Project title:	Brassicas, leafy salads, oilseed rape and legumes: Developing and evaluating management strategies to mitigate woodpigeon *Columba palumbus* damage to crops
Project number:	FV 426a
Project leader:	Dr Dave Parrott, National Wildlife Management Centre, Animal and Plant Health Agency
Report:	Final report, 31 March 2018
Previous report:	First Year and Second Year Annual Reports
Key staff:	Dr Dave Parrott (APHA), Rebecca Jones (APHA), Ed Tooth (APHA), David Fouracre (APHA), Ray Ridley (APHA), Jeff Sandon (APHA), Nigel MacDonald (Austin Consultancy)
Location of project:	Lincolnshire and East Yorkshire
Industry Representative:	Andy Richardson (Allium and Brassica Centre), Stephen Francis (Fen Peas Ltd), Dermot Tobin (PDM Produce UK Ltd.)
Date project commenced:	01/05/2015
Date project completed (or expected completion date):	31/03/2018

DISCLAIMER

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.

Dr Dave Parrott

Senior Wildlife Ecologist

Animal and Plant Health Agency

Signature .... Date .....22.03.2018............

Report authorised by:

Dr Giovanna Massei

Head of Wildlife Research and Control Team

Animal and Plant Health Agency

Signature Date 26/3/2018

Dr Graham Smith

Lead Scientist, National Wildlife Management Centre

Animal and Plant Health Agency

Signature .... Date ...22/3/2018...

CONTENTS

GROWER SUMMARY

Headline

Current woodpigeon management practices can be enhanced through a more strategic approach that incorporates lethal and non-lethal techniques, with growers cooperating and coordinating control activities at the landscape-scale. At the field-scale, both audio-visual deterrent techniques reinforced with live shooting and an automated laser independently reduced woodpigeon grazing and crop damage on brassicas. Lower crop damage was associated with greater crop head size and a higher percentage of plants harvested at first cut. At the landscape-scale, coordinated shooting focussed on pest removal can remove woodpigeons at a greater rate than intermittent shooting at the level of the individual holding or sports-shooting focussed on individual patches and bags.

Background

The woodpigeon *Columba palumbus* is recognised as a major agricultural pest in the UK, feeding on a range of arable crops including horticultural brassicas, leafy salads, oilseed rape and legumes. In addition to reducing yield, woodpigeons can impact on the harvesting schedule and also diminish the appearance and eventual saleability of produce. Existing woodpigeon management practices, across all crops, are frequently ineffective and often costly, particularly for high value horticultural brassicas. There is an extensive range of bird deterrents and management strategies deployed by growers, however evidence for their effectiveness is often lacking or is largely anecdotal. The current research project focussed on evaluating and developing management strategies that integrate the most promising deterrent techniques (current and novel) and other measures (e.g. shooting) – taking forward the current knowledge on woodpigeon management reviewed in FV 426.

This final project report details field trials undertaken in the final year (2017-18) and draws together the findings across all three years of the project.

Summary

Reinforced deterrents

- The effectiveness of visual and auditory deterrents (life-like mannequins, gas cannons and rope-bangers), reinforced with periods of live shooting by marksmen dressed identically to the mannequins, was evaluated in a series of 10-week field trials.

- Preliminary field trials (2015-16) on autumn-sown brassicas (life-like mannequins and gas cannons) with reinforced shooting showed that the effectiveness varied markedly between fields, from very effective to ineffective.

- Subsequent field trials (2016-17), with a modified deployment of the deterrents, compared woodpigeon grazing and crop damage between two groups of brassica fields (broccoli and cauliflower): Group 1 (treatment) received visual and auditory deterrents (life-like mannequins, gas cannons, rope-bangers) reinforced with live shooting (concentrated in the first two weeks); Group 2 (controls) received no deterrents other than those deployed by growers.

- A total of 15 fields were used: 7 treatment and 7 control; one further field was split into a treatment half and control half. Fields were arranged into six study groups based on their proximity and ownership; each study group contained both treatment and control field/s.

- In all fields crop damage measurements were undertaken at the initiation of the trial (prior to, or as near as possible to, the onset of woodpigeon grazing) and at 2-week intervals throughout the trial. Observations of woodpigeon activity were undertaken on all fields.

- In five of the six study groups, on Group 1 fields (treated): woodpigeon numbers and the time they spent on fields was lower; and the proportion of plants suffering high grazing damage was lower, compared to control fields.

- At the end of the trials, the median change in the percentage of plants scored as having high damage on treatment fields was a decrease of -30% to -38% compared to an increase of +27% to +43% on control fields (values dependent on sample groups).

- At harvest, the head size of mature plants was greater; and a higher percentage of plants was cut on first pass in areas of fields suffering low damage compared to areas receiving high damage.

Shooting – population management

- The effectiveness of shooting and impact on woodpigeon abundance within an 8,200ha area in Lincolnshire was evaluated over a 10-week period April to mid-June 2016.

- There were four categories of land with: (i) shooting undertaken by APHA staff only, (ii) shooting undertaken by APHA staff and landowner appointees, (iii) shooting undertaken only by landowner appointees, and (iv) no shooting. Landowners/growers provided shooting returns - this included a number of returns from land outside the study area.

- A total of 2137 woodpigeons were reported shot, 1575 within the study area.

- Of the 2137 woodpigeons reported shot, APHA marksmen accounted for 955 (45%) (60% of the 1575 shot within the study area). Of the 955 woodpigeons shot by APHA marksmen 57% involved shotguns and 43% air rifles.

- Numbers of woodpigeons observed in the study area decreased from a mean of 1661 in the first two weeks of April, thence remaining relatively steady over the following 8 weeks fluctuating around a mean of 728 (387-1386), i.e. there was not a continuous decline in woodpigeon numbers over the trial.

- There was little apparent cooperation between neighbouring growers, with individual growers restricting shooting effort on their land to vulnerable periods in the growing cycle of their own crops. An effect of this approach is that, outside of periods when vulnerable crops are available, woodpigeons have access to holdings that serve as safe havens.

- For sport shooting, the spatial and temporal distribution of the reported hunting appeared to be dictated by the convenience and protectionism of shooters' 'patches', with the onus on ensuring good days' bags for those with shooting rights; access to hunt by others being denied. An effect of sport shooting is that during the period between successive shoots, woodpigeons have access to holdings that serve as safe havens.

- Sport shooters were also resistant to what they perceived as overly intense shooting management (e.g. roost shooting with air rifles and night vision), seeking to retain healthy populations for sport.

- The current approach to shooting woodpigeons in the study area was not consistent with maximising population management; with implications for overall crop protection. Effort focussed at the scale of the needs of individual holdings and the aspirations of sport shooters constrains the overall impacts of wider control. A more effective approach to population management would require greater cooperation between growers and a strategic approach focussed at the landscape-scale.

Shooting – field scale

- The limited data gave some indication that at the field-scale, shooting (shotguns over decoys) reduced the numbers of woodpigeons utilising the immediate area (radius 250m) around a shooting site.

- Although, in most cases woodpigeons returned to the field in less than five days following the shooting session, their numbers were markedly lower (by an average of 73%).

- Caution needs to be taken, however, in drawing conclusion from these observations.

- Monitoring of woodpigeon numbers in the study area was designed to evaluate the effects of shooting at the landscape-scale, not at the field-scale. Therefore, it is not known how reliable field-scale counts were in respect to actual numbers of woodpigeons before and after shooting sessions.

- A robust evaluation of the effects of shooting at the field-scale requires a monitoring protocol based at the scale of the shooting sites.

Hand-held laser – roost dispersal

- A small-scale investigation (January 2017) tested whether a low-powered, hand-held laser could disperse woodpigeons from a habitual winter night time roost.

- The trial involved three sequential one week phases (pre-treatment, treatment, post-treatment) with a laser deployed at a roost at dusk on each of five consecutive evenings during the treatment period. A second untreated roost 6km away was simultaneously monitored for comparison.

- Complete (or near complete) dispersal was achieved by the end of the five consecutive evenings of treatment; the effect increasing incrementally over the treatment period.

- Roost dispersal was short-term, however, with numbers in the roost showing full recovery over a five day period post-treatment. This highlights the need for subsequent periodic use of the laser to maintain deterrence.

- During the five-day treatment, numbers of woodpigeons in the area surrounding the roost (1km radius) increased at a lower rate than around a similar untreated roost.

Hand-held laser – field scale

- A small-scale investigation tested whether low-powered hand-held lasers (a small 'laser-pointer' type and a larger, commercial 'bird-scaring' laser) could reduce woodpigeon grazing on a field of winter cabbage.

- Over a five week period, the lasers were deployed onto the field from a vehicle from the field edge, two to three times per week at different times of the day, but focussing around early morning and late evening when the laser was most visible.

- Both lasers consistently lifted grazing woodpigeon flocks off the field from up to a distance of 300m.

- Although the lasers were consistently successful in lifting woodpigeons this was short-lived with birds (original and/or new arrivals) often repeatedly re-landing in the field, usually at a greater distance from the source of the laser.

- Numbers of woodpigeons recorded on the field remained largely unchanged throughout the treatment period.

- It cannot be ruled out that a more frequent and persistent use of the laser would have a cumulative and longer-term deterrent effect.

Automated laser – field scale

- The effectiveness of an automated laser was tested in a cross-over experiment on two fields of autumn-sown sprouts. Field 1 was treated with the laser and the second field (Field 2) left untreated (control). After four weeks the laser treatment was switched between fields and the trial run for another four weeks.

- Over the initial four-week period, crop damage increased on both fields but was markedly lower on the laser-treated field (+9%) than on the control field (+89%). Switching of the laser between fields reversed these trends – crop damage decreased markedly on the now protected Field 2 (previously control) (-74%) and increased on the now unprotected Field 1 (previously laser-treated) (+33%).

- During monitoring periods over the initial four-weeks, only a single woodpigeon was recorded on the laser-treated Field 1, whilst control Field 2 received flocks of up to 86 woodpigeons. Following switching of the laser between fields, on the previously laser-treated Field 1, woodpigeons were now recorded in each observation session, up to a flock size of 183 birds. On Field 2, woodpigeon grazing continued although with smaller flocks. This apparent contradiction of continued woodpigeon grazing and yet marked decrease in crop damage across Field 2 appeared to be due to the topography creating small laser blind-spot areas, in which woodpigeons continued to graze.

- The results are consistent with a deterrent effect of the automated laser. Some caution is required, however, due to confounding variables - oilseed rape and peas in fields neighbouring Field 1 may have contributed to attracting woodpigeons away.

- Further replicated trials of the automated laser are required to confirm the magnitude and duration of the deterrent effect and also to refine its deployment in terms of optimising the siting and laser pattern of the device.

Drone

- A small-scale investigation tested whether flying an unmanned aerial vehicle (drone) could deter grazing woodpigeons from a field of brassica.

- Over three sequential days a drone was flown 37 times in response to flocks of woodpigeons (20 to 160 birds) landing in the trial field (13.2 ha).

- The deterrent effect of the drone was very short-term: woodpigeons flying from the field at the approach of the drone, and taking refuge in nearby trees or hedges; the median distance flown was 300m (100-420m).

- On 100% of occasions woodpigeons returned to the field; median time to return was <20 minutes (<3 to <45 minutes).

- There was no difference in the overall pattern of woodpigeon activity (median numbers of woodpigeons; and percentage time on field) on the treatment field (drone) and a similar control field (without drone) during pre-treatment, treatment and post-treatment periods.

Management strategy

- Current woodpigeon management practices can be enhanced through a more strategic approach that incorporates lethal and non-lethal techniques, with growers cooperating and coordinating control activities at the landscape-scale, across ownership boundaries.

- At the field-scale, both, audio-visual deterrent techniques reinforced with live shooting and an automated laser can independently be used to reduce woodpigeon grazing and crop damage at the field-scale.

- The use of shooting to reinforce deterrents should be concentrated in the first two weeks post-deployment of deterrents; with shooters reintroduced if necessary.

- When deploying an automated laser careful consideration of field topography is necessary in order to minimise laser blind-spots, which can continue to attract woodpigeons.

- Low-powered hand-held lasers can be used to alleviate grazing in the immediate term, whilst longer-term deterrents are installed. Lasers can also be used to disperse woodpigeon roosts with potential associated decrease in woodpigeon activity in the area around the roost.

- At the landscape-scale, coordinated shooting focussed on pest removal can remove woodpigeons at a greater rate than the episodic shooting associated with control at the level of the individual holding or sports-shooting focussed on individual hunting patches and bags. A dedicated full-time woodpigeon controller would facilitate control over large areas of contiguous land. Cooperation between a series of consortiums of local growers each with their own full-time woodpigeon controllers would enable strategic and coordinated management at the landscape-scale.

Financial Benefits

The median cost of deploying reinforced deterrents for a period of 10 weeks was £30 per ha. Average yield and farm gate price (2016) of the crops under consideration were: calabrese 9.7 tonnes per ha and £512 per tonne; cauliflower: 9.2 tonnes per ha and £579 per tonne (Defra data). The financial value of 1% of the crops is equivalent to £50/ha and £54/ha respectively. Thus, on average, reinforced deterrents are cost-effective if their deployment results in a reduction in yield loss of 1%.

The cost-effectiveness of an automated laser relies on a number of assumptions. A laser costs in the order of £10,000. Although this represents a significant outlay, this cost will be offset by the working life of the device (likely minimum of 5 years), and the area over which the laser is effective. In terms of area of effectiveness, the laser will easily cover the whole of a 20ha field (depending on topography) and the portability of the device facilitates movement between different fields in response to developing woodpigeon grazing pressures. Therefore, if protecting only two 20 ha brassica fields annually for 5 years, the unit cost of deployment is equivalent to £50 per ha. This compares to an average financial value for the crops as above.

Action Points

- A combination of visual and auditory deterrents (life-like mannequins, gas cannons and rope bangers) reinforced with periods of shooting (marksmen dressed identically to the mannequins) can reduce woodpigeon grazing and crop damage on fields of brassicas.

- An automated laser can reduce woodpigeon grazing intensity and crop damage levels. The laser has to be positioned with due consideration to field topography to minimise laser 'blind spots'.

- A low-powered, hand-held laser can lift woodpigeons off fields of crops from up to a distance of 300m. Persistent and repeated use of the laser is necessary for anything other than an immediate, short-term effect.

- A low-powered hand-held lasers can disperse woodpigeons from a traditional night roost, and potentially reduce the build-up of woodpigeons grazing fields in the area around the roost. Persistent and repeated use of the laser is necessary for anything other than an immediate, short-term effect.

- Shooting woodpigeons should be undertaken strategically at the landscape-scale through coordination with neighbouring landowners, rather than focused on the preferences of individual growers and shooters.

- Licensed shooting of woodpigeons at night roosts using air rifles and night vision is an effective additional removal technique to traditional shotguns over decoys.
- Use a strategic overall management approach that incorporates lethal and non-lethal techniques, with growers cooperating and coordinating control activities at the landscape-scale.

SCIENCE SECTION

Introduction

The woodpigeon is recognised as a major agricultural pest in the UK, feeding on a range of arable crops including horticultural brassicas, leafy salads, oilseed rape and legumes. The UK population has been estimated to have increased by 40% over the short-term (1995-2011) (Risely *et al*. 2013) and by 134% over the longer-term (1970-2011) (Eaton *et al.* 2013) and was last estimated formally in 2009 at 5.4 million pairs (Musgrove *et al*. 2013). The rate of population increase over this period has varied between different regions.

Current costs of woodpigeon damage to the individual grower sectors are not known. A recent estimate of woodpigeon damage to the overall UK oilseed rape crop was approximately £2 million for a ‘low impact’ year (2% of national crop severely damaged) and approximately £5 million for a ‘high impact’ year (5% of national crop severely damaged) – based on an average loss of £131 per ha for severely damaged crop (figures presented at a National Farmers Union Bird Deterrent Event, Dec 2014).

A previous review by APHA (FV 426: A review of the woodpigeon costs to brassicas, salad crops and oilseed rape and the effectiveness of management activities) detailed an extensive range of deterrents and techniques intended to control avian pests. Many of these are deployed by growers against woodpigeons, including visual and auditory scaring devices and shooting. However, evidence for their effectiveness in deterring woodpigeons and reducing crop damage is often lacking or is largely anecdotal.

The current project (FV 426a) took forward the findings of FV 426 in order to address gaps in practical woodpigeon management. The approach aimed to develop and evaluate different control measures, taking forward those techniques identified as having the most potential in FV 426, to reduce woodpigeon grazing activity, and by association crop damage, to acceptable levels and provide growers with best practice advice.

A series of field trials were undertaken between 2015 and 2018 on brassica crops in Lincolnshire and East Yorkshire. The techniques evaluated were: visual and auditory deterrents reinforced with shooting; low-powered hand-held lasers; an automated laser; shooting and an unmanned aerial vehicle (drone).

The schedule of field trials was:

2015-16	Reinforced deterrents on autumn-sown crops Hand-held laser at field-scale
2016-17	Shooting (landscape-scale) Shooting (field-scale) Hand-held laser (roost dispersal)
2017-18	Reinforced deterrents on spring-sown crops Automated laser at field-scale Drone at field-scale

Project aim

The overarching project aim was:

- To develop and evaluate the effectiveness of management measures to mitigate the impact of woodpigeon damage to horticultural brassicas, leafy salads, oilseed rape and legumes.

Project objectives

- To undertake field trials to evaluate the effectiveness of deterrents deployed in an integrated management strategy (IMS) on the crops of interest. The deterrent strategy involved life-like mannequins, gas cannons and rope-bangers reinforced with shooting by marksmen dressed identically to the mannequins.

- To undertake an evaluation of population management, using shooting, to reduce woodpigeon abundance.

- To undertake a small-scale investigation to evaluate whether low-powered, hand-held lasers can disperse or relocate woodpigeons from a habitual night roost.

- To undertake preliminary evaluation of the potential for the application of an automated laser to reduce woodpigeon grazing at field-level.

- To undertake preliminary evaluation of the potential for the application of an unmanned aerial vehicle (drone) in deterring woodpigeon grazing at field-level.

Previous annual project reports have detailed the work undertaken in year 1 (2015-16) and year 2 (2016-17). This final project report details work undertaken in year 3 (2017-18) and draws together all the findings over the three year project.

Materials and methods

Deterrents (mannequins, gas cannons, rope-bangers) reinforced with shooting

The second year (2017) of field trials on deterrents was modified from that in year 1 (2015/16) in order to achieve improvements in the effectiveness of deterrence and in monitoring changes in woodpigeon abundance (at field level) and associated crop damage.

Deterrents

Trial fields (treatment and control) were selected based on previous history of woodpigeon grazing and ongoing monitoring of woodpigeon activity. In all selected fields crop damage measurements were undertaken at the initiation of the trial (prior to, or as near as possible to, the onset of woodpigeon grazing) and at 2-week intervals throughout the trial. A total of 15 fields were used throughout the trial: 7 treatment and 7 control; one field was split into a treatment half and a control half.

The trial fields were arranged into six study groups (A-F) based on their proximity and ownership; study groups contained either two or three fields (**Table 1**, **Figure 1** and **2**). Within each group individual fields were allocated as either treatment (deterrents) or control fields (no deterrents). The allocation of treatment and control field pairings to each of the growers involved minimised, as far as possible, the influence of any factors extrinsic to the experimental treatment, such as location or grower practices.

Table 1. Details of trial fields - name, size, treatment allocation and crop

Group	Field	Ha	Treatment/Control	Crop
A	Blackjack 1	7.8	Treatment	Brocolli
	Blackjack 2	3.8	Treatment	Brocolli
	Blackjack 3	10.9	Control	Brocolli
B	Bratleys 1	1.5	Treatment	Brocolli
	Bratleys 2	2.2	Control	Brocolli
C	Glasshouse	4.9	Control	Brocolli
	Stackyard	9.5	Control/Treatment*	Brocolli
D	Crowtree Field	8.0	Control	Brocolli
	Wragg Marsh	16.6	Treatment	Brocolli
E	Little Lane	2.8	Treatment	Brocolli
	Crossways 1	14.2	Treatment	Brocolli
	Crossways 2	20.5	Control	Brocolli
F	Bingham Lodge 1	13.3	Treatment	Cauliflower
	Bingham Lodge 2	11.0	Control	Cauliflower
	Bingham Lodge 3	13.1	Control	Cauliflower

* Stackyard field was divided evenly into control and treatment halves

Figure 1. Map 1 of fields used in the deterrent trials. Dark green indicates treatment fields, light blue indicates control

Figure 2. Map 2 of fields used in the deterrent trials. Dark green indicates treatment fields, light blue indicates control

Individual trials were scheduled for a 10-week deployment of deterrents. At the onset of the trial, mannequins were deployed in the field along with a gas cannon and rope bangers (**Figure 3**). For the first two weeks, the mannequins, cannon and rope bangers were reinforced by the presence of a gunman (similarly-attired to the mannequins) who shot at any woodpigeons attempting to utilise the field; the rationale was to scare flocks of birds and not to kill lone birds, in an attempt to induce avoidance in surviving birds. During this two-week period, the gunman visited each trial field at least once a day and usually twice for an average period of 45 minutes per visit (excluding the intervening weekends). After the first two weeks the gunman were removed, apart from a short reinforcement period in week 6. Throughout the trials, reinforcement of the mannequins in each treatment field continued with the use of a gas cannon and rope-bangers. The latter were suspended from a cane placed within the field (in close proximity to a mannequin) and relocated within the field on different days; where appropriate rope bangers were also occasionally hung in other locations, including beneath trees used for loafing by woodpigeons on a field boundary. Using this approach, deterrent activity was most intense during the period when woodpigeons were first attempting to establish grazing on a field – as per commercial practice. The rationale of this combination of deterrents was to minimise the use of marksmen during the overall trial deterrent period.

Figure 3. A typical mannequin set-up in a treatment field with a bamboo cane for suspending rope bangers. The mannequin and rope-bangers are reinforced by the presence of a real marksman (identically dressed)

Crop damage

Crop damage assessment involved scoring the percentage of overall leaf cover that was missing (as a result of grazing) from a stratified random sample of plants. Individual plants were assessed at regular intervals (e.g. every 20th plant) within plant rows across the field (e.g. a plant row parallel with every 2nd tramline); these sampling intervals were adjusted according to the area of the field. Plants were scored on a scale from 1 to 4, where 1 = 0% leaf loss (zero damage), 2 = <10% leaf loss (minor loss), 3 = 10-50% leaf loss (moderate loss; harvest of crop likely to be extended) and 4 = >50% leaf loss (severe loss; likely that crop is unmarketable).

In addition, at the end of the trials, two further crop assessments were undertaken that compared areas of high and low woodpigeon damage within individual fields. Areas with a median damage of 1 or 2 over the trial period were classed as low damage areas, while areas with median damage of 3 or 4 were classed as high damage. In each field, plants were sampled for:

- *Percentage of crop harvested*: The percentage of crop cut was measured by using all plants within a defined sample area of high or low woodpigeon damage, and noting whether individual plants had been harvested or left uncut.

- *Size of crop head*: Measurements were taken of the head size (to the nearest 0.5cm) from a stratified random sample of plants within defined areas of high or low damage.

Woodpigeon numbers

Each trial field (treatment and control) was observed by a fieldworker for a minimum of 1 hour within four designated time periods; early morning, late morning/early afternoon, mid-afternoon and early/late evening. Each field was observed at least once in each of the four time periods. During each observation period, woodpigeon activity within the fields was recorded.

In addition to direct visual monitoring, remote movement-activated cameras were deployed at a number of locations within some of the fields to supplement the observations. A total of 18 cameras were placed across 10 fields during the deterrent trials - 9 on treatment fields and 9 on control fields. Cameras were usually attached to trees on field boundaries, but a few were placed on the ground and some on scarecrows in control fields. This positioning was to ensure that cameras were not in the way of the regular crop husbandry carried out in the fields during the trials.

Automated laser

During May 2017, the efficacy of an automated laser (Agrilaser® Autonomic) to reduce woodpigeon crop damage at the field level was undertaken in East Yorkshire. The study used a combined within field and paired-field cross-over experiment. Two fields of transplanted Brussels sprouts (Field 1/Gun Field, ca. 6.4 ha; Field 2/Quarry Field, ca. 9 ha) were selected based on previous history of woodpigeon grazing and ongoing monitoring of woodpigeon activity; fields were ca. 1.4 km apart (**Figure 4**). The fields differed in their topography – Gun Field was essentially flat whilst Quarry Field sloped in both a north-south and east-west direction. The sloped profile of Quarry Field presented 'blind spots' for the laser.

Field 1 (Gun Field) was split into two halves across the narrowest dimension – a treatment half and a control half. The half of the field with the highest woodpigeon crop damage (southern half) was selected as the treatment plot. The automated laser was installed in a hedge bordering the southern edge of the treatment half of the field. The laser was elevated on top of a stack of wooden pallets, in order to facilitate coverage of the treatment area. Immediately prior to the initiation of the trial, crop damage measurements were undertaken in both the treatment half and control half of field 1 (using the same methodology as in the reinforced deterrent trials). In field 2 (Quarry Field), a dummy laser was installed in a boundary hedge and crop damage measurements similarly undertaken.

The laser was set to operate from 1 hour before sunrise until 1 hour after sunset. The exact timing of the operating period was adjusted accordingly throughout the trial period to maintain operation during the hour before and after sunset. A standby interval of 10 minutes between ‘patterns’ (i.e. runs of the laser) was used. Full specifics for the laser system used are provided in Appendices 1 and 2.

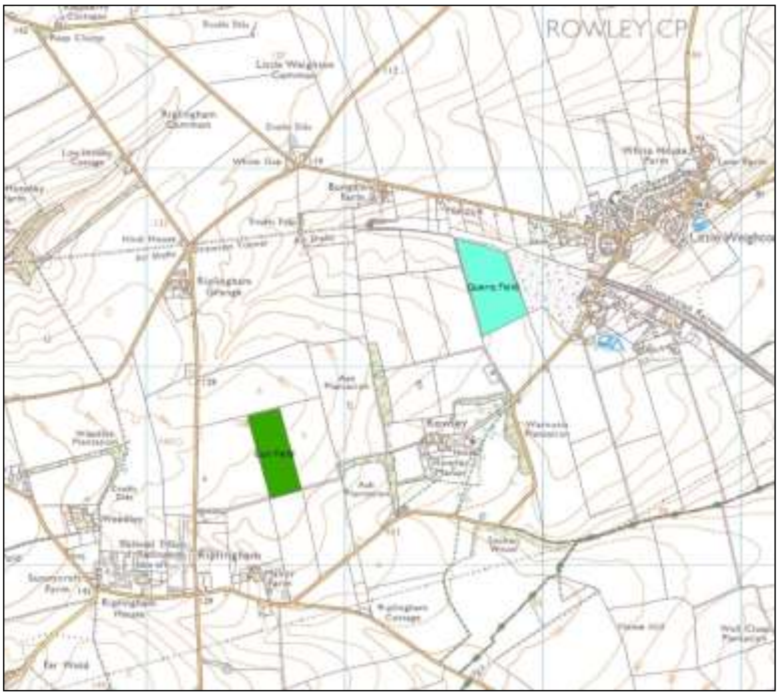


Figure 4. Location of the trial fields used for the automated laser trial

In order for the laser to pass as much of the field as possible a wavy ‘W’ and ‘M’ pattern was used, with the laser set to operate at it fastest speed. A ‘W’ pattern was used across the area from one side to the other, where on returning to the other side of the field an ‘M’ pattern was used. This process was repeated until 100 reference points (i.e. points which the laser beam would move to when switched on) had been inputted. The laser was checked weekly to make sure that it was secure, executing its pattern correctly, and that there were no foreign objects impeding the moving parts of the machine.

Prior to use a Risk Assessment was undertaken on the laser (Appendix 3), based upon the manufacturers recommendations, provided within the product manual. In short, incorrect use of the Agrilaser® Autonomic may cause damage to someone who looks either directly or indirectly into it. A risk assessment is therefore required to limit the risk to operators and the general public and control measures should be actioned if appropriate after this assessment. The laser is for professional use only and should not be projected at: the infinite sky, people, vehicles, aircraft vessels or at reflective surfaces. Signs should be erected near the laser operating area to warn of the laser hazard. Full training in safe and effective use of the system is now available via the UK distributer. Further information on general safety when using lasers can also be accessed at: https://www.gov.uk/government/publications/laser-radiation-safety-advice/laser-radiation-safety-advice.

The laser was deployed for a period of four weeks during which woodpigeon numbers were monitored (direct and remote cameras) on both treatment and control fields. Observations were undertaken on two days per week, from hides concealed in the hedges bordering the fields. On these days, observation sessions were undertaken within four designated time periods; early morning, late morning/early afternoon, mid-afternoon and early/late evening. On any observation day, monitoring periods of 90 minutes were alternated between the treatment and control fields; with two observation periods completed on each field per day.

At the end of the four week period, crop damage measurements were repeated in field 1 (Gun Field) (treatment and control halves) and field 2 (Quarry Field). Following crop damage assessments, the laser was switched between fields, so that field 2 (Quarry Field) now became the treatment field and field 1 (Gun Field) the control. The laser was located in order to cover as much of field 2 as possible. Due to the sloped topography, however, there were some 'blind spots' that the laser could not reach. Monitoring of woodpigeon numbers was repeated over another four weeks and crop damage assessed at the end of this period.

The overall experimental design and schedule is illustrated in **Table 2**.

Table 2. Schedule of paired field cross-over trial evaluating an automated laser

	Week							
	1	2	3	4	5	6	7	8
Field 1 (Gun Field)	Treatment (Laser)				Control			
Field 2 (Quarry Field)	Control				Treatment (Laser)			
Monitoring	* woodpigeon counts				* woodpigeon counts *			

* = crop damage assessments

Drone

A trial of an unmanned aerial vehicle, or drone (DJI Phantom 3 Advanced; a quadcopter), was undertaken in February/March 2018. The trial investigated whether flying the drone over a field in response to grazing woodpigeons acted as a deterrent and reduced woodpigeon utilisation of the field.

The investigation involved a single trial involving one 13.2 ha treatment field (drone) and one 2.2 ha control field (no drone); fields were approximately 10km apart and both owned by the same grower. The trial was scheduled to involve three sequential one week phases (pre-treatment, treatment, post-treatment) with a drone deployed over the treatment field in response to any incursions by woodpigeons during the treatment week. However, due to the extreme weather conditions (snow and sub-zero temperatures) that occurred during the scheduled treatment week, the design had to be modified. With the drone only able to undertake two flights on a single day during the scheduled treatment week, this week was used as a second pre-treatment week. The drone was deployed on three consecutive days during week three (treatment). Post-treatment monitoring was undertaken during week four.

On treatment days, the drone was deployed on each occasion that woodpigeons landed in the treatment field, with the drone flown towards the area of the field where the woodpigeons were located. On every occasion the drone was deployed, the woodpigeons took flight. The drone was returned to its take-off site following departure of the woodpigeons.

During each deployment of the drone, data was collected on the number of woodpigeons arriving in the field, the distance to which the woodpigeons withdrew, and the time for woodpigeons to return to the field.

In addition to recording the immediate response of woodpigeons to the drone, observations were undertaken to monitor daily woodpigeon activity on the treatment and control fields during each of the four weeks of the trial (pre-treatment, treatment and post-treatment phases). On any observation day, monitoring periods of 90 minutes were alternated between the treatment and control fields; with one or two observation periods completed on each field per day. During individual observation periods the numbers of woodpigeons on the field was recorded at five minute intervals. Observation sessions were undertaken within four designated time periods; early morning, late morning/early afternoon, mid-afternoon and early/late evening.

Woodpigeon activity was compared between treatment and control fields, in respect to daily: median woodpigeon numbers; and the percentage of time woodpigeons were present. On days when there were two observations the larger of the two counts was used.

Shooting – field scale (year 2 2016-17)

The effect of shooting on woodpigeon numbers at the landscape-scale was detailed in the second year annual report. The trial investigated the effectiveness of shooting and impact on woodpigeon abundance within an 8,200ha area in Lincolnshire over a 10-week period April to mid-June 2016.

During the shooting period, weekly surveys of woodpigeon abundance across the study area were undertaken. Individual surveys involved following a pre-determined driven transect (112km), using roads and farm tracks, through the study area to record woodpigeon activity.

Transects were completed twice per week, being followed in opposite directions on consecutive days. For all woodpigeons encountered, the number, location, habitat (e.g. field, trees, hedge) and activity (grazing, loafing, perched) were annotated onto large scale OS maps. The largest number of woodpigeons recorded on any one of the two consecutive survey days was taken as the maximum for that week. These counts represent an index of abundance and not a census of absolute numbers. However, as the observer effort (route and time taken) was comparable between surveys, the counts facilitated detection of changes in relative abundance and areas of activity across the study area.

The data was also examined in order to ascertain whether changes in woodpigeon numbers at the field-scale, or more precisely in the proximity of shooting sites, could be evaluated. However, as surveys of woodpigeon numbers was designed to monitor changes at the landscape-scale, the surveys only provided ‘snapshots’ of woodpigeon presence on individual fields. Consequently, for individual fields there was a predominance of zero counts; even at locations where shooting had been conducted.

For a small number (n=13) of shooting sessions there was a sufficient series of records of woodpigeon numbers at the associated locations to permit a tentative evaluation. For each of these sites, the peak number of woodpigeons present at any time in the two week period prior to the shooting sessions was compared with the peak number at any time in a period up to two weeks following the session. The number of days following the shooting session for woodpigeons to be recorded on the associated field was also recorded. For this evaluation, numbers of woodpigeons were recorded within an area of radius 250m around the shooting location.

Results

Deterrents (mannequins, gas cannons, rope-bangers) reinforced with shooting

Crop damage

Baseline crop damage scores differed between trial fields, due to variation in planting dates, the onset of woodpigeon grazing and the timing of selection for inclusion in the field trials. For the purposes of displaying changes in crop damage between fields in a comparable way, therefore, data indicates the percentage change in crop damage (i.e. moderate to severe loss - scores of 3 and 4 combined) between the original crop damage assessment and subsequent visits. In the following graphs, for example, columns marked 2 represent the percentage change in crop damage between visits 1 and 2, columns marked 3 represent the percentage change in crop damage between visits 1 and 3, and so on. The actual crop damage figures at each visit for each field are also presented in tables accompanying each graph.

Group 1 - Blackjack 1, 2 and 3

The two treatment fields (Blackjack 1 and 2) showed a greater overall reduction in crop damage (55% and 47% respectively) than the control field (18%), Blackjack 3 (**Figure 5**, **Table 3**). Damage was much higher on the treatment fields than the control field at the onset of the trial, but once deterrents were introduced there was an incremental decrease in damage. In comparison, on Blackjack 3 (control) damage increased through the trial; until the final assessment when a surge in plant growth reduced the level of damage on all three fields.

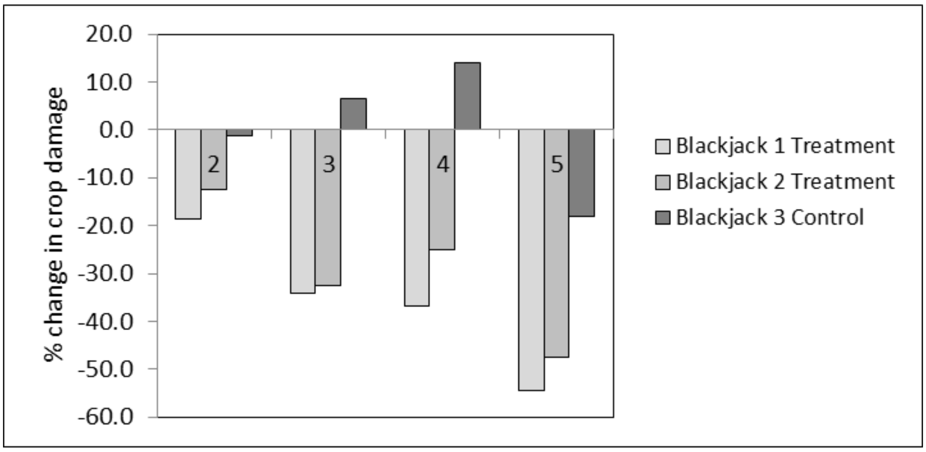


Figure 5. Comparison of percentage changes in crop damage in fields Blackjack 1 (Treatment), Blackjack 2 (Treatment) and Blackjack 3 (Control). Comparisons between visits 2, 3, 4 and 5 with baseline score on visit 1

Table 3. Crop damage (percentage of scores 3 and 4 combined) on Blackjack 1, 2 and 3 across all 5 assessments

	Treatment	Treatment	Control
Visit	Blackjack 1	Blackjack 2	Blackjack 3
1	73.1	85.2	49.7
2	54.6	72.8	48.5
3	39.0	52.7	56.2
4	36.3	60.1	63.7
5	18.6	37.8	31.6

Group 2 – Bratley's 1 and 2

Bratley's 1 (treatment) and Bratley's 2 (control) both showed an overall decrease in damage (9% and 55% respectively by visit 4) (**Figure 6**, **Table 4**). The increase in damage between visit 1 and 2 was 23% and 27% for Bratley's 1 and Bratley's 2 respectively, suggesting that that the deterrents may have been having some slight positive effect. After this point, damage decreased on Bratley's 1 and 2 down to some of the lowest recorded damage scores for the whole study: 13% and 8% respectively.

The trial of the deterrents on this group, however, was confounded by the provision of 'sacrificial' crops part way through the trial. Following visit 2, a large area of crop was uncovered from under polythene adjacent to Bratley's 2 (control); in addition peas were sewn in other neighbouring fields, providing the woodpigeons with alternative food sources seemingly preferred to the crops in the trial fields – particularly the adjacent control field.

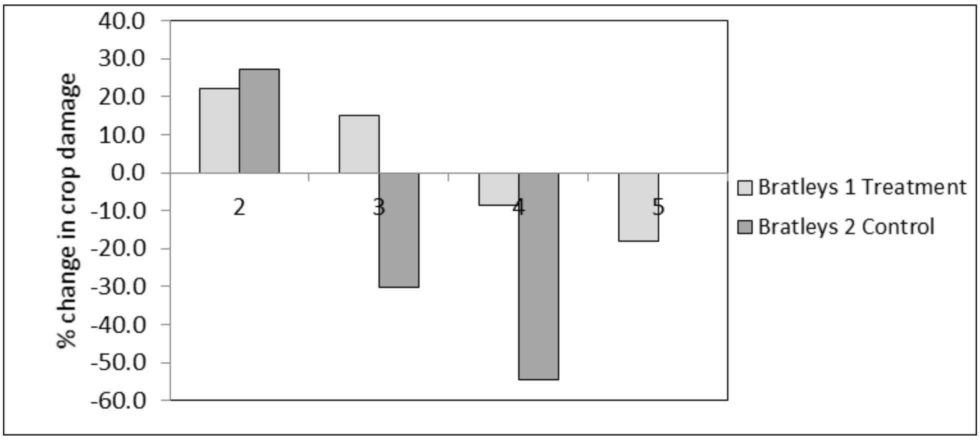


Figure 6. Comparison of percentage changes in crop damage in fields Bratley's 1 (Treatment) and 2 (Control). Comparisons between visits 2, 3, 4 and 5 with baseline score on visit 1. Note Bratley's 2 was harvested prior to the final crop damage assessment

Table 4. Crop damage (percentage of scores 3 and 4 combined) on Bratley's 1 and 2 across all 5 assessments

	Treatment	Control
Visit	Bratleys 1	Bratleys 2
1	30.9	62.9
2	53.2	90.2
3	45.9	32.7
4	22.4	8.4
5	13.0	-

Group 3 – Glasshouse and Stackyard

On Stackyard the treatment and control areas both showed a reduction in crop damage: 63% and 8% respectively; in comparison, damage on Glasshouse increased by 28% (**Figure 7**, **Table 5**). These results suggest that, despite only targeting one half of Stackyard field with deterrents, the effects appeared to have carried across the whole field, albeit to a lesser extent on the control side. Overall, there was a 34% reduction in damage across the whole of Stackyard field (treatment and control plots combined) compared to the 28% increase in damage on Glasshouse (control).

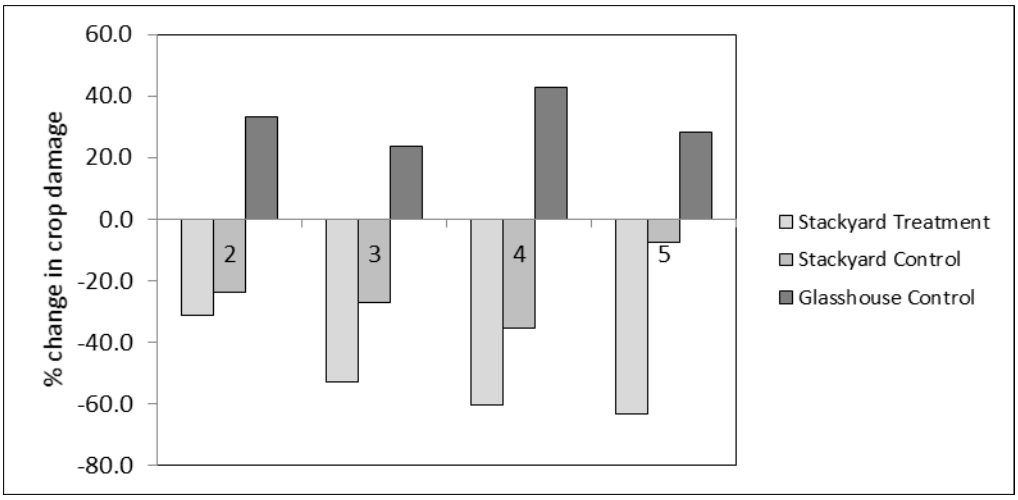


Figure 7. Comparison of percentage changes in crop damage in Stackyard (treatment//control) and Glasshouse (control) between visits 2, 3, 4 and 5 with baseline score on visit 1

Table 5. Crop damage (percentage of scores 3 and 4 combined) on Stackyard and Glasshouse across all 5 assessments

	Treatment	Control	Control
Visit	Stackyard	Stackyard	Glasshouse
1	98.2	64.8	27.5
2	66.9	41.1	60.7
3	45.5	37.6	51.0
4	37.9	35.5	70.1
5	34.8	57.2	55.8

Group 4 – Crowtree Field and Wragg Marsh

Both treatment (Wragg Marsh) and control (Crowtree) fields showed a decrease in crop damage across the trial period: 42% and 35% respectively (at visit 4) (**Figure 8**, **Table 6**). Up to visit 3, the decrease in crop damage was markedly higher on the treatment field: Wragg Marsh/treatment 37%; Crowtree/control 6%. Crowtree was the field that was transplanted earliest of all the trial fields (20th March).

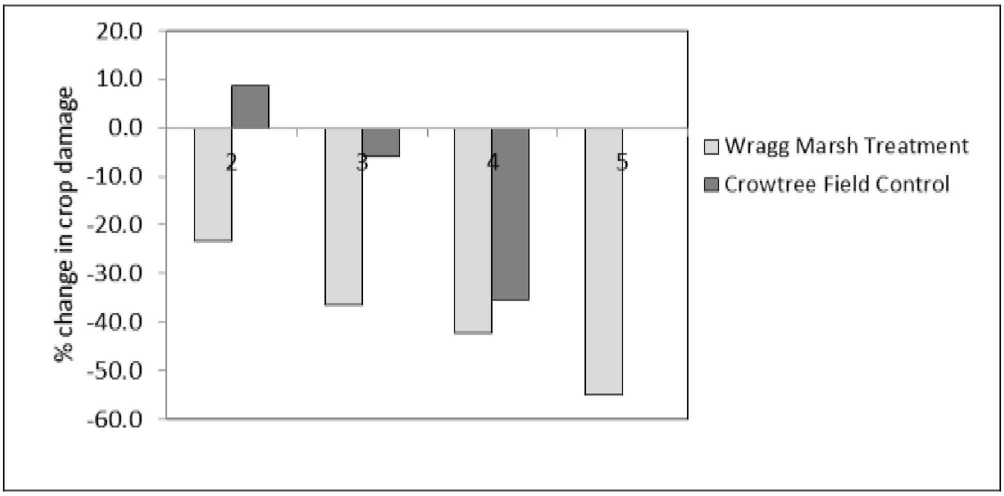


Figure 8. Comparison of percentage changes in crop damage in Wragg Marsh (treatment) Crowtree Field (control) between visits 2, 3, 4 and 5 with baseline score on visit 1. Note that the fifth crop damage assessment for Crowtree Field is missing, as the field had been harvested

Table 6. Crop damage (percentage of scores 3 and 4 combined) on Crowtree Field and Wragg Marsh across all 5 assessments

	Control	Treatment
Visit	Crowtree Field	Wragg Marsh
1	58.0	63.9
2	66.6	40.5
3	52.5	27.4
4	22.6	21.5
5	-	9.0

Group 5 – Little Lane and Crossways 1 and 2

Little Lane (treatment) showed an overall decrease in damage of 29%%, whilst both Crossways 1 (treatment) and Crossways 2 (control) showed overall increases in damage – 33% and 61% respectively (**Figure 9**, **Table 7**). Despite damage increasing on Crossways 1 (treatment), the increase in damage was lower than the increase in damage on Crossways 2 (control) at each visit.

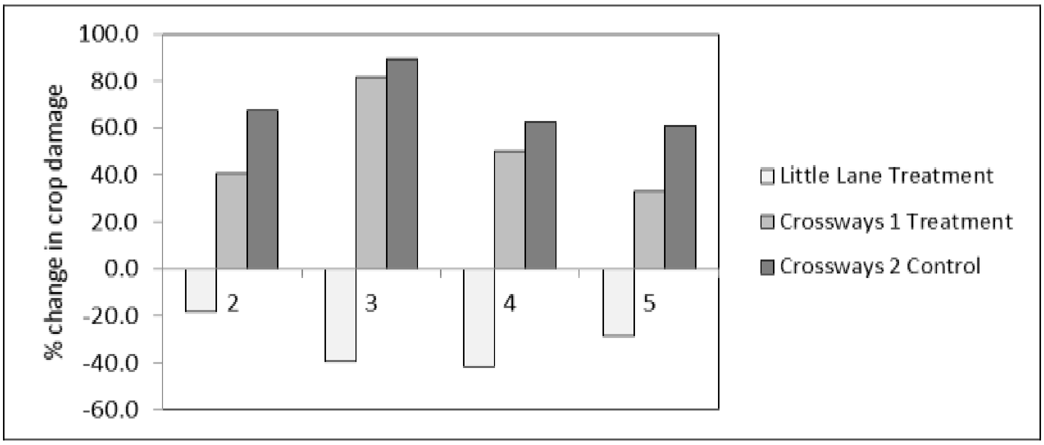


Figure 9. Comparison of percentage changes in crop damage in fields Little Lane (treatment), Crossways 1 (treatment) and Crossways 2 (control) between visits 2, 3, 4 and 5 with baseline score on visit

Table 7. Crop damage (percentage of scores 3 and 4 combined) on Little Lane, Crossways 1 and Crossways 2 across all 5 assessments

	Treatment	Treatment	Control
Visit	Little Lane	Crossways 1	Crossways 2
1	71.6	4.7	3.1
2	53.0	45.7	70.5
3	32.0	86.8	92.6
4	29.9	54.7	66.0
5	43.0	37.6	63.9

Group 6 – Bingham Lodge 1, 2 and 3

There was an overall increase in crop damage on all three fields: Bingham 1 (treatment); Bingham 2 (control); Bingham 3 (control) (**Figure 10**, **Table 8**). Despite damage increasing on Bingham 1 (treatment), the increase in damage was markedly lower than the increase in damage on either control field at each visit – a minimum of 50% lower

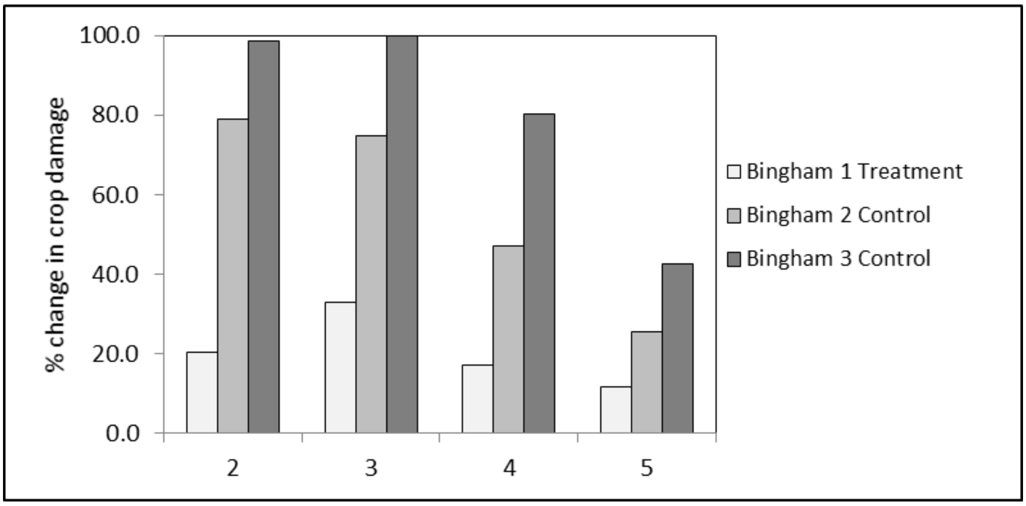


Figure 10. Comparison of percentage changes in crop damage in fields Bingham Lodge 1, 2 and 3 between visits 2, 3, 4 and 5 with baseline score on visit 1

Table 8. Crop damage (percentage of scores 3 and 4 combined) on Bingham 1, 2 and 3 across all 5 assessments. The initial score of 0 for Bingham 3 is due to the fact that the field was being planted while the assessments for Bingham 1 and 2 were being carried out

	Treatment	Control	Control
Visit	Bingham 1	Bingham 2	Bingham 3
1	14.7	0.6	0
2	35.2	79.7	98.5
3	47.6	75.3	100.0
4	31.8	47.8	80.3
5	26.5	26.2	42.6

Summary of deterrent trials

In five of the six trial field groups (A-F), treatment fields suffered less crop damage than control fields (**Figure 11**).

At the fourth visit (data available from all 15 fields) the median change in damage was -30% on treatment fields and +28% on control fields. The trial on group B fields was confounded by the exposure of a large area of 'decoy' crop adjacent to the control field part-way through the trial. If this group are excluded from the summary, then the median change in damage is -34% on treatment fields and +43% on control fields.

When considering only the fields for which data was available at the fifth visit (13 fields; i.e. excluding B1/B2 and Wragg/Crow pairings) the median change in damage was -38% on treatment fields and +27% on control fields.

That is, in all trial groups (excluding group B) treatment fields showed a greater decrease in damage than paired control fields, or where damage increased on treatment fields (groups E and F) this increase was lower than on paired control fields.

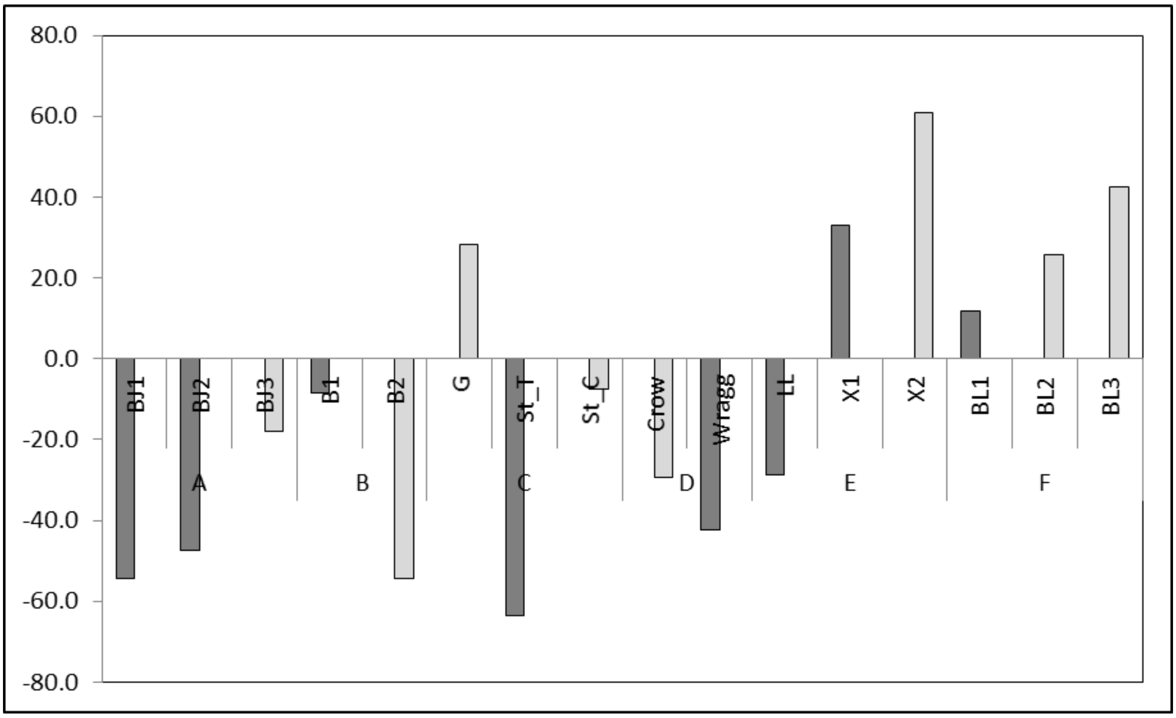


Figure 11. Summary of changes in crop damage on all trial fields over the 10-week trials (i.e. % change in high damage score measured at week 1 and week 10). Dark shaded bars = treatment, light shaded bars = control. B1/B2 and Crow/Wragg are values at week 8 (field visit 4) as no data was available for B2 and Crow at week 10 (field visit 5)

Woodpigeon activity

A total of 78 hours of observation of woodpigeon activity on trial fields was completed; encompassing a mean of 5.2 sessions and 5.2 hours per field.

Comparisons between treatment and control fields in terms of woodpigeon activity was expressed as: (i) percentage of time woodpigeons were present (i.e. percentage of total observation time), (ii) peak numbers of woodpigeons present (i.e. median peak number per observation session).

Time present

The percentage of time woodpigeons occupied trial fields varied between and within treatments. In five of the six groups, woodpigeons spent a lower percentage of time on treatment than on control fields (Stackyard considered as a whole treatment field) (**Table 9**).

Table 9. Median percentage of time each field was occupied by grazing woodpigeons during all observations. T= treatment, C = control

Group	Field Name	T/C	Pair No. [a]	Counts	Median time field occupied (%)	Peak no. woodpigeons (median)	Treatment compared to control
A	Blackjack 1	T	6	5	11.5	2.5	<
	Blackjack 2	T	7	5	50.0	4.5	<
	Blackjack 3	C	6/7	5	76.0	10.5	
B	Bratleys 1	T	10	6	0.0	0	=
	Bratleys 2	C	10	6	0.0	0	
C	Stackyard [b]	T	2/3	5	32.0	6	<
	Stackyard [b]	C	2	5	30.0	28	
	Glasshouse	C	3	6	95.0	9	
D	Wragg Marsh	T	1	5	0.0	0	<
	Crowtree	C	1	5	100.0	5	
E	Little Lane	T	4	5	0.0	0	<
	Crossways 1	T	5	5	58.5	6.5	<
	Crossways 2	C	4/5	5	75.0	14	
F	Bingham 1	T	8/9	5	0.0	0	<
	Bingham 2	C	8	5	83.0	4	
	Bingham 3	C	9	5	65.5	4	

[a] See **Figure 12** and **13** below

[b] Stackyard: whole field (treatment and control halves combined) compared to Glasshouse (all control).

Comparing all treatment fields/plots (n=8) and all control fields/plots (n=8), treatment fields/plots were occupied for significantly less time than control fields (Mann Whitney U-Test: $U = 9$, $p<0.05$). The woodpigeon presence data is summarised in **Figure 12** below.

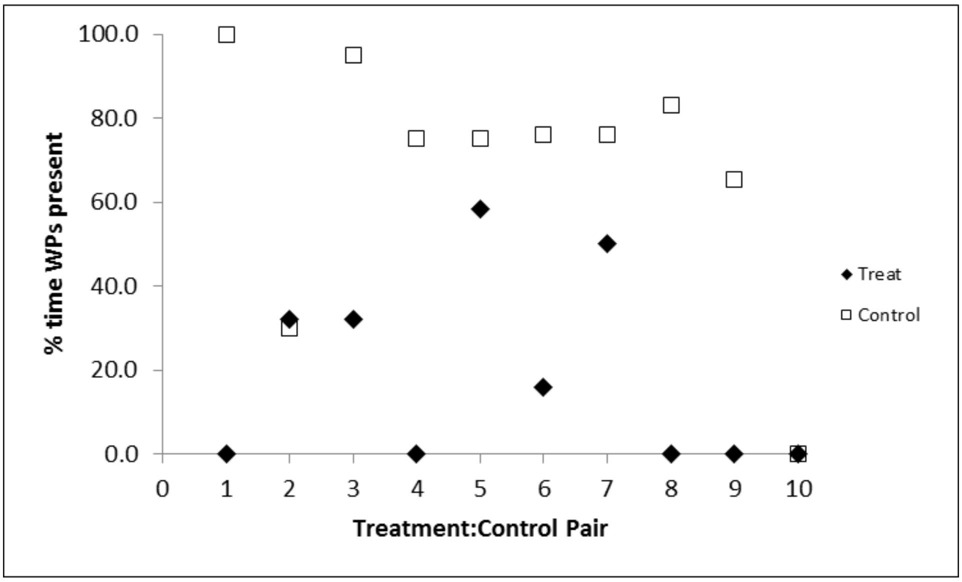


Figure 12. Percentage observation time that each of the trial fields were occupied by grazing woodpigeons, with comparison between pairs of treatment/control fields. See table above for paired field details

Number of woodpigeons

The size of flocks on treatment fields was consistently lower than on control fields; with numbers lower in nine of the ten paired field comparisons within trial groups (**Figure 13**).

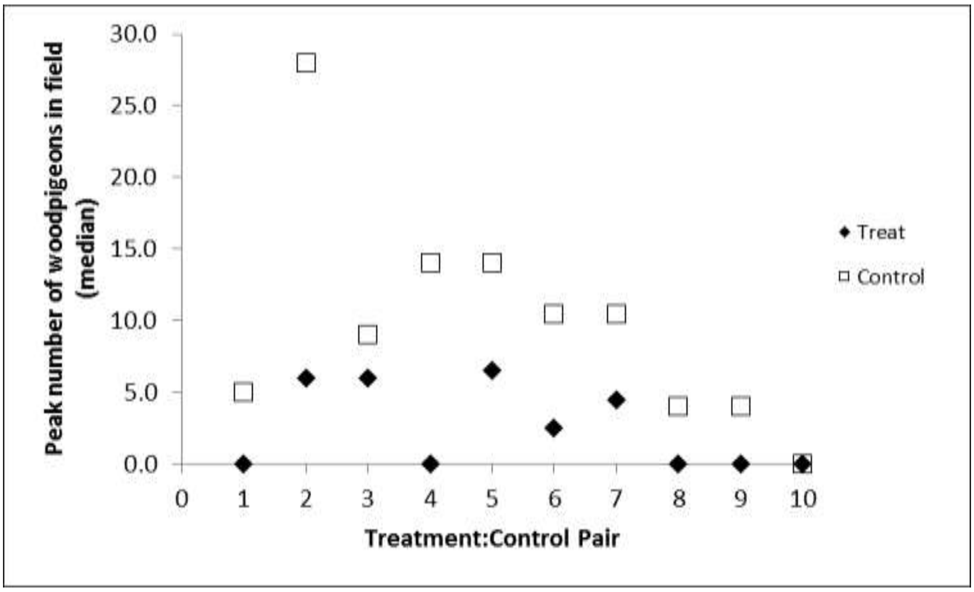


Figure 13. The median peak number of woodpigeons recorded in each field, with comparison between pairs of treatment and control fields. See above table for paired field details

The woodpigeon activity data (time present and numbers of birds) showed that almost all of the treatment fields had less activity on them than their paired control fields. There were two pairs of fields that did not show a difference in activity in either one or both parameters: pairs two and ten. For pair two, this is consistent with the data on crop damage that indicated that although only half the Stackyard field received deterrents, the effect appeared to extend somewhat across the whole field. Stackyard as a whole was occupied by woodpigeons for a lower proportion of time than the nearby Glasshouse control field (comparison 3 in **Figure 12**). For pair 10 (Bratley's), the removal of polythene covering from a significant area of crop immediately adjacent to the control field, half way through the trial, appeared to draw the woodpigeons away from both of the study fields, resulting in relatively little grazing activity and a reduction in crop damage.

Remote cameras

A total of 2,649 photos were taken with remote cameras, with woodpigeons recorded in only 136 (5.1%) (see **Figure 14** for an example). Of these 2,649 photos, 1656 were taken on treatment fields and 993 on control fields. Woodpigeons were recorded on photos less frequently on treatment fields than on control fields: treatment 3% of photos; control 7% of photos. The majority of animals recorded in photos were pheasant, hare and red-legged partridge.

The remote cameras provided very limited information on woodpigeon activity due to the limitations governing their placement and their relatively small area of detection. The cameras also provided little data on the numbers of woodpigeons associated with a detection event, recording only those woodpigeons in the recording frame – further woodpigeons potentially being simultaneously present outside the frame.

Although the information from the remote cameras was very limited, the data showing lower woodpigeon occurrence on treatment fields than control fields was consistent with the data on crop damage and direct visual observations of woodpigeons.

Figure 14. Photo a woodpigeon captured by remote camera on a trial field

Crop characteristics – high damage versus low damage areas

At the end of the deterrent trials, crop assessments were undertaken that compared crop quality (head size) and harvesting rates between areas of high and low woodpigeon damage within individual fields. Comparisons were made within individual fields to ensure all crop had equivalent crop treatments and growing period.

Crop head size

In the three fields assessed, crop head size was significantly smaller in areas of high woodpigeon grazing damage compared to areas that suffered low grazing damage (**Table 10**).

Table 10. Comparison of crop head size in areas of high and low woodpigeon damage

	Crop head size cm (mean ± SE)				
Field	n	High	n	Low	P[1]
Bingham 1	164	3.2 ± 0.18	211	9.4 ± 0.21	<0.00001
Bingham 2	227	3.3 ± 0.14	140	10.3 ± 0.30	<0.00001
Crowtree	277	5.9 ± 0.17	113	8.7 ± 0.42	<0.00001

[1]Mann-Whitney U-Test; Bingham = cauliflower; Crowtree = brocolli

Harvested crop (%)

In all three broccoli fields sampled the percentage of crop harvested was greater in areas with low damage than in areas of high damage (**Table 11**). On average 27% fewer plants were cut from areas of fields that suffered high crop damage compared to areas with low damage.

Table 11. Comparison of crop harvested (%) in areas of high and low woodpigeon damage

	Plants harvested				
	High damage area		Low damage area		Difference
Field	n	%	n	%	%
Blackjack 1	481	41	482	68	27
Bratley's 1	625	23	263	46	23
Crowtree	689	54	435	84	30

Cost of reinforced deterrents

The median cost of deploying reinforced deterrents for a period of 10 weeks was £30 per ha £14 - £156 per ha) (**Table 12**). The highest unit costs were associated with the smallest fields as an inherent consequence of scaling. Costs do not include staff-time for initial deployment of mannequins, gas cannon and rope-bangers.

Table 12. Cost of reinforced deterents – equipment and marksmen

Fields	ha	Mannequins £/ha	Gunman £/ha	Rope bangers £/ha	Gas Gun £/ha	Total over 10 weeks £/ha	Total cost per week £/ha
Blackjack1	7.8	4.62	9.76	4.70	11.41	30.48	3.05
Blackjack2	3.8	4.74	20.75	11.39	23.42	60.30	6.03
Little Lane	2.8	6.43	34.54	14.27	31.79	87.02	8.70
Stackyard	9.5	3.79	11.22	4.91	9.37	29.28	2.93
Bingham 1	13.3	2.71	5.86	3.25	6.69	18.51	1.85
Bratley's 1	1.5	18.00	56.40	22.20	59.33	155.93	15.59
Wragg Marsh	16.6	2.71	4.13	2.01	5.36	14.20	1.42
Crossway's 1	14.2	3.17	5.51	3.05	6.27	18.00	1.80

- Mannequin: £45 each discounted over 5 years
- Gunman: Standard worker rate of £7.05 per hour (www.daera-ni.gov.uk/articles/awb-agricultural-rates-pay-orders-and-reports)
- Rope-bangers: £3.33 per rope
- Gas gun: £445 each discounted over 5 years

Crop value

In 2016, the average yield and farm gate price for the crops under consideration in the field trials was:

- Calabrese: 9.7 tonnes per ha and £512 per tonne
- Cauliflower: 9.2 tonnes per ha and £579 per tonne

The farm-gate prices take into account the relative proportions and values of produce going through various supply chains to market (includes supermarkets, processing, direct sales on-farm etc. as well as through wholesale markets) (Defra data). Using these figures, estimates can be derived for the financial value of an increasing percentage of crop loss (**Table 13**).

Table 13. Financial value of lost crop at increasing percentage loss

Crop	Yield loss (%)	Mean Yield (tonnes /ha)	Loss (tonnes/ha)	Mean vale (£/tonne)	Loss (£/ha)
Calabrese	1	9.7	0.097	512	49.66
	2	9.7	0.194	512	99.33
	3	9.7	0.291	512	148.99
	4	9.7	0.388	512	198.66
Cauliflower	1	9.2	0.092	579	53.27
	2	9.2	0.184	579	106.54
	3	9.2	0.276	579	159.80

For both calabrese and cauliflower, the financial value of 1% of the crop (£50/ha and £54/ha) is greater than the median cost of deploying reinforced deterrents over a 10-week period (£30/ha). The value of 4% of the calbrese crop (£199/ha) exceeds the costliest deployment of deterrents on the smallest field (£156/ha).

Automated laser – within field

Crop damage

For the first four weeks of the trial, the laser was set up to only cover half of Gun Field, with the other half left as a control plot. Crop damage increased in both plots, with marginally lower increase on the treatment plot than on the control plot: treatment +8.2%; control 10.4% (**Figure 15**). Damage increased +9.3% across the whole field, i.e. treatment and control plots combined.

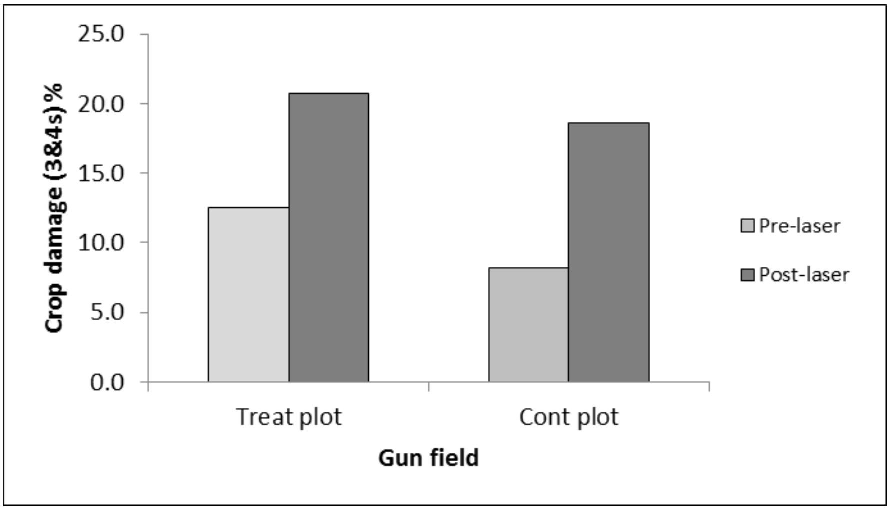


Figure 15. Crop damage (%) in treatment and control areas on Field 1 (Gun Field) pre and post four week laser deployment period

Woodpigeon numbers

During the four week period, only one woodpigeon was recorded on the Gun Field – in the treatment plot (**Table 14**).

Table 14. Woodpigeon numbers (mean and maximum counts) on laser treated plot and control plot on Gun Field

	Counts	Woodpigeon numbers	
Gun Field	n	Mean	Maximum
Treatment Plot (Laser)	14	0.07	1
Control Plot	14	0	0

Automated laser – between fields

Crop damage

During the same four week period, woodpigeon crop damage increased substantially on the paired control Field 2 (Quarry field): increasing from 5% to 94% (**Figure 16**). This 89% increase on Quarry Field was substantially greater than the 9% increase over the whole of Gun Field (treatment and control plots combined).

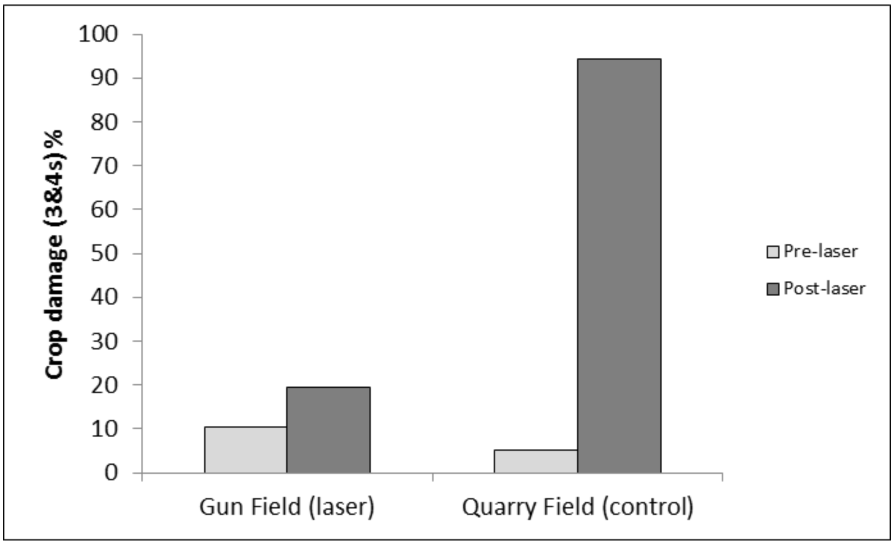


Figure 16. Crop damage (%) on Gun Field (laser treatment) over a 4-week period and on the paired control field (Quarry field) over the same period.

Woodpigeon numbers

During the four week period, woodpigeon numbers recorded were markedly lower on Gun Field than on Quarry Field (**Table 15**).

Table 15. Woodpigeon numbers (mean and maximum counts) on Gun Field (laser) and Quarry Field (control).

	Counts	Woodpigeon numbers	
	n	Mean	Maximum
Gun Field (Laser)	14	0.07	1
Quarry Field (Control)	13	15	86

Automated laser – cross-over

In the second phase of the trial, the laser was switched between fields, so that Quarry field now received the laser treatment whilst Gun Field became the unprotected control field.

During the switching of the laser between fields, the laser developed a technical problem and stopped working. Around this time, however, the landowner had purchased and installed his own identical automated laser. This second laser was set-up to cover Quarry Field, according to the landowner's own treatment timings and pattern preference. Following repair of the original laser, Quarry Field was treated with two lasers for the last week of this second four-week trial period.

Over this four week period crop damage decreased on Quarry Field and increased on Gun Field. On Quarry Field, damage decreased from 94% to 20% (a reduction of 74%); whilst on Gun Field damage increased from 9% to 42% (an increase of 33%) (**Figure 17**).

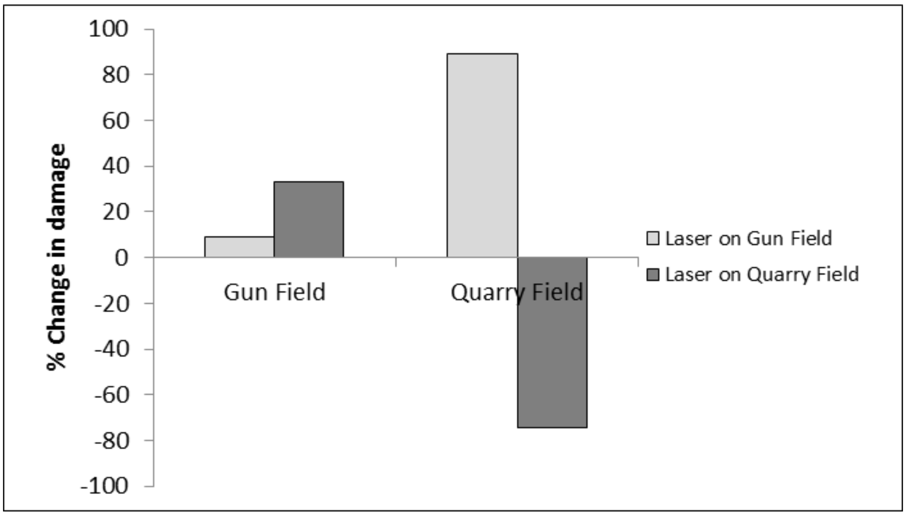


Figure 17. Change in crop damage (%) on Gun Field and Quarry Field in the presence and absence of the Agrilaser

Woodpigeon numbers

Following the switch of treatments between fields, woodpigeon numbers increased on Gun Field (now unprotected by the laser) and decreased on Quarry Field (now protected by the laser) (**Table 16**).

Table 16. Woodpigeon numbers (mean and maximum counts) on Gun Field and Quarry Field in the presence and absence of the Agrilaser

	Woodpigeon numbers			
	Laser		No laser	
	Mean	Maximum	Mean	Maximum
Gun Field	0.07	1	51	183
Quarry Field	12	47	15	86

Cost of automated laser

The cost of an automated laser is in the order of £10,000 with the longevity of the light source estimated at 5,000 hours. The device is essentially service free with regular checks and cleaning the only requirements of maintenance. Its maximum range is 1,500m at 20,000 Lux light conditions.

Drone

Immediate response to drone

During week 2 (originally scheduled as the treatment week) the weather conditions were harsh with heavy snow showers and sub-zero temperatures. On the Monday, only two drone flights were possible; strong winds and cold-impeded batteries preventing further flights. In response to both flights woodpigeons flew from the field to nearby trees. Birds returned to the field in <30 minutes after one flight. For the second flight birds had not returned after 25 minutes; poor visibility prevented an accurate assessment of when they did return.

In week 3 the weather improved but was not ideal for flying a drone. During the three days where weather was suitable, the drone was flown a total of 37 times, in response to woodpigeon flocks ranging in size from 20 to 160 birds (**Table 17**). In all but one instance all birds in the flock responded to the approach of the drone by flying to nearby trees or hedges (median distance flown = 300m). The deterrent effect was very short-term, however, as on each occasion birds subsequently returned to the field: median time to return <20 minutes (<3 to <45 minutes). In one instance the flock (83 birds) split with 53 birds leaving the field and 30 flying 100m along the field and re-landing; these birds were then deterred from the field by a second approach of the drone. The field was never vacant of woodpigeons for more than 45 minutes after a drone flight.

Table 17. Summary of drone flights – number of woodpigeons, distance flown and time for woodpigeons to return to field

Date	Flight	No. birds	Dist. birds flew (m)	Return time (mins)
07/03/2018	1	85	150	<30
	2	65	150	<15
	3	65	300	<15
	4	25	unknown	<25
	5	50	unknown	<35
	6	30	unknown	<35
	7	45	300	<10
	8	83	unknown	0
	9	30	300	<5
	10	160	110	<10
	11	56	110	<5
	12	80	110	<10

	13	150	100	<20
	14	75	100	<15
	15	75	100	<20
	16	40	150	<25
	17	60	420	unknown
08/03/2018	1	45	390	<5
	2	110	300	<10
	3	50	375	unknown
	4	30	unknown	<40
	5	25	unknown	<45
	6	20	unknown	<45
	7	30	300	<33
	8	100	325	<10
	9	65	300	<10
	10	116	325	<35
09/03/2018	1	77	unknown	<25
	2	47	unknown	<15
	3	74	unknown	<5
	4	54	unknown	<3
	5	20	unknown	<5
	6	45	300	<35
	7	30	unknown	<30
	8	45	325	<30
	9	65	300	<35
	10	25	350	unknown

Unknown = drone pilot preoccupied with flight and unable to visually track woodpigeons

Woodpigeon activity

There was no indication that the overall pattern of woodpigeon activity varied between treatment and control field over the four week trial. The median number of woodpigeons per week varied on both fields across the weeks (**Table 18**, **Figure 18** and **19**). During week 3 (drone flights) the relative decrease in numbers of woodpigeons on the treatment field (-28%) was lower than that on the control field (-67%).

The median percentage of observed time that woodpigeons were present on both fields varied more on the treatment field than on the control field over the four weeks (**Table 18**, **Figure 20** and **21**). The percentage of time that woodpigeons spent on the treatment field was greater during week 3 (drone flights) then during week 2.

Table 18. Summary of woodpigeon counts and percentage of time woodpigeons present on treatment and control fields during drone trial

		Week 1	Week 2	Week 3	Week 4
Woodpigeons [a]	Treatment	24	88	63	68
Woodpigeons	Control	62	144	47	118
% Time [b]	Treatment	68	42	58	76
% Time	Control	84	89	84	100

[a] median maximum daily count of woodpigeons on field
[b] median percentage time of observation period woodpigeons present on field

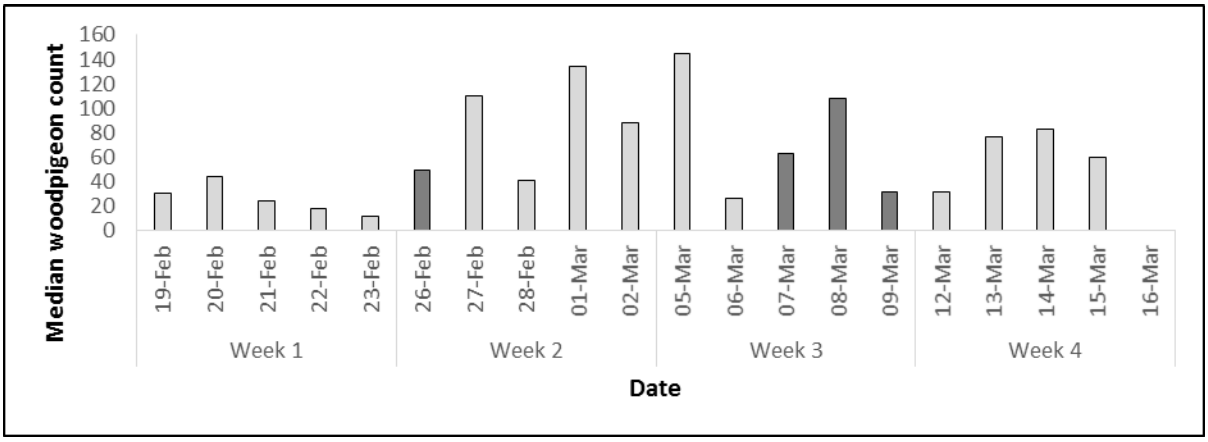


Figure 18. Daily median counts of woodpigeons present on treatment field. Dark grey bars indicate days where drone was active

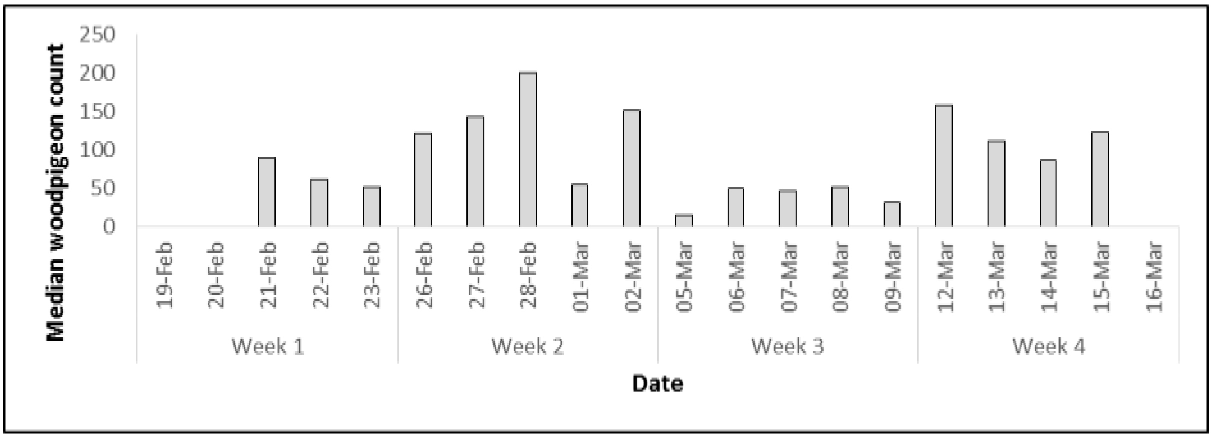


Figure 19. Daily median counts of woodpigeons present on control field

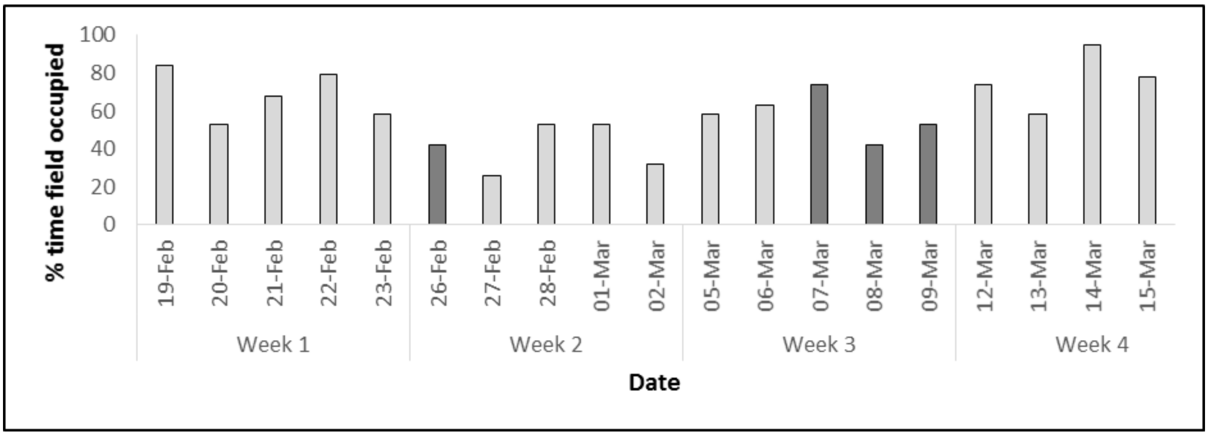


Figure 20. Percentage of observed time treatment field occupied by woodpigeons. Dark grey bars indicate days where drone was active

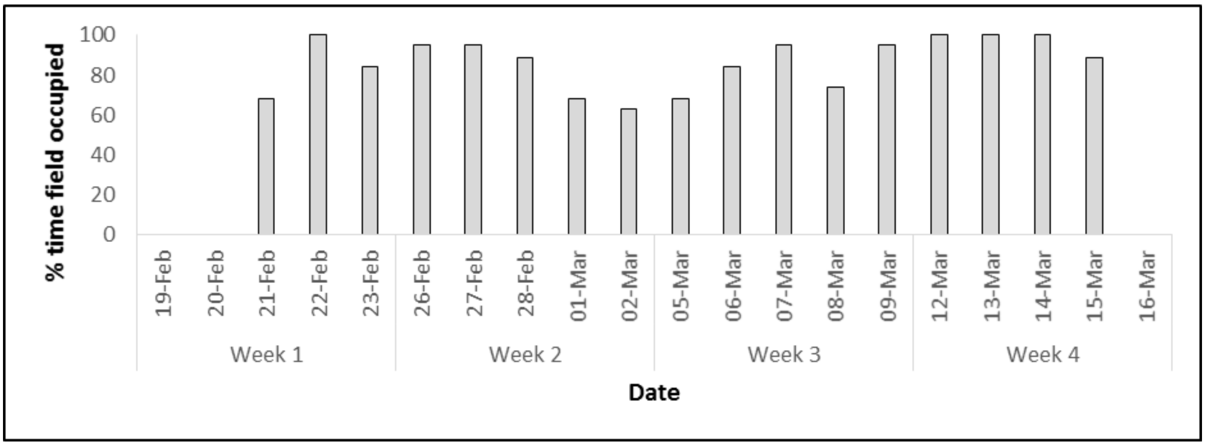


Figure 21. Percentage of time control field occupied by woodpigeons per day

Shooting – field scale (year 2 2016-17)

After shooting sessions there was an interval of 0 to 14 days before woodpigeons were first observed back on the field - on most occasions (62%) this interval was <5 days (**Table 19**). In the majority of cases (77%), there was a marked decrease in woodpigeon numbers initially returning; on average a 73% reduction in cases where woodpigeon numbers decreased. On three fields, numbers remained the same, or increased (+19% and +300%).

Observations of peak woodpigeon numbers occurred from 6 to 16 days prior to a shooting session.

Table 19. The peak numbers of woodpigeons observed within an area (radius 250m) around shooting sites pre and post shooting

Shooting Session	Days to Recover	Woodpigeons Numbers Pre	Woodpigeons Numbers Post	Change (%)
1	14	25 *(7)*	25	0
2	14	155 *(6)*	20	-87
3	1	470 *(11)*	86	-82
4	5	151 *(16)*	89	-41
5	0	50 (12)	32	-36
6	0	32 *(6)*	38	+19
7	6	35 *(6)*	18	-49
8	0	130 *(12)*	18	-86
9	no return	18 (13)	0	-100
10	0	500 *(6)*	3	-99
11	4	55 *(7)*	8	-85
12	0	8 (6)	32	+300
13	4	32 *(7)*	10	-69

Italicised figures in parentheses indicate the number of days prior to the shooting session that the peak number of woodpigeons was observed

Discussion

Reinforced deterrents (year 3 2017-18)

Audio-visual deterrents reinforced with live shooting was effective at reducing woodpigeon grazing and crop damage on fields of brassica (broccoli and cauliflower). It is of note, that one grower stated that he had not seen the crop (on one of his two treatment fields) looking so good for a number of years.

Trial fields in the treatment group were consistently exposed to lower woodpigeon activity and experienced lower levels of grazing damage, with a lower percentage of plants suffering moderate to severe loss of leaf cover (i.e. high damage) over the growing period. At harvest, crop plants in areas of fields that suffered high damage had significantly smaller head sizes than plants in areas in the same fields that had suffered low damage. Furthermore, a lower percentage of plants were harvested at first cut in areas of fields experiencing high damage than in areas of the same fields suffering low damage. As a lower percentage of plants in treatment fields suffered high damage compared to control fields, it follows that across the trial fields a greater percentage of plants will have had larger heads and be suitable for cutting on the first pass on treatment fields than on control fields.

Thus, the trials have detailed a process by which the reinforced deterrents reduced yield loss in fields of broccoli and cauliflower. The deterrents successfully reduced the numbers of woodpigeons visiting fields and the amount of time woodpigeons spent grazing. This reduced level of grazing decreased the proportion of plants suffering high levels of leaf loss and associated detrimental impacts on plant development and maturation. At harvest, this reduction in damage to plants was associated with larger size of crop heads and a greater proportion of plants taken at first cut. Extrapolating from this, it might be expected that with sufficient protection and mitigation in woodpigeon grazing and crop damage, the number of passes required to harvest a field could be reduced, saving the associated costs.

In terms of financial value, for a woodpigeon management strategy to be cost-effective the value of the crop saved by deployment of the deterrent measures must exceed the cost of implementation. In the current trials, the median cost of deployment of reinforced deterrents was £30/ha over a 10-week period. The cycle from planting to harvest in the trial fields was around 11-12 weeks, so crops were protected for the majority of their growing period. Based on average yields of 9.7 tonnes per ha and 9.2 tonnes per ha for calabrese and cauliflower respectively; and average farm gate prices of £512/tonne and £579/tonne respectively (Defra data), a reduction of 1% in loss of yield (equivalent to £50/ha and £54/ha respectively) would offset costs of deploying reinforced deterrents.

In project FV 426, a limited telephone consultation with growers indicated perceived losses of brassicas to woodpigeon grazing typically in the range of 10-40% and/or £330-£1,250/ha.

In the current project, information provided by growers indicated a cost per cut for broccoli and cauliflower of £285-£379/ha and £408-773/ha respectively. If reinforced deterrents can reduce the number of cuts required, then the cost-effectiveness of deterrents would be further increased. In the current trials, on average 27% more plants were cut from areas suffering low damage compared to areas with high damage; equivalent to several thousand plants per ha.

The relatively low cost of deploying deterrents (£30/ha) compared to the value of the crop saved provides affordable scope for increasing the intensity of the deterrent deployment (e.g. use of more rope-bangers and/or shooters) and potentially further reduction in yield loss.

Automated laser (year 3 2017-18)

The data from the trials are consistent with the automated laser providing a deterrent effect to reduce woodpigeon grazing. It is of note, that the grower's impression of the performance of the laser was such that he purchased his own laser part-way through the trial.

The results for Gun Field during the time the field was split into treatment and control plots suggest that the laser, despite only being set to cover half of the field, in fact acted as a deterrent across the entire field. Observations of woodpigeons on the field were virtually zero across both plots. Crop damage, however, increased on both plots (treatment +8%; control 10%) indicating that some woodpigeon grazing did occur outside of observation periods. When compared to the unprotected Quarry Field, however, this increase in crop damage was relatively very small. During this four week period, crop damage on Quarry Field increased by 89%; with observations of grazing flocks of up to 86 woodpigeons.

Switching of the laser between fields reversed these trends – crop damage decreased markedly on the now protected Quarry Field (-74%) and increased on the now unprotected Gun Field (+33%). On Gun Field, woodpigeons were recorded during each of the observation sessions, up to a flock size of 183 birds (where previously only a single woodpigeon had been recorded). On Quarry Field, woodpigeon grazing continued although with smaller flocks. This apparent contradiction of continued woodpigeon grazing and marked decrease in crop damage across Quarry Field is explained by the topography of this field. The sloped profile of the field meant that the laser could not cover the entire field from any one location. Indeed the topography was such that even when the two lasers were working for the last week of the trial there were still minor blind spots to the lasers. This presented itself in both the location of where woodpigeons were observed grazing and the crop damage score, with a majority of sightings and higher crop damage scores associated with three small areas of the field that it appeared the lasers couldn't reach. In these three areas average crop damage was 81%, compared with an average across the whole field of 20% (a reduction from 94% damage prior to deployment of the laser).

The results are consistent with a deterrent effect of the automated laser – although caution needs to be taken due to confounding variables associated with variation in the availability of alternative crops between the fields. For Gun Field, the surrounding fields were being used to grow oilseed rape and peas, with flocks of over 100 woodpigeons recorded on the rape and 60 on the peas. These two crops are known to be favoured by woodpigeons and may have attracted woodpigeons away from the trial field.

Further replicated trials of the automated laser are required to confirm the magnitude and duration of the deterrent effect and also to refine its deployment in terms of optimising the siting and laser pattern of the device.

In respect to cost-effectiveness, an automated laser costs in the order of £10,000. Although this represents a significant outlay, this cost will be offset by the working life of the device (likely minimum of 5 years), and the area over which the laser is effective. In terms of area of effectiveness, the laser will easily cover the whole of a 20ha field (depending on topography) and the portability of the device facilitates movement between different fields in response to developing woodpigeon grazing pressures. Therefore, if protecting only two 20 ha fields annually for 5 years, the unit cost of deployment is equivalent to around £50 per ha. This compares to an average financial value for 1% of the average yield of £50/ha and £54/ha for calabrese and cauliflower respectively.

Drone (year 3 2017-18)

There was no evidence that a quadcopter drone had anything other than a very short term deterrent effect on grazing woodpigeons. On each occasion that the drone was flown toward a flock of woodpigeons (20-160 birds) the birds flew away from the field into nearby cover (median distance 300m). On all occasions, however the woodpigeons returned to the field within a relatively short time (median <20 minutes). The repeated disturbance of the woodpigeons did not have an overall effect on woodpigeon activity on the field. The numbers of woodpigeons and the percentage of time spent on the treatment field showed a similar pattern to that observed on a separate control field (no drone flights). For example, a decrease in numbers of woodpigeons on the treatment field during week 3 (drone flights) was markedly lower than the reduction in numbers observed on the control field during the same period.

Woodpigeons also spent a greater percentage of time on the treatment field during week 3 (drone flights) than the preceding week.

The trial highlighted limitations in the practicality of using a drone as a deterrent against grazing woodpigeons. The drone was not able to be flown in strong winds and sub-zero temperatures drained the batteries preventing its use.

Shooting - population management (year 2 2016-17)

A number of different approaches to shooting woodpigeons were undertaken by landowners/growers in the overall study area – a number of which were not consistent with maximising effective population management and hence crop protection.

The effect of shooting on the numbers of woodpigeons within a defined area was undertaken over a 10-week period April to mid-June 2016. The trial took place in an area of approximately 8,200ha in Lincolnshire with cooperation from 20 landowners representing around 66% of that land area. On these holdings, landowners either allowed access to APHA marksmen to undertake shooting and/or undertook the shooting of woodpigeons themselves. All landowners/growers were requested to supply details of any woodpigeon shooting sessions that were conducted by their own appointed shooters during the 10-week trial. Of the 20 landowners/growers cooperating with the study, only four provided shooting returns; the remainder either traditionally never undertook shooting, or traditionally did undertake some shooting but reported not do so during the 10-week trial. Reasons for not shooting included an absence of vulnerable crops during the trial and hence no woodpigeon problems and being fully occupied on other tasks.

The APHA shooting team involved two marksmen who conducted a total of 380 gun-hours over the 10-week period; representing 66% of the combined total reported 575 gun-hours from all shooters. A total of 2,137 woodpigeons were reported shot (returns from all shooters) – a number of these from outside the delineated study area. APHA marksmen accounted for 955 (45%) of these woodpigeons. Inside the study area only, a total of 1575 woodpigeons were reported shot - APHA marksmen accounted for 942 (60%) of these. Thus, the deployment of a team specifically to undertake as much pest management of woodpigeons as possible over this period, significantly increased the magnitude of shooting undertaken and the number of woodpigeons killed in the area above, what is presumably, typical background levels.

If shooting was conducted at sufficient intensity to have an impact at the level of the local population, the numbers of woodpigeons in the study area would be expected to show a consistent decrease over the 10-week shooting period. However, there was no clear relationship between the abundance of woodpigeons in the study area and the number of woodpigeons shot. Although numbers decreased from a mean of 1,661 during the first two week period to fluctuate around a mean of 728 for the remainder of the trial period, there was no consistent decrease in abundance over the trial. The overall pattern of the relationship was suggestive of reactive shooting, whereby peaks in abundance of woodpigeons presented increased opportunities to target and kill woodpigeons, i.e. shooting tracked rather than caused local population fluctuations.

The returns from the various growers/landowners indicated that, overall, woodpigeon shooting was not conducted in a manner that is consistent with maximising effective population management – despite good practice from some growers. In order to be an effective management technique at the landscape-scale (the scale at which woodpigeons are active) shooting needs to involve sustained effort, be cooperative and coordinated between neighbouring landowners, and focussed on crop protection rather than sporting purposes. Effective population management, however, appeared to be constrained through inefficiency in these factors.

Cooperation and coordination between neighbouring growers in terms of woodpigeon shooting was limited. Growers tended to limit their own shooting to periods when crops in vulnerable growth stages were present on their own land. Once crops were no longer vulnerable (e.g. matured) or harvested, shooting activity ceased; the woodpigeons now being someone else’s problem. This focus on individual holding-level control meant that woodpigeons had access to ‘safe havens’ after having grazed on vulnerable crops on neighbouring land.

Sports shooting, undertaken on a number of holdings, presented similar problems with maximising the effectiveness of pest management. Discussions with shooters in the study area (and elsewhere) revealed attitudes inconsistent with maximising crop protection. For example, shooters were protective of their ‘patch’ and were resistant to allowing access to others to shoot. The overarching aim of sports shooting is to enjoy a ‘good day’s shoot’ which is inevitably associated with achieving a good day’s bag. In order to ensure a good bag over a limited period of a hunting trip, however, the sports shooter will leave woodpigeons undisturbed for a period between consecutive shooting sessions for numbers to build up. During this undisturbed period (in this study generally two weeks) woodpigeons again have access to safe havens on this ‘protected’ land. Further, sports shooters opposed intensive shooting regimes (e.g. regular use of air guns and night vision at roosts) in order to maintain a healthy flock for sporting purposes (i.e. shotguns over decoys). In the current study APHA marksmen used air rifles and night vision to good effect, accounting for 43% of all woodpigeons they shot. The technique, therefore, representing an effective alternative shooting method. It should be noted that the use of night scopes to shoot woodpigeons is not permitted by the General Licence to kill or take certain species of wild birds to prevent serious damage or disease (GL-04). Anyone wishing to use this technique must apply for an individual licence from Natural England.

There exists 'conflict' between growers and sports shooters in respect to their respective vested interests. For the most part, sports shooters have constraints on their time and inevitably shooting is limited to weekends and/or at times and locations most favourable to their convenience and desire to achieve a day's good bag. On the other hand, growers would prefer more frequent control. Growers have reported shooters turning down payment to manage woodpigeons so that the shooters could retain their independence and shoot to their own preferred schedule.

Shooting for pest control involves a sustained effort and hence cost, exemplified by the full-time pest controller employed by one of the largest growers in the study area. It is understandable, therefore, why growers are content to accept sport shooting as a means of pest management (rather than no management), with sport shooting either undertaken for free or shooting rights sold. However, a hidden cost to the grower of sport shooting is the failure of sport shooting to maximise crop protection.

A potential approach to address the costs associated with full-time woodpigeon shooting is for a number of growers to pool resources in order to pay for a full-time pest controller. The controller will then be able to shoot woodpigeons at the landscape-scale over a number of neighbouring holdings, removing the availability of 'safe havens' for woodpigeons associated with the current episodic and vested interest shooting. The use of air rifles and night vision at night roosts provides an additional effective technique. If this approach is replicated across neighbouring consortiums of growers, each with its own full-time woodpigeon controller, landscape-scale control will be further enhanced. Sport shooting would be additive, rather than alternative, to this approach to woodpigeon management.

It should be noted that it is not known how representative woodpigeon shooting in the study area (amongst growers/landowners providing information) is to woodpigeon shooting conducted elsewhere.

Shooting – field scale (year 2 2016-17)

The limited data gave some indication that at the field-scale, shooting reduced the numbers of woodpigeons utilising the immediate area around a shooting site (shotguns over decoys).

Although, in most cases woodpigeons returned to the field in less than five days following the session, their numbers were markedly lower (by an average of 73%).

Caution needs to be taken, however, in drawing conclusion from these observations. Surveys undertaken in the study area were designed to monitor woodpigeon numbers at the landscape-scale, associated with overall shooting effort across the study area. Therefore, counts of woodpigeons on any individual field at any one moment only represented a snapshot of woodpigeon activity for that location. The observed peak count for any field could vary markedly in consecutive weeks, or indeed on consecutive days, dependent on the time of day the field was observed during the whole study area transect. For all shooting sessions the observation of the peak number of woodpigeons occurred at least six days (and up to 16 days) prior to the shooting session. It is not known how representative these peak counts are of woodpigeon numbers in the immediate period before shooting was undertaken, or in the immediate period post-shooting; which would influence the evaluation of the effect of shooting. In terms of the period for woodpigeons to return to a site following shooting, the observations here represent a maximum recovery period; again due to the sporadic pattern of observations on any given field, recovery may have been earlier but unrecorded.

Hand-held laser – field scale (year 1 2015-16)

Low-powered hand-held lasers were consistently effective in lifting flocks of woodpigeons of a trial field of brassica (over-winter cabbage) but the effect was very short-lived.

A five-week trial was undertaken over February 2016 and involved two different green lasers: a smaller ‘laser-pointer’ type and a larger, commercial ‘bird-scaring’ laser; the smaller laser had a narrower beam. Lasers were deployed from a vehicle parked at the edge of the trial field. Woodpigeon flocks were persistently exposed to the laser until they left the field and the immediate neighbouring fields. In most instances, the smaller laser was initially deployed, switching to the larger laser if there was failure to lift the flock. Over a five week period, the trial field was visited 2-3 times per week at different times of the day, but focussing around early morning and late evening when the laser was most visible. Individual treatment sessions (5 minutes to 140 minutes on flocks of 9 to 300 woodpigeons) persisted until no woodpigeons remained on the trial field or immediate neighbouring fields.

On exposure to the laser, woodpigeons typically lifted and re-landed in the field but progressively more distant to the source of the laser; after several exposures relocating to neighbouring fields, or leaving the area completely. The effect, however, was short-term with numbers of woodpigeons recorded on the field remaining largely unchanged through the five week treatment period. The percentage of plants with moderate to severe leaf damage increased over the treatment period (from 58% to 71%).

Although the smaller laser had a narrower ‘pencil’ beam compared to the larger laser it was still consistently effective in lifting woodpigeon flocks. Although, the larger laser retained a disruptive effect at longer distances and in brighter ambient light.

It is not known whether more frequent use of the laser both on individual days and in the number of days would have increased the duration of any deterrent effect.

In respect to cost-effectiveness, a low-powered commercial hand-held laser costs in the order of £500. This cost will be offset by the working life of the device (likely minimum of 5 years), and the area over which the laser is effective. In the current study the laser was consistently effective in lifting flocks of woodpigeons from up to 300m away; and thus likely to be effective across an 18ha field. The smaller, laser-pointer cost in the order of £15.

Hand-held laser - roost dispersal (year 1 2015-16)

A low-powered hand-held laser was effective at dispersing woodpigeons from a traditional night roost.

A trial of the control of a selected traditional night roost using a low-powered, hand-held laser was undertaken in January 2016. Data on woodpigeon numbers within study roosts (treatment and control) and on neighbouring fields utilised by woodpigeons was compared before (pre-treatment), during (treatment) and after (post-treatment) disturbance with a laser. The laser was deployed from a distance of 180m around dusk on five consecutive evenings during the treatment phase. The laser was deployed on any woodpigeons perched in the roost and on birds attempting to land in the roost. The laser was deployed in short bursts to minimise the risk of burning out components; a risk if the laser is engaged continuously for extended periods. Complete (or near complete) dispersal was achieved by the end of five consecutive evenings of deployment of the laser; the effect of the laser appeared to increase incrementally over the five evenings. On consecutive evenings fewer birds attempted to enter the roost. It is presumed that dispersed birds relocated to a neighbouring alternative roost.

The effect of the roost dispersal was short-term, however, with numbers in the roost showing full recovery over the five day post-treatment period. This highlights the need for subsequent periodic reinforcement of the deterrent through further deployment following successful roost dispersal.

During the period of roost dispersal the numbers of woodpigeons on fields within a radius of 1km of the treatment roost increased by 25% - but this was a markedly lower increase than in an equivalent area around the control roost, where woodpigeon numbers increased by 87%. It is possible, therefore, that dispersal of the woodpigeons to alternative roost sites, influenced their choice of feeding site and, to a degree, supressed the build-up of birds grazing on fields in the area neighbouring the treatment roost compared to the control roost. Due to confounding variables, however, other factors cannot be discounted. Although the area around both treatment and control roost was predominantly similar (ploughed earth), there were differences in crop cover that may have influenced relative numbers of woodpigeons in the two areas (although both areas included crops at stages known to attract woodpigeons).

In respect to cost-effectiveness, a low-powered commercial hand-held laser costs in the order of £500. This cost will be offset by the working life of the device (likely minimum of 5 years).

Woodpigeon management strategy

In terms of an overall woodpigeon management strategy, current practices can be enhanced through a more strategic approach that incorporates lethal and non-lethal techniques, with growers cooperating and coordinating control activities at the landscape-scale.

At the field-scale, life-like audio-visual deterrents (mannequins, rope-bangers, gas-cannons) reinforced with live shooting can reduce woodpigeon grazing and crop damage. The use of reinforced shooting should be concentrated in the first two weeks post-deployment of deterrents; with shooters reintroduced if necessary. Success depends on regular movement and maintenance of the deterrents, adjusting the location and frequency of components (e.g. mannequins and rope-bangers) in response to woodpigeon activity.

A less labour intensive technique (but requiring greater financial outlay) is the deployment of an automated laser, which once set-up only requires periodic checking. Careful consideration is necessary when siting an automated laser, both in terms of coverage of the crop and human safety. The topography of the field will need to be taken into account and the laser raised off the ground in order to minimise laser blind-spots, the crop in which can continue to attract woodpigeons.

Low-powered hand-held lasers can be used to alleviate grazing in the immediate term, whilst longer-term deterrents are installed, such as reinforced deterrents or an automated laser.

At the landscape-scale, coordinated shooting focussed on pest removal can remove woodpigeons at a greater rate than the episodic shooting associated with control at the level of the individual holding or sports-shooting focussed on individual hunting patches and bags.

A dedicated full-time woodpigeon controller (as used by one of the larger growers in the study area) facilitates control over large areas of contiguous land. For growers with smaller holdings, the pooling of resources to appoint a controller over their combined holdings would provide similar larger-scale coverage. This approach would provide more efficient coverage than the existing situation in which growers and sports shooters tailor their shooting activities to address their own interests at the scale of their own holding. A series of consortiums of growers with their full-time woodpigeon controllers would enable strategic and coordinated management at the landscape-scale.

Conclusions

Current woodpigeon management practices can be enhanced through a more strategic approach that incorporates lethal and non-lethal techniques, with growers cooperating and coordinating control activities at the landscape-scale, across ownership boundaries.

Both, audio-visual deterrent techniques reinforced with live shooting and an automated laser independently reduced woodpigeon grazing and crop damage at the field-scale. Lower crop damage was associated with larger crop head size in broccoli and cauliflower; and with a greater percentage of plants suitable for harvesting at first cut.

Coordinated shooting focussed on pest removal at the landscape-scale can remove woodpigeons at a greater rate than intermittent shooting focussed at the level of the individual holding, or sports-shooting focussed on individual patches and bags.

Low-powered hand-held lasers can be used to alleviate grazing in the immediate term, whilst longer-term deterrents are installed. Lasers can also be used to disperse woodpigeon roosts with potential associated decrease in woodpigeon activity in the area around the roost.

Both reinforced deterrents and automated laser appear cost-effective. The degree of cost-effectiveness will depend on a number of factors, including field size, crop type/value and intensity of control required – all of which will vary between different settings.

An unmanned aerial vehicle, or drone, was ineffective in deterring grazing woodpigeons from a field, other than in the very short-term.

Knowledge and Technology Transfer

Factsheet 11/15: A review of the woodpigeon costs to Brassicas, salad crops and oilseed rape and the effectiveness of management activities.

Acknowledgements

APHA would like to thank all the growers, landowners and staff who cooperated with the project. Thanks also to Stockbridge Technology Centre for collaboration with the trial of the automated laser.

Disclaimer

APHA does not endorse any product or supplier identified in this report.

References

APHA (2014). A review of the woodpigeon costs to Brassicas, salad crops and oilseed rape and the effectiveness of management activities. Project (FV 426) report to the Agriculture and Horticulture Development Board.

Eaton MA, Balmer DE, Bright J, Cuthbert R, Grice PV, Hall C, Haywow DB, Heran RD, Holt CA, Knipe A, Mavor R, Noble DG, Oppel S, Risely K, Stroud DA, Wotton S. (2013). The State of the UK's Birds 2013. RSPB, BTO, WWT, NRW, JNCC, NIEA and SNH, Sandy, Bedfordshire.

Musgrove AJ, Aebischer NJ, Eaton MA, Hearn RD, Newson SE, Noble DG, Parson M, Risely K, Stroud DA. (2013). Population estimates of birds in Great Britain and the United Kingdom. British Birds 106: 64-100.

Risely K, Massimino D, Newson SE, Eaton MA, Musgrove AJ, Noble DG, Procter D, Baillie SR. (2013). The Breeding Bird Survey 2012. BTO Research Report 645, British Trust for Ornithology, Thetford.

Appendix 1: Specifics of the Agrilaser® Autonomic

Agrilaser® Autonomic – technical information	
Laser Class	3B
Laser beam colour	Green
Max. range at 500 lux light levels	5,000 meters
Max. range at 10,000 lux light levels	2,000 meters
Max. range at 20,000 lux light levels	1,500 meters
Service life laser source	5,000 (during normal operating conditions)
Wavelength	532 nm (green) continuous wave
Divergence	0.05 mrad
Diameter at aperture	40-50 mm
Lifetime (during normal operating conditions)	5,000 hours
Laser Nominal Ocular Hazard Distance (N.O.H.D.)	<1,540 m
Laser Maximum permissible exposure (MPE) *(assumed exposure duration of 0.25 seconds)*	25.4W/m²
Horizontal projection range	0° to +355°
Vertical projection range	-70° to +20°
Output power	<250 mW
Maximum pan speed	6°/second
Maximum tilt speed	4°/second
Operating voltage	12-15 VDC
Power consumption	60 W (peak operating power)
Power source	Power adapter (100 - 277 VAC)
Endurance	IP66 (suitable for indoor or outdoor use)
Relative humidity	20% to 95% (non-condensing)
Operating temperature	-10°C to +50°C (14°F to 122°F)
Security	• Password protection • Physical fixation to structures
Weight	Agrilaser® Autonomic: 10 kg (22 lb) • Supporting frame *(optional)*: 17 kg (37 lb) • Solar accessory *(optional)*: solar panel: 7 kg (15 lb) battery box: 35 kg (77 lb)
Dimensions	Agrilaser® Autonomic: 41 (16) x 41 (16) x 56 (22) cm (in) (LxWxH) • Supporting frame *(optional)*: 66 (26) x 66 (26) x 64 (25) cm (in) (LxWxH) • Solar accessory *(optional)*: - solar panel: 67 (26) x 46 (18) x 101 (40) cm (in) (LxWxH) - battery box: 46 (18) x 29 (11) x 33 (13) cm (in) (LxWxH)

Source - Agrilaser® Autonomic manual

Appendix 2: Internal Risk Assessment conducted prior to use of the Agrilaser® Autonomic

STOCKBRIDGE TECHNOLOGY CENTRE LTD
RISK ASSESSMENT

TASK:
Operation of Agrilaser® Autonomic.

ACTIONS INVOLVED:

1. Laser equipment operation.
2. Working in the line of sight of the laser.
3. Setting up laser equipment.
4. Maintenance.

HAZARD AND RISK ASSESSMENT:

1. Risk of eye contact with 3B laser beam.
2. Electric shock.
3. Battery explosion.
4. Battery weight.
5. Entrapment risk from the motor platform during operation.

PERSONS AT RISK:
All employees other stakeholders and the general public.

RECOMMENDATIONS /ACTIONS REQUIRED:

1. Do not point the laser at; humans, vehicles, aircraft, the sky, or any reflective surfaces such as water.
2. Operate and make observations from behind the laser
3. Use on a low risk area away from houses or roads, or public access.
4. Turn the laser off when stakeholders will be working near the equipment.
5. Make employees and stakeholders aware of the operating times to reduce the risk of issues occurring.
6. Connect battery to appropriate colour coded terminals.
7. Store the battery as stated in the manual.
8. Monitor equipment regularly to identify issues early.
9. Erect laser warning signs nearby.
10. Do not conduct any work on the wiring whilst it is connected to the battery.
11. Secure the stand securely to avoid the laser from moving from the set location

Signed ....

Name... Date............................

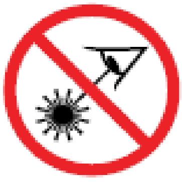
Source - Agrilaser® Autonomic manual

Appendix 3: Safety information provided within the product manual

Laser beam

WARNING: Prior to use, perform a risk assessment at the intended location and take precautions or control measures if necessary.

WARNING: Avoid direct eye exposure to the laser beam. Direct eye exposure and exposure to direct reflections can result in serious eye damage. Diffuse reflections are considered to be eye safe.



WARNING: This laser product may only be used in a controlled area.

CAUTION:

- To operate this product a laser safety training is required.
- The Agrilaser Autonomic is for professional use only.
- The Agrilaser Autonomic should be used by adults only.
- The Agrilaser Autonomic should be used for bird repelling purposes only.
- The laser module and motor platform have no user serviceable parts inside.
- Operate only in an undamaged condition. Use of the product when damaged may result in exposure to hazardous laser radiation.

CAUTION: The images below represent incorrect use of the Agrilaser Autonomic. For the safety of yourself and your surroundings, study these images carefully before operating the Agrilaser Autonomic.

Never project the laser device towards water or reflective surfaces such as mirrors, windows and metallic objects. Contact Bird Control Group (https://birdcontrolgroup.com/) for any questions related to product safety.

