Monitoring the humaneness of badger population reduction by controlled shooting

Report to the Independent Expert Panel and Defra

26 November 2013

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1. Introduction

1. As set out in Defra's policy statement published in December 2011 (Defra 2011), the Government has decided to proceed with a policy of enabling farmers and landowners to cull and/or vaccinate badgers, under licence, in areas of high incidence of TB in cattle.

2. Only two culling methods are permitted:

    1. Cage-trapping followed by shooting
    2. Controlled shooting

3. Best practice for controlled shooting of free-ranging badgers in the field is set out in Defra's Best Practice Guidance document (Defra 2013).

4. In response to concerns about the lack of evidence about the effectiveness and humaneness of controlled shooting of badgers, a precautionary approach was taken by piloting the method in two areas initially.

5. The design and evaluation of the pilot was overseen by a panel of independent experts, whose role included overseeing the design of the data collection, its analysis and interpretation.

6. The aim of the humaneness monitoring component of the pilot was to provide data to allow an assessment of the humaneness of the controlled shooting method.

7. The purpose of this report is to present the results of the humaneness monitoring component of the pilot on controlled shooting of free-ranging badgers.

8. The seven specific objectives of the humaneness monitoring component of the pilot were:

- **Objective 1**: To determine the time period between the first shot taken at the badger and death of the badger.
- **Objective 2**: To determine the proportion of badgers that are not recovered after being shot at with a firearm**,** and have firearm injuries.
- **Objective 3**: To describe the behaviour of badgers after being shot at with a firearm.
- **Objective 4**: To determine the location of rifle/shotgun entry wounds in the badger carcases recovered from observed and unobserved shootings.
- **Objective 5**: To determine the extent of internal firearm injuries in the badger carcases recovered from observed and unobserved shootings.
- **Objective 6**: To investigate whether there is any evidence of correlation between the times to death determined by Objective 1 and the firearm injuries recorded in badger carcases recovered from observed shootings.
- **Objective 7**: To compare the firearm injuries in badger carcases recovered from observed shootings with those in badger carcases recovered from unobserved shootings.

2. Materials and methods

9. Pilot culls were licensed in two areas, West Somerset and West Gloucestershire, and were organised by two separate cull companies. Shooters (referred to as contractors), who had been trained and assessed as competent to cull badgers using controlled shooting, were contracted by the cull companies to undertake the culling of badgers in the pilot areas. The activity of the contractors was overseen and co-ordinated by the cull companies, but the contractors undertook the actual badger control.

10. Humaneness monitoring activities were split into two components: a field component involving observation of shooting events and a laboratory component involving necropsy and radiological investigation of culled badgers. The cull companies were responsible for the sorting and delivery of carcases to the laboratory site. To achieve traceability of data between the field and the laboratory, the contractors attached electronic identification tags (EIDs) to every carcase recovered. Each tag had a unique code on it that identified both the contractor that had culled the badger and the individual badger.

11. The aim of the humaneness component of the pilot (as set out in the project protocol document – Appendix 1) was to observe at least 120 controlled shooting events with 120 different contractors; 60 events where the weapon was a rifle and 60 where the weapon was a shotgun. All licensed contractors were eligible for observation, and they were randomly assigned to a list that indicated the priority for observation. Contractors that were reported by the cull companies to be active on a particular night were then selected for observation according to the priority list and the number of observers available. The aim of the laboratory component of the pilot was to complete a detailed necropsy and radiological examination on a pair of badger carcases for each contractor who was observed taking a shot; one carcase selected at random from observed shooting events (if more than one culling was observed), and one selected at random from unobserved shooting events. The sampling protocol aimed to provide a sample in which the members of each pair were close together in time, and in which half the unobserved carcases were selected before their paired observation, and half after their paired observation.

12. During the pilot, it became apparent that, despite earlier indications, very few contractors were planning to use shotguns and it would not be possible to obtain a useful sample of observations relating to this type of weapon. All analyses for this subset of shooting events were dropped from the study**.** The results provided in this report for the seven specific Objectives of the humaneness monitoring component of the pilot are for rifle shooting events only. Descriptive information on two shotgun shooting events that occurred during the pilot is provided in Appendix 2.

13. The number of contractors using rifles was also lower than expected from initial discussions, and their success rate per night was lower than anticipated. As a consequence, it proved difficult to obtain observations of successful rifle shooting events from the planned 60 different contractors, although considerable effort was made to observe as many as possible.

14. Data to inform an assessment of the humaneness of controlled shooting by rifle were collected by:

- Field observation of 88 badgers that were shot at by 57 different contractors.
- Necropsy and radiological investigation of 64 carcases of badgers observed whilst being culled - ‘observed badgers’.
- Necropsy and radiological investigation of 94 carcases of badgers culled when an observer was not present - ‘unobserved badgers’.

2.1. Field observation

15. This aimed to provide a representative sample of most conditions under which badgers would be shot.

16. Contractors were accompanied by an observer during selected nights when the contractors were active. Observations on the outcome of all shooting events witnessed were recorded. Observers used thermal cameras enabling detection and observation of badgers (including recently dead carcases) during darkness. The behaviour of all badgers shot at whilst an observer was present was monitored and recorded. Data were recorded by the thermal cameras, by audio recordings and field notes. The distance between the location of the badger when it was shot and the location where the carcase was found was recorded. In instances where a carcase was not recovered, the area was searched for signs of tissue damage; a description of any signs found was recorded. Data were also collected on the following factors: weather, rifle calibre, ammunition, range at which shot taken, position of shooter taking shot, presence of other badgers when shot taken, number of shots taken.

17. The recorded thermal camera images were analysed in the field site offices to record the behaviour of the badgers. Where continuous observation of the badger occurred up until the animal's last movement, a time from first shot to last movement was recorded. For all cases where a carcase was recovered, a time from first shot to confirmation of death was recorded. The time to confirmation of death included any delay in locating and approaching the carcase for various reasons such as close proximity of anti-cull protesters.

18. A discrepancy of 10 seconds between field recorded and office analysed times to last movement and times to confirmation of death was permitted in the data. Where the discrepancy was greater than 10 seconds, the order of priority for the data source for the time to last movement and time to confirmation of death was:

- First priority: thermal camera image
- Second priority: audio recording
- Third priority: field notes

2.2. Necropsy and radiology (the laboratory component)

19. A necropsy of each selected badger carcase was undertaken to determine:

i. The location (based on defined anatomical units), entry/exit status, perforation status, size, appearance (based on defined morphological change categories) and infection status of any cutaneous firearm wounds.

ii. The location, appearance (based on defined morphological change categories) and infection status of any internal firearm injuries, and to which entry wound(s) these injuries related.

20. Radiological investigation of each selected badger carcase was undertaken to determine:

i. The presence and location of bullets and bullet fragments.

ii. The location and appearance (based on defined morphological change categories) of any skeletal firearm injuries, and to which entry wound(s) these injuries related.

21. Prior to the necropsy, a minimum set of four (two ventrodorsal and two lateral) radiographs of the entire carcase was obtained. The necropsy and radiological interpretation were carried out sequentially by the same veterinarian, to allow each activity to inform the other.

22. The veterinarian performing the necropsy and radiological interpretation was blind both to whether the shooting event was observed or unobserved, and to the data obtained in the field for those shooting events that were observed.

23. Further details of the necropsy and radiology procedures are provided in Appendix 3.

24. The data obtained from the necropsy and radiological investigation were captured on specific data capture forms (Appendix 4).

2.3. Databases

Necropsy and radiology data

25. The necropsy and radiology data were collected on laminated forms in the post mortem room and then entered onto a dedicated database via a dedicated web-based data entry application. This was a secured SQL Server 2005 database that was backed up.

26. Validation of the data entry was performed within the data entry web application and within the database structure, both limiting the entry of invalid data. In addition, extensive quality checking was undertaken to minimise errors in the dataset (see Appendix 5).

27. The database and data entry application used appropriate permission groups so that only authorised users were allowed access.

28. Storage of the data within the relational database also provided facilities to:

- Generate reports on the data for summary and detailed review of entered data during the study, and for generation of dedicated graphical outputs to aid grouping of lesion profiles.
- Import observation data and combine this with the necropsy and radiology data to form an integrated database.
- Export the datasets required for subsequent analysis for the study Objectives.

29. Photographs taken during the necropsies and the digital radiographs obtained were stored locally at the laboratory site and copied to secure backed up servers each day.

Observation data

30. The field data were collated from a complex set of sources – physical notes, audio recordings and thermal image recordings taken by observers. The audio recordings and thermal image recordings were copied to secure backed up servers each day. Extensive quality checking was undertaken to minimise errors in the dataset (see Appendix 5). The field data were processed and integrated and entered onto spreadsheets before being imported into the dedicated database for cross checking and feedback. Subsequent to this import processing, the observation data were integrated with the necropsy and radiology dataset and incorporated into the Objective analysis datasets.

2.4. Data analysis

31. Outlines of the methodology used for the analysis of each of the seven Objectives are described in the following subsections. Further details of the statistical analyses used for each objective are provided in Appendix 6. Where confidence intervals are provided in this report and the result value is zero, the upper 97.5% confidence limit is provided for consistency, rather than the upper 95% confidence limit.

2.4.1. Objective 1: To determine the time period between the first shot taken at the badger and death of the badger

32. This Objective was based on observations of all badgers at which a shot was taken.

33. The dataset of observations included three types of outcome:

A Continuous observation of the badger from first shot to last movement

B Sight of badger lost at some point after the first shot; no observation of last movement, but carcase subsequently recovered

C Sight of badger lost at some point after the first shot; no observation of last movement and no carcase recovered

34. The aim of the analysis of the dataset was to estimate how the time to death (TTD) for culled badgers was distributed. The TTD was estimated by the time from the first shot to the observed last movement of the badger. However, for observations where there was no observed time to last movement (B and C above), other measures of TTD, described below, were used.

- i Worst case: For C it was assumed that each shot resulted in a hit and that the time to death was long (longer than the longest estimated time to death).
- ii Censored case: As 1, but for C the status was treated as 'unknown' from the point at which sight of the badger was lost where this was recorded by thermal camera (4 cases) or at the longest type A or type B observation (6 cases).
- iii Modelled case: As 1, but for B the time to death was assumed to occur at some point, with uniform probability, between the last observed movement and the time at which death was confirmed.

Table 1: The treatment of three classes of observation for estimating the distribution of TTD

Treatment name	Type A observation	Type B observation	Type C observation
Worst case	Time from shot to last movement	Time from shot to confirmation of death	Greater than the longest type A or type B observation
Censored case	Time from shot to last movement	Time from shot to confirmation of death	Right censored at the time sight was lost where this was recorded by thermal camera (4 cases) or at the longest type A or type B observation (6 cases).
Modelled case	Time from shot to last movement	Random with uniform distribution between time of last observed movement and time of confirmation of death	Greater than the longest type A or type B observation

35. For each of these approaches, it was assumed that the observations represented an independent random sample from a large population of shots. The TTD for the population was estimated via a Kaplan-Meier survival curve for each treatment. TTD for 50%, 80%, 90% and 95% of badgers for treatments i, ii and iii were estimated by interpolation of upper and lower confidence intervals of the survival curve.

2.4.2. Objective 2: To determine the proportion of badgers that are not recovered after being shot at with a firearm, and have firearm injuries

36. The field component of this Objective was based on observations of all badgers at which a shot was taken.

37. Observed and unobserved badgers on which necropsy and radiological investigation had been undertaken were analysed together for the laboratory component of this Objective.

Field component

38. The proportion of badgers in the population that were shot at but a carcase was not recovered was estimated from a binomial confidence interval from the observed proportion of non-recovered badgers.

Laboratory component

39. The laboratory component aimed to look for any trend in firearm injuries categorised as 'non-acute' over the course of the pilot. The data captured from the necropsy and radiological investigation were used to categorise the firearm injuries, based on the appearance category recorded, as definite 'non-acute' injuries, possible 'non-acute' injuries and injuries that were definitely not 'non-acute'. The criteria used for this categorisation are provided in Table 27 in Appendix 6. It is important to note that the categorisation of injuries at this stage was based on their gross appearance at necropsy or, for skeletal injuries, their radiological appearance.

40. Based on the methodology outlined above, only two carcases were categorised as having either definite or possible 'non-acute' injuries present. Therefore, further histopathological investigation of the potential 'non-acute' injuries identified on these carcases was undertaken to provide further information on the likely age of the injuries.

2.4.3. Objective 3: To describe the behaviour of badgers after being shot at with a firearm

41. This Objective was based on all badgers at which a shot was taken and for which there was either a detailed description of the behaviour the badger displayed after the shot or thermal images of the behaviour after the shot had been recorded.

42. The thermal cameras recorded images at 15 frames per second, but they did not date or time stamp any of the images. The thermal camera images were reviewed both at recorded speed and frame by frame, using a video editing package (Virtual Dub 1.9.11) that indicated frame numbers rather than seconds. The frame at which the shot was taken was located by visually scanning all the images recorded. Markers used to indicate a shot had been fired included a change in the badger's behaviour, sudden movement of the camera and observation of the heat produced by the shot. The thermal images between the shot occurring and confirmation of death were then analysed using a continuous recording sampling schedule (0.5 second accuracy).

43. An ethogram was used for the behaviour recording (see Appendix 7).

44. The behaviour data recorded were analysed to determine the nature, duration and frequency of behaviours observed after shots were fired.

2.4.4. Objective 4: To determine the location of rifle entry wounds in the badger carcases recovered from observed and unobserved shootings

45. Observed and unobserved badgers on which necropsy and radiological investigation had been undertaken were analysed together and separately for this Objective.

46. The primary aim of this Objective was to determine the location of the entry wound (referred to as the 'first entry wound' in this report) caused by the first shot that hit the badger during the fatal shooting event. This was straightforward for carcases where a single confirmed entry wound was present and no firearm skin wounds of uncertain entry/exit status were present. However, this analysis was complicated by some carcases having a single firearm skin wound, which was of uncertain entry/exit status, and some having multiple actual or possible entry wounds. To deal with this complexity, the following approach was adopted:-

47. Each carcase was categorised based on the level of certainty (i.e. certain or uncertain) of the location of the first entry wound associated with the fatal shooting event. The first stage for this categorisation was to identify every wound on a carcase that could be a first entry wound ('candidate wound'). To be included as a candidate for the first entry wound, the wound had to be a non-exit wound (recorded in the raw data as an entry wound or a wound of uncertain entry/exit status) with an appearance category of 'H', 'HO' or 'U'. Definitions for the wound appearance categories are provided in Table 25 in Appendix 3. Each carcase with a single candidate wound was categorised as having a 'certain' status for first entry wound location. Each carcase with multiple candidate wounds (multiple actual or possible entry wounds) was categorised as having an 'uncertain' status for first entry wound location.

48. The location of the candidate wounds was then categorised in two ways: first, by anatomical unit (AU); secondly, by target area set, as either 'inside target area' or 'outside target area'. As described in Appendix 3, the AUs divided the badger surface into 14 areas; AU 7 was constructed to match the target area recommended in Defra's Best Practice Guidance document (see Figures 1 and 2 below). For the target area set analysis, any shot hitting AU 7 was categorised as 'inside target area' and any shot hitting an AU other than AU 7 was categorised as 'outside target area'.

Figure 1: Target site for a heart-lung shot from Defra's Best Practice Guidance document

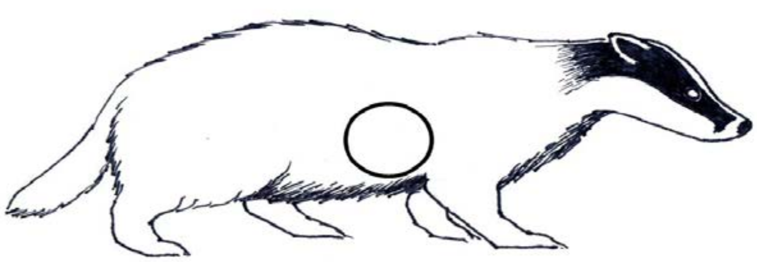
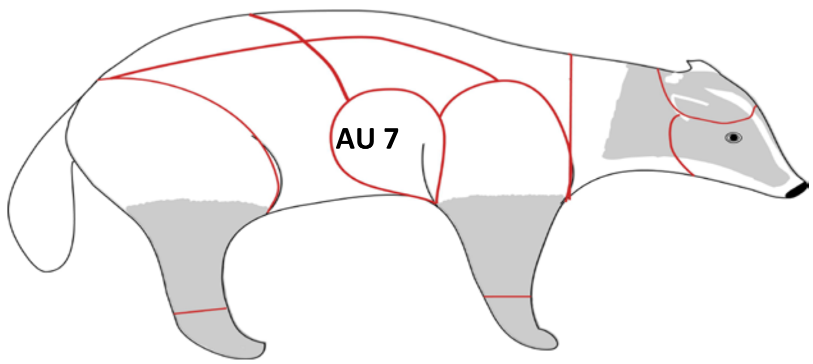


Figure 2: Location of anatomical unit (AU) 7 on one of the anatomical unit diagrams used for this study



49. Sensitivity analyses were performed to account for some carcases having an uncertain status for first entry wound location due to the presence of multiple candidate wounds. The sensitivity analyses are described in detail in Appendix 6. The sensitivity analysis approach enabled those carcases with multiple candidate wounds in more than one AU, or in both target area sets, to be included in the analysis. The sensitivity analyses provided minimum and maximum possible proportions of first entry wound locations by AU, and a 'best case scenario' and 'worst case scenario' by target area set. The sensitivity analysis approach allowed all candidate wounds in multiple candidate wound cases to be categorised as the first entry wound.

2.4.5. Objective 5: To determine the extent of internal firearm injuries in the badger carcases recovered from observed and unobserved shootings

50. Observed and unobserved badgers on which necropsy and radiological investigation had been undertaken were analysed together and separately for this Objective.

51. The data captured from the necropsy and radiological investigation were synthesised to produce a lesion profile for each carcase. The lesion profile for a carcase was based on the internal soft tissue and skeletal firearm injuries recorded for that carcase; the cutaneous firearm wounds were excluded from the lesion profile. The lesion profile was based only on injuries that the examining veterinarian was certain had been caused by a firearm. For the purpose of the lesion profile, the firearm injuries were categorised as 'acute' or 'non-acute'. All internal soft tissue and skeletal firearm injuries with appearance categories of 'H' and 'S' respectively were defined as 'acute'. Definitions of the appearance categories are provided in Tables 25 and 26 in Appendix 3.

52. The 'acute' lesion profile for each carcase was presented visually as a radar chart. For the purpose of this study, the variables on the radar chart comprised different anatomical structures or pathological observations, and included provision of an individual axis for each of a number of vital structures or critical observations. The position of the data point on each axis was determined by a number of factors:

- Whether firearm injuries had been detected with respect to the variable.
- The number of sub-variables that contributed to the cumulative 'count' for the variable.
- For heart, lungs and liver, the proportion of the organ(s) injured.
- For kidneys, front legs and hind legs, whether one or both of these paired structures were injured.

53. All 'acute' internal soft tissue and skeletal firearm injuries for a carcase were recorded as a single data series on a single radar chart. Where more than one shot had caused 'acute' injuries in a carcase, the 'acute' lesion profile included injuries caused by all of the shots. Examples of radar chart 'acute' lesion profiles are provided in Appendix 8. The details of the radar chart construction from the raw data are provided in Appendix 9.

54. The radar charts were used as a visual device to facilitate grouping of carcases with a similar 'acute' lesion profile. Groups of carcases with similar 'acute' lesion profiles were elicited by veterinary review, based on visual assessment of the radar charts by a small team of veterinarians. The 'acute' lesion profile groups were not pre-defined, but were determined once the 'acute' lesion profiles for all carcases were available. The grouping of carcases with similar 'acute' lesion profiles was completed blind, both to whether the shooting event was observed or unobserved, and to the data gathered in the field for those events that were observed.

55. The proportions of carcases in each 'acute' lesion profile group were calculated. Contingency tables were used to analyse the relationship between first entry wound location, in terms of AU, and 'acute' lesion profile group. Because of the potential for complication of this latter analysis by injuries caused by multiple shots, this excluded, subject to modification by veterinary review, any carcases in which either:

i. The examining veterinarian had concluded that the number of rifle shots hitting the carcase was more than one.

ii. The first entry wound location in terms of AU was uncertain.

2.4.6. Objective 6: To investigate whether there is any evidence of correlation between the times to death determined by Objective 1 and the firearm injuries in badger carcases recovered from observed shootings

56. This Objective was based only on observed badgers on which necropsy and radiological investigation had been undertaken.

57. Data were available from Objective 4 for first entry wound location and from Objective 5 for 'acute' lesion profile group.

58. The relationship between 'acute' lesion profile group and the field-observed time from first shot to last movement was investigated. Similarly, the relationship between first entry wound location in terms of the two target area sets, 'inside target area' and 'outside target area', and the field-observed time from first shot to last movement was investigated. Supplementary analyses were performed to account for some observed badgers not having an observed time of last movement. Because of the potential for complication of the analyses for this Objective by injuries caused by multiple shots, carcases were excluded, subject to modification by veterinary review, where either:

i. The examining veterinarian had concluded that the number of rifle shots hitting the carcase was more than one.

ii. For the target area set analysis, the first entry wound location in terms of target area set was uncertain.

2.4.7. Objective 7: To compare the firearm injuries in badger carcases recovered from observed shootings with those in badger carcases recovered from unobserved shootings

59. The outcomes of the necropsy and radiological investigation in observed and unobserved badgers were compared to investigate whether contractor shooting behaviour changed significantly when observed.

60. A paired analysis was carried out to compare the first entry wound locations in terms of the two target area sets, 'inside target area' and 'outside target area', for observed and unobserved badgers. Each pair comprised one observed badger and one unobserved badger, matched for contractor. This analysis only included pairs of badgers where the target area set was certain in both members of the pair.

61. The 'acute' lesion profile groups were compared in a similar paired fashion.

62. For some contractors, the paired analyses were complicated by the availability of more than a single pair of badgers to select from. In cases where this situation arose, the earliest observed badger and the earliest unobserved badger (based on the date of necropsy of the carcase) were selected for the paired analyses. If multiple candidate badgers were available from the same date, a single observed and/or unobserved badger was selected at random.

63. Unpaired analyses were also carried out, comparing the proportions of carcases in each of the two target area sets and in each 'acute' lesion profile group, for all observed and unobserved badgers.

3. Results

3.0. Contractor (shooter) activity

64. The pilot cull in West Somerset commenced on 26 August 2013 and finished on 7 October 2013. The pilot cull in West Gloucestershire commenced on 3 September 2013 and finished on 15 October 2013. The data from both areas were amalgamated for this study. An extension was granted in both areas, but no data were collected for this study during the extensions.

65. Over the 42 days of the pilot, the total number of contractors reported as being active by the cull companies and who used a rifle was 130; two further contractors made sole use of a shotgun. Contractors were on average active for 14 (range 1 to 40) nights over the pilot period. Rifle shot badger carcases were returned by 102 of the active contractors. Only two contractors returned shotgun shot badger carcases, of which only one contractor was reported as being active with a shotgun. The median number of rifle shot badger carcases returned by each contractor was 5 (range 0 to 42). One hundred and fifty eight eligible rifle shot carcases (64 observed and 94 unobserved) were subjected to necropsy and radiological investigation, from 82 different contractors.

66. One hundred and six contractors were accompanied in the field while they were active, one of which was using a shotgun. The total number of visits undertaken was 218, with a median number of visits per contractor of 2 (range 0 to 11). Observations of shots being taken were obtained with 57 different contractors using rifles and one contractor using a shotgun.

Figure 3: Distribution of data between contractors with different badger shooting experience. A visit refers to times that an observer accompanied a contractor in the field, irrespective of whether a shot was fired

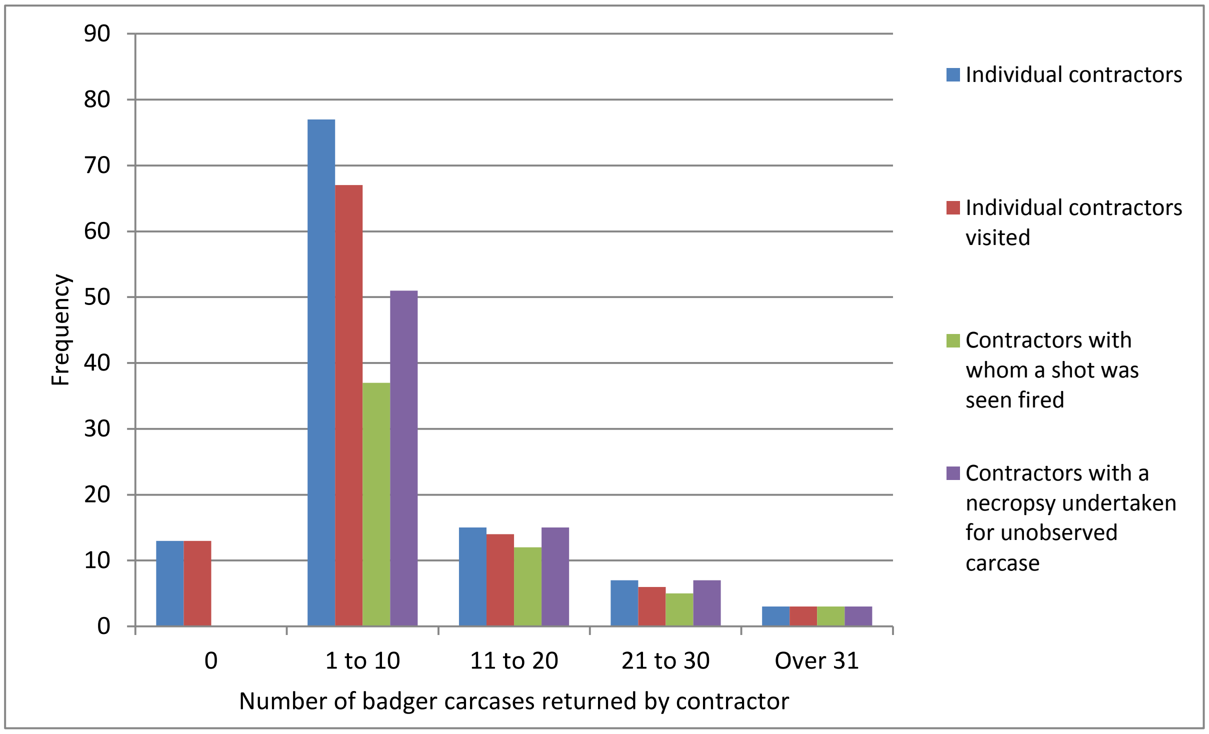


Table 2: Distribution of contractors with whom an observation was made by cull area

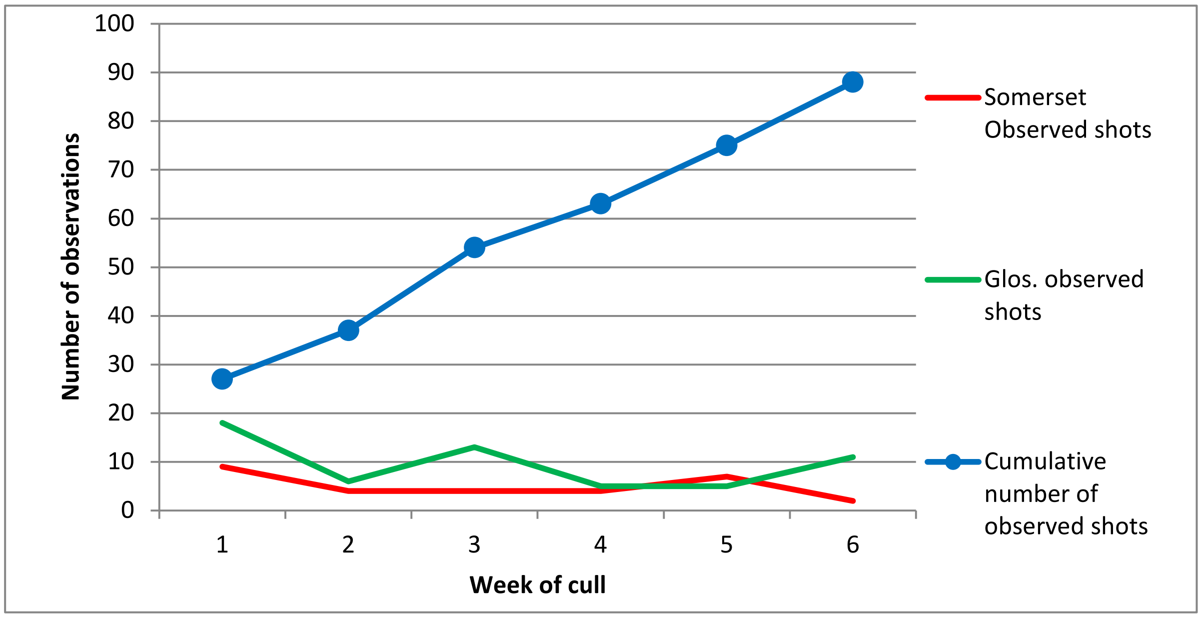
	Prior to commencement of the pilots, the number of contractors in each area with a license to use a rifle, and having rifle as their preferred method for culling	Number of contractors observed taking a shot with a rifle	Number of contractors reported to be active by the cull companies and using rifles over the 42 days of the pilot
West Somerset	46 (41%)	22 (39%)	69 (53%)
West Gloucestershire	65 (59%)	35 (61%)	61 (47%)

67. The proportion of contractors licensed per cull area differed from the eventual proportions of contractors that were active in these areas. The planning of what proportions to observe was based upon the numbers that were licensed and hence do not match the final or actual ‘active contractor’ proportions.

68. Observations and selections of unobserved carcases for necropsy and radiology were planned to be evenly distributed over the full 42 days of the pilot. Observations were not commenced until the fifth night of the pilot in West Somerset and the third night in West Gloucestershire. This delay was necessary for safety reasons to allow familiarisation of the contractors with the procedures and logistics of the study. In addition, there was a request to avoid observing contractors on the first night they were active, and to avoid visiting them twice within one week. The reduction towards the end of the pilot in total number of badgers returned each week by the contractors and the low overall activity rate made the even distribution difficult to achieve.

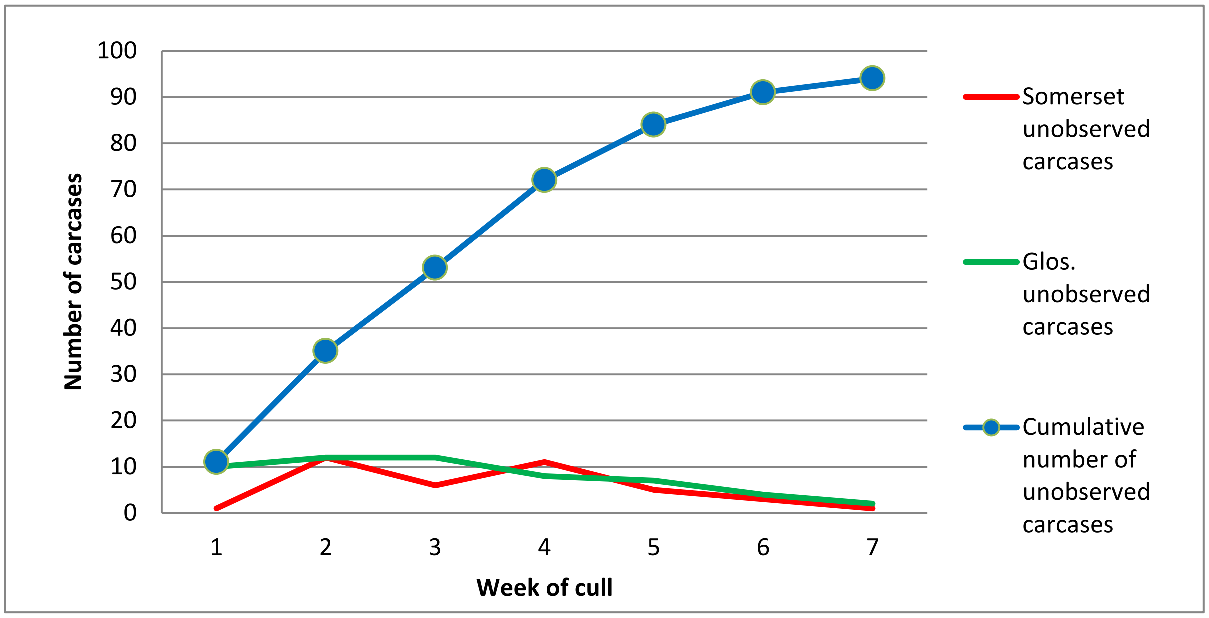
69. The number of observations achieved was not equally distributed across the 6 weeks of the pilot (chi sq 15.09, df=5, p value=0.01). More observations than planned were obtained in week 1 and less than planned were obtained in week 4, but within the range of tolerance.

Figure 4: The number of observations obtained per week over the duration of the pilot



70. The number of unobserved carcases for which necropsy and radiology were undertaken was not equally distributed across the 6 weeks of the pilot (chi sq 12.85, df=5, p value=0.025). A greater number of carcases than planned were examined during week 2, and a lower number during week 6, but within the range of tolerance.

Figure 5: The number of unobserved carcases for which necropsy and radiological examination were undertaken per week of the pilot (week 7 was included as carcases were submitted the morning after culling)



3.1. Objective 1: To determine the time period between the first shot taken at the badger and death of the badger

71. Observations were made on a total of 88 individual badgers that were shot at with rifles by 57 different contractors. Of 69 events with time of last movement observed (type A observations), 68 badgers had a time from first shot to last movement of 66 seconds or less. One further badger had the longest observed time from first shot to last movement, of 823 seconds (13 minutes and 43 seconds). Of the badgers recovered, 9 did not have continuous observation until last movement (type B observations). In seven of the 9 cases without an observation of last movement, confirmation of death occurred less than 9 minutes and 30 seconds after the first shot was fired. In the other 2 cases without an observation of last movement, confirmation of death occurred more than 60 minutes after the first shot was fired (see description in Appendix 10). Ten badgers were not recovered (type C observations). The details of each analysis and the Kaplan-Meier survival curves for the worst and censored cases of the proportion of badgers surviving over time after a shot was taken are provided in Appendix 11.

72. The times at which different percentages of animals died were calculated for three treatments of the data, 'worst case', 'censored case' and 'modelled case'. In each case, the time by which 50%, 80%, 90% and 95% of the animals had died was estimated. These results are presented in Table 3.

73. Under the 'censored' data treatment, it was estimated that somewhere between 62% and 81% of badgers were dead within 40 seconds of a shot being taken, and that somewhere between 80% and 94% of badgers were dead within 823 seconds of a shot being taken. The estimated time to death for 80% of the population was between 40 and 823 seconds with 95% confidence, hence, the time within which *at least* 80% of badgers were dead was estimated to be 823 seconds. It is possible that 80% of badgers were dead within 40 seconds of being shot.

74. Under the 'worst case' data treatment, it was estimated that somewhere between 62% and 81% of badgers were dead within 41 seconds of a shot being taken, and that somewhere between *just below* 80% and 94% of badgers were dead within 7200 seconds of a shot being taken. The estimated time to death for 80% of the population was at least 41 seconds, but an upper limit could not be estimated, hence, the time within which *at least* 80% of badgers were dead could not be estimated. It is possible that 80% of badgers may have been dead within 41 seconds.

Table 3: Estimated quantiles for time to death from each of the three methods of dealing with the data – worst case, censored case, and modelled case

Data treatment name	Percentage of animals dying within the period (%)	Estimate of time for that percentage of animals to die (seconds)	Lower Confidence[a] (seconds)	Upper Confidence (seconds)
Worst case	50	14	10	18
Censored case	50	14	10	18
Modelled case	50	(14 – 14)[b]	(9 – 10)[b]	(18- 18)[b]
Worst case	80	115	41	NA[c]
Censored case	80	66	40	823
Modelled case	80	(66 – 66)[b]	(27 - 40)[b]	(823 - 823)[b]
Worst case	90	NA	274	NA[c]
Censored case	90	5400	121	NA[c]
Modelled case	90	(5400 – 5400)[b]	(66 - 257)[b]	(NA[c] – NA[c])
Worst case	95	NA[c]	NA[c]	NA[c]
Censored case	95	NA[c]	5400	NA[c]
Modelled case	95	(NA[c] – NA[c])	(NA[c] – NA[c])	(NA[c] – NA[c])

a: from 95% confidence intervals for probability of survival

b: these intervals give the range of estimates for the time to death for the percentage of animals where the time to death lies somewhere between the last observed movement and the time to confirmed death for those badgers without an observed last movement. A comparison between this range and the worst case estimate shows how potentially conservative the worst case estimate is.

c: NA means that the value could not be estimated. NA can be taken to mean 'longer than we are able to estimate using these observations'.

3.2 Objective 2: To determine the proportion of badgers that are not recovered after being shot at with a firearm, and have firearm injuries

Field component

75. A total of 10 out of 88 observed shots had neither observation of last movement nor an observation for time to confirmed death because a carcase was not recovered. Signs of badger injury were found at the site of one of these non-recovered events. The shooters and observers reported the shots as misses in 6 of the non-recovered events. In three of the non-recovered events, behaviour indicating a hit was observed. Further descriptive information on each of these events is provided in Appendix 12.

76. From the binomial confidence interval for the observed proportion of non-recovered badgers, the proportion of non-recovered badgers after a rifle shot was estimated to lie somewhere between 6% and 19% (95% CI).

Laboratory component

77. One firearm associated skin wound categorised by the examining veterinarian based on the gross appearance of the wound at necropsy as a definite 'non-acute' injury (O appearance) was identified on a badger (unobserved) that was culled during week 5 of the pilot.

78. Two possible 'non-acute' firearm associated skin wounds (U appearance) were identified on a badger (observed) that was culled during week 6 of the pilot.

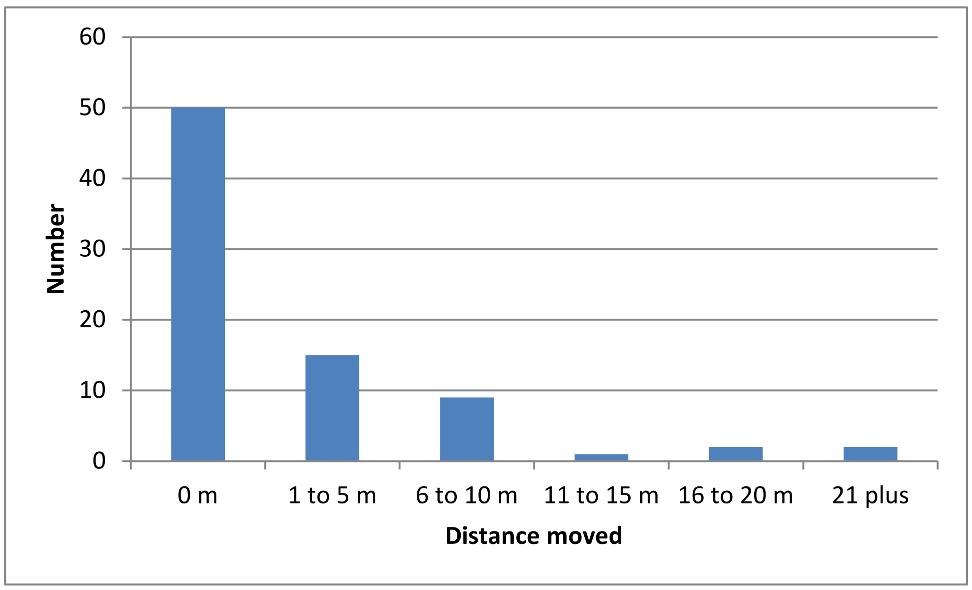
79. Histopathological investigation of the three skin wounds in the two carcases recorded above revealed evidence of peracute injury only; there was no histopathological evidence of an inflammatory or repair response in any of the wounds**.** Therefore, no confirmed 'non-acute' firearm injuries were detected in any of the 158 rifle shot badgers presented for necropsy. The absence of any confirmed 'non-acute' firearm injuries precluded any test for trend.

3.3 Objective 3: To describe the behaviour of badgers after being shot at with a firearm

80. Thermal image recordings of the behaviour of badgers after being shot at were obtained for 76 observed events where the weapon was a rifle (see Appendix 13 for an example). The behaviour of a further 7 badgers that were shot at was described in detail in the field notes. Audio recordings were available for the remaining 5 observed events, but insufficient detail was included to analyse the data for this Objective.

81. The behaviours displayed by badgers after being shot at included running (galloping and trotting), standing or sitting with fast erratic movement of the head, body and legs but no lateral movement, recumbency with smooth movement of the head, and recumbency with apparent involuntary movement of only the legs. Nineteen of the 74 badgers whose carcases were recovered and for which detailed behaviour was recorded ran after being shot at; the mean duration that badgers ran before collapsing was 7.5 seconds (range 1 to 15 seconds). Nine of the 10 badgers that were not recovered also ran after the shot was fired; the mean duration in view was 23 seconds (range 4 to 90 seconds). One of the non-recovered badgers initially collapsed, but had moved away from the shot site after a second shot was fired. Movement indicative of consciousness, including running, was seen in 58 of the 73 badgers whose carcases were recovered and detailed behaviour recorded. Behaviours indicative of consciousness continued for a mean of 30 seconds after the shot was taken (range 2 to 823 seconds). Badgers collapsed and showed only involuntary movement, if any, in 15 (18 %) of the recorded events. The mean distance that badger carcases were found away from where they were when the shot was taken was 3 metres (range 0 to 25 metres). Fifty (64%) of the recovered badger carcases were found at the site where they were shot. Vocalisations were heard in only a single event (1% of events). The vocalisation was described as a chatter.

Figure 6: The frequency with which badger carcases were found at different distance away from the site they were at when the shot was taken (n=78)



3.4 Objective 4: To determine the location of rifle entry wounds in the badger carcases recovered from observed and unobserved shootings

82. The results of the analysis, including sensitivity analysis, of first entry wound location in terms of anatomical unit (AU), for the 158 carcases presented for necropsy, are provided in Tables 4, 5 and 6. The results are presented for all carcases, and for the observed and unobserved subsets.

83. The results of the analysis, including sensitivity analysis, of first entry wound location in terms of target area set, for the 158 carcases presented for necropsy, are provided in Tables 7, 8 and 9. The results are presented for all carcases, and for the observed and unobserved subsets.

Table 4: Analysis of first entry wound location by anatomical unit – all carcases

	Results for carcases with certain† first entry wound location		Results of sensitivity analysis, which includes carcases with uncertain† first entry wound location			
			Minimum possible*		Maximum possible**	
Anatomical unit	**n**	**Proportion (95% CI)**	**n**	**Proportion (95% CI)**	**n**	**Proportion (95% CI)**
1	0	0% (0.0-2.4%)	0	0% (0.0-2.3%)	1	0.1% (0.0-3.5%)
2	4	2.7% (0.7-6.7%)	4	2.5% (0.7-6.4%)	5	3.2% (1.0-7.2%)
3	14	9.3% (5.2-15.2%)	14	8.9% (4.9-14.4%)	15	9.5% (5.4-15.2%)
4	31	20.7% (14.5-28.0%)	31	19.6%(13.7-26.7%)	34	21.5%(15.4-28.8%)
5	2	1.3% (0.2-4.7%)	2	1.3% (0.2-4.5%)	3	1.9% (0.4-5.4%)
6	25	16.7% (11.1-23.6%)	25	15.8%(10.5-22.5%)	27	17.1 (11.6-23.9%)
7	56	37.3% (29.6-45.6%)	56	35.4%(28.0-43.4%)	59	37.3%(29.8-45.4%)
8	0	0% (0.0-2.4%)	0	0% (0.0-2.3%)	0	0% (0.0-2.3%)
9	13	8.7% (4.7-14.4%)	13	8.2% (4.5-13.7%)	16	10.1 (5.9-15.9%)
10	5	3.3% (1.1-7.6%)	5	3.2% (1.0-7.2%)	7	4.4% (1.8-8.9%)
11	0	0% (0.0-2.4%)	0	0% (0.0-2.3%)	0	0% (0.0-2.3%)
12	0	0% (0.0-2.4%)	0	0% (0.0-2.3%)	0	0% (0.0-2.3%)
13	0	0% (0.0-2.4%)	0	0% (0.0-2.3%)	0	0% (0.0-2.3%)
14	0	0% (0.0-2.4%)	0	0% (0.0-2.3%)	0	0% (0.0-2.3%)
Total certain	150	100%				
Not certain	8	n/a				
Total	**158**					

*Minimum possible proportion of carcases with first entry wound in the AU; numerator = no. of carcases with certain status for first entry wound in that AU, denominator = all carcases (158)

**Maximum possible proportion of carcases with first entry wound in the AU; numerator = no. of carcases with certain or uncertain status for first entry wound in that AU, denominator = all carcases (158)

† in terms of AU

Minimum number of carcases with first entry wound location in AU 1, 2 or 3 was 18 (11.4% (CI: 6.9-17.4%)).

Table 5: Analysis of first entry wound location by anatomical unit – observed badgers

	Results for carcases with certain† first entry wound location		Results of sensitivity analysis, which includes carcases with uncertain† first entry wound location			
			Minimum possible*		Maximum possible**	
Anatomical unit	**n**	**Proportion (95% CI)**	**n**	**Proportion (95% CI)**	**n**	**Proportion (95% CI)**
1	0	0.0% (0.0-5.9%)	0	0.0% (0.0-5.6%)	0	0.0% (0.0-5.6%)
2	2	3.3% (0.4-11.3%)	2	3.1% (0.4-10.8%)	2	3.1% (0.4-10.8%)
3	3	4.9% (1.0-13.7%)	3	4.7% (1.0-13.1%)	4	6.3% (1.7-15.2%)
4	12	19.7% (10.6-31.8%)	12	18.8%(10.1-30.5%)	13	20.3%(11.3-32.2%)
5	0	0.0% (0.0-5.9%)	0	0.0% (0.0-5.6%)	0	0.0% (0.0-5.6%)
6	11	18.0% (9.4-30.0%)	11	17.2% (8.9-28.7%)	12	18.8%(10.1-30.5%)
7	27	44.3% (31.5-57.6%)	27	42.2%(29.9-55.2%)	28	43.8%(31.4-56.7%)
8	0	0.0% (0.0-5.9%)	0	0.0% (0.0-5.6%)	0	0.0% (0.0-5.6%)
9	6	9.8% (3.7-20.2%)	6	9.4% (3.5-19.3%)	6	9.4% (3.5-19.3%)
10	0	0.0% (0.0-5.9%)	0	0.0% (0.0-5.6%)	2	3.1% (0.4-10.8%)
11	0	0.0% (0.0-5.9%)	0	0.0% (0.0-5.6%)	0	0.0% (0.0-5.6%)
12	0	0.0% (0.0-5.9%)	0	0.0% (0.0-5.6%)	0	0.0% (0.0-5.6%)
13	0	0.0% (0.0-5.9%)	0	0.0% (0.0-5.6%)	0	0.0% (0.0-5.6%)
14	0	0.0% (0.0-5.9%)	0	0.0% (0.0-5.6%)	0	0.0% (0.0-5.6%)
Total certain	61	100%				
Not certain	3	n/a				
Total	**64**					

*Minimum possible proportion of carcases with first entry wound in the AU; numerator = no. of carcases with certain status for first entry wound in that AU, denominator = all observed carcases (64)

**Maximum possible proportion of carcases with first entry wound in the AU; numerator = no. of carcases with certain or uncertain status for first entry wound in that AU, denominator = all observed carcases (64)

† in terms of AU

Table 6: Analysis of first entry wound location by anatomical unit – unobserved badgers

	Results for carcases with certain† first entry wound location		**Results of sensitivity analysis, which includes carcases with uncertain† first entry wound location**			
			Minimum possible*		**Maximum possible****	
Anatomical unit	**n**	**Proportion (95% CI)**	**n**	**Proportion (95% CI)**	**n**	**Proportion (95% CI)**
1	0	0.0% (0.0-4.1%)	0	0.0% (0.0-3.8%)	1	1.1% (0.0-5.8%)
2	2	2.2% (0.3-7.9%)	2	2.1% (0.3-7.5%)	3	3.2% (0.7-9.0%)
3	11	12.4% (6.3-21.0%)	11	11.7% (6.0-20.0%)	11	11.7% (6.0-20.0%)
4	19	21.3% (13.4-31.3%)	19	20.2%(12.6-29.8%)	21	22.3%(14.4-32.1%)
5	2	2.2% (0.3-7.9%)	2	2.1% (0.3-7.5%)	3	3.2% (0.7-9.0%)
6	14	15.7% (8.9-25.0%)	14	14.9% (8.4-23.7%)	15	16.0% (9.2-25.0%)
7	29	32.6% (23.0-43.3%)	29	30.9%(21.7-41.2%)	31	33.0%(23.6-43.4%)
8	0	0.0% (0.0-4.1%)	0	0.0% (0.0-3.8%)	0	0.0% (0.0-3.8%)
9	7	7.9% (3.2-15.5%)	7	7.4% (3.0-14.7%)	10	10.6% (5.2-18.7%)
10	5	5.6% (1.8-12.6%)	5	5.3% (1.7-12.0%)	5	5.3% (1.7-12.0%)
11	0	0.0% (0.0-4.1%)	0	0.0% (0.0-3.8%)	0	0.0% (0.0-3.8%)
12	0	0.0% (0.0-4.1%)	0	0.0% (0.0-3.8%)	0	0.0% (0.0-3.8%)
13	0	0.0% (0.0-4.1%)	0	0.0% (0.0-3.8%)	0	0.0% (0.0-3.8%)
14	0	0.0% (0.0-4.1%)	0	0.0% (0.0-3.8%)	0	0.0% (0.0-3.8%)
Total certain	89	100%				
Not certain	5	n/a				
Total	**94**					

*Minimum possible proportion of carcases with first entry wound in the AU; numerator = no. of carcases with certain status for first entry wound in that AU, denominator = all unobserved carcases (94)

**Maximum possible proportion of carcases with first entry wound in the AU; numerator = no. of carcases with certain or uncertain status for first entry wound in that AU, denominator = all unobserved carcases (94)

† in terms of AU

Table 7: Analysis of first entry wound location by target area set – all carcases

	Results for carcases with certain† first entry wound location		Results of sensitivity analysis, which includes carcases with uncertain† first entry wound location			
			Best case scenario*		Worst case scenario**	
Target area set	**n**	**Proportion (95% CI)**	**n**	**Proportion (95% CI)**	**n**	**Proportion (95% CI)**
Inside target area	56	36.1% (28.6-44.2%)	59	37.3% (29.8-45.4%)	56	35.4% (28.0-43.4%)
Outside target area	99	63.9% (55.8-71.4%)	99	62.7% (54.6-70.2%)	102	64.6% (56.6-72.0%)
Total certain	155	100%				
Not certain	3	n/a				
Total	**158**	**100%**	**158**	**100%**	**158**	**100%**

*For carcases of uncertain status, it was assumed that the first entry wound location was actually present in the ‘inside target area’ set. Denominator = all carcases (158)

** For carcases of uncertain status, it was assumed that the first entry wound location was actually in the ‘outside target area’ set. Denominator = all carcases (158)

† in terms of target area set

Table 8: Analysis of first entry wound location by target area set - observed badgers

	Results for carcases with certain† first entry wound location		Results of sensitivity analysis, which includes carcases with uncertain† first entry wound location			
			Best case scenario*		Worst case scenario**	
Target area set	**n**	**Proportion (95% CI)**	**n**	**Proportion (95% CI)**	**n**	**Proportion (95% CI)**
Inside target area	27	42.9% (30.5-56.0%)	28	43.8% (31.4-56.7%)	27	42.2% (29.9-55.2%)
Outside target area	36	57.1% (44.0-69.5%)	36	56.3% (43.3-68.6%)	37	57.8% (44.8-70.1%)
Total certain	63	100%				
Not certain	1	n/a				
Total	**64**	**100%**	**64**	**100%**	**64**	**100%**

*For carcases of uncertain status, it was assumed that the first entry wound location was actually present in the 'inside target area' set. Denominator = all observed carcases (64)

** For carcases of uncertain status, it was assumed that the first entry wound location was actually in the 'outside target area' set. Denominator = all observed carcases (64)

† in terms of target area set

Table 9: Analysis of first entry wound location by target area set – unobserved badgers

	Results for carcases with certain† first entry wound location		Results of sensitivity analysis, which includes carcases with uncertain† first entry wound location			
			Best case scenario*		Worst case scenario**	
Target area set	**n**	**Proportion (95% CI)**	**n**	**Proportion (95% CI)**	**n**	**Proportion (95% CI)**
Inside target area	29	31.5% (22.2-42.0%)	31	33.0% (23.6-43.4%)	29	30.9% (21.7-41.2%)
Outside target area	63	68.5% (58.0-77.8%)	63	67.0% (56.6-76.4%)	65	69.1% (58.8-78.3%)
Total certain	92	100%				
Not certain	2	n/a				
Total	**94**	**100%**	**94**	**100%**	**94**	**100%**

*For carcases of uncertain status, it was assumed that the first entry wound location was actually present in the 'inside target area' set. Denominator = all unobserved carcases (94)

** For carcases of uncertain status, it was assumed that the first entry wound location was actually in the 'outside target area' set. Denominator = all unobserved carcases (94)

† in terms of target area set

Figure 7: Bar chart showing proportion of carcases with first entry wound location in each anatomical unit (carcases with certain AU first entry wound location only)

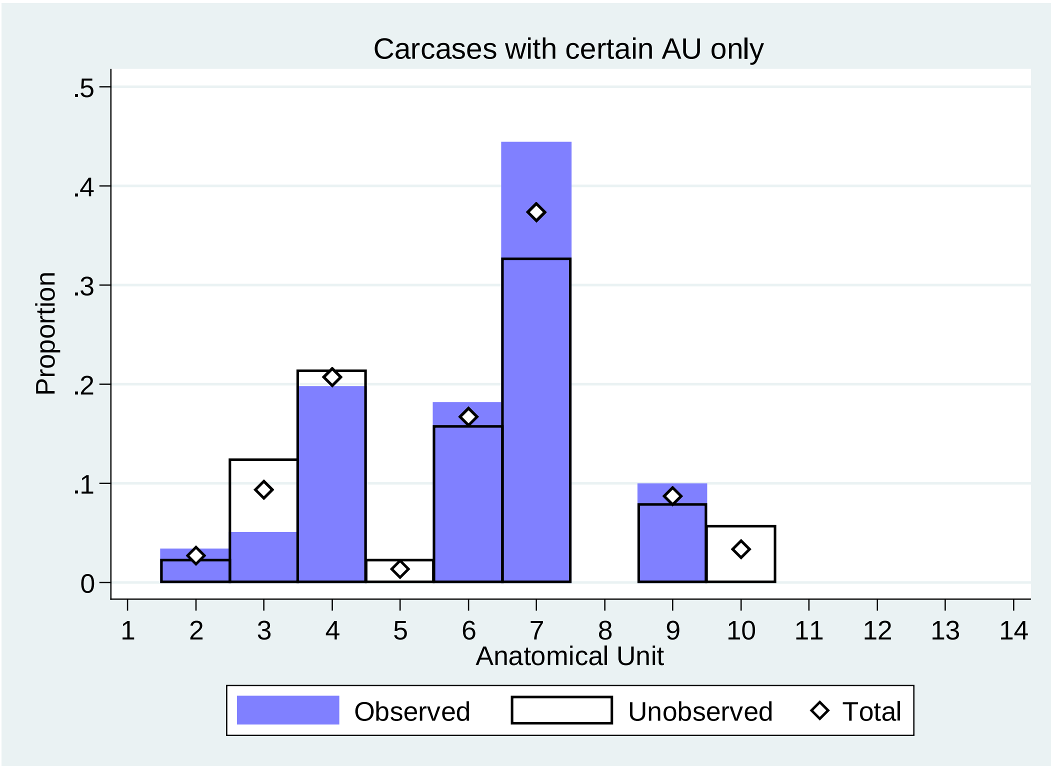


Figure 8: Bar chart showing proportion of carcases with first entry wound location in each target area set (carcases with certain target area set first entry wound location only)

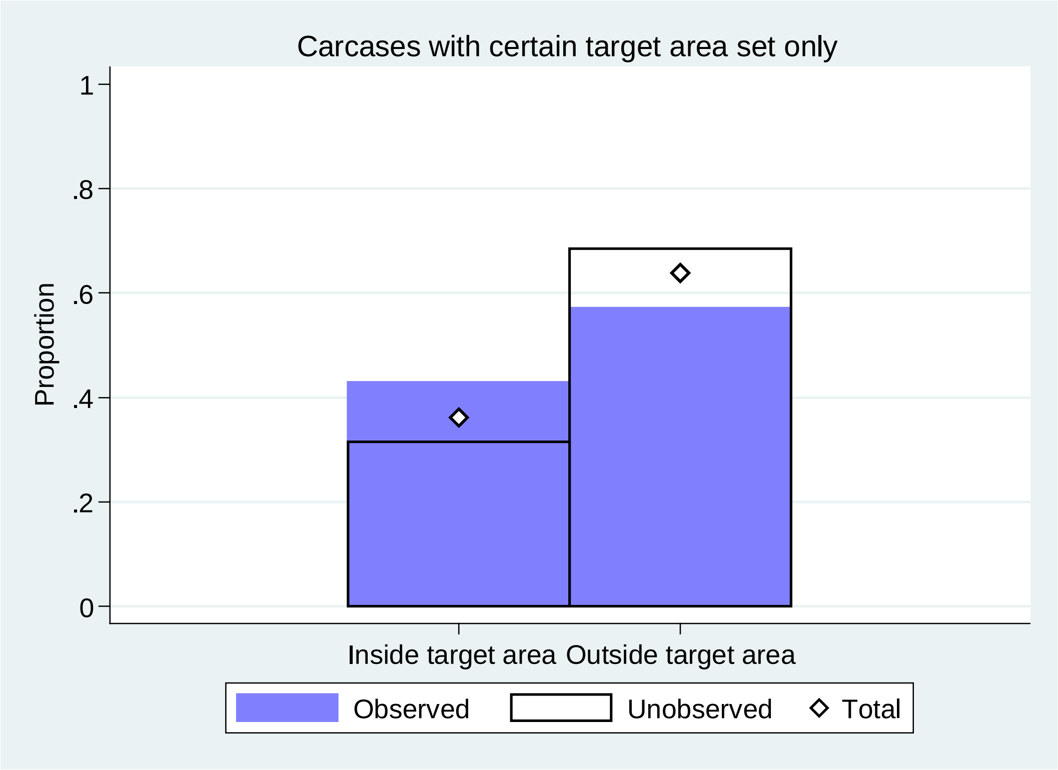


Figure 9: Diagram showing proportions of first entry wound locations by anatomical unit, for observed badgers (carcases with certain AU first entry wound location only)

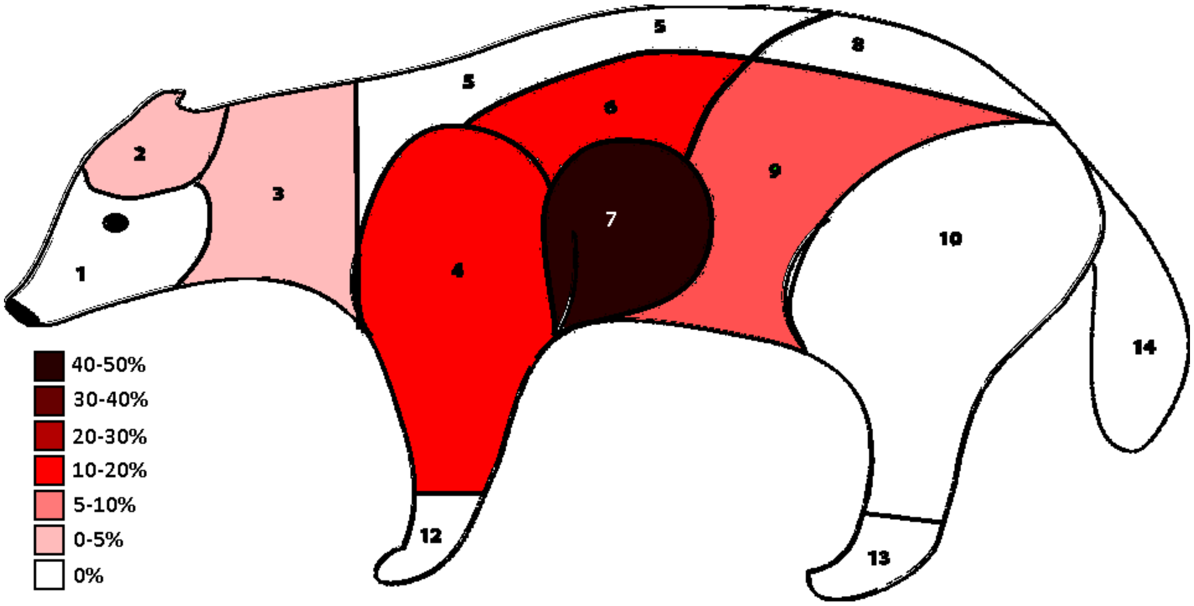
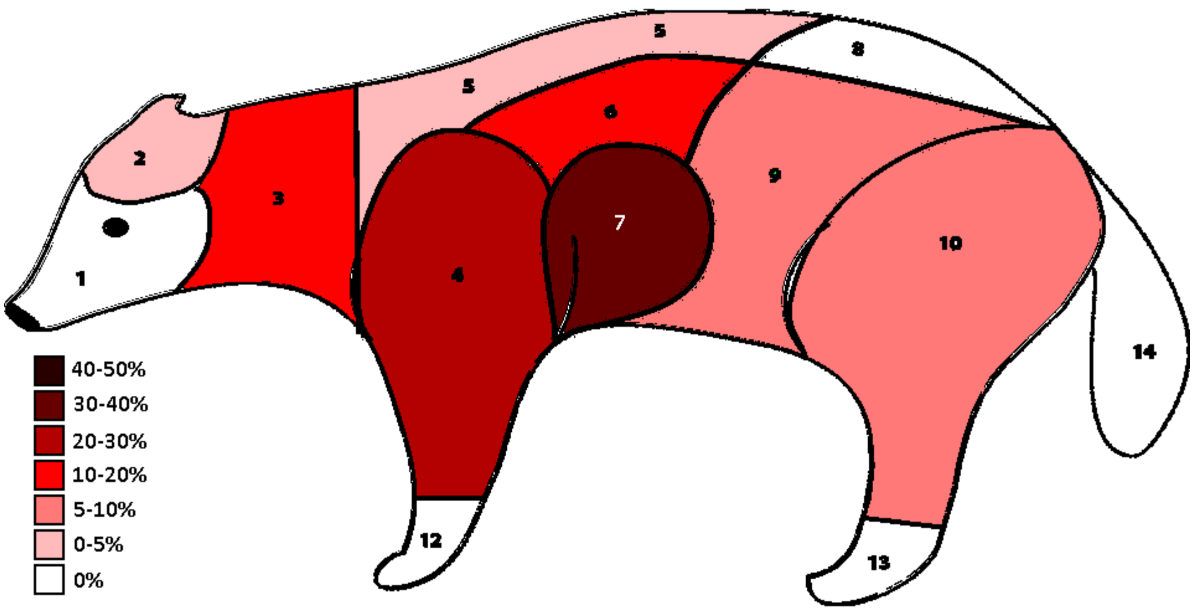


Figure 10: Diagram showing proportions of first entry wound locations by anatomical unit, for unobserved badgers (carcases with certain AU first entry wound location only)



84. For carcases where the target area set status could be determined with certainty, the proportion of first entry wounds that was ‘inside target area’ was 36.1% (28.6-44.2%). Assuming the ‘best case scenario’ (that the carcases of uncertain status actually had the first entry wound location in the ‘best’ of the possible set options (the ‘inside target area’ set)), the proportion of first entry wounds that was ‘inside target area’ was 37.3% (29.8-45.4%). Assuming the ‘worst case scenario’ (that the carcases of uncertain status actually had the first entry wound location in the ‘worst’ of the possible set options (the ‘outside target area’ set)), the proportion of first entry wounds that was ‘inside target area’ was 35.4% (28.0-43.4%).

85. For six of the eight carcases that had an uncertain status for first entry wound location in terms of AU, the examining veterinarian was confident that multiple shots had hit the badger during the fatal shooting event. In these cases, it was the multiple shots and associated multiple candidate first shot entry wound locations that resulted in the uncertainty about first entry wound location. These six carcases are included in Table 10, which summarises all carcases where laboratory investigation revealed evidence of multiple shots hitting the badger.

Table 10: Summary of carcases where laboratory examination revealed evidence of multiple shots hitting the badger

Carcase EID	Observation status	Number of shots that hit the badger (based on the necropsy and radiology findings)	Reported number of shots (from the field observations)	Anatomical units (AUs) where candidate entry wounds were present	Comment
CWG062 00012	Unobserved	2	Not applicable	7, 9	
CWG029 00026	Observed	2	2	7, 10	
CWG004 00005	Unobserved	3	Not applicable	1, 4, 9	
CWS099 00005	Unobserved	2	Not applicable	7, 9	
CWG060 00008	Unobserved	2	Not applicable	2, 4	
CWG048 00003	Observed	2	6	3, 6	
CWG005 00003	Observed	2	2	4, 10	Skin wounds associated with one of the shots were categorised as of uncertain 'age' based on their gross appearance.
CWG 073 00010	Unobserved	2	Not applicable	5, 7	Skin wound associated with one of the shots was categorised as 'non-acute' based on its gross appearance.

86. Further descriptive information on the necropsy findings for the 'multiple shot' carcases listed in Table 10 is provided in Appendix 14.

3.5. Objective 5: To determine the extent of internal firearm injuries in the badger carcases recovered from observed and unobserved shootings

87. The six ‘acute’ lesion profile groups derived by veterinary review are presented in Table 11. For the 158 carcases presented for necropsy, the proportion of carcases assigned to each ‘acute’ lesion profile group, based on veterinary opinion, is provided in Table 12. The proportions in Table 12 are presented for all carcases, and the observed and unobserved subsets.

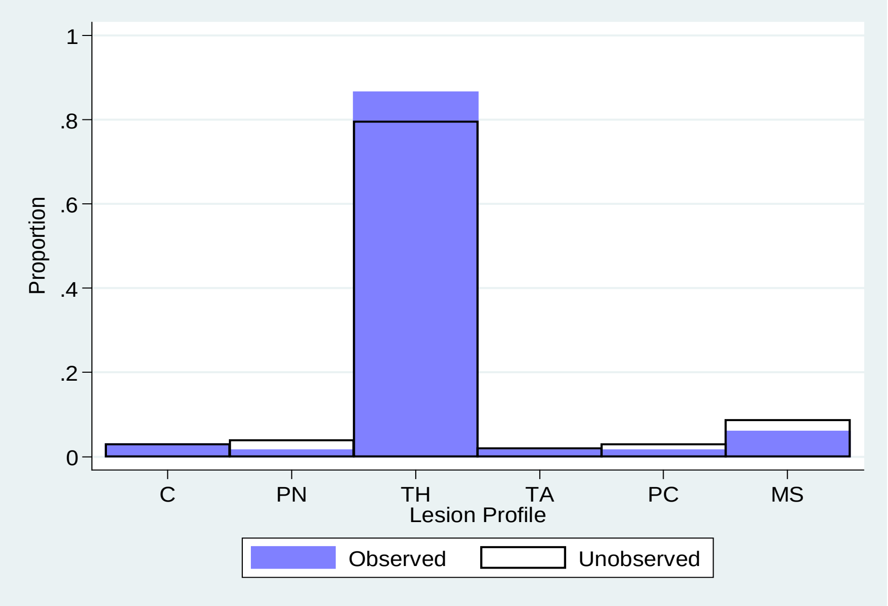
Table 11: The ‘acute’ lesion profile groups derived by veterinary review

Abbreviation for group name	Group name	Group characteristics
C	Cranium	Injury to the cranium
PN	Primary neck	Lesions were primarily recorded within cervical structures, with no injury to the cranium, and those where the thorax was involved had no heart injury or intra-thoracic haemorrhage resulting in >25ml of free blood in the thoracic cavity
TH	Thorax with heart injury and/or >25 ml of free blood in the thoracic cavity +/- injury to other tissues	Injury to the heart and/or the presence of >25 ml of free blood within the thoracic cavity (representing significant damage to thoracic major blood vessels and/or the heart)
TA	Thorax +/- abdomen with no record of heart injury or major blood vessel damage or haemorrhage of >25 ml into the abdominal/thoracic cavity	Injury to the thorax +/- abdomen, with no evidence of heart injury or significant haemorrhage into body cavities or damage to major blood vessels
PC	Primary caudal	Lesion distribution primarily involving the abdomen, lumbar spine and hind legs
MS	Multiple shots	The examining veterinarian’s findings were consistent with more than one shot hitting the badger during the fatal shooting event

Table 12: Proportion of carcases assigned to each 'acute' lesion profile group

Lesion profile group	Observed		Unobserved		Total	
	n	**% (95% CI)**	**n**	**% (95% CI)**	**n**	**% (95% CI)**
C	2	3.1% (0.4-10.8%)	3	3.2% (0.7-9.0%)	5	3.2% (1.0-7.2%)
PN	1	1.6% (0.0-8.4%)	4	4.3% (1.2-10.5%)	5	3.2% (1.0-7.2%)
TH	57	89.1% (78.8-95.5%)	78	83.0% (73.8-89.9%)	135	85.4% (79.0-90.5%)
TA	1	1.6% (0.0-8.4%)	2	2.1% (0.3-7.5%)	3	1.9% (0.4-5.4%)
PC	1	1.6% (0.0-8.4%)	3	3.2% (0.7-9.0%)	4	2.5% (0.7-6.4%)
MS	2	3.1% (0.4-10.8%)	4	4.3% (1.2-10.5%)	6	3.8% (1.4-8.1%)
Total	64	100%	94	100%	158	100%

Figure 11: Bar chart showing proportion of carcases in each 'acute' lesion profile group, for observed and unobserved badgers



88. For 10 of the carcases (4 observed and 6 unobserved) not assigned a 'TH' 'acute' lesion profile group, necropsy showed an absence of firearm injury to the heart and lungs, combined with an absence of significant intra-thoracic haemorrhage (>25ml of free blood within the thoracic cavity). Further descriptive information on the necropsy findings for these ten carcases is provided in Appendix 15.

Tables 13 and 14: Contingency tables for location of first entry wound (by anatomical unit) in a carcase versus the 'acute' lesion profile group of the carcase

Observed badgers (n=62)

'Acute' lesion profile group	Anatomical unit (AU) containing first entry wound													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
C	0	2	0	0	0	0	0	0	0	0	0	0	0	0
PC	0	0	0	0	0	0	0	0	1	0	0	0	0	0
PN	0	0	1	0	0	0	0	0	0	0	0	0	0	0
TA	0	0	0	0	0	0	0	0	1	0	0	0	0	0
TH	0	0	2	13	0	11	27	0	4	0	0	0	0	0
Total	0	2	3	13	0	11	27	0	6	0	0	0	0	0

Fisher's exact test of independence between 'acute' lesion profile group and AU: $p<0.001$

89. Both of the observed carcases assigned a lesion profile group category of 'MS' were excluded from this analysis. See section 2.4.5 for details of the exclusion criteria applied.

Unobserved badgers (n=89)

'Acute' lesion profile group	Anatomical unit (AU) containing first entry wound													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
C	0	2	0	1	0	0	0	0	0	0	0	0	0	0
PC	0	0	0	0	0	0	0	0	1	2	0	0	0	0
PN	0	0	3	1	0	0	0	0	0	0	0	0	0	0
TA	0	0	0	0	0	0	1	0	1	0	0	0	0	0
TH	0	0	8	17	2	14	28	0	5	3	0	0	0	0
Total	0	2	11	19	2	14	29	0	7	5	0	0	0	0

Fisher's exact test of independence between 'acute' lesion profile group and AU: $p<0.001$

90. All four of the unobserved carcases assigned an 'acute' lesion profile group category of 'MS' were excluded from this analysis. A single further carcase was excluded because its first entry wound location in terms of AU was uncertain. See section 2.4.5 for details of the exclusion criteria applied.

3.6. Objective 6: To investigate whether there is any evidence of correlation between the times to death determined by Objective 1 and the firearm injuries in badger carcases recovered from observed shootings

91. Seventy eight carcases were recovered from observed shooting events, but 14 of these carcases were not presented to the laboratory site for necropsy and radiological investigation. Three observed badgers submitted for necropsy and radiological investigation showed evidence of multiple shots having hit the badger (see Table 10), resulting in exclusion of these carcases from the analyses for this Objective, but the times to last movement associated with these three badgers are described separately at the end of this section.

92. Seven of the remaining 61 observed badgers did not have a time of last movement observed, resulting in an absence of a point estimate of time to death for these animals. The remaining 54 badgers compose the subset used for the main analysis for this Objective. Supplementary analyses were undertaken, which included the 61 badgers with and without an observed time from first shot to last movement.

93. None of the 61 badgers included in the analyses were of uncertain status for first entry wound location in terms of target area set.

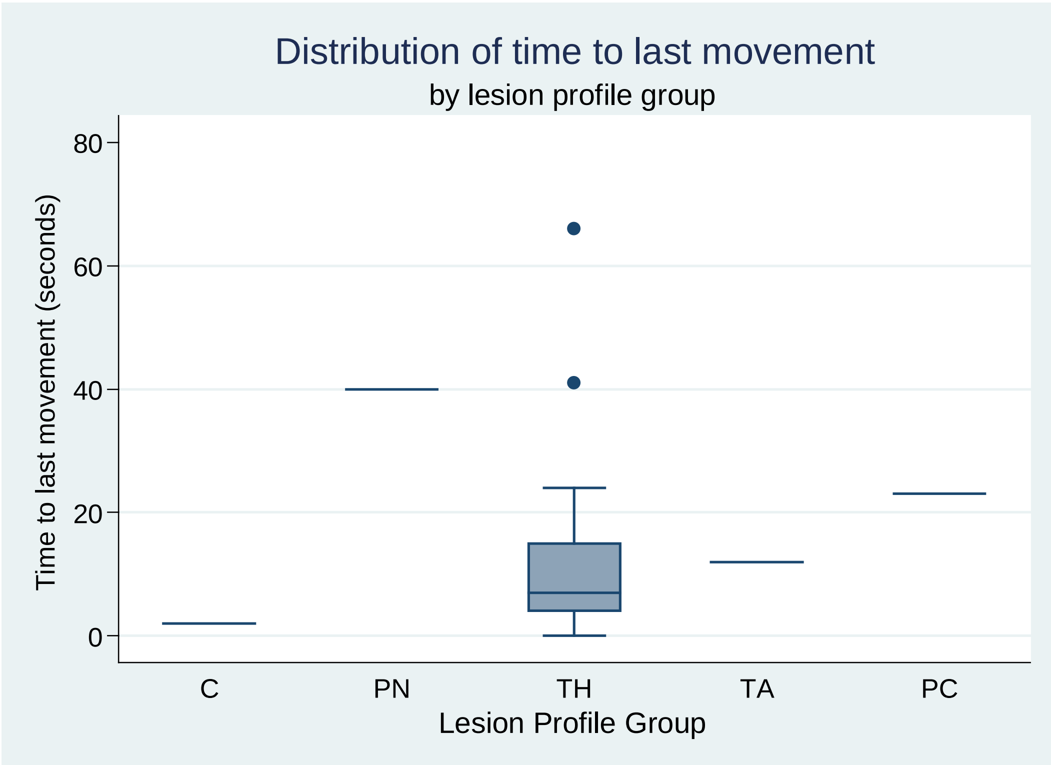
<u>Main Objective 6 analysis by 'acute' lesion profile group</u>

94. Table 15 and Figure 12 below show the distribution of time from first shot to last movement, by 'acute' lesion profile group, for the subset of 54 badgers.

Table 15: Distribution of time from first shot to last movement, by 'acute' lesion profile group, for the subset of 54 badgers

'Acute' lesion profile group	n	Median time from first shot to last movement (seconds)	Interquartile range of time from first shot to last movement (seconds)	Range of time from first shot to last movement (seconds)
C	1	2	Not applicable	Not applicable
PN	1	40	Not applicable	Not applicable
TH	50	7	4-15	0-66
TA	1	12	Not applicable	Not applicable
PC	1	23	Not applicable	Not applicable

Figure 12: Box and whisker plot of distribution of time from first shot to last movement, by 'acute' lesion profile group, for the subset of 54 badgers



Key: The box is the 25th-75th percentiles. The line in the box is the median. The ends of the whiskers are the limits of the bulk of the data. The dots are outliers.

95. The presence of only a single carcase in each of all but one of the five 'acute' lesion profile groups considered for this subset of badgers precluded any investigation for evidence of correlation between time from first shot to last movement and 'acute' lesion profile group.

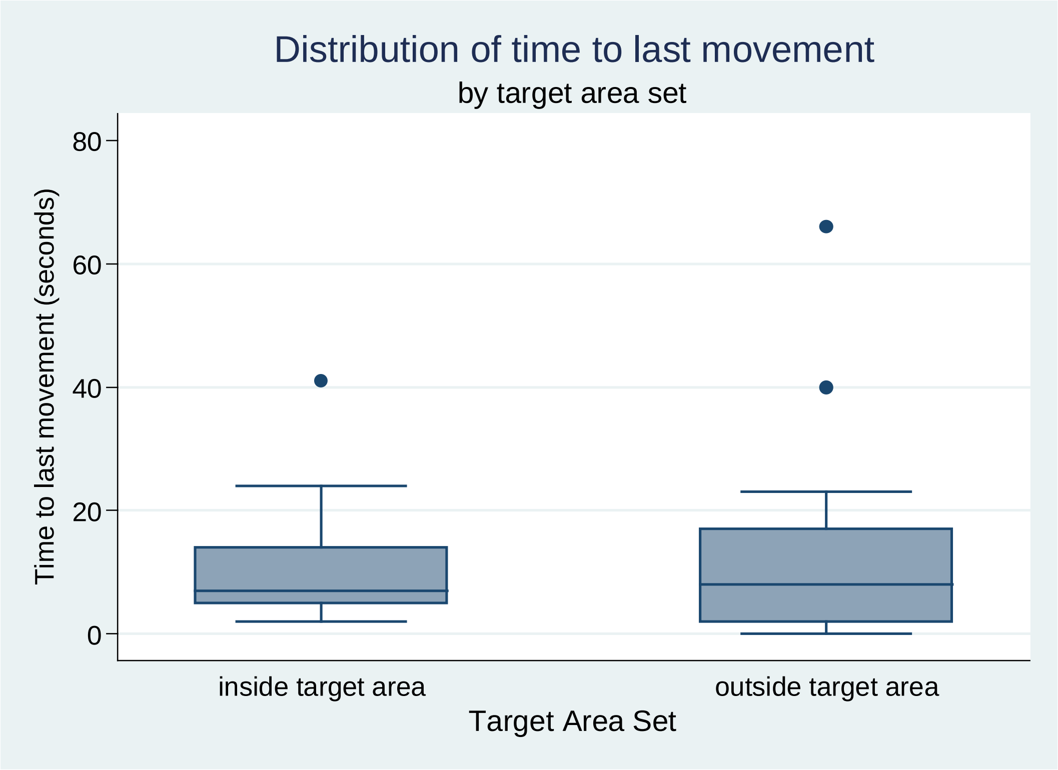
Main Objective 6 analysis by target area set

96. Table 16 and Figure 13 below show the distribution of time from first shot to last movement, by target area set, for the subset of 54 badgers.

Table 16: Distribution of time from first shot to last movement, by target area set, for the subset of 54 badgers

Target area set	n	Median time from first shot to last movement (seconds)	Interquartile range of time from first shot to last movement (seconds)	Range of time from first shot to last movement (seconds)
Inside target area	23	7	5-14	2-41
Outside target area	31	8	2-17	0-66

Figure 13: Box and whisker plot of distribution of time from first shot to last movement, by target area set, for the subset of 54 badgers



Key: The box is the 25th-75th percentiles. The line in the box is the median. The ends of the whiskers are the limits of the bulk of the data. The dots are outliers.

97. Comparison of the distributions of time from first shot to last movement for the two target area sets, using the Kolmogorov-Smirnov test, gave a result of p=0.762. There was no evidence of a significant difference in distribution of time from first shot to last movement between carcases categorised as having first entry wounds 'inside target area' and those categorised as having first entry wounds 'outside target area'.

98. All 54 badgers that composed the subset for the main analysis for Objective 6 had a time from first shot to last movement of 66 seconds or less.

Supplementary Objective 6 analysis

99. For this supplementary analysis, the 'acute' lesion profile groups and target area sets for the badgers with (n=54) and without (n=7) an observed time from first shot to last movement were tabulated and tested for any important differences between the group with an observed time of last movement and the group without an observed time of last movement.

Table 17: 'Acute' lesion profile groups for carcases with and without an observed time of last movement

'Acute' lesion profile group	Time of last movement not observed		Time of last movement observed	
	n	% (95% CI)	n	% (95% CI)
C	1	14.3% (0.4-57.9%)	1	1.9% (0.0-9.9%)
PN	0	0% (0-41.0%)	1	1.9% (0.0-9.9%)
TH	6	85.7% (42.1-99.6%)	50	92.6% (82.1-97.9%)
TA	0	0% (0-41.0%)	1	1.9% (0.0-9.9%)
PC	0	0% (0-41.0%)	1	1.9% (0.0-9.9%)
Total	7	100%	54	100%

Fisher's exact test of independence between 'acute' lesion profile group and whether or not last movement was observed: p=0.468

100. There was no evidence of a relationship between 'acute' lesion profile group and whether or not a time of last movement was observed.

Table 18: Target area sets for carcases with and without an observed time of last movement

Target area set	Time of last movement not observed		Time of last movement observed	
	n	% (95% CI)	n	% (95% CI)
Inside target area	4	57.1% (18.4-90.1%)	23	42.6% (29.2-56.8%)
Outside target area	3	42.9% (9.9-81.6%)	31	57.4% (43.2-70.8%)
Total	7	100%	54	100%

Fisher's exact test of independence between target area set and whether or not last movement was observed: p=0.689

101. There was no evidence of a relationship between target area set and whether or not a time of last movement was observed.

<u>Observed badgers hit by multiple shots</u>

102. A time from first shot to last movement was available for each of the three observed badgers that had been hit by multiple shots. The times to last movement for these badgers are provided in Table 19 below.

Table 19: Time from first shot to last movement, 'acute' lesion profile group and target area set for the three observed badgers hit by multiple shots

Carcase EID	Time from first shot to last movement (seconds)	'Acute' lesion profile group	Target area set
CWG005 00003	14	TH	Outside target area
CWG029 00026	27	MS	Uncertain
CWG048 00003	823	MS	Outside target area

3.7. Objective 7: To compare the firearm injuries in badger carcases recovered from observed shootings with those in badger carcases recovered from unobserved shootings

Paired analyses

103. The selection protocol for the pairs of badgers resulted in 22 pairs where the necropsy of the unobserved badger was carried out before that of its paired observation, and 21 pairs where the necropsy of the unobserved badger was carried out on a date after that of its paired observation. For two pairs, necropsy of the observed and unobserved badgers was carried out on the same date.

Table 20: Classification of badger pairs (one observed and one unobserved badger per pair), matched for contractor, in terms of 'acute' lesion profile group ('TH' or 'not-TH') (n=45)

For this classification, the 'acute lesion profile groups were collapsed to 'TH' and 'not-TH'

		Unobserved	
		'TH'	**'Not-TH'**
Observed	**'TH'**	35	**6**
	'Not-TH'	*4*	0

Exact McNemar's test: p=0.754

104. The numbers in **bold** and *italics* are for pairs where the unobserved badger classification was different to the observed badger classification. Numbers in plain text are for pairs where both members of the pair had the same classification.

105. The exact McNemar's test was used to consider the 'discordant' cells (the pairs where the observed and unobserved badgers did not have the same classification).This test considers whether the numbers in these two cells were spread evenly between the two cells; the null hypothesis was that the numbers in the two cells do not differ. This test gave a result of p=0.754. Therefore, for the pairs of badgers where the outcome of each event was different, there was no evidence that the unobserved shooting events were less likely to result in a 'TH' 'acute' lesion profile group than observed shooting events.

Table 21: Classification of badger pairs (one observed and one unobserved badger per pair), matched for contractor, in terms of target area set – pairs where both members had a certain target area set (n=43)

		Unobserved	
		Inside target area	**Outside target area**
Observed	**Inside target area**	7	**13**
	Outside target area	*5*	18

Exact McNemar's test: p=0.096

106. The number in **bold** and *italics* are for pairs where the unobserved badger classification was different to the observed badger classification. Numbers in plain text are for pairs where both members of the pair had the same classification.

107. The exact McNemar's test gave a result of p=0.096, showing weak evidence of a tendency for observed shooting events to be more 'on target' than unobserved shooting events amongst the pairs where each event had a different outcome.

Unpaired analyses

Table 22: Distribution of target area set after carcases with an uncertain target area set have been assigned a target area set to maximise the difference between observed and unobserved badgers

	Observed		**Unobserved**		**Total**
	n	**% (95% CI)**	**n**	**% (95% CI)**	
Inside target area	28	43.8% (31.4-56.7%)	29	30.9% (21.7-41.2%)	57
Outside target area	36	56.3% (43.3-68.6%)	65	69.1% (58.8-78.3%)	101
Total	64		94		158

Chi-squared test of independence between target area set and observation status: p=0.097

108. In Table 22 above, the difference between observed and unobserved badgers was maximised by assigning the 'inside target area' set to one observed badger of uncertain status and the 'outside target area' set to two unobserved badgers of uncertain status, resulting in a difference in proportion of 'inside target area', between observed and unobserved, of 12.9%. Even when assigning the target area set for badgers of uncertain status in this way, the chi-squared test of independence between target area set and observation status was not significant at the 5% level.

Table 23: Distribution of 'acute' lesion profile group, for observed and unobserved badgers

	Observed		Unobserved		Total	
	n	**% (95% CI)**	**n**	**% (95% CI)**	**n**	**% (95% CI)**
C	2	3.1% (0.4-10.8%)	3	3.2% (0.7-9.0%)	5	3.2% (1.0-7.2%)
PN	1	1.6% (0.0-8.4%)	4	4.3% (1.2-10.5%)	5	3.2% (1.0-7.2%)
TH	57	89.1% (78.8-95.5%)	78	83.0% (73.8-89.9%)	135	85.4% (79.0-90.5%
TA	1	1.6% (0.0-8.4%)	2	2.1% (0.3-7.5%)	3	1.9% (0.4-5.4%)
PC	1	1.6% (0.0-8.4%)	3	3.2% (0.7-9.0%)	4	2.5% (0.7-6.4%)
MS	2	3.1% (0.4-10.8%)	4	4.3% (1.2-10.5%)	6	3.8% (1.4-8.1%)
Total	64	100%	94	100%	158	100%

Fisher's exact test of independence between 'acute' lesion profile group and observation status: p=0.937.

109. There was no evidence of a relationship between 'acute' lesion profile group and the observation status of the badger.

3.8. Other results

110. Additional descriptive statistics from the field observations and laboratory investigations are provided in Appendices 16 and 17 respectively.

4. Discussion

111. The overall aim of this monitoring study was to collect data and present results to allow an assessment of the humaneness of culling badgers using controlled shooting. To undertake such an assessment, a comparison with shooting of other wild animal species could be undertaken. Such an assessment will not be discussed by the authors of this report, but data relating to the humaneness of management techniques employing culling in other wild animal species are presented in Appendix 18.

4.1. Objective 1: To determine the time period between the first shot taken at the badger and death of the badger, and

Objective 2 (Field component): To determine the proportion of badgers that are not recovered after being shot at with a firearm, and have firearm injuries

112. The aim of these Objectives was to determine the time to death for badgers after being shot and the proportion of non-recovered carcases. The time to death was different for each individual badger. Hence, the time to death for the population was summarised as the time by which a certain proportion of badgers were dead after being shot. Due to the non-recovered badgers impacting on the statistical analysis for Objective 1, a discussion of these two Objectives was combined. The time to death was not directly observed for all badgers shot at, and secondly the observations were a sample from a larger population, therefore these summary times were given as an interval rather than a single value. If the observations were a representative random sample from the whole population, and the assumptions underlying the data treatments were true, then the true value of the time to death lies within this interval with high confidence.

113. The time to death for the population was estimated using three data treatments; worst case, censored case and modelled case. For both the worst and censored data treatments, it was assumed that the time to death for badgers where the last movement was not observed but carcases were recovered occurred immediately prior to confirmation of death. Where carcases were not recovered, a conservative outcome was assumed for these badgers, i.e. death occurred at a time longer than the longest estimated time of death, for the modelled and worst data treatments. The Independent Expert Panel will need to consider the most appropriate approach to deal with the uncertainties associated with the incomplete observations.

114. Under the 'censored' data treatment, it was estimated that somewhere between 62% and 81% of badgers were dead within 40 seconds of a shot being taken, and that somewhere between 80% and 94% of badgers were dead within 823 seconds of a shot being taken. The estimated time to death for 80% of the population was between 40 and 823 seconds with 95% confidence, hence, the time within which *at least* 80% of badgers were dead was estimated to be 823 seconds. It was possible that 80% of badgers were dead within 40 seconds of being shot.

115. Under the 'worst case' data treatment, it was estimated that somewhere between 62% and 81% of badgers were dead within 41 seconds of a shot being taken, and that somewhere between *just below* 80% and 94% of badgers were dead within 7200 seconds of a shot being taken. The estimated time to death for 80% of the population was at least 41 seconds, but an upper limit could not be estimated, hence, the time within which *at least* 80% of badgers were dead could not be estimated. It is possible that 80% of badgers may be dead within 41 seconds.

116. Under the 'modelled case', it was estimated that the time within which *at least* 80% of badgers were dead was 823 seconds.

117. The results from Objective 6 can be used to indicate which of the assumptions behind the treatment of data relating to badgers whose carcases were recovered but the times of last movement were not observed was likely to be met in practice. The 'acute' lesion profile and shot-placement results of the badgers to which these data treatments were applied were found to be more similar than expected by chance to the badgers for which a time from first shot to last movement was observed; this suggests that these badgers were from the same population as the 69 badgers for whom a time from first shot to last movement was recorded. Hence, the modelled treatment may be the most appropriate.

118. Intervals for time to death by which *at least* 80% of badgers were dead cannot be estimated because of the influence of the 10 badgers that were not recovered and the assumption that the time to death for these badgers was ‘long’.

119. It was estimated that between 6% and 19% (95% CI) of badgers shot at during controlled shooting with a rifle were not recovered. Given the uncertainty about the outcome of the observed events where badgers were not recovered, the Independent Expert Panel will need to consider how best to assess the possible rate of wounding.

120. It had been highlighted prior to the study that the classification of events where a shot was taken but no carcase was recovered was likely to be difficult. It had therefore been agreed with the Independent Expert Panel prior to the study, that all non-recovered carcase events would be classified as events where the badger had been hit by the bullet, irrespective of the evidence in the field. This follows convention in other areas of animal welfare and the approach taken in medical trials, i.e. to assign the worst case outcome for these events. One of the non-recovered badgers collapsed after the first shot was fired, and left a pool of blood at the shot site (Event ID: **170913/417/01**). A second non-recovered badger was reported by the observer to run with an abnormal gait (Event ID: **300913/522/01**). A third non-recovered badger appeared to have a heat spot indicative of an injury after the shot had been fired, and to show an abnormal gait (Event ID: **310813/19/01**).

121. Seven of the ten badgers that were shot at and not recovered ran with a normal gait after the shot had been fired; blood and/or visceral tissue was not found at the shot site. Identical observations and an initial belief by the contractor that the shot was a miss were witnessed for one badger whose carcase was recovered two hours after the event (Event ID: **050913/417/01**).

122. Furthermore, the initial behavioural response of many badgers that were fatally wounded was to run, without showing any abnormal gait at least at the outset. Many of the badgers whose carcases were recovered did not leave any blood or body tissue at the shot site. This latter observation was supported by the necropsy observations, where entry wounds were usually of a small diameter, and not all carcases had exit wounds present; therefore limiting the potential for blood or tissue to exit the body in some cases.

123. To ensure that the data obtained were representative of all badgers killed by rifle, all factors that could influence the outcome must feature within the sample population. The observation data were gathered under weather conditions from mild through to wet and windy. The main category of weather conditions under which shots were not observed was during temperatures close to and below freezing, in both wet and dry situations. The topography of the landscape was restricted to West Somerset and West Gloucestershire; these two areas are different and representative of the landscape types found within the South West of England. The observed contractors used 11 different calibres of rifle and 13 different bullet weights, with either soft or ballistic tips (see Appendix 16).

124. All contractors issued with a licence to kill badgers had attended and passed a training course, however none of the contractors had previous experience of shooting badgers. Over the course of the pilot some contractors gained much experience of shooting badgers and others much less. Observations were obtained for all types of contractor, those who shot only very few badgers and those who shot many. Halfway through the pilot in West Somerset, additional contractors who were not familiar with the area were deployed; data were also obtained from these contractors. Towards the end of the cull, there may have been an increased pressure on the contractors to take less than ideal shots. Observations were obtained over the whole of the pilot period until the last night of activity. The aim was to obtain observations with as wide a range of scenarios as possible, the Independent Expert Panel will need to consider if the sample population was representative of the contractor population.

125. For this Objective, time from first shot to last movement was used as a proxy for time to death. This approach has been used in several previous wildlife studies of shooting (e.g. Butterworth et al 2007). On no occasion was a

badger that had become immobile found alive when contact was made. In all but one badger, any movements continued for several seconds before decreasing in complexity and then ceasing. The badger that was conscious for 13 minutes and 43 seconds after the first shot was taken, showed 6 periods of inactivity, ranging from 4 to 22 seconds. This was the only badger that showed behaviour consistent with consciousness after a period of observed inactivity.

126. In 70% of cases, time from first shot to last movement was determined to be shorter during review of the thermal camera images than that measured using a stopwatch by the observers in the field. This was not unexpected given the difficult conditions that the observers were working in while collecting the data. The extreme conditions the observers experienced were working during darkness, working in the presence of anti-cull protestors and working with contractors who may not have been used to shooting with the presence of an observer. In addition, the thermal images caused mild eye strain if viewed for long periods of time, and the screens on the cameras were small. In contrast, analysis of the thermal images was undertaken in an office on a large screen and for as long as was necessary to come to a decision.

127. No studies or reports could be found on the time taken for badgers to die after being hit by rifle bullets. Defra's Best Practice Guidance document on controlled shooting of badgers in the field advises contractors to wait for at least three minutes before approaching any shot badgers. This was not followed by over half of the contractors taking observed shots where a carcase was recovered. It was reported that the presence of anti-cull protestors in the pilot areas influenced the actions taken by each contractor after a badger had been shot. If no protestors were thought to be in close proximity, the contractors quickly picked up the badger, placed it in a bag and moved to a safe location. If protestors were close by, the contractors, buddies and observers concealed themselves until the protestors had moved away. Only at that time did they then approach the carcase, put it in a bag and tag it.

128. A variety of methods were employed by the contractors to confirm death of shot badgers. The Best Practice Guidance document advises the contractors to confirm death based on absence of an eye blink reflex. The first contact with a carcase was most often a nudge of the body, with either a boot or the gun. If the badger did not respond to this contact, the contractors did not voluntarily check the eye blink reflex, unless requested by the observer. In many cases, due to anti-cull activity as highlighted above, the contractors picked up the badger carcase by a leg, placed it into a bag and transported it to a safer place before carrying out the tagging procedure. When this occurred, no check of the reflexes was carried out.

129. Shots that resulted in non-recovered carcases were evenly distributed over the 42 days of the pilot, and were distributed across the two pilot areas.

4.2. Objective 2 (laboratory component): To determine the proportion of badgers that are not recovered after being shot at with a firearm, and have firearm injuries

Laboratory component

130. No confirmed 'non-acute' firearm injuries were detected in any of the 158 rifle shot badgers presented for necropsy.

131. Histopathology was undertaken to investigate three firearm associated skin wounds (on two carcases), which based on their gross appearance, had been categorised by the examining veterinarian as definite or possible 'non-acute' injuries. The histopathological examinations revealed evidence of peracute injury only, with no evidence of an inflammatory or repair response in any of the three wounds.

132. For the carcase categorised as having possible 'non-acute' skin wounds, field observation data that reported that two shots had been taken during the fatal shooting event provided further circumstantial support for the conclusion that the 'uncertain' appearance skin wounds were not 'non-acute'.

133. For the carcase categorised as having a definite 'non-acute' skin wound (EID CWG073 00010), the relatively non-haemorrhagic nature of this superficial wound combined with possible heat-induced changes to the margins of the wound may have complicated the interpretation of its gross appearance (see Appendix 14). No field observation data was available for this carcase.

4.3. Objective 3: To describe the behaviour of badgers after being shot at with a firearm

134. The primary aim of this Objective was to describe the behaviour of badgers after being shot at.

135. A small proportion (18%) of badgers collapsed immediately after being shot at with rifles. The majority of animals showed behaviour indicating consciousness for several seconds after the shot was fired. The complexity of the behaviour tended to decrease as time progressed, until no further movement could be detected.

136. Vocalisations are a conscious behaviour that have previously been interpreted as having meaning and indicating emotion in some species (Seaforth and Cheyney 2003). Vocalisations were heard only during one event, despite other behaviour indicating consciousness occurring.

137. The thermal cameras provided images that could be analysed, but the quality of the images was variable. Where the badger was viewed at a distance of approximately 30 metres, the images were clear, and all movements of legs and heads could be observed without difficulty. Where the badger was viewed at a distance greater than 60 metres, small movements were hard to determine. At this range, the images could be used to indicate the body position of the badger, i.e. standing, running, recumbent on the ground, but movements of the legs were generally impossible to distinguish. Whether movement was occurring was determined from whether the heat signature was changing.

138. Prior to the study, it was a concern that many of the badgers would not be visible on the thermal cameras after the shot had been taken. This was not found to be the case during the study. The badgers were all shot while they were foraging on grassland and/or visiting bait points. The bait points were all situated at least ten metres away from any vegetation that would conceal the badger's body. Most of the badgers whose carcases were recovered were unable to move any significant distance towards the vegetation, and the grass was not long enough to conceal the badger's' body. Where the badger disappeared out of sight, for example into a ditch, the contractors in five out of ten cases quickly approached the site to find the badgers. Anti-cull protestor activity in the area influenced the demonstration of this response by the contractors.

4.4. Objective 4: To determine the location of rifle entry wounds in the badger carcases recovered from observed and unobserved shootings

139. The primary aim of this Objective was to determine the location of the entry wound caused by the first shot that hit the badger during the fatal shooting event. As noted in the methods section for this Objective, this was straightforward for carcases with a single confirmed entry wound and no firearm skin wounds of uncertain entry/exit status. The analysis was less straightforward for carcases where there was only a single firearm skin wound, which was of uncertain entry/exit status, and for carcases with multiple actual or possible entry wounds. The approach adopted for this analysis resulted in the 'single uncertain entry/exit status' skin wounds being counted as certain first entry wounds, and all candidate wounds in the 'multiple actual or possible entry wound' cases being counted as potential first entry wounds.

140. The decision to count all 'single uncertain entry/exit status' skin wounds (n=7) as certain first entry wounds was taken on the basis that it was considered likely that these wounds represented exit events that had obliterated the true entry wound. The exact location of the true (obliterated) entry wound may have been obscured to some degree by the exit events in these cases.

141. The majority of the candidate wounds in the 'multiple actual or possible entry wound' cases were confirmed entry wounds. Although it was possible to speculate on the chronology of the candidate wounds in these 'multiple actual or possible entry wound' cases (through attempts to make logical assumptions on the chronology of the wounds, based on their locations), this was not attempted. Therefore, all candidate wounds in these cases were counted as potential first entry wounds through the sensitivity analysis approach.

142. Defra's Best Practice Guidance document on controlled shooting of badgers in the field states that the correct target area for shooting badgers in the field is the heart/lung area of the chest. In the context of this guidance, the following outcomes for Objective 4 are highlighted:

- In the 'best case scenario' analysis, 37.3% (CI: 29.8-45.4%) of carcases (n=158) were categorised as having a first entry wound location in the 'inside target area' set (Table 7).
- At least 18 (11.4% (CI: 6.9-17.4%)) carcases (n=158) were categorised as having a first entry wound location involving the head or neck regions (AUs 1, 2 or 3) (Table 4).
- At least 5 (3.2% (CI: 1.0-7.2%)) carcases (n=158) were categorised as having a first entry wound location on a hind leg (AUs 10 or 13) (Table 4).

143. The anatomical unit (AU) assigned to a cutaneous firearm wound was determined by a visual assessment by the examining veterinarian. With respect to the target area sets, each candidate wound was either 'inside target area' or 'outside target area'; no account was taken of the possibility of a candidate wound in the 'outside target area' set being 'close' to AU 7.

144. Six (3.8%) carcases (n=158) were examined where the examining veterinarians were confident that multiple shots had hit the badger during the fatal shooting event (Table 10). In all carcases hit by multiple shots, at least one of the candidate entry wounds was outside AU 7, i.e. was 'outside target area'.

4.5. Objective 5: To determine the extent of internal firearm injuries in the badger carcases recovered from observed and unobserved shootings

145. In the context of Defra's Best Practice Guidance, which recommends a target area of the heart/lung area of the chest, the following points are highlighted:

- Ten (6.3%) carcases (n=158) were examined where the examining veterinarian's observations revealed an absence of firearm injury to the heart and lungs, combined with an absence of significant intra-thoracic haemorrhage (Section 3.5). Further descriptive information on the necropsy findings for these ten carcases is provided in Appendix 15. Four of these ten badgers had an observed shooting event, and of these four, three had an observed time of last movement; in all three cases the time from first shot to last movement was 40 seconds or less.

- Although in the 'best case scenario' analysis (Table 7), 37.3% (CI: 29.8-45.4%) of carcases (n=158) were categorised as having a first entry wound location in the 'inside target area' set, 85.4% (CI: 79.0-90.5%) of carcases had an 'acute' lesion profile group category of 'TH' (considered to represent significant damage to thoracic major blood vessels and/or the heart) (Table 12).

146. When contingency tables (Tables 13 and 14) were used to analyse the relationship between first entry wound location, in terms of AU, and 'acute' lesion profile group, the test for independence was highly significant, suggesting a relationship between the two classifications. This was not surprising as the 'acute' lesion profile groups were largely defined by location of damage, so correlation with entry wound location was anticipated. In the contingency tables, all carcases with a first entry wound location in AU 7, except one, were assigned the 'TH' 'acute' lesion profile group. However, it is noteworthy that the 'TH' 'acute' lesion profile group was associated with first entry wound locations in AUs 3, 4, 5, 6, 7, 9 and 10.

147. A key observation from the necropsies conducted on the rifle shot carcases for the pilot was the substantial degree of fragmentation of the rifle bullets used that occurred on impact with the badger. The effect of the bullets on tissues was often destructive, resulting in extensive tissue injury. This observation probably partly explains why first entry wound locations outside AU 7 ('outside target area') often resulted in a 'TH' (considered to represent significant damage to thoracic major blood vessels and/or the heart) 'acute' lesion profile group. It is possible to speculate that other factors, such as selection of bullet impact angle by shooters, may also have influenced the relationship between entry wound location and internal tissue injuries, but such speculation was outside the scope of this report. Analysis of any relationship between different bullet calibres/types used and injuries caused was outside the scope of the study.

148. The radar charts provided a simple visual device for assessing the location, extent, and to a degree, the nature of the internal injuries in each carcase caused by the fatal shooting event.

149. The radar charts are a reflection of the tissue injury as result of rifle bullet velocity, impact location, impact angle, type of bullet, bullet fragmentation, and bullet momentum and dispersal within the carcase, as well as the characteristics of the tissues.

150. Tissue and organ trauma associated with rifle bullets result from the permanent wound cavity caused by direct destruction by the bullet, and also from radial stretching of surrounding tissues causing a temporary wound cavity. The pathophysiology following bullet wound injury is complex involving direct trauma, the effects of shock/pressure waves, and shock through hypovolaemia, cardiogenic or neurogenic mechanisms. Therefore, the radar charts are not by themselves an indication of time to death.

Figure 14: Radiograph (lateral view) showing rifle bullet fragmentation

Figure 15: Photograph showing the severely damaged neck region of the badger carcase presented in the radiograph above (photograph taken after skinning the carcase)

151. Certain axes on the radar chart represent cumulative data from certain anatomical regions, whereas others reflect individual observations. The decision to combine some data and not others into individual axes was based upon the perceived significance of certain structures and pathological findings. For example, a significant quantity (>25 ml) of free blood within the thoracic cavity was deemed important to highlight separately, because rapid exsanguination into the pleural cavities would lead to hypovolaemic shock, unconsciousness and death. In addition, the number of axes on the radar chart was a compromise based on reviewer ability to evaluate a limited number of variables. This inevitably meant certain axes had to consist of combined data from some anatomical regions. Although present on the necropsy data capture sheets, two variables (extreme carcase pallor and tail injury) were excluded from the radar charts because a positive response was not recorded for either of these variables for any of the 158 carcases examined.

152. Following assessment based on veterinary opinion, individual radar charts were grouped into a number of broad categories that reflected the nature of the injuries and their distribution. Six ‘acute’ lesion profile group categories were identified, as presented in the results section for this Objective. Discussion of some of the major pathophysiological events (Kumar et al 2004; Maxie 2007; Maiden 2009) likely to be associated with the injuries in each group follows:

C - Cranium: injury to the cranium was used as an indicator of brain injury as the latter was not directly assessed. Injury to the brain can result in concussion, contusion and laceration with potential disruption of normal central nervous system function leading to unconsciousness.

PN - Primary Neck: lesions were primarily recorded within cervical structures with no injury to the cranium, and those where the thorax was involved had no heart injury or intra-thoracic haemorrhage resulting in >25ml of free blood in the thoracic cavity. Injury at this site could potentially lead to immobilisation if cervical vertebrae (and enclosed spinal cord) were affected either through the permanent wound cavity or following temporary cavitation, which can have the same effect as spinal cord severance. Major cervical blood vessel injury would result in blood loss and potential hypovolaemic shock and the likelihood of decreased blood supply to the brain if arteries are involved, leading to hypoxia and unconsciousness.

TH - Thorax with heart injury and/or >25 ml of free blood in the thoracic cavity +/- injury to other tissues: characterised by injury to the heart and/or the presence of >25 ml of free blood within the thoracic cavity (representing significant damage to thoracic major blood vessels and/or the heart). A number of other anatomical tissues/organs may also be involved in these cases and the changes may have contributed to the onset of shock/death. Significant rapid bleeding into the pleural cavities would result in hypovolaemic shock and pulmonary atelectasis (compounded by any pneumothorax), the latter resulting in decreased ventilation with subsequent hypoxia. Injury to the heart could result in chamber rupture with ineffectual myocardial contractility, pericardial tamponade with decreased ventricular filling and peracute myocardial necrosis leading to arrhythmia (fibrillation) - all of these would result in cardiogenic shock. In addition injury to the lungs, diaphragm, ribs and sternum would affect ventilation. Decreased ventilation would result in hypoxic injury with effects upon the central nervous system and cardiac function. Increased intra-thoracic pressure can lead to reduced cardiac return, cardiac compression and reduced end-diastolic volume.

TA - Thorax +/- abdomen with no record of heart injury or major blood vessel damage or haemorrhage of >25 ml into the abdominal/thoracic cavity: characterised by injury to the thorax +/- abdomen, with no evidence of heart injury or significant haemorrhage into body cavities or damage to major blood vessels. The mechanisms resulting in death in these cases are complex with many of the factors described above (associated with the ‘TH’ category) possibly being applicable. In addition shockwaves following firearm injury involving the thoracic cavity can lead to traumatic brain injury.

PC - Primary caudal: lesion distribution primarily involving the abdomen, lumbar spine and hind legs. Factors involved in death could include exsanguination (intra-abdominal or from hind leg major blood vessel injury), direct organ injury, changes in abdominal perfusion, reduced cardiac return and effects on pulmonary function through increased intra-abdominal pressure. Immobilisation as a result of lumbar spinal injury could also be a potential outcome.

MS - Multiple shots: this category was established based on the examining veterinarian having recorded that there was necropsy and radiological evidence of more than one shot hitting the animal. Two ‘multiple shot’ carcases were excluded from this category; it was concluded, for both of these carcases, that the ‘acute’ lesion profile was associated with only one of the shots. For some of the carcases in this category, the ‘acute’ lesion profiles were complex and it was often difficult to discern which lesions were associated with which specific bullet because of potential overlap of affected tissues/organs.

4.6. Objective 6: To investigate whether there is any evidence of correlation between the times to death determined by Objective 1 and the firearm injuries in badger carcases recovered from observed shootings

153. For the subset of 54 observed badgers considered in the main analysis for Objective 6, there was no evidence of a significant difference in distribution of time from first shot to last movement between carcases categorised as having 'inside target area' first entry wounds and those categorised as having first entry wounds 'outside target area' (Table 16) The available data precluded any investigation of correlation between time from first shot to last movement and 'acute' lesion profile group due to the presence of only a single carcase in each of all but one of the five 'acute' lesion profile groups considered.

154. Considering the subset of 57 observed badgers for which a time of last movement was observed and necropsy and radiological investigation were undertaken, all but one of these badgers had a time from first shot to last movement of 66 seconds or less (Tables 15 and 19). The exception was a badger (CWG048 00003) that had a time from first shot to last movement of 823 seconds (13 minutes and 43 seconds), and in which the carcase showed evidence of multiple shots having hit the badger during the fatal shooting event. Further descriptive information on the necropsy findings for this badger is provided in Appendix 14 and further descriptive information on the observations recorded during its shooting event is provided in Appendix 19.

155. For the subset of 61 observed badgers considered in the supplementary analyses for this Objective, 54 of these badgers (the subset of 54 used for the main analysis for Objective 6) had a time of last movement observed and 7 did not have a time of last movement observed. The 7 without an observed time of last movement, by definition, did not have a point estimate of time to death. No evidence was identified of any significant differences between the group with an observed time of last movement (n=54) and the group without an observed time of last movement (n=7), in terms of 'acute' lesion profile group assigned or target area set in which the first entry wound was located. Six of the seven badgers without an observed time of last movement were assigned a 'TH' 'acute' lesion profile group; the remaining badger in this group was assigned a 'C' (Cranium) 'acute' lesion profile group (see Table 17).

4.7. Objective 7: To compare the firearm injuries in badger carcases recovered from observed shootings with those in badger carcases recovered from unobserved shootings

156. The analyses carried out for this Objective did not reveal any important differences between the observed and unobserved groups.

157. It was highlighted, prior to the pilot, that the presence of observers could influence the behaviour of contractors in two ways; either better or worse, in the presence of an observer. It has previously been found that more experienced shooters tend to perform less well during formal assessment (Fox et al 2005). Alternatively, contractors may have taken a more cautious approach while an observer was present, and therefore performed better under these circumstances.

158. The estimated power of the paired analysis comparing observed and unobserved badgers in terms of their target area set was low (40-50%) based on the numbers seen in this study. From the paired data that were collected, it would have been possible to detect a difference between the 'discordant' cells in Table 21 with 80% power (assuming the 'discordant' cells summed to 18), if the difference between the cells was as large as fifteen versus three.

159. With respect to the paired analyses for this Objective, it is also important to note a contractor non-compliance issue highlighted in Appendix 5 of this report. On two occasions during the field observations, the observer noted that the EID tag used on the carcase did not correspond to the contractor taking the shot. This occurrence was accounted for in the observed badger data used in the paired analyses (in fact, the two observed badger carcases affected were not eligible for the paired analyses, due to the absence of corresponding unobserved badgers), but the impact on the analyses of any similar events that occurred in unobserved badgers is unknown, because no information is available on how often an 'incorrect' EID tag may have been used on unobserved badgers that were shot. This issue triggered the unpaired analyses reported for this Objective, in addition to the planned paired analyses.

4.8. Protocol for selection of contractors (shooters) for observation and carcases for laboratory investigation

160. An underlying principle for this study was that contractors (shooters) should be selected at random for observation. Prior to the pilot, an automated process was developed to facilitate the random selection of contractors for observation each night and the associated selection of carcases for laboratory investigation. This would separately select contractors intending to use rifles or shotguns for observation each night.

161. At the start of the pilot, the field team was provided with a list of the contractors working in each of the pilot areas and their intended use of rifles and shotguns. It was apparent that only a small number of contractors were intending to use shotguns and that it would not be possible to collect observations from sufficient contractors to assess the humaneness of this method of shooting. A decision was taken on 27 August 2013, after discussion with Defra, to collect the small number of shotgun observations that may be possible, but to accept that the original protocol with respect to shotgun shooting events could not be followed and that the planned sample size for shotgun shooting events was unachievable.

162. As the pilot progressed, the number of contractors active and therefore available for observation each night became a limiting factor. In addition, last minute changes by the contractors about whether to operate on a particular night resulted in frequent reallocation of observers. These practical issues made the use of the intended automated selection process challenging, and a decision was taken on 13 September 2013 (implemented on the 16 September 2013) to proceed with manual selection from then on. This manual selection was still based on the underlying principle of random selection of contractors to observe; it was a logistical change rather than an alteration to the study design.

163. The total number of observed carcases for which necropsy and radiological examination had been completed was highlighted as a concern during the second week of the pilot in West Somerset. A decision was made to select all observed carcases for necropsy and radiology from then on. For cases where multiple observed carcases were available for one contractor from the same day, a random selection of carcases was then made for the paired analyses in Objective 7.

164. As well as determining which contractors should be observed and the selection of observed carcases for laboratory investigation from animals observed being shot, the selection process also identified carcases from unobserved shootings by the same contractor for laboratory investigation.

165. The arrival of requested carcases at the laboratory site was dependent on the successful completion of a number of sequential steps. The cull companies were responsible for the physical separation and delivery of the requested carcases to the laboratory site. This process was undertaken each night between 4am and 7am, but proved logistically challenging. As a consequence, only 181 of the 199 carcases that were requested for delivery to the laboratory site (not all for necropsy and radiological investigation as part of the humaneness project) were delivered. In addition, cull company procedures resulted in four observed carcases eligible for the study being delivered to the laboratory site despite not being requested by the field team.

166. During the last week of the pilot in West Gloucestershire, it became clear that the number of contractors remaining active and from whom an observation had yet to be collected was very small. As a consequence of this, these were repeatedly selected for observation. This led to concerns from the contractors and it was agreed that observer effort would be spread across the contractors to make best use of the observer resources available. This included re-selecting a number of contractors who had been observed taking a shot earlier in the pilot, as well as continuing to select the small number who had not been observed.

167. Although the selection of contractors to observe did not proceed exactly as planned, it is thought that neither the changes that were introduced nor the lower activity levels of the contractors introduced bias into the sample population of contractors observed. Indeed, a statistical analysis comparing first entry wound location by target area set for unobserved carcases from contractors that were observed at least once (at some stage during the pilot) against carcases from other contractors that were never observed did not reveal any important differences between the two groups of contractors.

168. A record of the carcases delivered to the laboratory site is provided in Appendix 20.

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Appendix 1

Protocol to be used for the operation of the pilot

This Appendix, consisting of 31 pages, is provided as a separate document, to reduce the bulk of the report and to avoid confusion over pagination.

Appendix 2

Descriptive information for two shotgun shooting events that occurred during the pilot

Field observations

Event ID: 020913/418/01 (Carcase EID: CWS063 00008): There was only one badger in sight when the shot was taken. A single shot was fired at the badger from a range of 10 metres. Immediately after the shot was taken, the badger collapsed. It disappeared from view due to falling into the vegetation of a shallow ditch and hedge. The carcase was located and death was confirmed 5 minutes and 26 seconds after the shot had been fired.

Laboratory findings

Carcase EID CWS063 00027 (necropsy date 31/08/13): There was evidence of a single shotgun shot. There was a cluster of entry wounds on the left side of the thorax with injuries to the heart, lung, ribs/sternum, diaphragm, liver and the right front leg. All of the injuries were haemorrhagic.

Carcase EID CWS063 00008 (necropsy date 03/09/13): There was evidence of a single shotgun shot. There were widespread shotgun pellet entry wounds on the right side of body, from the neck to the abdomen. There were firearm injuries to the neck, thoracic spine, lumbar spine, heart, lung, ribs/sternum, diaphragm, liver and other abdominal organs, and both front legs. All of the injuries were haemorrhagic.

Appendix 3

Further details on the necropsy and radiological investigation

The weight and sex of each carcase were recorded (see Appendix 17).

The first step in the necropsy dissection process was skinning of the carcase, with the aim of removing the pelt in one piece. A standardised approach to skinning the carcase was adopted. The location of cutaneous and subcutaneous firearm wounds was determined by examination of the internal surface of the pelt and the external surface of the skinned carcase. The badger body surface was visualised into defined anatomical units as indicated in Figure 16.

The wounds were classified as entry or exit where possible. The locations of the wounds were recorded based on which anatomical unit was affected (based on a visual assessment of the location); they were also plotted on a diagram of the badger body surface. The degree of perforation, appearance (based on standard morphological change categories) and infection status of each wound were recorded. The definitions for the wound perforation and appearance categories are provided in Tables 24 and 25 below. The maximum diameter of each wound was measured on the internal surface of the pelt and recorded.

After recording all cutaneous and subcutaneous firearm wounds, dissection was progressed to facilitate examination of the carcase for evidence of internal soft tissue firearm injuries. The head, neck, front legs, thoracic cavity and its contents, abdominal cavity and its contents, pelvic cavity and its contents, hind legs and tail were examined.

Internal soft tissue and skeletal firearm injuries in defined anatomical regions/structures were recorded as detected or not detected (with an additional category option of 'uncertain' for internal soft tissue injuries). For heart, lungs and liver, an estimate of the proportion of the organ(s) injured was recorded. For injuries detected in the kidneys or limbs, bilateral injuries were differentiated from unilateral injuries. The appearance (based on standard morphological change categories -Table 25 below) and infection status of internal soft tissue firearm injuries were recorded. Skeletal firearm injuries identified on the radiographs were characterised according to their appearance (based on standard morphological change categories - Table 26 below). Where possible, internal soft tissue and skeletal firearm injuries were attributed to a specific entry wound. The presence of free blood in the thoracic and abdominal cavities, the presence of generalised extreme pallor and the presence of pulmonary emphysema due to firearm injury were recorded as detected or not detected (with an additional category option of 'uncertain'). Damage to the central nervous system was not directly investigated, but was presumed based on injury to the surrounding tissues (cranial bones and vertebral column).

Informed by the necropsy and radiology findings, a single cause of death category was selected for each animal from a list of five cause of death category options. The five cause of death categories were: fatal firearm injury; firearm injury with subsequent infection; firearm injury with major disablement; other cause with incidental firearm injury; and other cause with no firearm injury.

Figure 16: Diagrams showing the division of the badger body surface into defined anatomical units

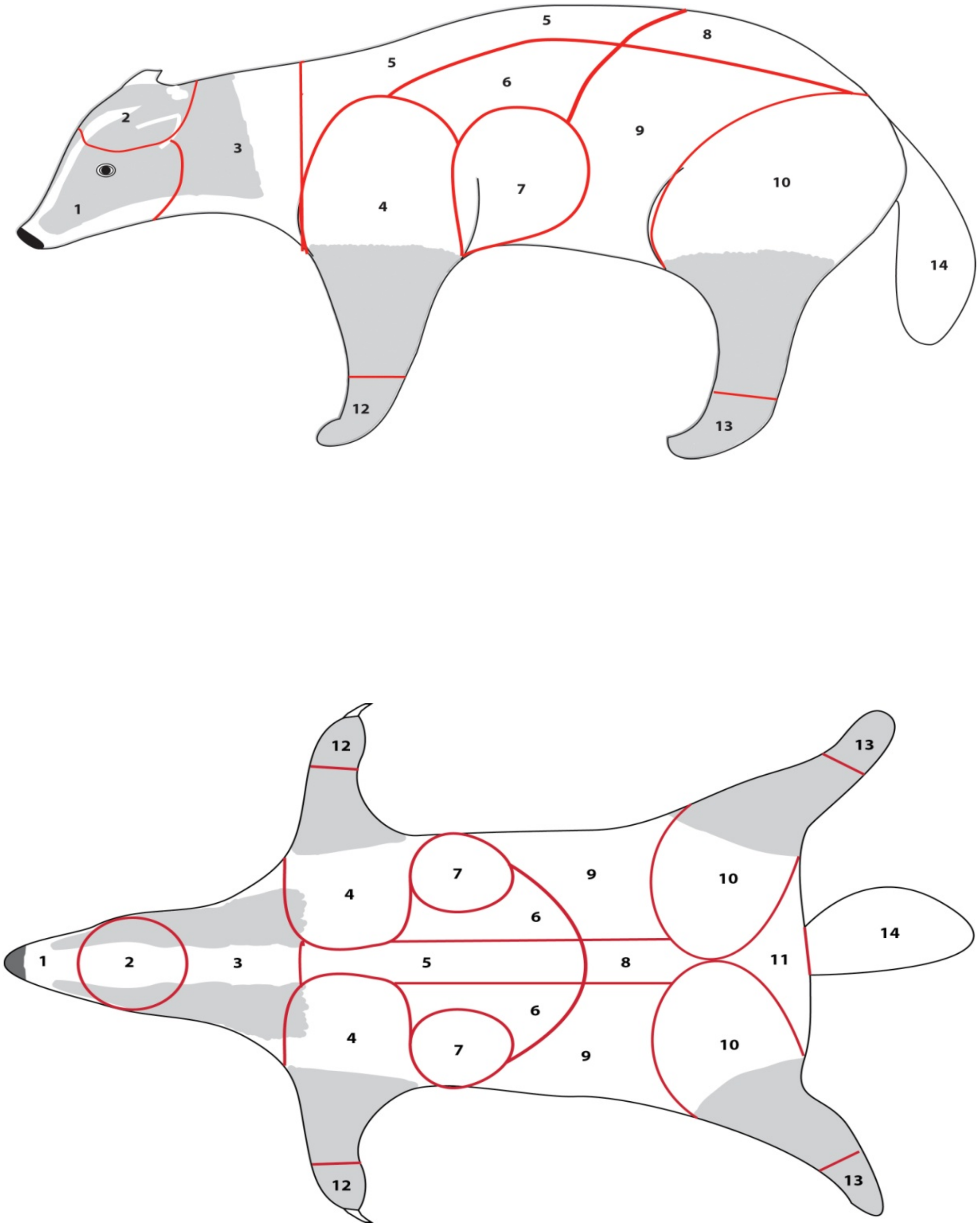


Table 24: Definitions of the degree of perforation categories for cutaneous firearm wounds

Category	**Definition**
N (Non-penetrating)	Damage detected only in the skin and subcutaneous tissue.
P (Penetrating/non-exiting)	Penetrating entry wound with internal tissue damage; no exit wound.
T (Through)	Entry and associated exit wound identified.
U (Uncertain)	Perforation status of the wound is uncertain.

Table 25: Definitions of the appearance categories for cutaneous firearm wounds and internal firearm injuries

Category	**Definition**
H (Fresh frank haemorrhage and/or oedema)	Dissecting. Haematoma or free red blood (liquid or clotted blood) +/- gelatinous white or pink material present. Margins are sharp, jagged and well-defined. Inferred duration of lesion development is acute.
O (Organising blood clot/exudate)	Central dull red to brown colouration of organising blood. Soft easily broken down adhesions. Crust formation and/or pale blunt margins. Inferred duration of lesion development is subacute.
F (Fibrosis and scar formation)	Firm white/grey/light brown/yellow tissue present. Inferred duration of lesion development is chronic.
U (Uncertain)	Appearance status of the wound/injury is uncertain.
HO	Certain F is not applicable, but unable to choose between H and O.
OF	Certain H is not applicable, but unable to choose between O and F.
p (Post-mortem)	Appearance of wound/injury is consistent with injury inflicted after death.
c (Complex)	Appearance of injury is complex and not covered by available appearance categories.

Table 26: Definitions of the radiological appearance categories for skeletal firearm injuries

Category	Definition
S (Sharp)	Sharp skeletal fragment edges at fracture site. Tissue loss. Inferred duration of lesion development is acute.
R (Rounded)	Rounded skeletal fragment edges at fracture site. Inferred duration of lesion development is subacute.
C (Remodelling and callus)	Replacement of lost tissue and callus formation. Inferred duration of lesion development is chronic.
U (Uncertain)	Radiological appearance status of injury is uncertain.
x (Complex)	Radiological appearance of injury is complex and not covered by available appearance categories.

Appendix 4

Data capture forms for the necropsy and radiological investigation

These forms are available on GOV.UK.

Appendix 5

Quality assurance for the study

Field staff

Training

All staff engaged in the field component of the study received training in use of the electronic equipment, conflict resolution and identification of involuntary movement after death. Training was also completed by the whole team for project specific Standard Operating Procedures and safe working practices. This training was documented in individual training records. During in field training, assessments of staff competence were carried out and recorded in the training records. Ongoing assessments of staff competence were made by monitoring of the quality of the thermal images, audio recordings and field notes, with feedback or additional training completed where necessary.

Behaviour interpretation

The interpretation of the behaviour recorded by the thermal cameras for this study was undertaken by a small team of animal welfare scientists. Although, prior to the study, the scientists had limited experience of behavioural responses following chest shots, all of the team had extensive experience of recording behaviour from digital images and determining time to death in wild animal species. Prior to the study, the lead scientist acquired experience of the responses of foxes, rabbits and badgers after being shot at by accompanying experienced hunters, in the UK and elsewhere in Europe, while in the field during darkness with a thermal camera. The lead scientist oversaw the behaviour assessment of the thermal images and was always available to discuss any images that were difficult to interpret.

Data integrity

Prior to hand over of the daily summary sheets, each driver ensured that all fields had been completed by the observer. These data were then checked by the field manager, prior to being entered into the system. Data entry of information, other than the time to death, and time of confirmation of death were visually checked by a third person. Time to death and time to confirmation of death was taken from the behavioural decoding of the thermal images and were checked for entry into the database by a third person.

Laboratory staff

Veterinary competence

The necropsies and radiological examinations for this study were performed by a small team of veterinarians. All radiography procedures were performed by veterinarians. The training and establishment of competence of these veterinarians with respect to the objectives of the study was undertaken by a team of three lead veterinarians. Although, prior to the study, the lead veterinarians had fairly limited experience of pathology induced by firearms, all three have extensive experience of performing diagnostic necropsies on a number of different species including the badger. The lead veterinarians acquired some experience of rifle bullet injuries in Muntjac deer before the study through specialist training. The lead veterinarians mentored and supervised the other members of the veterinary team for the duration of the laboratory operational activities. Technical support was provided by a small team of trained technicians.

Training

All staff engaged in the laboratory component of the study, including the veterinary team described above, received training in relevant procedures (including project specific Standard Operating Procedures) and processes. This training was documented in individual training records. Subsequent to the training, initial assessments of staff competence were carried out and recorded in the individual training records. Ongoing assessments of staff competence were made by regular observations, with feedback or additional training provided when necessary.

Data integrity

Prior to disposal of individual carcases in the post mortem room, all data capture sheets were reviewed by a 'data quality supervisor', with the aim of ensuring all relevant data fields had been completed and all data capture rules had been observed.

A system of internal veterinary peer review was put in place, with the aim of validating the raw data captured for each carcase, using the digital radiographs as a reference point. This peer review was carried out by the lead veterinarians, with the proviso that self-review was not valid.

For all carcases examined, verification of data entry was carried out through a double visual check, carried out by a different reviewer on each occasion.

Contractors

The cull companies and their contractors were responsible for culling the badgers and the electronic identification of the culled badgers. This part of the study was not independently audited. The data collected indicated that agreed procedures were not followed in at least 3 different ways:

i. The electronic carcase identity system used to identify each carcase to a specific contractor was not followed.

ii. *Rendez-vous* of the contractors with the carcase collection agents was compromised due to the actions of anti-cull protestors.

iii. The sorting procedures undertaken in the field, and subsequent delivery of carcases to the laboratory site, were found to have weaknesses.

These deviations from the agreed procedures had the potential to affect the integrity and completeness of the study data in four main ways:-

i. *Independent selection of an observed carcase for an observed contractor:* Several observed carcases were not delivered to the laboratory site and two observed carcases had the tag (EID) of a different contractor from the one taking the shot. The EID tag placed into each observed badger carcase was noted by the observer. Each tag had a unique EID number and could not be reused. This ensured that the carcases that were delivered to the laboratory site, with EIDs that had been recorded by the observers, were the carcases of the observed badgers.

ii. *Independent selection of an unobserved carcase for each observed contractor:* Several unobserved carcases that had not been selected by the field team were delivered to the laboratory site. The reasons for substituting an unselected carcase were unknown; however, the inclusion of these carcases in the dataset would have negated the independence of the study. Only unobserved carcases with EID numbers that had been selected by the field team were included in the dataset.

iii. *EID tag not a reliable indicator of true contractor identity:* On two occasions during field observations, the EID tag used on the carcase did not correspond to the contractor taking the shot. Many contractors worked in pairs, providing an opportunity for a carcase to be identified by an EID tag belonging to the member of the pair that did not take the shot. It is unknown how often an ‘incorrect’ EID tag was used on unobserved badgers that were shot (see discussion of Objective 7).

iv. *Carcase delivery date not a reliable indicator of day of culling:* No contractor shot an observed and unobserved badger on the same night. However, during the data analysis, it became apparent that, on three occasions, observed and unobserved carcases were delivered to the laboratory site on the same day. The cull companies confirmed that if the *rendez-vous* with the collection agent was compromised, the contractors would delay submission of carcases until the following day. This occurred in both pilot areas. This issue partly contributed to the choice of protocol for the selection of matched pairs for the paired analyses in Objective 7; a protocol was used that selected carcases based on the date of necropsy, rather than the date of culling. The contractors were unaware that all the carcases they delivered to a collection agent on a night they had been accompanied by an observer would be selected for laboratory investigation, so they were not aware that they could secure laboratory investigation of an unobserved carcase by delaying delivery of unobserved carcases until after a night of observation.

In addition to the above points, the laboratory results for two carcases subjected to necropsy/radiological investigation raised concerns pertaining to contractor compliance. One of the carcases showed evidence of having previously been frozen and the radiographs for this carcase revealed an absence of either rifle bullet fragments or shotgun pellets. The second carcase had been shot by shotgun, but the carcase showed evidence of severe post mortem change and all of the shotgun associated injuries appeared to have occurred as a post mortem event. Both carcases were excluded from the humaneness study.

Appendix 6

Further details on the statistical analyses

Objectives 1 and 2 (field component)

1. TTD in individual cases was estimated by the observed time from first shot to last movement.
2. Based on the assumption that observations were a random sample from the population of shots, quantiles of TTD for the population were estimated from the empirical distribution of TTDs via a Kaplan-Meier survival curve [Genstat 14, or the 'survival' package in R 3.01].
3. Cases where a carcase was not recovered after a shot was taken were treated in two ways 1) censored at the maximum observed time to death, 2) censored at the last observed movement recorded on the thermal cameras. For cases where no thermal recording was available the observation was recorded as censored at the maximum observed Type A or Type B observation.
4. Cases where a carcase was recovered after a shot was taken but the last movement was not observed were treated in two ways 1) censored at the last observed movement, [based on assumption that these observations came from the same population as shots where the last movement was observed] 2) treated as TTD = time at which death was confirmed [a conservative treatment which does not assume these observations came from the same population, but includes the time to find, approach and confirm death in the estimated TTD].
5. CIs for quantiles were estimated from inverting 95% CIs for KM estimates of the probability of survival.
6. The probability that a badger escapes after a shot is taken was estimated via a 95% binomial CI for the observed proportion of cases where a badger escaped after a shot was taken.

Objective 3

1. The number of animals that showed behaviour indicative of consciousness was presented.
2. The mean, minimum and maximum duration that running and conscious behaviour were displayed after badgers had been shot were presented.
3. The mean, minimum and maximum distance that badgers were found away from the shot site were presented.
4. A histogram of the distance badgers were found away from the shot site was presented.

Objective 2 (laboratory component) and Objectives 4, 5, 6 and 7

Shotgun shooting events were excluded from all analyses.

Objective 2 (laboratory component): To determine the proportion of badgers that are not recovered after being shot at with a firearm, and have firearm injuries

Definition of 'non-acute' injuries

Table 27 below shows which wounds/injuries were categorised as certain and possible 'non-acute' wounds/injuries, for each category observed at necropsy: skin wounds, internal soft tissue injuries, and skeletal injuries.

Table 27: Classification of certain, possible and definitely not 'non-acute' wounds/injuries

	Definite 'non-acute'	Possible 'non-acute'	Definitely not 'non-acute'
Skin wounds	O, F, OF	HO, U	H, p
Internal soft tissue injuries	O, F, OF	HO, U, c	H, p
Skeletal injuries	R, C	U, x	S

Analyses

All carcases were included in these analyses (n=158).

A plot of the cumulative proportion of carcases displaying definite 'non-acute' firearm injuries for each day of the cull, along with 95% exact binomial CI was provided. The staggered starting dates of the cull in the two geographical areas were taken into account on the x-axis of estimated shooting date. Due to histopathology revealing that the single definite 'non-acute' injury included in this plot was in fact peracute (definitely not 'non-acute'), this graph was not included in the Objective 2 (laboratory component) results.

Carcases with 'non-acute' firearm injuries were tabulated as a total of the carcases examined in each week (again, staggered starting dates were taken into account); proportions and binomial 95% CIs were calculated. The planned analysis was to test for trend under the 'certain', 'best', and 'worst' case scenarios (as described below) using the chi-squared test for independence. However very small numbers meant this was not appropriate and so this analysis was not performed.

Complication from uncertain 'non-acute' injuries

There was a possibility of carcases being examined where the existence of a 'non-acute' firearm injury was uncertain i.e. an injury existed but it was not possible to determine whether it was 'non-acute' with certainty, and there were no certain 'non-acute' injuries present. To acknowledge this complication, sensitivity analyses were performed as follows:

First, the above analyses were performed only including carcases whose status with respect to 'non-acute' injuries could be determined with certainty: either they had no definite or possible 'non-acute' injuries, or they had (at least one) definite 'non-acute' injury. In this 'certain' analysis, the proportion of carcases with 'non-acute' injuries was calculated as follows: the numerator was the number with a definite 'non-acute' injury, the denominator was the number whose 'non-acute' injury status could be determined with certainty.

Secondly, sensitivity analyses were performed under 'best' and 'worst' case scenarios. For both of these analyses, the denominator of the proportion was the total number of carcases.

For the 'worst case' analysis, the numerator of the proportion was the number of carcases with definite or possible 'non-acute' injuries.

For the 'best case' analysis, the numerator was the number of carcases with definite 'non-acute' injuries.

Again, due to the histopathology results concluding the single definite 'non-acute' injury was in fact peracute, the above analyses were not presented in the report.

Objective 4: To determine the location of rifle entry wounds in the badger carcases recovered from observed and unobserved shootings

The main aim of these analyses was to calculate the proportion of carcases with a first entry wound in each of the location categories: anatomical units (AUs), and target area sets.

All carcases were included in this objective (n=158).

Definition of first entry wound

The first requirement for this objective was to be able to identify every firearm skin wound on a carcase that was a candidate for being the first entry wound (the entry wound caused by the first shot that hit the badger during the fatal shooting event). Candidate first entry wound locations were any 'non-exit' wounds with an appearance category of H, HO or U.

The second requirement was to determine, for each carcase, whether it was possible to be certain about the location of the first entry wound. If a carcase had only a single candidate wound, then it was categorised as having a certain status for first entry wound location. If a carcase had multiple candidate wounds, then it was categorised as having an uncertain status for first entry wound location.

Analyses

<u>Analysis by anatomical unit (AU)</u>

Candidate first entry wound locations were tabulated according to their anatomical unit; proportions and binomial 95% CIs were calculated. This was repeated for sensitivity analyses as described below.

A bar chart was presented of proportions for observed, unobserved and all carcases, for each AU, for the certain status carcases only.

<u>Analysis by target area set ('inside target area' and 'outside target area')</u>

To analyse how good shot placement was in relation to Defra's Best Practice Guidance, the AUs were classified into two simple sets of target areas: 'inside target area' (AU 7 only), or 'outside target area' (all other AUs).

Candidate first entry wound locations were tabulated according to target area set; proportions and binomial 95% CIs were calculated. This was repeated for sensitivity analyses as described below.

A bar chart was presented of proportions for observed, unobserved and all carcases, for the certain status carcases only.

Complication from uncertain location of first entry wound

If a carcase had multiple actual or possible first entry wounds, it was not possible for the first entry wound location to be determined with certainty. To account for this, sensitivity analyses were performed as described below:

<u>Analysis by anatomical unit (AU)</u>

First analysis – carcases with a 'certain' status:

For those carcases where the first entry wound location was determined with certainty, the proportions of first entry wounds within each of the defined AUs was calculated. Carcases with multiple actual or possible entry wounds, all located in the same AU, were included in this analysis. Two-tailed 95% confidence intervals (CI) were identified for each of the proportions based on a standard model of random sampling from a binomial distribution. Where an observed proportion was zero, a one-tailed 97.5% upper CI was reported.

Second analysis (sensitivity analysis) – carcases with 'certain' and 'uncertain' status:

The second analysis included carcases with an 'uncertain' first entry wound location, in addition to those with a 'certain' status. The carcases with an 'uncertain' status had multiple candidate first entry wounds, in more than one AU. The minimum and maximum number and proportion of first entry wounds that could fall in each AU were calculated as follows:

The minimum proportion of first entry wounds in each AU was calculated by dividing the number of carcases with a 'certain' first entry wound location in that AU by the total number of carcases.

The maximum proportion was calculated by dividing the number of carcases with a 'certain' or 'uncertain' first entry wound location in that AU by the total number of carcases.

<u>Analysis by target area set ('inside target area' and 'outside target area')</u>

First analysis – carcases with a 'certain' status:

For those carcases where the target area set of the first entry wound location was determined with certainty, the proportion of first entry wounds within each set was calculated. Carcases with multiple actual or possible entry wounds, all located in the same target area set, were included in this analysis, even if the wounds were in different AUs. Two-tailed 95% binomial CIs were reported for each set.

Second analysis (sensitivity analysis) – carcases with 'certain' and 'uncertain' status:

The second analysis included carcases with an 'uncertain' target area set status, in addition to those where it had been determined with certainty. The carcases with an 'uncertain' status had candidate first entry wound locations across both target area sets. Analyses were carried out to calculate a 'best case scenario' and a 'worst case scenario' for the number and proportion of first entry wounds that could fall in each set. The sets were clearly ranked: 'inside target area' was 'better' than 'outside target area'.

For the 'worst case scenario', it was assumed, for the carcases of uncertain status, that the first entry wound was actually present in the 'outside target area' set.

For the 'best case scenario', it was assumed, for carcases of uncertain status, that the first entry wound was actually present in the 'inside target area' set.

For both scenarios, the proportions were calculated using the total number of carcases as the denominator. The number and proportion of first entry wounds within each target area set were reported for each scenario, along with 95% binomial CIs.

Objective 5: To determine the extent of internal firearms injuries in the badger carcases recovered from observed and unobserved shootings

The outcome of the classification exercise was six 'acute' lesion profile groups.

All carcases (n=158) were included; further exclusion criteria were implemented as they were required.

Analyses

The number of carcases in each 'acute' lesion profile group was tabulated; proportions and binomial 95% CIs were calculated. A bar chart was presented showing the proportions for observed and unobserved badgers.

Contingency tables, presented separately for observed and unobserved badgers, were used to describe the relationship between first entry wound location (in terms of AU) and 'acute' lesion profile group. Carcases were included in these tables subject to the following rules:

Carcases with a 'number of shots' count that was not Rifle 1/Shotgun 0 were excluded.

Carcases excluded through 1 could be brought back into the analysis group on the basis of veterinary review.

Carcases with an uncertain first entry wound location, in terms of AU, were excluded (see Objective 4 for a fuller description).

Due to small numbers in most cells of the contingency tables, the Fisher's exact test was used instead of the planned chi-squared test for independence (n=62 observed, 89 unobserved).

Objective 6: To investigate whether there is any evidence of correlation between the times to death determined by Objective 1 and the firearm injuries recorded in badger carcases recovered from observed shootings

Data were available from Objective 4 on first entry wound locations, and from Objective 5 on 'acute' lesion profile groups. These were compared with the field-determined time from first shot to last movement, for observations where this measurement was available.

Only observed shooting events where carcases were recovered and submitted for necropsy and radiological investigation were included in this analysis (n=64). Additionally, carcases were included in the analyses for this Objective subject to the following rules:

Carcases with a 'number of shots' count that was not Rifle 1/Shotgun 0 were excluded.

Carcases excluded through 1 could be brought back into the analysis group on the basis of veterinary review.

Carcases with an uncertain first entry wound location, in terms of target area set, were excluded.

This left n=61 carcases remaining.

Analyses

Complication from absence of observation of time of last movement

For some shooting events where a carcase was recovered, because sight of the badger was lost some time after the first shot, a time from first shot to last movement was not recorded. By definition, these badgers did not have a point estimate of time from first shot to death. To account for this, the analyses in this objective were performed as follows:

Analysis only including badgers where time of last movement was observed

Seven of the 61 carcases did not have the time of last movement observed, leaving n=54 for this analysis.

Median, IQR, minimum and maximum time from first shot to last movement for carcases in each of 5 ‘acute’ lesion profile groups were presented (the MS group was excluded due to exclusion criterion 1 above). The distributions were also shown in a box and whisker plot. The data were not sufficiently balanced to perform ANOVA.

Median, IQR, minimum and maximum time from first shot to last movement for carcases in each of the two target area sets were presented. The distributions were also shown in a box and whisker plot. The distributions were compared using the Kolmogorov-Smirnov test.

Analysis including badgers with and without an observed time of last movement

The original plan was to estimate time from first shot to last movement for the carcases that did not have this time observed; however, there was no evidence of any relationship between time from first shot to last movement and time from first shot to confirmed death to inform such an estimate. Instead, a decision was made to compare the badgers in the two groups (with and without time of last movement observed) in terms of ‘acute’ lesion profile group and target area set assigned, to ascertain whether there were important differences between them. n=61 for these analyses.

The ‘acute’ lesion profile groups were tabulated by whether or not time of last movement was observed; proportion and binomial 95% CI were calculated. Fisher’s exact test was used to test for differences between the two groups.

The target area sets were tabulated by whether or not time of last movement was observed; proportion and binomial 95% CI were calculated. Fisher’s exact test was used to test for differences between the two groups.

Excluded badgers

Data for the three carcases excluded under the exclusion criteria were presented.

Objective 7: To compare the firearm entry wounds and injuries in badger carcases recovered from observed shootings with those in badger carcases recovered from unobserved shootings

Observed and unobserved shooting events from the same shooter were compared to provide information on whether the shooting behaviour of shooters changes in an important way when they are observed.

All carcases are potentially included in these analyses (n=158).

Analyses

Paired analyses

This analysis included only pairs of (observed/unobserved) badgers from unique contractors. There were n=45 pairs.

The observed and unobserved members of the pairs were tabulated in terms of target area set, including only pairs where both members of the pair were of certain status for target area set (this was not explicitly described in the analysis plan). McNemar's test was performed on this table (n=43 pairs (2 pairs excluded because one member of the pair was of uncertain status for target area set)).

Simulation was used to estimate the power of this test.

(The originally planned test of proportions was recognised to be invalid and so not performed).

The pairs were also tabulated in terms of 'acute' lesion profile group of each member of the pair. As the 'acute' lesion profile groups do not have a natural ranking, the extended McNemar test could not be used on this table (n=45 pairs). Instead, the 'acute' lesion profile groups were categorised as 'TH' and 'not-TH' (n=45 pairs).

Unpaired analyses

As a result of a lower than anticipated number of pairs available for inclusion in the paired analyses, the unpaired analyses assumed greater importance than originally planned. These unpaired analyses include all observed and unobserved badgers on which necropsy and radiological investigation had been undertaken.

The target area set was tabulated by observed and unobserved, and the chi-squared test for independence performed. This was carried out for:

Certain target area set status only (n=155)

'Best case scenario' (in terms of all uncertain status carcases being 'inside target area') (n=158)

'Worst case scenario' (in terms of all uncertain status carcases being 'outside target area') (n=158)

'Minimal difference scenario' (where uncertain status carcases are assigned in order to minimise the difference between observed and unobserved badgers in terms of proportion in 'inside target area') (n=158)

'Maximal difference scenario' (where uncertain status carcases are assigned in order to maximise the difference between observed and unobserved badgers in terms of proportion in 'inside target area') (n=158)

Only the 'maximal difference scenario' was included in the report.

Simulation was used to estimate the power of the 'certain' analysis.

The 'acute' lesion profile groups were tabulated by observed and unobserved, and Fisher's exact test performed due to small numbers in many cells (n=158).

Additional analyses

Due to the challenges faced with selection of contractors for observation, the target area set hit by contractors who had never been observed, and those who had been observed (at some stage in the pilot), was compared as a crude check for selection bias. A chi-squared test for independence was performed. To make the comparison as fair as possible, only unobserved carcases and carcases with a certain target area set were included. For this analysis, n=24 for 'never observed' contractors and n=47 for 'observed' contractors.

Demographics etc.

All carcases were included in these analyses (n=158)

Carcase sex for observed and unobserved badgers was tabulated. A test for significance of difference between the groups was performed.

The mean, standard deviation, median and IQR for carcase weight were presented for observed and unobserved badgers. The carcase weights were corrected for the presence of the plastic submission bags by subtracting 200g from every recorded carcase weight. A histogram for carcase weight for observed and unobserved badgers was presented.

The following variables for observed and unobserved badgers were tabulated:

- Evidence of significant post mortem change
- Cause of death (CoD)
- Level of confidence of CoD

Appendix 7

Ethogram of behaviour and indication as to whether indicative of consciousness

Running; animal's body supported by both front and back legs, animal moving laterally, using a two (trot), three (canter) or four (gallop) beat gait.

Flailing/squirming; no lateral movement, erratic and fast movement of the head, body and legs.

Recumbent, lifting head; body in contact with ground, head moving either up into the air, or up and down.

Movement; the exact part of the body moving could not be determined; the heat signature of the carcase was changing consistent with movement of some part of the body.

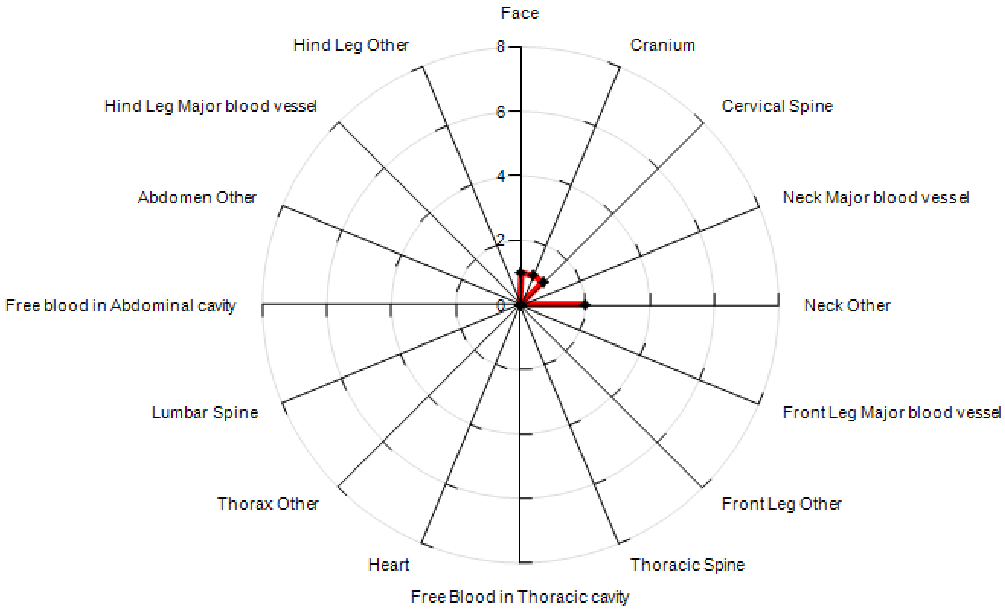
Tumble; while running the animal does a somersault.

Collapse; muscle tone disappears from the body and the body of the animal falls to the ground.

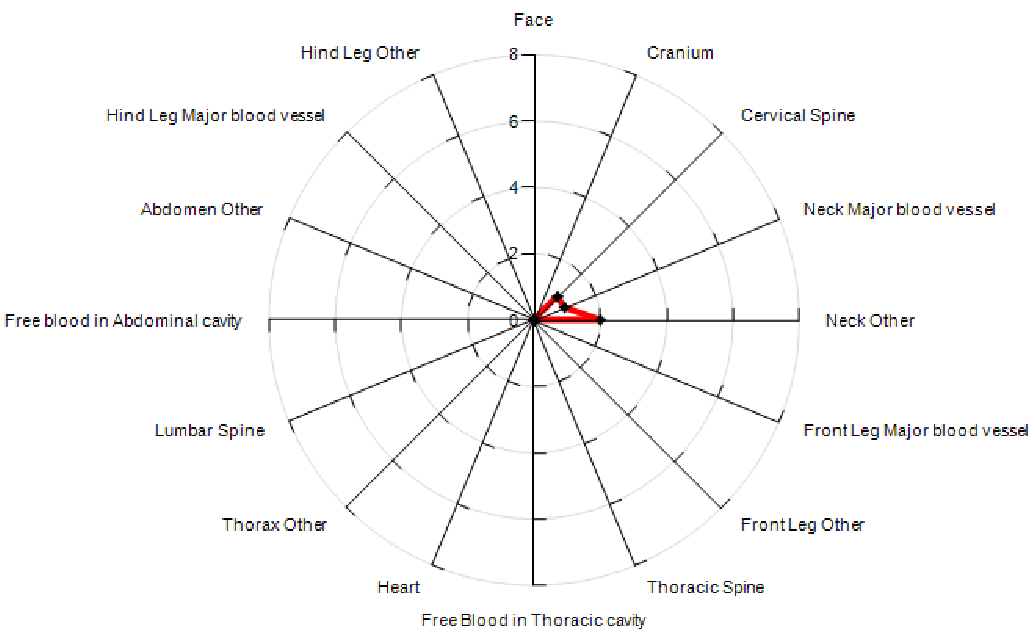
Appendix 8

Examples of radar chart 'acute' lesion profiles

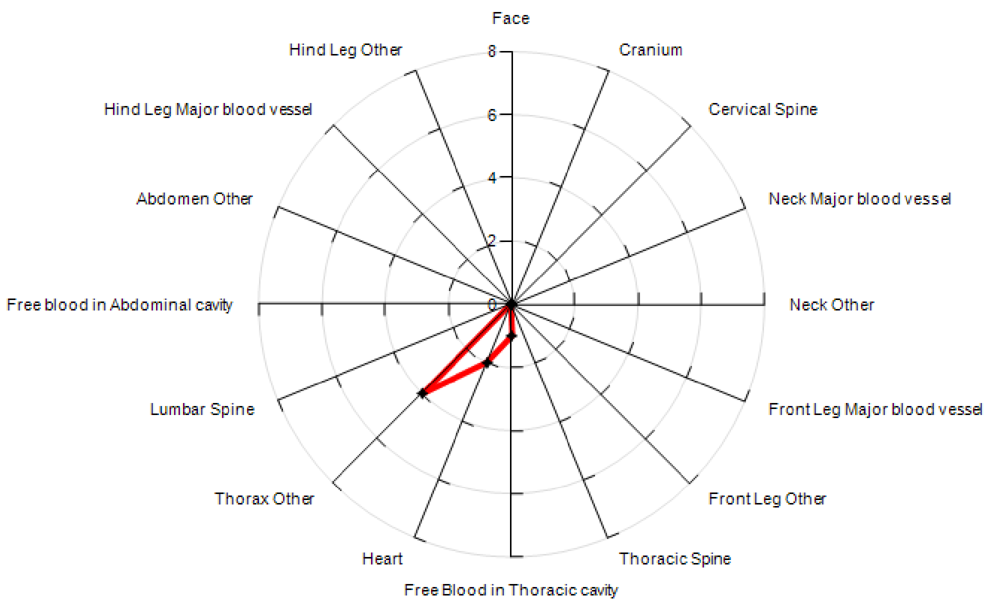
Radar chart for CWG002 00004 – 'Acute' lesion profile group C



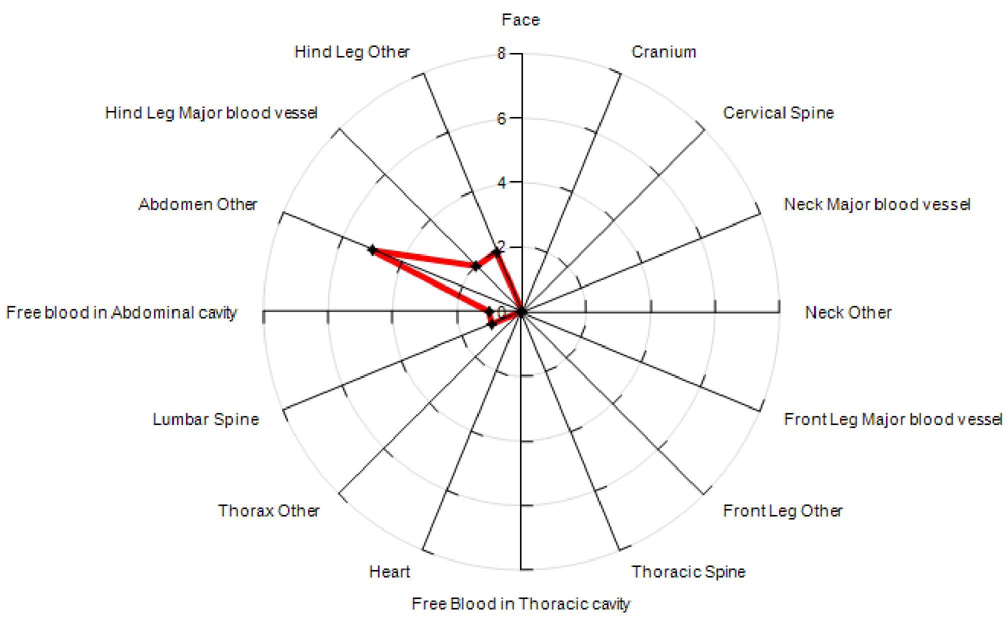
Radar chart for CWG072 00017 – 'Acute' lesion profile group PN



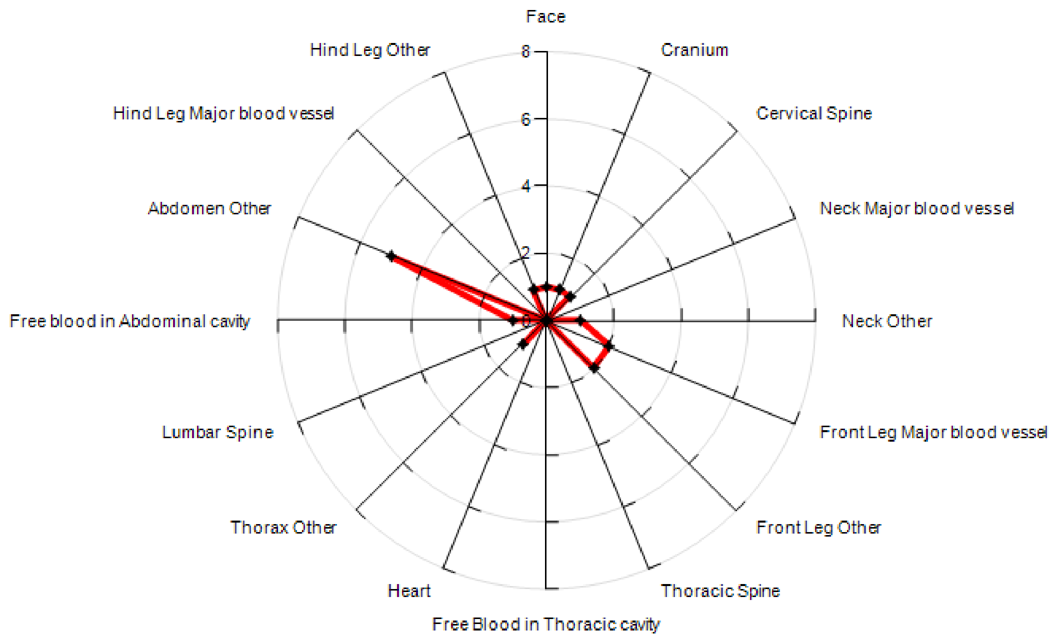
Radar chart for CWG007 00014 – 'Acute' lesion profile group TH



Radar chart for CWG031 00009 – 'Acute' lesion profile group PC



Radar chart for CWG004 00005 – 'Acute' lsion profile group MS



Appendix 9

Details of radar chart (lesion profile) construction from raw data

Table 28: Construction of radar diagrams

Radar chart variable		Max value	Max value
FACE	If “yes” for *Face* (n) and/or *Facial bones* (r), value = 1	1	1
CRANIUM	If “yes” for *Cranium* (n) and/or *Cranium* (r), value = 1	1	1
CERVICAL SPINE	If “yes” for *Cervical spine* (r), value = 1	1	1
NECK MAJOR BLOOD VESSEL	If “yes” for *Neck major blood vessel* (n), value = 1	1	1
NECK OTHER	If “yes” for *Neck muscles* (n), value = 1	1	2
	If “yes” for *Trachea/oesophagus* (n), value = 1	1	
FRONT LEG MAJOR BLOOD VESSEL	If “yes” for *Front leg major blood vessel* (n), add 1 to value for each front leg affected	2	2
FRONT LEG OTHER	If “yes” for *Front leg muscles/tendons* (n) and/or *Front leg foot* (n) and/or *Scapula, humerus, radius and ulna* (r) and/or *Carpi, metacarpi and phalanges* (r), add 1 to value for each front leg affected	2	2
THORACIC SPINE	If “yes” for *Thoracic spine* (r), value = 1	1	1
FREE BLOOD IN THORACIC CAVITY	If “yes” for *>25ml free blood in thoracic cavity* (n), value = 1	1	1
HEART	If “yes” for *Heart* (n), add value of 1, 2 or 3 based on proportion (≤5%, >5% - ≤ 20%, >20% - ≤100%) of organ injured	3	3
THORAX OTHER	If “yes” for *Lungs* (n), add value of 1, 2 or 3 based on proportion (≤33%, >33% - ≤ 66%, >66% - ≤100%) of organ injured	3	6
	If “yes” for *Pulmonary emphysema* (n), value = 1	1	
	If “yes” for *Diaphragm* (n), value = 1	1	
	If “yes” for *Ribs and sternum* (r), value = 1	1	
LUMBAR SPINE	If “yes” for *Lumbar spine* (r), value = 1	1	1
FREE BLOOD IN ABDOMINAL CAVITY	If “yes” for *>25ml free blood in abdominal cavity* (n), value = 1	1	1
ABDOMEN OTHER	If “yes” for *Liver* (n), add value of 1, 2 or 3 based on proportion (≤33%, >33% - ≤ 66%, >66% - ≤100%) of organ injured	3	8
	If “yes” for *Spleen* (n), value = 1	1	
	If “yes” for *Intestine* (n), value = 1	1	
	If “yes” for *Kidneys* (n), add value of 1 for unilateral injury; value of 2 for bilateral injury	2	
	If “yes” for *Sacrum/pelvis* (r), value = 1	1	
HIND LEG MAJOR BLOOD VESSEL	If “yes” for *Hind leg major blood vessel* (n), add 1 to value for each hind leg affected	2	2

HIND LEG OTHER	If "yes" for *Hind leg muscles/tendons* (n) and/or *Hind leg foot* (n) and/or *Femur, tibia and fibula* (r) and/or *Tarsi, metatarsi and phalanges* (r), add 1 to value for each hind leg affected	2	2

Explanatory information

Column 2: Scoring system for sub-variables contributing to the radar chart variable

- n: derived from necropsy data capture sheets
- r: derived from radiology data capture sheets
- "yes" indicates firearm injury detected

Columns 3 and 4 indicate maximum values for the sub-variables and variables

Appendix 10

Further descriptive information on the shooting events for which last movement was not observed and the duration between the first shot taken to confirmation of death was over 60 minutes

Event ID: 010913/522/02 (carcase EID CWS045 00024): The badger was observed to move erratically for 16 seconds before running into a ditch after the shot had been taken. The duration from first shot to disappearance was 34 seconds. Movement had decreased in complexity for 6 seconds prior to the badger being lost from sight. The contractor did not check the carcase before moving to other bait points. The observer was not permitted to check the carcase on their own. When the carcase was checked 90 minutes after the shot had been fired, the badger was dead and the carcase was found in the ditch very close to where it had disappeared.

Event ID: 050913/417/01 (carcase EID CWG046 00017): The badger was observed to run for 13 seconds immediately after the shot had been taken; the badger then disappeared from sight into a hedge. The badger galloped with a normal action during this time. The contractor informed the observer that the shot was a miss. The site where the badger was when it was shot was examined for blood and tissue; none were found. The contractor then decided to finish for the evening. The observer was dropped with the driver. The contractor then decided to revisit the area where the badger had been shot. Upon a more thorough search of the hedge, the carcase was found. The contractor contacted the observer who was still in the area, and arranged for the observer to revisit the shooting site. The carcase was found very close to the point in the hedge, where the badger disappeared. The carcase was still warm and was most probably the badger that the observer had seen shot. Death was confirmed 2 hours after the initial shot had been fired.

Appendix 11

Statistical output for Objective 1, time to death

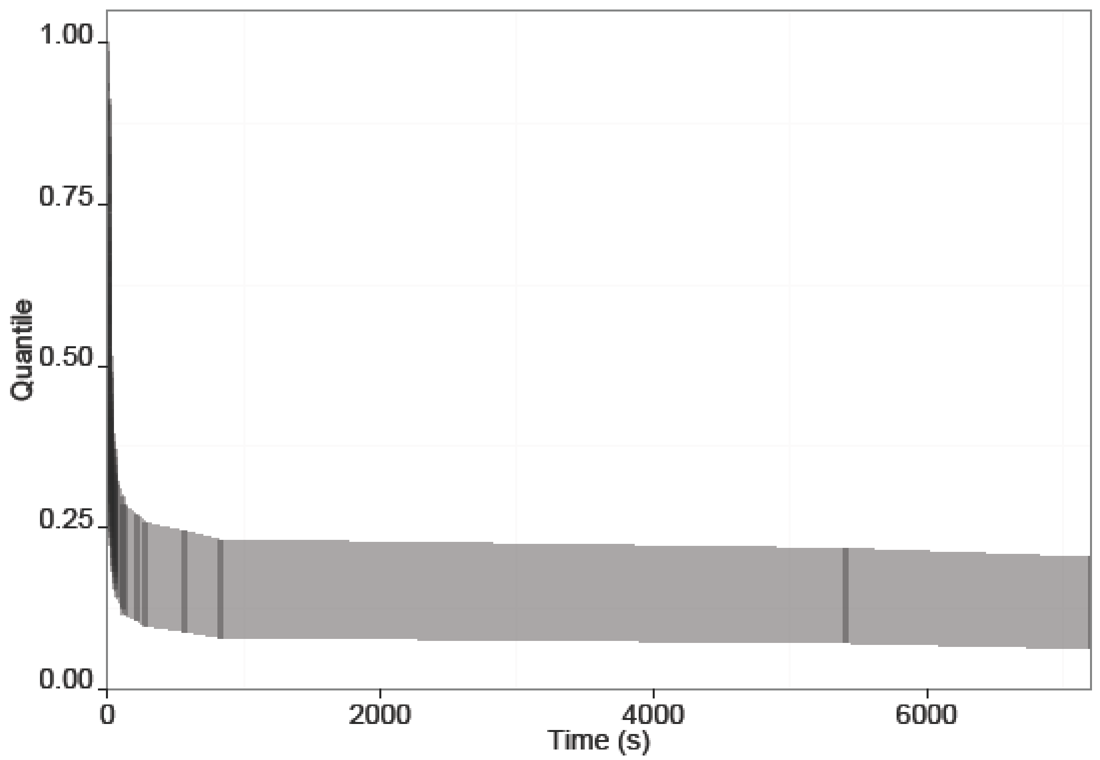
A Kaplan-Meier survival curve of the proportion of badgers surviving over time after a shot was taken is given in Table 29 and Figure 17 (data treatment '*worst case*').

Table 29: Kaplan-Meier survival curve for badgers at which a shot was taken (data treatment 'worst case'; time to death for cases where no carcase was recovered assumed to be the longest estimated time to death)

Time (seconds)	Lower Confidence[a]	Estimate	Upper Confidence	Time (seconds)	Lower Confidence	Estimate	Upper Confidence
0	0.929	0.966	1	23	0.255	0.341	0.456
1	0.881	0.932	0.986	25	0.245	0.33	0.444
2	0.795	0.864	0.938	27	0.234	0.318	0.432
3	0.755	0.83	0.912	30	0.224	0.307	0.42
4	0.741	0.818	0.903	40	0.204	0.284	0.396
5	0.677	0.761	0.856	41	0.194	0.273	0.384
6	0.64	0.727	0.827	47	0.184	0.261	0.371
7	0.567	0.659	0.766	50	0.174	0.25	0.359
8	0.532	0.625	0.735	53	0.164	0.239	0.347
9	0.508	0.602	0.714	60	0.155	0.227	0.334
10	0.485	0.58	0.692	66	0.145	0.216	0.322
11	0.462	0.557	0.671	115	0.126	0.193	0.296
12	0.451	0.545	0.66	121	0.117	0.182	0.283
13	0.417	0.511	0.627	210	0.108	0.17	0.27
14	0.384	0.477	0.594	274	0.098	0.159	0.257
15	0.318	0.409	0.526	570	0.089	0.148	0.244
17	0.308	0.398	0.514	823	0.081	0.136	0.231
18	0.286	0.375	0.491	5400	0.072	0.125	0.217
22	0.276	0.364	0.479	7200	0.063	0.114	0.204

a: 95% confidence intervals

Figure 17: Kaplan-Meier survival curve for badgers at which a shot was taken (data treatment 'worst case'; time to death for cases where no carcase was recovered assumed to be the longest estimated time to death)



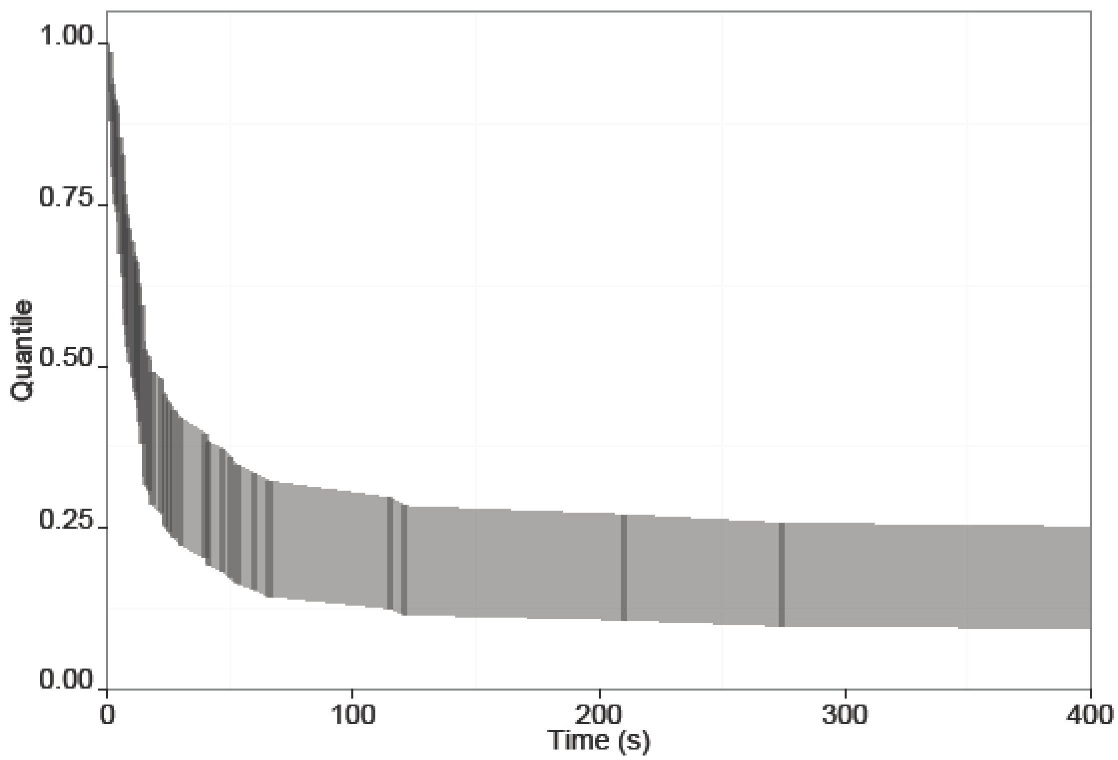


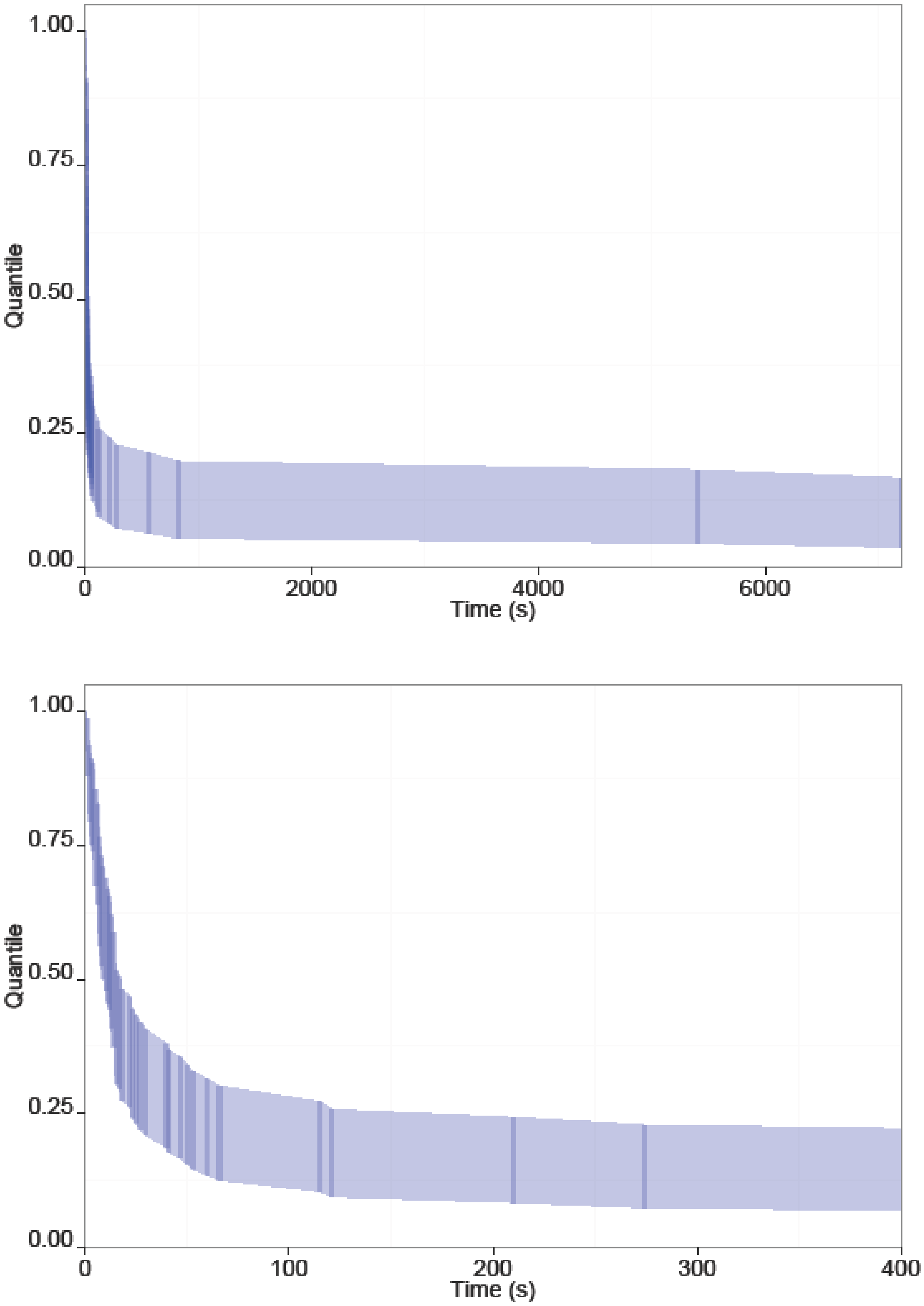
Table 30 and Figure 18 give the estimated survival curve and quantiles for time to death under treatment *'censored'* where the status was treated as 'unknown' from the point at which sight of the badger was lost where this was recorded by thermal camera (4 cases) or at the longest type A or type B observation (6 cases).

Table 30: Kaplan-Meier survival curve for badgers at which a shot was taken (data treatment *'censored'*; the status was treated as 'unknown' from the point at which sight of the badger was lost where this was recorded by thermal camera (4 cases) or at the longest type A or type B observation (6 cases)).

Time (seconds)	Lower Confidence[a]	Estimate	Upper Confidence	Time (seconds)	Lower Confidence	Estimate	Upper Confidence
0	0.929	0.966	1.000	23	0.242	0.328	0.444
1	0.881	0.932	0.986	25	0.231	0.316	0.432
2	0.795	0.864	0.938	27	0.220	0.304	0.419
3	0.755	0.830	0.912	30	0.210	0.292	0.406
4	0.741	0.818	0.903	40	0.188	0.267	0.380
5	0.677	0.761	0.856	41	0.177	0.255	0.367
6	0.639	0.727	0.826	47	0.167	0.243	0.354
7	0.564	0.656	0.764	50	0.156	0.231	0.341
8	0.527	0.621	0.732	53	0.146	0.219	0.328
9	0.503	0.598	0.710	60	0.136	0.207	0.314
10	0.479	0.574	0.689	66	0.126	0.194	0.301
11	0.455	0.551	0.666	115	0.104	0.169	0.272
12	0.444	0.539	0.655	121	0.094	0.156	0.257
13	0.409	0.504	0.621	210	0.084	0.143	0.243
14	0.374	0.469	0.587	274	0.074	0.130	0.228
15	0.307	0.399	0.517	570	0.064	0.117	0.213
17	0.296	0.387	0.505	823	0.055	0.104	0.197
18	0.275	0.363	0.481	5400	0.045	0.091	0.182
22	0.264	0.352	0.469	7200	0.036	0.078	0.166

a: 95% confidence intervals

Figure 18: Kaplan-Meier survival curve for badgers at which a shot was taken (data treatment *'censored'*; the status was treated as 'unknown' from the point at which sight of the badger was lost where this was recorded by thermal camera (4 cases) or at the longest type A or type B observation (6 cases)).



1000 analyses were carried out for the modelled case, the outputs looked very similar to the previous tables and curves and are summarised in the results section.

At the request of the IEP, an estimate of the distribution of TTD was made which was based on only the 69 observations where the time between the first shot and final movement was observed. This may be considered to be an *optimistic scenario* where the distribution of TTD reflects only the best outcomes.

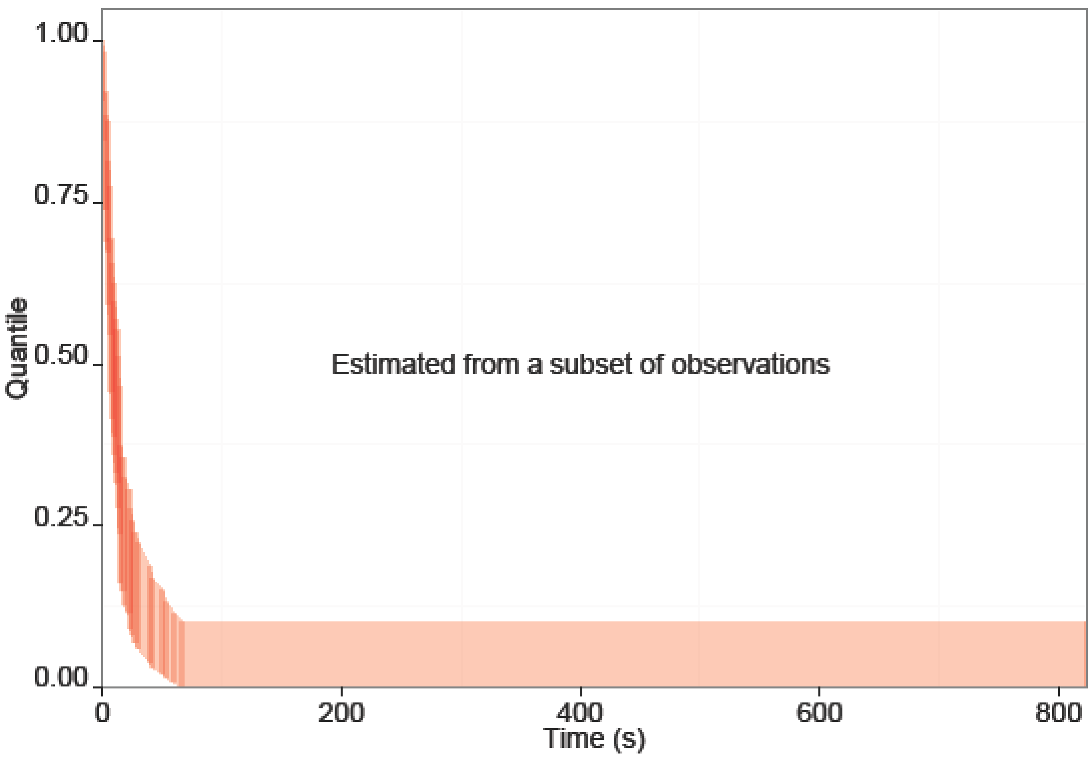
Table 31 and figure 19 give the survival curves for just those badgers with an observation of time of last movement (69 out of 88 observed shots).

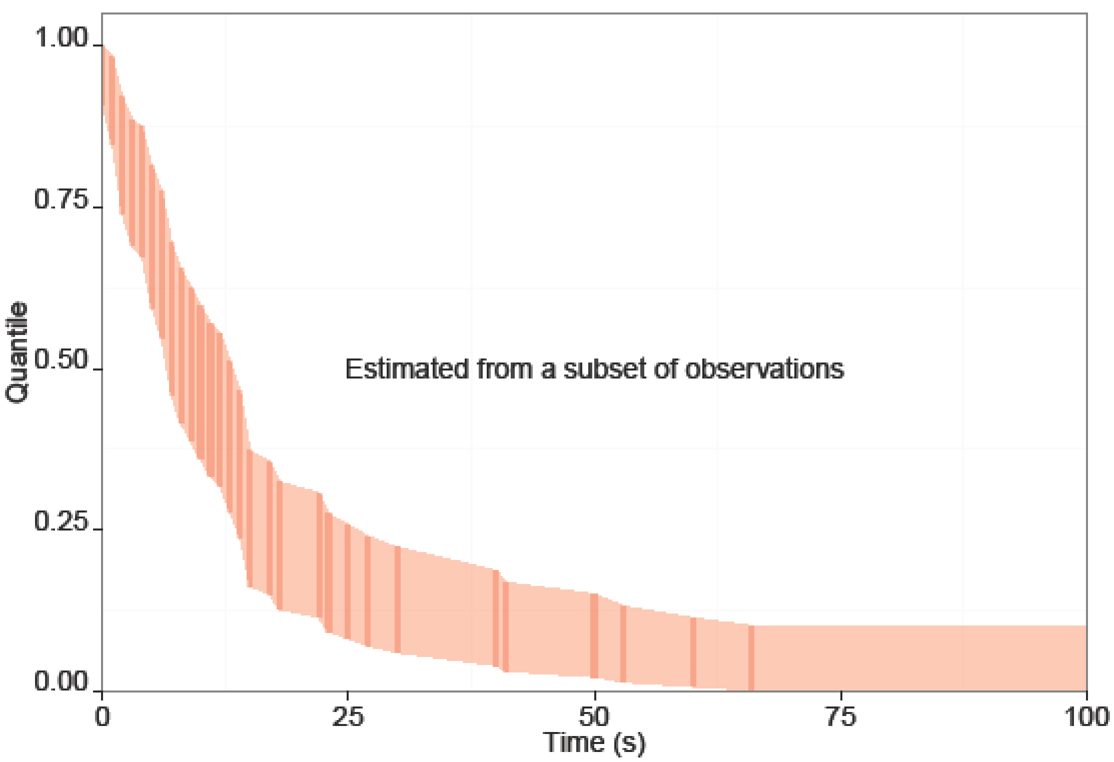
Table 31: Kaplan-Meier survival curve for the subset of badgers at which a shot was taken and for which an observation of time to last movement was recorded

Time (seconds)	Lower Confidence[a]	Estimate	Upper Confidence	Time (seconds)	Lower Confidence	Estimate	Upper Confidence
Estimated from a subset of observed shots				Estimated from a subset of observed shots			
0	0.910	0.957	1.000	15	0.163	0.246	0.372
1	0.849	0.913	0.982	17	0.151	0.232	0.356
2	0.741	0.826	0.921	18	0.127	0.203	0.324
3	0.691	0.783	0.886	22	0.115	0.188	0.307
4	0.675	0.768	0.874	23	0.093	0.159	0.274
5	0.595	0.696	0.813	25	0.082	0.145	0.257
6	0.549	0.652	0.775	27	0.071	0.130	0.24
7	0.460	0.565	0.695	30	0.060	0.116	0.222
8	0.416	0.522	0.654	40	0.040	0.087	0.187
9	0.388	0.493	0.626	41	0.031	0.072	0.169
10	0.360	0.464	0.598	50	0.022	0.058	0.150
11	0.332	0.435	0.569	53	0.014	0.043	0.131
12	0.319	0.420	0.554	60	0.007	0.029	0.114
13	0.278	0.377	0.510	66	0.002	0.014	0.101
14	0.239	0.333	0.465	823	NA	0.000	NA

a: 95% confidence intervals, NA: not estimated,

Figure 19: Kaplan-Meier survival curve treatment of the data using a best case scenario, excluding 19 observations (69 out of 88 observed shots)





This is presented here for information but must be considered as an incomplete presentation of the data as it excludes animals known to have had longer TTD even though the times remained uncertain.

Appendix 12

Further descriptive information on the observed shooting events where a carcase was not recovered

Event ID: 300913/522/01: From field notes. Two badgers in sight when the shot was taken. The badger that was shot at ran away from the other badger and away from where the sett was located. The badgers gait was noted as abnormal by the observer who had a clear view of the badger through the thermal camera. The badger was observed for approximately 90 seconds before it ran into a hedge, where it went out of sight. A search of the site where the badger had been when the shot was taken was carried out; no blood or tissue was found. No search of the hedge where the badger had disappeared was undertaken.

Event ID: **310813/19/01**: From thermal camera recording. One badger in sight when the shot was taken. The badger ran towards the hedge immediately after the shot was taken. The badger disappeared from view 7 seconds after the shot was fired. The gait of the badger as it ran could not be confirmed as unhindered. In addition a heat spot appeared on the rump of the badger after the shot had been fired; this heat spot was not present prior to the shot being fired. The contractor did not search the site for blood or tissue. The contractor stated that in his opinion the shot had missed the badger.

Event ID: 310813/17/01: From field notes. Two badgers in sight when shot taken. Both badgers ran towards the hedge immediately after the first shot was taken. A second shot was taken at one of the badgers. The two badgers continued running, with no abnormal gait, towards the hedge. The duration from the first shot to disappearance of the badgers was 12 seconds. The contractor and the observer stated that the shots were misses in their opinion. On closer inspection of the rifle, it was found that the scope was loose.

Event ID: 050913/408/02: From thermal camera recording. One badger was in sight on a hillside. Immediately after the shot was taken, the badger ran back along the hill; it paused momentarily at the entrance to a sett and then disappeared from view 6 seconds after the shot was taken. No blood or tissue was found at the site where the badger was when the shot was taken. The contractor and observer stated that in their opinion the shot was a miss.

Event ID: 060913/421/02: From thermal camera recording. One badger in sight when the shot was fired. The badger ran immediately after the shot was fired. The badger ran back towards the field boundary, across a stream, under a gate; it was then out of site for a few seconds before being seen running up a hill. It finally disappeared from sight 38 seconds after the first shot was fired. No search of the site was undertaken.

Event ID: 090913/837/01: From field notes. One badger in sight when the shot was taken. The badger ran for 14 seconds away from the contractor immediately after the shot was fired. The badger ran normally with a gallop gait directly towards where the sett was located within the woods, and disappeared from sight when it entered the tree line. The contractor and observer carried out extensive searching of the shot site, the path the badger had taken towards the wood and the area around the sett located in the wood. No blood or tissue was found.

Event ID: 170913/417/01: From thermal camera recording. Three badgers were in sight when the shot was taken. The badger that was shot collapsed to the ground immediately after the shot was taken. The badger lay still for 19 seconds before rolling around on the ground. A second shot was fired 3 minutes 20 seconds after the first shot. The contractor was using a lamp to illuminate the badger; the lamp was switched off after the shot was taken. The contractor asked the observer if the badger was still moving. On confirmation of movement, the spotter took many seconds to locate the badger. The observer noted that the badger was still moving after the second shot was fired and that the badger moved out of sight within 10 seconds of the second shot being fired. At this point the contractor decided to approach the site where the badger had last been seen. Although heat signatures were observed on the approach to the shot site, they were not confirmed as the badger. When the shot site was reached, the badger could not be found. A pool of blood was found. Extensive searching of the area was carried out. The incident was reported to the cull company operations centre. The cull company reported that the following morning blood scenting dogs were taken to the site, and they followed a trail back to a nearby sett.

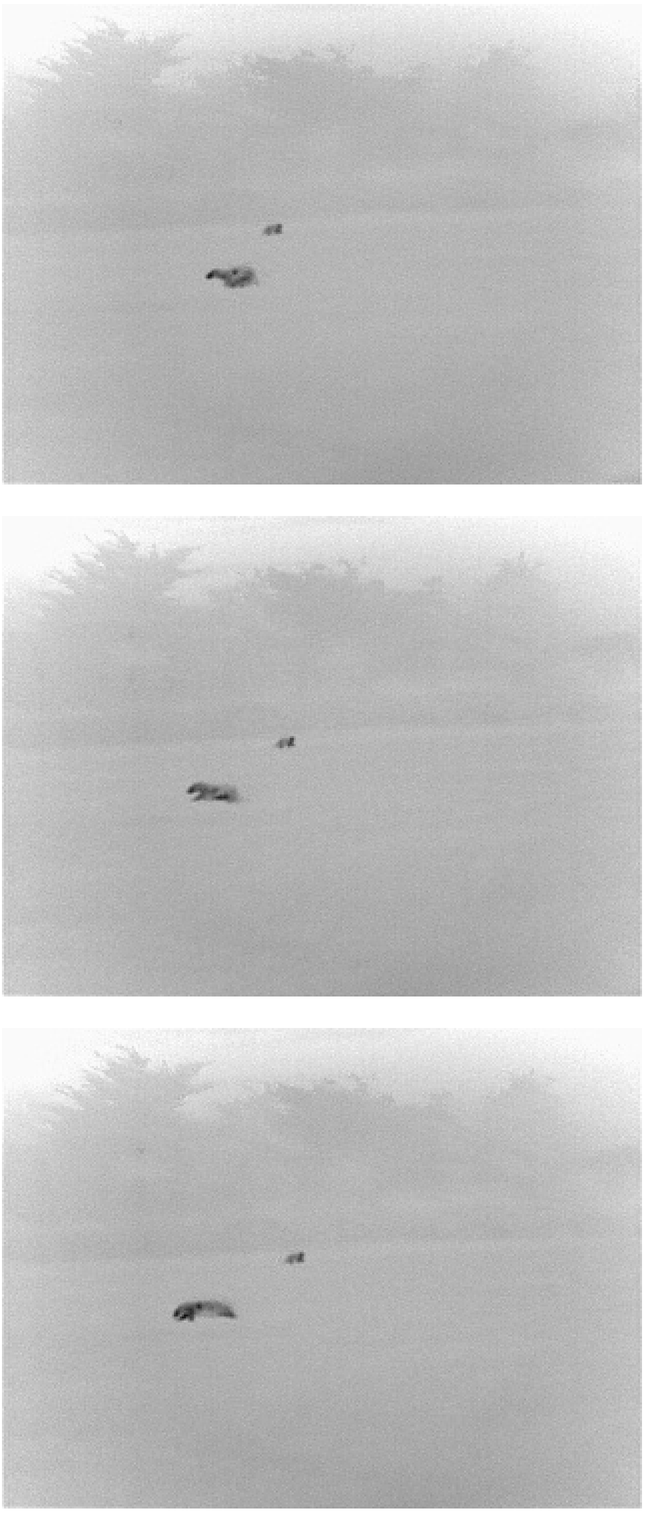
Event ID: 021013/044/01: From field notes. One badger was in sight when the first shot was taken. The badger was thought by the observer and spotter to move when the spotlight was illuminated, immediately prior to the shot been fired. The badger ran immediately after the first shot was fired. The second shot was fired at the badger as it was running. The badger was then seen to run before disappearing from sight. The badger was observed for 30 seconds after the first shot was taken. During this time it was running with a normal gait, and ran in a straight line across the path of the observer. The badger ran down the hill and disappeared into a hedge. The contractor and observer both stated that in their opinion the shots had missed. No blood was found at the sites where the badger was when the shots were taken.

Event ID: 081013/740/01: From field notes. One badger in sight when the shot taken. The badger ran immediately after the shot was taken up the hill towards a sett entrance. The badger was observed running for 4 seconds. Gait was confirmed to be normal. The contractor did not search the site. The contractor and observer stated that in their opinion the badger had not been hit. The contractor had a new scope and informed the observer that he had not zeroed it in very well. After 10 minutes a badger reappeared at the sett entrance that the shot badger was observed running into. This was repeated at least 5 times. It is unknown whether this was the badger that had been shot at.

Event ID: 081013/740/02: From field notes. One badger in sight at the same location as event ID **081013/740/01.** Badger ran immediately after the shot was taken up the hill towards the sett entrance and was seen entering the sett. The badger ran faster than the first animal that was shot at. The badger was observed running for approximately 4 seconds. The contractor informed the observer that he had compensated for the reduced accuracy of the sights on the rifle. The contractor stated that the shot was a miss as he had seen soil disturbed above the badger. A badger was seen to reappear at the sett entrance a few minutes later.

Appendix 13

Behaviour of badgers following shooting: thermographic images



Three consecutive frames recorded, 3.5 seconds after the badger had been shot

Badger image recorded 1 second prior to shot being taken

Badger image recorded 3 seconds after shot was taken.

Appendix 14

Further descriptive information on the 'multiple shot' carcases

Carcase EID CWG062 00012: There were two rifle entry wounds. One entry wound was located on the left abdomen, with injuries to the muscles/tendons of the left hind leg. The other entry wound was located on the right side of the thorax, with injuries to the heart, lung, diaphragm, liver and spleen. Firearm injuries were also noted in the intestine. The appearance of both entry wounds was haemorrhagic. Firearm skeletal damage was noted in the sacrum/pelvis, ribs/sternum and left hind leg. There was more than 25 ml of free blood in both the thoracic and abdominal cavities.

Carcase EID CWG029 00026: There were two rifle entry wounds. One entry wound was located on the left hind leg, with injuries to this limb, the lumbar spine and sacrum/pelvis. The other entry wound was on the right side of the thorax, with injuries to the muscles/tendons of the left front leg, ribs/sternum, lung and spleen. Firearm injuries were also noted in the diaphragm, liver and intestine. The appearance of both entry wounds was haemorrhagic. There was more than 25ml of free blood in the abdominal cavity.

Carcase EID CWG004 00005: There were three rifle entry wounds. One entry wound was on the right front leg with injuries to the neck muscles, cervical spine and ribs/sternum. The humeri of both front legs were fractured. A second shot caused superficial injuries to the left side of head, with damage to the skin and temporal muscles. A third entry wound was on the caudal abdomen and caused damage to abdominal organs including liver, spleen, intestine and one kidney, as well as to muscles/tendons of the right hind leg and the sacrum/pelvis. The appearance of all three entry wounds was haemorrhagic. There was more than 25ml of free blood in the abdominal cavity.

Carcase EID CWS099 00005: There were two rifle entry wounds. One entry wound was on the left abdomen and one on the right side of the thorax. The appearance of both entry wounds was haemorrhagic. Firearm injuries were recorded in lung, diaphragm, liver, spleen, intestine and the muscles/tendons and major blood vessels of the right front leg. Firearm skeletal damage was noted in the ribs/sternum and right front leg. There was more than 25ml of free blood in the thoracic cavity.

Carcase EID CWG060 00008: There were two rifle entry wounds. One entry wound was located on the right front leg, with injuries to the front legs, thoracic spine and neck muscles. The other entry wound was on the head, with injuries to the cranium, neck (including cervical spine, major blood vessels and trachea/oesophagus) and lung. The appearance of both entry wounds was haemorrhagic.

Carcase EID CWG048 00003: One entry wound was located on the left side of the neck, with injuries to the neck (including neck major blood vessels and cervical spine) and right front leg muscles/tendons. Another firearm skin wound was present in the left dorsal thoracic region. This wound was consistent with an entry wound that had been obliterated by its own exit wound; it was associated with injuries to the ribs/sternum and lung. The appearance of both wounds was haemorrhagic. There was more than 25ml of free blood in the thoracic cavity.

Carcase EID CWG005 00003: There were two rifle entry wounds. One entry wound was located on the right front leg, with injuries to this limb, heart, lung, diaphragm, liver and intestine. Firearm skeletal damage was noted in the ribs/sternum and right front leg. The appearance of right front leg entry wound was haemorrhagic. The other entry wound was on the right hind leg, with injuries restricted to the skin and subcutaneous fat. Based on gross observations, the appearance of this entry wound was categorised as uncertain; it was unclear whether this entry wound was ‘acute’, ‘non-acute’ or ‘post mortem’. Subsequent histopathological investigation of the hind leg entry wound revealed evidence of peracute injury only. There was more than 25ml of free blood in the thoracic cavity.

Carcase EID CWG073 00010: There was evidence of injuries consistent with two separate rifle shots. One set of entry and exit wounds was haemorrhagic and related to a rifle shot through the thorax, with damage to lung, heart, muscles/tendons of the right front leg and ribs/sternum. The other wound was on the dorsum, 85 mm long, and consistent with a glancing rifle wound creating a combined entry/exit wound in the skin with limited damage to deeper structures. Based on its gross appearance, the changes in this latter lesion were considered consistent with a ‘non-acute’ injury. Subsequent histopathological investigation of this lesion revealed evidence of peracute injury only. There was more than 25ml of free blood in the thoracic cavity.

Appendix 15

Further descriptive information on the carcases with an absence of firearm injury to the heart and lungs, combined with an absence of significant intra-thoracic haemorrhage (>25ml of free blood within the thoracic cavity)

Carcase EID CWG002 00004: There was a penetrating rifle head wound. Firearm injuries were detected in the face, cranium, neck muscles, trachea and cervical spine.

Carcase EID CWS009 00009: One rifle neck entry wound with three different exit wounds also in the neck area. Internal firearm injuries were detected in the trachea, oesophagus and muscles and major blood vessels of the neck. The appearance of these injuries was haemorrhagic. There was firearm skeletal damage to the cervical spine.

Carcase EID CWG072 00017: One rifle entry wound in the shoulder area with a single exit wound in the neck area. Internal firearm injuries were detected in the trachea, oesophagus and muscles and major blood vessels of the neck. The appearance of these injuries was haemorrhagic. There was firearm skeletal damage to the cervical spine.

Carcase EID CWS025 00004: One rifle entry wound in the dorsal area of the right shoulder with two exit wounds in the right shoulder and one exit wound in the neck. Internal firearm injuries were detected in the cranium, trachea, oesophagus, muscles and major blood vessels of the neck and right front leg. The appearance of these injuries was haemorrhagic. There was skeletal damage to the cranium, cervical spine and right front leg.

Carcase EID CWS094 00008: One rifle entry wound on the right side of the head with two exit wounds on the left side of the neck. Internal firearm injuries were detected in the cranium, trachea, oesophagus, muscles and major blood vessels of the neck and muscles/tendons of the left front leg. The appearance of these injuries was haemorrhagic. There was firearm skeletal damage to the cranium and cervical spine.

Carcase EID CWG021 00003: Internal firearm injuries were detected in the face region, trachea, oesophagus and muscles and major blood vessels of the neck. The appearance of these injuries was haemorrhagic. There was firearm skeletal damage to the facial bones and the cervical spine.

Carcase EID CWG031 00009: One rifle shot with entry wound in the abdomen and exit wound in a hind leg. Firearm injuries were detected in liver, spleen, kidneys, intestine and muscles and major blood vessels of both hind legs. Firearm skeletal damage was noted in the lumbar spine, sacrum/pelvis, coccyx/tail and right hind leg. There was more than 25ml of free blood in the abdominal cavity.

Carcase EID CWS022 00008: One rifle entry wound on the left hind leg with an exit wound on the right hind leg. Firearms injuries were detected in the left and right hind legs (including injury to major blood vessels in both hind legs), lumbar spine, pelvis/sacrum and intestine. The appearance of these injuries was haemorrhagic.

Carcase EID CWG061 00019: One rifle head wound, with injury to the face, cranium, brain and neck muscles. The appearance of these injuries was haemorrhagic. Firearm skeletal damage was detected in the facial bones and cranium.

Carcase EID CWG004 00005: There were three rifle entry wounds. One entry wound was on the right front leg with injuries to the neck muscles, cervical spine and ribs/sternum. The humeri of both front legs were fractured. A second shot caused superficial injuries to the left side of head, with damage to the skin and temporal muscles. A third entry wound was on the caudal abdomen and caused damage to abdominal organs including liver, spleen, intestine and one kidney, as well as to muscles/tendons of the right hind leg and the sacrum/pelvis. The appearance of all three entry wounds was haemorrhagic. There was more than 25ml of free blood in the abdominal cavity.

Appendix 16

Additional descriptive statistics from the field observations

Figure 20: Range at which shots were taken for all observed rifle shooting events

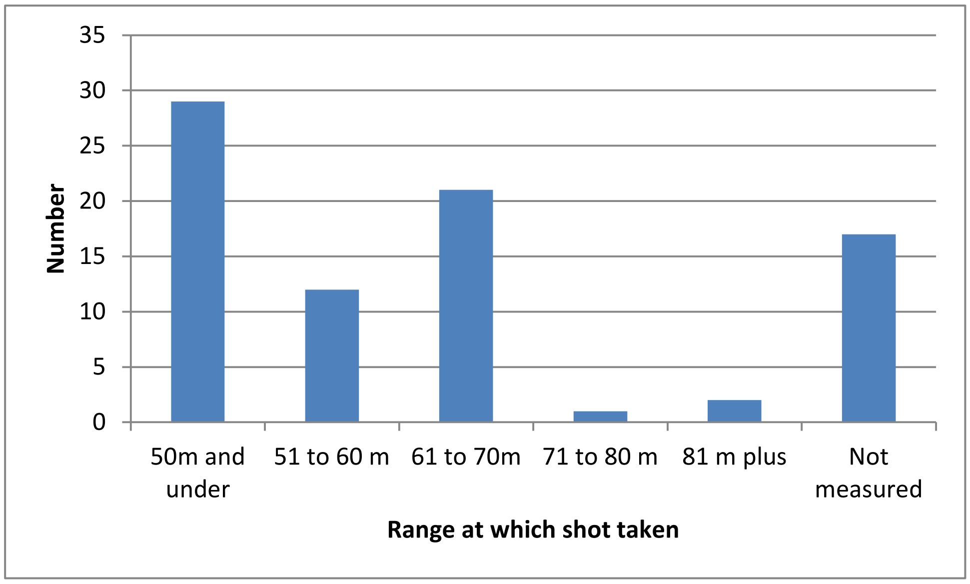


Table 32: Rifle calibres used by contractors with whom an observation was obtained

Rifle calibre
220
222
223
243
250
308
6.5 x 55
25 06
65 sika
6mm tuley
7mil08

Table 33: Weight of ammunition used by contractors with whom an observation was obtained

Ammunition weight
50 grain
55 grain
63 grain
70 grain
75 grain
85 grain
100 grain
117 grain
120 grain
123 grain
125 grain
150 grain
156 grain

Table 34: Range of weather conditions under which observations were obtained

Clear, calm
Dry, light breeze
Cloudy, cool
Warm, clear
Overcast, still
Drizzle, low visibility
Continuous rain
Heavy showers
Windy, overcast

Appendix 17

Additional descriptive statistics for the 158 rifle shot badger carcases on which necropsy and radiological investigation were undertaken

Table 35: Carcase sex

	Observed	Unobserved	Total
Female	31 (48.4%)	61 (64.9%)	92 (58.2%)
Male	33 (51.6%)	33 (35.1%)	66 (41.8%)
Total	64 (100%)	94 (100%)	158 (100%)

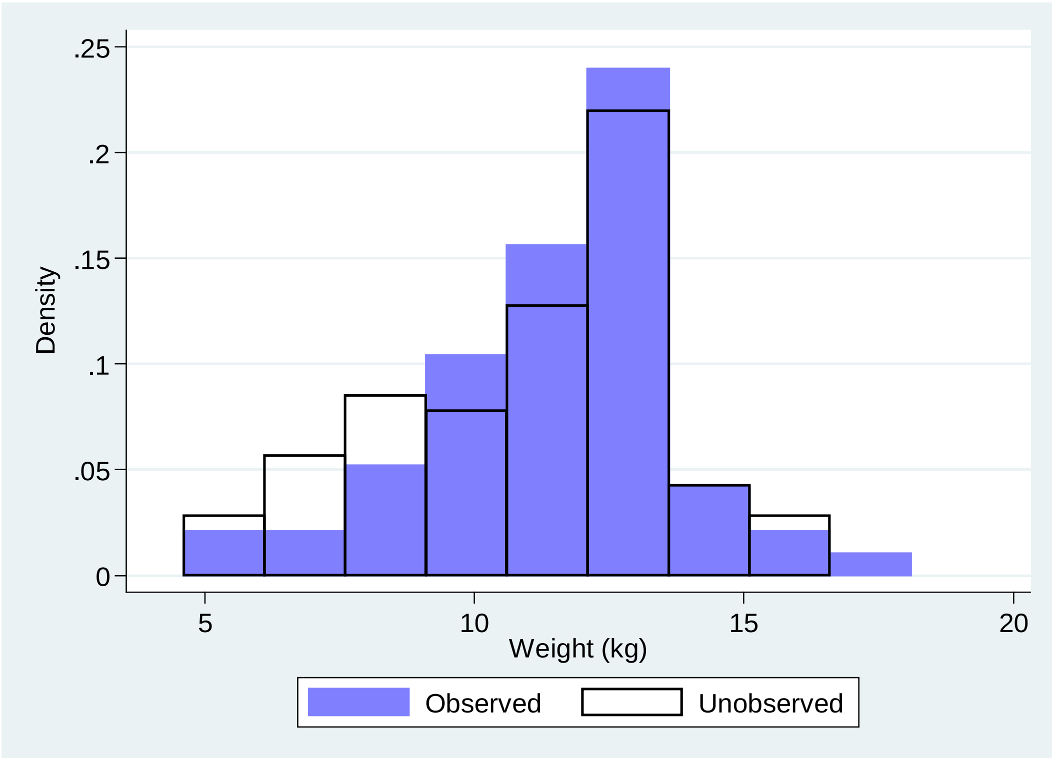
There is a borderline significant difference in the distribution of sexes between observed and unobserved badgers (p=0.039).

Table 36: Carcase weight (kg)

	Observed	Unobserved	Total
n	64	94	158
Mean (sd)	11.5 (2.3)	11.0 (2.6)	11.2 (2.5)
Median (IQR)	12.0 (10.1-13.1)	11.5 (9.1-12.8)	11.6 (9.4-13.0)

IQR = interquartile range = 25th and 75th percentiles of the data (so half the data falls in this range)

Figure 21: Histogram of distribution of carcase weight within observed and unobserved badgers



The distribution of carcase weight within observed and unobserved badgers was probably influenced by the lower proportion of female badgers in the observed group.

Table 37: Record of responses to the question: 'Is there evidence of significant post mortem change, to the degree that this necropsy is uninterpretable with respect to the aims of the study?'

	Observed	Unobserved	Total
Response = 'No'	64 (100%)	94 (100%)	158 (100%)
Response = 'Yes'	0 (0%)	0 (0%)	0 (0%)
Total	64 (100%)	94 (100%)	158 (100%)

None of the 158 eligible rifle shot carcases examined showed evidence of significant post mortem change to the degree that the necropsy was uninterpretable with respect to the aims of the study.

Table 38: Record of overall assessment of cause of death

Cause of death	Observed	Unobserved	Total
Fatal firearm injury	64 (100%)	94 (100%)	158 (100%)
Firearm injury with subsequent infection	0 (0%)	0 (0%)	0 (0%)
Firearm injury with major disablement	0 (0%)	0 (0%)	0 (0%)
Other cause with incidental firearm injury	0 (0%)	0 (0%)	0 (0%)
Other cause with no firearm injury	0 (0%)	0 (0%)	0 (0%)
Total	64 (100%)	94 (100%)	158 (100%)

Table 39: Record of level of confidence assigned to the overall assessment of cause of death (CoD)

Level of confidence	Observed	Unobserved	Total
Very confident (no reasonable doubt about the CoD)	64 (100%)	94 (100%)	158 (100%)
Fairly confident (the CoD is likely to be correct, but there is some doubt)	0 (0%)	0 (0%)	0 (0%)
Not confident (the CoD recorded is considered the most likely of the 5 options, but there is significant doubt)	0 (0%)	0 (0%)	0 (0%)
Total	64 (100%)	94 (100%)	158 (100%)

The overall assessment of cause of death assigned to all 158 eligible rifle shot carcases was ‘fatal firearms injury’. The level of confidence assigned by the examining veterinarian for all of these assessments was ‘very confident – no reasonable doubt about the cause of death’. These outcomes are not surprising in the light of the fact that eligible carcases were presented as a result of culling by the controlled shooting method.

Table 40: Distribution of carcases by pilot area

	Somerset		Gloucestershire	
	n	**% (95% CI)**	**n**	**% (95% CI)**
Observed	39	68.4% (54.8-80.1%)	55	54.5% (44.2-63.4%)
Unobserved	18	31.6% (20.0-45.2%)	46	45.5% (35.6-55.8%)
Total	57	100%	101	100%

Appendix 18

Context for the humaneness assessment of the data collected during the pilot

Introduction

This appendix is intended to provide context to the humaneness assessment of the data collected during the pilot culls. This is provided in the form of information from previous studies that measured similar variables (time to death, and the likelihood of non-fatal wounding) in other wild animal species, killed by various techniques.

It is important that when comparing the information from the current pilot culls to that given below, the differences in natural history and behaviour of the species concerned are taken into account. It should also be noted that some of the figures given below are based on studies of a limited sample size, and/or on a limited number of individual operators.

Measurements of time to death

It may be helpful to make comparisons with information available on shot wild animals, including wild deer, beavers, moose and seals. There is also some information available describing the duration of time to death of wild animal species that is considered acceptable due to the important benefits the actions provide to society.

A study in 2011 in Scotland that compared different methods of culling red deer reported that 75% of 114 wild deer shot with a rifle, were dead (apparent death) within 3 min, and 82% were dead (apparent death) within 48 minutes. The longest recorded time to apparent death was 50 minutes[1]. These data were collected by observers independent of the shooters.

Some data on time to death are available on wild beavers shot with rifles in Norway between 1991 and 1999 (data collected by shooters). The study found that 98% (111) of the animals recovered appeared to die instantly. These animals were shot either in the thorax (58), abdomen, (26) or head/neck (27) areas[2].

A study on moose shooting in Norway, where data were collected by the hunters, and that had the chest as the target area, found that no more than 21% of 105 animals died either instantaneously or very quickly[3].

A report, based on video data collected between 2003 and 2007 on Canadian seals, killed using a rifle, found that the mean time to death for 49 animals was 49 seconds, the longest observed time to death was 34 minutes[4]. A 2002 study on rifle shot Canadian seals estimated that 85% of 43 seals, were dead within 60 seconds [5].

Ç

[1] For the 11 deer that did not collapse within 50m of their location the time from the first shot to apparent death was mean 0.441h se 0.132. Median 0.333h Q1=0.05h, Q3 = 0.80.Cockram, MS., Shaw, DJ., Milne, E., Bryce, R., McClean, C. & Daniels, MJ. (2011). Comparison of effects of different methods of culling red deer (*Cervus elaphus*) by shooting on behaviour and post mortem measurements of blood chemistry, muscle glycogen and carcase characteristics. *Animal Welfare* **20**: 211-224.

[2] Twenty two amateur hunters with varying degrees of experience carried out body shots on 163 beavers by centre fire rifle using splinter or controlled expansion projectiles between 1991-1999. The 98% of animals (n = 111) recovered appeared to die instantly. Parker, H., Rosell, F. & Danielsen, J. (2006). Efficacy of cartridge type and projectable design in the harvest of beaver. *Wildlife Society Bulletin* **34**(1):127-130.

[3] (Oen, 1995, cited in Knudsen 2005). Oen carried out research for a PhD on Moose hunting in Norway, data was collected by hunters, and no peer-reviewed papers were published from the study. Time to death (TTD) was based on post mortem investigations, testing of the corneal reflexes and behavioural observations, however, no definition of very quickly was given.

The Agreement on International Humane Trapping Standards, signed by Canada, the EU and Russia, states that 80% of animals caught in a kill trap must be dead (irreversibly unconscious) within 45 seconds for ermine, 180 seconds for pine marten and 5 minutes for seventeen other fur-bearing species included in the Agreement[6].

A survey on trapping found that 65% (3233) of European hunters and trappers thought the longest acceptable time to death for killing traps should be 30 seconds or less, and an additional 10% (519) thought it should be 1 minute or less[7].

Anticoagulant rodenticides are classified by PSD as 'markedly inhumane', with rodents experiencing poor welfare for at least 24 hours prior to death[8]. The current status of anticoagulant rodenticides, is that they are necessary in order to protect human and animal health.

Assessments of non-fatal wounding i.e. no confirmed death

There are a limited number of studies that report actual non-recovery of animals that have been shot at during shooting or other wildlife management techniques.

In the study of beavers shot by 22 amateur hunters using centre fire rifles, reported hit and non-recovery rates were 5.9% and 2.6% for the two types of projectiles used[9]. The number of shots described as misses was not recorded.

In the study of methods of culling wild deer in Scotland, all 114 wild deer that were shot at with rifles were recovered[1].

A study of hunters using rifle to shoot deer in South Carolina, USA, reported that from 603 shots fired 493 (82%) deer carcases were recovered. Trained dogs were used to determine if non-recovered deer had been hit: The responses of the dogs indicated that 34 of the 110 shots resulting in non-recovered carcases had caused injuries (6% of total shots taken). The outcome of a further 119 shots would not have been known if dogs had not been utilised, due to the lack of evidence that could be detected by hunters. In this study of deer shooting, the outcome of

[4] Film of the seal cull for each year between 2003 and 2007 was analysed. Lack of co-ordinated movement were used to indicate death, Butterworth A, Gallego P, Gregory N, Harris S, Soulsbury C. Welfare aspects of the Canadian seal hunt: preliminary report, 30 p. and final report, 45 p Document submittedtoEFSA;2007. /http://www.efsa.europa.eu/en/ scdocs/doc/610.pdfS [accessed July 2013].

[5] When seals were shot from vessels, sealers commonly struck them with their hakapik as soon as they reached them on the ice, whether or not these seals showed any evidence of life. In most cases (estimated ≥ 85%), the interval between the shot and the blow(s) (resulting primarily from the time required for the vessel to get close enough to the ice floe for 1 of the sealers to land) was ≤ 1 min. Three of eight, in one instance where exact records were kept were still alive during that interval, as shown by the conspicuous movements of their head. Daoust, P.-Y., Crook, A., Bollinger, T.K., Campbell, K.G. and Wong J., 2002. Animal welfare and the harp seal hunt in Atlantic Canada. *Canadian Veterinary Journal* 43, 687-694.

[6] International Humane Trapping Standard, http://ec.europa.eu/environment/biodiversity/animal_welfare/hts/pdf/l_21919980807en00260037.pdf, [accessed July 2013].

[7] A survey carried out for the European Commission asked all responders their opinion on an appropriate time to death for killing traps. For all respondents that agreed with killing wild animals 60.4% thought it should be under 30seconds, and hunters and trappers did not vary significantly from this. Talling J.C. & Inglis I.R. (2009) Improvements to trapping standards.DG ENV. http://ec.europa.eu/environment/biodiversity/animal_welfare/hts/pdf/final_report.pdf. [Accessed 31/7/2013].

[8] PSD (Pesticide Safety Directorate) 1997. Assessment of Humaneness of Vertebrate Control Agents - Evaluation of Fully Approved or Provisionally Approved Products, No 171 (December 1997). Pesticides Safety Directorate: York, UK.

[9] The data for this study were self reported

229 shots (38%) were determined by the responses of the dogs, i.e. without dogs 229 shots would have been classified as non recovered[10].

Analysis of deer stalkers' records and examination of deer carcases was used in a study to estimate that 2% of deer shot with a rifle escaped wounded, the total number of shot at and not recovered was not estimated[11]).

A study was undertaken to determine the placement of shots after hunters had used rifles to shoot at images of foxes. From the results the authors predicted that 84% of shots would have caused either serious wounding or rapid kills. The remaining 16% of shots were predicted to result 5% of the shots causing 'light wounds' and 11% being complete misses. The authors did not differentiate between serious wounds that would have allowed location of the injured animal and those where the animal would have been able to escape. The number of rifle shots fired at foxes predicted to result in non-recovery of a carcase was therefore predicted to lie somewhere between 16 and 44%[12].

A study of impala shot in the head at night by one skilled marksman found that 6.3% of shots fired led to wounding, but that all animals shot at were recovered[13].

In 2001, observed struck and lost rates during seal hunts taking place in Canada were one out of 70 (1.4%) for clubbed animals and 3 out of 57 rifle shot animals (5%)[14]. A similar study also carried out in 2001 found that 9 out of 167, (5%) seals either shot or struck were not recovered [15].Seals that were shot at and not recovered was not observed during this study.

Struck and lost rates for beater seal pups have been estimated at 10–25%[16],5%[17], 2% (for beaters taken on the ice) and 0–10% (for seals shot at using a rifle in the water).

Ç

[10] Hunters familiar with working on University led studies, collected the data for this study for which the main aim was to determine the importance of using dogs to locate deer. 603 shots were recorded, and 493 white tailed deer were harvested, a further 34 deer were hit but not harvested, because they ran away. 253 (51%) of the harvested deer dropped in their tracks, and 240 (49%) deer ran when shot. Trained dogs were used to determine if deer had been hit. 85 of the shot deer found dead would not have been recovered without a dog and 33% of deer harvested left very poor signs of a hit. Nineteen of the non-harvested animals were later found using a dog. Answering Questions About Guns, Ammo, and Man's Best Friend. by Charles Ruth. http://www.dnr.sc.gov/wildlife/deer/articlegad.html Accessed 31/7/2013.

[11] This study estimated that 11% of deer culled by rifle required 2 or more shots to kill, 7% took 2-15 minutes to die and 2% escaped wounded, although the latter may be an underestimate because it relied on retrospective and current stalkers' records and analysis of deer carcases rather than direct observation. Bradshaw, EL. & Bateson, P. (2000). Welfare implications of culling red deer (*Cervus elaphus*). *Animal Welfare* **9**: 3-24.

[12] This study was carried out to estimate fox wounding rates based on shots taken at moving and static targets. The shot targets were categorised by two veterinary experts into four groups: kill, serious wound, light wound or miss. The study is not explicit in describing the overall percentage of targets falling in to each category but this can be calculated as 44% kill rate (35% shotgun & 56% rifle), 37% serious wound (44% shotgun & 28% rifle), 6% light wound (6% shotgun & 4% rifle), and 14% miss (16% shotgun & 11% rifle). The results are hard to interpret because serious wounding includes both fatal and non-fatal outcomes. Fox, NC., Blay, N., Greenwood, AG., Wise, D. & Potapov, E. (2005). Wounding rates in shooting foxes. Animal Welfare 14: 93-102.

[13] Impala (n = 856) were shot at night by one skilled marksman over 8 nights using a .222 calibre high velocity rifle fitted with a 4x telescopic sight from a vehicle with the aid of spotlights. Animals were shot primarily in the head and, when this was not possible, high in the neck. A high proportion (93.7%) of shot animals were killed instantaneously by the first shot, with 6.3% of all shots fired wounding animals. Lewis, AR., Pinchin, AM. & Kestin, SC. (1997). Welfare implications of the night shooting of wild impala (*Aepyceros melampus*). *Animal Welfare* **6**: 123-131.

[14]Observations were undertaken from helicopters, on four separate days, using either zoom cameras recorded onto video film or binoculars. Burdon, R.L., Gripper, J., Longair, J.A., Robinson, I. and Ruehlmann, D., 2001. Rapporteur: Fielder, J.. Veterinary Report Canadian commercial seal hunt Prince Edward Island, March 2001, Canada. Report of an International Veterinary Panel, 36 pp. <http://www.ifaw.org/ifaw/dfiles/file_95.pdf>. Accessed 30/7/2013.

[15] Daoust, P.-Y., Crook, A., Bollinger, T.K., Campbell, K.G. and Wong J., 2002. Animal welfare and the harp seal hunt in Atlantic Canada. *Canadian Veterinary Journal* 43, 687-694.

[16] Lavigne DM. Estimating total kill of northwest Atlantic Harp seals. 1994–1998. Mar Mamm Sci 1999;15(3):871–8.

[17] Gagne J. Proceedings of the National Marine Mammal Review Committee; 1999. www.dfo-mpo.gc.ca/csas/Csas/Proceedings/1999/p99_14.pdf S [accessed July 2013].

In 2006, 10% of foxes living wild in nature reserves in Denmark were found to be carrying shotgun pellets, indicating a previous hit and non-recovery. This does not include any animals that may have been wounded, not recovered and then subsequently died as a result of their injuries[18].

While undertaking ruddy duck control with shot guns, out of 2023 birds shot at and believed to have been hit, 79 (3.9%) were not found[19]. The number of animals shot at and believed to be a miss was not recorded.

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[18] All foxes within a nature reserve were shot under licence with ammunition that is not permitted for general use in Denmark. All carcases were then x-rayed to determine the number that had shot embedded within them.. Noer, H., Hartmann, P. & Madsen, J. (2006) Anskydning af vildt: Konklusioner på undersøgelser 1997–2005 (Wounding of game: Conclusions from investigations 1997–2005). *NERI Technical Report*, no. 569.

[19] Data on shot and not recovered were collected by wildlife management staff (formerly CSL) while undertaking control of ruddy ducks between September 2006 and August 2007.

Appendix 19

Further descriptive information on the event where a badger was observed conscious later than five minutes after the first shot was taken

Event ID: 131013/408/01 (Carcase EID CWG048 00003): One badger was in sight when the shot was taken. The badger was shot at a range of 30 metres, across a flooded ditch. From where the shot was taken, to get to the badger, the observer had to walk several hundred metres along the ditch to a bridge, and then back along the other side of the ditch. The thermal camera continuously recorded the whole event. Shots were fired at 0, 30, 60, 511, 539 and 814 seconds. * indicates the time period within which a shot was taken in the following behavioural description. The necropsy and radiology results for this badger are presented in Appendix 14.

*0 seconds; after the badger was shot it collapsed to the ground.

*0 to 48 seconds; the body is off the ground supported only by its front legs; the badger has no use of its back legs, the badger is trying to move.

49 to 50 seconds; recumbent, lifting head.

*51 to 67 seconds; immobile

68 to 72 seconds; recumbent, lifting head.

73 to 74 seconds; front of body off ground trying to move

75 to 76 seconds; out of view

77 to 99 seconds; immobile

100 to 367 seconds; out of view (observer and spotter walk to badger, contractor with gun stays at original shooting position)

368 to 407 seconds; recumbent, lifting head

408 to 412 seconds; out of view

413 seconds; recumbent, lifting head

414 to 428 seconds; unable to determine behaviour

429 to 436 seconds; recumbent, lifting head

437 to 476 seconds; unknown behaviour

477 to 496 seconds; immobile

**497 to 594 seconds; recumbent, lifting head

595 to 603 seconds; immobile

604 to 610 seconds; recumbent, lifting head (contractor starts to walk towards badger)

611 to 615 seconds; immobile

616 to 679 seconds; recumbent, lifting head

680 to 708 seconds; out of view

709 to 731 seconds; recumbent, lifting head up

732 to 738 seconds; trying to move laterally

738 to 750 seconds; immobile

751 to 770 seconds; recumbent, lifting head up

771 to 776 seconds; out of view

777 to 813 seconds; recumbent, lifting head up

*814 seconds; shot at close range (contractor arrived at site of badger)

815 to 870 seconds; immobile[†]

870 seconds; death confirmed

[†] A discrepancy of 10 seconds between thermal image and field recorded time was permitted. The time to last movement is described as 823 seconds in the rest of the report.

Appendix 20

Record of the badger carcases delivered to the laboratory site

Table 41:

Reason for submission to the laboratory site	Number of carcases
Necropsy/radiological investigation requested by field team. Carcase eligible for the humaneness study	160
Necropsy/radiological investigation requested by field team. Carcase later identified as ineligible for the humaneness study. See further details below*	5
For disposal. Necropsy/radiological investigation not requested by field team.	95
Private necropsy for purpose of TB diagnosis requested	4

*Further details provided below:

Reason ineligible for the humaneness study	Number of carcases
Necropsy/radiological investigation revealed an absence of firearm associated injuries	1
Necropsy/radiological investigation revealed evidence of post mortem inflicted firearm injuries only	1
Radiological investigation revealed evidence of animal having been cage-trapped, rather than having been shot when free-ranging	3

Glossary of acronyms and technical terminology

Term used	Meaning
Acute	In the context of this report, this term is used for injuries of rapid onset and relatively short duration. Injury severity is not described by this term. The term 'non-acute' therefore describes injuries of longer duration.
AU (Anatomical Unit)	The surface of the badger carcase was divided into 14 separate units: a diagram appears on page 79
Binomial confidence interval	A confidence interval for a proportion in a statistical population calculated using the binomial distribution
C: Lesion profile	Cranium - injury to the cranium (the part of the skull enclosing the brain)
Chi squared test	Any statistical hypothesis test in which the sampling distribution of the test statistic is a chi-squared distribution when the null hypothesis is true
Chi squared test for independence	A type of chi squared test used to test whether observations on two variables, expressed in a contingency table, are independent of each other. Also called Pearson's chi-squared test.
Defra	Department for Food, Environment and Rural Affairs
EID	Electronic identification device (tag)
Ethogram	A method of representing animal behaviour diagramatically
(Exact) McNemar's test	McNemar's test is a type of chi squared test used with 2 x 2 contingency tables, where the data comes from two subjects which are matched or paired in some way. It is used to test whether the row and column marginal frequencies are equal. The 'Exact' version is used when cell numbers are small.
Fisher's exact test	A statistical significance test used in the analysis of contingency tables. It is an 'exact' alternative to the chi-squared test for independence, used when cell numbers are small.
IEP	Independent Expert Panel
Kaplan-Meier survival curve	The Kaplan-Meier survival curve is defined as the probability of surviving in a given length of time while considering time in many small intervals
Kolmogorov-Smirnov test	A nonparametric test for the equality of continuous, one-dimensional probability distributions that can be used to compare a sample with a reference probability distribution (one-sample K–S test), or to compare two samples (two-sample K–S test).
MS: Lesion profile	Multiple shots.
Necropsy	Dissection and examination of an animal carcase after death
PC: Lesion profile	Primary caudal: Lesion distribution primarily involving the abdomen, lumbar spine and hind legs

Peracute	In the context of this report, this term is used for injuries of very short duration. See 'Acute'.
PN: Lesion profile	Primary Neck: Lesions primarily in the neck region with no injury to the cranium.
Radar chart	Pictorial representation of lesions detected in a carcase
Radiological investigation	The use of x-rays to produce an image of the animal, and the subsequent interpretation of the image created
Sensitivity analysis	Sensitivity analysis is the study of how the uncertainty in the output of a mathematical model or system (numerical or otherwise) can be apportioned to different sources of uncertainty in its inputs. In this report, it refers to repeating the analyses under various different assumptions, to determine how sensitive the results are to known uncertainty in the data.
TA: Lesion profile	Thorax +/- abdomen, no heart injury or major blood vessel damage or haemorrhage of >25 ml blood into abdominal or thoracic cavity
TH: Lesion profile	Thorax with heart injury and/or >25 ml blood in thoracic cavity, with or without injury to other tissues
TTD	Either the time to last movement, or the time to confirmation of death where the time to last movement was not observed.
Upper / lower confidence limits	A type of interval estimate of a population parameter, used to indicate the reliability of an estimate