LIFE15 ENV/UK/000386

Final Report

Covering the project activities from 01/09/2016 to 31/09/2020

Reporting Date

30/12/2020

Laser systems for the prevention of food chain poisoning and minimization of chemical exposure to the environment

Data Project	
Project location:	United Kingdom, Netherlands, Spain
Project start date:	14/09/2016
Project end date:	30/09/2020
Total budget:	€ 3,135,928
EU contribution:	€ 1,777,985
(%) of eligible costs:	60%
Data Beneficiary	
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This table comprises an essential part of the report and should be filled in before submission

Please note that the evaluation of your report may only commence if the package complies with all the elements in this receivability check. The evaluation will be stopped if any obligatory elements are missing.

Package completeness and correctness check	
Obligatory elements	**✓ or N/A**
Technical report	
The correct latest template for the type of project (e.g. traditional) has been followed and all sections have been filled in, in English *In electronic version only*	✓
Index of deliverables with short description annexed, in English *In electronic version only*	✓
Mid-term report: Deliverables due in the reporting period (from project start) annexed Final report: Deliverables not already submitted with the MTR annexed including the Layman's report and after-LIFE plan Deliverables in language(s) other than English include a summary in English *In electronic version only*	✓
Financial report	
The reporting period in the financial report (consolidated financial statement **and** financial statement of each Individual Beneficiary) is the same as in the technical report with the exception of any terminated beneficiary for which the end period should be the date of the termination.	✓
Consolidated Financial Statement with all 5 forms duly filled in and signed and dated *On paper (signed and dated originals*) and in electronic version (pdfs of signed sheets + full Excel file)*	
Financial Statement(s) of the Coordinating Beneficiary, of each Associated Beneficiary and of each affiliate (if involved), with all forms duly filled in (signed and dated). The Financial Statement(s) of Beneficiaries with affiliate(s) include the total cost of each affiliate in 1 line per cost category. *In electronic version (pdfs of signed sheets + full Excel files) + in the case of the Final report the overall summary forms of each beneficiary on paper (signed and dated originals*)*	✓
Amounts, names and other data (e.g. bank account) are correct and consistent with the Grant Agreement / across the different forms (e.g. figures from the individual statements are the same as those reported in the consolidated statement)	✓
Mid-term report (for all projects except IPs): the threshold for the second pre-financing payment has been reached	
Beneficiary's certificate for Durable Goods included (if required, i.e. beneficiaries claiming 100% cost for durable goods) *On paper (signed and dated originals*) and in electronic version (pdfs of signed sheets)*	N/A
Certificate on financial statements (if required, i.e. for beneficiaries with EU contribution ≥750,000 € in the budget) *On paper (signed original) and in electronic version (pdf)*	N/A
Other checks	
Additional information / clarifications and supporting documents requested in previous EASME letters (unless already submitted or not yet due) *In electronic version only*	✓
This table, page 2 of the Mid-term / Final report, is completed - each tick box is filled in *In electronic version only*	✓

**original signature by a legal or statutory representative of the beneficiary / affiliate concerned*

1 Table of Contents

2 List of key-words and abbreviations

Agrilaser	The avian deterrence laser system, produced by BCG, to be further developed during the project to produce the Laser Fence prototype systems.
Angel Camacho Alimentatión (ACA)	Refers to the beneficiaries Cucanoche, Cuarterola and Eoloarroz collectively, all of whom played key roles in demonstrating the Agrilaser system implementation in Spain.
BCG	Bird Control Group, project beneficiary based in the Netherlands and responsible for the development of the Laser Fence virtual fencing technology underpinning the project. Also responsible for demonstration of Laser Fence technology in Northern Europe
Cucanoche	*See Angel Camacho Alimentatión.*
Cuarterola	*See Angel Camacho Alimentatión.*
Cheshire Wildlife Trust (CWT)	Cheshire Wildlife Trust provided one of LJMU's testing partners at Bickley Hall, Malpas, England, UK.
EASME	The Executive Agency for Small and Medium-sized Enterprises (EASME)[1] was set-up by the European Commission to manage several EU programmes, including the LIFE programme.
Eoloarroz	*See Angel Camacho Alimentatión*
FNYH	Fundación Naturaleza y Hombre
GA	Grant Agreement, the specific document or contract with the Commission, detailing the project objectives, deliverables, time line, financial expectations, etc.
Game and Wildlife Conservation Trust (GWCT)	Game and Wildlife Conservation Trust, owners of the Scottish Demonstration Farm, and operating across Britain to *"use science to promote game and wildlife management as an essential part of nature conservation."*
Game and Wildlife Scottish Demonstration Farm (GWSDF)	Game and Wildlife Scottish Demonstration Farm, a beneficiary, responsible for demonstration of the Laser Fence system in Scotland, UK.
Health and Safety Executive (HSE)	The Health and Safety Executive (HSE)[2] is a non-departmental public body of the UK, and is responsible for the encouragement, regulation and enforcement of workplace health, safety and welfare.
IRIS	IRIS, project beneficiary based in Spain, and responsible for remote sensing and photogrammetry using Unmanned Aerial Vehicles (UAV) in all testing and demonstration areas

[1] See https://ec.europa.eu/easme/en/about-easme

[2] See http://www.hse.gov.uk/aboutus/index.htm

LIFE	The LIFE programme[3] is the EU's funding instrument for the environment and climate action. The general objective of LIFE is to contribute to the implementation, updating and development of EU environmental and climate policy and legislation by co-financing projects with European added value.
LIFE Toolkit	Refers to documents[4], manuals and templates provided for the purposes of managing the project by the Commission and/or EASME
Liverpool John Moores University (LJMU)	Liverpool John Moores University, co-ordinating beneficiary, responsible for overall financial and technical administration of the project, in addition to providing facilities and expertise relating to the project implementation. Also responsible for demonstration of Laser Fence systems in England, UK.
MTR	Mid Term Report
Monitoring officer	A representative of NEEMO, dedicated to oversight of the project activities and financial matters.
NEEMO	NEEMO[5] is responsible for the monitoring of LIFE projects (LIFE Action grants) and of NGOs that receive funding from the LIFE Programme (LIFE Operational Grants). The team deals also with all the communication aspects of the LIFE programme.
NGO	Non-governmental organisation.
PA	Partner Agreement, the formal agreement between the partners in matters relating to and governing the project management and delivery
Royal Society for the Protection of Birds (RSPB)	The Royal Society for the Protection of Birds[6], is the UK charity working to secure a healthy environment for birds and all wildlife. Provided a demonstration site for LJMU in Cheshire.
SC	Steering Committee, consisting of key members of the project beneficiaries.
Volterra	Volterra Ecosystems, project beneficiary, largely responsible for project communications and ensuring implementation of Laser Fence in Spain.

[3] See http://ec.europa.eu/environment/life/about/

[4] See https://ec.europa.eu/environment/archives/life/toolkit/pmtools/lifeplus/index.htm

[5] See https://neemo.eu/about-neemo/

[6] See https://www.rspb.org.uk/about-the-rspb/

3 Executive Summary

3.1 Introduction

Agriculture produces food and other commodities to sustain our global population and economy. This requires intensive production and as this intensity has developed throughout the 20th Century, increasing amounts of chemicals were deployed to control a range of issues. These included rodenticides, as well as other chemicals to control insects and weeds.

The side effects of using these chemicals have become clear. Poisoning of non-pest species occurs. Many attempts have been made to produce non-chemical and non-lethal control methods, but high efficacy and long term solutions have not been achieved. In addition, there is the loss of livestock to predators, diseases and the reduction of feed (i.e. grass). Then there is simply the destruction of crop plants by intrusion of wild animals.

Fig. 3-1 A rabbit with laser beam approaching, June 2017

There is a need to isolate livestock and crops, from pests and intrusion. Fencing can achieve this to some degree. But it is difficult to use physical fencing to exclude the smaller animal (rodents).

An alternative is needed. Laser Fence is a project to determine the potential for lasers to provide a virtual fencing solution based on the successful development of laser based avian deterrents by one of the project partners.

3.2 Project

The LIFE Laser Fence project started in September 2016. Partner managed trial sites were established, laser systems were prepared, and monitoring methods developed including an imaging drone platform.

Fig. 3-2 Blue autonomic Laser Fence laser deterring a rat, 2020

Testing the efficacy of lasers requires a number of monitoring actions. These can range from the simple recording of a laser operator's observations of the interaction with an animal, to the use of trail cameras and CCTV. These generate a large amount of video data for analysis.

Successful trials would demonstrate the viability of using lasers as virtual fences for ground animals. The aim of the project is to demonstrate a Laser Fence that is capable of controlling mammalian pest species, allowing a reduction in use of rodenticide, separating wild animals from livestock and protecting vulnerable species (e.g. the eggs of breeding migrant birds).

Partner led trials would be replicated on third party sites, to evaluate efficacy and economic benefits of the Laser Fence. The findings of these trials would be promoted and disseminated widely to a range of stakeholders from the public to national and European government.

3.3 Outcomes

Fig. 3-3 Wolves responding to a blue Laser Fence handheld, Zamora, Dec 2020.

Six partner managed trial sites were established by May 2017: three Angel Camacho farms near Seville, the GWCT demonstration farm (GWSDF) in Scotland and two sites in England managed by LJMU. The first trials focussed on rabbits, birds, fox, and wild boar.

Initial trials were disappointing, animals did not respond to the laser in the same way as birds. The "response rate" (how many reacted to the approaching laser spot) was very low compared to the high rates with birds. While all species were able to respond to the beam, see Figs. 3.1-3, the majority ignored the beam. Such a response rate could not provide a pest control benefit.

The nature of the project changed, to understand why and improve the efficacy. The planned replication trials conducted at third party sites now sought to improve performance. New methods were developed, particularly how to "pester" the animals with handhelds. Time-consuming analysis of large amount of video clips and data took place, particularly for autonomic trials. Different colour lasers were deployed.

Over the next two years, the number of trials increased: Grain stores in Cheshire (rats); grey squirrel trials conducted at Welsh Mountain Zoo; a field in Germany with boar, deer and hare; a trial site in Galicia with similar animals; replication farms in the Cádiz; and at the end of project, wolves in Zamora, Analysis of data from these trials revealed that a more subtle response was occurring. Handheld lasers could pester animals to move animals away. Autonomic projection of the laser did reduce animal prevalence and activity in the projection area. Highlight results were: 78% of badgers were moved away using a handheld laser, and a 93% reduction of rat activity at a grain store.

These results were obtained towards the end of the project, and the Covid-19 restrictions prevented further development of trials. Unfortunately, the project has not demonstrated any reductions of rodenticide, this would require new trials. The final results are encouraging and an After Life plan has been produced to take forward Laser Fence. The team believe a "Detect and Deter" approach can deliver a pest control system. Animals moving in an exclusion zone would be detected, and the system would bring the laser to "pester" them to leave the zone.

There have been many dissemination activities throughout the project. A number of exhibitions and meetings have been attended, including trade exhibitions and meetings with influential NGO's. Representatives of the Scottish government have met the project team in Scotland where there has also been a good degree of public exposure. The Spanish partners have networked with other crop producers, NGO's and other LIFE projects.

A website, http://laserfence.eu , has been maintained and updated with news and other relevant content. Social media channels have been opened on Facebook and YouTube. A Twitter hashtag #laserfence has been used by project partners on their own accounts.

Without a proven pest control system, it has been difficult to identify areas where the project could influence national and European policies. The After Life project intends to deliver Laser Fence as a non-lethal pest control system. This would allow the project team to promote an increase in pressure to reduce or eliminate rodenticide use and other lethal measures.

4 Introduction

4.1 Description of background and problems addressed

There are a number of animals that have a negative impact on farming and agriculture. These include birds, predators, and disease-carrying species. Several species of birds can damage crop, pigeons eat seedlings, passerines can severely damage fruit and vines. Birds can cause problems outside of agriculture. Flocks of geese can have a very dangerous impact around airport grounds, a possible threat to aircraft taking off and landing. In built environments fouling from flocks of birds such as pigeon and seagulls can cause a health hazard or damage equipment, particularly roof mounted air conditioning equipment, and drainage.

Fig. 4-1 Bird Control Group laser operating in an orchard

Lasers have been investigated as a potential deterrent device for birds since the early 1970's. The nature of lasers at this time, made the potential use mainly impractical. Interest grew in the early 2000's in several research trials. But with the advent of low cost low power diode lasers, becoming common as laser pointers, the potential use of battery powered low cost lasers made this idea more attractive. Bird Control Group, (BCG), a partner in Laser Fence was founded in 2012 and developed handheld and autonomic laser products that could displace a variety of pest birds, Fig. 4-1.

Rodents are a particular problem; these animals destroy crops, eat livestock feed and can transmit disease. Chemical controls, particularly rodenticides, are used to control rodent populations. Rodenticide use is strictly controlled in the EU, as it can put other species at risk. Studies show that anticoagulant rodenticides contribute to the deaths of a variety of mammals and birds. Other agricultural chemicals, e.g. insecticides and herbicides, are also a hazard to animals that inhabit the agricultural ecosystem. These chemicals can enter the trophic chain and so represent a hazard in food production.

There are other species that cause significant losses in agriculture. Rabbits can reduce grass quantity in pastures used for feeding sheep and cattle, reducing yields and causing financial losses. Uncontrolled, rabbits can consume over 50% of seedlings in a sunflower field. Larger animals such as badgers and wild boar can damage other crops as they forage. Badgers are a potential vector for bovine tuberculosis. Badgers and Foxes threaten other wildlife that may already be at risk, e.g. ground nesting birds. These species represent a significant cost to agriculture through the loss of yield and costs of prevention methods.

Finally, there are predators. The reintroduction and protection of wolves is a desirable action, but when these predators begin to interact with livestock farming, leisure activities and human habitation, problems and conflicts arise.

The main method used to control the undesirable presence of these animals is usually lethal, trapping and shooting. European legislation requires this to be done humanely. This is costly, often ineffective in its level of control. And it is increasingly controversial, with animal welfare and protection groups increasingly seeking alternatives or even a ban on all forms of control. So, can the laser technology, so successfully deployed against birds by BCG, be a solution to these issues?

The LIFE project, Laser Fence, attempted to develop the BCG technology for the control of animals on the ground. The main aim of the project was to develop a Laser Fence system to create virtual fencing to exclude or contain ground animals. The prime target species is the rat, and other rodents, and also to reduce, or eliminate, the use of rodenticide. A reduction or elimination of chemical use will reduce the risk of accidental poisoning to animals and humans, and the build-up of toxic chemicals in the trophic chain. Related aims were the separation of wild animals form livestock, e.g. badgers from dairy cattle to reduce transmission of bovine tuberculosis, or wolves from sheep. The technology could be used to protect bird breeding grounds from egg scavengers, an important application for maintaining biodiversity.

4.2 Main Objectives

The project's main objectives were to demonstrate and replicate:

1. A reduction of the impact that chemicals have on fauna by the minimisation of exposure to toxic chemicals through the application of the innovative Laser Fence. This would deter animals intruding into agricultural fields, thus preventing poison entering the trophic chain.

2. Calibration and improvement of the functionality and efficacy of the laser deterrence systems towards animals other than birds (rodents, rabbits, deer, wild boars, badgers, etc.) in ecologically sensitive areas where nature conservation increasingly conflicts with agriculture

3. Cost-efficient and more sustainable agricultural management practices through incorporation of Laser Fence systems, which are accurate and cost effective, to monitor farmlands, protected or difficult to reach areas, and over long distances. The project also aimed to demonstrate to farmers and land owners the positive economics of this sustainable practice due to lower operating costs and an increase in yield.

4. The project aimed to show that the Laser Fence system could be developed from the BCG Technology to have an impact beyond avian species and contribute significantly to tackling the issues of agricultural chemical use (i.e. rodenticides) and of crop yield losses. This would be achieved by conducting trials across a range of crop and pest types in different parts of Europe, and documentation of such trials such that results can be compared with replication studies in the latter stages of the project.

4.3 Expected longer term results

The expected results of the project were:

- To demonstrate that the Laser Fence technology can achieve **a rodenticide reduction up to 100%** in trial areas by the end of the project.
- Demonstrate that Laser Fence can **lower exposure of birds to herbicides and pesticides.**
- **Decrease in crop losses** caused by animal intrusion in the agricultural fields **by 50%.**
- **Increased awareness and dissemination** for reducing the use of **chemicals** and their **impacts on the environment** among other stakeholders (particularly on EU relevant legislation and objectives).

Longer term the project would continue to raise awareness and promote policies that aim to reduce chemical use in European and global agriculture, by the adoption of innovative laser based solutions. This will be achieved by continuing replication trials and dissemination activity

5 Administration

5.1 Project Management

The project is managed by LJMU. Dr Martin Sharp has managed the project since 1st June 2017 following the departure of Dr Alex Mason. Administrative assistance from Laura Bellinger, and accounts support by Mark Fealey from September 2017.

Ten steering committee meetings (SCM) executed. Six were held as physical meetings, four of which were also monitoring missions with Neil Wilkie, one was the kick-off meeting in Liverpool in September 2016, and the remaining physical meetings were in Delft, February 2017; Sevilla, November 2017; Auchnerran, September 2018; Sevilla, March 2019 (coinciding with a Technical Seminar), and Liverpool, September 2019. The other four meetings were virtual meetings, the last being the final SCM and mission, September 2020.

These meetings contained a review of actions, partner presentations of activity, a review of all the project actions, a review of KPI, deliverables and milestones and financial issues. Physical meetings were accompanied by a visit to the local project trial sites. These meetings were very productive, particularly mission meetings, where Neil Wilkie provided not only monitoring oversight, but also guidance and encouragement to the team. With the challenging nature of the project becoming clear by the end of 2017, these meetings took on a greater importance to consider and plan activity to improve the efficacy of Laser Fence and hopefully demonstrate results supporting the KPI.

To ensure that the partners were communicating regularly, monthly Zoom meetings were initiated in December 2017, with all partners participating. These proved vital in allowing partners to share recent results, insight and new ideas around the consortium.

The lack of efficacy of Laser Fence for ground animals was unexpected as the related laser technology, Agrilaser, used for bird deterrence, works well. The resulting project work program character changed to that of finding ways to improve the efficacy of Laser Fence rather than replicating a demonstrated viable system. The monthly meetings supported this through knowledge transfer, along technical staff visits from one partner to another.

5.2 Communications with EASME and the monitoring team.

Following each mission and report submission, EASME issued a letter on the meeting or report and requesting further technical and financial information. These were replied to either in the following monitoring report. These communications undertaken are collected in Annex 1. This includes a response to the technical question in the letter after the final meeting.

5.3 Extensions

The lack of efficacy of Laser Fence technology, combined with difficulties in trial sites with suitable numbers of rats, meant that a viable rat control system had not been achieved by July 2019. An extension was granted to move the project end from December 2019 to June 2020. Deliverables and milestones were adjusted accordingly.

The aim was to ensure that trials could continue through the winter and spring seasons in 2020, to offer a longer time to conduct trials with rats to attempt to impact the the main KPI of rodenticide reduction. Encouraging results were obtained, but Covid-19 restrictions began to impact in March 2020, greatly restricting the ability to conduct trials particularly in the UK.

Covid-19 also prevented the anticipated physical final meeting, due in April 2020. This was postponed this meeting to September 2020, and a further extension was agreed to the end of September with the hope of holding a physical meeting, however ongoing Covid-19 restrictions forced this final meeting to be held using Zoom.

6 Technical Report

In this section the technical progress of the project is reported.

6.1 Technical Progress

The progress of the project of each action is presented in this section

6.1.1 Action A – Preparatory

6.1.1.1 A1: Scoping of Areas

Action Schedule			
Planned start date:	14/09/16	Actual start date:	14/09/16
Planned end date:	31/12/16	Actual end date:	12/10/18

Scoping of the test areas was intended to provide a body of knowledge of six test sites in order to inform and plan the intended trials to be conducted during implementation actions.

Four of these sites were owned and managed by beneficiary partners, the ACA farms Cuarterola, Cucanoche and Eoloarroz, and GWSDF who manage the Auchnerran site. For LJMU, a small test site in Shotwick, Cheshire, was available immediately at the start of the project. Another test site, Bickley Hall Farm was secured by an agreement with the Cheshire Wildlife Trust (CWT), allowing free access to their land, where a particular site was identified within their farm ("The Warren"). Table 6.1 lists these sites:

Beneficiary	**Test site name and location**	**Comments**
LJMU	Shotwick, Cheshire, UK	Owned by Dr Jenny Sneddon of LJMU
	Bickley Hall Farm, Cheshire, UK	Owned by the Cheshire Wildlife Trust
ACA	Cuarterola SL, Morón de la Frontera, Spain	Secured, owned by beneficiary.
	Cucanoche SL, Sevilla, Spain	Secured, owned by beneficiary.
	Eoloarroz, Sevilla, Spain	Secured, owned by beneficiary.
GWSDF	Auchnerran Farm, Aberdeenshire, UK.	Secured, managed by beneficiary.

Table 6-1- Secured Test Sites

It was anticipated that BCG would also secure a test site, however access to the sites as anticipated at the time of the grant agreement could not be secured. BCG managed to gain access to a site at Wölferlingen, in Germany, that provided an equivalent challenge with intrusion into crop fields by a range of mammals. This site was initially considered to be a test site, and written up in the scoping report deliverable. Following the submission of the MTR and subsequent SCM7 held at Auchnerran, it was agreed that the six sites listed in Table 6-1 would be considered as test sites, with Wölferlingen and other sites acquired considered to be replication sites[7]

Test Site:	Partner Responsible	Country	Site Area (Ha)	Municipal Authority		
					Population	Area (km^2)
Auchnerran	GWSDF	UK	484	Aberdeenshire	261,470	6,313
Cuarterola	Cuarterola	ES	290	Province of Seville	1,917,097	14,042

[7] Reference – EASME Letter: Ref. Ares(2018)5240659 - 12/10/2018

Cucanoche	Cucanoche	ES	463	Province of Seville	0	0
Eoloarroz	Eoloarroz	ES	3	Province of Seville	0	0
Bickley Hall	LJMU	UK	86	Cheshire West and Cheshire	343,071	917
Shotwick	LJMU	UK	1	Cheshire West and Cheshire	0	0

Table 6-2 Geographic data for test sites

Geographic data for the test sites is presented in Table 6-2. The site area is indicated, and the area and population of the site's municipality is presented. The latter figures are used to indicate the sites' contribution to the relevant Project Specific Indicators (PSI) as indicated in Table 6-3.

Contribution to project specific indicators	
Indicators	**Achievements**
Trial areas – Cropland - Pest control - reduction of impact of pest species, e.g. Rabbits, Rodents, Wild Boar, Squirrel, Birds (e.g. Storks)	Five of the six main trial sites have conducted trials based on reducing the impact of pest species, e.g. rabbits, rats, wild boar, storks.
Trial areas - Grassland - Disease control - controlling access to dairy farming by Badger, considered a vector for Bovine TB	Bickley Hall was investigated for Badger trials, but the major trials on badgers were conducted on a replication site.
Trial areas - Grassland - protection of vulnerable species - nesting birds including waders and migrating birds. Protection from e.g. Rodents, foxes and badgers	GWSDF Auchnerran, Cuarterola and Cucanoche were particularly interested in protecting wild birds from mammals and agricultural practices.
Areas near to Natura 2000 sites	All sites are close to Natura 2000 sites of varying sizes.
Local Population and Municipal Areas	Data in Table 6-2 above

Table 6-3 Contribution to PSI

IRIS have conducted drone assessments of each of the test sites giving the responsible partners further insight into their test sites and immediate surroundings.

All these sites have provided testing areas throughout the project and are expected to remain available to the project partners for further After LIFE activity. Hence contact with various authorities has been made by all partners; in relation to the Laser Fence trials conducted at partner sites and replications sites. These are detailed in the deliverable "Evidence of contact with national parks and conservation areas".

Deviations

No specific deviations to be reported. Due to the progress of the project and a lower than expected response from the target species, activities were conducted throughout the project duration at these partner test sites.

Deliverables:

- **Scoping Report:** Delivered by LJMU with final acceptance in October 2018.
- **Evidence of contact with national parks and conservation areas:** Initially delivered by LJMU, 31/12/2016. Amendments requested and a revised deliverable reported was submitted on 14/9/2020 for SCM10.

Milestone name	**Expected date**	**Actual date**
Final Selection of sites	31/12/2016	30/12/2016

The original six trial sites (Spanish partners, 3 UK sites) were agreed by Dec 2016.

6.1.1.2 A2 – Preparation of Equipment and Infrastructure

Action Schedule			
Planned Start date:	14/09/16	Actual Start Date:	16/10/16
Planned End date:	31/06/17	Actual End Date:	31/03/17

This action centred on the provision of equipment and resources in order to undertake the implementation activities of Action B. The main activity was conducted by BCG to supply Laser Fence laser systems (handheld and autonomic) to the partners to undertake trials in their sites and for use in the replication trials. The first systems were delivered and commissioned at GWSDF in March 2017.

Fig. 6-1 Laser training at GWSDF March 2017

All partners received a minimum of an autonomic system and a handheld system, and some initially received multiple systems. In the second half of 2018, BCG developed handheld lasers of different colours – red, yellow and blue in addition to the standard green. Subsequently the blue laser was incorporated into an autonomic system as there was evidence from trials of some benefit in using a blue laser.

IRIS procured two drones and a support van for travelling with the drone equipment to the various sites around Europe. It also conducted training and calibration trials with the different drones and camera equipment. First flights over test sites took place in October 2017.

At LJMU a dedicated laser laboratory had been indicated. A room had been identified prior to the start of the project. It was then found it was not possible to have exclusive access to this room, so portable laser screens were procured for safety. Another room was identified, and was used for some time, but again exclusive use could not be secured (e.g. a electromagnetic test chamber was installed). It was decided not to refurbish this laboratory as exclusive use could not be agreed with estates management, and a quotation to do such work would not have represented good value for money. In late 2018, the estates department informed that this room was to be repurposed. As a result, an office was secured next door to the industrial laser laboratory. Work space was found in this laboratory for the Laser Fence activities. It was found that all necessary work could be conducted in a timely fashion within these arrangements. Some activities (monitoring propagation of the laser beams) could not be conducted within any of the rooms, but such work could, and was, conducted at the LJMU test site at Bickley Hall, or the replication site at Cheshire Farm A.

A supercontinuum laser and wavelength filter were procured and packaged for supervised external use. This laser would allow for the selection of any visible colour beam. It was taken and trialled at the replication site at Welsh Mountain Zoo, but its weight and construction proved difficult to move on to the actual range used for laser trials. It was also taken to RSPB Burton, where there was better access. By this time, coloured handhelds were available. Trials with these coloured handhelds established that the poor response to the green laser beam was not a colour issue, as the BCG blue laser performed as well as the green laser (arguably better), and there was response to red and yellow lasers, but at a lower response level. It was felt that the low response of the ground animals would not simply improve by finding a suitable colour of light, and it was the behaviour of how the beam was applied to deterring the

animals that would be the key to improving the response. Trials based on such a development were better with hand-held lasers or the blue autonomic.

A key requirement of the trials was the recording of animal activity and interactions of the animals with the laser beam. This required partners to invest in "trail cameras", IR viewing equipment and at LJMU, a CCTV with IR illumination was deployed. While some of this equipment was not explicitly recognised in the grant agreement, it proved invaluable in delivering our final understandings of how the Laser Fence concept may be developed into a viable pest control solution. It has also resulted in a significant amount of image data being captured and analysed, which has been valuable in itself.

Fig. 6-2 Installation of autonomic at Cuarterola

All partners have participated in this action by installing and deploying Laser Fence systems. Training activities have been provided by BCG for deployments at project sites. BCG have visited all installations, , and checked their compliance to operational and safety protocols. These protocols are the subject of a deliverable "Protocol for calibration of Laser Fence" delivered by BCG.

BCG have continued to develop additional features for the Laser Fence products as the project has progressed. This has included a level sensor to prevent the handheld laser beam being unintentionally exposed upwards above the horizon, remote controls for the autonomic systems and more robust autonomic systems. They also delivered the Laser Fence systems in four colours – Red, Yellow, Green, Blue.

Contributions to Project Specific Indicators.

Indicators	**Achievements**
Investment costs of fencing 1 area of 500 ha (approx. 9.000 m perimeter)	Traditional fencing originally estimated at €63k, revised at the end of the project to €98,000 + installation Current capital estimate for LaserFence solution - €72,000

Deviations:

This project action was planned for completion at the end of Quarter 2, 2017, and in essence it was: equipment had been delivered, a protocol for operation delivered and training procedures established. However, as the project progressed and worked towards increasing the response of the animals to the laser, ongoing work continued.

Deliverables: – **Protocol for calibration of LaserFence***;* Delivered by BCG on 08/11/2016.		
Milestone name	**Expected date**	**Actual date**
Training courses for partners realised	31/03/2017	01/03/2017

6.1.2 Action B – Implementation

6.1.2.1 Action B1 – Large scale implementation in all areas

Action Schedule			
Planned start date:	03/04/17	Actual Start Date:	15/11/16
Planned end date:	30/06/20	Actual End date:	31/09/20

GWSDF were the first beneficiary to begin substantial trials in early 2017. LJMU began trials at Shotwick in early June 2017, and began trials with a LaserFence autonomic at Bickley Hall in mid-July 2017. Handheld trials begun in ACA sites around the same time.

In September 2017 the UK's Health and Safety Executive (HSE) visited GWSDF Auchnerran. A few days later they told GWSDF and subsequently LJMU to stop using autonomic systems unless they were supervised. This results from the Class 3B classification of the laser systems under the international Laser Standard IEC60825. All partners were advised of this action and asked to review their safety risk assessments and operating procedures, particularly for autonomic systems.

Trial plans were revised and trials continued to be progressed at all sites. Further discussion of the impact of the HSE ruling is given in section 6.2.1

GWSDF have conducted Laser Fence handheld trials and autonomic trials, principally aimed at Rabbits and Rats, with the occasional trial relating to deer and predators.

Handheld trials provided initial insight into the response of rabbits to the Laser Fence product, a low response was indicated around 20% in initial trials. Subsequent trials refined these results and tested the effect of different colour laser beams and different powers, Fig. 6-3. Of note is the increase in response at the shorter wavelength colours, blue and green, compared to red and yellow. In terms of power, the results suggest that 5mW and 0.4mW lasers may have some response, but less than the higher power class 3B lasers. Note that the response ratio relates to a noticeable response from the animal, not necessarily that the rabbits were deterred or "chased away".

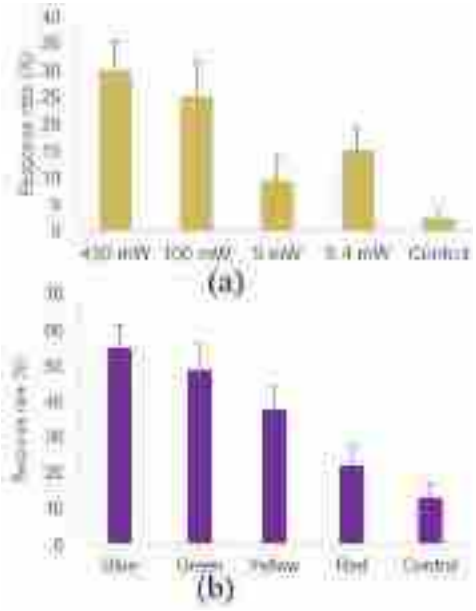

Fig. 6-3 Handheld vs Rabbits results - (a) Laser power (b) Laser colour

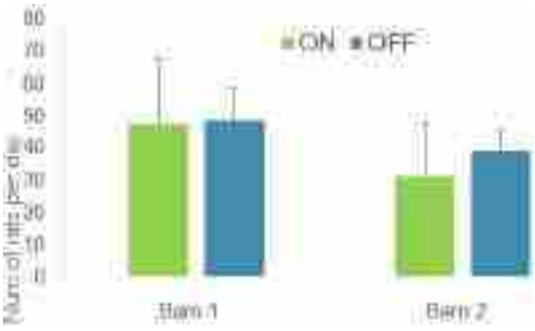

Fig. 6-4 Autonomic Trial with rats at two barns

The autonomic trials were restricted by both the HSE restrictions and also some issues with the devices themselves, possibly due to adverse weather conditions experienced in Scotland. However, autonomic trials were conducted testing the response of rats to the laser, by operating the autonomic safely within a disused barn. There was no statistical difference in the number of rats counted in the barns with the laser on or off. This result was confirmed in a repeat trial that followed immediately. Later attempts at rat trials were thwarted by the surprising scarcity of rats over the winter of 2019 / 20, and a marked decline in numbers of rabbits at Auchnerran also undermined the later rabbit trials.

LJMU To test the performance of the autonomic devices an autonomic LaserFence system was installed in Shotwick with aim to exclude a small number of sheep from the corner of a plot that was frequently grazed. Camera traps were deployed and revealed a mixed response. Behavioural analysis was conducted using "Animal Behaviour Pro"[8] The Shotwick trial results suggested that the sheep might spend more time being "vigilant" when the laser is projecting.

The Bickley Hall farm set up of a Laser Fence Autonomic. A 100mW green autonomic laser projected on to the North West face of a mound (the "Warren") with a control area on the opposite face. Several trail cameras surrounded the projection area. The trial began in July 2017. Initial analyses of rabbit data were undertaken using the trail camera imagery, backed by grass sward height analysis. It was hoped that this would provide evidence of response rate of rabbits to encroaching laser beams, as well as any underlying evidence of the rabbits feeding in the grass in the projection zone. The grass height initially suggested that rabbits moved from the laser to the control area. After a few weeks, grass data suggested that the rabbits habituated to the laser. It was felt that both the monitoring methods were not giving a complete picture. Trail cameras were often triggered but had no images of animals, or animal / laser interactions. It was decided to procure a CCTV system with IR illumination and a wireless link to the recording equipment some 800m distance in the Bickley Hall farm offices. This provides a 24/7 recording of activity at the site, and Terabytes of data. The CCTV helped identify a relative scarcity of rabbits.

On 28th September 2017 the laser was turned off due to the HSE intervention at GWSDF. Subsequently neutral optical filters were fitted to reduce the laser to 1mW, a power at which the laser could be safely left running, together with a remote emergency stop button. It was switched on at this power level at the beginning of June 2018. It was noticed that the beam could not be seen in daylight. On 21st June it was found that the CCTV was not working, later found to be cables being cut. Preliminary examination of CCTV and trial cameras failed to identify laser beam sightings.

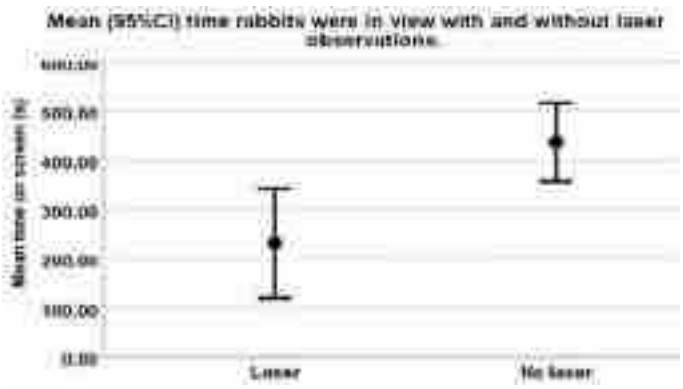

Fig. 6-5 Time spent by rabbits in the projection zone

From this point, resources were reassigned to developing trials at replication sites, and undertaking more detailed analysis of the image data from the Warren. The image analysis carried on to the end of the project, with support of MSc students. Overall analysis of the image data, revealed that there was a significant reduction in the time spent by rabbits in the laser projection zone, Fig. 6-5.

In late 2019, adjacent to the Warren, two areas of dairy pasture hosted a herd of cattle each year. A badger set was identified at the edge of one of these areas, and plans were being developed to undertake a trial using an autonomic laser to deter badgers from entering the pasture. It was not possible to start the planned trials before Covid-19 restrictions came into force.

[8] https://research.kent.ac.uk/lprg/software

ACA Farms Autonomic systems were set up in Cuarterola and Cucanoche, and a portable autonomic was used at Eoloarroz. Initial trials began in January 2018 and concentrated on rabbits, passerine birds and partridges in crops (sunflower) at Cuarterola and Cucanoche, and also wetland birds at Eoloarroz. Trials were monitored by trail cameras. Observing interactions between animals and the laser beams from the autonomic systems did not create much data, while handheld trials allowed for more targeted interactions. So, more trial work was conducted using handhelds. This included the new colour handhelds. As seen in GWSDF and LJMU, the effectiveness of the laser was greatly reduced for the mammals compared with birds. The green laser worked slightly better for birds than the blue laser for birds, while the blue laser worked better than the green laser for mammals. The red laser appeared to work as well as the blue laser for the mammals. Further trials were conducted on replication farms (Implementation action B2).

	RABBITS	RODENTS	BIRDS
GREEN	5%	6%	85-95%
BLUE	13%	12%	80-85%
RED	12%	15%	65-75%
YELLOW	4%	5%	85-90%

Fig. 6-6 Summary results for laser trials at ACA farms

Lessons learned from trials The trials conducted at the partner trial sites did not yield successful control of pests and this became apparent at trials progressed in to 2018. Additionally, rodents' trials were limited, and so trials were extended into replication farms and the project moved towards seeking an understanding of the interaction of ground animals towards Laser Fence, and how this response can be improved with the intention of delivering a pest control solution.

The sole deliverable for this action, B1, is a report on lessons learnt. These lessons represent lessons learnt from the overall work conducted in B1 and B2. They relate to stakeholder and public awareness, the response of wildlife to the laser, the complexity of animal behaviour, the identification of potential technological improvements to Laser Fence, and the regulatory issues surrounding laser use and pest control.

The contribution to the project specific indicators arising from actions B1 and B2 will be aggregated and reported in the technical progress report for B2.

Deviations

The trials conducted both on the partner and replication sites indicate a relatively low interaction of the Laser Fence deterrent with animals. There is evidence of animals responding to and moving away from the projected laser beam, sometimes quite startled. But on many occasions the animal appears oblivious to the laser beam.

Trials in the UK and other sites have been affected by the adoption of safe working procedures as prescribed by the UK HSE.

While the evidence presented from the trials has clearly indicated the low response rate, the understanding of the reasons for this have been hampered by the scarcity of target animals at the partner trial sites, and hence a low number of direct observations of interactions, particularly caught on equipment such as trail cameras.

These concerns have, to some degree, been overcome by indirect measurements, e.g. grass height measurements, and data obtained by, for instance, CCTV observations and extended manual recording of interactions. In particular, monitoring "residence" time and return times shows evidence of a reduction of activity in the laser projection zone.

Deliverables: – **Report on lessons learned from trials***;* Delivered 14/09/2020		
Milestone name	**Expected date**	**Actual date**

First trials realised	30/09/2017	31/05/2017
First handheld trials and autonomic trials began in May 2017 at GWSDF Auchnerran Farm		
Second trials realised	30/09/2018	7/6/2018
Lower power trials began at Bickley Hall		
Third trials realised	30/09/2019	01/09/2019
Protection of grain sheds from rats at Cheshire Farm A		

6.1.2.2 Action B2 – Replication with third parties

Action Schedule			
Planned start date:	02/07/18	Actual Start Date:	4/01/18
Planned end date:	30/09/20	Actual or anticipated end date:	30/09/20[9]

Replication trials were originally expected to take the basic pest control technology of Laser Fence and put it to test in third party establishments, principally farming and other agricultural enterprises. By the end of 2017 the low response of the ground animals to the Laser Fence laser beams had been identified, so this type of replication was not possible. There was also a need to establish trials with rats. It was decided to pursue further Laser Fence development trials in third party sites, under the auspice of replication.

Over the remaining period of the project 14 replication sites were established. These are listed in Table 6-4.

Site	Partner Responsible	Country	Site Area (ha)	Municipal Authority		
				Name	Population	Area (km^2)
Wölferlingen	BCG	DE	79	Westerwaldkreis	201,597	989
Cheshire Farm B	LJMU	UK	34	Cheshire West and Cheshire	343,071	917
Cheshire Farm A	LJMU	UK	34	Cheshire West and Cheshire	0	0
Welsh Mountain Zoo (WMZ)	LJMU	UK	15	Conwy County Borough	117,181	1,130
RSPB Burton Point	LJMU	UK	97	Cheshire West and Cheshire	0	0
LCR Farm A	LJMU	UK	12	Liverpool City Region	1,533,350	724
As Neve	IRIS	ES	117	Province of Pontevedra	942,665	4,495
Salamanca, Campanarios de Azaba	Volterra	ES	598	Province of Salamanca	331,473	12,349
Zamora, Sierra de la Culebra	Volterra	ES	195	Province of Zamora	174,544	10,559
El Chorreadero, Cádiz	ACA	ES	903	Cádiz	1,240,175	17,000
Malabrigo, Cádiz	ACA	ES	428	Cádiz	0	0
Boghead Farm	GWSDF	UK	35	Aberdeenshire	261,470	6,313
Balgonie Estate	GWSDF	UK	750	Fife	371,910	1,325
Whitburgh Farms	GWSDF	UK	995	Midlothian	91,340	354
				Total	5,608,776	56,155

Table 6-4 Replication Sites

[9] Wolf trials in Sierra de la Culebra, Spain led by Volterra began on 28th September 2020, and are continuing

The replication sites are described in more detail in the deliverable "Report with pictures of replication sites". Here follows a summary of the trials attempted at these sites.

Wölferlingen This site in Germany was established by BCG in January 2018. The site is meadowland surrounded by woods, and is visited by deer, boar, fox, hare. An autonomic device was established and the site monitored by trail cameras. Monitoring periods were winter and spring. In spring and summer, the presence of hunters prevented laser use. Trail camera video clips were inspected and interactions (or lack of) recorded. Monitoring finished in April 2020. A significant increase in animal and video activity was recorded during the Covid-19 restrictions.

Cheshire Farm B, LCR Farm A Cheshire Farm B was LJMU's first replication site, principally for rat trials, starting in February 2018. The trials centred on a grain drying installation inside a building. An autonomic system was set up with a bait tray in its projection zone. Trail cameras were positioned to cover the bait tray. However, rat numbers were very low, and interactions were not observed. The farm also offered their rodenticide records, but these never materialised. LCR Farm A also suggested they regularly saw rats, but on two evening visits only one was observed, and was eventually moved off straw bales with a blue handheld laser.

Cheshire Farm A This arable farm is privately owned, who also offer grain storage and transport services. Starting in February 2018, a number of trials were set around the grain storage buildings with a green autonomic deployed in the first instance. Initial trials were inconclusive, and bait trays were trialled to entice rats, but this did not work well. A rat run in another building was illuminated by the autonomic overnight, with trail cameras to observe. Some interactions were observed but were not conclusive. A concrete wall was identified in the combine harvester shed where rats were running to gain access to the grain stores. A trial was set up with a green and then a blue autonomic projecting on to the top of this wall, and the CCTV from Bickley Hall was used to provide full time observation. Several examples of rats being deterred from the wall were captured.

Fig. 6-7 Blue/Green Autonomic used at Cheshire Farm A

Another access point was determined inside a grain shed. A double-headed blue / green laser was set up inside this grain shed, Fig. 6-7, was positioned to "patrol" this access point and produced a significant reduction in rat activity. Further developments planned for this shed were prevented by Covid-19 restrictions.

Welsh Mountain Zoo (WMZ) This zoo is based in North Wales. LJMU had held conversations with the SciuriousLIFE EU project about using Laser Fence to control squirrels. The rifle range at WMZ was suggested as a site for trials to test the efficacy of Laser Fence against squirrels. The trials began in November 2018. There was a good number of squirrels in this area that was suitably secluded from the zoo's public areas. The range consisted of a platform at one end and a palisade at the other. For this project, the handheld lasers were used, again operated from the platform. Several feeder boxes were positioned on the palisade and down range. Feeders were monitored using trial cameras and visual observations a number of trial patterns were employed.

RSPB Burton At the RSPB Burton reserve there was an issue in protecting the migrant wader population nesting site, with badgers identified as a prime culprit, so agreement was reached

for LJMU to attend in the evenings to look for badgers and trial the handheld lasers. The first visit was in March 2019. Trials were conducted from a vantage point looking over a feeding station known to be visited by badgers and other animals. Further out from here were grass fields, and hedgerows. Badgers, and other species, e.g. rabbits, were targeted. In one example, a badger was diverted from moving towards the feed station at a distance of 300m. A night vision monoscope and infrared illuminator was used to record these instances. LJMU proposed a new trial to the local RSPB for the following winter, however this was not adopted by the RSPB.

As Neve, Pontevedra Throughout the project, IRIS had conducted several trials in Spain, where a drone flight was used to detect the presence of a target animal. A ground operator was then able to move to a position to expose the laser towards the animals and observe the interactions. In 2019 IRIS were able to organise a replication site for autonomic trials. The autonomic laser was installed in November 2019, projecting on to an identified area of passage for animals. The laser was programmed to expose for two hours at nightfall, midnight and sunrise. Two trail cameras were positioned to monitor the area and have the laser in the field of view. A reduction in the number of animals is seen in the data, but more trials would be needed to confirm this is in response to the laser.

Campanarios and Sierra de la Culebra Volterra have engaged with Fundación Naturaleza y Hombre (FNYH) throughout the project. This led to two replication sites – Campanarios in Salamanca and Sierra de la Culebra, Zamora. Handheld trials were conducted at Campanarios over the summer, autumn and winter 2019-2020 with mixed results for species such as deer, marten, fox, hare and boar. Response rates were again low. Negotiations continued with FNYH and finally agreement was reached with FNYH to conduct trials with wolves in Sierra de la Culebra with the first trial taking place at the end of September 2020. This was conducted in daylight, and the targeted wolf did not respond. (Postscript: During a dusk visit in December, a couple of wolves responded to the blue laser beam)

Scottish Replication Farms GWSDF made agreements with three farms – Boghead Farm, Balgonie Estate and Whitburgh Farm to conduct trials in the latter part of the project. At Boghead, an outbuilding reported as regularly infested with rats was to be used to conduct an autonomic trial. However pre-trial scoping using trail cameras showed no rat activity. Handheld trials were to be undertaken at the two other farms where feeders are present for the game birds, and an attraction for rats, were found to have too low a number of rats present for handheld trials.

El Chorreadero and Malabrigo: The tests on these farms began in the summer of 2018. These sites were chosen due to the large number of rabbits in the area, which cause economic losses in crops of great importance, in cultivation where the chemicals used are very powerful . Due to the number of these animals, we have been able to develop the project practically all year round, mainly conducting tests in winter and summer. The tests were carried out using the handheld lasers. At both replication farms, the owners were present throughout the trials and showed great interest in the project. , Bird control is also a big problem in the area. In conjunction with the rabbit trials, other trials were developed with partridges and small passerine birds. In the same way, tests with rodents could be carried out in some of the houses and barns located on the same farms, and these results were compared with those obtained with rabbits, showing practically equal percentages of success.

Rodenticide reduction. The aim of replication sites is to demonstrate a technology that had demonstrated the potential to control pest species. In the grant agreement, such species included pests such as rabbits and rats. As rodenticide can only legally be used with rats, then only trials conducted for controlling rats could lead to rodenticide reduction.

Trials for rat control were conducted at GWSDF, ACA and by LJMU at its replication sites, Cheshire Farm B and Cheshire Farm A. Only the final trial, prior to Covid-19 restrictions, at

Cheshire Farm A showed promising results, in showing a significant reduction in rat activity at an entry point to a grain store.

While some rodenticide usage data was available from sites such as GWSDF and Cheshire Farm A, the project had yet to demonstrate sufficient efficacy to trial a link between the use of Laser Fence and a reduction in rodenticide use. This is discussed further in our response to the technical question raised in the EASME response letter to the last mission (steering committee meeting 10) in LJMU, Sept 2020) and section 6.2.4

Contributions to Project Specific Indicators

Indicators	**Achievements**
Chemical Substitution	At proposal an estimate of 1620kg rodenticide use would be substituted. The efficacy of Laser Fence for the control of rats has been improved throughout the project, and an understanding of how the system might be further developed to a level of efficacy to allow it to substitute rodenticide in the control of rats. As such the project has not been able to prove a reduction of rodenticide at this stage.
Total saving expected	Based on successful use of LaserFence for fencing applications, an estimated saving of €468,000 could be achieved on traditional fencing. As with Chemical Substitution it has not yet been possible to demonstrate a level of containment with the laser to allow for traditional fencing to be substituted.

Deviations

Replication sites were intended as sites where a proven Laser Fence pest control system could be deployed and its efficacy confirmed. As it was not possible to develop Laser Fence to a level where its use as a pest control system could be promoted, the project's replication sites were recruited as sites where developmental trials could be continued and extended. As such they still provided the benefits of dissemination, engagement and promotion of the Laser Fence project, and an invaluable resource for the project.

Deliverables:

- **Report on the reductions of rodenticide at delivery sites: Submitted 14/9/20**
- **Report with pictures of replication sites: Submitted 14/9/20**

Milestone name	**Expected date**	**Actual date**
Replications started	30/09/2018	15/02/2018
LJMU began replication trial at Cheshire Farm B on 15/02/2018		

6.1.3 Action C: Monitoring of the impact of the project actions

6.1.3.1 Action C1: Project Performance Indicators

Action Schedule			
Planned start date:	14/09/16	Actual Start Date:	14/09/16
Planned end date:	30/09/20	Actual End Date:	30/09/20

The primary aim of this project was to demonstrate that a laser based avian deterrence system could be developed in to a pest control system for ground animals. A number of pest species are identified – rat, rabbit, wild boar, deer, badgers and predatory species. Control of rats would allow for reduction in the use of rodenticide, while control of some of the other animals, not controlled by rodenticide, would allow the reduction of other lethal methods of control. The reduction of rodenticide is enshrined in discrete Key Performance Indicator, while other impacts are covered by other indicators e.g. outcomes in ecosystems (grassland, cropland), and cost benefits of replacing traditional fencing by Laser Fence systems.

The outcomes mentioned above depend on the demonstration of the efficacy of the Laser Fence developments. This would be achieved by conducting a range of trials, with the expectation of identifying the potential of Laser Fence to be a pest control system capable of delivering the expected outcomes.

Monitoring of trials

A more detailed summary of the most relevant trials is provided as Annex 2. The outcomes of these trials are further summarised in Table 6-5. Trial numbers relate to the numbers used in the trial summary, Annex 2.

No.	Trial Site	Period	Partner	Species	System	Outcome
1	Auchnerran	2017 to 2018	GWSDF	Rabbit	Handheld, (movement pattern & exposure time), Autonomic	Response rates of 25% maximum observed.
2	Auchnerran	2018 to 2019	GWSDF	Rabbit	Handheld (Coloured and filtered)	Response rates up to 50% recorded for blue laser. Green is a little lower response. Red and Yellow poor. Response decreases with laser power.
3	Auchnerran	2017-2018	GWSDF	Rats	Autonomic	Conducted in an outbuilding. Slight reduction in rat numbers but not statistically significant.
4	Shotwick	2017	LJMU	Sheep	Autonomic	The amount of time sheep spent in the projection zone initially reduced but behavioural analysis suggested habituation occurs.
5	Bickley Hall Farm	2017-2019	LJMU	Rabbit	Autonomic	Initial results suggested low response. Grass height measurements suggested an effect but possible habituation. But later analysis of imagery suggests more alertness and

No.	Trial Site	Period	Partner	Species	System	Outcome
						a reduced presence in the projection zone.
6	Cuarterola, Cucanoche, Eoloarroz	2018 to 2020	ACA	Rats, Rabbits, Birds	Handheld, Autonomic	Good response for birds. Blue and Green work well Response for animals is low (<20%). Blue and Red work well.
7	Wölferlingen	2018 to 2020	BCG	Boar Deer Badger Fox Others	Autonomic	Generally low responses. Subsequent analysis suggests there were less animals present when laser was active.
8	Welsh Mountain Zoo	2018 to 2019	LJMU	Squirrel	Handheld (various colours)	Low response rate. Behavioural analysis suggest squirrels were agitated, and taking longer to return to the bait boxes.
9	RSPB Burton	2019	LJMU	Badger	Handheld	Strong responses, with a response rate over 75% indicated with blue laser
10	Cheshire Farm B	2018	LJMU	Rat	Autonomic	Analysis of trail cameras indicate a 40% response of the rats to the laser
11	Cheshire Farm A	2018-2020	LJMU	Rat	Autonomic	Several trials conducted showing increasing evidence of deterrence culminating in a final trial “protecting” an entry point into a grain store that reduced rat activity by 83%
12	As Neve	2019-2020	IRIS	Boar Deer Fox	Handheld, Autonomic	Animal numbers reduced with the presence of laser, further trials needed to confirm
13	Companarios de Azaba	2019 to 2020	Volterra	Deer Marten Fox Hare Boar	Handheld	The trials showed a moderate reaction in Deer and a lower reaction with Wild Boar. The other species did not react
14	Sierra de la Culebra	2020	Volterra	Wolf	Handheld	No response in daylight. Sunset trials to be conducted in winter 2020-21

Table 6-5 Summary of relevant trials

Drones Throughout the project IRIS provided support using Drone technology consisting of a fixed wing UAV and a quadcopter drone. These were fitted with a range of cameras. Together with geolocation, GPS and various pieces of software, detailed images of the landscape, terrain and animal locations could be identified.

Fig. 6-8 shows how a thermal imaging camera was able to locate a wild boar resting in fauna. This could not have been found from the ground.

Fig. 6-8 Thermal vision detection of hidden boar at Eoloarroz

In 2017 IRIS toured the partner sites in the UK, Netherlands and Spain and took baseline imagery of the sites and their environs. In the following years there was continued monitoring at the Spanish sites, but changes in the UK drone regulations proved a barrier to further flights in the UK.

However, with the continued concerns over the low response of ground animals to lasers, IRIS conducted their own trials with a combination of using the drones to identify the whereabouts of target species, then targeting them with a handheld, or simply identifying a potential area and awaiting target animals. In 2019, IRIS established a site in Galicia at As Neves to conduct both handheld and autonomic trials.

Welfare The lasers employed in these trials are class 3B lasers that are therefore regarded as potentially hazardous to people. Deliverable "Report on the monitoring the effects of Agrilasers on targeted and non-targeted animals" was submitted in February 2018. This reviewed the welfare issues and prescribed that there must be welfare monitoring in the project. This was conducted by Dr Sharp (LJMU) and Dr Parish (GWSDF), who met each month to formally review any welfare issues. It was also an agenda item on the monthly zoom meetings. The main requirement on all partners was to report any observations of animals that behaved abnormally after possibly being exposed to the moving laser beam, particularly on the face. Abnormal behaviour would include disorientation, behaviour suggesting a dazzling effect on their vision, or evidence of discomfort in the area exposed. No observations were reported. Had there been a report, then trials would have been stopped pending an investigation.

GWSDF had attempted to retrieve the eyes of rabbits that had been shot in other activities outside of this project at LJMU, for veterinary assessment. This would have sought to identify any eye injury that was consistent with exposure to a laser beam. However, it proved impractical to deliver these eyes to the laboratory without degradation and this assessment could not be carried out.

Project Specific Indicators Monitoring of project activities would, of course, inform the progress of the Project Specific Indicators. These were recorded four times in this project as formal deliverables, at Mid-Term report, two progress reports and this final report.

Good progress was made on dissemination type activities, and the development of trial sites. The inability to develop viable pest control for ground animals and rats, in particular, has not allowed progress on the major PSI – rodenticide reduction. The project team was encouraged by the last trial results at Cheshire Farm A, and without the Covid-19 restrictions a trial attempting to demonstrate an actual reduction in rodenticide may have been undertaken in the project timescale.

Contribution to Project Specific Indicators.

Indicators	Achievements
This action supports the implementation actions, providing the environment in which data is collected to monitor the progress towards the product specific indicators.	Monitoring and analysis methodologies have been developed, and continue to be introduced for the various trials under implementation and for future replication.

Deviations

In addition to the impact of the Health and Safety impacts on trials, two significant deviations are the lack of response from the animals and also the unexpected scarcity of animals. This is discussed under deviations in Action B. The trials conducted encouraged the development of monitoring techniques that have yielded significant insight into the behaviour of the animals to the laser beam and this will inform the development of future trials under AfterLife activity.

Additional drone visits to the UK were not possible. At the time of the first visit to the UK sites (Oct 2017), the drone flights were conducted in accordance with the prevailing regulations. Soon after the UK Civil Aviation Authorities introduced more stringent regulations and documentation requirements. Several attempts were made by IRIS to meet these requirements but these were unsuccessful. This did not create any problems for the UK trials. The lack of these overseas flights was usefully replaced by conducting laser trials in Spain to help drive forward the project's desire to better understand the issue of the lack of response and to improve upon this response.

Deliverables:

- **Report on the monitoring the effects of Agrilasers on targeted and non-targeted animals:** *C*ompleted 20/02/2018 delivered with Mid Term Report
- **Life Project Specific Indicators Table sent in with Mid Term Report:** Delivered 28/02/2018
- **Life Project Specific Indicators Table sent in with Progress Reports:** Delivered in April 2019 (Progress report 1) and July 2020 (Progress report 2)
- **Life Project Specific Indicators Table sent in with Final Report :** Delivery due 31/12/2020

Milestone name	Expected date	Actual date
Notes of interviews with stakeholders	31/12/2019	31/03/2020

6.1.3.2 Action C2: Conclusions and Recommendations

Action Schedule			
Planned Start date:	01/01/20	Actual Start Date:	06/01/20
Planned End date:	30/09/20	Actual End date:	30/09/20

There were high expectations for this project. There was strong evidence that lasers were a good technology for avian deterrence, indeed the partner Bird Control Group (BCG) had grown form a start-up company based on its activities on this area.

The reality for attempting to deter ground animals proved very different. The response of ground animals appeared significantly less than that for birds. As a result the project has had to concentrate on developing an understanding of this difference in response, and seeking techniques to increase this response to deliver a viable pest control technology.

By 2020 a picture had begun to emerge that suggested that using a handheld to pester animals showed a significantly improved response. Further analysis of previous trials also indicated that general projection of the laser over an area appeared to reduce animal activity. Then, of

course, the Covid-19 pandemic hit and halted virtually all practical activity, though analysing data of previous trials continued.

These results had an impact on stakeholder engagement, as without positive successful results and a working pest control system, it was quite difficult to seek opinions, etc., on technology.

Question	Average (1-4)
There are rodents / birds / other animals that feed on our crops and/or harvests	3.32
Rodenticides or other chemicals are used to deter these animals from our plots and/or harvests	2.5
We are familiar with the Laser Technology (e.g. Bird Control Group's Laser Fence technology) to scare away animals	2.87
We are interested to change the use of rodenticides or other chemicals for the Laser Fence technology	3.26
We believe that governmental institutions at EU, national, regional and/or local level could improve policies about the use of rodenticides or other chemicals in agriculture	3.37
Natural Parks could apply laser technology (Laser Fence) to maintain wolves /predators inside the reserve and prevent those animals from entering livestock/grazing areas	3.03
We would be interested to participate in training activities about the use of lasers and exchange experiences with other farmers/landowners	3.24
We would purchase the Laser Fence technology	2.92
We think this project in the future could be beneficial to the environment and economically attractive	37/39 Yes
Our enterprise's financial position is positive	2.79
Responses: 1 = totally disagree, 2 = disagree, 3 = agree, 4 =totally agree	

Table 6-6 Survey results

The planned survey and interviews were delayed so that there was a significant body of activity and knowledge available to support this activity, as well as contact with interested parties. Additionally, the survey was submitted to the LJMU research ethics committee, to ensure compliance with LJMU policy. The survey was prepared in Survey Monkey in both Spanish and English and over 100 stakeholders, partner organisations and people were invited to take the survey. It was launched in late March 2020. There were 40 responses, and the results are summarised in Table 6-6. Of the 40 respondees, 8 agreed to give interviews. These were recorded, and transcripts produced.

The result of the survey was encouraging, considering that the results of the Laser Fence project had yet to identify a compelling offer for a laser-based pest solution.

Also, in March 2020, preparations were made to conduct a review of the Socio-Economic Impact of the Laser Fence project. After discussion with partners and the monitoring officer in the previous steering committee meeting (SCM9, Sept. 2019), the assessment was conducted independently by ERS (ers.org.uk). who were appointed following a procurement process. A kick-off meeting was held on 4th May 2020, and over the following weeks, ERS accessed our grant agreement, monitoring documents, surveys and interview transcripts. They also conducted their own interviews with members of the project delivery teams for each

partner and also stakeholders. A final version was agreed on the 24th August 2020. This was submitted as a deliverable at the SCM10, Sept. 2020.

A conclusions and recommendations report has been compiled as a deliverable for this action at Final Report. All partners identified their most important conclusions and recommendations and these were collated and compiled into the deliverable report. The conclusions were grouped into these four categories: Wildlife activity and responses, Trial methodology and laser techniques, Stakeholder / public engagement, regulatory issues. Recommendations were grouped as: Trial methodology and laser techniques, Further development of the Laser Fence, Stakeholder / public engagement, regulatory issues.

Regulatory issues principally discussed health and safety and animal welfare. At this point in the development of Laser Fence, and without a viable pest control system, it appears difficult to have the ability to influence policy. Once a system is demonstrated that works well, e.g. for protecting grain sheds from rats, or dairy cattle from badger, then it would be possible to exert influence on the policy makers.

Contribution to Project Specific Indicators

Indicators	**Achievements**
NGO supporting EU environment and/or climate change policies	The project has ongoing interactions with the Game and Wildlife Conservation Trust, FUNDACIÓN NATURALEZA Y HOMBRE, Cheshire Wildlife Trust, RSPB and have had discussions with the Campaign for Responsible Rodenticide Use.
Surveys - general public, NGO, private companies, local authorities, regional authorities, national authorities, civil society organisation	Surveys completed in Q2 / 2020, and results collated together with interviews.

Deviations

Some of the important KPI's, particularly rodenticide reduction, were not met. This is discussed further in §6.3.2.

Deliverables:

- **Socio-economic impact report included with conclusions and recommendations report:** Delivered at SCM10 Sept 2020
- **Conclusions and recommendations report handed in with final report:** Report compiled and will be submitted with final report in December 2020

Milestone name	**Expected date**	**Actual date**
Consultations with at least 1 governmental institution and 1 relevant NGO to compile policy review	31/12/2019	31/03/2020
Several NGO's and government agencies have interacted with the project through its life time. Some of the discussions have involved policies around rodenticide, health and safety. However, no specific areas of policy were able to be mooted for review until such time as a working pest control system is established.		
Notes from interviews with relevant stakeholders	31/03/2020	March 2020 to June 2020

Survey invites to 100+ stakeholders, contacts. 40 responses and 8 interviews

6.1.4 Action D - Public awareness and dissemination of results

6.1.4.1 D1: Dissemination planning and execution

Action Schedule			
Planned Start date:	01/10/16	Actual Start Date:	01/10/16
Planned End date:	30/09/20	Actual End date:	30/09/20

This action aimed to deliver suitable materials, resources and networking to raise public awareness of the Laser Fence project. One of the first activities in this action was to design and print a number of banners and posters to place at the partner's implementation sites and at their offices. The display of these banners and posters is documented in the deliverable "Report on the placing of LIFE+ Information boards" (submitted Nov 2017).

Fig. 6-9 Laser Fence banner at Auchnerran (GWSDF)

Networking with LIFE projects

A number of networking activities have been conducted by the project partners. In Spain, Volterra has networked with a number of LIFE projects: Life Zero Residues, relating to olive production; Life Crops for better soils and Life Steppe Farming (with FNYH), both deal with farmers who have issues with rabbits, deer and boar. GWSDF has cooperated with LIFE Waders for Real throughout the Laser Fence project, with reciprocal visits, and GWSDF presenting about Laser Fence at the Waders for Real final conference. LJMU held several meetings with the SciuriousLIFE about the potential to use Laser Fence to prevent grey squirrels entering the Island of Anglesey. This led to the squirrel trials at Welsh Mountain Zoo.

Website The website was launched by the end of November 2016 in Spanish and English. News regarding the project (visits, pictures, technical activities and results) are uploaded regularly on to the project website. A deliverable report on the launch of the website and associated social media was supplied at MTR. At the SCM10, close to the practical completion date, unique website visitors were recorded as 4,902, some 164% above the target of 2,995 visitors. There were 158 news items against a target of 120.

Fig. 6-10 Cover of Layman's Report

Social Media: The project Facebook page has been online since September 2016. News articles are posted on a weekly basis. A YouTube channel had also been created. It carries 12 videos as of September 2020. All partners maintained a Twitter feed and employed the hashtag #LaserFence to publicise the project. Evidence indicates at least 10,400 individuals have looked at social media articles.

Project leaflets 3,000 copies of a project leaflet in English and Spanish were printed in October 2019 and distributed to all partners. The leaflet is presented in a deliverable "General public leaflets" submitted prior to SCM10.

Layman's report A Layman's report was compiled and published in Spanish and English. 200 copies were printed by the beginning of March 2020 and circulated to partners and was available at the final technical conference. The cover of the report is shown in Fig. 6-10.

Contribution to Project specific indicators:

Indicators	**Achievements**
Participation in networking events with other LIFE and EU projects	190 people (106%)
Diverse public that will participate in the project per area	2390 people (70%)
Unique visitors to the website News articles published on website	4902 (164%) 158 (132%)
Information board Leaflets	Information banners and posters at all sites (6) 3000 Leaflets printed, due before July 2019
Layman Report	200 Report booklets printed
Social Media	10,400 interactions

Deviations

No deviations specific to this action

Deliverables:

- **Report on the placing of LIFE+ Information boards:** Delivered November 2017
- **Report on the launching of project website:** Delivered 13/02/2017
- **General public leaflets:** Deliverable report delivered 14/09/2020
- **Layman's report:** Deliverable report delivered 14/09/2020

Milestone name	**Expected date**	**Actual date**
Project website launched	31/01/2017	30/11/2016
The website was launched by the end of November 2016 in Spanish and English and tested and improved in December		
Information boards placed	31/12/2016	31/12/2017
Notice boards were placed before December 2016		

6.1.4.2 D2: Information and awareness-raising

Action Schedule			
Planned Start date:	01/12/16	Actual Start Date:	03/10/16
Planned End date:	31/12/19	Actual End date:	31/03/20

This action complements the dissemination activity of action D1and is designed to engage end-users, stakeholders and local and/or general audiences in the project's development and conclusions.

Events: There have been a significant number of events attended and these have been summarised in the deliverable "Presentations at Conferences and Exhibitions", delivered 14/9/2020. These events presented Laser Fence with a reach of over 5000 people with more detailed presentations and discussions identified as 1822.

Additionally, there have been additional meetings and events that involved stakeholders. Details are included in the deliverable report "Relevant Stakeholders Interest", delivered 14/9/2020. An example was an event at the UK replication site, Cheshire Farm A, an award-winning farm.

The Laser fence team were invited to attend the ceremony and took the opportunity to promote the project to the visitors, mainly from the Cheshire farming community.

Fig. 6-11 Review of drone capability at the University of Sevilla

Technical Conference A Laser Fence technical meeting was held in cooperation with the University of Sevilla in March 2019 at their agricultural college. Approximately 40 people attended. After a review of the college's drone capabilities, a tour was given of the research field This was followed by presentations by the Laser Fence partners.

Fig. 6-12 Final Conference - Jessica Magnus, UK LIFE National Contact Point, JNCC, presenting

Final Conference The Laser Fence Final Conference was held at LJMU on the 3rd and 4th March 2020, less than two weeks before the Covid-19 forced the closure of university buildings, and as travel concerns had begun. This may have subdued the number of attendees. As well as all the partners presenting on the Laser Fence project itself, Angel Camacho presented on its zero residues initiative. Bird Control

Group discussed bird control in more detail. A talk by Dr Ruth Cox, of the UK's Animal and Plant Health Authority, covered Deep Learning in the automatic identification of animals in video data. This is an important technique that is hoped can support future developments of Laser Fence. A session on innovations in Agritech was held with a presentation from Santiago Martinez Rodriguez (IRIS) on the use of drone technology, Patricia Onnis (LJMU) spoke about metal pollution in river catchments, with Martin Sharp (LJMU) looking at other possible laser applications in agriculture. Following presentations on Laser Fence trials and results, the final session started with a talk from Jessica Magnus, of Joint Nature Conservancy Committee, on the 2020 LIFE Call. Marta Múgica of Volterra then presented on delivering Life Projects.

Press and media Partners have continued to seek opportunity to obtain press and media coverage of the project. all these efforts have generated 45 press articles/radio/TV attentions of which 4 were articles released by the Spanish national press, 3 articles by local press, 9 articles by specialised press, 22 by specialised web pages, 2 by EU commission DG and 7 other. Copies of the press articles are collected in the D2 deliverable "Press Recognition Portfolio" delivered on 14/09/20

Contribution to Project Specific Indicators:

Indicators	**Achievements**
Publications in traditional media (25)	45 Publications (180%)
Participation in congresses, conferences and presentations (1350 people)	Based on attendances at these types of events listed in the deliverable – 1822 (135%)
First technical seminar in November 2018	Conducted at the University of Seville, March 2019
Final conference February 2020	Held at LJMU 3rd / 4th March 2020

Deviations

There were no specific deviations to this action during the project.

Deliverables:

- **Relevant stakeholders' interest in project results and outcomes:** Delivered 14/09/2020
- **Presentation at national and international conferences proceedings:** Delivered 14/09/2020
- **Press recognition portfolio:** Delivered 14/09/2020

Milestone name	**Expected date**	**Actual date**
Technical Seminar	30/11/2018	20/3/2019
Technical Seminar conducted at the University of Sevilla, 20th March 2019		
Final Conference Organised	29/02/2020	03/03/2020
Final Technical Conference held at LJMU on 3rd / 4th March 2020		
Life Networking Achieved	30/09/2020	30/09/2020
All required networking activities in project duration completed		

6.1.5 Action E – Project Management

Action Schedule			
Planned Start date:	03/10/16	Actual Start Date:	03/10/16

Planned End date:	30/09/20	Actual End date:	30/09/20

The project formally started on 3rd October 2016 following the first steering committee meeting held at LJMU on 14-15th September 2016.

The project has requested two extensions, both granted. The first extension was requested to take the practical completion date from 31/12/2019 to 30/06/2020. This was principally to allow an extension of trials, particularly related to trials involving rats over the winter season. By March 2020, the Covid-19 pandemic had reached Europe and it was agreed to delay the final steering committee meeting until September 2020 in the hope a physical meeting could be held in Liverpool. A second extension was requested to take the practical completion date to 30/9/2020 to cover the delayed steering committee. This set the latest date for submission of this final report to 31/12/2020.

The following steering committee meetings were held:

SCM	Date(s)	Location	Mission
1	14-15/12/2016	LJMU, Liverpool, UK	Yes
2	14/12/2016	Zoom Meeting	
3	28/02-01/03/2017	BCG, Delft, NL	Yes
4	13/09/2017	Zoom Meeting	
5	14-15/11/2017	ACA, Seville, ES	Yes
6	24/04/2018	Zoom Meeting	
7	20-21/09/2018	GWSDF, Auchnerran, UK	Yes
8	21/03/2019	ACA, Seville, ES (alongside Technical Conference)	
9	10-11/09/2019	LJMU, Liverpool, UK	Yes
10	22/09/2020	Zoom	Yes

Table 6-7 Steering Committee Meetings

Fig. 6-13 SCM10 Meeting by Zoom

Dr Alex Mason (LJMU) was the project director at the start of the project. Alex left LJMU at the end of May 2017, and Dr Martin Sharp took over as project director at the beginning of June 2017. There were no other significant management changes in the course of the project.

Following the 5th steering committee meeting, the project adopted monthly meetings held using Zoom. These have allowed the partners to keep in more regular contact, share practices and results, identify dissemination activities, and prepare for events such as the technical and final conferences.

Financial monitoring of the project has been conducted by Mark Fealey (LJMU), who has compiled the financial costings and summaries for submission with this Final Report. Changes in the LIFE reporting regulations mean that the audit report, originally required with this final report, is no longer needed.

Fig. 6-14 AfterLIFE Plan

AfterLIFE Plan The project partners have produced an AfterLIFE plan. In response to the increased understanding of the laser beam / animal interaction, gained during the project, and positive feedback from stakeholders, partners will use their own resources and seek other funds to offer a more competitive technology and support market uptake. The AfterLIFE activities foreseen include development of the Laser Fence system – higher scanning speed systems, intelligent systems and ultimately the "Detect and Deter" system, together with the trials necesaary to prove that these developments deliver viable pest control systems. Together with the network of stakeholders and replication partners, the project team are hopeful of bringing laser based pest control to the ground animal in agricultural settings.

Contribution to Project Specific Indicators

Indicators	**Achievements**
Personnel hired during the project execution (20 FTE)	10 FTE positions created

Deviations

The reduced FTE on personnel reflects on the lack of a successful replication system being established in replication farms and other partners. As a result the personnel hired during the project were based with the Laser Fence partners.

Deliverables:

- **Signed partnership agreement:** Delivered 31/10/2016
- **After LIFE plan delivered in final report:** Prepared. Delivery due 31/12/2020
- **Audit report available in final report:** No longer needed

Milestone name	**Expected date**	**Actual date**
No milestones for this action		

6.2 Main deviations, problems and corrective actions implemented

There have been several significant circumstances that have caused a deviation in the project activity or ability to deliver the expected outcomes. These are presented in the following sections, in no particular order of severity or impact on the project.

6.2.1 Health and Safety

The range of laser powers employed as avian deterrents, and to develop Laser Fence, were 100mW to 500mW. These lasers are classified as Class 3B under the European Laser Standard IEC60825, this standard being universally applied across the EU for determining the safe use of lasers. In September 2017, Stewart Robertson, of UK's Health and Safety Executive, visited the GWSDF site to see the Autonomic lasers. He subsequently determined that these were not being operated in accordance with the guidance of IEC60825, and hence were in breach of the Control of Artificial Optical Radiation at Work Regulations 2010, the UK implementation of the EU Artificial Optical Radiation directive.

In simple terms, IEC60825 requires that either people are physically prevented from entering the projection area of the laser, or that the laser exposure was directly under the control of a trained operator, who would cease laser exposure if the risk of the laser beam being exposed to another person was detected. So the use of a handheld laser was allowed, but not an autonomic laser system operating unsupervised. As the HSE action was, in effect, their interpretation of an EU directive, all Laser Fence partners were informed of this action and all were required to establish safe working procedures for their use of autonomics based on either their supervised operation or a very low probability of intrusion in to the projection zone, preferably by physically preventing access to this zone. With these modifications it was possible to continue using autonomics in trials, although the number of trials were reduced, and delays were introduced by the additional planning required for the trials.

While trials continued, consideration was given to the impact of Health and Safety requirements on the potential adoption of a working Laser Fence system, if developed, and the impact on the existing avian deterrence market of the partner BCG. Following a conversation with the UK Public Health England's lead on laser safety, the key points were found to be – the maximum permissible exposure limits listed in IEC60825 are the result of experiments and then agreed values that indicate safe working limits of exposure. The laser classifications are based on this. It is unlikely these can be changed with out significant further experimentation and compelling evidence that higher values would be safe. It is possible to propose a standard for the use of lasers in animal deterrence. Such a standard would have to revert back to maximum permissible exposures, as well as defining safe operating procedures. Adoption of the proposed standard would require the agreement of company and user representatives, assumed to want the standard, and the occupational safety community who would want to be certain the proposed standard provides safe working. The project team concluded that the current Health and Safety regime is not a barrier to the growth in use of laser deterrents, but it can be a restriction. While handheld lasers are not greatly restricted, unattended autonomics will be more restricted in their application. There does not appear to be a policy position that could be addressed to change this view.

6.2.2 Scarcity of Animals

The project intended to demonstrate a laser-based animal deterrence system for ground animals with an efficacy similar to that found with laser avian deterrence. It expected to do this in real settings e.g. fields, farms, farm buildings etc. Some sites had significant numbers of target species e.g., rabbits in Auchnerran (1300+ rabbits in first set of trials), but the prevalence of animals at other sites could be scarce. At Bickley Hall, the number of rabbit / laser events recorded were low, and CCTV revealed that while rabbits were present in and

around the projection zone, numbers were low, and on some days no rabbits were present. This extended the trial.

Similarly, with rats – Several sites were investigated or trials were set up and the rat numbers were either very low or non-existent. GWSDF attempted a trial at a replication site in a shed that was said to have significant numbers, but when an initial survey was undertaken there were no rats, or too few to undertake a trial of significance.

As a result, time was lost setting up or taking trials that did not deliver any results of use. At Cheshire Farm A the autonomic was moved to several positions within the grain stores, and this increased numbers of interactions, and eventually led to a significant result, but this took time, and further trials to confirm, enhance or even attempt a trial planned to reduce rodenticide use was prevented by the Covid-19 pandemic.

The length of time the trials were taking was a concern, but during this time, the imagery data was continually reviewed. The CCTV data from Bickley Hall was particularly interesting as it provided evidence not captured by interactions with trail cameras. In the last year of the project more data analysis was conducted looking to see if the prevalence of animals was lower when the lasers were projecting. Overall, it now appears that the data does suggest that numbers of the target were lowered by the projection of the laser. Further trials would have been necessary to validate this, and time was not available, particularly as practical work was truncated by Covid-19.

6.2.3 Low efficacy and lack of pest control system

From the start of the project interaction events between animal and laser beam were recorded that evidenced a strong interaction between the laser and a target animal, – cat, cow, sheep, wolf, rabbit, rat, badger, squirrel, hare, deer, etc. But there were more events captured that showed a lack of immediate response, or no response. So, in the early part of the project the team concluded the efficacy is poor, generally < 25%, and often < 10%.

Additionally, trail cameras failed to capture many interactions of lasers and target animal, and even fewer positive reactions. Such a lack of efficacy presented a real problem for the premise of the project. Without efficacy, then there is no pest control system.

The activity of the project moved to trials testing new ideas of how to increase efficacy (e.g., different colour lasers), and increased analysis of existing data to look for other evidence that the lasers could be having an effect, not initially apparent from seeking more immediate reactions of the animals to the laser beams. This approach has not led to a Laser System that can be described as a “pest control system”. But it has led to a greater understanding of how such a system may be developed e.g., “detect and deter”, and the observation that the projection of a laser beam into an area does appear to have the ability to reduce animal prevalence.

Progress has been made, and towards the end of the project, results have improved, e.g., rat activity reduction at Cheshire Farm A, and animal activity at Wölferlingen. The Covid-19 pandemic has cut short such project activity, and the trials conducted required longer periods of data gathering and analysis, but as this project concludes, the project team now feel that there is potential for pest control, and are keen to pursue with AfterLIFE activity.

6.2.4 Reduction of Rodenticide

The project’s main Key Performance Indicator (KPI) is rodenticide reduction. Based on a nominal area of trial sites, and estimated use of rodenticide per hectare, a figure of 1620 kg of rodenticide use was identified, and the KPI target was to reduce this use to zero. In the grant agreement, there was also other requirements in terms of demonstrating the efficacy of Laser Fence to control other pest species. Implicit in this requirement, is to control these other species by a non-lethal method. Partner trials were established to identify the ability of Laser

Fence to provide such a non-lethal method of pest control, whether to reduce rodenticide or eliminate lethal control (e.g. culling of badgers in the UK).

To facilitate trials where rodenticide reduction might be achieved, then it was necessary to demonstrate the ability of the Laser Fence to control rat populations. This was attempted by trials at GWSDF and ACA farms, as partner sites, and for LJMU at the replication sites of Cheshire Farm B and Cheshire Farm A. These initial trials revealed a lack of efficacy in control of rats, as described in §6.2.3. Further rat trials were developed throughout the project. Some were unable to deliver results due to an unexpected, and unexplained, lack of rats. Trials at Cheshire Farm A developed to target specific rat activity, and while numbers were low, a significant reduction of rats was recorded in the last trial conducted before Covid-19 restrictions.

Limited rodenticide use data was provided by sites, e.g. Cheshire Farm A, Auchnerran and ACA farms. The rodenticide use indicated was applied at certain baiting points. In order to establish a link between Laser Fence and rodenticide reduction, it would need more specific trials to be conducted. Such a trial would require a building, store or known area, or field, that was protected by specific rodenticide baiting points. A Laser Fence installation would be set up in an area where rodenticide is currently used and applied specifically to protect that area over a given period. Over the same period, the use of rodenticide would be reduced and monitoring would confirm whether the level of protection was maintained by the Laser Fence system Ultimately it would have to be demonstrated that rats did not access the area for a significant period of time, possibly a year or more. Then, and only then, could a reduction in rodenticide be claimed.

At Cheshire Farm A, a point had been reached where the next trial would have attempted to direct the laser beam over the whole internal perimeter of the grain shed, and recorded the impact on the number of rats entering the building, as evidenced by video observation. If this trial had been successful in controlling the entry of rats into the grain store, then a negotiation would have taken place with the owners of Cheshire Farm A to identify how to reduce their use of rodenticide targeted at protecting that grain store.

Of course, if the stage had been reached, as indicated above, where there was substantial evidence of the control and prevention of rat entry into a building, then additional replication sites could have been sought, and recruited to conduct trials of Laser Fence technology while maintaining a record of reduction in rodenticide use. However, without that compelling evidence, then it would be difficult to recruit additional replication sites.

6.2.5 Covid-19 Pandemic

In Spring 2020, the Covid-19 pandemic hit Europe with all partners activities restricted by national lockdowns by the end of March 2020. The planned SCM10 meeting in April 2020 was postponed to September 2020, with the project receiving its second extension to accommodate this.

The national restrictions had an impact on the trials underway in early 2020, and due to start in spring 2020. It prevented a planned trial on badgers at Bickley Hall Farm, and stopped further rat trials at Cheshire Farm A that were planned to move towards a specific trial in rat reduction. In Auchnerran trials were halted. Maintenance of trail cameras (replacement of batteries was not possible in Wölferlingen, trials at ACA and its replication farms were greatly reduced, and trials by IRIS and Volterra, were delayed until later in the Summer. Indeed, Wolf trials by Volterra were started in the last week of the project.

This resulted in a reduction of new data for analysis arising from trials that were planned to further develop our understanding of how to operate Laser Fence to increase efficacy. However, it did provide the opportunity for further analysis of the copious data from previous

trials and this helped the team identify the potential for autonomic Laser Fence systems to reduce the prevalence and activity of target animals in area covered by the projection zone.

6.3 Evaluation of Project Implementation

In this section, a review of the project implementation is presented. This includes an evaluation of the methodology of the project, followed by an evaluation of the results obtained and is concluded with an overall project commentary.

6.3.1 Evaluation of methodology

The overall aim of the project, as set out in the grant agreement, was to demonstrate the Laser Fence concept as a viable pest control technology over a number of target species, with a primary target of rats (rodents) with the aim of eliminating the use of rodenticide. Following this, replication sites would be recruited to confirm the benefits and promote the use of Laser Fence technology. Based on this success, public awareness events, dissemination activity would alert the agricultural and related communities to the benefits of Laser Fence and advocate its use.

The partner trial sites were established quickly. LJMU and BCG had to seek sites owned by third parties, but by the middle of 2017, trials were being conducted at these sites. These sites offered good numbers of some of the target animals, and these were targeted in the second half of 2017. It was recognised that rat trials had to begin over the winter of 2017 / 18.

By the time of the Mid-Term report, in February 2018, indications were that Laser Fence appeared to offer a low efficacy in immediate deterrence of animals, the percentage of animals showing an immediate response to the approaching laser beam was seen to be 25% and below. As a result, the methodology of the project had to be modified. The following represents some of the key methodologies developed in 2018 and used for the remainder of the project were:

a) Rats. The primary KPI of Laser Fence was a reduction of rodenticide use. As a result rat trials were a prime activity for the winter seasons in the following years, as it was believed that rats would be attracted towards farm buildings where could be targeted better by both handhelds and autonomics. However, no sites were found to offer an abundance of rats. Some promising results were obtained at Cheshire Farm A as work concentrated on the use of an autonomic system around grain stores. But it was not possible to conduct any trials specifically to attempt rodenticide reduction. The Covid-19 pandemic prevented a possible trial of this nature at Cheshire Farm A.

b) Interactions and Trials. A lot of the early trials were looking for an immediate response to an approaching laser spot, preferably a flee response as observed with laser avian deterrents. Handheld trials kept records of such interactions; autonomics relied on video imagery to provide these records. Ad hoc periods of handheld activity, perhaps enabled by visits to new areas, or similar opportunities to target species with a handheld increased the number of species tackled and interaction reports. But to start to tease out why the response rate increasingly required planned trials, with controls and more rigorous analysis. It was agreed that this dual approach to trials should continue, encouraging partners to take all opportunities to create laser / animal interactions while also conducting longer planned trial. This approach led to the identification of two key outcomes of the project – the concept of "detect and deter" where it appears more animals can be moved or deterred by a persistent and erratic approach of the laser spot, and the potential for the reduction of prevalence in animals in a laser projection zone.

c) Monitoring of trials and analysis of data

Whereas the initial analysis of image data concentrated on the interaction of the laser beam spot with animals, and their immediate reaction, there was an increasing belief that although

there was a low likelihood of an immediate deterrent response, the target animals were not settled when the laser was being projected in their immediate environment. So the methods of analysis turned more to analysis of the animal behaviour, either from CCTV or trail camera videos (even if a laser spot interaction occurred or not). This was developed further into looking at the prevalence of animals when the laser was projecting and not projecting, and times that animals spent at feed stations, time spent in the trial zones etc. This analysis could be undertaking on the historic trial data captured on trial cameras, and CCTV footage. A range of data was available from the initial trials at Auchnerran, Bickley Hall, ACA farms, then the BCG site at Wölferlingen and additional sites ran by LJMU. The reduction in physical trial activity gave time for teams to analyse such trials data during the Covid-19 restrictions, and the results of these analyses point to a noticeable reduction of activity of target animals in laser projection areas.

d) Detect and Deter. As mentioned earlier the concept of Detect and Deter arose as the project progressed. In practical terms this meant during the later handheld trials the method of application moved more towards identifying a target animal and "pestering" it with the spot of the laser beam by playing the spot in its field of view and persisting with it for many seconds. While this did not guarantee a response, more positive responses did occur.

e) Health and Safety. Although the intervention of the UK HSE impacted the project, methods were adapted to ensure trials were carried out in compliance with health and safety requirements and the partners were able to conduct their trials with the aim of improving the efficacy of Laser Fence.

In summary, the methodologies of the project were adapted as the project progress with the aim of understanding the animal response to the laser spots and then improving efficacy. The project has made significant progress in these areas and has the intention of progressing the Laser Fence solution as outlined in the After Life plan document.

6.3.2 Evaluation of results

An evaluation of the results of each action is provided in the table below. For reference the expected results of each action as indicated in the Grant Agreement is provide.

<table>
<tr><td colspan="2">Action: A1 Scoping of the areas</td></tr>
<tr><td colspan="2">Objectives:
The scoping and characterisation of the partner trial areas for conducting trials to demonstrate the Laser Fence technology.
Expected results:
Six trial sites to be characterised
During project implementation and replication, a target of 3000ha of land to be accessed.</td></tr>
<tr><td>Achieved: The six partner trial sites were established and a scoping report covering these was delivered.
The sites are the three ACA farm partners – Cuarterola, Cucanoche and Eoloarroz. In the UK there is the GWSDF Auchnerran farm, and LJMU have established access to two sites, Bickley Hall (CWT) and Shotwick.
This represents 1327 ha of land available for trial sites.</td><td>Evaluation: This action has been successfully completed. BCG were expected to host a site in Northern Europe, but this proved difficult as most potential sites examined were used by parties with conflicting interests. They secured access to Wölferlingen in late 2017, this is reported as a replication site.</td></tr>
</table>

<table>
<tr><td colspan="2">A2: Preparation of equipment and infrastructure</td></tr>
<tr><td colspan="2">Objectives:
To provide facilities to develop and characterise lasers.
To provide tools for monitoring the interaction of animals with the laser beams, and the analysis of data.
To develop UAV solutions for characterising trial areas and identifying animals.
Expected results:
Development of imaging techniques to capture interactions between laser spots and animals.
Develop data analysis techniques and animal behaviour monitoring.
Development of a UAV platform with multiple imaging capability.</td></tr>
<tr><td>Achieved:
Equipment was procured to develop the Laser Fence technology, characterise the laser beams. A supercontinuum laser was procured, and coloured (red, yellow and blue (in addition to green)) lasers were introduced.
Necessary adaptations to the BCG laser systems introduced to improve compliance with Health and Safety guidance.
Animal monitoring via CCTV and Camera Traps was established. Software for animal behaviour monitoring was identified.
Quadcopter and fixed wing UAV (drone) procured and fitted with RGB and thermal imaging cameras.
Workshop was held to review how to analyse the data created from handheld and autonomic systems.</td><td>Evaluation:
Since trials were conducted in the field, then a dedicated laser lab was not completed at LJMU, partly due to space pressures and a lack of exclusive use. However, laser development activities could be supported by an industrial laser lab as necessary.
In order to capture laser beam / animal interactions, trial cameras were the starting point. However, it was found necessary to develop additional necessary image capture. This included a radio link CCTV system, night vision telescope and thermal imaging. A RGB and Thermal camera was deployed with the drones by IRIS.
This equipment creates a significant amount of image and video data that needs analysing. Animal behaviour reporting software partly automated this process, but the basic activity still required manual input and was time consuming identified there is a need to seek automation of this activity. At the final conference a presentation was given by the UK Animal and Plant Health Authority on Deep Learning technique for animal identification on videos. This could be beneficial for After-Life work.
The drone flights over all the partner’s main sites were completed in 2017. Issues registering activity with UK Civil Aviation Authority prevented further drone deployment in the UK, but drone activity continued in Spain.</td></tr>
<tr><td colspan="2">Action: B1 Large scale implementation in all areas</td></tr>
<tr><td colspan="2">Objectives:
To conduct Laser Fence field trials at the six partner sites</td></tr>
</table>

Expected results:

To demonstrate the use of laser fencing to exclude animals from areas, e.g. to exclude pest species from a field.

Overall, the aim of these trials is to demonstrate the ability of Laser Fence to reduce rat and pest intrusion and so reduce agricultural pests and eliminate rodenticide use.

Achieved: This action continued throughout the project as partners conducted trials to try and improve the efficacy of the Laser Fence system as a pest control technology.	*Evaluation:* The initial trials at the partner sites gave the first indications that the use of Laser Fence for ground animal pest control was not going to replicate the results seen with laser avian deterrence.
	Trials conducted using handheld devices show that efficacy against rabbits is around 20%
	Camera trap and CCTV observations provided some understanding of the behaviour of animals to the laser beam. While there were often not immediate responses to the beam, there was some indication that the animals were disturbed by the beam.
	In September 2017, objections were raised to trials, by the UK Health and Safety Executive. This forced some trials to be replanned, but overall trials were able to be continued with increased awareness of health and safety requirements. .
	The project teams prioritised trials that aim to measure the efficacy of the laser, particularly with rats in winter season, and then other target species. Trials were also begun at other sites, that were classified as replication sites (B2).
	These trials covered a number of target species, particularly rats, rabbits, boar, badger, squirrel, wolf, sheep, etc.
	At the conclusion of the project, the partners had identified a benefit of blue lasers, (and red lasers in Spain).
	While all animals had shown an immediate response at some point in the trails this typically occurred in <20% of interactions. However persistent and erratic application of the laser to a single animal would often have some effect, and later analysis of video data suggested that the use of autonomic systems would reduce the prevalence and activity of animals.

Action: B2 Replication of trials with third parties

Objectives:

<table>
<tr><td colspan="2">To replicate the LaserFence trials at third parties. Trials to be the responsibility of a project beneficiary.
Expected results:
Transfer knowledge to civil society and gain market uptake for the LaserFence technology.</td></tr>
<tr><td>Achieved: As described in section B1 above, the lack of demonstrating a robust pest control system in the partner implementation trials did not allow the original objective of this action to be pursued.
Instead, third party sites were procured in support of developing further understanding of Laser Fence technology, and to seek a mode of operation for Laser Fence that gave a high degree of pest control.
14 replication sites were brought into the project, by all six partners (see Table 6-4), representing a range of habitats and target species, and adding 2600 ha to the available trials area.
The owners and managers of these sites included farmers, conservation charities, private landowners, and a zoo. These sites provided an excellent partner opportunity, informing them about the Laser Fence Technology, as well as in disseminating and raising awareness and the underlying problems surrounding rodenticide use.</td><td>Evaluation: For the original objective, the replication sites would have hosted trials involving Laser Fence technology proven to have a viable pest control ability.
Such an ability was clearly not available at the end of 2017, so additional sites were sought to increase to increase the range of target species and settings, particularly rat trials, with a desire to improve the efficacy of the Laser Fence, and provide a trial site to undertake confirmation trials had a truly viable pest control system had been developed. As the latter was not realised, these sites were considered as replication sites, and provided an invaluable contribution to the project partner’s efforts to establish a working technology.
They also helped provide the audience for the public awareness raising activities, and other dissemination.</td></tr>
<tr><td colspan="2">Action: C1 Project performance indicators</td></tr>
<tr><td colspan="2">Objectives:
Monitoring the impact of the project.
Evaluation and update of the project specific indicators
Monitoring of the welfare of animals in the laser trials area.
Expected results:
Delivery of the targets in the Project Specific Indicators
Monitoring protocols for the Project Specific Indicators.</td></tr>
</table>

Achieved: The final Project Specific Indicators is indicated and discussed in §7. A report on the welfare monitoring of animals in laser trials has been completed. Animal welfare was monitored throughout the project, and considered by Martin Sharp (LJMU) and David Parish (GWSDF). No reports of concern for animal welfare were raised.	*Evaluation:* The delivery of the required outputs to satisfy the KPI of this project has guided the activities of the project partners. However, as it was not possible to achieve a robust pest control system, the most important KPI's, particularly rodenticide reduction has suffered. Indeed it was not possible to document any reduction in rodenticide use identified in a trial using Laser Fence equipment. Cheshire Farm A had produced encouraging results in terms of the control of entry to a grain store, but any opportunity to set a trial to test this, was cut short by the Covid-19 pandemic restrictions. Efforts were made to meet the KPI in areas of public awareness, dissemination and stakeholder engagement, and many of the KPI were met in this area. Had there been an ability to demonstrate a working pest control system, significantly increased returns would have been achieved for the KPI.
Action: C2 Conclusions and recommendations	
Objectives: Assessment of the socio-economic impact of the project Recommendations for Replication Consultations with stakeholders including governmental institutions, NGO, stakeholders *Expected results:* A report outlining the conclusions and recommendations of the project Recommendations for replication	
Achieved: A survey was offered to some 100 stakeholders. There were 40 responses, followed by interview with 8 respondees. The Socio-Economic Assessment of the project was conducted by an independent consultancy, ERS Ltd, who had previous experience of such assessments with LIFE projects The partners submitted their own conclusions and recommendations of the project and these were then reconciled into a single deliverable report.	*Evaluation*: With an inability to demonstrate a viable pest control solution, with the consequent lack of progress in certain KPI and the impact that would ensue from achieving a positive outcome, then the results of this action would not be as expected. However, the action was completed in full, and provided a valuable contribution to the project team's conclusions and recommendations at the project's conclusion, The survey and questionnaire confirmed a real interest in the agricultural and conservation community for a viable alternative to rodenticide and other lethal pest control measures, and if Laser Fence were to achieve this, then there would be interest. The Socio-Economic assessment recognised that certain KPI's were not met, and that this limited the impact of the project. Equally it acknowledged the

	work done by the project team in disseminating the project and its concern for rodenticide and pest control issues. It recognised the commitment of the partners to develop Laser Fence to a viable technology and the commitment to After-Life projects. This leads to the conclusions and recommendations that relate to the following key areas: i) Wildlife activities and responses ii) Trial methodologies and laser techniques iii) Further development of the Laser Fence iv) Stakeholder / Public Engagement v) Regulatory issues
Action: D1 Dissemination planning and execution	
Objectives: Make the project concept visible beyond its local execution *Expected results:* Increased awareness and dissemination of the issues of chemicals in agriculture and the role of modern technologies to reduce / eliminate this. Project website Social Media activity Layman's Report	
Achieved: The activity of the project in conducting trials, particularly in replication sites, promoted the pest control agenda, particularly in rodent-icide reduction. This was supported by posters and noticeboards. A website was created and was updated regularly throughout the project. It attracted some 4900 unique visitors and 170 news items were posted. The main social media channels were Facebook, YouTube and this was complemented by partners Twitter account activities using the hashtag #LaserFence. Over 10,000 individual interactions with these social media channels were identified. A "Layman's Report" was produced and is available for circulation, and also download from the website.	*Evaluation:* Promotion and awareness of the project and its aims was performed well and attracted the anticipated interest. It would surely have been instrumental in creating a market for Laser Fence if a viable pest control system had been demonstrated, Social media supported this activity well, particularly the use of the hashtag #Laserfence in Twitter. The Layman's report, published in early 2020 ready for the final conference held in March 2020 as the Covid-19 pandemic ran through Europe, was well received. However, the lack of physical events to be attended during the various EU members lockdowns and responses to the pandemic severely curtail physical distribution of the booklet. The booklet could be downloaded in pdf form, in English and Spanish from the website.
Action: D2 Information and awareness-raising	

<table>
<tr><td colspan="2">Objectives:
Planned events and activities designed to involve end-users, stakeholders and local and/or general audiences
Expected results:
Press coverage
Presentations at exhibitions and conferences
Technical Seminar
Final Conference
LIFE project networking</td></tr>
<tr><td>Achieved: The project was presented in 49 news items published in the press. Partners attended a number of exhibitions, meetings and conferences to present the project. The project held two conferences, a technical seminar at the University of Sevilla in March 2019 and the final conference at LJMU in March 2020.
Project partners met with several other active LIFE projects,</td><td>Evaluation: Throughout the project attendance and presenting at exhibitions, meetings and conferences has provided valuable exposure for the project and its aims.
This has been supported by a good number of press articles, some of these instigated by press releases from the project.
Care has had to be taken with these releases and how LaserFence was presented. Firstly, there was not the opportunity to present Laser Fence as a proven pest control activity, and secondly, there was also a concern that there were certain “animal rights” groups who would not support any intervention to control animals even if they are widely regarded as a pest requiring control. This was witnessed in respect of opposition to the projects working to protect the red squirrel in the UK with protesters opposing any intervention to control the grey squirrel. This was an example of the project’s interaction with another LIFE project – SciuriousLIFE. It led to the squirrel trials at Welsh Mountain Zoo.
The project conferences provided a good opportunity to disseminate the project results and receive feedback as well as to invite complementary talks from related practitioners.</td></tr>
<tr><td colspan="2">Action : E1 Project management</td></tr>
<tr><td colspan="2">Objectives:

Management over the whole project
Finances
After Life Plan
Expected results:
Successful delivery of project, achieving results and impact.
After-Life plan</td></tr>
</table>

Achieved: Partner agreement signed off. 10 Steering committee meetings held, 4 of which were held using Zoom teleconferencing, and one was held in coordination with the Technical Conference. The kick off meeting was in Sept 2016 and 5 missions with the monitoring officer were held. Monthly zoom meetings of all parties began in December 2017. An After-Life has been produced and was presented as a deliverable prior to the final Steering Committee meeting held as a zoom meeting due to Covid-19 restrictions.	*Evaluation:* The original project director, Dr Alex Mason, left LJMU in May 2017. Dr Martin Sharp took over the role in June 2017. No other senior management changes have taken place in the lifetime of the project. Steering committee meetings have been held in a timely fashion, including five as mission meetings with the monitoring officer Dr Neil Wilkie of Neemo. The final virtual SCM was attended by Manuel Montero Ramírez . The project team have received excellent guidance and support from Dr Wilkie and would take this opportunity to express our thanks for this. Two extensions were requested, both to extend the end date of the project from its original date. The first extension of six months from end December 2019 to end June 2020, was principally to enable further trials, particularly for rats over the winter season, and develop and deliver additional trials on wolves and badgers. The second extension was to enable the postponed SCM to take place in September 2020 prior to an end September finish date. The latter trials proposed in the first extension were disrupted by Covid-19 restrictions. Some good results were achieved in rat trials at the Cheshire Farm A replication site prior to lockdown, tbe proposed badger trials could not be conducted and the first Wolf encounter took place two days before the end of the project. The After-Life plan proposes projects to further develop the "detect and deter" concept, with supporting work looking how to improve the safety features of the equipment, the ability to automate analysis of video data using deep learning. Such projects would require the partners to seek funding in support of them, though there is the opportunity to consider smaller projects using students from LJMU.

6.3.3 Commentary

At the outset of this project, the aim was to transfer what is clearly a successful avian deterrence technology into ground animal pest control system. Having demonstrated this, replication trials would be conducted and a successful introduction of this technology would follow. In particular, rats, and other rodents, were a specific target species, and the aim was to eliminate rodenticide use.

By the end of the first year, it was clear that such ground animals were not responding as birds do. It had not been possible to demonstrate a deterrent effect. The optimism at the third

SCM in Delft, February 2017, was under threat by the 5th SCM in Sevilla, November 2017. The project needed to concentrate on improving the efficacy of the Laser Fence as a pest control tool, and multiple routes were needed to pursue this endeavour. Handheld trials were conducted when the opportunity arose to observe the interaction of animals with the laser spots, trials were conducted using autonomics where possible under the better understood health and safety requirements. Regular monthly zoom meetings kept the partners in touch with the latest trial results and proposals for further work. Eventually two related modes of operation were becoming to emerge – the detect and deter approach to "pester" individual animals and encourage them to move away from the area being protected, and the reduction of activity and prevalence of animals within the projection zone of an autonomics.

As trials were developed to further demonstrate these effects and improve the efficacy, Covid-19 arrived in Europe and left these developments unfulfilled. However, the project team were left encouraged by the last trials and results and this informed the development of the After-Life plan. The project team are committed and optimistic that Laser Fence can be further developed into a worthwhile pest control system.

Despite the lack of a viable pest control solution in the project timeframe, the team remained fully aware of the primary aim of the project to reduce rodenticide use and trials had continued towards the achievement of this target. Results at Cheshire Farm A in the UK were very encouraging, but follow up trials were prevented by Covid-19.

The project team also worked hard to deliver the networking, public awareness and dissemination, despite the lack of demonstration of pest control. The rodenticide reduction and non-lethal control of pest species agenda provided ample interest in the project, and this was delivered in multiple channels, social media, traditional press, exhibition and meeting presentations etc.

This project has proven to be difficult in its delivery, and frustrating in its lack of ability to deliver some of the most important KPI's. However, throughout the project duration, the whole project team continued to strive to deliver the best progress possible towards the desired outcomes.

6.4 Analysis of benefits

6.4.1 Environmental Benefits

The main benefit foreseen was the reduction, or elimination, of rodenticide use. This would reduce or eliminate trophic chain poisoning arising from the use of rodenticide. EU regulations prohibit the use of rodenticide in open fields, but it is has been found to be used illegally, and causes poisoning of predators.

It is also used in factories and grain stores, etc. for rat control. The elimination of rodenticide use in such areas could be significant. However, the rats may travel external to such facilities so can still cause poisoning in the food chain.

Reduction of CO2 emissions would occur from the reduction in rodenticide manufacture, packaging and distribution.

Laser fence is a clean system without harmful chemical emissions – it can be run from solar panels with back up batteries in the field, or from mains electricity around buildings.

Of course, these benefits accrue from the successful use of Laser Fence to reduce rodenticide use. It was not able to demonstrate this within the timescale of this project, but progress was made in increasing the efficacy of Laser Fence, with some good results in the last trial that would have lead on to a trial to attempt rodenticide reduction. In view of this progress and the highly desirable benefits outlined above, the project team are keen to pursue further developments in the After-Life plan.

6.4.2 Economic Benefits

At proposal stage the main economic benefits identified for a successful Laser Fence solution would be in terms of the savings in the costs of fencing. This mainly applies to the larger target species. There will be savings in terms of not paying for rodenticide (and additional charges where contractors are used to deploy rodenticide). Finally, there would be significant cost savings in terms of the reduction in crop losses. ACA reports that it is possible to lose 50% of a sunflower crop at seedling stage due to rabbits. A Laser Fence system that reduced or eliminated such destruction of crop could protect against this loss.

Again, this economic benefit only accrues when Laser Fence successfully displaces existing solutions. Based on the experience gained in the project a more realistic projection of the cost benefit for fencing is presented in the KPI. While the cost benefit is reduced the result remains attractive and positive.

This is where replication would have been important if the viability of the current Laser Fence could be demonstrated, and needs ongoing consideration in the After-Life plan. When successful use of Laser Fence is demonstrated for an application, multiple replications of this would be required to confirm the economic benefit of the technology to bring that application to market.

6.4.3 Social Benefits

The key social benefit that would arise from this project is the reduction of rodenticide poisoning in the trophic chain and thus improvement in biodiversity and food safety.

In addition, the general benefits of having a non-lethal technology for the control of pest species would generally be appreciated by the majority of the population. Such segregation of pest species from crops or livestock animals is often controversial and divisive (e.g. badger and cattle, rabbits and cattle pasture / sunflower plots, wolves and livestock / habitations). A working Laser Fence solution would provide a technology that could address this without harm, helping to deliver the principle of animal welfare that is enshrined in EU legislation, and is clearly demanded by the population.

The examples listed before have impacted the project team as real examples from collaborations with e.g., replication sites, and driven our attempts to deliver a Laser Fence solution, that will continue in the After Life. Such a solution will impact society and general population as indicated in the key performance indicators. Our reporting on this is based on areas where trials have taken place, as this provides a measure of the potential size of population that would be aware of the project and its aims.

6.4.4 Replicability, transferability, cooperation: Potential for technical and commercial application

There has been good interest in the project from a range of communities, and in general the project has benefited from working with replication who have genuine interest in the technology and the problems it would tackle.

For wider replication there would have to be definitive results clearly demonstrating the benefit of the technology. The project team believe this project has provided the basic understanding and experience of how to develop the technology and test it for specific applications. This is the next step to be addressed in the After-Life activity.

This will depend on the cooperation of the owners and managers of replication sites to host trial, again this project gives the confidence that these are quite readily found.

The technology, as it stands, is relatively simple to set up, and use. But to deliver the necessary viability, there is likely to be some increase in complexity. It has been noted that any solution will need to be robust and reliable. This is particularly true at certain times when

a crop is critically vulnerable and while this may only be for a few days, the system must perform. It is possible that the farm team may not have the necessary skills (IT, electronic and optical) to maintain the equipment, so equipment design and business models may be around "swapping out" key equipment, and possibly cloud software management of the system. These skills and models are likely to become increasingly necessary in a high-tech agricultural setting as yield, productivity and efficiency continue to be significant drivers.

At the endpoint of this project, the team are confident there is a role for Laser Fence, with suitable developments. It is unlikely to launch into widespread use, but will build a market application by application.

6.4.5 Best Practice

The project has allowed the partners to establish methods of applying the Laser Fence to increase efficacy, and so this offers the current best practice for using this system with ground animals. For handheld use, the idea of "pestering" the animals has grown, recognising that you cannot expect an immediate response. For autonomics, there is the concept of "detect and deter". Patrolling large areas does not appear to reduce prevalence and activity of animals, but the detect and deter approach of detecting an animal at risk of encroaching on the protected area, and creating a "pestering" action could deliver a viable solution.

The other major area of best practice is in the safe use of these class 3B lasers. Not only has he project adapted its trials to operate in a safe way according to the international standards, but BCG have adapted and developed procedures for improved safe operation, not only of Laser Fence, but also its Agrilaser avian deterrence systems. These adaptations and increased understanding of laser safety for these applications may allow for the development of an international standard for the safe operation of deterrent lasers.

6.4.6 Innovation and Demonstration

The proposed project was very attractive for its potential results, and based on a technology that worked well with birds. In practice the ground animals did not respond to the laser spot like the birds. Subsequently the project team has worked hard, pursuing a range of trials on different species in different settings. It is not possible to claim that a working pest control system, capable of displacing rodenticide use, and physical fencing, has now been developed. The project, however, has achieved a considerable understanding of the interaction between the laser spot and ground animals, and the project team is in the position to continue towards a working deterrent system with After-Life activity.

This could not have happened without the funding and support of the EU LIFE grant. This has brought together a multinational team of diverse experience to develop an understanding of the technology and its deployment against a range of target species in different habitats. This team has then had to interact with and exchange knowledge with external enterprises to supplement this knowledge and experience.

The LIFE funding has also ensured that the project team has raised awareness, not only on the Laser Fence technology, but also on the issues it should address.

The funding has been unique in these respects. The project team intend to realise a return on this investment by using After-Life activity to develop pest control solutions for targted applications that realise the benefits and expectations of the Laser Fence project as originally conceived.

6.4.7 Policy Implications

The project did not achieve a position where it could influence European Legislation or regulation. There are clear regulations and resultant legislation that covers the use of

rodenticide in the control of rats, and animal welfare regulations and legislation have a significant impact on other physical lethal and non-lethal control of other ground pests.

The interaction with the UK HSE early on in the project did highlight issues relating to laser safety in the operation of the Laser Fence systems. The lasers are classified as Class 3B lasers, a category that spans lasers from 5mW that border intrinsically safe lasers to 500mW lasers that border a category of lasers considered harmful. The classification is based on European Standard IEN 60825, and this has been developed over 40 years with the basic concept of "Maximum Permissible Exposure" (MPE) levels ultimately determined by exposure tests. The MPE levels are very well established and determine safe operation. It would require significant animal testing, and consultation to raise these levels, even if it is possible. Further, the legislation implementing laser safety derives from the EU artificial optical radiation (AOR) directives. The UK and other EU members use MPE's to implement the AOR legislation. All that remains then, would be to attempt to establish a European standard covering the safe operation of laser deterrents. This would most likely still use the MPE's to guide the safe use, but could provide a professional framework for the safe installation and use of Laser Fence devices.

Once a viable and safe laser fence solution is achieved, it could have an impact on regulations surrounding rodenticide and animal welfare. It is clear that rodenticide is used widely (and often illegally) because the users perceive it as the only solution that works (with the possible exception of shooting). Having strong and robust, non-lethal deterrents would allow regulators to argue for stronger restrictions on rodenticide use, if sound, working, alternatives exist.

A question that has been asked on some occasions by interested parties is that if we are not killing pests, just excluding them from our site, surely they will move to our neighbours causing them problems? So, some form of policy development may be required to provide for land areas where such problem can be displaced safely,

7 Key Project-level Indicators

Table 7-1 Project Specific Indicators Analysis**Error! Reference source not found.** provides a commentary on the final status of Product Specific Indicators (PSI). The final PSI table is provided in pdf form as a deliverable, annexed to this report.

Indicator	Expected	Current	%	Comparison to project start
Chemical Substitution (Source: p.24 GA – Note 1620Kg total not 1620 kg / ha eProposal[10] xls 4.1.2 "Chemicals Substitution")	1620kg rodenticide eliminated	0 kg	0	Substitution of rodenticide chemicals at relevant sites No substitution can be claimed as it was not possible to establish a Laser Fence system of sufficient efficacy within the project timescale (see section 6.2.4)
Ecosystems (eProposal xls 7.2 "Ecosystems")	Cropland – Pest control 900 ha	1050 ha	117%	eProposal xls 7.2 "Ecosystems" Amended at Extension request April 2019

[10] Downloaded from eProposal Jan 2017

Indicator	Expected	Current	%	Comparison to project start
Ecosystems (eProposal xls 7.2 "Ecosystems")	Grassland – Disease Control 150ha	180 ha	120%	eProposal xls 7.2 "Ecosystems" Amended at Extension request April 2019"
Ecosystems (eProposal xls 7.2 "Ecosystems")	Grassland – Protection of vulnerable species 500 ha	1100 ha	220%	eProposal xls 7.2 "Ecosystems" Amended at Extension request April 2019
Areas near to Natura 2000 sites (eProposal xls 9.2 "Particularly vulnerable areas")	1,500 ha	2330	155%	The following sites are near Natura 2000 sites: Auchnerran, Cuarterola, Cucanoche, Eoloarroz, Bickley Hall, Cheshire Farm B, Wölferlingen, RSPB Burton, Campanarios de Azaba, Sierra de la Culebra
Local Population (eProposal xls 10.1 "Total human population to be affected by the project")	58,465,651	7,526,000	13%	Final figure calculated on the population of the municipal county / province containing Laser Fence test sites
Municipal units where the demonstrations are performed (eProposal xls 10.2 "Total area to be affected by this project")	209,536 km^2	70,197	34%	Areas of the municipal county / province containing Laser Fence test sites
NGO supporting EU environment and/or climate change policies eProposal xls 11.2 "Implication of NGO")	5	2	250	The project has worked with: Game and Wildlife Conservation Trust (GWCT), FUNDACIÓN NATURALEZA Y HOMBRE (FNYH), Cheshire Wildlife Trust (CWT), RSPB Campaign for Responsible Rodenticide Use (CRRU).
Unique visitors to the website (eProposal xls 12.1.1 "Website")	7,750 visits	4902	63%	The unique visitors to the website are monitored using Google Analytics.

Indicator	Expected	Current	%	Comparison to project start
News articles published on website (eProposal xls 12.1.1 "Website")	150 articles	170	113%	Number of news items on project website
Publications in traditional media (eProposal xls 12.1.2 "Website" "Other tools")	25	49	196%	Articles in press (printed, websites, etc.)
Information board (eProposal xls 12.1.2 "Website" "Other tools")	6	6	100%	Information boards posted at demonstration sites across Europe.
Leaflets (eProposal xls 12.1.2 "Website" "Other tools")	1,000	3,000	300%	Design and printing arranged by Volterra
Social media	7,750 people	10,413	134%	Facebook, twitter, etc. Ref – Volterra MTR d1 and D2 report eProposal xls 12.1.2 "Website" "Other tools"
Diverse public that will participate directly or indirectly in the project per area (eProposal xls 12.1.2 "Website" "Other tools")	3,408 people	2390	70%	Our figure is based on tourists passing through Auchnerran farm to the Morven Hill's, and gun parties visiting the farm who are introduced to Laser Fence. Volterra and the Angel Camacho farms have received fellow producers and NGO's
Layman report (eProposal xls 12.1.2 "Website" "Other tools")	1,000	200	20%	Layman report, batch printed for final conference, and also circulated as PDF (not included in this figure)

Indicator	Expected	Current	%	Comparison to project start
Surveys - general public, NGO, private companies, local authorities, regional authorities, national authorities, civil society organisation (eProposal xls 12.1.3 "Website" "Surveys carried out…")	120 Surveys 120 Individuals covered	40 Surveys 8 Interviews	40%	Survey and interviews conducted in Q2 2020.
Participation in networking events with other LIFE and EU projects (eProposal xls 13.1 "Networking")	180 people (trained)	190	106%	Visits to other LIFE projects, and incoming visits from other projects.
Participation in congresses, conferences and presentations (eProposal xls 13.1 "Networking")	1,350 people	1822	135%	Based on events attended, see deliverable D2 Presentations at conferences and exhibitions
Personnel hired during the project execution (eProposal xls 14 "Fulltime Equivalents")	20 FTE	10.8 FTE	54%	Staff hired at: LJMU, GWSDF, Volterra, Angel Camacho, BCG, IRIS
Investment costs of fencing 1 area of 500 ha (approx. 9.000 m perimeter) (eProposal xls 15.2 "Capital cost expected in case of replication…")	€ 63,000	€ 72,000	-14%	€72,000 is based on 8 off Laser Fence systems each with an optimum range of 500m, against an estimate of €11 per m for badger proof fence that equates to €98,000 + installation costs.

Indicator	Expected	Current	%	Comparison to project start
Total saving expected (eProposal xls 15.2 "Capital cost expected in case of replication …")	€ 774,000	€ 468,000	60%	Based on the implementation of the systems in 3 times as many areas as within the project duration.

Table 7-1 Project Specific Indicators Analysis

8 Annex

The following document is presented as an Annexes to this document:

1. Annex 1 – Summary of trial results