodium sylvaticum,* Cocksfoot *Dactylis glomerata* and Red Fescue *Festuca rubra*) which will provide nesting habitat for all of the nine ground nesting species. As with hedges, management of the vegetation is important, suitable sward structure varies widely from Stone Curlew, which nests in very low, sparse vegetation, to gamebirds that tend to nest in dense vegetation often at the base of hedgerows. Thus, the management of grass swards, timing of cutting etc., will greatly influence the suitability of the resulting cover for birds (Green 1988, Aebischer *et al.* 1994).

A species rich, tussocky plant community at the hedge-base provides valuable nesting habitat for a range of bird species and plants such as Cleavers *Galium aparine*, white Dead-nettle *Lamium album,* Creeping Thistle *Cardus acanthoides* and Welted Thistle *Cirsium arvense,* Field Bindweed *Convolvulus arvensis* and Nettle *Urtica dioica* may all be valuable components of such a hedge base community. However the important features of such a habitat are related to structure rather than species composition. As long as the area provides a fairly dense and diverse sward the exact species composition is likely to be far less important.

3.2.4 Summary

Harmful effects of pesticides on non-target plants may reduce food resources directly by reducing the abundance of seeds, fruits or green material from food plants. The most serious effects are likely to derive from reductions in the abundance of annual weeds (Polygonaceae, Chenopodiaceae, Caryophyllaceae and Compositae) and grassland plants (Caryophyllaceae, Leguminosae, Compositae and Gramineae). These are particularly important as direct food sources for farmland birds. Species within these families have been recorded in the diet of a large number of farmland birds and many are considered as important components of the diet of individual species.

There may also be an indirect reduction in food availability since many of these non-target plants are host species for invertebrates that are important in the diet of many farmland birds, especially during the nestling phase. Indirect food reduction is likely to be most severe as a result of losses of plants that serve as food plants for Coleoptera, Diptera, Hemiptera, Hymenoptera and Lepidoptera. These include two of the three tree, shrub and climber species listed in Section One, all the annual weeds, three of the nine woodland/hedge ground flora, seven of the eight tall herbs and eight of the nine grassland species. Thus, the range of non-target plants that provide indirect food resources is much broader than that of non-target plants providing food directly. Once again, annual weeds and grasses are important but so too are tall herbs and trees, shrubs and climbers.

The potentially most serious losses of nesting habitat, resulting from the effects of pesticides on non-target plants, will arise from losses of hedgerow species including those of the hedge itself and the hedge-base. The importance of hedges for a large proportion of the British avifauna has been highlighted in a number of reviews of habitat use by birds in a lowland arable landscape (e.g. O'Connor *et al.* 1987, Lack 1992, Green et al. *1994*, Parish *et al.* 1994 & 1995). Sensitively managed hedges and hedge bottom flora can provide a range of resources for birds, in addition to nest sites, including food, shelter and protection from predators (Barr *et al.* 1995). In this context losses of species such as Hawthorn and Hazel may be particularly detrimental. In addition, a number of farmland bird species are ground nesting. For these birds it is the grass species Graminea that commonly provide vital breeding habitats either at the base of hedgerows, for species like Pheasants, Partridges and Yellowhammers or in open fields for species like Skylark. In general these ground cover plants would seem more likely to suffer serious damage from pesticides than the woody hedgerow species.

The fact that many of these species nest close to or within hedgerows suggests that conserving non-target plants in field margins and boundaries may be more important than conserving non-target plants in field centres. In addition to their value as nesting sites the availability of these plants as direct and indirect food resources is probably higher if they are located in field margins rather than field centres. Field margins are used as foraging habitat by a wide range of bird species and avoided by very few (Vickery & Fuller 1998) and the abundance of other food resources such as dicotyledonous arable weed seedlings (Marshall 1989, Wilson & Aebischer 1995) and invertebrate groups such as Coleoptera and Brachycera all decline with distance from the field boundary (Chiverton & Sotherton 1991, Moreby *et al.* 1994, Gates *et al*. 1997). There are exceptions to this as a small number of species are known to avoid field margins in winter and summer or both. For example wintering Golden Plover, wintering and breeding Lapwing and breeding Skylarks. The value of food resources in field margins may be particularly high in the summer possibly when birds may be constrained by the need to remain close to a hedgerow nest site. In winter field centres may become more important as foraging areas for large flocks of plovers, finches and buntings.

Table 3.2.1. The relative importance of 21 plant families as direct food sources for farmland birds (measured as the number and percent of bird species that include each plant family in the diet). Only those plant families that contain one or more of the non-target plant species listed in Section One are considered. A food taxon is considered important in the diet if it comprises a mean of more than 5% of the diet over all quantitative studies reviewed, see section 3.2.2 (important families are sub set of those 'present'). 'All farmland birds' refers to the 39 species listed in Appendix 3.2.1. 'Biodiversity Action Plan Bird Species' refers to the ten farmland species listed in the UK Biodiversity Group Reports (Anon 1995 & 1998) and listed in Appendix 3.2.1.

	All Farmland Birds		**Biodiveristy Action Plan Bird Species**	
Plant Family	**Present in Diet**	**Important in Diet**	**Present in Diet**	**Important in Diet**
Corylaceae	7(18%)	0	0	0
Urticaceae	14(36%)	2(5%)	6(60%)	0
Polygonaceae	24(62%)	14(36%)	8(80%)	5(50%)
Chenopodiaceae	20(51%)	12(31%)	6(60%)	5(50%)
Carophyllaceae	25(64%)	13(33%)	7(70%)	4(40%)
Ranunculaceae	16(41%)	3(8%)	6(60%)	0
Papaveraceae	7(18%)	0	3(30%)	0
Cruciferae	21(54%)	8(21%)	6(60%)	3(30%)
Rosaceae	26(67%)	9(23%)	5(50%)	0
Leguminosae	22(56%)	7(18%)	6(60%)	3(30%)
Onagraceae	7(18%)	0	2(20%)	0
Umbelliferae	4(10%)	0	0	0
Primulaceae	7(18%)	0	4(40%)	0
Convolvulaceae	6(15%)	0	2(20%)	0
Rubiaceae	10(26%)	1(3%)	2(20%)	0
Labiatae	15(38%)	4(10%)	5(50%)	2(20%)
Scrophulariaceae	13(33%)	1(3%)	5(50%)	0
Compositae	20(51%)	10(26%)	7(70%)	2(20%)
Dipsacaceae	5(13%)	1(3%)	0	0
Liliaceae	4(10%)	0	1(10%)	0
Gramineae	28(72%)	22(56%)	10(100%)	9(90%)

Table 3.2.2. The relative importance of 14 plant genera as direct food sources for farmland birds (measured as the number and percent of bird species that include each plant genus in the diet). Only those plant genera that contain one or more of the non-target plant species listed in Section One are considered. A food taxon is considered important in the diet if it comprises a mean of more than 5% of the diet over all quantitative studies reviewed, see section 3.2.2. (important families are sub set of those 'present'). 'All farmland birds' refers to the 39 species listed in Appendix 3.2.1. 'Biodiversity Action Plan Bird Species' refers those listed in the in the UK Biodiversity Group Reports (Anon 1995 & 1998) and listed in Appendix 3.2.1.

	All Farmland Birds		**Biodiversity Action Plan Bird Species**	
Plant Genera	**Present in Diet**	**Important in Diet**	**Present in Diet**	**Important in Diet**
Polygonum	20(51%)	12(31%)	6(60%)	5(50%)
Chenopodium	17(44%)	9(23%)	5(50%)	4(40%)
Alliaria	3(8%)	0	1(10%)	0
Crataegus	8(21%)	3(8%)	1(10%)	0
Vicia	11(28%)	3(8%)	2(20%)	1(10%)
Trifolium	14(36%)	4(10%)	3(30%)	1(10%)
Lotus	2(5%)	0	0	0
Taraxacum	8(21%)	4(10%)	1(10%)	1(10%)
Centaurea	9(23%)	1(3%)	3(30%)	0
Cirsium	5(13%)	2(5%)	1(10%)	1(10%)
Carduus	3(8%)	0	1(10%)	0
Festuca	4(10%)	2(5%)	3(30%)	1(10%)
Dactylis	2(5%)	0	1(10%)	0
Agrostis	2(5%)	1(3%)	1(10%)	0

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3.4 MAMMALS

3.4.1. Introduction

This section describes the importance of the 40 plant species identified, as a food source and habitat for mammals. Mammals use terrestrial plants in two ways:

- as food, grazing on the plant or feeding on its fruits or seeds.
- as cover, nesting material or a structure to build a nest around.

This section of the review has investigated the degree to which mammals depend on any of the 40 listed species and considers the consequences of their reduction from pesticide use.

3.4.2. Sources of data

Two major reviews have been consulted. Gurney *et al.* (1997) is an extensive review of mammal diets, and Packer (1995) provided some guidance on structural importance. Additional information was collected from original papers and reports.

3.4.3. Results

Table 3.3 presents a summary of information which is relevant to the assessment of importance of the 40 plant species, and contains references to specific utilisation of the individual plants. Direct evidence of utilisation of nine of the 40 plants has been found in 10 species of mammal.

Diet

Many studies of mammalian diets do not give detailed information down to the level of particular plant species. It is therefore not surprising that relatively little mention of the 40 plant species considered in this review appears in the scientific literature (Gurney *et al.* 1995). The distribution of smaller mammals however is thought to be largely determined by food resource available (Packer, 1995). Small mammals (mice, voles and shrews) are known to regularly occur within the farmland landscape, particularly the Bank vole *Clethrionomys glareolus* (Pollard and Relton, 1970), Field vole *Microtus agrestis* (Corbet & Harris, 1991), Wood mouse *Apodemus sylvaticus* (Green, 1979), Harvest mouse *Micromys minutus* (Harris, 1979), Common and Pygmy shrews *Sorex araneus* and *S. minutus* (Tew *et al.* 1994). The shrews are insectivorous, and are therefore only likely to have indirect associations with any of the 40 plants.

Table 3.3 Summary of the use of the selected plant species by mammals.

Plant species	**Common name**	**Mammal species**	**How used**
Corylus avellana	Hazel	Bank vole	Eats nuts.
		Dormouse	East nuts and leaves. Supports nests.
		Grey squirrel	Eats nuts and shoots.
		Wood mouse	Eats nuts.
Crataegus monogyna	Hawthorn	Bank vole	Eats berries.
		Dormouse	Eats flowers in spring
		Grey squirrel	Eats shoots
		Roe deer	Eats March-April.
		Wood mouse	Eats berries in November
Galium aparine	Cleavers	Wood mouse	NOT eaten
Hyacinthoides non-scripta	Bluebell	Muntjac	Eats plants.
Chamerion angustifolium	Willowherb	Dormouse	Pollen and spores in diet, occasionally uses as nest material.
		Roe deer	Eats plants.
Urtica dioica	Nettle	Rabbit	Eats plants.
		Roe deer	Eats plants
Centaurea nigra	Knapweed	Wood mouse	NOT eaten
Lychnis flos-cuculi	Ragged robin	Field vole	Eats plants.
Agrostis stolonifera	Creeping bent	Harvest mouse	Nest building.
Brachypodium sylvaticum	False broom	Field vole	Eats plants.
		Harvest mouse	Nest building
		Roe deer	Avoids
Dactylis glomerata	Cocksfoot	Brown hare	Eats plants.
		Field vole	Eats plants.
		Harvest mouse	Nest building.
		Roe deer	Eats plants.
Festuca rubra	Red fescue	Brown hare	Eats plants.
		Field vole	Eats plants.
		Rabbit	Eats plants

Wood mice are common in field boundaries, but can also survive entirely within cultivated areas (Pollard and Relton, 1970). There is a very strong association between the abundance of hedgerow berries and Wood mice capture rates (Poulton, 1994; Angelstam *et al*. 1987), Hawthorn *Crataegus monogyna* berries comprised 3% of the stomach content of Wood mice during November (Watts, 1968), and they also eat, and sometimes cache large supplies of hazel nuts. Where food was supplied to captive animals, Wood mice did not eat seeds of Common knapweed *Centaurea nigra* or Hogweed *Heracleum sphondylium* (Plesner Jensen, 1992). Cleavers *Galium aparine* were also rejected by captive animals, whereas a radio-tracking study by Tew and Todd (1996) found that Wood mice were more likely to feed in those areas of wheat fields that had high numbers of Cleavers *Galium aparine*, Chickweed *Stella media*, Black grass *Alopecurus myosuroides* and Barren brome *Bromus sterilis*.

The stomachs of Bank voles were found to contain 32% fruit during September, the majority of which was hawthorn *Crataegus monogyna* (Flowerdew and Gardner, 1978), Bank voles also eat and cache hazel *Corylus avellana* nuts. Field voles are herbivorous, feeding primarily on green leaves and stems of grasses (Corbet and Harris, 1991). Red fescue *Festuca rubra*, cocksfoot *Dactylis glomerata* and false brome *Brachypodium sylvaticim* all feature largely in their diet (Evans, 1973; Ferns 1976), and Ragged robin *Lychnis flos-cuculi* was found to comprise 18% of stomach contents during June in the Netherlands (Faber and Ma, 1986). The latter study showed that while grasses made up the bulk of the diet at two study sites, field voles consumed mainly *Holcus lanatus* at the site where it predominated and *Deschampsia flexuosa* at the site where it was the most abundant grass species. Thus although a particular plant species may be important in animals diet does not necessarily mean that the animal could not survive without it.

Common dormice have a limited distribution. Their preferred habitat is an association of scrub, hedgerow and bramble. Hence, they are only likely to be present in farm landscapes where there are woodlands connected by continuous lengths of hedgerow. Hazel *Corylus avellana* is the most frequently recorded tree species where dormice occur (Hurrell and McIntosh, 1984). Hawthorn *Crataegus monogyna* flowers are an important food resource in spring (Bright and Morris, 1989), and gnawed hazel *Corylus avellana* nuts are often used as an indication of the presence of dormice (Hurrell and McIntosh, 1984). Green leaves have also been found to comprise 45% of faecal pellets, including some hazel *Corylus avellana*. The spores and pollen of Rosebay willowherb *Chamerion angustifolium* have also been found in pellets (Richards *et al.* 1984).

Lagomorphs are common on farmland, and rabbits *Oryctolagus cuniculus* especially, are major pests to agriculture. Rabbits droppings were found to contain up to 50% *Festuca* spp., and nettles *Urtica dioica* as a minor component of the diet (Williams *et al.* 1974). Brown hare *Lepus europaeus* stomach contents contained 3-10% Red fescue *Festuca rubra* and 6% cocksfoot *Dactylis glomerata* during October - December (Frylestam, 1986).

Grey Squirrels eat and cache hazel *Corylus avellana* nuts, and also eat hazel *Corylus avellana* shoots (MacKinnon, 1976).

Muntjac *Muntiacus reevesi* and Roe deer *Capreolus capreolus* are frequently found in agricultural habitats (Packer, 1995). In an analysis of Muntjac rumens during late winter, bluebell *Hyacinthoides non-scripta* occurred in 81% of samples, averaging 8% volume of rumen (Jackson *et al.* 1977). Roe deer have been found to graze on a number of the 40 species. Cocksfoot *Dactylis glomerata* was found in an analysis of Roe faecal pellets during December and March (max. 21% of pellets). Nettles *Urtica dioca* were found throughout the year (max 100% of pellets), and hawthorn *Crataegus monogyna* was present in small amounts during March - April (Hearney and Jennings, 1983). Rosebay willowherb *Chamerion angustifolium* was found in an analysis of rumens', with a maximum of 24% volume of rumen during June (Henry, 1978). Jackson (1980) found that Roe deer seem to avoid False brome *Brachypodium sylvaticum*.

Cover and Nesting
Field boundary, and especially hedgerow structure, is an important factor in the distribution of mammals, particularly small mammals (Kotzageorgis and Mason, 1997; Fitzgibbon, 1997). However, other larger mammals such as badgers *Meles meles* are also dependent on boundary features (Harris and Woollard, 1990). There is very little data available on species specific structural requirements, however Boone and Tinklin (1988) have found that hedgerows with more cover and food had higher densities of mice and voles. This is reflected in increased predator populations, and leads to the conclusion that an interconnecting hedgerow with adequate basal vegetation is important for maintaining both predator and prey populations.

Small mammals make nests, and two species the Common dormouse and Harvest mouse build nests supported by a plant structure. Dormice create nests in thick tangles of vegetation, sometimes supported in hazel *Corylus avellana* (5% of nests found (Hurrell and McIntosh, 1984)). The nests themselves are mostly made from grass, but have also contained willowherb *Chamerion angustifolium*.

Harvest mice make nests in a wide variety of habitats, and use a range of monocotyledonous plants for nest building. Of those identified, the most regular nesting material was cocksfoot *Dactylis glomerata* 20.7% of nests, but False brome *Brachypodium sylvaticum* (0.5%) and Creeping bent *Agrostis stolonifera* (0.25%) were also used (Harris, 1979).

Indirect effects of pesticide use
The indirect effects of changes in insect and other invertebrate populations resulting from pesticide use are considered with respect to mammals.

Common shrews *Sorex araneus* are opportunistic feeders on a wide variety of invertebrates. Ground beetles, earthworms, woodlice, spiders, slugs, snails and insect larvae predominate in their diet (Corbet and Harris, 1991). Coleoptera adults have been found to comprise up to 45% wet weight in Common shrew stomachs (Pernetta, 1976).

Pygmy shrews *Sorex minutus* have a similar diverse diet as Common shrews, apart from earthworms which are not eaten. The most important species eaten are beetles (up to 52% of faeces containing item), woodlice (up to 48%) and harvestman (up to 64%)(Churchfield, 1994).

Hedgehogs *Erinaceous europaeus* feed almost entirely on ground living invertebrates. Lepidoptera larvae, scarabid beetles and earthworms formed 55% of the diet by weight (Yalden, 1976).

Bats (order Chiroptera) have several different feeding strategies, but their diet consists mainly of moths (Lepidoptera), flies (Diptera), Caddis flies (Trichoptera), cockchafers and beetles.

Hazel *Corylus avellana* and hawthorn *Crataegus monogyna* are hosts to over 40 species of beetles belonging to nine different families. The ground vegetation in field habitats appears to be more attractive to some over-wintering predatory beetles when associated with hedges or shelter belts of hawthorn *Crataegus monogyna* or other shrub and tree species. Species such as cocksfoot *Dactylis glomerata* and other tussock forming grasses are known to harbour large numbers of predatory carabid and staphylinid beetles.

The principal larval foodplants of butterflies and larger moths are listed in section 3.2.3. The two tree species, hazel *Corylus avellana* and hawthorn *Crataegus monogyna* support over 20 species of larger moths belonging to several families.

3.4.4. Conclusion

There are relatively few good data showing the degree to which mammals may depend on the 40 plant species identified as being at risk from the non target effects of pesticides. Mammals, particularly small mammals, are largely regulated by their food supply. The most regular source of food for those omnivorous mammals are the fruits and berries of hedgerow plants. Within our list, hazel *Corylus avellana* and hawthorn *Crataegus monogyna* are important fruiting trees. Hazel is one vitally important habitat requirement for dormice, without which it might not be able to survive. Other plant species are eaten, but no other species are vital components of a mammal species diet. Where large proportions of the diet comprise any of the 40 plant species (ie. Field vole - Red fescue *Festuca rubra* or cocksfoot *Dactylis glomerata*; Roe deer - nettles *Urtica diocia*) it is highly likely that in the absence of these species, alternatives would be readily available.

The insectivores discussed above are generalist opportunists. Many invertebrate species are taken as food, the proportions of which tend to reflect the availability of that species in the environment. It is considered that if some species are affected either directly or indirectly by herbicide applications, the insectivores would compensate by increasing the intake of alternative species. If the overall invertebrate biomass is reduced by herbicide applications, alternative food sources may not be available, therefore affecting insectivore populations.

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3.5 SUMMARY

In view of the range of routes through which herbicides may affect invertebrates, birds and mammals different plants are of variable importance to different groups of fauna. However, some plants on the selected list have emerged as generally being of greater importance than others. An attempt to highlight these in an accessible fashion has been made in tables 3.4, 3.5 and 3.6 which are presented at the end of this summary. The details relating to these selection are highlighted in the following text.

<u>Invertebrates</u>

Direct and indirect effects of herbicides are an important consideration in risk assessment procedures which can be difficult to establish comprehensively and cost effectively. The main routes of these effects for invertebrates are summarised in Fig 3.1.

Direct toxicity:

- Most herbicides, when used at the recommended field-dose rates have no insecticidal activity and therefore pose little or no threat of direct toxicity to invertebrates
- The main exceptions to his rule appear to be the triazine herbicides (cyanazine, simazine etc) which can be moderately toxic to soil-inhabiting invertebrates and, in laboratory tests, bipyridyl herbicides (eg paraquat) which affect aphids.
- However, field studies have shown paraquat to have relatively little impact on field populations of most inveterbrates, at least compared to its indirect effect of removing food and shelter for these species.

Indirect effects:

<u>Nectar and pollen plants</u>

- Most insects that feed on nectar and pollen are beneficial, often playing an important role in pollination and seed production.
- Maintaining plants that encourage nectar and pollen feeding insects is vital for insect and plant conservation, and of benefit to commercial crop production.
- Many commercial fruit, vegetable and seed crops depend on insect pollination (eg apples, pears, plums, strawberries, field beans, runner beans, oilseed rape, linseed).
- Some insects whose larval stages are considered important natural enemies of crop pests (eg syrphids, hymenopterous parasitoids) are nectar/pollen feeders as adults and their abundance depends in part on the proximity of local pollen/nectar sources.
- The selection of nectar and pollen sources differs widely between insect taxa and species emphasising the importance of maintaining floral diversity.
- The literature on this subject is fragmentary and the data available centres on a few intensively studies systems and thus the importance of less studied plants may be underestimated.
- Plants listed as important nectar/pollen plants on the selected list include *Crataegus monogyna*, many Umbelliferae (*Daucus, Heracleum*), Asteracea (*Centaurea, Cirsium, Carduus, Leucanthemum, Taraxicum*), Leguminosae (*Lotus, Trifolium, Vicia*), Labiatae (*Lamium*) and Scrophulariacea (*Digitalis*).

<u>Herbivore plants</u>

- Those plants which support fewer invertebrate taxa may be less important for the maintenance of biodiversity than those which support more.

- The phytophagous species of 5 insect taxa (Lepidoptera, Symphyta, Coleoptera, Heteroptera, Diptera) were used to indicate the importance of the selected species as food plants and the results are summarised in Fig 3.3.
- The most important herbivore plants included *Crataegus monogyna, Corylus avellana, Trifolium, Lotus, Cirsium, Carduus, Taraxicum, Vicia, Polygonum, Gallium and Uticae.*
- Of the genera noted as being important for nectar/pollen insects, all except *Leucanthemum Lamium and Digitalis* were noted as being important for at least one group of insects as herbivore plants.
- Some phytophagous insects attack crop plants and thus their wild hosts could be considered as potential reservoirs for pests. The main sources of crop pests from the selected list included: Trifolium, Crataegus, various gramineae, Chenopodium, Urtica and Vicia. Data is summarised in Fig 3.4. However, most of the pests are polyphagous and thus none of these plants are considered high risk sources when growing in diverse agroecosystems.

Vegetational structure and shelter

- Overwintering success, abundance and distribution of arthropods is determined in part by local climate mediated by microclimate provided by vegetation.
- Factors influencing climate and overwintering success of arthropods include soil type, soil depth, soil moisture, height above surface, and vegetation structure.
- The survival of individual insect species to a particular host plant at the critical stages of its life cycle often relies on a specific interaction with its host plant and mediation of these effects is reliant on the availability of the correct host plant. Thus maintenance of a wide floral diversity is vital to enable the winter survival of most native insects.
- More widely than winter survival, there are numerous studies which indicate that many predatory insects and spiders occur in much greater numbers under dense vegetation than under impoverished vegetation.
- Many predatory beetles (eg Carabidae, Staphylinidae) are more numerous in boundary habitats associated with *Crataegus monogyna* or other shrub/tree species which is also important for as a herbivore and nectar/pollen plant for invertebrates.
- Predatory beetles (Carabidae, Staphylinidae) are also known to be harboured by tussock-forming grasses such as *Dactylis*.

Invertebrates in the diets of birds

Loss of plant diversity as a result of herbicide drift may, through its effect on invertebrate populations, affect the populations of birds which prey on those invertebrates.

- The most important insect orders providing food for birds included the Coleoptera, Diptera, Hemiptera, Hymenoptera, and Lepidoptera. Specific host plant data was available for all five orders, although for Hymenoptera it only covered the sub-order symphyta.
- Less important groups included the Orthoptera, Collembola, Dermaptera, Ephemeroptera, Odonata and Trichoptera.
- Strong similarities occurred between the range of plants highlighted as being important in sustaining biodiversity and those reported as being important as providing food for birds.
- Diverse assemblages of phytophagous Coleoptera have Been recorded on several plant species on the selected list including *Crataegus monogyna* and *Corylus avellana* both of which have been featured as important in earlier invertebrate and the mammals sections. Other plants important in the provision of bird food include *Chenopodium, Vicia, Trifolium, Carduus* and *Cirsium*.

- In addition to acting as food plants, the effect of vegetation structure and dense plant cover may increase the number of insects, providing more bird food. However, the effect may be mediated to some extent by the provision of refuges from predation.
- Diptera provide an important component of the diet of at least 25 bird species, but information on the importance of various species of plant to this group appears to be fragmentary and incomplete.
- Plants can act as feeding sites for Dipterans or as sources of nectar/pollen both of which will attract or arrest bird food in a particular area.
- Plants highlighted as being important in the maintenance of thriving populations of appropriate groups of Dipterans include: as feeding sites a range of grass species, *Hyacinthoides* and *Primula*; as nectar/pollen sources: *Crataegus monogyna, Heracleum, Centaurea, Daucus,* and *Torilis*.
- Numerous Hemipterans are associated with *Corylus avellana, Crataegus, Urtica, Trifolium,* and various grasses. However, as before the literature is fragmentary and the relative importance of various host plants needs confirmation by further work.
- The food plants of Lepidopterans are also well represented on the list and reduced incidence of many of these plant species would reduce the availability of prey items.
- Important plants include *Crataegus monogyna, Corylus avellana, Urtica, Trifolium, Lotus, Gallium, Taraxacum,* and various grasses.
- Less information on the host plants of the Hymenoptera. However amongst the important hosts of sawflies (sub-order symphyta) are *Crataegus monogyna, Corylus avallana, Galium* and *Trifolium*.
- Potential pests of cultivated plants which also occur in wild hosts are also known occur on wild hosts and feature in bird diets. Potential hosts include *Crataegus monogyna, Trifolium, Chenopodium, Urtica, Vicia* and various grasses.

<u>Birds</u>

The use of pesticides may effect farmland birds via both direct and indirect routes. Indirect routes include a reduction in the availability of food both through the reduction of seeds and fruits of non-crop plant species, and by reducing the abundance of plants that serve as host species of invertebrates which are important bird prey. In addition the reduction in the availability of nesting habitat is also important.

Many bird species nest or forage close to or within hedgerows suggests that conserving non-target plants in boundaries and margins may be more important than conserving them in the centre of fields. However, in the winter field centres become more important for foraging of several bird species.

Direct effects:

- Most herbicides have relatively low toxicity to birds , although for some there is a potential risk of adverse effects under worst case conditions.

Indirect effects:

<u>Availability of food</u>

- Considering the plant families represented in the list of 40 selected plants, the most important appeared to be Polygonaceae (bistorts and docks), Chenopodiaceae (goosefoots and oraches), Caryophyllaceae (pinks and allies), Cruciferae (cabbages and allies), Rosaceae (roses and allies), Leguminosae (peas and allies), Compositae (daisies and allies) and Gramineae (wild grasses and cultivated cereals).

- The eight families listed above are also important in the diet of priority bird species in the UK Biodiversity Action Plans, with four (Polygonaceae, Caryophyllaceae, Compositae, Graminae) present in the diet of 70% of the priority species.
- Overall it was concluded that the most serious effects are likely to derive from reduction in the abundance of Polygonaceae, Caryophyllaceae, Compositae, Gramineae, Chenopodiaceae and Leguminosae.
- At the lower taxonomic level, the most important genera for which data is available were *Polygonum, Chenopodium, Trifolium, Vicia, Centaurea, Crataegus monogyna, Cirsium and Taraxacum*. All of these were highlighted as being important in two or more of the categories invertebrate discussion above.
- There is some evidence that some birds can adapt their foraging behaviour to changes in food availability but the consequences of these dietry changes are unknown.
- The importance of non-target plant species as hosts for invertebrates that are eaten by birds has been summarised above.

Nesting habitats

- The importance of different plant species is determined by structural characteristics and few birds are limited to nested in one or two plant species only.
- Most farmland birds nest in trees, shrubs or hedges although 10 species are ground nesters, and thus the most serious losses of nesting habitats would result in damage to these areas.
- Appropriately managed hedges and bottom flora can provide nest sites, food, shelter and protection from predators.
- Losses of such species as *Crataegus monogyna,* and to a lesser extent *Corylus avellana,* may be particularly detrimental which provide nesting sites for at least 10 species of woodland birds. In addition many ground nesting species will select the base of hedgerows.
- Although *Crataegus monogyna* is often cited as a key hedgerow species, the structure and management of hedgerows is also significant with bird species richness increasing with size and species richness of the hedge.
- For example species rich, tussocky plant communities at hedge bases including plants such as *Galium, Carduus, Cirsium* and *Urtica* provides valuable nesting sites.
- For ground nesting birds grass species (Gramineae) such as pheasants, partridges, yellowhammers and skylarks. These ground cover species are more likely to suffer serious damage from herbicides than woody hedgerow species.
- As with hedges management of the vegetation is important with time of cutting etc greatly influencing the suitability of resulting cover for birds.

Mammals

There are relatively few data showing the degree to which mammals depend on the selected plant species. Small mammals known to occur regularly on in agroecosystems include mice, voles and shrews, particularly the bank vole, field vole, wood mouse, harvest mouse, common and pigmy shrews, hedgehogs, bats, lagomorphs and deer.

Diet:

Data on the utlisation of the selected plant species in the diets of mammals is fragmentary.

- Mammals, particularly small mammals, are largely regulated by their food supply. Of the above list the shrews are insectivorous and are therefore only likely to have indirect associations with any of the plants. Those supporting or encouraging large numbers if insects (see section 3.2) are likely to be important for shrews.
- The most regular source of food for those omnivorous mammals are fruits and berries of hedgerow plants. Of the list of selected species are *Crataegus monogyna* and *Corylus avellana* are important fruiting trees.
- Wood mice utlise both *Crataegus monogyna* and *Corylus* avellana as food sources in autumn.
- In laboratory tests wood mice <u>did not</u> eat seeds of *Centaurea*,or *Heracleum*. *Galium* was rejected by captive animals although there is evidence of feeding in areas with high numbers of cleavers, *Stella* and the grass *Alopecurus* from radio tracking in the field.
- Bank voles utilise *Crataegus monogyna* and *Corylus avellana* in autumn. Field voles feed mainly on green leaves and grass stems, particularly *Dactylis*, *Festuca* and *Brachypodium*.
- Common dormice are most frequently found in association with scrub, hedgerow and bramble. Corylus avellana is the most frequently recorded tree where dormice occur. Crataegus monoguyna flowers are important food source in spring. Green leaves are also taken.
- Lagomorphs are common on farmland. Rabbits are recorded as eating a variety of grasses (eg *Festuca*), with nettles (*Urtica*) as a minor component of the diet. Brown hare are recorded as eating *Festuca* and *Dactylis* during autumn.
- Grey squirrels utilise *Corylus avellana* as a food source.
- Deer are frequently found on farmland and amongst others, *Dactylis, Urtica* and *Crataegus monogyna* has been recorded as being eaten.
- Compared with the list of important plants for invertebrates and birds, *Crataegus monogyna* and *Corylus avellana* are also important as food sources for small mammals.

Cover and nesting:
Little information is available on the specific structural requirements of
of hedgerows, but those with more cover and food have higher densities of voles and shrews leading to increased predator populations.
- Dormice nests are built in thick, tangled vegetation, sometimes supported in *Corylus avellana*, and the nests themselves are often made of grasses.
- Harvest mice make nests in a range of monocotyledonous plants, including *Dactylis*, and *Agrostis*.
- Compared with the list of important plants for invertebrates and birds, *Crataegus monogyna Corylus avellana* is also important as nesting sites for small mammals

Indirect effects of pesticide use:
- Common and pigmy shrews, hedgehogs and bats feed on a wide variety of invertebrates. Thus changes in the prevalence of plants listed above (sections 3.2, 3.5) as being important for maintenance of a diverse and common insect fauna will potentially have a detrimental effects on some or all of these mammal populations.

Several mammals, eg common shrews will feed on soil inhabiting invertebrates. There is little information available on the potential direct or indirect effects of herbicides on many groups of such invertebrates such as earthworms.

Table 3.4 An estimate of the relative importance of the selected plant species for invertebrates, based on the available datasets. *** = very important, ** = important, * = moderately important, blank = little importance or inadequate data available.

	INVERTEBRATES		
Non Target Plant	Direct Food Plants	Indirect Food Plants	
Hazel *Corylus avellana*	***	***	
Hawthorn *Crataegus monogyna*	***	***	
Black Bryony *Tamus communis*			
Cornflower *Centaurea cyanus*	***	**	
Fathen *Chenopodium album*		*	
Corn Marigold *Chrysanthemum segetum*			
Cleavers *G. aparine*		**	
Scented Mayweed *Matricaria recutita*		*	
Poppy *Papaver rhoeas*			
Knotgrass *Polygonum aviculare*		**	
Garlic Mustard *Alliaria peteolata*			
Lords-and-ladies *Arum maculatum*			
Foxglove *Digitalis purpurea*	***		
Hedge Bedstraw *Galium mollugo*		**	
Bluebell *Hyacinthoides non-scripta*	*		
Yellow Archangel *Lamiastrum galeobdolon*			
White Deadnettle *Larnium album*	**		
Primrose *Primula vulgaris*		*	
Bush Vetch *Vicia sepium*	***	**	
Welted Thistle *Carduus acanthoides*	***	**	
Creeping Thistle *Cirsium arvense*	*	**	
Teasel *Dipsacus fullonum*	*		
Rosebay Willowherb *Chamerion angustifolium*			
Hogweed *Heracleum sphondylium*	***	*	
Upright Hedge Parsley *Torilis japonica*		*	
Nettle *Urtica dioica*		***	
Knapweed *Centaurea nigra*	**	*	

Wild Carrot *Daucus carota*	**	*	
Ox-eye Daisy *Leucanthemum vulgare*	*	*	
Birds-foot Trefoil *Lotus corniculatus*	***	***	
Ragged Robin *Lychnis flos-cuculi*			
Creeping Buttercup *Ranunculus repens*		*	
Dandelion *Taraxacum officinale*	***	**	
White Clover *Trifolium repens*	***	***	
Common Vetch *Vicia sativa*	*	**	
Creeping Bent *Agrostis stolonifera*			
False Brome *Brachypodium sylvaticim*			
Cocksfoot *Dactylis glomerata*		**	
Red Fescue *Festuca rubra*		**	

Table 3.5 An estimate of the relative importance of the selected plant species for birds, based on the available datasets. *** = very important, ** = important, * = moderately important, blank = little importance or inadequate data available.

	BIRDS		
Non Target Plant	Direct Food Plants	Indirect Food Plants	Nest Sites
Hazel *Corylus avellana*		***	***
Hawthorn *Crataegus monogyna*	***	***	***
Black Bryony *Tamus communis*			
Cornflower *Centaurea cyanus*	***		
Fathen *Chenopodium album*	***	**	
Corn Marigold *Chrysanthemum segetum*	***	*	
Cleavers *G. aparine*		*	**
Scented Mayweed *Matricaria recutita*		**	
Poppy *Papaver rhoeas*		*	
Knotgrass *Polygonum aviculare*	***	*	
Garlic Mustard *Alliaria peteolata*	***		
Lords-and-ladies *Arum maculatum*			
Foxglove *Digitalis purpurea*			
Hedge Bedstraw *Galium mollugo*		*	
Bluebell *Hyacinthoides non-scripta*		*	
Yellow Archangel *Lamiastrum galeobdolon*			
White Deadnettle *Larnium album*		*	**
Primrose *Primula vulgaris*		*	
Bush Vetch *Vicia sepium*	***	*	
Welted Thistle *Carduus acanthoides*	***	*	**
Creeping Thistle *Cirsium arvense*	***	*	**
Teasel *Dipsacus fullonum*			
Rosebay Willowherb *Chamerion angustifolium*			
Hogweed *Heracleum sphondylium*			
Upright Hedge Parsley *Torilis japonica*			
Nettle *Urtica dioica*			**
Knapweed *Centaurea nigra*	***		

Wild Carrot *Daucus carota*			
Ox-eye Daisy *Leucanthemum vulgare*	***		
Birds-foot Trefoil *Lotus corniculatus*	***		
Ragged Robin *Lychnis flos-cuculi*	***		
Creeping Buttercup *Ranunculus repens*			
Dandelion *Taraxacum officinale*	***		
White Clover *Trifolium repens*	***	*	
Common Vetch *Vicia sativa*	***	*	
Creeping Bent *Agrostis stolonifera*	***		*
False Brome *Brachypodium sylvaticim*	***		*
Cocksfoot *Dactylis glomerata*	***		*
Red Fescue *Festuca rubra*	***		*

Table 3.6 An estimate of the relative importance of the selected plant species for mammals, based on the available datasets. *** = very important, ** = important, * = moderately important, blank = little importance or inadequate data available.

	MAMMALS		
Non Target Plant	Direct Food Plants	Indirect Food Plants	Nest Sites
Hazel *Corylus avellana*	***	***	***
Hawthorn *Crataegus monogyna*	***	***	
Black Bryony *Tamus communis*			
Cornflower *Centaurea cyanus*			
Fathen *Chenopodium album*			
Corn Marigold *Chrysanthemum segetum*			
Cleavers *G. aparine*			
Scented Mayweed *Matricaria recutita*			
Poppy *Papaver rhoeas*			
Knotgrass *Polygonum aviculare*			
Garlic Mustard *Alliaria peteolata*			
Lords-and-ladies *Arum maculatum*			
Foxglove *Digitalis purpurea*			
Hedge Bedstraw *Galium mollugo*			
Bluebell *Hyacinthoides non-scripta*	**		
Yellow Archangel *Lamiastrum galeobdolon*			
White Deadnettle *Larnium album*			
Primrose *Primula vulgaris*			
Bush Vetch *Vicia sepium*			
Welted Thistle *Carduus acanthoides*			
Creeping Thistle *Cirsium arvense*			
Teasel *Dipsacus fullonum*			
Rosebay Willowherb *Chamerion angustifolium*	*		
Hogweed *Heracleum sphondylium*			
Upright Hedge Parsley *Torilis japonica*			
Nettle *Urtica dioica*	***		
Knapweed *Centaurea nigra*			

Wild Carrot *Daucus carota*			
Ox-eye Daisy *Leucanthemum vulgare*			
Birds-foot Trefoil *Lotus corniculatus*			
Ragged Robin *Lychnis flos-cuculi*	***		
Creeping Buttercup *Ranunculus repens*			
Dandelion *Taraxacum officinale*			
White Clover *Trifolium repens*			
Common Vetch *Vicia sativa*			
Creeping Bent *Agrostis stolonifera*			*
False Brome *Brachypodium sylvaticim*	***		*
Cocksfoot *Dactylis glomerata*	***	**	***
Red Fescue *Festuca rubra*	***		