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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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GROWER SUMMARY

Headline

Empirical data on woodpigeon damage to Brassicas and salad crops and the cost-effectiveness of mitigation measures is limited and constrains the identification of the optimum management plan. Current best practice advice is to devise integrated strategies that incorporate and vary the deployment of different combinations of mitigation techniques.

Background

The woodpigeon *Columba palumbus* is recognised as a major agricultural pest in the UK, feeding on a range of arable crops including oilseed rape, other brassicas and leafy salads.

For growers, the development of a cost-effective woodpigeon management plan requires assessments of the economic value of the crop damage, against which the financial value realised through a reduction in damage achieved by implementing management measures can be assessed.

Research into woodpigeon crop damage and the effectiveness of management measures to mitigate woodpigeon damage, however, are largely historical. The current project, therefore, reviewed both the evidence for the levels of damage caused by woodpigeons to brassicas and salads and the efficacy and cost-effectiveness of deterrents and other management techniques currently available, including any novel and emerging techniques that might be applied to the problem.

Summary

- The woodpigeon is recognised as a major agricultural pest in the UK. The population has grown significantly over the last 40 years and was estimated at 5.4 million pairs in 2009.

- A review of woodpigeon damage to brassicas, salad crops and oilseed rape revealed very little empirically derived data. One of the very few studies (1989) indicated that yield loss in severely damaged areas of fields of oilseed rape was a mean of 9% (±6%) lower than in areas that had negligible damage. These damage estimates, however, are historical with no contemporary studies undertaken in the context of current woodpigeon populations and farming practices.
- A limited phone-based consultation exercise with a sample of brassica, oilseed rape (OSR) salad and legume growers indicated that woodpigeons were perceived to impose a significant impact on crops – generally considered to be in the order of 10-40% loss in yield. The problem was considered to be increasing.
- Attempts to mitigate damage using scaring techniques were undertaken by all growers consulted, with the majority utilising two or more different types of device. The most frequently used were pyrotechnics and gas cannons. The majority of proponents of these methods considered them to be at least moderately effective (i.e. at least 25% decrease in woodpigeon numbers or crop damage).
- Amongst growers woodpigeons were shot using flighting/decoying, roaming (rough shooting) and roost shooting. In all cases where a view was expressed shooting was considered to be at least moderately effective (i.e. at least 25% decrease in woodpigeon numbers or crop damage).
- The integration of additional categories of mitigation measure was more limited with exclusion methods (netting, covers) being used only on salads and legumes and habitat modification (sacrificial crop) reported by only one grower.
- The growers' estimates of the economic loss associated with crop damage ranged from £125/ha for OSR, £250/ha for peas and £330-£1,250/ha for brassicas but in general estimates were often broad, lacked detail or not provided.
- Cooperation and coordination of woodpigeon management between neighbouring growers was almost invariably very limited and restricted to

shooting. At one extreme, cooperation was avoided as woodpigeons on neighbouring crops was considered preferable to having the birds on one's own farm.

- A review of avian management techniques was carried out that focussed on methods that had been applied to woodpigeons, or other Columbiformes. However, the review also included the evaluation of selected measures used against avian species in other settings (e.g. airports) for their potential applicability to the context of woodpigeon crop damage, and to any new developing deterrent technologies.
- Traditional visual and auditory scaring techniques varied in their efficacy, from very effective to ineffective. All techniques in these categories are subject to habituation and hence benefit is short-term. Habituation can be delayed and the effectiveness maximised by integrating a number of different techniques and varying their combinations and presentation.
- Topographical features were associated with the level of crop damage. In fields of OSR damage levels were inversely related to the proportion of the field bordered by house and/or roads, and positively related to the presence of a woodpigeon roost within 1km. For Brussels-sprouts and cabbages the severest damage occurred on fields that were peripheral to the main concentration of the crop. The scope for consistently locating crops away from the most vulnerable locations is very limited.
- Chemical repellents used to protect crops from avian damage have been shown to be very varied in their effectiveness. These techniques are often found to be very effective in laboratory and cage trials, but less effective in the field due to practical problems such as persistence (the chemical soon washes off) and presentation of treated bait. The greatest barrier to their use is legislation; only one chemical is licensed for use as a bird repellent in the UK (aluminium ammonium sulphate).
- There is growing interest in using fertility control to manage wildlife and associated conflicts. Overseas, the application of Nicarbazin (a bird-specific oral

contraceptive) has been reported to have reduced the productivity in captive pigeons and the size of feral urban populations. Elsewhere, evidence for population-level effects is equivocal. In the UK, no fertility control chemicals are licensed for use in wild birds.

- Exclusion techniques (nets, covers, wires) have generally been evaluated as very effective in reducing avian crop damage. Netting is often recommended as the only technique that is consistently effective in preventing bird damage. The greater the degree of exclusion, however, the more expensive the technique is. For this reason netting tends to be restricted to high value crops.
- Prior to the widespread introduction of oilseed rape into the UK, woodpigeon numbers were naturally controlled by winter starvation with shooting an ineffective method of population control as it simply removed the ‘doomed surplus’ thereby reducing competition for resources and facilitating greater over-winter survival.
- However, since the large-scale planting of autumn-sown oilseed rape and thereby the removal of over-winter starvation as a constraint on population numbers shooting now has the potential to reduce local woodpigeon numbers. The effectiveness, however, will be dependent on factors such as the scale of immigration into the area and the strategic nature of the shooting. Whilst research indicates that shooting during the summer has the potential to have a far greater effect on woodpigeon numbers than winter shooting, the majority of shooting has traditionally been undertaken during the winter.
- An NFU/BASC nationwide survey showed that farmers regarded shooting as the most effective means of crop protection. Of those growers undertaking shooting, 75% rated its effectiveness as moderate to high; reported by the survey as markedly ahead of the other main protective measures bangers and scarecrows (although 68% reported bangers to be moderately or highly effective).
- The strategy with which shooting is traditionally undertaken (concealed gunmen), however, is not consistent with maximising its deterrent effect but with maximising the sporting aspect and/or the number of woodpigeons killed. For any

pest-resource conflict it is important that the effectiveness of pest control should be evaluated in terms of damage prevented and not the numbers of animals killed. The deterrent effect of shooting can be maximised by reinforcing the presentation of scaring stimuli with unpredictable episodes of shooting to kill.

- Bird management advice advocates that scaring techniques should be optimised by targeting deployment relative to the temporal and spatial scale at which damage occurs. For example, delaying actions until the vulnerable period of the crop cycle or targeting efforts at the vulnerable section of crop.
- A recurring theme in the mitigation of crop damage by avian pests is the necessity for an integrated management strategy (IMS). Such an approach advocates where possible choosing fields least likely to be subject to woodpigeon damage, and combining and interchanging a suite of spatially and temporally unpredictable scaring techniques reinforced with shooting and supplemented with habitat-based and exclusion-based techniques. The specific nature of any IMS will be site and context dependent.
- A number of options are currently available to incorporate into an IMS. These include the adoption or expansion of existing effective practices (e.g. exclusion, planting patterns, sacrificial crops); or their refinement in terms of their nature, mode of deployment and strategic targeting (deterrents); a mixed shooting strategy that attempts to maximise the effects of both shooting to deter woodpigeons from crops and shooting to reduce their number; nest and egg control; and cooperation between growers so that control is targeted at the landscape-scale. Further options require the evaluation of some novel techniques.
- The development of an economically viable IMS, however, depends on accurate information on the relative costs of crop damage and the efficacy and cost–effectiveness of mitigation measures. At present, there are significant gaps in knowledge that constrain identification of the ‘optimum’ strategy.
- A framework for the development of a strategic woodpigeon management plan is presented that involves: evaluating the damage, setting management objectives,

selecting and implementing specific damage mitigation measures, monitoring and evaluating the outcome, and adjusting the approach as appropriate.

- Further research is encouraged to gain a better understanding of the interactions between woodpigeons and the crops under consideration and inform the development of an optimum IMS: (i) a national questionnaire survey of growers, (ii) investigation of woodpigeon use of habitat and movements and of their interactions with crops and response to management, (iii) evaluation of the magnitude, timing and costs of damage to crops at the level of the individual field, (iv) field evaluation of avian management techniques to minimise crop damage – the refinement of existing techniques and testing of novel techniques, (v) refinement of best-practice advice based on the preceding empirical investigations.

Financial Benefits

The development of an optimal economic management strategy to mitigate woodpigeon impacts depends on accurate information on the relative costs of crop damage and on the efficacy and cost–effectiveness of mitigation measures. This requisite information, however, is either not available or has not been evaluated in the context of current woodpigeon populations and agricultural practices.

Action Points

In the immediate term, in order to mitigate the impacts of woodpigeons on crops a number of proposals are available for growers to consider:

- Consider the topography and locate susceptible crops away from vulnerable areas (e.g. adjacent to woodland, tree lines or in isolated fields).
- Consider expanding the area of crops under cover (e.g. poly-tunnel, net, fleece) or prolonging the duration over which crops are covered. This needs to be

weighed against any potential risks of reduced yield, reduced produce quality or increased disease associated with covering.

- Investigate alternative materials for covering or the mode of deployment of covers that might mitigate the associated risks of reduced yield, reduced produce quality or increased disease.
- Use sacrificial crops located away from vulnerable fields; ensuring that sufficient resources are available throughout the vulnerable crop period. Strips of decoy crop e.g. kale or OSR at low density along the margins of fields near woods etc. can also be beneficial.
- Ensure that deterrent techniques are deployed according to best practice guidelines, i.e. unpredictable, threatening, reinforced and/or switched with alternative deterrents, so that habituation is delayed.
- Deploy an integrated management strategy that incorporates different mitigation techniques, i.e. deterrents, exclusion, habitat management, planting regimes, sacrificial crops and shooting.
- Deploy a mixed shooting strategy that incorporates overt shooting (highly visible shooters) associated with visual cues to maximise the scaring effect and the numbers of birds deterred from fields, and covert shooting (concealed shooters) to reduce woodpigeon numbers; the latter concentrated during the summer rather than the winter.
- Consider the control of nests and eggs to suppress local woodpigeon breeding success and population recruitment.
- Coordinate management activities with neighbouring growers so that control is undertaken at the landscape-level.

SCIENCE SECTION

Introduction

The woodpigeon *Columba palumbus* is recognised as a major agricultural pest in the UK, feeding on a range of arable crops including cereals, oilseed rape, other brassicas and leafy salads. The damage they cause to brassicas and salad crops is somewhat different to that on cereals and oilseed rape, as these crops are composed of the plant itself and thus any damage caused stays with the plant throughout its life. Not only may yield be reduced by woodpigeon damage, but also the appearance and eventual saleability. Woodpigeons are considered to damage crops in the following ways:

- Direct physical damage through pecking of leaves, and shoots in young stalks.
- Direct physical damage to seeds and fruit through pecking and consumption.
- Deposition of faecal material providing a source of microbial infection for crop consumers.
- Deposition of weed plant seeds through faecal material, reducing yield in crops through competition.

Historical estimates of woodpigeon damage were £1-2 million per annum to cereals (Grazio 1978). In the late 1970s/early 1980s Inglis *et al*. (1989) produced a cautious estimate of £2.2 million overall loss of oilseed rape nationally due to woodpigeon grazing. This estimate pre-dated the marked expansion in planting of oilseed rape and some horticultural crops and the dramatic growth in the woodpigeon population since that time. Contemporary data on the cost and disruption caused by woodpigeons feeding on crops, including brassicas is unavailable (MacDonald 2005). In order to formulate cost-effective management strategies, accurate information on the costs of crop damage are required as a baseline against which to evaluate costs of deploying mitigation measures.

A number of techniques are available to deter avian pests from vulnerable crops, including audio-visual scaring devices, exclusion methods, sacrificial crops and lethal techniques such as shooting. However, evidence of the relative efficacy and cost-effectiveness of the different techniques is either limited or has not been investigated in the context of contemporary woodpigeon populations. In addition to the techniques currently available within the agricultural industry, there are a number of measures deployed in other industries where management and deterrence of avian pests is required. An example of this is the management of birds on airfields in order to prevent bird strikes. Techniques developed here may potentially be applicable to the problem in question. Similarly, there may also be techniques developed in other countries on other species that also might potentially be applicable to this problem.

A contemporary review of woodpigeon damage to crops and its management is necessary because although woodpigeons are well studied and their status as a crop pest well-documented, previous work was carried out at least 15 years ago. Historically, the majority of research on woodpigeons was undertaken on rural populations by the Ministry of Agriculture, Fisheries and Food (MAFF) (e.g. Inglis *et al*. 1989, 1990, 1994, 1997; Murton 1958, 1965), much of it prior to the large-scale introduction of oilseed rape. Since then woodpigeon populations have increased markedly and farming practices in the UK have changed. Also, the avian management techniques available and/or their mode of deployment have developed in ways that allow more cost-effective management.

Aims

The overarching project aims are:

- To review evidence for the extent and magnitude to which woodpigeons cause serious damage to agricultural crops - specifically brassicas, salad and oilseed rape.
- To review evidence regarding the cost-effectiveness of management measures to mitigate the impact of woodpigeon damage to agricultural crops – specifically brassicas, salad and oilseed rape.

Specific project objectives are:

- To review and summarize the current knowledge, both from peer reviewed and grey literature on the impacts of woodpigeons on brassicas, salad and oilseed rape.
- To review and evaluate the current techniques available to mitigate avian pest damage to agricultural crops.
- To undertake a limited consultation with selected growers to collate information on the perceived magnitude and extent of woodpigeon damage and its management.
- To undertake a simple cost-benefit analysis on the basis of the data collated in the reviews of damage and management measures.
- Identify requirements for any further research necessary to realise practical management strategies for woodpigeons. For example, to identify the most promising techniques that could be evaluated in future field trials (such field trials are outside the scope of the present study).

Materials and methods

A review was undertaken to quantify the damage caused by woodpigeons to brassicas, oilseed rape and leafy salad crops using both published and grey literature.

A concurrent review was carried out to look at the effectiveness of management techniques that are currently available, and any techniques developed by other industries, both in the UK and abroad.

In addition, a very small-scale consultation process with pre-identified growers was undertaken to collate information on first-hand experiences with woodpigeon crop damage and its management.

The separate strands of the study were brought together with a view to assess the cost effectiveness of different management techniques in relation to the typical levels of damage imposed.

Information for both reviews was obtained by a comprehensive literature search. This incorporated a search of the peer reviewed academic literature using on-line databases. Internet search engines were used to locate further, unpublished articles relating to woodpigeon impacts; links to relevant web-sites listed in sourced articles were also visited. AHVLA's National Wildlife Management Centre also exploited its extensive collection of information relating to bird damage and control and links to overseas experts.

3.1 Crop damage

Review

All relevant references that were identified in these searches were reviewed and the following information extracted, as far as possible: the country, the affected crop, surrounding habitat, period over which damage occurs (i.e. seasonal damage), period of day during which damage occurs (i.e. diurnal pattern), spatial pattern of damage (i.e. margins or centre of field), yield loss and/or economic loss and whether loss was inferred or measured.

In addition to damage to agricultural crops, information was collated from dietary studies of woodpigeons to identify the full range of food types taken.

Natural England's Wildlife Management and Licensing Service (NEWLMS) (responsible for assessing licence applications to control 'pest' birds) was contacted to ascertain the level of interaction the Service has with growers concerning complaints and/or advice in relation to woodpigeon damage and their management.

Spatial analysis

The potential for using spatial analysis to explore woodpigeon crop damage at a landscape scale was investigated. It was anticipated that such an approach would involve developing a number of data layers, incorporating: land-use, in particular agricultural land use; woodpigeon distribution and actual and perceived levels of crop damage. In this way, it might have been possible to identify economic hotspots of woodpigeon damage across the country.

Preliminary investigations, however, indicated a lack of availability of the required data – most specifically estimates of crop damage across different geographic regions and/or landscape levels. Thus, in light of the present data gaps detailed spatial analysis was not feasible.

Appropriate data were available, however, to illustrate regional relationships between crop density (oilseed rape and field crops) and both woodpigeon density and change in woodpigeon numbers.

3.2 Review of mitigation and management techniques

There is a very extensive body of literature relating to the management and control of avian pest species. Much of this, however, is not directly related to the present study as it deals with species and circumstances unrepresentative of the issue of woodpigeon impact on agricultural crops (e.g. bird control at fisheries, land-fill sites and airports). However, to ensure that all potential techniques were considered the review included a range of studies that have investigated promising control techniques against other avian species in other settings and circumstances that might potentially be adapted to the agricultural context under consideration.

For each technique, reasons or biological principles behind its use were described, along with any factors or practices that might determine its efficacy. Examples of effective use were described, along with examples where its use was less successful.

For each document, the following information was extracted: the target species, the category of deterrent and type of device, the country in which the work was conducted, whether it was a field trial, laboratory study or a review and whether the technique was considered to be effective.

Evaluation of management measures

Replicated field trials (as opposed to ‘one-off’ studies) were prioritised for evaluation. Unreplicated or ‘pilot’ trials, provide an indication of the potential usefulness of a technique, but provide less robust evidence of technique effectiveness. Studies based on cage or pen trials with captive birds, are also less persuasive, as such trials are designed to maximise expression of the deterrent effect. Results are often not repeated when controlled and replicated field trials are subsequently carried out (Avery *et al*. 1993).

Techniques that were considered effective (resulting in over 50% reduction in damage or number of birds) were scored 2, those that were partially effective (resulting in up to 50% reduction in damage or birds) scored 1 and ineffective (no significant reduction in damage or number of birds) scored 0.

3.3 Consultation

A limited phone-based consultation exercise was designed in collaboration with HDC. This was then carried out with a sample of stakeholders identified by HDC, and incorporated a range of questions, ranging from quantifiable data, through to qualitative/subjective assessments and personal experience. The questions covered the following areas:

- Farm location, size and crop type
- Woodpigeon numbers and status of the problem
- The timing and perceived severity of crop damage
- Estimates of yield loss and financial loss
- Techniques used to mitigate crop damage and cost of its deployment
- Perceived levels of success with different techniques and how measured
- The use and mode of shooting to manage woodpigeons

Consultations were undertaken with 14 members from across four stakeholder groups; brassica growers, oil seed rape growers, salad growers and legume growers. A copy of the full questionnaire is provided in Appendix 1.

3.4 Cost benefit

The costs of damage versus the costs of control (and the effectiveness of that control at reducing damage) will allow crop growers to best decide how and when to apply control techniques, thus maximising the cost-effectiveness of management measures.

The costs of a range of management options were estimated using published information on the costs of mitigation devices and farm labour. Further data on costs was obtained from the phone-based consultation with a small sample of growers.

The financial value of crop damage was taken either directly from the findings of the review, the phone-based consultation or by relating quoted yield losses to the market values of crops.

The two datasets were compared to make preliminary evaluations of whether management techniques to mitigate woodpigeon damage yielded a net financial benefit.

Results

4.1 Woodpigeons and crops

Woodpigeon population status

The woodpigeon is the UK's largest and commonest pigeon. The UK population was last estimated at 5.4 million pairs in 2009 (Musgrove *et al*. 2013).

The British Trust for Ornithology's Breeding Bird Survey reports regional 'short-term' trends in populations of woodpigeon between 1995-2011: UK +40%*; England +46%*; Scotland +6%; Wales +41%* (*statistically significant; Risely *et al*. 2013;

BTO/JNCC/RSPB) (Figure 4.1). The longer-term (1970-2011) UK population trend has been estimated as +134% (Eaton *et al.* 2013).

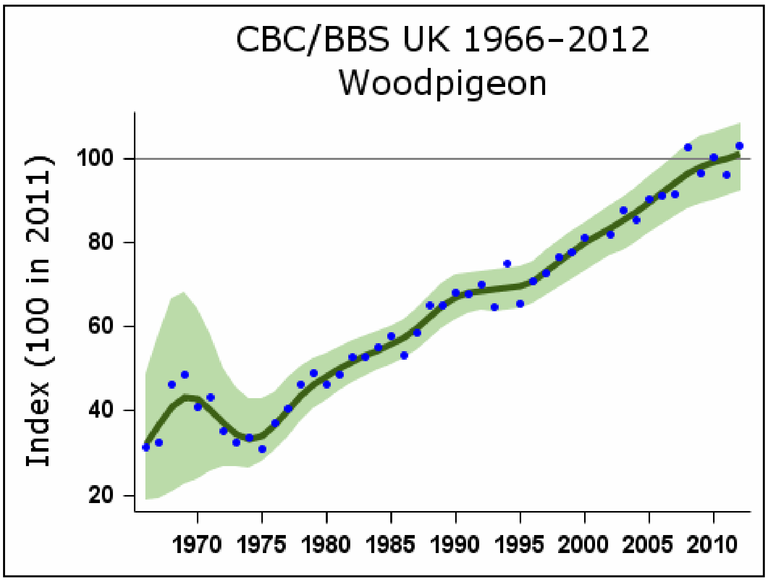

Figure 4.1 Population changes for the woodpigeon in the UK between 1966 and 2012. Figure published on the BTO's website http://blx1.bto.org/birdtrends/species.jsp?&s=woodp

The driver for the marked population growth is considered to be the spread of intensive arable cultivation, especially autumn-sown oilseed rape. Prior to this intensification, during the course of the winter woodpigeon grazing depleted food resources (e.g. clover) so that by late winter rates of mortality were very high. With the spread of autumn-sown oilseed rape and the availability of food resources throughout the winter mortality decreased (Inglis *et al*. 1997). Since the introduction of oilseed rape the number of young fledged has a greater impact on the population size than over-winter mortality; that is the population is no longer limited by winter food availability (Inglis *et al*. 1997). These empirical findings presaged recent modelling that showed increased reproductive output during the breeding season is a more likely mechanism behind the sustained population increase than a decline in density-dependent mortality (O'Regan *et al*. 2012). Although the main woodpigeon nesting period is between April and October, they have been recorded breeding in every month of the year (BTO).

Woodpigeon and crop distribution

The size of the over-wintering woodpigeon population has been shown to be determined by the area of oilseed rape (Inglis *et al*. 1997). More recent maps illustrate the association between the density of the woodpigeon population and the density of oilseed rape across the UK (Figure 4.2).

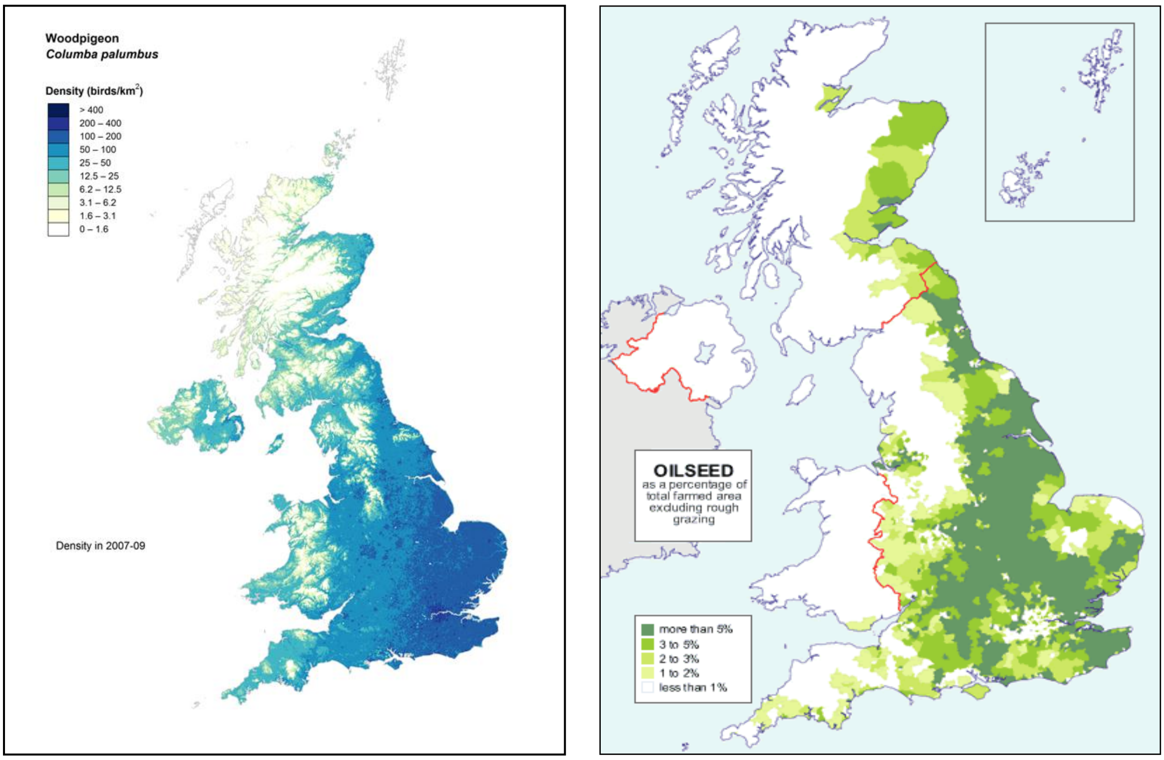

Figure 4.2 UK distribution of (a) woodpigeon density (http://www.bto.org/volunteer-surveys/bbs/latest-results/maps-population-density-and-trends), and (ii) oilseed rape density.

Although the size of the woodpigeon population in England has shown a marked increase between 1995 and 2011, the size of the increase has varied between different regions. The largest increases have been in Yorkshire, North West, London and east of England (all >50% increase) (Risely *et al*. 2013) (Table 4.1).

Table 4.1 Trends in English regional woodpigeon populations during 1995-2011.

English Region	% change in numbers
North West	65*
North East	32*
Yorkshire	88*
East Midlands	37*
East of England	51*
West Midlands	31*
South east	32*
South West	46*
London	61*

Horticultural production is concentrated in eastern and south eastern England (Figure 4.3): vegetables in the east; commercial orchards and soft fruit in Kent and also Herefordshire and Worcestershire (Crane and Vaughn 2008).

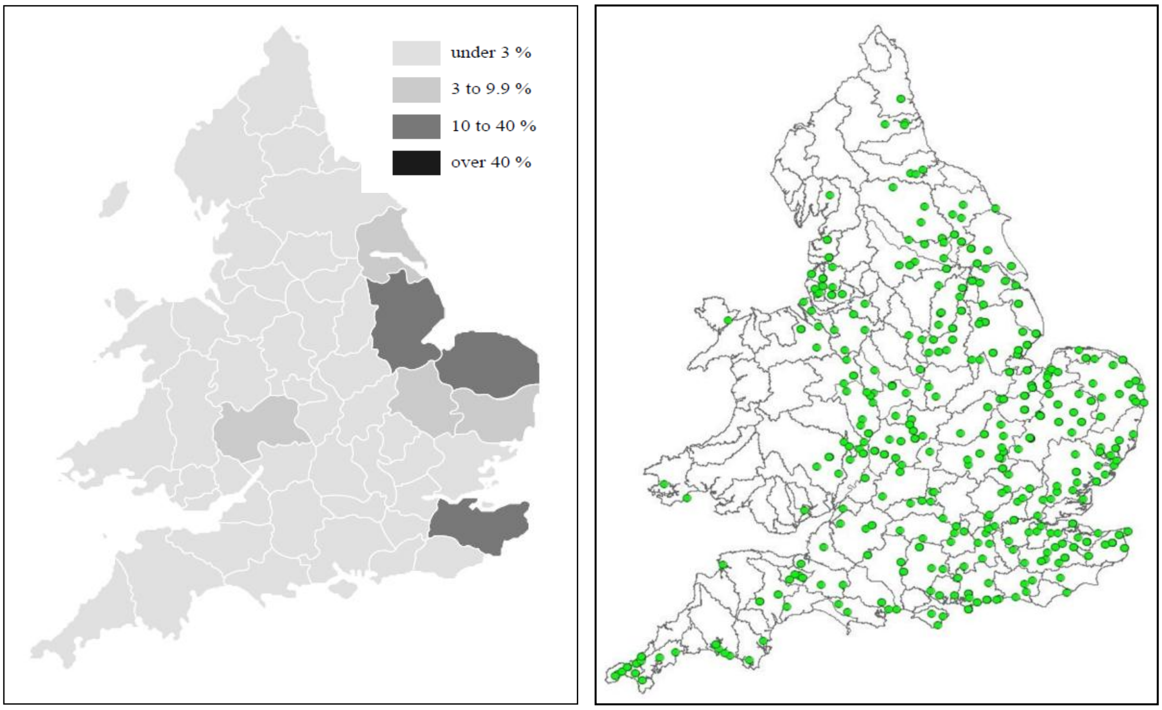

Figure 4.3 (a) Percentage of horticultural production by county as a percentage of the total horticultural production in England and Wales (from Crane and Vaughn 2008), (b) Distribution of growers involved in field vegetable production (FV) in England and Wales (based on HDC membership database 2008).

In 2013, the total area of oilseed rape in the UK was 715,000 ha (Defra Farming Statistics 2013). For horticultural crops there were 163,000 ha of which vegetables and salads for human consumption accounted for around 71% (116,000 ha): 37,000 ha of peas and beans, and 79,000 ha of other horticultural crops. The regions with the highest hectarage of oilseed rape and the greatest relative proportion of the national horticultural crop also hold the highest population densities of woodpigeons (Table 4.2).

In an NFU survey of the problems cause by woodpigeons (Smith *et al*. 1995), the region with the lowest proportion of holdings reporting problems was the North West (38% of holdings compared to 76-93% in all other regions) (Table 4.2). Although the

North West held the lowest woodpigeon density for any NFU region, it has experienced one of the highest increases (65%) in regional density over the past decade or so. It is not known if there has been an associated increase in the proportion of holdings in the region being impacted by woodpigeons over this period.

Table 4.2 Regional distribution of woodpigeon density and area of oilseed rape (hectares) and horticultural crops (% of total production) grown in England and proportion of holdings reporting woodpigeon problems (1994).

BTO Region	WP density 2007-09 (birds/km^2)	WP change 1995-2011 (%)	OSR (ha) [1]	Hort. (%)[2]	% Holdings[3]
North West	25-50	65	6,232	<3	37.8
North East	50-100	32	29,335	<3	91.0
Yorkshire	50-100	88	99,634	3-9.9	
East Midlands	100-200	37	181,162	10-40	93.0
East of England	200-400	51	168,241	10-40	91.2
West Midlands	25-50	31	61,664	3-9.9	87.2
London	200-400	61	101,317	10-40	DD
South East	200-400	32			88.0 (93.7)[4]
South West	50-100	46	65,086	<3	76.2 (93.7)[4]

[1]Garthwaite *et al*. 2012

[2] % of horticultural production as a % of the total horticultural production in England and Wales.

[3] % holdings reporting problems with woodpigeons (Smith *et al*. 1995).

[4] NFU 'Central' region is incorporated into 'South East' and 'South West' BTO regions.

In the UK, woodpigeon problems on crops are exacerbated by their sedentary nature; in contrast to the large migratory movements shown by woodpigeons on the continent (Haynes *et al*. 2003). Following the expansion in the planting of oilseed rape, woodpigeons moved smaller distances (Inglis *et al*. 1997). Radio-tracking has shown that during the summer both adults and juveniles remain relatively close to the nest area, whilst during the autumn birds extend their range, with this greater for juveniles than adults (Haynes *et al*. 2003). This pattern of movement is confirmed by ringing recovery data which indicates that woodpigeons leave their natal areas during their first winter and return the following summer (Haynes *et al*. 2003).

In addition to an increase in the rural population of woodpigeons, there have been marked increases in urban areas. As recorded by the BTO's Garden Birdwatch the woodpigeon is now the one of the most commonly seen birds in gardens. The percentage of gardens reporting woodpigeons has increased from around 50% in the 1995 to around 80% in 2012; in some regions (West Midlands, Hertfordshire, Norfolk, Hampshire, Surrey) it is found in over 92% of gardens (www.bto.org).

Urban woodpigeons are potentially contributing to agricultural damage in some areas. In Sefton Park, Liverpool woodpigeons bred at densities as high as those on some farmland and had higher breeding success (Slater 2001). The study also concluded that many adult birds flew out to feed on farmland (minimum 6km) during the breeding season. This was consistent with previous ringing recoveries showing that birds reared in suburban areas moved out to agricultural land (Merseyside Ringing Group Annual Reports 1993–95).

4.2. Review of agricultural damage

4.2.1 Extent of crop damage

Only 14 documents were sourced that reported data on the occurrence or level of damage by woodpigeons to crops in the UK or recorded observations of feeding behaviour (Appendix 2). The majority of these documents were published 25 years or more ago.

The very few estimates of damage provided ranged from 9% ±6% to 40% dependent on the type of crop (Table 4.3). The majority of documents were limited to a description of the nature and seasonal timing of damage.

Table 4.3 Summary of the level of woodpigeon damage to crops from UK studies. Further details are in Appendix 2.

Crop	Damage	Reference
Red clover *Trifolium pratense* White clover *Trifolium repens*	Up to 46%	Murton *et al*. (1964a)
Red clover White clover	unaffected: >50% but recovered	Murton *et al.* (1966)
Spring cabbage	mean £105/acre	Murton & Jones (1973)
Oilseed rape *Brassica napus oliferia*	9% ± 6%	Inglis *et al*. (1989)

During the winters of 1978/79 and 1980/81 in central and southern England woodpigeon damage was recorded in 48 of 52 fields of oilseed rape (Inglis *et al*. 1989). Visual estimates of woodpigeon damage were shown to be positively correlated with measurements of yield at harvest. On a subset of ten fields which had large areas of both negligible and severe damage in April, yield in the severely damaged areas was a mean of 9% (±6%) lower than in the areas that had negligible damage. Severe woodpigeon damage resulted in fewer seeds that were lighter and had lower oil content. There were no significant differences between the two different rape varieties grown in these fields in response to severe woodpigeon damage.

In the Vale of Evesham, financial damage to fields of spring cabbages was estimated by growers to be a mean of £105 per acre across two different study areas five miles apart (Murton & Jones 1973). These estimates of damage by growers agreed well with independent assessments of crop damage from field surveys in one area but not in the second where surveys predicted lower financial loss.

The majority of documents on the impacts of woodpigeons on crops were descriptive and lacked empirical measurements of damage levels, for example Dunning (1974) reported that during the late-1960s, woodpigeon damage to sugar beet occurred between April and July with damage most prevalent in June and July on late sown crops.

4.2.2 Timing of damage

Woodpigeon diet varies throughout the year according to the availability and growing stage of crops (Appendices 3 & 4).

For example, a National Farmers Union (NFU) questionnaire survey of farmers provided information from 964 returns on the seasonal pattern of woodpigeon damage (Smith *et al*. 1995). Peak months for damage were: oilseed rape December to March; cereals July to October; beans/peas March to May; linseed April to May; grass/clover January to April; stubble August to October.

Murton and Jones (1973) studied woodpigeon damage to cabbages and Brussels-sprouts in the Vale of Evesham during the three winters between 1969/70 and 1970/71. Brussels-sprouts were attacked earlier in the season than cabbages with peak damage to cabbages in March.

Damage to sugar beet was most prevalent on late sown crops in June-July (Dunning 1974).

On Brussels-sprouts and turnip tops, flock formation has been recorded during December to mid-March (Kenward & Sibly 1978).

Inglis *et al*. (1989) reported that damage to oilseed rape was negligible in December, increased sequentially through January, February and March before decreasing in April. The occurrence of the highest damage in February and March was considered to be due to alternative food sources being at their lowest during this period.

When foraging, woodpigeons exhibit periods of feeding and resting as a consequence of food accumulating in the crop faster than the rate of digestion (Kenward & Sibly 1978). More resting on Brassica than on clover appears to be related to the faster ingestion of Brassicas. During the last two hours before dusk woodpigeons increase the length of the foraging bout in order to fill their crops prior to roosting for the night. The consequence of woodpigeons only part-filling their crops before switching to a resting period is that disturbing the birds from the field for long periods may not effectively reduce the overall consumption of crop.

4.2.3 Patterns of damage

In the Vale of Evesham (1969/70-1970/71), woodpigeons usually ate only the cabbage-like top of the Brussels-sprouts plants leaving the buttons undamaged (Murton and Jones 1973). In both sprouts and cabbages woodpigeons showed a tendency to select plants that were different from the rest of the crop, particularly plants that were smaller than average. The authors reported that disease or other factors resulting in stunted plant growth appeared to improve the nutritive properties rendering the plants more attractive to birds. The severest damage to Brussels-sprouts and cabbages occurred on fields that were peripheral to the main concentration of the crop.

Across 52 fields of oilseed rape distributed throughout central and southern England, the amount of woodpigeon damage (measured by visual estimates) was inversely related to the level of bird scaring and to the proportion of the field boundary bordered by homes and/or roads (Inglis *et al*. 1989). The amount of damage was also positively correlated with the presence of a woodpigeon roost within 1km of the field.

In an NFU questionnaire survey of its members across England, Scotland and Wales the proportion of holdings reporting problems with woodpigeons was highest in eastern regions (Smith *et al*. 1995). There was an association between the presence of woodland (present on 60% of total holdings) and reported woodpigeon problems. Approximately 55% of total holdings held an area of woodland <50 acres - of these holdings 50% reported problems with woodpigeons and only 5% reported no problems. Similarly, 11.5% of total holdings possessed woodland >50 acres, of which 10.5% reported problems compared to 1% untroubled.

4.2.4 Dietary range

Woodpigeons have a wide and varied diet; consuming a wide range of plant material in addition to agricultural crops. In UK studies, woodpigeons have been recorded consuming 31 different plant types: 19 categories of crop and 12 wild plants (Appendix 3). In Ireland, a recent study identified 49 species of plant (seven species of cereal or cultivate); in summer and autumn the grains of cereal crops predominated, whilst in spring and winter the diet was dominated by the fruit and seeds of trees (O'hUallachain & Dunne 2013).

4.2.5 Current damage

The number of studies investigating crop damage by woodpigeons in the past decade is extremely small (e.g. O'hUallachain & Dunne 2013).

The last national survey that collated information on the magnitude and extent of the conflict between farmers and woodpigeons was conducted 20 years ago (Smith *et al*. 1995).

As woodpigeons are listed on a general licence for the purposes of preventing serious damage growers wishing to act under this licence do not need to supply crop damage data to support the issuing of a licence. Consequently, Natural England does not routinely keep records of crop damage caused by woodpigeons.

As a consequence of this lack of contemporary data the current status of the magnitude of woodpigeon damage to oilseed rape, other brassicas and leafy salads, at the field, farm, landscape, regional or national level is not known.

4.3 Review of management and control measures

A summary of the documents on management and control techniques relating to woodpigeons and agricultural/horticultural crops and other selected relevant avian management scenarios, and details within, are presented in Appendix 5.

Avian management techniques can be categorised into visual deterrents, auditory deterrents, chemical deterrents, fertility control, exclusion, habitat modification and lethal control.

4.3.1 Visual deterrents

Lasers

As the demand for non-lethal, environmentally safe methods of bird scaring has increased, interest has grown in the use of lasers, particularly low-power lasers that work under low light conditions (APHIS 2003). The low power levels, accuracy over distance, silence and the ability to direct them on specific problem birds makes laser devices an attractive alternative to other avian scaring devices. Birds are startled by the strong contrast between the ambient light and the laser beam. During low light conditions this technique is very selective, but at night the light beam is visible over a large distance and poses a risk of non-selective disturbance.

Low-powered hand-held lasers have been used successfully to disperse a number of avian species (Glahn *et al*. 2001, Blackwell 2002ab). The effectiveness, however, varies between species and is context dependent. In captive trials, mallards *Anas platyrhynchos* and rock doves *Columba livia* were deterred from treated areas but habituated after several minutes; Canada geese *Branta canadensis* exhibited marked avoidance behaviour (Blackwell *et al*. 2002ab); starlings *Sturnus vulgaris* and brown-headed cowbirds *Molothrus ater* were not deterred. In the wild, double-crested cormorants *Phalacrocorax auritus* (Glahn *et al*. 2001) and great cormorants *Phalacrocorax carbo* (McKay *et al*. 1999a) have been deterred from roosts sites. In captive trials, Canada geese have also been deterred from plots by a motion-activated laser hazing system (Werner & Clark 2006).

For American crows *Corvus brachyrhynchos* deterrence appeared to be more effective at a rural roost than at urban roosts; probably associated with differences in the ambient light and human activity (Blackwell *et al*. 2002b). At established urban roosts, crows reacted to the laser by immediately leaving the roost but reoccupied all roosts the same night (Gorenzel *et al*. 2002). Application of lasers at less well established roosts and when birds were entering the roost for the evening (as opposed to already settled in the roost) were not tested.

Lasers are not known to have been tested specifically against <u>woodpigeons</u>.

Dogs

The control of birds and other wildlife such as deer through harassment by trained border collies has been used at aerodromes, golf courses and agricultural land (Castelli and Sleggs 2000). The dogs represent an actual, not just perceived threat, and so elicit flight reactions. Habituation is unlikely as they can continually pursue and change their behaviour. Border collies are used as they are working dogs bred to herd animals and to avoid attack, and they respond well to whistle and verbal commands (Erwin 1999). A single border collie and its handler can keep an area of approximately 50 square kilometres free of larger birds and wildlife (Carter, undated). Although they are effective at deterring ground foraging birds such as waders and wildfowl, they are not so useful for species that spend most of their time flying or perching, such as raptors and swallows (Erwin 1999).

In 1999 Southwest Florida International Airport became the first commercial airport in the world to employ a border collie in an airfield wildlife control programme (Carter, undated). After the use of the collie, numbers and species of birds on the airport declined and most birds that remained congregated in a drainage ditch away from the runway. The number of bird strikes dropped to zero compared to 13 for the same period the previous year (Carter 2000). Several other airports and airbases subsequently started similar programmes.

At Dover Air Force Base, Delaware, bird strike damage to aircraft caused by birds was reduced from an average of US $600,000/year for the preceding two years to US$24,000/year after the initiation of a bird control programme that included the use of border collies (Carter undated).

In Ottawa, Canada, border collies have been used to scare Canada geese from 300ha of fields at an experimental farm used to develop new crops, including wheat, soybeans, barley, corn and other crops (http://o.canada.com/news/canadian-government-to-hire-dogs-to-scare-geese-away-from-experimental-farm/). The work involved two collies and a trained handler.

The use of dogs, however, is labour-intensive, as the dogs need to be constantly directed by a trained handler. The initial costs of implementing a border-collie programme may be high with the purchase of dogs, training, plus food and veterinary bills, and they may be no more effective than a human bird-controller. In addition, safety is an issue on runways.

An alternative method of using a dog is to allow the dog to roam freely in a pre-determined area that is delineated with an ‘invisible’ fence. An invisible fence is an electronic system consisting of a buried wire that is energised by coded signals and an electronic shock collar. If the dog wearing the collar crosses the boundary a mild electric shock is delivered by the collar. The location of the boundary can be physically marked with flags to indicate to the dog the area in which it is free to roam. Alternative set-ups dispense with a physical wire, by using either a radio signal from a central source that activates the collar when the dog travels beyond a set radius from the unit, or GPS signals that determine proximity to a predetermined boundary.

In the USA, dogs confined by an invisible electric fence successfully protected fields of fruit and vegetable from deer damage, whereas damage occurred in fields protected by traditional electric polytape fencing (Vercauteren *et al*. 2005).

Human-scarer

Human activity can disturb birds from specific areas either deliberately by direct harassment (Vickery & Summers 1992), or indirectly through, for example, leisure activities (Bell & Austin 1985; Owens 1976). Those sites where man is absent or rarely present, particularly on foot, such as airfields, are particularly attractive to birds. Human presence is a feature of many bird deterrent methods, and it should be appreciated that it is difficult to separate the effects of the device, e.g. pyrotechnics, from the effects of human presence.

Fiedler *et al*. (1991) describes the employment in many countries of human-scarers who patrol fields and deter birds using a variety of visual and auditory methods. To be effective the approach has to be properly timed, persistent and to use a combination of methods. Effectiveness, however, is influenced by a number of variables, such as the season, the type and maturation stage of the crop, the problem species and its abundance, the size of the field and the diligence and enthusiasm of the scarers.

In the UK, brent geese were cost-effectively scared from fields of arable crops (winter wheat and oil-seed rape) by a full-time human bird-scarer (Vickery and Summers 1992). The scarer, equipped with a four-wheel motorcycle for quick access to each field, worked a six-day week (the farmer scared on the seventh) from approximately dawn until dusk. The geese were scared off immediately the birds had landed with the occasional bird shot under licence. The intensity and duration of grazing was reduced compared with that of previous years when conventional scaring was used or coloured tapes were suspended over the crops. Following one month of intensive disturbance by the human bird-scarer geese rarely attempted to utilise the wheat fields; except during a period of exceptionally harsh winter weather.

Kenward (1978b) compared the influence of man and goshawks on woodpigeon activity in Brassica fields. Human presence almost completely excluded woodpigeons from the sites. In contrast, goshawk attacks usually failed to keep the pigeons off the field for any length of time. One possible explanation forwarded was that the absence of significant goshawk predation in England for at least 200 years may have reduced the normal anti-predator response, whereas significant human persecution may have increased the anti-predator response to man.

Scarecrows

Scarecrows are common, traditional methods used in attempts to scare avian species. They mimic the appearance of a predator and so cause birds to take flight to avoid potential predation (Harris and Davis 1998). Most scarecrows are human-shaped effigies, usually constructed from inexpensive materials.

To maximise effectiveness devices should possess biological significance, appear life-like, be highly visible and their location changed frequently in order to extend the period of habituation (Vaudry 1979). The effectiveness of scarecrows may be enhanced if fitted with loose clothing and bright streamers that move and create noise in the wind (Vaudry 1979) - effectively becoming a moving visual.

Several types of moving, inflatable human effigies are commercially available. For example, Scarey Man® is a life-size plastic effigy powered by a 12 volt car battery that inflates rapidly, emits a high pitched wail and may illuminate at night. In the USA, double-crested cormorants, black-crowned night-herons *Nycticorax nycticorax* and great blue herons *Ardea Herodias* were initially deterred from commercial fisheries but habituated after a few days (Andelt *et al*. 1997). Stickley and King (1995) successfully used Scarey Man® to reduce numbers of double-crested cormorants *Phalacrocoax auritus* on catfish ponds over periods of 10 to 19 days. In a longer term trial, Scarey Man® (one device per 14ha water) was superimposed on harassment patrols. Cormorant numbers decreased during the first week of use, but by the 11th day had begun to lose their effectiveness. The devices were supplemented with other scaring activities - placing hats and camouflage masks on the devices, gas cannons and substituting shooters for Scarey Man®, but numbers of birds could not be reduced further. It was concluded that Scarey Man® could be recommended in cases where cormorant depredations were a serious problem.

In 1994, the NFU (in association with BASC) undertook a questionnaire survey of its membership to obtain an account of the problems caused by woodpigeons (Smith et al. 1995). The survey encompassed nearly 1,000 farmers throughout England, Scotland and Wales with 964 returns. Of these respondents, 55% reported the use of scarecrows, with 29.5% of these rating scarecrows as moderately effective and only 1.2% as highly effective.

Ultimately, however lifelike, under most circumstances scarecrows do not present a threat that is sufficiently alarming to birds (Inglis 1980). Over a period of time birds learn that effigies or models do not represent an actual threat and are no longer alarmed by them. To increase the threat and therefore the habituation time, it is recommended that these devices be reinforced with other sound-producing or visual deterrents. Ideally, for example, scarecrows should be periodically reinforced by human activity.

In Israel, a recent novel application to protect crops has involved reinforcing the deployment of scarecrows with the occasional intervention of shooting to scare by a man located amongst and imitating the scarecrows (Nemtzov & Galili 2006). In the UK, during the early 1980s a prototype scarecrow was built that consisted of the torso of a man holding a gun (Inglis pers. comm.). This torso was moved up and down a pole by an electric motor that was activated by a sensor attached to the mechanism of a gas cannon. A few seconds before the cannon fired the torso was raised and it was then held at the top of the pole for approximately five seconds after the explosion, before being lowered. Several straw bale hides were placed in a field of oilseed rape and the torso/gas cannon was moved between these hides every couple of days. In addition, for a few hours each weekend a person hid in one or other of the hides and shot at any birds on the field. This person wore the same colour jacket as that draped over the torso. It was found that woodpigeons avoided all the hides and in this way a large area of oilseed rape were successfully protected throughout the four weeks of the trial (Inglis & Isaacson unpublished data). It was thought that the additional use of woodpigeon corpses (see Section 7.1.6) might have increased the protective area still further.

Raptor models

The basis for this deterrent is mimicry of real predators and evocation of fear and avoidance in the target species. Most potential prey species react to predator models; the strength of the response, however, varies between species (Conover 1979), and in some cases raptor models can attract rather than repel birds as species like blackbirds and crows often mob owls or owl models (Conover 1983, cited in Harris and Davis 1998).

Model raptors, however, fail to incorporate behavioural cues that may be critical to the induction of fear and avoidance in the target species. Falcons which are "in the mood" to hunt are said to be "sharp set", such birds are invariably hungry enough to fly at quarry (Inglis 1980). Although it is difficult for human observers to differentiate between a falcon when it is sharp set or conversely, well fed, birds will mob a hawk more frequently when sharp set than when well fed. Thus, model raptors will be inherently less threatening and consequently less effective than live raptors.

Similar to scarecrows, movement can enhance scaring effectiveness. An animated crow-killing owl model was more effective in protecting vegetable plots from crows than an unanimated model (Conover 1985). This model consisted of a plastic owl model with a plastic crow model in its talons that either had wings that moved in the breeze or battery-powered wings that could move in the absence of wind. Both versions of this device reduced crop damage by 81%. The deterrent effect was maximised by combining movement with an implicit risk. No indication is given of how long the deterrent effect lasted.

Two commercial scarers, each vaguely resembling a large raptor (placed atop a 5m pole), proved ineffective against <u>woodpigeons</u> within a clover ley (Inglis 1980). A maximum of 125 <u>woodpigeons</u> were observed feeding within 50m of one or other device throughout a three hour observation period.

Corpses

An alternative use of models to deter birds has involved deploying dead specimens or taxidermic effigies in a manner which signals danger to conspecifics. Initially birds often approach the corpse but usually leave when they see the unnatural position of the bird. This approach has been frequently used in attempts to deter gulls from airports (Harris & Davies 1998) and has been shown to be effective and persistent in deterring vultures from roosts on communication towers (Avery *et al*. 2002).

In a series of field experiments Inglis and Isaacson (1987) investigated the aversive properties of woodpigeon corpses on clover leys (14-20 ha): real woodpigeon bodies with outstretched wings provided significant protection over a nine-week period; pairs of wings were as effective as whole carcasses; three-dimensional life-like models were as effective as carcasses; crude woodpigeon silhouettes were ineffective. The final experiment showed that real woodpigeon bodies or wings had to be in good condition to maintain effectiveness. This was achieved by raising the decoys above the ground on wire ‘T’ pieces; whereas if left on the ground, decoys deteriorated through the action of scavengers and waterlogging.

In citing research on the effectiveness of deterring gulls from airfields by deploying corpses of gulls in the outstretched wing posture, Inglis and Isaacson (1987) reported that frequent movement of the bodies greatly retarded habituation and that all deterrence was lost once the feathers became bedraggled (supporting the findings on woodpigeon decoys).

Intraspecific visual displays

This approach uses models to mimic specific visual displays (e.g. pre-flight display) to elicit a desired response in the pest species (Inglis 1980). The specific posture of woodpigeon decoys was found to influence whether other woodpigeons were either attracted into the field or deterred (Murton 1970, 1974; Murton *et al*. 1974). Decoys with either open or closed wings were laid out and birds passing overhead were observed for the exhibition of a positive response (i.e. dipping, circling, attempting to land, or actually settling). Although the initial response rate was similar for both types of decoy, with closed-wing decoys 54% of responding birds actually settled in the field compared to only 4% with open-wing decoys.

Hunter (1974) found that woodpigeons responded the same to painted metal models of woodpigeons with wings extended to display the white wing marks and to dead woodpigeons similarly displayed. On fields of spring cabbages model pigeons (around 100 models arranged in a grid pattern) reduced damage appreciably compared to control fields for a period of about four weeks.

Subsequent work investigated the use of single woodpigeon wings, with 49 wings laid out in a 5 yard grid within a clover ley (Inglis 1980). Damage estimates were made at intervals during a 78 day period within the experimental area and a control area. Damage levels (clover leaves pecked) were consistently lower in the area with wings than in the control area. Elsewhere, a two acre cabbage field in which open-wing woodpigeon models were deployed suffered less damage than two similar adjacent control fields over a four week period; however after a fifth week damage levels were similar to the control fields.

Inglis (1980) reported the testing of simple wind-driven devices that mimicked the flashing of the white bars on the wings of woodpigeons. Field trials showed that such devices deterred woodpigeons for a period of around three weeks from a 7 acre test portion of a 36 acre pasture. However, although the proto-type devices showed promise, they did not always perform significantly better relative to commercial wind-driven scarers that lacked white bars.

The deterrent effect of the open-wing display of the decoys has been shown not to be derived from the posture of the decoy *per se* but from the white wing markings, as once the markings are erased, by painting over, all repellence was lost (Inglis and Isaacson 1984).

Eyespots

Eyespot patterns are a commonly used avian deterrent, either painted onto a substrate or on devices such as balloons and kites. These patterns are images of eyes composed of a small circle (the ‘pupil’) centred in a larger circle of another colour (the ‘iris’). These eyes mimic the eyes of large raptors, but may also mimic the eyes of conspecifics, which is alarming as many avian species have frontal threat displays in which the eyes are prominent (Inglis 1980). Laboratory studies have shown that eyespot patterns can induce an aversive response in starlings (Inglis *et al*. 1983). McNamara *et al*. (2002) found that ‘eyes’ painted on the black plastic which covered silage bales reduced damage to the bales by 65%. Inglis *et al*. (1983), in an investigation of the efficacy of eyespots as bird deterrents, concluded that simple eye patterns could deter starlings from foraging within their vicinity; effectiveness was dependant on a distinction between ‘pupil’ and ‘iris’. Habituation to eyespots, however, was rapid.

Balloons

Balloons tethered in a crop are an inexpensive method of bird deterrence, but studies show that they are not very effective and birds quickly habituate to them. Toy balloons tied to the branches of cherry and blueberry trees deterred starlings, but robins and Baltimore orioles *Icterus galbula* were seen to continue feeding only a few feet away (Pearson 1958).

An 18ha field of early-sown barley was successfully protected from rooks for the 13 days up to plant emergence using five single balloons tethered at a height of 30m (Feare 1974). On a second field containing late-sown oats, however, a higher density of balloons was completely ineffective.

To increase the effectiveness of balloons, eyespots can be printed on the side. McLennan *et al.* (1995) evaluated eyespot balls as a bird deterrent in vineyards. In the first three weeks the balls repelled 90% of all birds except song thrushes, which had started to ignore them in the second week. Their deterrent effect had almost ceased after four weeks, but by this stage the grapes had ripened and become increasingly attractive to the birds. It could not be determined whether the balls failed because the birds had habituated to them or because the lure of food overcame the deterrent effect.

Kites

Kites and kite-hawks (kites that simulate birds of prey) work as mobile predator models, which birds perceive as a threat. The kites bear an image of a soaring raptor and are tethered to the ground. Conover (1983, cited in Harris and Davis 1998) tested four designs of hawk-kites, but none effectively deterred birds from feeding on corn. To be effective, kite-hawks need to be 'flown' beneath helium balloons in order to possess sufficient 'threatening' movement (Conover 1984). When this was done, the kites became more effective at scaring birds from the cornfields.

In Southern Australia, kite-hawks were reported to be effective in reducing crop damage by little corellas *Cacatua sanguinea* (DEH 2007). The technique involved launching the kite each morning and then tethering it on 300-400m of line. The method is considered effective on paddocks up to 40ha.

In the UK, kites were effective in greatly reducing woodpigeon damage to fields of spring cabbage on two farms (Fazlul Haque and Broom 1985). The kite was flown continuously during experimental periods at a height of approximately 55m. Damage to cabbage was markedly lower during experimental periods when the kite was flown compared to alternating periods when no bird scaring device was used. The kite also reduced damage considerably (compared to fields protected by bangers and scarecrows) when flown over an extended period of three months (January to March).

Feare *et al*. (1988) report unpublished work by one of the authors that involved flying seven identical kites for different durations on adjacent fields of oilseed rape. Flying a kite for two or four days per week decreased the percentage of plants (27% and 10% of plants respectively) within 100m of the tethering post that were damaged by woodpigeons, compared to a flight frequency of only one day per fortnight (65% of plants were damaged).

In the late 1970s a prototype helium-filled kite was developed (Inglis pers. comm.). This was a large delta kite in which the backbone and cross struts were tubes filled with helium. In a strong wind this device operated as a kite but it would also stay aloft in calm conditions. The kite string was attached to a pulley that in turn could move up and down a horizontal rope stretched across the field. In this way the kite would move to different parts of the field depending on the wind direction. Although successful in deterring woodpigeons for many weeks it was never commercially marketed as it used large quantities of helium gas, which was then expensive to buy and difficult for farmers to obtain.

One disadvantage with kites is the labour required to maintain them aloft. Falzul and Haque (1985) found that kites had to be re-launched on most mornings. Feare *et al*. (1988), however, considered that the frequent grounding of kites may increase their effectiveness through reducing their exposure and prolonging habituation.

Falconry

The success of this method of bird control is based on the fact that many birds have a natural fear of falcons and hawks as predators, so their presence in the area encourages problem species to disperse. The natural reaction of most prey species is to form a flock and attempt to fly above the falcon. If this fails, they will attempt to fly for cover and leave the area (Transport Canada, undated).

In trials at landfill sites the number of scavenging gulls and corvids was reduced during all flights of falcons but this was not achieved during flights of hawks (Baxter and Robinson 2007). Both falcons and hawks failed to clear all birds all of the time due to the impracticality of continuously flying birds.

Although falconry has shown some promising results (mainly at airports) there are a number of issues that impact detrimentally on its effectiveness; the birds cannot be flown under certain weather conditions (strong winds, rain, fog) and when in moult; the birds' behaviour can sometimes be unpredictable; and the dependency on a trained falconer renders the techniques relatively expensive (Erickson *et al*. 1990). With few exceptions, it has been necessary to deploy other scaring techniques in conjunction with falconry.

The use of falconry in agricultural and other settings has been very limited. Kenward (1978b) compared the influence of man and goshawks on woodpigeon activity in Brassica fields. Goshawk attacks, even when repeated and successful, usually failed to keep the pigeons off the field for any length of time. Woodpigeons resettled on the field immediately after 23% of attacks and returned to the field within the same day following 50% of attacks. In contrast, the presence of man almost completely excluded woodpigeons from the sites. One possible explanation that was suggested was that whereas the absence of significant goshawk predation in England for at least 200 years may have reduced the normal anti-predator response, significant human persecution may have increased the anti-predator response to man.

Goshawk attacks on woodpigeons at Brassica sites were more successful in the last hour before sunset (Kenward 1978a).

Radio-controlled aircraft

Radio-controlled model aircraft have been used to scare or 'haze' birds since the early 1980s, mainly over airfields (Smith *et al.* 1999), but have also been used over agricultural areas, fisheries and landfill sites. This method has been shown to be relatively effective and birds habituate more slowly to a treatment in which they are being actively hazed.

Amir (1989) described a radio-controlled aircraft equipped with airborne pyrotechnic devices. It was claimed that this technique had maintained a virtually 'bird free dome' around Ben Gurion International Airport, Israel for the 'last eight years'.

Radio-controlled model birds of prey

The use of falconry and radio-controlled aircraft has been combined in the development of remote-controlled model aircraft in the shape of a bird of prey (e.g. FALCO ROBOT Battistoni *et al*. undated). One example involves a life-size model of a female goshawk with a 1.6m wingspan. Powered flight, driven by a small electric motor, is replaced by dynamic gliding shortly after take-off. The model can be deployed reactively to disperse birds present or proactively to maintain an area clear of birds. The effectiveness of the device is said to be strengthened by playing distress calls of the target species. An alternative model incorporates wing-flapping in its flight action.

Currently, in Belgium, work is ongoing to develop an affordable radio-controlled eagle model; tests with prototypes are reported to have been promising (Huysentruyt pers comm).

Mirrors/reflectors

Mirrors and reflectors work on the principle that sudden bright flashes of light produce a startle response and drive the bird from an area. However, the response of free-living birds to mirrors has been investigated in only a handful of species. Reflective objects have been reported as effective in deterring raptors, such as sparrowhawks and goshawks, from game release pens (Lloyd 1976). Foraging by black-capped chickadees *Parus atricapillus* at feeding stations was depressed by the presentation of either a standard mirror or an aluminium foil covered mirror; feeding was depressed the most by the standard mirror (Censky & Ficken 1982). Mirrors, although slightly repellent under some configurations, were not a practical method for deterring starlings from nesting in boxes (Seamans *et al*. 2001). The use of mirrors alone and mirrors reflecting sunlight have failed to repel pigeons or gulls (Belant 1976 cited in Seamans *et al*. 2003).

A device consisting of a rotating pyramid of mirrors has been recommended for deterring birds in a number of settings including the protection of crops. This device is available in the UK and the manufacturer provides a number of testimonials from customers, including brassica growers with pigeon problems. There is, however, little scientific research into the effectiveness of this device (or other mirrors/reflectors). In New Zealand, such a device had minimal effect on reduction in bird (mainly starling) damage to grapes, relative to an eye-spot balloon (Fukuda *et al*. 2008). Both the device and the balloon reduced damage to grape clusters within 15m but had no measurable effect on clusters more distant. It was concluded that neither device would provide growers with an economically significant reduction in damage. In the USA, a rotating (clear) mirror device did not reduce the number of birds captured in decoy traps over two five-day periods relative to control traps (Seamans *et al*. 2003). However, when red mirrors were used fewer total birds were captured, specifically common grackles *Quiscalus quiscula*; there was no difference in the numbers of any other species captured. It was concluded that there was at least a species-specific initial reaction to rotating red mirrors.

Although, easy and inexpensive to deploy and easy to relocate, the effectiveness of mirrors and reflectors as a bird scaring technique is variable. Also, as they are only effective when there is sunlight to reflect they are best combined with other methods of scaring.

Tapes

Tapes as a scaring device act as a combination of visual deterrence and exclusion. They are easy to erect and a wide selection of twines and tapes are readily available.

Reflecting tape such as Mylar tape has been used in attempts to deter birds in a number of circumstances. The tape has a silver metal coating on one side that reflects sunlight and also produces a humming or crackling noise when moved by the wind. A variety of birds have been deterred by tape suspended in parallel rows over ripening crops (Bruggers *et al*. 1986).

Other studies have found reflective tape to be ineffective. Tobin *et al*. (1988) found that birds were not deterred from eating blueberries or from flying into taped plots, and Conover and Dolbeer (1989) found that tapes in cornfields did not reduce damage by red-winged blackbirds.

Brent geese were cost-effectively deterred from fields of winter wheat using red fluorescent tape suspended between poles (Summers and Hillman 1990). However, in a second trial when no un-taped wheat fields (tape was deployed in all fields) were available the geese landed between the rows of tape and grazed.

Fazlul Haque and Broom (1985) found little evidence of woodpigeon damage for a period of a week when humming line was suspended over a field of cabbage. However, damage rose to 50% and 90% of plants after weeks two and three respectively.

Flags, rags and streamers (fladry)

The placing of flags, usually made from old sacks, amongst a crop, is one of the simplest and cheapest forms of bird scaring. The movement of the flag or rag in the wind is perceived as a threat by birds, which then avoid the area.

Flags (plastic bags on posts) were ineffective in deterring mute swans from grazing on test plots in fields of oilseed rape (McKay and Parrott 2002).

4.3.2 Auditory deterrents

Humans can detect sounds within the approximate range 20-20,000 Hz (Bomford and O'Brien 1990). Ultrasonic frequencies are those above 20,000 Hz and infrasonic frequencies are those below 20 Hz. Birds appear to be most receptive to sounds within the range 1,000-3,000 Hz. Pigeons can detect frequencies as low as 0.05 Hz but it is not known how this capability is used. Empirical evidence indicating that birds can hear and respond to ultrasound is lacking.

Auditory deterrent devices include gas cannons, pyrotechnics, bio-acoustics, acoustics, ultrasonics and high intensity sound.

Gas cannons

Gas cannons (or ‘exploders’ in the USA) are mechanical devices that produce loud banging noises by igniting either acetylene or propane gas. The unexpected bang produced causes a ‘startle’ reflex and promotes escape flight (Harris and Davis 1998). Feare *et al*. (1988), however, consider their effectiveness is not solely a consequence of the startle response, as a variety of other acoustic scarers produce sounds of similar intensity but were considered to be less efficient than gas cannons.

In agricultural settings, acetylene exploders successfully reduced or stopped blackbird damage to ripening maize (Cardinell and Hayne 1944) and De Grazio (1961, cited in Potvin and Bergeron 1964) found that blackbird damage to corn was reduced by 98%. Sugden (1976, cited in Harris and Davis 1998) indicated that gas cannons were useful for reducing waterfowl damage to grain crops. However, other studies have shown that single gas cannons can be less effective in reducing bird damage. A single gas cannon, fired every two minutes offered no protection to a corn field from blackbirds (Potvin and Bergeron 1981), though two pivoting cannons with desynchronised detonations reduced losses by 73% and one double detonation synchronized cannon by 66%.

The effectiveness of gas cannons is variable and dependent upon the method of their deployment, the bird species involved and the availability of alternative feeding areas. The area protected by single cannon varies: maize/blackbirds 4ha (Cardinell and Hayne 1944), 4-10ha for blackbirds, one per 20ha waterfowl (Potvin and Bergeron 1981; Transport Canada 1994). Thus by placing one cannon in too large an area of crop, effective protection will not be achieved throughout the whole area. In addition, the number required to cover a large area may be prohibitive. However, it is possible to enlarge the area protected by a single gas cannon by building several hides made, for example, from straw bales and then to move the gas cannon frequently between them; in that way the woodpigeons come to avoid all the hides (Inglis & Isaacson unpublished data).

Habituation is the main reason for their loss of effectiveness. Experimental studies were conducted in a soundproof chamber to see how quickly the startle responses of starlings to a repeated sound (in this case a burst of white noise) habituated in relation to a) the intensity, b) the duration, and c) the inter-stimulus interval of the stimulus. It was found that the speed of habituation decreased with a) increasing intensity, b) decreasing stimulus duration, and c) increasing inter-stimulus interval (Inglis unpublished data). Patterns of noise were also investigated and it was found that for a given intensity and inter-stimulus interval having two bursts of sound close together resulted in slower habituation than having a stimulus consisting of either one or three bursts of noise. This suggests that gas cannons that produce a double explosion may be more effective than those emitting a single bang. Having a variable inter-stimulus interval also resulted in slower habituation than did having a fixed interval. Moving the cannon every few days is recommended (NFU undated; Transport Canada 1994; Harris and Davis 1998; Gorenzel *et al.* 1994), along with variable firing intervals (Harris and Davis 1998).

Inglis *et al*. (1989) recommended that a single scaring device such as a gas cannon should be deployed as soon as patches of damage begin to appear. This scarer can then be moved around the field to spread the damage so that no area suffers severe grazing pressure. From mid-January onwards, coinciding with the period of greatest woodpigeon grazing (oilseed rape), different types of scarer can be used in rotation. Using this approach a 30ha field of oilseed rape bordering a wood was successfully protected throughout the winter.

When used near human habitation gas cannons need to be deployed sympathetically with regard to potential noise nuisance. Straw bales make effective baffles and can greatly help in directing the sound away from sensitive areas (Inglis & Haynes unpublished data).

Pyrotechnics

Pyrotechnics include a wide variety of noise-producing cartridges usually fired from rockets or rope bangers, or on aerodromes from modified pistols or shotguns, which produce a loud bang and emit flashes of light. They include shell-crackers, screamer shells and whistling projectiles, exploding projectiles, bird-bangers and flares. Cartridges are projected from a shotgun with a range of 45-90m, or pistol (range approximately 25m), and then explode.

Pyrotechnic-charged cartridges (e.g. Bird Frite®) provide a combined visual and aural stimulus. A pyrotechnic shell is fired from a conventional 12-gauge shotgun, which produces a small report when the trigger is pulled, and a much louder report when the shell explodes after leaving the gun. The explosion of the shell produces a bright flash and smoke. Most species of birds immediately take flight in response. Best practice is to aim the shell so as to burst a few metres from the target birds (e.g. Anon. undated). Using 12-gauge blanks in amongst the more expensive pyrotechnic cartridges can reduce the costs of this technique. In Australia, the use of Bird Frite® in combination with gas cannons, when applied correctly, is considered to be effective against a range of species, including parrots and cockatoos (DEC 2007).

Rope-firecrackers are inexpensive, commercially available and require little manpower (Booth 1994). Fuses of the firecrackers are inserted through an 8 or 9.5 mm cotton rope. The rope is ignited and as it burns the firecrackers produce a series of loud explosions at approximately 20 minute intervals (Henley 1992). Their noise levels can be enhanced by placing them inside empty oils drums (P. Haynes pers. comm.). Weather conditions can affect the burning speed of the rope and there is also a danger of creating a fire hazard.

In 1994, the NFU (in association with BASC) undertook a questionnaire survey of its membership to obtain an account of the problems caused by woodpigeons (Smith *et al*. 1995). The survey encompassed nearly 1,000 farmers throughout England, Scotland and Wales with 964 returns. Of these respondents, 80% reported the use of bangers; 63% of these rated bangers as moderately effective and 6% as highly effective.

Pyrotechnic rockets were effective at reducing gull and corvid numbers at landfill sites (Baxter and Robinson 2007). However, the frequency of firings had to be increased over the 12-week study period to maintain effectiveness.

Bio-acoustics and other acoustics

Bio-acoustic deterrents are sonic devices that transmit sounds of biological relevance: recorded bird alarm and distress calls. In general, alarm calls are given when birds perceive danger, whilst distress calls are vocalised when birds are captured, restrained or injured. These calls are species-specific and can cause conspecifics to take flight. Alarm and distress calls, however, may also evoke a response in other species that are taxonomically related to the call-producing species (Baxter *et al*. 1999) or which closely associate with it. Responding to alarm/distress calls has a high survival value, therefore such biologically meaningful sounds are more repellent and more resistant to habituation than other sounds (Bomford and O'Brien 1990, Harris and Davis 1998). However reactions to distress calls can vary both with the species and the individual bird (Schmidt and Johnson 1983); in some groups such as gulls, alarm/distress calls initially act as an attractant with birds approaching the source, apparently to investigate, before flying away (Brough 1968). Although such systems can be placed in a field on a random timer sequence, birds will quickly habituate to such a device if it is not frequently moved, and it may cause noise nuisance in adjacent areas. A manually-operated system that is used only when birds are present will be more expensive but will also be more effective and less likely to become a nuisance.

With all systems, sound transmission will be influenced by ambient temperature, wind direction and reflections from surrounding features such as buildings, and such factors need to be taken into consideration when siting sonic devices. Success requires high-quality recordings of suitable calls and specific calls changed frequently (Bomford and Sinclair 2002). The use of predator calls to disperse crows (*Corvus corone)* from roosts showed that the effectiveness varied with specific predator call, camouflage of device, sound quality and volume, and the length of play and pause periods of the recording (Koyuncu and Lule 2009). As with most methods of bird control, an integrated approach using a variety of techniques is likely to be more effective and reduce habituation rates (Schmidt and Johnson 1983).

Sonic systems that produce a variety of electronically-produced sounds are also commercially available. The range of loud and sudden noises they produce can frighten birds but as they have no biological meaning the risk of habituation is great (Harris and Davis 1998). With static systems, frequent changes in location and adjustments to the sounds can reduce habituation (Harris and Davis 1998).

Hunter (1974) found that a device which transmitted electronically synthesised sound provided some limited and transient protection to a field of sprouts from woodpigeons. After four days light damage had occurred in the field with very little within 100 feet of the device. After three weeks moderate damage had occurred almost up to the device; there was negligible surrounding undamaged area.

There is no evidence that ultrasonic devices deter birds (Bomford and O'Brien 1990). In fact, evidence indicates that most species of birds do not hear in the ultrasonic range (>20kHz) (Erickson *et al*. 1992, Harris and Davis 1998) and so there is no biological basis for their use. Haag-Wackernagel (2000) and Woronecki (1988) both found that pigeons were undeterred by an ultrasonic system.

4.3.3 Chemical repellents

Taste repellents

Taste repellents can be divided into primary and secondary repellents. Primary repellents are agents that are avoided upon first exposure because they smell or taste offensive or cause irritation. Secondary repellents are not immediately offensive, but cause illness or an unpleasant experience following ingestion that the bird relates to the taste of the treated-food (conditioned taste aversion). In future encounters the bird will avoid the treated food. Secondary repellents are usually regarded as the more effective form of deterrent.

In the late-1960s and early-1970s in England, anthraquinone, methiocarb (secondary repellents) and thiram (primary repellent) were not effective in decreasing the extent of woodpigeon grazing on sugar beet in small-plot (2.5m x 6.1m) trials (Dunning 1974).

Cinnamamide (primary repellent) has been shown to modify the foraging behaviour of free-living birds, with woodland edge species (principally greenfinch *Carduelis chloris* and tits) avoiding treated bait (Gill *et al*. 1998a). In a subsequent pilot trial, woodpigeon damage to oilseed rape sprayed with cinnamamide was reduced: the proportion of plants with damaged inner leaves was reduced by ≤44% and the number of plants with severely damaged outer leaves by ≤57% (Gill *et al*. 1998b). The persistence of cinnamamide on the leaves was poor; declining by up to 30% after three days and undetectable after 13 days. A later trial, using a more weatherproof and persistent formula, reduced the damage on treated plots by 73% (Cotterill *et al*. 2001). Cinnamamide is not registered as an avian repellent in the UK.

Generalist pests, including woodpigeon, have been shown to be deterred by increased levels of glucosinolates (GSLs) in the leaves of oilseed rape (Giamoustaris and Mithen 1995). In trials with fields sown with developed lines of oilseed rape with enhanced GSLs in their leaves, the majority of test fields received reduced levels of woodpigeon grazing compared to surrounding fields (Cotterill *et al*. 2001). With so many confounding factors it was not possible to conclude which was the most important in reducing grazing damage. Overall, however, the evidence suggested that the altered taste was having some repellent effect on woodpigeons.

Tactile repellents

Tactile repellents involve the use of sticking substances that discourage birds because of their ‘tacky’ feel. They can be applied as clay-based seed coatings, or as pastes and liquids on ledges and other roosting structures to deter settling birds. Tactile repellents to deter perching contain polybutene and may contain other substances to induce a chemical reaction that gives the bird a mild ‘hot foot’ (Transport Canada 1994). Such ‘hot foot’ repellents are not licensed for use in the UK.

Repellent gel

Over recent years another type of repellent has been developed and marketed as ‘bird free optical gel’. This product is a non-toxic gel that is laid in small dishes and fixed to problem areas. The gel appears orange to humans. The visual spectrum of birds, however, includes ultra-violet light and it is claimed by the manufacturers that through an optical illusion the gel appears to birds as fire, which they avoid. The gel is used in urban environments largely to deter pigeons and gulls from buildings. In an agricultural setting there is the potential to deploy the gel on structures that woodpigeons habitually use for roosting.

A recent study, however, concluded that the gel showed a restricted, transient repellent effect but failed to prove the claimed complete effectiveness (Stock and Haag-Wackernagel 2014).

Repellents in the UK

At present, only one chemical is registered for use in the UK as a bird repellent by the Chemical Regulations Directorate. Aluminium ammonium sulphate is marketed under several product names and can be used in ‘agricultural premises, all top fruit, broad beans, bush fruit, cane fruit, carrots, flowerhead brassicas, forest nursery beds, forestry plantations, grain stores, leaf brassicas, peas, permanent grassland, spring barley, spring field beans, spring oats, spring oilseed rape, spring wheat, strawberries, sugar beet, winter barley, winter field beans, winter oats, winter oilseed rape, winter wheat; all edible crops (outdoor), all non-edible crops (outdoor), amenity grassland, forest, hard surfaces, managed amenity turf, amenity vegetation’ (The UK Pesticide Guide 2012).

Bruggers (1979) found some evidence for the efficacy of aluminium ammonium sulphate in protecting ripening crops (sorghum, miller, rice) in West Africa. Tracey *et* *al*. (2007), however, report no evidence for its efficacy in deterring birds from feeding.

4.3.4 Fertility control

There is growing interest in using fertility control to manage wildlife and associated conflicts (Massei and Cowan 2014). Nicarbazin is a bird-specific oral contraceptive which acts through interfering with egg production and reducing hatchability. It is registered in the USA for use with Canada geese and feral pigeons and in Italy to control urban populations of feral pigeons. The treatment is delivered to birds as a constituent of ready-to-use bait.

In captive trials, pairs of nesting pigeons hatched 59% fewer eggs when supplied with Nicarbazin bait compared to a pre-treatment period (Avery *et al*. 2008). In a post-treatment phase, nestling production recovered to that during pre-treatment.

In Italy, the population size of colonies of feral pigeons treated with Nicarbazine decreased by a mean of 6-39% over periods of two to seven years. For the four cities in which counts were conducted at six-monthly intervals (two were counted annually) the reduction in numbers of pigeons in the first 18 months averaged 28-50%.

Elsewhere, evidence for population-level effects is equivocal; although this may be influenced by the necessity for Nicarbazin to be fed continuously before and during egg-laying to be effective (Massei and Cowan 2014).

A significant challenge in the application of fertility control is ensuring that only the target species is treated, and in the case of Nicarbazin that delivery is persistent throughout the critical egg-production period. These criteria can be met far more easily for feral pigeons in an urban environment than in the case of woodpigeons in an agricultural setting.

In the UK, at the present time, no fertility control chemicals are licensed for use in wild birds. Registration of Nicarbazin for use in the UK would be a lengthy and expensive process but potentially less so than for other un-licensed products since the precedence of registration in another EU-member State (Italy).

4.3.5 Physical deterrents and exclusion

Nets

The use of nets to cover crops and totally exclude birds is considered one of the most effective bird deterrents. It is used to prevent birds from feeding on high value crops such as cherries, blueberries and grapes (Grun 1978, Biber and Meylan 1984 both cited in Harris & Davis 1998).

Although netting has proved effective (Stucky 1973, Foster 1979) the cost of materials and perceived difficulty in erecting and removing the netting has discouraged many growers from adopting this method (Fuller-Perrine and Tobin 1993). For high-value crops, however, the deployment of costly protection measures may be warranted. In the USA, Fuller-Perinne and Tobin (1993) evaluated the costs associated with deploying and removing netting from vineyards with tractor-mounted mechanical units. The netting system provided cost-effective protection where high levels of damage were anticipated, but may not be practical in small vineyards or where damage levels are typically low. The system had some issues with vine shoots growing through and becoming entangled in the netting, which hampered net removal and sometimes caused net tearing. In the Marlborough region of New Zealand, a concern of growers was that the quality of grapes may be affected by the increased humidity and shading from netting (Boyce *et al*. 1999a). In New South Wales, Australia, the use of netting in vineyards where damage levels averaged 15% has been shown to be a profitable investment (Tracey *et al*. 2007).

In the USA, Tilman *et al*. (2000) concluded that where losses to birds are regular and substantial it is likely that a cost-effective netting scheme could be devised; particularly if costs are spread over the lifetime of the net. In Australia, economic analyses indicated that netting can be cost-effective for high-value crops even when damage levels are not significant; but not for low-value crops (Department of Environment & Conservation 2007). Netting of some high value vegetable seed crops and of soft fruit crops such as grapes is commonplace in New Zealand (Coleman and Spurr 2006).

Suspended lines/tapes

Studies investigating the effectiveness of suspended tapes or lines in deterring birds from crops have provided mixed results (Pochop *et al*. 1990). For example, reflective tape was effective in deterring red-winged blackbirds *Agelaius phoeniceus* and brown-headed cowbirds *Molothrus ater* from ripening crops (Bruggers *et al*. 1986; Dolbeer *et al*. 1986), whilst brent geese *Branta bernicla* were deterred from fields of winter wheat by suspended red fluorescent tape (Summers & Hillman, 1990). Conversely, Tobin *et al*. (1988) found that birds were not deterred from eating blueberries or from flying into taped plots, and Conover and Dolbeer (1989) found that tapes in cornfields did not reduce damage by red-winged blackbirds.

A number of factors are believed to influence the effectiveness of tapes and lines in deterring birds, including the coverage and configuration of lines, the size of the bird species, attractiveness of the site and the availability of alternative resources. In some cases where lines were ineffective, large spaces between rows of tapes may have allowed birds to avoid the tapes and enter the crop (Tobin *et al*. 1988; Conover and Dolbeer 1989).

Although a close configuration of tapes may be successful in terms of crop protection, it can interfere with crop husbandry and increase costs in terms of labour and materials. In such situations, this technique is best suited to small areas of high value crops. Good maintenance of the tapes is essential in order to prevent them from becoming tangled in the crop, and to stop gaps resulting from broken tapes being exploited as entry points by birds.

For crows, the colour of lines has been shown to influence the deterrent effect. Crows exhibited a higher risk of collision with matte black wire-lines compared to metallic wires (Honda 2012). Deterrence was also higher with matte black lines than metallic lines; the author hypothesized that lower visibility lines incur higher collision risk and thus have a greater deterrence effect on the crows.

4.3.6 Habitat modification

Decoy crops

Planting decoy or sacrificial crops is a technique used to divert feeding flocks away from the susceptible crop. The effectiveness of this technique varies with the bird species and crop type. Sacrificial crops should be used in conjunction with scaring deployed at the susceptible crops as part of an integrated wildlife management programme. Decoy crops should be made available prior to the problem birds first arriving, as it is more difficult to shift birds to the sacrificial crops if they develop a pattern of feeding on the susceptible crops.

Strips of kale are sometimes planted along the edges of fields for use by game birds; these also form valuable decoy crops for woodpigeons (Inglis & Haynes unpublished data). A sacrificial crop can be created along the edges of oilseed rape fields by simply sowing the rape at a lower density in these areas; woodpigeons prefer to forage in the less density areas of the crop (Inglis & Isaacson unpublished data).

There is, however, a potential danger in providing supplementary food, which is that in the long-term it may lead to an increase in species-density, if the availability of food resources is limiting numbers. Supplementary food may also increase the survival rates of young birds and exacerbate the long-term problem.

Decoy feeding programmes have to be carried out at sufficient intensity. In Australia, a preliminary trial involving the provisioning of 20 tonnes of oats to 4,000 long-billed corellas was cost-effective in protecting commercial crops. In the following year, however, when local farmers took over control of the decoy feeding programme it failed. This was due to the farmers not being consistent or persistent enough with the provisioning regime to keep birds at the feeding site and away from the commercial crops (Alexander 1990 cited in Bomford and Sinclair 2002).

Perch removal

Natural roosting substrate can be made less attractive to birds by thinning or pruning vegetation and trees (Fiedler *et al*. 1991; Booth 1994). In deterring galahs from a field of wheat a combination of habitat manipulations were deployed (Jarman and McKenzie 1983). Birds were discouraged from perching on the field's perimeter fence by the erecting of a hessian screen. Alternative perches were erected 50m from the crop, beneath which alternative food was supplied. No bird damage occurred in the crop.

Nesting habitat

Woodpigeon nesting density varies between different habitats. Murton (1960) found that hedgerow supported the highest number of nests per acre and deciduous woodland the lowest. Inglis *et al*. (1994) investigated the breeding density of woodpigeons in hedges and woods of different size, shape and composition in order to provide advice on the type of woodland least favourable for nesting woodpigeons. Hedgerows (containing trees) had a significantly higher nest density than woods; small woods <5ha) had higher nest densities than medium woods (5-10ha) which in turn had higher densities than large wood (>10ha); nest density increased with increase in the proportion of edge habitat of the wood.

In order to limit the growth in local woodpigeon numbers it was concluded that wherever possible to plant a single large woodland rather than many dispersed small woodland blocks. Extending existing woodland rather than creating new copses and shelterbelts would be the preferred option. The authors did stress, however, that whilst these actions would benefit limiting the local woodpigeon population, networks of woodlands linked by hedgerows represented important ecological networks beneficial to biodiversity.

Planting patterns

Inglis *et al*. (1989) suggested that in areas with high woodpigeon numbers growers should consider switching from autumn-sown oilseed rape to spring-grown. The rationale was that as spring-sown rape is usually sown between mid-March and April and harvested around mid-September it is grown during a period when alternative foods are available to woodpigeons. The availability of alternative food resources would facilitate greater effectiveness of techniques used to scare the woodpigeons from the fields of oilseed rape. The lower yield returned from spring grown rape compared to autumn-sown rape would be offset, to a degree, by the reduction in severe woodpigeon damage.

A 1994 questionnaire survey of farmers revealed that of the 75% of respondents that provided information 38% reported that woodpigeons had precipitated changes in cropping patterns; 37% reported no change (Smith *et al*. 1995). Changes in crop management included: avoidance of vulnerable crops near woodland or in isolated areas, switch to spring-sown from winter-sown oilseed rape, abandonment of growing vulnerable crops, particularly oilseed rape and beans/peas. The outcome of these changes was not reported.

In Smith *et al*.'s (1995) survey a significant proportion of holdings with specific main crop types reported no problems with woodpigeons. For example, 43% of cereal, 19% of beans/peas and 17% of linseed holdings were without problems. It is not known to what extent and in what context holdings without problems differed from holdings with problems. Such information would be beneficial in the formulation of crop damage mitigation strategies.

Screening crops

Screening crops involves deploying vision barriers, either natural or artificial, that prevent birds having a clear line of sight; the technique is used against cockatoos in Australia (DEH 2007). When used in combination with other habitat manipulations screening was effective in deterring Galahs from a wheat field (Jarman and McKenzie 1983).

Topography

Across 52 fields of oilseed rape distributed throughout central and southern England, the amount of woodpigeon damage (measured by visual estimates) was inversely related to the level of bird scaring and to the proportion of the field boundary bordered by homes and/or roads (Inglis *et al*. 1989). The amount of damage was also positively correlated with the presence of a woodpigeon roost within 1km of the field.

In the Vale of Evesham, the severest woodpigeon damage to Brussels-sprouts and cabbages occurred on fields that were peripheral to the main concentration of the crop (Murton and Jones 1973).

4.3.7 Lethal

Shooting

Woodpigeons can be shot throughout the year under a Natural England General Licence for the purpose of preventing serious damage to livestock and their foodstuffs, crops, vegetables, fruit, growing timber; and for preventing the spread of disease; and for the purpose of preserving public health or safety. Woodpigeons are killed during three types of shooting: decoying/flighting, roost shooting and 'other' shooting (rough shooting, game shooting and wildfowling) (Reynolds and Harradine 1996; Harradine and Reynolds 1997). Decoying/flighting and roost shooting involve gunmen firing from concealed positions.

In 1994, the NFU (in association with BASC) undertook a questionnaire survey of its membership to obtain an account of the problems caused by woodpigeons (Smith *et al*. 1995). The survey encompassed nearly 1,000 farmers throughout England, Scotland and Wales with 964 returns (1.1% of the NFU/SNFU farming membership). Shooting was the most frequent control method used being undertaken by 97% of respondents. Seventy-five percent rated the effectiveness of shooting as moderate to high; reported by the authors as markedly ahead of the other main protective measures, bangers and scarecrows (although 68% reported bangers to be moderately or highly effective). There is, however, no objective data to compare the effectiveness of shooting as a means of crop protection with that of other techniques; mainly because shooting is used in conjunction with other techniques and the relative efficiencies cannot be disentangled (CSL 2000). Inglis *et al*. (1989) found that shooting effort was not significantly correlated with damage levels to oilseed rape and that adding varying degrees of shooting pressure to a field already containing a scaring device had little effect; it was acknowledged, however, that the measurement of shooting effort was potentially not very accurate.

Smith *et al*. (1995) revealed that the monthly pattern of shooting tended to correspond with crop damage patterns, with a peak of shooting visits during winter and a smaller peak during summer. A separate survey of BASC members confirmed this seasonal pattern, with the highly seasonal roost shooting and 'other' shooting emphasising the frequency of winter shooting (Reynolds and Harradine 1996; Harradine and Reynolds 1997).

In a review of the use of wild living resources in the UK, Murray and Simcox (2003) reported an estimate of 5-7 million woodpigeons shot each year. An alternative estimate of 3.6 million woodpigeon shot in 2004 was provided by PACEC (2006) as part of an economic and environmental assessment of sporting shooting in the UK. An updated report (PACEC 2014) estimated at least 1.1 million woodpigeons shot in 2012/13. Around 70% of BASC members participated in shooting woodpigeons (1997/98), with an additional large number of farmers and non-BASC members also shooting (BASC 2001); estimated at more than 200,000 people shooting woodpigeon in the UK every year (www.basc.org.uk). Shooting over decoys accounts for the majority of woodpigeons killed; the majority of decoying visits are to oilseed rape (BASC 2001).

Despite its unchanged status as a quarry species, the woodpigeon population has increased regularly in abundance despite heavy shooting. An analysis of recoveries of birds ringed between 1965 and 1990 showed that hunting had no deleterious effects on either population size or annual survivorship (Aebischer 1995).

Field studies of a variety of species have shown that, due to compensatory demographic processes, predation or human harvest may not influence spring-breeding or pre-harvest season densities (Boyce *et al*. 1999b). Following predation or harvest, compensation mediated by density dependence, can occur either through a decrease in natural mortality, or alternatively via an increase in reproductive output (natality) as a consequence of an increase in the availability of food for survivors.

Murton *et al*. (1974) showed that during the course of the winter woodpigeons depleted food resources so that by late winter in unharvested woodpigeon populations rates of mortality were very high. When winter battue shoots (coordinated roost shoots) reduced density each individual woodpigeon that survived hunting had sufficient food to ensure over-winter survival. As a result, most of the woodpigeons that survived hunting also survived over winter. Spring breeding densities in hunted populations were actually higher than in non-hunted populations. Shooting, however implemented, served only to remove a small, expendable and surplus fraction of the population; changes in the area under clover and oilseed rape had much greater effects on their numbers (Jones and Jones 1984).

In the same study, decoy shooting was also undertaken (Murton *et al*. 1974). Although total mortality during late summer-winter was increased by shooting there was no clear indication of a reduction in the size of the subsequent breeding population.

In the Vale of Evesham (winters 1968/69 to 1970/71) shooting to protect fields of cabbages and Brussels-sprouts was not effective in terms of the numbers of woodpigeons killed (Murton and Jones 1973). The incidence of crop damage did not differ between study areas where shooting did and did not occur. It was concluded that in circumstances in which woodpigeons were difficult to target (resulting in few birds killed) the shooter's main value lay in scaring pigeons from the crops. The authors raised the point that although a shooter roving around fields was the least effective method of killing woodpigeons it was the most effective way of keeping birds off the crops. This emphasised the importance of judging the effectiveness of pest control in terms of damage prevented and not the numbers of animals killed.

The change in the pattern of woodpigeon population regulation with changes in crop patterns introduced from the mid-1970s had potential implications for shooting as a method of control (Inglis *et al*. 1990). In the 1960s spring-sown barley was the major crop with relatively small areas of winter-sown wheat. The size of the woodpigeon population that persisted from the November post-breeding peak in an area was regulated by the size of the areas of winter-sown cereals and the availability of clover ley in January and February (exacerbated by any snow cover). As discussed, with the population size fixed by the availability of winter food the battue shoots of the 1960s simply served to reduce the competition for resources and allowed more birds to survive over winter than in the absence of shooting. From the mid-1970s winter-sown cereals predominated and with the introduction and marked expansion of oilseed rape woodpigeon populations were no longer limited by over-winter mortality from starvation. Winter shooting now, therefore, has the potential to reduce local woodpigeon numbers (Inglis *et al*. 1990; CSL 2000). The effectiveness, however, will be dependent on factors such as the scale of immigration into the area and the strategic nature of the shooting. In addition, the effect of any localised winter shooting will be constrained by the winter dispersion of juvenile birds that will return to breed the following spring (Haynes *et al*. 2003).

CSL (2000) cited NFU data that indicated approximately 66% of shooting occurred during the winter months. Mathematical modelling, however, has indicated that shooting during summer has a far greater long-term effect on woodpigeon numbers than does winter shooting (CSL 2000). During the summer, shooting removes members of breeding pairs resulting in nest desertion and predation of eggs and young. Shooting at this time of year will also remove juveniles that would otherwise disperse during autumn to return the following spring (Haynes *et al*. 2003). Summer shooting, therefore, has the potential to have a far greater influence on population size than winter shooting. In addition, the local birds removed are less likely to be replaced via immigration during summer when home ranges are smaller than in winter (CSL 2000; Haynes *et al*. 2003). Similarly, modelling has shown that an annual shooting season that follows the period of density-dependent mortality is the most effective control strategy because it simultaneously removes adult and juvenile woodpigeons (O'Regan *et al*. 2012).

Stupefying baits

In the UK, the Wildlife and Countryside Act (1981) permitted the use of certain stupefying baits, under license, against birds listed on the General Licence. This method of control had been used mainly against feral pigeons, house sparrows *Passer domesticus* and gulls (RDS 2005). Suitable bait is treated with a stupefying drug (alphachloralose) and placed were the target species normally feed. A period of pre-baiting may be required using untreated bait. On taking the treated bait the birds become stupefied and were collected and humanely despatched.

During 1959-60, a series of field trials investigated the use of baits treated with alphachlorolose to capture woodpigeons grazing on a variety of crops (Murton 1962; Murton *et al*. 1963b). In total, 57% (n = 1,408) of birds narcotised were woodpigeons. The risk to other species was lowest on pasture, where 74% of birds captured were woodpigeons. From observations of feeding flocks it was concluded that narcotic baiting techniques could be highly efficient (32%-62% capture efficiency). It was estimated that the method was cheaper than nest destruction and shooting.

Bait treated with alphachloralose has also been used at nests to narcotise and capture over 100 woodpigeons for the purposes of examination and marking (Murton *et al*. 1965).

Under a recent EU revue programme, however, alphachlorolose did not get inclusion for use in bird control; the last date of permitted use for bird control products was 31st January 2013.

Trapping

In urban environments, cage traps are one method used by pest controllers to remove feral pigeons. The traps are repeat-capture and permit the removal of multiple birds. In an agricultural environment adult woodpigeons have been caught in whoosh nets for the purpose of ringing and release for research studies. For effective crop protection purposes larger-scale removal would be required involving the simultaneous capture of dozens or scores of birds. Cannon-netting is a technique designed to simultaneously capture large numbers of birds. Its applicability to the regular capture of large numbers of woodpigeons is untested.

Nest and egg control

In some situations, egg control may be used to limit population size and reduce the rate at which bird numbers increase (RDS 2005).

Historically, the destruction of woodpigeon nests (and contents) was carried out under the rabbit clearance society scheme. This was initially a Government grant-aided scheme that aimed to support coordinated control of rabbits in order to maintain a low level (post-myxomatosis) or further reduce numbers (McKillop 1988). A number of rabbit clearance societies also undertook destruction of woodpigeon nests as part of its overall pest control plan (Inglis *et al*. 1994).

The destruction of birds' nests and their contents alone is not always successful as birds will often rebuild nests at the same site, or a nearby site, whilst replacement clutches of eggs can be laid. The risk of rebuilding and relaying can be minimised by leaving nests and eggs in place, whilst preventing the eggs from hatching. The pricking of eggs with a needle allows bacteria to enter the egg as well as desiccate its contents (French and Parkhurst 2001), but some pricked eggs may still hatch, and birds may abandon clutches to relay. Egg oiling is a cheaper, more effective and more humane method of egg control. It involves coating the eggshells with oil such as liquid paraffin (Baker *et al.* 1993). This stops air from passing through the shell to the embryo and prevents it from developing properly. This technique has been used successfully against, for example, Canada geese (Baker *et al*. 1993) and ring-billed and herring gulls (Christens and Blokpoel 1991). Eggs can also be replaced with hard-boiled or wooden replicas (Baker *et al.* 1993). The latter techniques, however, are far more labour intensive than nest destruction.

Given the population size and density of breeding pairs, nest and egg control in order to control woodpigeon numbers would require coordinated action over a relatively large area.

Murton (1960) described trials of woodpigeon nest destruction in East Anglia during 1956 and 1957. In 1956, during three nest destruction periods (mid-late summer, early-autumn and late autumn) the mean effort per occupied nest was 0.4 man-hours for the first two periods and 3.2 man-hours for the third period. In 1957, in further trials involving only two nest destruction periods, it was estimated that about 63% of young expected to leave their nests were prevented from doing so. It was further estimated that if three periods of nest destruction had been carried out an 80% success rate could have been achieved. It was concluded that nest destruction appeared to be *'..a little more expensive than shooting…'* but that organised nest destruction appeared to be more efficient than shooting and could be performed by relatively less skilled operators.

During a study of woodpigeon shooting, Murton *et al*. (1974) showed that the percentage of woodpigeon eggs predated was highest for years in which many adults were shot during the main breeding season of July-September. The main egg predator was jays *Garrulus glandarius*. Egg predation was lowest during years when predatory birds were intensively controlled. In the 1980s and 90s corvids and grey squirrels were the main egg predators (Inglis & Isaacson unpublished data).

More recently, however, modelling has indicated that egg control would be a less effective strategy for reducing woodpigeon numbers than an annual harvest season (O'Regan *et al*. 2012).

4.3.8 Integrated management

Integrated pest management involves the simultaneous and/or sequential use of a variety of different deterrent techniques (visual and/or auditory). The replacement of one deterrent device with another or the deployment of an additional device to supplement a first will prolong the habituation process.

In south-western Australia, recommendations for controlling damage by black cockatoos, are to deploy gas guns in combination with motor cycle harassment and/or shooting to scare (using pyrotechnic shells), and to vary the combinations of treatments. It should be borne in mind that although combining treatments is more effective it will also be more costly (Tracey *et al*. 2007). It was recommended that deterrence should be initiated as soon as birds first begin foraging on a crop and not to allow the establishment of a foraging habit, otherwise birds will be more resistant to being repelled (e.g. anon).

In England, an example of the integrated use of scaring devices to successfully protect a 30ha field of oilseed rape was described by Inglis *et al*. (1989). In December, as soon as patches of damage first appeared, a single gas cannon was deployed and subsequently moved around the field to spread the grazing pressure so that no one area suffered severe damage. Then from mid-January (the start of the critical damage period) a variety of scarers was used in rotation.

In addition to scaring devices, different categories of mitigation measure are also frequently applied in conjunction with deterrents. For example, the deployment of visual and auditory deterrents at the site of the vulnerable crop may be augmented by the provision of a sacrificial feeding area at a distance from the site. Scaring birds from a crop will be more effective if there are alternative foraging opportunities available.

The most frequent component of woodpigeon management strategies has been shooting, involving one or more of the techniques, flighting, roost shooting or roaming (rough shooting).

4.3.9 Evaluation of management and control measures

Of the 54 documents relating to avian management and control (Appendix 5), 26 involved Columbidae (pigeons and doves) and were considered for more detailed evaluation (Appendices 6 & 7). These 26 studies included 26 treatments that allowed some evaluation of their relative effectiveness: auditory and/or visual (8), chemical (7), fertility control (4) and lethal (7).

Chemical repellents and fertility control were relatively the most effective, followed by visual/auditory deterrents and lethal techniques were least effective (Figure 4.4). The sample sizes for all techniques were very small.

In terms of application, however, the categories of chemical repellents and fertility control almost without exception involved substances that are not registered for use in GB. In the lethal category, three of the four ineffective treatments related to historical winter battue shooting.

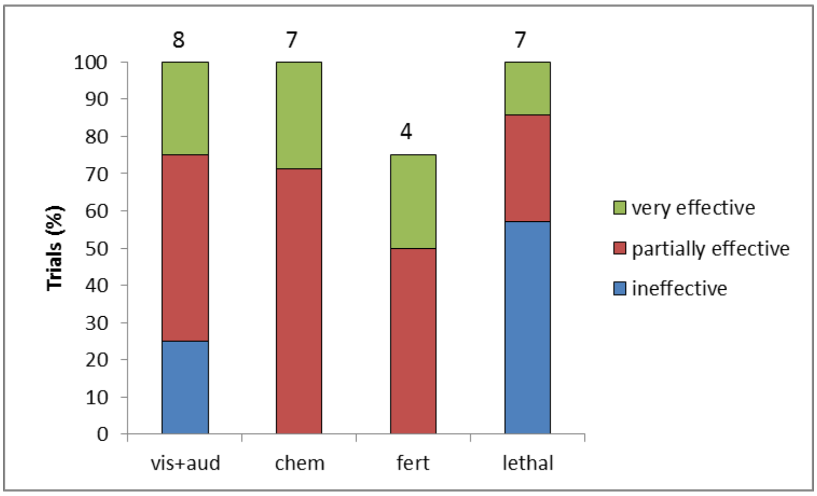

Figure 4.4 The relative effectiveness of deterrents of different categories, as found in 26 experimental treatments on Columbidae. 'Very effective': >50% reduction in damage or number of birds; 'partially effective': up to 50% reduction in damage or numbers of birds; 'ineffective': no significant reduction in damage or number of birds.

The 26 studies involving Columbidae also included a number of further cases where any evaluation of their effectiveness was not possible due to relevant data from field applications not presented, or involved interpretations from correlational analyses (e.g. effect of available nesting habitat).

Only four studies, that used techniques legal in GB, provided some economic analysis of the application of control – all from 40 years ago.

The potential benefits and costs of the different categories of avian management methods is summarised in Table 4.4 below. A summary of the general effectiveness of individual mitigation techniques and whether they have been used against woodpigeons is presented in Table 4.5.

Table 4.4 Summary of different categories of avian control methods.

Category	Application	Benefits	Costs
Scaring	- Various visual and auditory devices - Most effective when used in combinations	- Individual techniques are relatively cheap - Humane	- Continual scaring with rotation of techniques in combination can become expensive - Noise (e.g. gas cannons) and safety issues (e.g. pyrotechnics) with some techniques
Hazing	- Active deterrence involving humans, dogs, radio-controlled models, falconry or lasers	- Pursuit and deterrence prevents birds settling - Techniques more threatening	- Can be expensive (capital costs and/or trained operatives) - Can be limitations in deployment (e.g. falconry)
Repellents	- Applied onto crops or onto bait broadcast amongst the crop, or onto roosting structures	- Promotes active avoidance by birds - Non-lethal	- Issues with weathering limiting persistence on the crop - Only one licensed product in UK
Fertility control	- Presented on treated bait at feeding stations. - Species-specific feeders	- Long-term reduction of population - Humane	- Possible exposure of non-target species - Technique in development stage - Can require continuous application - No product licensed in UK for wild birds
Netting/covers	- Enclose crops with temporary or permanent netting or other cover	- Effective and long-term - Humane	- High initial capital outlay. - Not economic for low-value crops - May obstruct farm practices. - Requires maintenance. - Reduces air movement so may increase risk of crop diseases
Habitat modification	- Reduce the attractiveness of the crop site - Alternative attractive food source is supplied away from the sensitive crop (scaring should continue at the sensitive crop) - Remove/modify habitat selected by birds (e.g. nesting/roosting sites)	- Long-term - Non-lethal - Humane	- Potential actions are site-specific - Sacrificial food must be continually available during damage season - The additional food may attract increased numbers of birds to the area, increasing the risk to the crop - Undesirable environmental impacts
Lethal	- Birds can be shot or trapped at the site of damage or at roosts site - Nest and egg removal/control	- Effective if used intensively to reduce numbers - Humane if carried out correctly	- Requires detailed attention to safety, particularly near urban areas - Must be applied intensively. - Birds may change behaviour to avoid shooters/traps

Table 4.5 Summary of avian control techniques, overall general perceptions of effectiveness and whether studies have been undertaken on Columbiformes.

Category	Technique	Effective	Notes
Auditory	Gas cannons	Yes	Effectiveness depends on number and mode of deployment; has been used effectively against ***woodpigeons*** as part of an integrated strategy.
	Pyrotechnics	Yes	Effectiveness depends on number and mode of deployment; increased firings can become expensive; no examples with pigeons.
	Bioacoustics	Varied	Distress calls effective against gulls and corvids at landfill sites; used globally at airfields to disperse gulls; ***woodpigeons*** have no such calls.
	Acoustics	Varied	Habituation is quick. Electronically synthesised sound protected sprouts from ***woodpigeon*** damage but habituation within 3 weeks.
	Ultrasonics	No	No biological basis for birds to detect ultrasonics; ***pigeons*** undeterred.
Visual	Lasers	Varied	Successfully dispersed a number of species; context and species-specific response; in captivity ***rock doves*** habituated within several minutes.
	Human-scarer	Yes	Brent geese cost-effectively deterred from winter crops by full-time scarer; human presence more effective than goshawk at deterring ***woodpigeons*** from brassica fields.
	Dogs	Yes	Effective at deterring ground foraging birds from airfields and agricultural crops; can be expensive and labour-intensive if handler required. No examples with pigeons.
	Scarecrows	Varied	Short-term (days); best combined with other visual & auditory techniques; as such ***woodpigeons*** deterred from large area of OSR for 4 weeks.
	Predator/raptor model	Varied	Need to be realistic and incorporate movement and 'threat'; model vaguely resembling raptor ineffective against ***woodpigeons*** on clover ley.
	Corpses	Yes	***Woodpigeon*** carcasses (outstretched wings) provided significant protection over a 9-week period; pairs of wings and 3D-models were also effective; silhouettes were not effective; carcasses have to be in good condition.
	Intraspecific displays	Yes	Presentation of ***woodpigeon*** white wing markings on carcasses, single wings or painted models reduced crop damage (up to four weeks).
	Eye-spots	Limited	Can deter starlings; habituation rapid; no examples with pigeons.
	Balloons	Varied	Plain balloons not very effective (rapid habituation); eye-spots printed on balloons may increase effectiveness; no examples with pigeons.
	Kites/hawk-kites	Yes	Reduced ***woodpigeon*** damage considerably over extended period of 3-months; labour intensive (re-launching).

Category	Technique	Effective	Notes
	Falconry	Varied	Promising at airports; relatively expensive (handler); goshawk failed to deter ***woodpigeons*** from brassica fields for any length of time
	Radio-controlled aircraft	DD	Claimed to be relatively effective over airfields, agricultural areas, fisheries and landfill sites; no examples with pigeons.
	Radio-controlled raptor model	DD	Claimed to be relatively effective; improved when distress calls of target species played; no examples with pigeons.
	Mirrors/reflectors	Limited	Only effective in sunlight; some indications that red mirrors more effective than plain; no examples with pigeons
	Tapes	Varied	Species and context specific; humming line protected field of cabbage for 1 week; no examples with pigeons
	Flags, rags, streamers	DD	No examples with pigeons.
Category	**Technique**	**Effective**	**Notes**
Habitat	Vegetative management	Yes	Used extensively on airfields; ***rock doves*** more attracted to short grass.
	Decoy crops	Yes	Species and context specific; used in conjunction with deterrence on vulnerable crop; no examples with pigeons.
	Perch removal	DD	Deter birds from perching/roosting near vulnerable resources; no examples with pigeons.
	Nesting habitat	DD	Limit availability of preferred nesting habitat; for ***woodpigeons*** plant single large woodland rather than many dispersed small woodland blocks; but detrimental in terms of ecological networks.
	Crop management	DD	For woodpigeons, avoid planting susceptible crops in vulnerable areas (e.g. next to woodland, isolated fields); switch to less vulnerable crop.
Exclusion	Nets	Yes	Effective but costly; cost-effective where high damage levels and/or high value crops; no examples with pigeons.
	Lines/Tapes	Varied	Effectiveness related to coverage and configuration; indications that the colour of the lines affects deterrence; no examples with pigeons.
Chemical	Taste	Yes	Cinnamamide - some alteration in feeding behaviour; reduced ***woodpigeon*** damage to OSR; not registered for use in UK.
	Tactile	DD	Not registered for use in UK
	Repellent/optical gel	DD	Potentially restricted, transient effect.
	Fertility control	Yes	Nicarbazin has reduced productivity of captive feral pigeons and size of urban populations of ***feral pigeons***; not registered in UK.
Lethal	Shooting	DD	Despite perceptions that shooting is effective there is no objective data to compare the effectiveness of shooting as a means of crop protection with that of other techniques; despite heavy shooting the ***woodpigeon*** population has increased consistently; summer shooting has the potential to have a far greater influence on population size than winter shooting.
	Nest/egg destruction	Yes	***Woodpigeon*** nests and contents historically undertaken as part of rabbit clearance scheme; labour intensive; requires coordination over large area.
	Stupefying baits	Yes	Alpha-chloralose treated bait used to remove ‘pest’ birds; has been used to capture ***woodpigeons***; alphachlorolose no longer licensed in UK.
	Trapping	DD	***Feral pigeons*** controlled in urban areas using cage traps; large scale captures (e.g. cannon netting) untested.

DD = Data deficient

4.4 Consultation with growers

A telephone consultation was undertaken with a small number of growers of oilseed rape, other brassicas, salads and legumes that encompassed a number of different geographical regions (Table 4.6). The consultation covered a range of questions on woodpigeon crop damage and management (Appendix 1). The sample size was extremely small which precluded any statistical analysis. The consultation did, however, serve to sample the views and experiences of typical growers.

4.4.1 Results

Farm details

Consultations were held with 14 growers whose holdings ranged in size from around 15ha to 2,400ha. The sample of growers was categorised into four groups designated by the main crop (where more than one crop was grown): outdoor salad, OSR, brassica, peas/beans (legumes) (Table 4.6).

Table 4.6 Distribution of growers consulted by crop type and region.

Crop	No.	Region
Outdoor Salad	5	Dorset (1), Essex (1), Lincs. (1), Shrops. (1), 'Kent/Wilts./Hamps./Dorset' (1)
OSR	3	Essex (1), Lincs. (1), Notts. (1)
Brassicas	4	Cornwall (1), Lancs. (1), Lincs. (2)
Peas/Beans	2	Lincs. (1), Norfolk (1)

Woodpigeon problem status

The majority of holdings (79%) considered woodpigeons to be a major problem, with the remainder rating them as a moderate or moderate to major problem. The majority of holdings (86%) also perceived the problem to be increasing.

A number of holdings (14%), however, reported other species to pose equivalent or greater problems, specifically rabbits and partridges.

Crop damage

Growers' estimates of crop damage varied but the perception of the majority (57%) was that yield loss lay within the range 10-40% (Table 4.7). A significant number of growers (43%), however, were not able to provide estimates of yield loss and/or economic loss.

Table 4.7 Estimates of yield loss and economic loss provided by growers.

		Economic Loss (£)	
Crop	**Yield Loss**	**Per ha**	**Total**
Outdoor Salad	10-15% to 40%	nd	£8-25k to £50k
OSR	1.2 tonne/ha (~35%) to 100% field	£125	£8k to £30k+
Brassicas	10-20% to 30-40%	£330/ha to £1,250/ha	£10,000s
Peas/Beans	12% to 40%	£250/ha	£100k+

Only two growers (brassica) provided information on the spatial distribution of crop damage. In both cases damage was predominantly around the field edges and near woods and power lines, which provided perching and roosting opportunities for woodpigeons.

Across all the holdings, crop damage was reported in every month of the year; specific months dependent on crop type were generally: OSR - November to March, salads April to July, brassica – October to March or March to June; and peas/beans - March to June.

Woodpigeon management

Across all growers a range of bird management categories were deployed – exclusion, scaring, habitat modification, shooting and crop patterns (Table 4.8). Of these the most frequent methods used were scaring and shooting.

Table 4.8 Categories of bird management used by growers.

Crop	No. Growers	Exclusion	Scaring	Habitat	Shooting	Cropping
Outdoor Salad	5	4	5	1	3	1
OSR	3	0	3	0	3	0
Brassicas	4	0	4	0	3	0
Peas/Beans	2	1	2	0	2	0
All	14	6	14	1	11	1

Of the scaring techniques the most frequently used were shooting, pyrotechnics and gas cannons (Table 4.9). With such a small sample size it is not possible to draw any firm conclusions concerning the relative effectiveness between different techniques. For some individual techniques, however, the majority of growers that supplied a view considered the method to be at least moderately effective (i.e. at least 25% decrease in woodpigeon numbers or crop damage) – gas cannon, pyrotechnics, human, kite, falconry and shooting. In particular, falconry was rated very effective (i.e. >50% decrease in woodpigeon numbers or crop damage) by both growers utilising this method. The majority of growers (86%) used more than one type of scaring device.

Table 4.9 Bird scaring techniques deployed by growers: relative frequency of use, cost per year and perceived effectiveness.

			Effectiveness [1]				
	No. growers	Cost/year (£)	?	0%	<25%	>25%<50%	>50%
Scarecrow	3	£500		1	2		
Flags	3	£500	1		2		
Gas cannon	8	£40-50 - £7,000			3	4	1
Pyrotechnics	11	£50-£10,000	1		4	6	
Human	4	£40k	1		1	1	1
Kite/Hawk kite	7	£70-£3,000	1	1		2	2
Bioacoustic	1	£250			1		
Falconry	2	£200/day					2
Shooting	10	£0 - £70k	2			6	2

[1] Decrease in woodpigeon numbers and/or decrease in crop damage.

The costs of other mitigation measures can be higher than for scaring devices. For example, one grower reported costs of netting of £80k; equivalent to £16-20k per year with a lifespan for the netting of 4-5 years.

Woodpigeon shooting

Across all growers a number of different types of shooting were conducted – flighting/decoying, roost shooting and roaming (rough shooting). In all cases where a view was expressed shooting was considered to be at least moderately effective (i.e. at least 25% decrease in woodpigeon numbers or crop damage) (Table 4.10).

Table 4.10 Shooting techniques deployed by growers: relative frequency and perceived effectiveness.

Technique	No. Growers			Effectiveness		
	(n=12)	nd	0%	<25%	>25%<50%	>50%
Roost	2			1	1	
Flighting (hides)	5	1		1	3	
Roam	6	1			3	2
Hi-visibility	3	2			1	

Note: number of growers using individual techniques exceeds the total number of growers as some deployed more than one shooting technique.

Only one grower reported a financial income from woodpigeon shooting – through leasing the shooting rights to a club.

Shooting directly over crops is not appropriate in all cases with one salad grower expressing the need to avoid shot ‘catching’ and contaminating leafy crops.

Discussion

5.1 Crop damage

Although woodpigeons have been relatively well studied in the UK, this interest is largely historical and with extremely limited empirical information on the extent and magnitude of woodpigeon damage to agricultural crops. Apart from single estimates for oilseed rape (9% ±6%) (1989) and spring cabbage (mean £105 per acre) (1973) empirical estimates of crop damage were not available for the crops of concern.

Most studies on agricultural impacts were limited to descriptions of the temporal and spatial nature of crop damage. In this respect, damage varied throughout the year dependent on the crops available and their stage of development. Further interest centred on woodpigeon ecology.

A number of factors, both natural and man-made, were associated with the occurrence or magnitude of damage to individual fields of crops, including topography, habitat features and human disturbance.

In order to collate information on growers' perceptions of the current levels of woodpigeon damage a limited consultation was undertaken with a small sample of growers (Section 5.3).

5.2 Woodpigeon management

Visual and auditory techniques varied in their effectiveness. Most animals exhibit fear or wariness towards any novel object or stimulus placed in their environment and will avoid it. Dispersal can also be induced through a startle reflex as a result of the sudden presentation of visual or auditory stimuli. However, animals come to realise that the deterrent does not actually present a real threat and gradually ignore the stimulus; a process called habituation. Thus, for all visual and auditory deterrents any initial effectiveness will inevitably decline. To maximise effectiveness, through prolonging the process of habituation, deterrents should: (i) be as realistic as possible, (ii) be temporally and spatially unpredictable, (iii) present as real a threat as possible, (iv) be presented as infrequently as possible, and (v) be reinforced or replaced with alternative type/s of devices. To achieve this, effigies and models, for example, should be constructed to be physically lifelike and animated, moved frequently between different locations, interchanged with alternative models, and reinforced with other stimuli. Essentially, the more biologically meaningful a deterrent is the greater the period of habituation. Visual scarers that are based solely on novelty and invoking neophobia in the pest species have the potential over time to become attractive rather than remain aversive (Inglis 1980). Birds may begin to associate the presence of such visual scarers with good feeding areas.

The timing of the deployment of deterrents is also important (Feare *et al*. 1988). In the UK, woodpigeons feed on oilseed rape from the end of November to the beginning of May; most farmers deploy deterrents as soon as feeding begins. Field experiments were conducted on oilseed rape plants protected by netting. Severe woodpigeon damage was caused by manually clipping plants at different times throughout the growing period. It was found that damage before mid-January and after the beginning of April had no significant difference on yields; it was therefore recommended that intensive scaring should not begin until mid-January and then be continued up to the end of March (Inglis *et al*. 1989).

Deterrence using visual and auditory techniques is an ongoing process in which a pro-active and integrated approach is necessary. In England, woodpigeon damage to oilseed rape was negatively correlated with scaring intensity – growers who used several different scaring devices suffered less damage than growers using only a single device (almost invariably a gas cannon), who in turn suffered less damage than growers using no scarers (Inglis *et al*. 1989).

Chemical repellents varied in their effectiveness. These techniques can be very effective in laboratory and cage trials, but less effective in the field due to practical problems such as persistence (the chemical soon washes off) and presentation of treated bait. In UK field trials, however, cinnamamide did reduce the amount of woodpigeon damage to oilseed rape (Gill *et al*. 1998b) but was not subsequently registered for use as a repellent. The niche nature of the potential bird repellent market meant that taking such a product through the regulatory process, i.e. the EU Plant Protection Products Directive, was considered commercially unsustainable. Indeed the greatest barrier to the use of repellents is legislation; only one chemical is licensed for use as a bird repellent in the UK (aluminium ammonium sulphate) - evidence for its effectiveness or not is lacking.

The interest in ***fertility control*** to manage over-abundant problem species has grown over recent years (Massei and Cowan 2014). Several studies have indicated that technique can be successfully used to limit population growth (particularly in enclosed populations) and reduce human-wildlife conflicts. The avian contraceptive Nicarbazin is registered for use in the USA for use with Canada geese and feral pigeons and in Italy to control urban populations of feral pigeons; for which effective population reduction has been reported. At the present time, however, no avian fertility products are licensed for use in the UK.

Exclusion techniques (nets, covers, closely spaced wires) are generally considered to be very effective. Effectiveness depends on the degree to which birds are excluded (e.g. closer spacing between wires); the closer that wires are installed the more they approximate to a net. Properly installed and maintained netting will provide complete protection for a crop and is often recommended as the only technique that is consistently effective in preventing bird damage. The greater the degree of exclusion, however, the more expensive the technique is. For this reason netting tends to be restricted to high value crops.

The consultation revealed that some individual growers either prolonged the time over which coverings (e.g. fleece) were deployed in order to extend the period of protection from woodpigeons, or initiated the use of fleece where previously it had not been used. One potential area of crop protection that may have potential for development is the more extensive use of coverings, such as fleece and netting.

Elsewhere, however, there were concerns amongst growers with the use of nets and other coverings as the micro-habitat beneath the cover can result in reductions in some aspects of produce quality (e.g. firmness and shelf-life) and the facilitation of disease.

Changes in ***crop management*** involving a variety of measures have been reported (Smith *et al*. 1995). These have involved consideration of ***topographical features*** to avoid siting vulnerable crops in high risk areas, such as adjacent to woodland or in isolated, undisturbed fields. Changes in ***planting patterns*** have included switch to spring-sown from winter-sown oilseed rape, abandonment of growing vulnerable crops, particularly oilseed rape and beans/peas. Such measures can represent a financial loss in themselves as a result of foregone income: spring-sown OSR has lower yields than autumn-sown, less vulnerable crops may command lower market prices. However, a proportion of the foregone income will be recouped through overall lower financial loss as a result of decreased levels of crop damage and lower bird management costs. Planting sacrificial areas of crop along the margins of fields can help reduce woodpigeon pressure on the main crop area. Scope for growers to implement changes in crop management in respect to siting vulnerable crops and adopting alternative (potentially novel) less vulnerable crops will depend on farm-specific factors and market forces.

Lethal techniques used against woodpigeons (essentially shooting) have, historically been evaluated as ineffective. Prior to the expansion in oilseed rape during the late 1970s and 1980s competition for limited winter food resources determined the population size. Shooting served to simply remove that proportion of the population that would have died over-winter anyway. Since the expansion in growing of oilseed rape the woodpigeon population is no longer limited by winter food supplies and, therefore, shooting has the potential to control numbers (Inglis *et al*. 1990; CSL 2000; Haynes *et al*. 2003). However, despite shooting being the most widely used and considered by growers to be the most effective control measure (Smith *et al*. 1995), woodpigeon numbers and conflict with agriculture has continued to increase.

There are two aspects involved in shooting in respect to attempts to reduce crop damage. First, is the action of shooting as a scaring technique to deter woodpigeons from fields of crops. Second, is the reduction in the numbers of woodpigeons available to graze those crops. Entwined in this is a potential 'conflict' between growers and shooters in regard to their respective functional and sporting interests. Shooters, for example, may prefer to limit shooting to weekends and/or at times and locations most favourable to their convenience. Whereas, in order to maximise crop protection an alternative shooting strategy might be more appropriate. Although it should be remembered that shooters may be willing to pay for the shooting rights.

In the UK, the most common strategy with which shooting is undertaken (i.e. with concealed gunmen) is consistent with attempting to maximise the number of woodpigeons killed, rather than maximising the deterrent effect of shooting. This 'conflict' between the scaring effects of shooting and successfully killing woodpigeons is exemplified in Harradine and Reynolds (1997). The authors state '…*the low numbers shot in January to March reflect that during the winter woodpigeons form large flocks, particularly over oilseed rape crops, and, consequently are difficult to decoy. Furthermore, a large flock at this time is easily disturbed and scared away, with only limited opportunities for birds to be shot and is not rapidly replaced by another flock, since such flocks are relatively widely dispersed*…'. To a large extent the crop protection value of shooting depends on it acting as a scaring mechanism (Murton *et al*. 1974). In examining the economics of woodpigeon damage to brassicae, Murton and Jones (1973) noted that although a gunman roving around fields was the least effective method of killing woodpigeons it was the most effective way of keeping birds off the crops. Similarly, in respect to wildfowling it has been suggested that retrieval of kills and injured birds may cause as much disturbance as or, on occasion, more disturbance to the wildfowl than the shot itself (Townshend and O'Connor

1993).

It is important, therefore, to judge the effectiveness of pest control in terms of damage prevented and not the numbers of animals killed. For lethal techniques in general, an important but often over-looked aspect is the requirement to monitor changes in the extent of crop damage. A lethal control programme must have some defined measurable objective and the level that over abundant species must be reduced to (to get the desired response of the resource, e.g. reduced crop damage) must be known. If such information is not available there is a risk that lethal control focuses on killing individuals and not on the benefits or outcomes.

In respect to reducing the numbers of pigeons locally, shooting has the potential to have a greater effect on local woodpigeon numbers if activities are concentrated during the spring and summer than during the autumn and winter. During the former period, shooting will remove both adults and juveniles and also disrupt breeding attempts, productivity and recruitment. Also, birds removed locally are less likely to be replaced through immigration as woodpigeon movements are smaller at this time of year. In contrast, shooting during the later period will focus on individuals only, fail to disrupt ongoing breeding attempts and may fail to target dispersing juveniles. Indications are, however that the majority of shooting is carried out during the winter months (CSL 2000).

There is scope to adapt the way in which woodpigeon shooting is undertaken in respect to crop protection. Crop protection will be enhanced with a strategic approach that attempts to maximise the impacts of both shooting to scare and shooting to reduce the number of woodpigeons. In regard to the latter, the persistent long-term increase in woodpigeon numbers in the UK since the late 1970s indicates that historically shooting has not been sufficiently intense, or targeted, to impact on population growth. Such an improved strategy requires recognition that shooting to maximise crop protection and shooting for sport are not necessarily compatible. Also, greater cooperation and coordination between neighbouring growers is necessary so that woodpigeon populations are targeted at the wider landscape-scale rather than local or farm scale.

Shooting represents a potential financial income for growers, either through direct sale of shot woodpigeon or through the sale of shooting rights. This income could contribute to off-setting the costs of woodpigeon impacts. Presently, however, the channels for supplying woodpigeon to game dealers or restaurants is said not to be well developed. The general variability in the numbers and seasonality of woodpigeons shot results in an *ad hoc* informal supply to outlets rather than an agreed regular supply and associated contracted income stream. In Britain, the wholesale value of shot woodpigeons (5-7 million birds) was estimated at £1.1 to 1.5 million – based on 55% of shot birds sold at a unit price of £0.40 (Murray and Simcox 2003).

A recurring theme in the mitigation of crop damage by avian pests is the necessity for an ***integrated management strategy***. Such an approach involves combining and interchanging a suite of different scaring techniques deployed unpredictably both spatially and temporally. Scaring can be reinforced with shooting. In addition, habitat-based techniques should be utilised, where possible, such as diversionary (sacrificial) feeding areas and siting crops with respect to local topography (e.g. away from woods, close to human disturbance). Exclusion methods such as poly-tunnels and netting should also be applied when appropriate. Although the adoption of an integrated strategy is accepted as best practice, the actual nature of any management programme (i.e. techniques, intensity, timing and duration) will need to be developed to address the site-specific features and context of individual sites.

In respect to the wider ecological perspective, for any bird deterrent its effectiveness will depend on a number of factors in addition to the deterrent itself, such as the ***motivational state*** of the animal and the ***availability of alternative resources***. Motivational state will be influenced, for example, by the degree of hunger or the drive to feed young. Birds will be more easily deterred from crops where there are plentiful alternative food resources available than from sites where there are few alternatives; hence the value of sacrificial crops in some circumstances.

Finally, it should be noted that under some circumstances a bird management strategy that promotes ***ineffective scaring*** has the potential to have the opposite effect to that desired and actually exacerbate crop damage. For example, in circumstances where crop specimens are pecked rather than plucked, if birds are scared from the crop they may simply return to another, un-grazed part of the crop. The consequence of such cyclical activity is less severe damage spread over a larger proportion of the crop rather than more severe but restricted damage. The dispersed bird damage may promote more extensive secondary insect damage and fungal infection than otherwise. On the other hand plants like oilseed can recover from slight damage by increased tillering such that the seed yield at harvest is not reduced (Inglis *et al*. 1989). Under these circumstances 'spreading the damage' may have an overall beneficial effect in respect to relative crop damage. The relative importance of these effects will depend on the bird species, the specific crop and the context in which the crop plant is used and marketed. Another issue associated with incomplete scaring involves the daily energy requirements of the pest species. Scaring that result in the birds repeatedly flying away from the crop to return later will increase the birds' typical daily energy demands. To satisfy this extra demand the birds will need to increase their food intake above that in the absence of repeated disturbance (Bomford and Sinclair 2002). For woodpigeons, due to the cyclical phases of feeding and resting within the crop, periodic disturbance from the field may not reduce the total crop consumed (Kenward and Sibly 1978).

5.3 Consultation

The majority of holdings involved in the consultation considered woodpigeons to be a major and increasing problem. In a number of cases, however, rabbits and partridges were considered to be as great or greater problem than woodpigeons.

The limited data indicated that growers perceived woodpigeons to impose a significant detrimental impact on crops – generally in the order of 10-40% loss in yield. Estimates of annual financial loss provided by growers were £125/ha for OSR, £250/ha for peas and £330-£1,250/ha for brassicas. However, in general estimates of economic loss were often broad, lacked detail or not provided.

All growers deployed at least one type of scaring device with the majority utilising two or more types. The integration of additional categories of mitigation measure was more limited with exclusion methods (netting, covers) being used only on salads and legumes and habitat modification (sacrificial crop) reported by only one grower.

Fifty percent of growers reported some cooperation and coordination with neighbouring growers in respect to woodpigeon control. However, the extent of cooperation was almost invariably very limited and restricted to shooting. Where it occurred, the extent of coordinated shooting itself was very limited being constrained, at best, to a handful of events during the year. At one extreme, cooperation was avoided as woodpigeons on neighbouring crops was considered preferable to having the birds on one's own farm.

Although the consultation permitted some insight into growers experiences in respect to woodpigeons, caution must be taken in any extrapolation to the wider grower community as a consequence of the extremely small sample size (14 growers) and the sole representation of growers with significant woodpigeon problems.

6. Draft management plan – outline framework

6.1 Development process

Developing a management plan for woodpigeons (as for any problem species) requires a number of steps: planning, implementation and evaluation. This process requires consideration of a number of activities (Coleman and Spurr 2006; Tracey *et al*. 2007):

- Evaluate the nature of the damage to the crop, i.e. the yield loss, the spatial pattern (e.g. any variation in damage across the field) and temporal pattern (e.g. stage of crop growth) of damage. Information on damage in relation to surrounding habitat and structural features is also useful. It may be possible to gather the required information from knowledge of past patterns of damage. It may, however, be necessary to evaluate contemporary levels of damage from empirical field studies.

- Calculate the economic value of the damage. This will represent a baseline against which potential benefits possible from implementation of management can be estimated. The appropriate figure is the gross margin realised from the value of the crop minus the various costs associated with producing the crop.

- The desired objectives and resolution of the problem need to be formulated. The optimum resolution that can be achieved will depend on local and landscape level woodpigeon ecology and the degree of cooperation and coordination between neighbouring growers.

- Determine the strategic options and particular methods that are available. The appropriate management option for achieving the desired objectives needs to be developed and implemented. The development of the appropriate strategy and specific control techniques will be informed by current knowledge of woodpigeon ecology - research may need to be undertaken to fill in gaps in knowledge before development can be completed.

- Initiate a programme of management when benefits likely to be accrued exceed the economic costs of implementing control.

- Monitor the effectiveness of the management programme. Monitoring will involve assessing any reductions in yield loss and changes in the pattern of damage. Where evidence indicates positive outcomes, methods can be explored for fine-tuning the management actions in successive years. Further research may be required to achieve this improvement or to adapt the efficiency and effectiveness of the programme. In the event that gains from management become exceeded by the costs of implementation then the programme should be stopped and options re-visited. Objectives may need to be modified in light of the monitoring and evaluation. The basic process is illustrated in Figure 6.1.

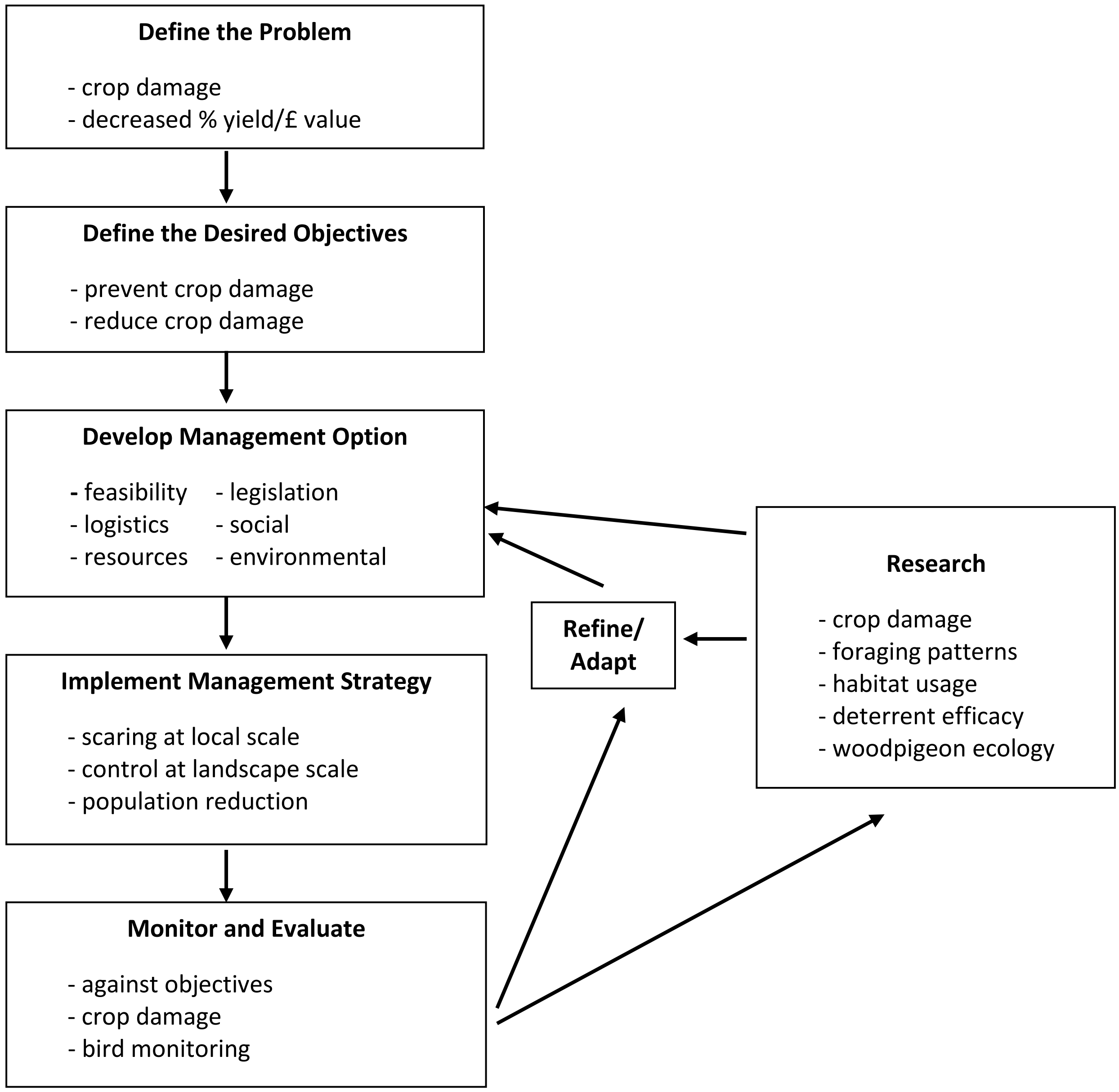

Figure 6.1 Schematic outline framework for the management process in relation to woodpigeon damage to agricultural crops.

6.2 Management options

In terms of management options there are three main approaches for managing species involved in human-wildlife conflicts: do nothing, sustained control, and eradication; sustained control itself has a number of approaches: one-off, sustained, targeted and crisis control (Coleman and Spurr 2006; DEC 2007, Tracey *et al*. 2007). Each method needs to be based on a sound understanding of the biology of the problem species, including its population dynamics, its impacts and the relation between those impacts and population density, the effectiveness of available control options, non-target and other environmental consequences of the techniques used and their social acceptance, and the long-term cost of applying any selected strategy.

1) Eradication

This is the permanent elimination of the entire population from a defined area. A number of factors have to be considered in assessing the feasibility of eradication: ecological viability, sufficient public support, landowner cooperation and financial and political commitment. This strategy is usually limited to the removal of relatively small populations of invasive non-native species. In the case of the super-abundant native woodpigeon this is not a feasible option.

2) Sustained control

This option is the most strategically difficult because to be effective it requires some understanding of the relationship between the abundance of the problem species and the resource being impacted. That is, the programme must have some defined measurable objective and the level that abundance must be reduced to (to get the desired response of the resource) must be known. If such information is not available there is a risk that woodpigeon management focuses on killing woodpigeons and not on the benefits or outcomes. However, if the required information is not known then management can be structured in such a way that this information is obtained and further refined over time as management progresses.

i) Strategic one-off control

This involves the implementation of a single, long-term management action. Perhaps the only existing option is the installation of permanent netting over vulnerable crops. This is an expensive option and requires detailed cost-benefit analysis but can be economically viable for high-value crops. Other types of covering include poly-tunnels, fleece and plastic.

ii) Strategic sustained control

A strategy that involves sustained effort over a period of time in order to reduce crop damage. This approach may involve restricting the population within a specific region or area (containment) or reducing and maintaining the population to low numbers through culling (suppression). Alternatively, it may involve the continuous ongoing deployment of deterrent measures, irrespective of the relative numbers of pest birds and risk of crop damage. The latter will involve the integrated use of different deterrent techniques.

iii) Strategic targeted control

Involves the deployment of control measures only during periods when conditions indicate that the risk of damage is high. Examples include the installation of suitable netting when damage is expected to be severe, or the integrated use of scaring devices during vulnerable periods of the crop cycle.

iv) Crisis management

This is a reactive management approach with little, or no, forward planning. This approach has been adopted frequently with respect to bird control throughout the world. Significant action is not taken until damage levels have reached unacceptable levels. By this time, however, alleviating damage is often difficult due to the birds establishing behavioural feeding patterns that are difficult to disrupt; or much of the damage has already been done and the birds have moved elsewhere.

3) Do nothing

This can be a viable economic option in cases where the costs of control are greater than the benefits accrued from pest management. An associated option is to cease growing the vulnerable crop and replace with an alternative that is less attractive to the pest birds; accepting a lower but more guaranteed return.

Present woodpigeon strategy

The consultation indicated that growers' present strategy toward woodpigeon management is one of sustained control, with individual growers deploying one or more strategic elements - one-off control, sustained or targeted control, dependent on site-specific factors, most specifically crop type.

One-off control is practised by salad growers and legume growers with the use of netting, poly-tunnels and covers. Exclusion is largely effective but has associated concerns with some potential detrimental effects on crop management and quality; large-scale netting is also relatively expensive. *The challenge here is to develop exclusion materials and methods that are more cost-effective and with reduced risk of any detrimental effects; facilitating the expansion of this control method.* Other opportunities for one-off control, such as planting patterns are site-specific.

Strategic sustained control has been manifest in the wide-scale shooting of woodpigeons. Shooting is the most frequent control method undertaken with 97% of farmers responding to an NFU/BASC survey using it for control (Smith *et al*. 1995). It has been estimated that over 200,000 people shoot woodpigeons annually in the UK, with a million plus birds removed each year. Despite this intensity of shooting, however, it has not been effective in reducing, or indeed halting population growth, or the scale of the conflict. *The challenge here is to develop a more targeted and effective shooting strategy and that is clearly focussed on crop protection rather than sporting interests.*

Strategic sustained control and strategic targeted control is practised through the deployment of one or more deterrents, such as scaring devices. It is not clear however to what extent growers' efforts are partitioned between sustained and targeted strategies. The more cost-effective approach is to target control so that effort is focussed on the most vulnerable periods during which woodpigeon grazing imposes the greatest impacts. Another unknown is the extent to which growers target control by following the guidelines designed to prolong habituation and maximise effectiveness of scaring devices. *The challenge here is to refine the deployment of existing scaring devices and other control methods to ensure an integrated strategy that focusses on the most vulnerable periods. A further challenge is to identify new methods (devices and/or modes of deployment) to supplement or replace existing ones.*

7. Economics

The development of a cost-effective bird management plan requires assessments of the economic value of the crop damage. This value then serves as a baseline against which the financial value realised through a reduction in damage achieved by implementing management measures can be assessed.

Measures used to assess crop damage include: (i) questionnaire surveys, (ii) direct measures - counting, weighing and visual evaluation, (iii) indirect measures – monitoring bird numbers and avian energy demands (Tracey *et al*. 2007).

7.1 Questionnaire surveys

Wildlife damage surveys have used face-to-face interviews, telephone interviews and mail surveys. The more personal the technique the greater is the specific detail that can be collated, e.g. face-to-face interviews allow the communication of more complex information than mail surveys. In all types of surveys it is important that the questions are phrased correctly and objectively to maximise the probability of respondents fully understanding the context of the question and to avoid leading responses. There is a trade-off between the different types of survey in terms of the complexity of the information that can be obtained and the time, costs and sample size involved.

In any questionnaire survey there are a number of potential biases, including targeting a non-representative sample, a lack of response from a category of the targeted sample, and variation between respondents in their perceptions and evaluation of damage. Some of these potential biases can be resolved by, for example, following-up a proportion of the non-responses.

7.2 Direct measures

Direct measures include weighing, counting and visual assessments of the crop. The approach involves the use of systematic sampling procedures to evaluate a representative proportion of the crop. Weighing involves comparing the yield between grazed (damaged) and ungrazed (undamaged) sample plots (e.g. oilseed rape, Parrott & Watola 2008). For horticultural crops, however, there are problems with weighing due to variation in the size and weight of individual produce and also to the occurrence of partially damaged produce. A batch of produce in which all specimens have a few peck marks will not have lost any appreciable weight compared to an undamaged batch, but will represent an economic loss if such peck-marked fruit is unsaleable.

Counting damaged and undamaged samples within a crop and using visual estimations are more widely used. Visual assessments are preferred because they are a relatively rapid method that involve estimating percentage loss or assign damage rankings. Such assessments can be calibrated by counting or weighing samples that have been visually assessed for damage.

7.3 Indirect measures

Indirect measures include: (i) monitoring bird numbers on the crop, and (ii) calculations based on the species diet and energy requirements.

The *density of birds* grazing on the crop can be used to predict the level of damage.

This method, however, requires knowledge of the form of the relationship between bird density and damage – information that is rarely known and labour-intensive to collate. There are a number of potential relationships between bird density and crop damage (Figure 7.1).

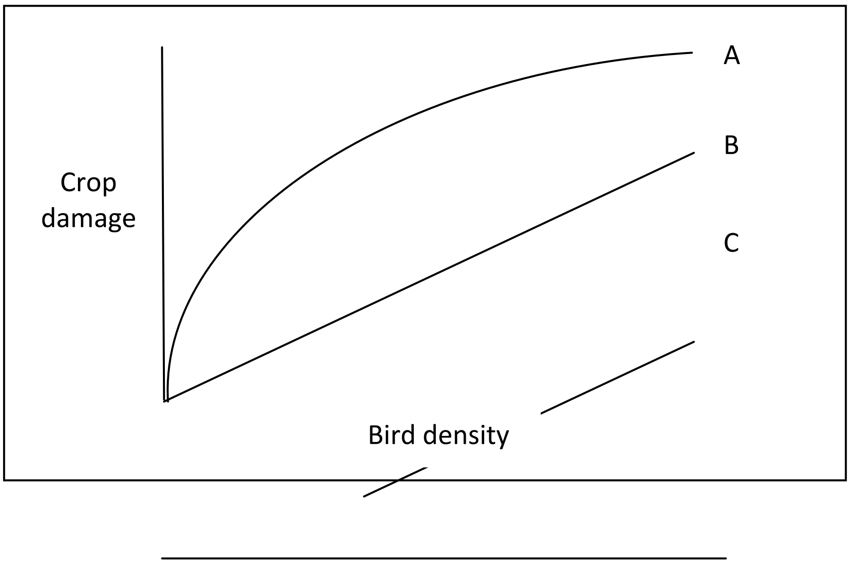

Figure 7.1 Some potential relationships between bird density and crop damage (adapted from Tracey *et al*. 2007).

In figure 7.1, line A represents a situation where low numbers of birds inflict a disproportionately high level of damage; line B indicates a proportional increase in damage with higher numbers of birds; line C shows that damage does not occur until the numbers of birds reaches some threshold level of density.

The shape of the density-damage relationship for most species, and specifically of interest here woodpigeons, feeding on horticultural or other crops is not known. In order to determine this relationship a series of field evaluations are required that measure the damage incurred over time under different bird densities.

Estimates of bird damage can also be derived from data on the species *dietary and energy requirements*. This approach involves translating the proportion of the crop in the species typical daily food intake into the amount of crop removed and extrapolating to the bird population utilising the crop. The method requires a significant amount of ecological information derived from long-term research.

7.4 Secondary and indirect costs of woodpigeon damage

In addition to the direct consumption of crop plants or parts of plants, growers have identified a number of secondary and indirect costs:

- the promotion of fungal and insect damage arising from bird damage,
- delayed ripening and disruption of the harvesting schedule,
- reduction in the aesthetic quality and saleability of the crop,
- effort spent on production lines sorting out contaminated (e.g. faeces) produce,
- yield reduction from the use of bird-proof mesh,
- softer crop, reduced shelf life and increased risk of disease from the use of bird-proof mesh,
- restrictions to crop rotation to ensure that specific fields vulnerable to woodpigeon grazing (e.g. adjacent to woods) are not planted with susceptible crops at vulnerable times of the year,
- poor relations with local authorities and neighbours from the use of gas cannons and/or shooting, and consequent potential limitations on such control,
- discord with shooters, who may prefer sole shooting rights but only wish to shoot at their convenience.

Many of these secondary and indirect costs are difficult to quantify in terms of financial loss.

7.5 Economic decision making

Different types of economic analysis are available to assist in the formulation of pest management strategies (Tracey *et al*. 2007). Descriptive models help develop an understanding of economic relationships, e.g. marginal analysis which investigates the level of bird control or bird density that has the maximum economic benefit. Descriptive models require accurate data on numerous factors, including the relationship between bird density and the level of damage imposed and the benefits of applying different levels of control. Much of this information is lacking in respect to pest birds and crop damage in general and to woodpigeons and brassicas and salad crops in this specific case. In comparison, prescriptive models utilise value judgements and compare different management strategies using specific, subjective criteria.

7.6 Present study

In the present study a partial economic analysis of woodpigeon damage was limited to a simple, preliminary comparison of the costs of likely levels of crop damage and the cost and benefits of utilising different management options. The exercise compared the estimated costs of crop damage per unit area supplied by growers during the consultation with the estimated costs per unit area of various deterrent methods.

Cost of crop damage

Estimates of annual financial loss provided by growers in the consultation (section 4.4) were £125/ha for OSR, £250/ha for peas and £330-£1,250/ha for brassicas.

Costs of avian deterrents

Typical examples of the unit cost of a range of deterrent devices were either sourced from the internet or taken from information supplied during the grower consultation. Using published information on the effective area for these types of devices, estimates were derived for the cost of deploying these devices per unit area (ha).

Additional costs

In addition to the costs of the deterrent devices themselves there will be additional costs associated with labour required to deploy and maintain the measures. Labour costs were taken to be 'standard worker' rate of £9.57 per hour (Nix 2014). Potential secondary or indirect costs (section 7.4) are not considered here.

Comparison of costs of crop damage and costs of mitigation

For most of the techniques, the costs per ha (Table 7.1) represent the first year (start-up) unit costs (the costs for falconry and labour will represent annual recurring costs). Costs in subsequent years will be lower and will represent running costs (e.g. labour to repair and maintain devices). The initial capital costs in year one can be discounted or depreciated over the lifetime of a specific device.

Previous research has advocated that woodpigeon management on OSR is concentrated during the most vulnerable growing period from mid-January to the end of March (Inglis *et al*. 1989). Therefore, using this as a basis, additional costs of labour to deploy and maintain the deterrents was assumed to be 7.5 hours per day for 3.5 days a week over a 10 week period (i.e. 263 hours in total) (assumes that devices are checked/moved every two days) and that one worker could cover deterrent devices across 500ha.

Table 7.1 Estimated cost per ha of different deterrent devices.

Device	**£/unit**	**Effective area (ha)**	**£ per ha (1st year)**
Helikite	119	10	11.90
Birdscarer (+kite pole)	155	4	38.75
Bioacoustic device 1	419	8	52.38
Bioacoustic device II	659	16	41.19
Scarey-man	325	10	32.50
Scarecrow	135	3.5	38.57
Gas cannon	399	7	57.00
Falconry [a]	£200/day	135	59.00
Labour (OSR) [b]	£9.57/hour	500	5.02

[a] Falconry: based on flying twice per week April-August @ £200 per day (from grower consultation).

[b] Labour costs taken to be *typical annual labour cost* at *standard worker rate* of £9.57 per hour (Nix 2014).

Under the selected examples and assumptions used in Table 7.1, the first-year costs of deterrent devices ranged from around £12-£59 per ha with significantly lower running costs in subsequent years. These costs of mitigation can be compared with the estimated costs of crop damage reported by growers during the consultation: £125/ha for OSR, £250/ha for peas and £330-£1,250/ha for brassicas (associated with reported yield losses of 10-25%). Comparison of the two sets of estimated values indicates that the unit costs of crop damage are markedly higher than the unit costs of deterrent devices (even in the most expensive start-up year).

In the growers consultation, for some deterrents (gas cannon, pyrotechnics, human, kite, falconry and shooting) the majority of growers that supplied a view considered the method to be at least moderately effective (i.e. at least 25% decrease in woodpigeon numbers or crop damage). Therefore, an assumption can be made that, in general, without the deployment of deterrents damage levels would be at least 25% greater, equivalent to increased economic loss of £42/ha to £417/ha dependent on the crop.

It is emphasised that this exercise is for illustrative purposes only. The development of an individual management plan based on an evaluation of costs and benefits will need to consider site-specific factors. For example, these may include: some locations may not be suitable for certain devices (e.g. gas cannons adjacent to habitation); devices may have to be deployed more densely or moved more frequently under some circumstances than others; labour may involve either existing staff or staff hired especially for woodpigeon control (which may involve different financial rates) and the period over which woodpigeon management is required will vary between different crops.

In general, based on estimates of crop damage provided by growers, it would appear that the use of deterrents is potentially economically cost-effective (note - excludes consideration of secondary or indirect economic losses). The challenge, however, is to maximise cost-effectiveness by deploying the most efficient deterrents in the optimum manner – information that is currently lacking.

8. Gaps in knowledge

There are a number of gaps in knowledge relating to the ecology of woodpigeons and their interaction with agricultural and horticultural crops in England. Consequently, there are currently significant constraints in the ability to formulate optimum practical and cost-effective control and management strategies.

The scale of management effort is an important consideration. Avian crop damage problems are at the level of the field or orchard and this is the scale at which control is usually directed. The problem birds, however, utilise the habitat at a much larger scale. Management strategies could be designed at the landscape scale (coordinating neighbouring growers), taking account of movements and habitat use by woodpigeons and the temporal and spatial distribution of vulnerable crops.

At the level of the field or orchard, knowledge about the relative cost-effectiveness of different control measures is critical for growers to be able to derive an economical management strategy. However, other than anecdotal reports, contemporary data on the extent and pattern of damage imposed by woodpigeons on crops is not well documented. Measurements of yield loss in susceptible crops due to woodpigeon damage, on the relationship between damage and woodpigeon abundance and on the effectiveness and costs of different control techniques are required. Parameters that need to be measured include the magnitude of yield loss against which the effectiveness and costs of mitigation measures can be compared. In addition, information on the temporal and spatial patterns of damage within fields of crops will facilitate the most effective and economic targeting of control measures. There is, however, a paucity of empirical studies that have assessed crop damage, especially in the context of the present status of the woodpigeon population.

At the landscape level, there is a lack of information on how woodpigeons utilise different habitats. The relationships between roost sites, feeding sites and breeding sites and how these vary in response to natural (e.g. population growth) and unnatural factors (e.g. management) is little understood. Knowledge on woodpigeon movements is incomplete with, for example, conflicting information on potential mass seasonal movements of birds. Understanding how woodpigeons utilise the landscape will facilitate the development of population-scale management measures and their potential consequences for woodpigeon impacts on agricultural and horticultural interests.

Conclusions

The current project has: (i) reviewed the evidence for woodpigeon damage to brassicas, salad crops and oilseed rape, (ii) reviewed the effectiveness of avian management measures to mitigate woodpigeon damage, (iii) outlined a framework for the development of cost-effective woodpigeon management plans, (iv) identified current management options, (v) identified gaps in knowledge that currently constrain the development of optimum woodpigeon management strategies, and (v) made proposal for further options to address the gaps in knowledge.

9.1 Crop damage

The woodpigeon is recognised as a major agricultural pest in the UK including on brassicas, salads and oilseed rape. In addition to reducing yield, woodpigeons can impact on the harvesting schedule and also diminish the appearance and eventual saleability of produce. The majority of research on woodpigeons is historical, with most studies having been undertaken decades ago, prior to the large-scale introduction of oilseed rape. Since then the woodpigeon population has increased markedly; changes in farming practices have also occurred over this period.

A review of woodpigeon damage to brassicas, salad crops and oilseed rape revealed that the majority of documents were descriptive and lacked empirical measurements of damage. One of the very few published estimates recorded a mean yield loss of 9% (±6%) in severely damaged areas of fields of oilseed rape compared to areas that had negligible damage. For Spring cabbages, financial damage was estimated by growers to be a mean of £105 per acre across two different study areas - these estimates agreed well with independent assessments of crop damage in one area but not in the second. These crop damage estimates, however, are historical with no contemporary studies undertaken in the context of current woodpigeon populations and farming practices (including the new varieties of oilseed rape that, being far shorter than the old varieties, may be susceptible to woodpigeon attack for longer).

A very limited consultation with growers indicated that the majority considered woodpigeons to be a major and increasing problem. The limited data indicated that growers perceived woodpigeons to impose a significant detrimental impact on crops

– generally in the order of 10-40% loss in yield. Estimates of annual financial loss provided by growers in the consultation (section 4.4) were £125/ha for OSR, £250/ha for peas and £330-£1,250/ha for brassicas. However, estimates of the economic loss associated with this yield loss were often broad, lacked detail or not provided.

9.2 Mitigation measures

A review of management measures against woodpigeons (and some other avian crop pests) indicated that a wide range of techniques have been deployed, ranging from non-lethal scaring to attempted population reduction. For all techniques the effectiveness varied, although some methods were consistently more effective than others (e.g. exclusion techniques). Recommendations and best practice advice is to devise integrated strategies that incorporate and vary the deployment of different combinations of mitigation techniques. Also, to incorporate considerations of woodpigeon behavioural and ecological dynamics in the management approach, including patterns of the timing and damage within plots of crops. However, as for estimates of crop damage, empirical studies of the effectiveness of measures to mitigate woodpigeon crop damage have not been undertaken in the context of current populations.

The limited consultation with growers revealed that all deployed at least one type of scaring device with the majority utilising two or more types. Of the scaring techniques the most frequently used were shooting, pyrotechnics and gas cannons. The integration of additional categories of mitigation measure was more limited with exclusion methods (netting, covers) being used only on salads and legumes and habitat modification (sacrificial crop) reported by only one grower.

It is not known to what extent growers vary in the extent to which guidelines for maximising the effectiveness of deterrents and other mitigation measures is followed. Also, it is not known what other factors may vary between holdings that experience woodpigeon problems and those holdings without problems.

The extent of cooperation between neighbouring growers was very limited and largely restricted to shooting. Where it occurred, the extent of coordinated shooting itself was very limited being constrained, at best, to a handful of events during the year.

9.3 Management strategy

The consultation indicated that growers' present strategy toward woodpigeon management is to deploy one or more strategic elements - one-off control, sustained or targeted control. One-off control is practised by salad growers and legume growers with the use of netting, poly-tunnels and covers. Exclusion is largely effective but has associated concerns with some potential detrimental effects on crop management and quality. Strategic sustained control has been manifest in the wide-scale shooting of woodpigeons. Despite this intensity of shooting, however, it has not been effective in reducing, or indeed halting population growth, or the scale of the conflict. Strategic sustained control and strategic targeted control is practised through the deployment of deterrents. It is not clear however to what extent growers' are optimising their efforts either through targeting control in respect to the most vulnerable periods of the crop cycle, or the extent to which best practice guidelines for deploying deterrents and other control measures are followed.

A framework for the development of a strategic woodpigeon management plan involves: evaluating the damage, setting management objectives, selecting and implementing specific damage mitigation measures, monitoring and evaluating the outcome, and adjusting the approach as appropriate. At present, however, there are significant gaps in knowledge that constrain the comparison of different potential management approaches and hence the identification of the 'optimum' management strategy. Further research is recommended to gain a better understanding of a number of elements in the woodpigeon-crop dynamic. Such information will help inform the refinement of practical, cost-effective and humane management.

9.4 Current options

The review identified a number of management options to mitigate woodpigeon damage that are currently available for growers to consider:

- Deploy an integrated management strategy that incorporates different mitigation techniques, i.e. deterrents, exclusion, habitat management, planting regimes, sacrificial crops and shooting.
- Ensure that deterrent techniques are deployed according to best practice guidelines, i.e. unpredictable, threatening, reinforced and/or switched with alternative deterrents, so that habituation is delayed.
- Use sacrificial crops located away from vulnerable fields; ensuring that sufficient resources are available throughout the vulnerable crop period. Strips of decoy crop e.g. kale or OSR at low density along the margins of fields near woods etc. can also be beneficial.
- Consider the topography and locate susceptible crops away from vulnerable areas (e.g. adjacent to woodland, tree lines or in isolated fields).
- Consider expanding the area of crops under cover (e.g. poly-tunnel, net, fleece) or prolonging the duration over which crops are covered. This needs to be weighed against any potential risks of reduced yield, reduced produce quality or increased disease associated with covering.
- Investigate alternative materials for covering or the mode of deployment of covers that might mitigate the associated risks of reduced yield, reduced produce quality or increased disease.
- Deploy a mixed shooting strategy that incorporates overt shooting (highly visible shooters) associated with visual cues to maximise the scaring effect and the numbers of birds deterred from fields, and covert shooting (concealed shooters) to reduce woodpigeon numbers; the latter concentrated during the summer rather than the winter.
- Consider the control of nests and eggs to suppress local woodpigeon breeding success and population recruitment.
- Coordinate management activities with neighbouring growers so that control is undertaken at the landscape-level.

9.5 Further options

In order to inform the further development of a practical, cost-effective and humane management strategy for woodpigeons there are a number of areas in which further research would address existing gaps in knowledge:

(i) National questionnaire survey

A national questionnaire survey of growers would elucidate the extent and magnitude of woodpigeon damage to brassica and salad crops both nationally and regionally. Additionally, it is not known to what extent and in what context holdings without woodpigeon problems differ from holdings with problems. Such information may be beneficial in the formulation of crop damage mitigation strategies. For example, there may be consistent differences between the two groups in factors such as cropping patterns, the type and manner of deployment of deterrents, the use of exclusion methods and the approach to shooting. The most recent questionnaire/survey of farmer-woodpigeon problems (Smith *et al*. 1995) was constrained by a relatively very small sample size (1.1% of NFU/SNFU membership) and potentially an over-representation of farmers with problems responding to the survey.

Options for research:

- *A comprehensive questionnaire survey or consultation process that samples the full spectrum of woodpigeon-grower problems. The survey to be designed so that subsequent analysis is able to identify significant factors associated with both woodpigeon grazing and its absence.*

(ii) Woodpigeon ecology, diet and patterns of movement associated with agricultural and horticultural crops.

An understanding of woodpigeons’ use of habitat and movements and of their interactions with crops and response to management will facilitate the refinement of more efficient and cost-effective crop protection measures. Information is required at both field-level and landscape level.

Options for research:

- *Monitor the spatial and temporal usage of the agricultural landscape using direct visual and radio-tracking techniques. This will involve monitoring the movements and numbers of woodpigeons in respect to individual fields and the wider landscape.*
- *If carried out in conjunction with field trials on avian control techniques, changes in the behaviour and movements of woodpigeons in response to control and the consequences for crop damage (at field and landscape level) can be investigated.*

(iii) The extent, timing and costs of damage to crops.

Information on the extent, pattern and costs of woodpigeon damage at the level of the individual field are needed to in order to advise on the cost-effectiveness of different control techniques and in the formulation of cost-effective strategies to minimise losses. This should include investigation of the relationship between woodpigeon abundance and the magnitude of damage (density-damage relationships).

Options for research:

- *Evaluation of the change in yield of selected crops that are grazed at a range of woodpigeon densities will provide empirical data on the level of crop damage sustained under different grazing pressures. The work will require identifying a number of holdings in which woodpigeon damage habitually occurs. Such empirical measurements will facilitate calibration of growers' own estimates which will help in the formulation of cost-effective management strategies.*

(iv) Evaluation of existing avian control techniques to minimise damage to crops.

There is an absence of empirical data on the effectiveness of bird control techniques for managing crop damage, especially in the context of current woodpigeon populations and agricultural practices. Information is needed on the relative efficacy and cost-effectiveness of different damage mitigation techniques (e.g. deterrents, shooting, exclosure, habitat modification) at the scale of the individual field and larger landscape level. Field evaluations would involve existing and novel techniques.

Options for research:

<u>*Deterrents*</u>

- *Evaluation of integrated visual and auditory deterrents; deployed according to recommended guidelines.*
- *Reinforcement of visual and auditory deterrents with random, occasional human activity, including shooting.*
- *Evaluation of radio-controlled raptor model to actively scare woodpigeons.*
- *Disturbance of woodpigeons from night roosts using lasers.*

<u>*Exclusion*</u>

- *Investigate the use of netting (drape-over and overhead) and poly-tunnels.*
- *Investigate the use of red coloured coverings.*
- *Investigate the use of coverings such as fleece.*

<u>*Habitat*</u>

- *Investigate the use of sacrificial crops, such as clover.*

<u>*Shooting*</u>

- *Evaluate a shooting strategy that focusses on minimising woodpigeon grazing on crops rather than maximising the number of woodpigeons killed. This will involve marksmen shooting from exposed positions so that overt human presence reinforces shooting disturbance. This shooting activity will link in with the reinforcement of non-lethal scaring devices recommended above (deterrents).*
- *Undertake covert shooting following the period of density dependent mortality (i.e. during spring/summer); shooting should be coordinated at a landscape-level across neighbouring holdings. In contrast to shooting to scare above, the*

objective of coordinated shooting would be to reduce woodpigeon numbers. This form of shooting might be incorporated alongside the provision of sacrificial or decoy crops.

<u>Cannon-netting</u>

- *Evaluate the use of cannon-netting for the simultaneous trapping of large numbers of woodpigeons.*

(v) Formulation and promotion of best practice for protecting crops from woodpigeon damage.

There is a need to advise growers on how to devise an integrated management strategy and how to tailor 'best practice' advice to the specific conditions pertaining at any particular site. To refine existing 'best practice' advice, information from the further investigations recommended above is required (see points above).

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Knowledge and Technology Transfer

There has been no knowledge and technology transfer activities during the project life-cycle. However, there are a number of opportunities for knowledge sharing following project completion:

- ***Advisory publication***

An advisory document on best practice management measures to mitigate the impact of woodpigeons on agricultural crops could potentially be drawn from the findings of the current report.

- ***National woodpigeon forum***

Integration with a HDC-proposed National Woodpigeon Forum, which incorporates relevant stakeholders, such as growers, their representative bodies and allied industries. Results from this study could be disseminated to the forum which is envisaged as a medium for ongoing discussions into best practise, exchange of ideas and knowledge transfer.

- ***NFU bird deterrent event***

Presentation of relevant findings to appropriate audiences, such as an upcoming NFU-sponsored bird deterrent event (scheduled for December 2014).

- ***Scientific publication***

There is the potential for producing a manuscript from the report for submission to a scientific journal.

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Appendices

Appendix 1: Telephone consultation questionnaire

Appendix 2: Crop damage documents reviewed and observations of feeding behaviour

Appendix 3: Species on which woodpigeons are known to feed

Appendix 4: Seasonal consumption of different plant types

Appendix 5: Bird deterrent documents reviewed

Appendix 6: System used to evaluate studies investigating avian management techniques

Appendix 7: Selected studies investigating avian management techniques

Appendix 1 Telephone consultation questionnaire.

1. Farm Details

a) Name:

b) Address:

c) Telephone:

d) Email:

e) Size of holding:

f) Woodland area (if any, including copses):

g) Surrounding habitat (e.g. grassland; similar farm, etc):

2. Woodpigeons

a) How serious a problem are woodpigeons (tick box):

Not	Minor	Moderate	Major

b) Size of local woodpigeon population (tick box):

<250	250-500	500-1000	>1000

c) Location of roost (relative to affected fields) (tick box):

unknown	adjacent	<500m	500-1000m	1000-2000m	>2000m

3. Crop Damage

a) Crops affected and month (tick box; add crop types):

	OSR	**Cereals**	**Beans/Peas**	**Cabbage**	**Sprouts**	**Lettuce**						
Jan												
Feb												
Mar												
April												
May												
June												
July												
Aug												
Sept												
Oct												
Nov												
Dec												

b) Time of day (tick box):

	Sunrise to mid-AM	**Mid-AM to mid-day**	**Mid-day to Mid-PM**	**Mid-PM to sunset**
Spring (Mar-May)				
Summer (June-Aug)				
Autumn (Sept-Nov)				
Winter (Dec-Feb)				

c) Damage levels:

Crop	Description of damage[1]	Yield loss (%)	Financial loss (£)	How loss measured[2]

[1] e.g. which parts of plants, which part of field, etc
[2] e.g. comparison of yields between damaged and undamaged fields; visual estimate; etc

d) Status of problem (tick box):

Increasing	
Static	
Decreasing	
Variable	

4. Woodpigeon Management

a) Methods used

Category	**Method**	**Cost per year (£)**	**Effectiveness**			
			Not	**Slight**	**Moderate**	**Very**
			See 4b below			
			0%	**<25%**	**>25<50%**	**>50%**
Crop Protection	Netting					
	Poly-tunnel					
	Covering					
Scaring	Scarecrow					
	Flags/bags					
	Gas cannon					
	Pyrotechnics					
	Human					
Shooting	Hides/decoys					
	Roaming					
	Roost					
Crop patterns	Change to spring-sown					
	Avoid isolated fields					
	Avoid proximity to roost					
Cooperation	Coordinated deterrence or shooting					

b) How is effectiveness measured (tick box):

Decrease in bird nos.	
Decrease in visual damage	
Increase in yield from ‘damage’ years (i.e. when no control)	
Comparison of yield from damaged and undamaged fields	
Comparison of yield from damaged and undamaged parts of same field	

5. Shooting

a) Who undertakes woodpigeon shooting (tick box):

Landowner	
Employees	
Invited shooters	
Shooting Club	
Professional/Sold days	

b) When shooting is undertaken:

Month	Shooting	No. Shot
Jan		
Feb		
Mar		
April		
May		
June		
July		
Aug		
Sept		
Oct		
Nov		
Dec		

c) Any income from shooting?

	£	**Period**
Yes		
No		

6. Any other comments:

Appendix 2 Crop damage documents reviewed and observations of feeding behaviour**.**

NO.	REFERENCE	COUNTRY	CROP	HABITAT[1]	SEASON	DIURNAL	YIELD LOSS	LOSS £	COMMENTS
1	Dunning (1974)	UK	Sugar beet	Sugar factory crop areas	Apr - Jul	No direct observations of feeding reported	Not given	Not given	Damage most prevalent on late sown crops, June-July.
2	O'Huallachain *et al*. (2013)	Ireland 2000-2002	Cereal grains Veg./cultivated crops Tree material Clover Buttercup Weed material Grass/moss Animal material Other	Grassland/ arable farmland	Spring Summer Autumn Winter	No direct observations of feeding reported	Dominant seasonal crop content: Fruit/seeds of trees 55%; Cereal (27%), clover 22%), weeds (19%), grass (12%); Cereals (52%), clover (16%); Tree mat. (44%), cereals 25%	Not given	Crop content of shot birds. 49 species of plant and 26 species of animal. Plant: animal 97.7%:0.3% Diet dominated by fruit and seeds of trees and cereal grains; the proportion and occurrence varying by season. Note: OSR consumption low due to only 0.3% of farmland sown with rape.
3	Inglis *et al.* (1989)	UK	Oilseed rape *Brassica napus oliferia*	Arable farmland	Dec – Apr	No direct observations of feeding reported	9% (± 6%)	£52/ha of severely damaged crop (1978/79 prices)	Damage negligible during December, increased Jan-Mar, fell April. Recommend intensive scaring mid-Jan to end-Mar.
4	Inglis *et al.* (1990)	UK 1961 – 1972	Cereal stubble Clover leys Kale Charlock, chickweed Spring cereal sowings	Arable farmland	Oct – Nov Dec – Mar Jan – Feb Jan onwards Feb onwards	No direct observations of feeding reported	Not given	Not given	When clover covered in snow the birds switch to brassicas if available

NO.	REFERENCE	COUNTRY	CROP	HABITAT[1]	SEASON	DIURNAL	YIELD LOSS	LOSS £	COMMENTS
		UK 1975 – 1986	Cereal sowings Cereal stubble Oilseed rape Pea sowings/sprouting Spring cereal sowings Pasture		Oct – Nov Nov –Dec Jan – Feb Mar – Apr Mar – May Mar – May	No direct observations of feeding reported	Not given	Not given	Preference for sowings over stubble: reduction in time that stubble is available. Clover leys still available but no longer preferred. Area of spring sowings much reduced.
5	Inglis *et al.* (1997)	UK	Oil-seed rape	Arable (cereal and pasture)	Winter: Nov to Mar	No direct observations of feeding reported	Not given	Not given	Oilseed rape as nutritious as clover and more effectively gathered. Before the introduction of oil-seed rape, fed on clover and weeds during the winter months. Since the introduction of oilseed rape, the number of fledged young produced has a more important effect upon the woodpigeon population size than winter mortality from starvation.
6	Isaacson *et al.* (2002)	UK	Cereal sowings Cereal stubble Clover Kale Oilseed rape Legume sowings Germinating legumes	Arable (cereal and pasture)	Autumn & spring Aut-early winter Winter & spring Winter Winter Spring Spring	No direct observations of feeding reported	Not given	Not given	Strong trend for young leaves to be rejected. Mature leaves 1.66 times more strongly preferred than emerging ones. Emerging leaves are more protected by glucosinolate
7	Lambdon *et al.* (2003)	UK	Oil-seed rape *Brassica napus* *Brassica oleifera* *Brassica rapa*	Crops	Winter	No direct observations of feeding reported	Not given	Not given	

NO.	REFERENCE	COUNTRY	CROP	HABITAT[1]	SEASON	DIURNAL	YIELD LOSS	LOSS £	COMMENTS
8	Murton *et al.* (1963a)	UK	a) Spring barley b) Stooked wheat c) Ripe standing corn d) Stubble beans e) Stubble wheat/barley f) Autumn wheat g) Clover ley	Arable	a) Mar – Apr b) Aug c) Summer d) September e) Sept – Oct f) Oct g) May, Nov – Dec	a) 07:00 – 17:30 b) 07:00 – 09:30, 14:00 – 20:00 c) No time given d) 06:30 – 18:30 e) 06:30 – 17:30 f) 07:30 – 09:30, 12:30 – 16:30 g) 08:00 – 16:00	Not given	Not given	Preferred clover fields were those with clover and sainfoin grown for fodder. Weed seeds and other natural foods April-June.
9	Murton *et al.* (1964a)	UK	Red clover *Trifolium pratense* White clover *Trifolium repens* Barley Wheat	Arable	Highest percentage eaten: Clover: late Jan – early Mar Grain: Sept – Oct (autumn)	No direct observations of feeding reported	Not given	Not given	The amount of food available in late February and early March determined how many pigeons the study area could support.
10	Murton *et al.* (1964b)	UK	Clover, pasture and *Brassicae* Cereal and Legume sowings, clover and tree leaves, tree buds and flowers Ripe grain Grain from stubbles, ripe tree fruits (beech nuts and acorns)	Arable, some permanent pasture and coppices	Jan – Mar Apr – June Jul – Sep Oct - Dec	All daylight hours Shorter feeding day (increased resting time) Half day resting, half feeding All daylight hours			Winter – primarily clover leaves, supplemented by weed leaves. *Brassicae* during periods of snow. Spring – cereal sowings supplemented with tree leaf and flower buds. Wheat preferred to barley.

NO.	REFERENCE	COUNTRY	CROP	HABITAT[1]	SEASON	DIURNAL	YIELD LOSS	LOSS £	COMMENTS
11	Murton *et al.* (1966a)	UK	Red clover *Trifolium pratense* White clover *Trifolium repens*	Arable farmland – pasture, stubble and woodland	Nov - Mar	Recordings 09:45 – 15:15	Unaffected: >50% of clover crop eaten mid-winter but crop recovered early spring	Not given	Suggests that if flock size is too high relative to food availability, some birds have below optimum feeding rates and leave the flock to forage elsewhere.
12	Murton *et al.* (1971)	UK	Clover Chickweed Buttercup	Arable	Jan - Feb	08:00 – 16:00	Not given	Not given	The study was carried out in January and February to coincide with the availability of clover leaves.
13	Murton & Jones (1973)	UK	Spring Cabbage Brussels sprouts *Brassica olevacea spp.*	Agriculture, woods clover, cereals, ley	Peak damage: Cabbage-Mar Brussels sprouts-Feb-early Mar	No direct observations of feeding reported	Not given	Cabbage £105/acre	No/less economic damage to Brussels sprouts because marketable buttons untouched. The proximity of Brussels sprout crops may protect the fields of cabbage.
14	Smith *et al.* (1995)	UK	Oilseed rape Cereal Beans/peas Linseed Grass/Clover Set-aside Stubble	Agriculture	Peak damage: Nov-Mar Jul-Oct Mar-May Mar-May Jan-Apr Sept-Mar Aug-Oct	No direct observations of feeding reported	Not given	Not given	In general, the great majority pf holdings suffer from woodpigeon crop damage, particularly in the eastern half of the country.

[1] Habitat= habitat surrounding crop

Appendix 3 Species on which woodpigeons are known to feed.

	LATIN NAME	COMMON NAME	PART(S) OF PLANT EATEN	SEASON
Brassicae	*Brassica spp.*	In general [6]	Leaves [7, 9]	November[6] December[6] January[6] February[6, 9] March[6]
	Brassica olevacea spp.	Cabbage [8]	Leaves	December – May[8] (peak damage in March)
	Brassica olevacea spp.	Brussel sprout	Tops (buttons not pecked)	December[8] January[8] February[8] March[8]
	Brassica olevacea spp.	Kale [3, 5]	Leaves	December[3,5] January[3,5] February[3,5]
	Brassica napus oliferia	Oil-seed rape [1, 3, 9, 10, 11]	Leaves [2, 4, 12]	November[2,9,10] December - March[1,2,3,9,10,11] April[1,3,10] May[9]
	Brassica rapa	Turnip [12]	Leaves [4]	
	Brassica sp.	Mustard[*]		May[*] June[*] July[*]
Cereal	(**)	Cereal [8, 10]	Sowings [3, 11,12]	March – April[3,10,12] October – November[3,10,11]
	(**)	Cereal [3, 10]	Stubble [3, 12]	July–September[10,12] October[3,10] November[10,11] December[3,10,11] January[10]
	Hordeum vulgare L	Barley	Sowing [5, 12]	March - April[5,12]
	Hordeum vulgare L	Barley [6]	Standing/Stubble [3, 5,9, 12]	August[9,12] September[5,6,9,12] October[5,6,11,12] November[6,12] December[12]
	Triticum spp.	Wheat	Sowing [12]	February[12] October [12] November[12] December[12]
	Triticum spp.	Wheat	Growing [12]	July[12] August[12]
	Triticum spp.	Wheat [6]	Standing/Stubble [3, 5, 9, 12]	August[5,9,12] September[5,6,9,12] October[5,6,11,12] November[6,12] January[12]
	Zea mays	Maize	Stubble [9]	February[9]
	Avena spp.	Oats [3]	Green oats [12]	Late June[12]
Pastur e	*Onobrychis spp.*	Sainfoin [12]		December–April[12]
	Trifolium pratense	Red Clover [3, 8, 10]	Leaves [5, 6, 7, 12]	November[6,7] December–March[3,5,6,7,12] April[3,5,12] May[5,10,12] June[10,12]
	Trifolium repens	White Clover [3, 8, 10]	Leaves [5, 6, 7, 12]	November[6,7] December–March[3,5,6,7,12] April[3,5,12] May[5,10,12] June[10,12]
	Poaceae (spp)	Grass [10, 12]		Year round[10,12]
Cr o	*Beta vulgaris*	Sugar beet [13]	Tops/ leaves [9, 12]	November[9] January[9] April–July[13]
	Linum usitatissimum	Linseed [9, 10]		March[10] April[9,10] May[10] June[10]

	LATIN NAME	COMMON NAME	PART(S) OF PLANT EATEN	SEASON
	(Peas, Beans)	Legumes [10, 11]	Sowings [3, 9, 11]	March[3,9,10,11] April[3,10,11]
	(Peas, Beans)	Legumes [10]	Germinating / vines [3,9, 11]	March[3,10,11] April[3,9,10,11] May-June[9,10] July[9,10,12] August[10,12] November[9]
	(Peas, Beans)	Legumes	Stubble [5, 9]	August[9] September[5,9]
	Sinapsis alba	White mustard [*]	Leaves [12]	March[12] May[12,*] June[12,*] July[12,*]
	Symphytum tuberosum	Potatoes [9]	(Frosted)	January[9] December[9]
Wild/weeds	*Cerastium holosteoides*	Common chickweed [3, 14]	Leaves [12]	January[12,14] February[12,14]
	Cerastium holosteoides	Common chickweed	Seeds [12]	May[12] June[12]
	Corylus avellana	Hazel	Buds [12]	March – May[12]
	Crataegus spp.	Hawthorn	Berries	January[*]
	Crataegus spp.	Hawthorn	Buds [5, 12]	Late March - May[5,12]
	Fagus sylvatica	Beech	Mast [3, 9]/ Nuts [9, 12]	October[9, 12] November[3,12] December[3,12]
	Fagus sylvatica	Beech	Acorns [3, 9, 12]	October[9] November[3,12] December[3,12]
	Fagus sylvatica	Beech	Buds / flowers [12]	May[12]
	Fraxinus spp.	Ash	Buds / leaves [12]	March – May[12]
	Hedera helix	Ivy [*]	Berries [6, 12]	January[12,*]
	Potentilla anserina	Silverweed	Fleshy rhizomes [12]	December[12] January[12] February[12]
	Ranunculus spp.	Buttercup [14]	Leaves [12]	January[12,14] February[12,14]
	Ranunculus repens	Buttercup	Seed [12]	May[12] June[12]
	Salix spp.	Willow	Buds [12]	March[12] April[12]
	Sinapis arvensis	Charlock/Wild mustard [3,*]	Leaves [12]	April[12] May[12,*] June[12,*] July[12,*] August[12] September[12] October[12]
	Sinapis arvensis	Charlock/Wild mustard [*]	Seed [12]	April – October[12]
	Stellaria media	Chickweed [14]	Leaves	January [14] February [14]
	Stellaria media	Chickweed	Seed [12]	May [12] June[9,12]
	-	Weed	Leaves [8, 12]	January [12] February[12] March [12] April[5,12] May[5,12] June[5,9]
	-	Weed	Flower bud [8]	
	-	Weed	Seed [5, 8, 9]	June[9] July[9]
	Veronica spp.	Speedwell / gypsyweed	Leaves [12]	January[12] February[12]
	Viola tricolor	Heartsease [12]	Seed [12]	May[12] June[12]

[1] Inglis *et al*. (1989), [2] Inglis *et al*. (1997), [3] Isaacson *et al*. (2002), [4] Lambdon *et al* (2003), [5] Murton *et al.* (1963a), [6] Murton *et al*. (1964a), [7] Murton *et al.* (1966a), [8] Murton & Jones (1973)
[9] http://www.pigeonwatch.co.uk/crops.htm, [10] Smith *et al.* (1995), [11] Inglis *et al.* (1990), [12] Murton *et al*. (1964b), [13] Dunning (1974), [14] Murton *et al*. (1971b), [*]Fact sheet, ([**]) Wheat, Barley and Oats

Appendix 4 Seasonal consumption of different plant types.

	Latin name	Common name	Part	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Au	Sep	Oct	Nov	Dec
Brassicae	*Brassica olevacea spp.*	Cabbage	Leaves												
	Brassica olevacea spp.	Brussel sprout	Tops												
	Brassica olevacea spp.	Kale	Leaves												
	Brassica napus oliferia	Oil-seed rape	Leaves												
	Brassica rapa	Turnip	Leaves												
	Brassica sp.	Mustard													
Cereal		Cereal	Sowings												
		Cereal	Stubble												
	Hordeum vulgare L	Barley	Sowings												
	Hordeum vulgare L	Barley	Standing												
	Triticum spp.	Wheat	Sowings												
	Triticum spp.	Wheat	Standing												
	Zea mays	Maize	Stubble												
	Avena spp.	Oats	Green												
Pasture	*Onobrychis spp.*	Sainfoin													
	Trifolium pratense	Red Clover	Leaves												
	Trifolium repens	White Clover	Leaves												
	Poaceae (spp)	Grass													
Crops misc.	*Beta vulgaris*	Sugar beet	Tops/leaves												
	Linum usitatissimum	Linseed													
	(Peas, Beans)	Legumes	Sowings												
	(Peas, Beans)	Legumes	Germinating												
	(Peas, Beans)	Legumes	Stubble												
	Sinapsis alba	White mustard	Leaves												
	Symphytum tuberosum	Potatoes													
Wild/weeds	*Cerastium holosteoides*	Chickweed	Leaves												
	Cerastium holosteoides	Chickweed	Seeds												
	Corylus avellana	Hazel	Buds												
	Crataegus spp.	Hawthorn	Berries												
	Crataegus spp.	Hawthorn	Buds												
	Fagus sylvatica	Beech	Mast/acorns												
	Fagus sylvatica	Beech	Buds/flowers												
	Fraxinus spp.	Ash	Buds/leaves												
	Hedera helix	Ivy	Berries												
	Potentilla anserina	Silverweed	Rhizomes												
	Ranunculus repens	Buttercup	Leaves												
	Ranunculus repens	Buttercup	Seeds												
	Salix spp.	Willow	Buds												
	Sinapis arvensis	Charlock	Leaves/seeds												
	Stellaria media	Common chickweed	Leaves												
	Stellaria media	Common chickweed	Seeds												
		Weed	Leaves												
		Weed	Seeds												
	Veronica spp.	Speedwell	Leaves												
	Viola tricolor	Heartsease	Seeds												

Month eaten

Peak damage

Appendix 5 Bird deterrent documents reviewed

No.	Reference	Bird species	Category	Device	Effective?	Country	Site	Crop	
1	Areson (1986)	Starlings Pigeon	Chemical – Roost sites	Avicide – BCF7000	Yes	USA	Field - Refinery	N/A	*
2	Avery (1992)	Cedar waxwings starlings	Chemical – Crop spray	Methyl anthranilate 10%(g/g), 11% (g/g)	No	USA	Flight pen	Blueberry	
3	Avery *et al.* (2008)	Feral pigeons	Chemical – Fertility control	Nicarbazin 40g of 5000ppm/day	Yes	USA	Aviary	N/A	*
4	Barras & Seamans (2002)	Various	Habitat management	Vegetation height and structure	Needs further investigation	USA	Field	Airport	
5	Belant *et al.* (1997)	Brown-headed cow birds Canada geese	Chemical – mix grain turf powder turf slurry	Hydrated lime 6.25, 12.5, 25.0%(g/g) 544kg/ha 1:20(g/g)	yes partial partial	USA	Cage and pen	N/A	
6	Blackwell *et al.* (2002a)	Brown-headed cow birds European starlings Rock doves Canada geese Mallards	Visual	Laser	no no Partial yes partial	USA	Cage	N/A	*
7	Central Science Laboratory (2000)	Woodpigeon	Lethal - Shooting	Shooting – summer v winter	Summer far greater influence	UK	Modelling	N/A	
8	Clark (1998)	Various	Repellents - review	Primary repellents Secondary repellents	Not if no other food source is available Generally toxic	Various	N/A	N/A	
9	Conover (1979)	Various	Scaring – Raptor models	Sharp-shinned hawk model Goshawk model Plastic kite	Partial Yes Yes (most effective)	USA	Field	Feeders Blueberry	
10	Cotterill *et al*. (2001)	Woodpigeon	Chemical	Cinnamamide	Partially	UK	Lab/Field	Oilseed rape	*
11	Crocker & Perry (1990)	Various inc. Feral pigeons	Chemical – Review	Varied Cinnamamide 0.5% (w/w/)	UK	UK	Lab. Aviary	Oil seed rape	
12	Dolbeer *et al.* (1998)	Canada geese Brown-headed cowbirds	Chemical – Spray grass Seed treat.	Flight Control™ (Anthraquinone) 2.02kg/ha 0.1, 0.5, 1.0%	Yes Yes	USA	Pen Aviary	N/A	
13	Erickson *et al.* (1990)	Various	Hazing - Review	Raptors	Partial	Various	Field	N/A	
14	Fazlul & Broom (1984)	Woodpigeon	Visual	Kite (red)	Yes	UK	Field	Spring	*

No.	Reference	Bird species	Category	Device	Effective?	Countr y	Site	Crop	
			Visual Auditory Visual + auditory	Scarecrow Humming line Gas banger	No No Partial			Cabbage	
15	Ferri *et al*. (2009)	Feral pigeon	Chemical	Nicarbazin 8-10g of 800ppm/day	Partial	Italy	Urban	N/A	*
16	Fukuda et al. (2008)	starlings	Visual	Peacful Pyramid Eye-spot balloon	No	New Zeal.	Field	grapes	
17	Gill *et al*. (1998a)	Passerines	Chemical – Peanut treat	Cinnamamide 0.6% (w/w)	Yes – effective for flock feeders	UK	Field – Feeding stations	Woodland edge	
18	Gill *et al.* (1998b)	Woodpigeon	Chemical – Spray crop	Cinnamamide 2kg/ha	Partial	UK	Field	Oilseed rape	*
19	Gill *et al.* (1999)	Various incl. woodpigeons	Chemical – Review	Various repellents	Varied	UK	Lab &Field	Various	
20	Gilsdorf *et al.* (2002)	Various incl. pigeons	Review	Visual and auditory scaring devices	Varied	USA	Field	Various	
21	Giunchi *et al.* (2007)	Feral Pigeon	Chemical – Fertility control	Nicarbazin 38-82mg/day	Partial	Italy	Aviary	N/A	*
22	Gorenzel *et al*. (2002)	American crows	Visual	Laser	No	USA	Urban roosts	N/A	
23	Guarino (1972)	Various	Chemical – Seed treatment Crop spray	Methiocarb on: Sprouting seeds Ripening Grain (rice) Grain sorgum Fruit	 Yes Partial Yes Yes	USA	Field	Various	
24	Harris and Davies (1998)	Gulls, waterfowl, rock doves, starlings, snow buntings	Review	Habitat modification Auditory Visual Chemical Exclusion Removal	Varied	Various	Airports	N/A	
25	Hunter (1974)	Woodpigeon	Visual Auditory	Pigeon carcasses (wings extended) Metal pigeon models (wings extended) Broadcasting electronically synthesised sound	carcass & models equal habituation 1to 5 weeks habituation 1 to 3 weeks	UK	Field	Cabbage Spouts	*
26	Inglis & Isaacson (1987)	Woodpigeon	Visual	Corpses Wings Models	Corpses, models, pairs wings - Yes Single wings, Silhouettes - No	UK	Field	Clover	*
27	Inglis *et al*. (1989)	Woodpigeon	lethal auditory visual auditory + visual Habitat	shooting gas cannon Scarecrows, bags, windmill-type , kites	No Partial partial Yes Yes	UK	Field	oilseed rape	*

No.	Reference	Bird species	Category	Device	Effective?	Country	Site	Crop	
				Presence of roads/homes					
28	Inglis *et al. (*1994)	Woodpigeon	Habitat management	Extend existing woodland rather than create new copses and shelter belts	No data	UK	Field and woodland	N/A	*
29	Koyuncu and Lule (2009)	Crow	Auditory	Predator call: Falcon (*Buteo lagopus*)	Yes: call period 1min play, 6 min pause	Turkey	Urban	N/A (roosts)	
30	Lambdon *et al*. (2003)	Woodpigeon	Chemical-repellent	Chemical defences - Glucosinolates	Preference for more mature leaves (low glucosinolates) over young leaves (high glucosinolates)	UK	Field Aivary	Brassica	*
31	Lofts *et al.* (1968)	Pigeon	Chemical – fertility control	22,25-Diazacholesterol dihydrochloiride (compound SC-12937) 30mg SC-12937 60mg SC-12937	30mg: Partial effect on courtship behaviour; meiosis inhibited 60mg: Yes – courtship beh. suppressed; meiosis inhibited	UK	Cage	N/A	*
32	Mason & Clark (1992)	Various	Review – Chemical Deployment	Various	Varied	USA	Field	N/A	
33	Marsh (1992)	Various	Visual	Scarecrows Predator models	Varying – more effective when accompanies by auditory scaring. Habituation occurs.	USA	Review	N/A	
34	McKay *et al*. (1999b)	Woodpigeon	Pesticide – Seed treatment	Fonofos	Partial avoidance	UK	Field	Cereal	
35	Murton (1960)	Woodpigeon	Lethal	Nest destruction	Yes - 63% expected young unfledged	UK	Field/woodland	N/A	*
36	Murton (1962)	Woodpigeon	Chemical	Cereal and pea baits with 1.5% α-chloralose (alpha-chloralose)	Yes	UK	Field	various	
37	Murton *et al.* (1963b)	Woodpigeon	Chemical	Cereal and pea baits with 1.5% α-chloralose	Yes	UK	Field	Various	*
38	Murton & Vizoso (1963)	Woodpigeon	Chemical – Seed treatment	aldrin, dieldrin, heptachlor, Ɣ-BHC autumn sowings less important than spring sowings	aldrin, dieldrin and heptachlor: woodpigeon mortality 8%	UK	Field	Cereal	*
39	Murton *et al.* (1964a)	Woodpigeon	Lethal - Shooting	Battue shooting	No	UK	Field	Wheat, Barley, Clover	*
40	Murton *et al.* (1965)	Woodpigeon	Chemical	Bait: Wheat with 3% alpha-chloralose	Stupefying (5% mortality)	UK	Field	Nest site	*
41	Murton (1966)	Woodpigeon	Lethal - Shooting	Statistically modelling the effect of shooting	No	UK	Desk-based	N/A	*
42	Murton *et al.* (1968)	Woodpigeon	Chemical	Bait: Tic beans with 2% alpha-chloralose	Yes - temporary reduction in local numbers	UK	Field	Brassicas	*
43	Murton (1971)	Woodpigeon	Chemical	Alpha-chloralose bait:	Yes - woodpigeons	UK	Field	Clover	*

No.	Reference	Bird species	Category	Device	Effective?	Country	Site	Crop	
				Tic beans , Maple peas, green peas	successfully caught for crop analysis				
44	Murton *et al.* (1972)	Feral pigeon	Lethal – chemical + trapping	Stupefying bait + trapping and killing	No	UK	Docks	N/A	*
45	Murton & Jones (1973)	Woodpigeon	Lethal - Shooting	Shooting –cartridges provided	No	UK	Field	Cabbage Brussel sprouts	*
46	Murton *et al.* (1974)	Woodpigeon	Lethal – Shooting Decoy carcasses Decoy models	Battue (roost) shoots decoy shooting Varying numbers of decoys	No Partial Partial	UK	Field	Clover and cereals	*
47	Rodriguez *et al.* (1995)	Eared-dove	Chemical	methiocarb calcium carbonate 'paint' Methiocarb + Calciium carbonate 'paint'	Yes - calcium carbonate most repellent	Uruguay	lab aviary field	Sunflower	*
48	Seamans *et al*. (2007)	Common grackle, European starling, American robin, Red-winged blackbird, Eastern meadow lark, northern flicker	Habitat Management	Manipulation of vegetation height	Unclear-potentially less flocking birds using tall vegetation	USA	Field	N/A	
49	Sivaraj *et al.(*2012)	Parrot Sparrow Mynah Pigeon Peacock	Auditory and visual	Locally constructed scarer, 'wind chime' like	ND	India	Field	Sorghum maize sunflower millet	
50	Smith *et al.* (1995)	Woodpigeon	Lethal Auditory Visual	Shooting Bangers Scarecrows	Yes Yes Slight	UK	Field	Oilseed rape Cereal Beans/peas Linseed Grass/Clover Set-aside Stubble	
51	Staples *et al.*(1998)	N/A	Chemical - seedling toxicity	Methyl anthranilate	N/A	Australia	Lab.	N/A	
52	Vercauteren *et al*. (2005)	Deer	Dog	Invisible fence	Yes	USA	Field	Fruit & vegetable	

No.	Reference	Bird species	Category	Device	Effective?	Country	Site	Crop
53	Vogt (1992)	Gull, duck	Chemical	ReJeX-iT AG-12 (active ingredient - Methyl Anthranilate) added to water bodies	Yes – but application problems	USA	Pen	Fruit trees, golf courses
54	York *et al.* (2000)	Horned lark	Chemical	flight control™ mesurol®	Moderate	USA	Field enclosures	Lettuce seedlings

EFFECTIVE? = decision based on the information available in the document; * = studies selected for further evaluation, DD = Data Deficient

Appendix 6 System used to evaluate studies investigating avian management techniques.

Criteria	Score	Description
Context	0	Non-UK studies where neither bird species or crop are present in the UK
	1	Non-UK studies where either bird species or crop are present in the UK whilst the other is absent
	2	UK studies where both bird species and crop are present in the UK
Treatment	0	Treatments applied at unrealistic levels of intensity or using techniques not legal or recommended in the UK
	1	Some treatments applied at unrealistic levels or using techniques not legal or recommended in the UK
	2	All treatments applied at practical, legal and recommended levels (relevant to the UK)
Experimental Design	0	Lacks adequate control and/or sufficient replication.
	1	Has control and replication, but does not adequately address habituation, or is confounded by other factors.
	2	Adequate control, replication and addresses confounding factors.
Cost/benefit analysis	0	Costs and benefits not measured.
	1	Costs and/or benefits partially measured
	2	Cost/benefit analysis carried out in full.

Appendix 7 Studies investigating avian management techniques on Columbiformes.

Effectiveness score: 2 = effective (>50% reduction in damage or number of birds), 1 = partially effective (up to 50% reduction), 0 = ineffective (no significant reduction).

REFERENCE	TECHNIQUES EVALUATED	CONCLUSIONS OF STUDY	CONTEXT	TREAT.	EXP. DESIGN	COST-BENEFIT	RESULTS	EFFECTIVENESS OF TECHNIQUE
Areson (1986)	Chemical (Lethal) – Avicide BCF 7000	Effective	1	0	0	0	Roosting pigeon and starling population reduced to zero. Minor reinfestation of pigeons, zero starlings.	2
Avery (2008)	Chemical – Fertility control (Nicarbazin, 40g at 5000ppm/day)	Effective	1	0	1	0	59% reduction in number of nestlings. Combination of control methods would be most successful.	2
Blackwell *et al.* (2002a)	Visual: Lasers	Partially effective	1	2	2	0	Limited avoidance behaviour by rock doves. Has potential but further controlled studies required.	1
Cotterill *et al*. (2001)	Chemical Rape variety	Effective Effective	1 1	0 2	1 1	0 0	Mid-Jan to early-March less damage to Cinnamamide plots than control plots (max. 23% reduction). High glucosinolate line less damage than control line (max. 32% reduction). Most protection on plots with both Cinnamamide and high glucosinolate. But reduction in damage not translated into increased yield at harvest.	1 1
Fazlul & Broom (1984)	Visual: Kite	Effective	2	2	0	0	Woodpigeons avoided flying or settling within 250m. Severely damaged plants; Year 1: 0.6% per week (control 14.7% per week). Year 2: 1.3% per week (no control)	2
	Auditory: Gas banger	Partially effective	2	2	0	0	Severely damaged plants: Year 1: 1.3% per week (control 14.7% per week). Year 2: 14.5% per week (no control)	1
	Visual: Scarecrow	Ineffective	2	2	0	0	Severely damaged plants: Year 2: 49.9-84.6% total	0
	Auditory: Humming line	Ineffective	2	2	0	0	Severely damaged plants: week 1: 2.6% week 2: 19.5% week 3: 64.7%	0
Ferri *et al*. (2009)	Chemical – Nicarbazin 8-10G OF 800PPM/DAY	Partially effective	2	0	1	0	Population size of urban colonies of feral pigeons reduced by a mean of 6-39% over 2-7 years. In four cities, 28-50% reduction in first 18 months.	1
Gill *et al*. (1998b)	Chemical – Cinnamamide 2kg/ha	Partially effective	2	0	2	0	Reduced damage to inner leaves by ≤44%. Outer leaves by ≤57%. Lack of persistence on leaves.	1
Giunchi *et al*. (2007)	Chemical – Fertility control Nicarbazin 38-82mg/day	Partially effective	1	0	1	0	In 4 trials, change in productivity of +2%, -13%, -46%, -48%.	0

REFERENCE	TECHNIQUES EVALUATED	CONCLUSIONS OF STUDY	CONTEXT	TREAT.	EXP. DESIGN	COST-BENEFIT	RESULTS	EFFECTIVENESS OF TECHNIQUE
Hunter (1974)	Visual: Pigeon carcassess, metal pigeon models	Partially effective	2	2	0	0	No difference in response to pigeon carcass or metal model. Models reduced the damage to crops until the flock became habituated within 1 to 5 weeks.	1
	Auditory: Electronically synthesised sound	Partially effective	2	2	0	0	Habituation within 1-3 weeks.	1
Inglis & Isaacson (1987)	Open-winged woodpigeon corpses	Effective	2	2	2	0	Significant protection over 9 weeks.	2
	Pairs of woodpigeon wings	Effective	2	2	2	0	As effective as whole bodies	2
	Single wings (real and artificial)	Ineffective	2	2	2	0	Single wings did not elicit strong avoidance; real wing significantly more aversive than artificial wing.	0
	3D lifelike models	Effective	2	2	2	0	As effective as corpses	2
	Silhouettes	Ineffective	2	2	2	0	No more effective than plastic discs.	0
Inglis *et al*. (1989)	Lethal – Shooting Auditory and visual Habitat Management	Ineffective Effective Effective	2 2 2	2 2 2	0 0 0	0 0 0	Amount of crop damage caused is inversely proportional to the level of scaring and proportion of field boundary bordered by homes and/or roads. Positively correlated to the presence of a roost within 1km.	ND
Inglis *et al.* (1994)	Habitat management	Correlated	2	2	0	0	Woodpigeon nest density increased as the size of woodland decreased: Extension of existing woodlands rather than creation of new copses is preferable.	ND
Lambdon *et al*. (2003)	Chemical - Glucosinolates	Potential	2	2	2	0	Mature leaves 1.7 times more likely to be damaged; mature leaves low in glucosinolates; whilst young leaves have high concentration. Plants natural defence to protect the inner leaves against herbivores.	NA
Lofts *et al.* (1968)	Chemical - Reproduction inhibitor 22,25-Diazacholesterol dihydrochloride	Partial	2	0	2	0	60-mg: all courtship suppressed; meiosis inhibited. 30-mg: limited effect on courtship; meiosis inhibited.	1
Murton (1960)	Lethal – nest destruction	Effective	2	1	1	1	Effective in reducing the number of fledglings by 63%, labour intensive. Crop damage not assessed.	2
Murton *et al*. (1963b)	Chemical –Alpha-chloralose	Partially effective	2	0	2	1	Overall: 57% birds caught were woodpigeons On pasture: 74% were wood-pigeons Cheaper and more efficient than shooting and nest destruction but more investigation required.	1
Murton & Vizoso (1963)	Chemical - aldrin, dieldrin, heptachlor, and ɣ-BHC- dressed grain	Effective in the short term. As autumn sowings are less important to pigeons than spring sowings, treatment should concentrate on	2	0	0	0	1961: 8% of woodpigeon population poisoned 1961: withdrawal of aldrin, dieldrin, heptachlor - mortality too low to measure.	NA

REFERENCE	TECHNIQUES EVALUATED	CONCLUSIONS OF STUDY	CONTEXT	TREAT.	EXP. DESIGN	COST-BENEFIT	RESULTS	EFFECTIVENESS OF TECHNIQUE
		the Springtime.						
Murton *et al*. (1964a)	Lethal - Shooting	Ineffective	2	2	1	0	Battue shooting (Feb-Mar) did not exceed natural winter mortality. Higher percentage of birds killed at low population densities. To be most effective at preventing clover damage, shooting required in December.	0
Murton *et al*.(1965)	Chemical – stupefying baits (wheat with 3% Alpha-chloralose)	Effective	2	0	0	0	Woodpigeons successfully captured; 5% mortality.	ND
Murton (1966)	Lethal - Shooting	Ineffective	2	2	1	0	Statistical modelling from ringing data indicated that shooting is ineffective; population remained constant.	0
Murton *et al*.(1968)	Chemical – Tic beans with 2% Alpha-chloralose	Effective	2	0	1	1	89% of birds caught were woodpigeons. About half the trials were 'successful' in that most of the pigeons which were on crops were caught. Temporarily reduces local grazing pressure; birds replaced.	2
Murton (1971)	Chemical - Alpha-chloralose	Effective	2	0	0	0	133 and 162 woodpigeons successfully caught ; unknown % of population.	ND
Murton *et al*.(1972)	Chemical – alphachlorolose + cage trapping	Partially effective	2	0	0	1	More pigeons killed than docks population at any one time; removed birds replaced by immigrants. Around 9,000 birds killed over two years to hold population at half its former level (2,600 birds to 1,300).	1
Murton & Jones (1973)	Visual/auditory scaring - gas cannons, rope-bangers, scarecrows, glitter strips Lethal - Shooting	Unknown Ineffective	2 2	2 2	2 2	2 2	No areas without control for comparison. Amount of damage not correlated with amount spent on crop protection. Shooting applied in addition to other control. No difference in damage between shooting and non-shooting sites	0
Murton *et al*. (1974)	Lethal - Shooting	Battue shoots – Ineffective Decoying – Partially effective	2	2	1	1	Battue: No increase in total winter mortality. Decoying: Increased late-summer to winter mortality but no clear reduction in subsequent breeding numbers. Decoy shooting most effective for single birds or small flocks (ignoring any scaring benefit). Decoy shooter: £0.24/killed bird for shooting; about £0.50/killed bird for shooting to affect population size; £0.13/bird with stupefying bait.	0 1
		Carcass decoys Model decoys	2 2	2 2	1 1	1 1	Increase in the number of pigeon carcass decoys with closed wings to about 80, or with open wings to about 40, led to an increase in numbers of birds shot; but with more decoys birds were repelled. With 5 closed wing decoys 7% of pigeons 'at risk' were killed, 20 decoys 14%, 80 decoys 23%. Model decoys less effective (13-46%) than pigeon carcasses.	1 1
Rodriguez *et al*. (1995)	Methiocarb and calcium carbonate 'paint'	Effective	1	0	2	2	Calcium carbonate most repellent and cost-effective. Treating only field borders as effective as treating whole field.	1