Monitoring the humaneness of badger population reduction by controlled shooting

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Aim and Objectives

The aim of this project is to collect data to allow an assessment of the humaneness of controlled shooting of free ranging badgers.

To allow the assessment of the humaneness of shooting badgers, the specific objectives are:

1. To determine the time period between the moment of impact of the ammunition until death or irreversible unconsciousness.
2. To determine the proportion of badgers that escape with possible injuries after being shot at with a firearm.
3. To describe the behaviour of badgers after being shot at with a firearm.
4. To determine the location of cutaneous wounds in the badger carcases recovered from observed and unobserved shootings and compare the location of the entry wound to the shot placement set out in Defra and Natural England's Best Practice Guidance for controlled shooting of badgers[1].
5. To determine the extent of internal firearms injuries observed in recovered badger carcases.
6. To investigate whether there is any evidence of correlation between the time to death (TTD) and the observed lesions induced by firearms injuries in badger carcases recovered from observed controlled shootings.
7. To establish if the pattern of injuries in the sample of badgers killed in the presence of field observers is comparable to that detected in unobserved shootings

Policy Rationale

As part of Defra's policy on badger control, two culling techniques will be permitted in licensed areas: controlled shooting (by rifle or shotgun), and cage trapping and shooting using frangible ammunition. It is assumed that controlled shooting is an acceptable method for culling badgers. However, no scientific data are available to either confirm or negate this hypothesis. Controlled shooting is a method already used to control other species such as fox, deer and rabbit. In the best practice guidance, necessary training and competency tests and the types of firearms, ammunition, shooting distances etc are stipulated for the controlled shooting of badgers. This experience and guidance provide a good basis to believe the technique should be humane. However, as controlled shooting of badgers has not been carried out under scientific observation, objective data to judge its relative humaneness is lacking.

Approach – controlled shooting of free ranging badgers

Field observations

Killing techniques that are instantaneous without imposing any stress on the animal are universally accepted as being the ideal and having a low welfare cost. Welfare costs are assessed in two dimensions: duration and intensity of suffering. There is a complex relationship between duration and intensity. We will attempt to measure both, but will prioritise recording the maximum possible duration of suffering. This approach has been used as the basis of research in farm and laboratory animals to assess the relative humaneness of killing techniques. A similar framework has been used in Australia to review some methods of killing wild and feral animals, e.g. ground shooting of foxes and cage trapping and shooting of foxes (FERAL 2010 a, b) and rodenticides for rat and mouse control in the UK (PSD 1997).
When animals are shot as set out in the Best Practice Guidance, there are five possible outcomes:

1. Death caused directly by the shooting due to severe trauma to vital organs
2. Death caused indirectly by the shooting due to non lethal wounding associated with secondary infections and starvation because of reduced mobility.
3. Non-fatal wounding and recovery
4. Non-fatal wounding with persistent disability
5. Missed shots

Wild animal species in which time to unconsciousness or death after shooting has been measured are red deer, moose, impala, seals and whales. However, the studies in impala, seals and whales had the brain as the target area; the chest was the target for the moose. The target area for the red deer in one study was not stated but in a second was the chest. The study on moose shooting in Norway that had the chest as the target area, found that no more than 21% of 105 animals died either instantaneously or very quickly, (very quickly not defined) (Oen, 1995, cited in Knudsen 2005). Time to death (TTD) was based on post mortem investigations, testing of the corneal reflexes and behavioural observations. A study on a smaller sample size found that 71% of 31 deer shot by a rifle during daylight, 52% of 21 deer shot by a rifle during darkness collapsed immediately (Cockram et al. 2010). Observations were made by researchers in this study. Ten percent of the daytime shot deer and 43% of the night shot deer collapsed within

50m. Nineteen and 5%, respectively, moved away and did not collapse within 50m. From shooting records of red deer, the number of deer that were not unconscious within 2 minutes was 7.5% with one group of stalkers and 4.5% with a second group (Bradshaw and Bateson 2000). The target area was not reported. Anecdotal reports from deer, moose, black bear and wild boar hunters that aim to place a shot in the heart-lung area, suggest that animals can take over 30 seconds to drop dead or can run for over 100 yards. However, none of these findings have been verified in scientific reports.

There is the possibility that animals that are fatally chest shot, but still conscious prior to death have the possibility of a short period of suffering. However, the extent of suffering will vary depending on which tissues are damaged and the rate of blood loss. During severe haemorrhaging, there is likely to be an increase in respiratory rates (tachypnoea) and hyperventilation, which indicates that there is a sense of breathlessness before the loss of consciousness (Gregory 2004, 2005). If chest shot, animals may be rendered unconscious by the mechanism of shock, if they do not regain consciousness prior to death, they are unlikely to experience distress or pain.

Wild animals that are head shot, show similar responses to domestic animals that are head shot, in that irreversible unconsciousness occurs within 30 seconds (Lewis and others 1997). Badgers restrained in cage traps that were head shot were found to become unconscious within a mean of 30 seconds (range 5 s to 117 s) (Kirkwood 2000).

Laboratory investigations

The laboratory investigations proposed are radiography and post-mortem examination:

- *Radiography* is an effective method to determine the type of ammunition (rifle, shotgun) as well as the number and location of the bullets, bullet fragments and shotgun pellets. In addition, it is possible to determine bone injury such as damage to the skull, vertebral column, ribs and the long bones of the leg in a relatively short period of time (min/hours). In contrast, it takes considerable time (days/weeks) to dissect and prepare affected bones and their fragments.
- *Post mortem examination (PME)* is the method of choice to assess soft tissue damage (i.e. heart, lung, liver, entry and exit wounds)

Therefore, a combination of radiography and PME is the method of choice for the investigation of firearms injuries. (Amanda J 2010; Green 1980; Keep 1970; Knight and Saukko 2004; Levy and Harcke 2011; Munro and Munro 2011; Munro and Munro 2008).

Objective 1: To determine the time period between the moment of impact of the rifle bullet/shotgun pellets until death or irreversible unconsciousness

Rationale

The time to irreversible unconsciousness (TIU) from when a badger is hit by a bullet will indicate the maximum possible duration which the animal could feel pain or distress. The shorter the TIU, the more humane the killing technique is assumed to be. Assessment of palpebral or corneal reflexes is the recommended method to determine unconsciousness after application of killing techniques in farm animals (Gregory 2004). Some welfare scientists also propose the use of behavioural signs within animal slaughter facilities(Grandin 1994).

In the one previous study where TIU was determined for animals shot in the wild, researchers rather than shooters measured time to irreversible unconsciousness (Lewis and others 1997). In this study they were able to approach the target animals immediately after each shot was fired. To ensure that testing of unconsciousness was possible immediately after a badger had been shot in every observed shooting in the pilot areas would require changes to the Guidance of Best practice for the pilots and therefore would bring the current study under Animals Scientific Procedures Act (1986). A key requirement of the current study is that it is recording the effects of shooting in the field as carried out by private operatives under licence. The collection of data must not influence or interfere with the actions of the shooters. Therefore the researchers will not be able to approach the badger, and so assess its state of consciousness, until after the shooter has confirmed his or her belief that the badger is dead.

Collection of appropriate data for an assessment of the humaneness of killing methods for wild animals while they are living freely has been extensively discussed in relation to whales (reviewed by Knudsen 2005): In 2003 a paper was presented at the International Whaling Commission Workshop on Whale Killing Methods and Associated Welfare Issues *(IWC/55/WK4 (Evaluating possible indicators of insensibility and death in cetacean)* that proposed the indicators that should be used in the field to determine time of death*.*

The International Whale Commission agreed that they should use behavioural signs to estimate time to death (TTD), the signs being '…the time taken for the mouth to slacken, the flippers to slacken and all movements to cease'. At sea, veterinary officers used a combination of behaviour, heart and respiration cessation confirmation and post mortem examination to estimate time to death in whales. The post mortem is used to confirm complete destruction of a vital organ in cases where observations of behaviour suggest a very rapid death(Knudsen 2005). Monitoring of the seal cull in Canada uses behavioural indicators such as signs of movement, to estimate time to death. However, there has been much debate over the validity of these signs and they are routinely discussed at the annual IWC meetings.

In spite of these concerns, the detection of behavioural signs in conjunction with clinical assessment and post-mortem examination appears to be the most robust approach available to assess the humaneness of controlled shooting of badgers in the current study. A similar approach to that used to determine 'time to death' (TTD) in whales is therefore proposed for the current study.

The mechanism of death for brain shot and chest shot animals is significantly different and therefore it is thought that the behavioural indicators identified for observing whales and outlined in IWC/55/WK4, may not be appropriate for chest shot badgers. There are no published studies on chest shot animals and therefore held a workshop, with relevant experts to investigate potential indicators of death for chest shot badgers. This workshop is described in Annex E of this document.

There are many factors that may influence the accuracy and effect of a shot and consequently the TTD. No shooter will have prior experience of shooting badgers and, therefore, as time progresses experience in this factor will accrue, and this may have an impact on shooting performance. As the number of badgers removed from the environment increases, the opportunities available to kill and shoot badgers are expected to decrease and shooters may attempt shots under less than ideal conditions and outside the recommended range. The weather conditions, habitat and range may all be factors that influence TTD. As all shooters will have been trained and assessed and therefore they should all meet the minimum skill level to ensure an accurate within range shot, we will not assess the proficiency of individual operators. However, we will collect data on other factors that could conceivably influence performance (listed below).

Data collection

To ensure the minimum amount of bias in the data collected, at least one badger shooting will be observed with each of at least 60 of the 120 to 180 anticipated shooters. Observations will be spread over the whole of the culling period from week 1 through to week 6. If more than one badger is observed being shot on any one night, the observational data from all badgers will be used, and post mortem examinations will be carried out on a single badger selected at random.

- Time taken from first shot to last observed movement (not respiration).(where the badger can be observed after the shot has been taken).
- Time taken from first shot fired until confirmation of unconsciousness/death using palpebral reflexes, heart rate and respiration.
- Distance the badger has moved from where it was when shot taken. And description of evidence base for this.
- The firearm used, if the contractor is carrying both types.

Where a carcase cannot be located by the shooter, see variables collected in Objective 2.

Data on the following variables/factors will be collected:

- Range when first shot fired.
- Number of shots fired at the badger.
- Time of second or follow up shots.
- The body position of the shooter.
- Whether the badger was present at a bait point.
- Number of badgers in sight when shot taken.
- The position of the badger (side on/facing forward/facing backward).
- The local weather conditions

For each night of activity the following information will be collected:

- The weather conditions.
- The firearm and ammunition used.

For each contractor the following information will be collected:

- The night shooting experience of the shooter.
- The deer shooting experience of the shooter.
- The fox shooting experience of the shooter.
- The number of years that they have been shooting.

Data collation and presentation

The time used in the analysis will be time to death (TTD).

Estimated time to death will be determined by the lead scientist using the following criteria:

Animal is shot and is in view throughout the process. No obvious conscious movement is detected, on examination the palpebral reflex absent	Time from first shot until last observed movement
Animal is shot and disappears from view (into cover). The carcase is found within 10 m of the place when shot taken. On examination the palpebral reflex is absent.	A range will be given, the minimum being zero and the maximum being the duration from first shot to confirmed unconsciousness.
Animal is shot and disappears from view (into cover). The carcase is found further than 10 m from the place when shot taken. On examination the palpebral reflex is absent.	A range will be given. The minimum will be determined by calculating the time that it would take a badger travelling at 30km/hour to cover the distance that the carcase was found away from the spot where the shot was taken. The maximum being the duration from first shot to confirmed unconsciousness.
Animal is shot and disappears from view (into cover). When the carcase is found the animal is performing obvious movements and /or a palpebral reflex is present. A second shot is taken. No more movement is detected and palpebral reflex absent.	Time from first shot until second shot.
Animal is shot and is in view throughout the process. Movement, believed to be conscious is detected, a second shot is taken. No more movement is detected and the palpebral reflex	Time from first shot until second shot.

absent.	
Animal is shot at and disappears from view (into cover). No carcase is found.	Undetermined TTD

The results will be presented in a histogram, to illustrate the spread within the data. The results will be used to estimate the time to death that a specific proportion of the total population of badgers shot will experience and the confidence intervals for the population estimates for that proportion.

Those badgers for which a carcase was not obtained, and therefore an estimate of the TTD could not made, will be included in the analysis, but will not be assigned a value.

A minimum of 60 replicates for both rifles and shot guns will be obtained. If all these observations are within an acceptable time limit, this would indicate the number of badgers taking longer to die than this time was less than 5 % with 95% CI.

A multi-factorial analysis of the TTD data will also be undertaken and reported (statistical task 3). This will allow exploration of the impact of factors that may influence the TTD. Factors that we will explore include weather, range, experience of the shooter, time of night that shooting is undertaken, progression of the cull.

More complex statistical techniques will be explored to attempt to obtain greater precision in the estimated distribution of time to death; these may include Bayesian modelling and / or survival analysis.

Objective 2: To determine the proportion of badgers that escape with possible injuries after being shot at with a firearm

Rationale

It is likely that not all shots will result in retrieval of a badger carcase. Some shots may completely miss the animal whereas others may cause injuries which either result in recovery or in death at a later time. Some badgers hit with a non-lethal shot may be killed by a subsequent shot (see Objective 1), but some may escape again. There is no established method to assess in unrestrained animals the proportion of individuals in which this occurs. We do not know if shots where a badger's death is confirmed will provide environmental evidence, such as detectable blood spots, of the shot hitting the target animal. Therefore environmental evidence such as detectable blood spots may not be a reliable method for distinguishing between shots that completely miss and those that cause injuries.

Those animals that receive non-lethal injuries and recover may be killed (and their carcases recovered) at a later stage of the cull. Comparison of the occurrence of old shot injuries between carcases recovered at the beginning of the cull with those at the end of the cull by post-mortem examination may suggest the frequency of non-lethal shots occurring. However, it is not always possible to determine the sequence of firearm wounds.

Data collection

Both field observations and post-mortem data will contribute to this Objective. In field observations, a located badger will be observed using thermal image scopes, and the following variables will be measured:

- The response of the badger to the shot being fired, such as a flinch or jump in a specific direction.
- Any vocalisations made by the target badger.
- If the badger is moving, and can be seen, it will be observed to try and determine if it is moving normally, limping, or dragging part of its body.
- If a carcase cannot be found, then a thorough examination of the location where the badger was when the shot was fired will be undertaken; the position and approximate amount of any blood or body tissue found will be recorded.

The presence of all firearms injuries will be noted in badger carcases undergoing PME. As recently healed wounds may be masked by fur and not easily detected by visual inspection, it is anticipated that the use of radiography would improve detection of bullet fragments or shotgun pellets. The PME protocol does *not* include the investigation of the wounds/injuries by histopathology to determine the degree of healing which has occurred.

Data collation and presentation.

Outputs for the panel from this Objective will be:

- The number of badgers that were believed to be hit by a shot but for which a carcase was not recovered.
- An estimate of the proportion (plus 95% CI) of badgers of all those killed by controlled free shooting that would be hit by a shot and for which a carcase was not recovered.

- A figure showing the trend over the duration of the cull on the proportion of carcases having evidence of old shooting injuries.

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

Rationale

Observation of a shot animal's behaviour and vocalisations is the only method available to determine the degree of pain that may be experienced during the dying process after application of a killing technique, and has been undertaken in laboratory and farm animals for this purpose (Gregory 2004; PSD 1997).

Data collection

The protocol for recording behaviour has been developed based on the output of the workshop described in annex E, and a preliminary observation session undertaken in Europe, where badgers are killed using controlled shooting.

The following variables will be collected from field observations:

- Movement of a specific area of the body after being hit by the ammunition, i.e. rapid elevation of the rump.
- Description of any movements detected and their duration.

Data collation and presentation

These data will be analysed in conjunction with post-mortem data on shot location collected under Objective 4. Statistical analysis will be undertaken to determine if there is a relationship between immediate response of the animal and shot location. The frequency of different responses by the badgers will be determined and presented in a series of tables and figures in the final report.

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

Rationale

The location of the firearm wounds will convey where the animal was hit. Therefore, it may be possible to infer from this the extent to which shooting is occurring in line with the Best Practice Guidance (Defra 2011), i.e. that shooters are aiming for the chest region of the badger. This guidance on shot placement has been drafted with the aim of ensuring that the shooter is confident of an accurate and humane shot.

Data collection

The location of cutaneous and subcutaneous wounds will be recorded at post mortem examination by recording wounds on the internal surface of the pelt as well as the external surface of the skinned carcase. This approach is based on investigations carried out in deer (Urquhart and McKendrick 2006). Due to the number of carcases which will need to be processed it is not feasible to shave the carcases to determine the external wounding pattern. Similar to the studies in deer, the badger is going to be divided into anatomical units (Anatomical units (AU) page 17) and the wounds will be allocated to one of these units. In addition, the location will be plotted on a diagram to determine the location within any particular anatomical unit. Furthermore, the shot is scored as 'no wound detected', 'non penetrating' (only damage to skin and subcutaneous tissue), 'penetrating/non exiting' and 'perforating' (entrance and exit wound), loosely based on Gugala and Lindsey, 2003. If possible, the maximum diameter of the wounds will be measured.

Because of the fundamental difference between rifle and shotgun wounds, the two weapons are going to be analysed separately.

Data collation and presentation

The location of the cutaneous wounds in carcases from observed and unobserved shootings will be summarised and analysed in a similar way to the data analysis of Urquart and McKendrick (2003, 2006). Outputs will primarily be descriptive, in terms of the proportions of cutaneous wounds observed in parts of the carcase defined by anatomical features. There have been no equivalent studies of the impacts of shooting on badgers, so summary and analysis will probably include classifications defined after studying the observations. Hence there will be a compromise between the clarity of interpretation of outputs and their statistical rigour.

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

Rationale

During firearms injuries, some or all of the kinetic energy of the missile has to be absorbed by the target tissues, where it dissipates as heat, noise and mechanical disruption (Knight and Saukko 2004). Depending on the type of ammunition used as well as of the trajectory and velocity of the missile, the character of the tissue damage varies from a simple wound track in a non-vital tissue to complete destruction of the targeted body part. By carrying out radiography and PME, it will be possible to determine the extent of damage to vital and non vital organs.

Lack of visible damage does not rule out a short period to time of unconsciousness or time of death. An example would be sudden death due to functional heart disease. On the other hand, it is fair to assume that extensive destruction of a vital organ such as brain, heart or aorta will have resulted in a relatively short TTD, even assuming that shock does not result in rapid loss of consciousness (Beverland and Rutherford 1983; Campbell et al 1997; Parmley et al 1958a; Parmley et al 1958b; Svendsen et al 2008).

Lateral and dorso-ventral radiographs will be taken of the whole body and a post mortem examination will be carried out. The data capture will consist of the assessment of the presence or absence of each of a pre-agreed list of potential lesions, using a scoring system to allow statistical analysis. The scoring system includes the location and chronicity of a particular lesion. This system will allow capturing of lesions caused by recent events as well as lesions from previous shootings. During this process, detailed information will be lost and accurate representation of the extent of tissue damage may not be practical in every circumstance.

Data collection

Each type of soft tissue and skeletal lesion will be scored as detected/not detected (1 or 0) or as a percentage of tissue damage such as in heart, lung and liver. In addition, each lesion will be scored using standard morphologic change categories. These latter categories are based upon the changes seen on post mortem examination according to an inferred duration of the lesion (see Appendix 3: Necropsy data capture sheets - Glossary). Damage to the central nervous system will not be directly investigated but presumed based on the destruction of the surrounding tissue (cranial bones, spinal column). The details on the captured data are given in Appendix C

Based on the post mortem findings, each animal will be assigned a cause of death based on the following five categories: fatal firearms injury, firearms injury with subsequent infection, firearms injury with major disablement, other causes with incidental firearms injuries and other cause with no firearms injury. The post mortem examination will be carried out blind with respect to the estimated (field-observed) TTD; hence the veterinarians performing the procedures will not know the estimated TTD recorded in the field.

It is important to emphasise that the lack of visible and/or extensive lesions does not rule out a short period of time to unconsciousness or to death. In addition, the score is to be seen as an indicator for lesions to a particular anatomic unit and does not provide any direct information on the degree of suffering inflicted by the injury observed. Furthermore, any score has to be taken into account with the other scores from the same region, for example there may be soft tissue damage of the neck in the absence of damage to the cervical spine. No particular weight is given to any particular score.

Data collation and presentation

All scores will be analysed from each animal and combined in a score per region resulting in a lesion profile. In other words, each lesion profile will represent the summary of the tissue damage observed in a single animal. For example, a clear chest shot would have a high score for that anatomical area and no or very low scores for the other areas.

Based on this analysis, animals with similar lesion profiles (for example severe acute heart lesions, severe acute lung damage, etc.) will be grouped together. These lesion profiles will be used to allow the statistical analysis carried out in Objectives 5 and 6.

Injuries that permit grouping of lesion profiles are expected to be associated with shots hitting the target areas set out in the Best Practice Guidance. Consistent, repeat lesion profiles are likely to be identified only for injuries associated with entry wounds within, or close to, the chest area. Impacts outside the recommended target areas may cause injuries that cannot be grouped.

It is important to note that the lesion profiles will **not** be pre-defined. The classification of lesion profiles will be carried out by veterinarians (based on expert judgement) once the data from post mortem examinations and interpretation of radiographs are available. The classification will combine evidence from the post mortem examinations and interpretation of radiographs.

Objective 6: To investigate whether there is any evidence of correlation between the time to death (TTD) and the firearms injuries in badger carcases recovered from observed controlled shootings

Rationale.

Lesion classification and lesion profiling is a useful tool, because it allows the summarisation of complex data. In the field of human medicine, this technique has been developed over several years to produce lesion scores to assess survival/mortality rates from firearm wounds and blast injuries (Beverland and Rutherford 1983; Gugala and Lindsey 2003; Yelveton 1996).

It is generally accepted that a well placed chest shot results in a relatively rapid death. This assumption will be explored by comparing the visually estimated (field-observed) TTD data with the pathology data, as described below.

Data collection.

This objective will use the data collected from Objectives 1, 4 and 5.

An analysis will be carried out to explore how the different classes of pathology (obtained from data generated by Objectives 4 and 5) might be associated with the different field-observed TTD. This analysis will use the original classification of injuries from Objective 5, by applying standard statistical methods to determine whether there are significant differences in TTD between injury classes.

It is important to note that the different classes of pathology will not be pre-defined, and there will be **no** attempt to classify the pathology into three pre-defined categories regardless of the pathology observations recorded.

The persons carrying out the radiography and post-mortem examination will not know the field-observed TTD when carrying out the examinations, ensuring unbiased assessment of the pathology observed.

Data collation and presentation

The output from this objective will be the number of animals which had certain pathology profiles for each of the three field-observed TTD groups.

Based on the overall study design, it is anticipated that carcases from animals which are not immediately immobilised whilst being shot at will be underrepresented in this study since their carcases are less likely to be retrieved. This limits the statistical analysis since the number of animals with a long time to death may be relatively low.

Shotguns and rifles cause injury by different processes and the patterns and locations of their wounds are not directly comparable. Therefore no statistical comparison between them will be carried out.

The raw pathology data for each animal will be submitted in an appendix to the final report.

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

Rationale

Shooters may behave differently when they are being observed by the scientists, and therefore the TTD and wounding rate data gathered from the observed population may not be representative of all badgers shot.

Comparing radiography and PME results between badger carcases from observed and unobserved shootings would allow comparisons of the lesion profile between these two groups. If the lesions are within the same range, it would support the hypothesis that the shooters' behaviours are similar. An attempt will be made to avoid any possible bias in the sample selection from unobserved shootings (see Data collection). It does however not give any information on the number of missed shots or badgers that are shot but not retrieved. If sufficient shooters provide samples from observed and unobserved shooting, data will be collected on at least 60 replicates, matched pairs, for both rifles and shotguns.

Data collection.

Shooters will be requested to write on each carcase bag: their unique id, and weapon used (rifle or shot gun). Field staff based at the incineration plants will collect the required carcases when they are delivered by the shooters. Each carcase will be given a unique identification code.

Unobserved carcases will be selected that are matched to the observed sample for shooter and weapon. To avoid bias, the unobserved samples will be spread over the duration of the cull to match the distribution over time of observed samples. The collected unobserved carcases will be delivered to the PME facilities with the observed carcases.

In the situation that more than one unobserved carcase from a particular shooter and weapon undergoes post mortem, the following process will be followed to produce a matched pair of carcases for the paired analyses in this Objective. The unobserved carcase shot closest in time to the observed carcase will be chosen as its pair; if there are multiple unobserved carcases shot on the same night, one will be selected at random. Any remaining unobserved carcases will be excluded from paired analyses in this Objective.

The lesion profiles obtained for each badger from the field observed shootings for which estimated TTD is available will provide baseline data on which other unobserved shootings can be assessed. This will produce a more objective and unbiased result.

Thus the carcase injuries will initially be classified based on observed lesion profiles and the pathologists' judgement about which injuries are important or critical. Once the original classification has been compared with the observed time to death for Objective 6, the pathologists may take the opportunity to modify the classification in light of the TTD information. For example, the original classification may combine lesion profiles with two different scores in the chest region, in the belief that the difference is not important. Analysis for Objective 6 might find that the injury class is associated with a range of TTD and that the TTD within the class is correlated with the score in the chest region. This might suggest that the final classification from the study should divide the original injury class according to the score in the chest region. Of course the adjusted classification should not be used for a repeat analysis of the relationship between injury and TTD.

Data collation and presentation

Based on the overall design of the experiment with replicates of 60 observed and unobserved badger shootings for each weapon, it will be possible to carry out statistical analysis of the number of shots on target (entrance wounds in the heart area) in carcases from observed and unobserved shootings using paired sample parametric tests. It will also be possible to analyse the number of carcases with severe heart lesions from both observed and unobserved shootings. However, the precise comparisons made between observed and unobserved shootings will depend on the actual wounds and pathology observed in the study. The distribution of carcases among injury classes for unobserved shootings will also be compared with carcases from observed shooting to determine whether the distributions are significantly different. The statistical analysis will take account of the use of the data to examine two or more different outcomes (Table 6).

Communication and delivery of reports

In addition to the daily reports described later in this document (under ethical conflicts, study level), an initial report on the basic results from Objective 1 will be delivered to Defra within two weeks of the end of the cull. A full report that will contain all the statistical analysis and post mortem results will be delivered to Defra within 25 working days of the end of the cull. The report concerning Objectives 4, 5, 6 and 7 is going to include descriptive pathology data and the statistical analysis as detailed at the end of each objective.

Raw data for field observations and post mortem examination will be provided to all parties (i.e. collaborators, Defra and independent expert panel) on request.

Immediate communication with Defra will take place if any concerns regarding safety to staff and property as well as animal welfare are identified.

Potential ethical conflicts between field observation protocol and animal welfare

1. Individual researcher level

While observing the behaviour of badgers with thermal imagers after they have been shot at, the scientists may potentially observe the badger getting to its feet and moving slowly away from the target site or displaying signs of consciousness. The Guidance document recommends that shooters should take a second shot if there is any indication that the animal is still alive. However, we cannot guarantee that shooters will continue to observe such animals, or take the appropriate action.

If alerted to the movement of the badger by the scientist the shooter may have the opportunity to fire a second shot at the badger. In the protocol issued to researchers, we will make explicit that the shooters have to behave as if the scientists were not present, and under normal circumstances that the scientists cannot interfere with the actions of the shooter.

However, to avoid creating a potential ethical dilemma for the researcher, we propose to advise researchers that if they believe there are signs of consciousness but judge that the shooter does not indicate an intention to take a second shot, they are permitted to alert the shooter to these signs of consciousness. The approval of this study protocol by the Fera ethics committee is contingent on the researchers being given this freedom.

It is recommended that rules for when action should be taken by researchers and/or Defra officials are agreed before culling commences, so that field scientists are not required to make a judgement on appropriate action whilst in the field.

On occasions where a researcher intervenes in this way, the following information will be recorded:

- The time after the first shot at which the researcher intervenes, and:
- The response of the shooter to this intervention.

2. Study level

It is possible that data accumulated on either the level of non-lethal shots or the TTD may indicate an unacceptable level of humaneness before the end of the six week cull. A decision could be taken on the acceptability of the technique at this point that either the cull in its entirety or the use of certain methods should be suspended. Any such decision would need to be based on a robust sample size.

On a daily basis the project leader will provide Defra with information on

- The total number of shots where badgers are believed to have been hit but no carcase recovered, and the estimated proportion of observations that this will occur in after 60 observations have been made.
- The number of observations for which the estimated TTD was longer than 5 minutes, and the estimated proportion of observations that this will occur in after 60 observations have been made.

Potential risks to the study

1. Problems with Post mortem examinations.

- Laboratory capacity to carry out post mortem examinations may be exceeded. Currently, the maximum number of badger carcases to be processed is estimated at 12 carcases/day using the targeted PME.
- Significant delay of PMEs may occur due to logistical problems experienced during field studies.
- Carcases may be accidentally damaged or tampered with before arrival at the post mortem facility, obscuring pre-existing pathologies.
- Based on the current management of institution B, no weekend working by staff is in place for this institution, therefore only badgers submitted Sunday to Thursday night will be examined promptly.
- Examination of badgers may be interrupted/curtailed by protestors/activists demonstrating and/or entering the laboratory.
- Equipment failure – radiography, downdraught tables, respirators, (camera). All equipment will be either new or checked prior to commencement of the cull to try and avoid equipment failures.

A contingency plan is being developed by organisation B.

2. Risk to personal safety and damage to property due to public interruption.

Likelihood: Medium
Impact: High

Action: Project leader will liaise with security experts and devise appropriate guidelines for use by field staff. A pool of hire vehicles will be used by the field team; these will be rotated on a weekly basis, to reduce the chances of a particular vehicle being followed. If the details of any vehicle are discovered by opponents to the cull, this car will be immediately switched. The safety of staff will take priority over data collection. The thermal imagers will be used to scan the area for unauthorised/ unknown persons while shooting is taking place. Any safety concerns will be immediately communicated to Defra via the project leader. Collection of carcases and delivery to post mortem facilities will be arranged by industry, in consultation with police and researchers, to minimise risk of disruption.

3. Insufficient staff in institution A to carryout field observations.

Likelihood: Medium
Impact: Medium
Action: The fieldwork component of this project is extremely high for a two month period. Wherever possible we will use current staff to run this project. We will seek to recruit sufficient additional staff (up to 20) on short term contracts (Three months, to allow two weeks for training and logistics management). In order to avoid potential impacts of infiltration by those who might seek to interfere with the study, half of the new staff will be paired with current staff during all fieldwork, and the other half will be used to backfill current staff removed from current projects in order to staff this project. All staff will undergo extensive training on the protocols, and observations/ measurements to be made.

4. Differentiation between recent and previous firearms injury.

It is known that a number of wild animals have evidence of old gunshot injuries (Bertsden, cited by Fox and others 2005). Radiography is essential for the detection of all ammunition fragments in the carcase. However, it is not possible to determine the time elapsed between injury and post mortem without including extensive additional testing such as histopathology. Even with additional testing, it is often not possible to differentiate between timing of different wounds.

Although organisation B has extensive experience of field and targeted post mortem examinations in many species including badgers, there is limited expertise in ballistics. Determination of range of the shot fired and exact type of ammunition would need the advice of a firearms and ballistics' expert. Even with such an expert, it may not be possible to determine the sequence of the shots and, in the case of a shotgun, the number of shots fired.

Likelihood: Medium
Impact: Low

5. Insufficient replicates and bias in data collected.

It is expected that more badgers will be shot at the beginning of the six week cull period than at the end. This could potentially bias the replicates towards one type of weapon or situation. To try and avoid this, the sampling protocol will be flexible and changes will be made during the trial, based on the carcases collected to date, to try and ensure the minimum amount of bias. A low number of carcases may be received because of lack of retrieved carcases from injured or missed badgers. The results from the post mortem will be used to try and establish the relationship between field observations of TTD and injury data. A shortfall in post mortem replicates would not diminish the robust field observations.

6. Large number of non-lethal shots.

Not all gunshot wounds are lethal (Munro and Munro 2008) and potentially injured badgers may therefore not be retrieved. The potential ethical implications of this have been discussed elsewhere in this paper (Potential ethical conflicts between field observation protocol and animal welfare, 2. Study level, page 13). Calculations of current estimates of likely outcome will be communicated to Defra on a daily basis, so that ministers are aware of any welfare issues and if deemed necessary could halt the cull. However, there is also the risk of loss of data and introduction of potential biases.
Likelihood: low,
Impact: high.
Action: Only shooters that have attended the training course and passed a practical assessment will be licensed to shoot badgers. The primary aim of the training program is to try and ensure that non-lethal shots are not fired.

7. Transport and handling of infectious material including *Mycobacterium* sp infected carcases.

Likelihood: high,
Impact: High.
Action: All procedures will be carried out according to the required H&S standards for handling potentially mycobacterium-infected badgers and many of the required risk assessments are already in place or can be used following minor amendments.

8. Study ended prematurely due to ethical conflicts

Likelihood: medium
Impact: High.

Action: Data analysis will only be carried out if sufficient data are available.

Annexes

Annex A: Logistics of the field observations:

Details removed from this document.

Annex B: Detailed SOP for field observations available from project lead.

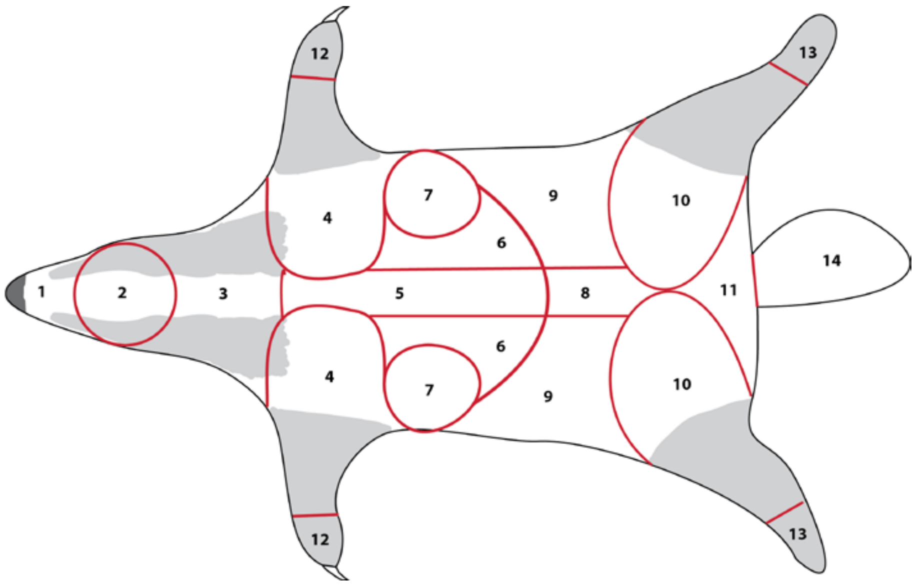
Final version not signed off, due to further refinement with field team, in light of training and dry run exercises.

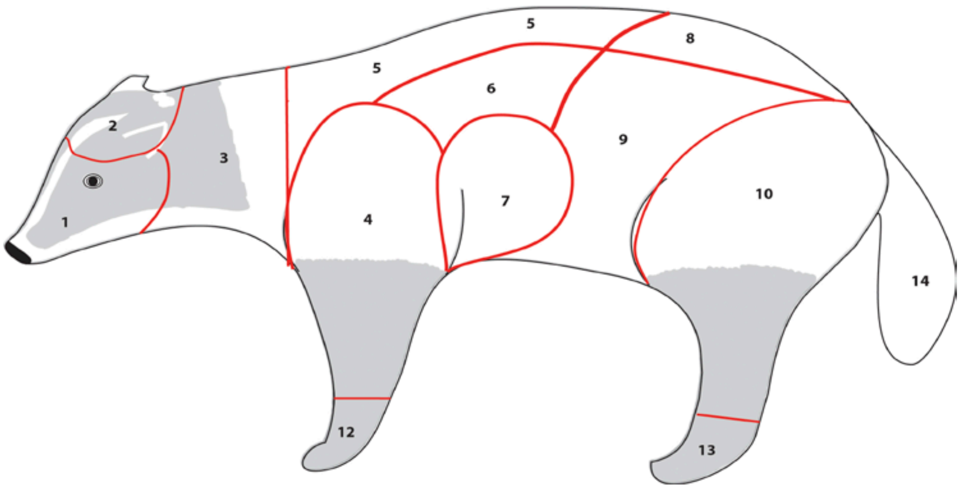
Annex C: Detailed pathology

Anatomical units (AU)

Anatomical units have been designed to allow the statistical analysis of the PM data observed. The system is loosely based on that published in deer

	Skeletal basis	Main soft tissue
1	Facial bones	Eyes, airways, muscles, etc
2	Cranial bones	Brain
3	Cervical spine	Muscle, trachea, oesophagus
4	Scapulae, humerus, radius and ulna	Muscles, tendons, ligaments
5	Thoracic spine	Muscles, tendons, ligaments
6	Ribs	Lung
7	Rib/sternum	Heart/Lung
8	Lumbar spine	Muscles, ligaments etc
9		Abdominal and pelvic viscera
10	Pelvis, femur, tibia and fibula	Muscles, tendons, ligaments
11		Perineum and underlying soft tissue
12	Carpus, metacarpus and phalanges	Muscles, tendons, ligaments
13	Tarsus, metatarsus and phalanges	Muscles, tendons, ligaments
14	Coccygeal vertebrae	Muscles, tendons, ligaments





Restricted: Radiography Data Capture Sheet for the Detection of Ammunition and Skeletal Damage Induced by Firearms

Project P10109OT-HUM-SOP 4 Data Capture from Radiographs

1. EID Number ☐

2. Characterisation of the Shooting event

Ammunition: (√)	Shotgun pellets	☐	bullet fragments	☐	none detected	☐
Number of shots:					Comment:	

Rifle:	*	Not possible to determine:	☐
Shotgun:	*	Not possible to determine:	☐

*Please note number (including zero shots) and record	

3. Location of Ammunition

	(√)	**Intra-thoracic fragments**				**Fragments in front leg**				**Other affected areas**	**corresponding entrance wound**
Rifle K	ND☐	Yes	☐	No	☐	Yes	☐	No	☐		
Rifle L	ND☐	Yes	☐	No	☐	Yes	☐	No	☐		
Rifle M	ND☐	Yes	☐	No	☐	Yes	☐	No	☐		
Shotgun R	ND☐	Yes	☐	No	☐	Yes	☐	No	☐		
Shotgun S	ND☐	Yes	☐	No	☐	Yes	☐	No	☐		

If any *additional shots* are being identified please note in comments section overleaf and assign N, O, etc; *Other affected areas* please note the number of the appropriate Anatomical Unit(s) (AU)- please see the diagram in SOP4 Appendix 3. If there are none, write '**0**'. The letter of the *corresponding entrance wound* identified on the necropsy data capture form should be entered here. If undetermined/uncertain, please write U.

4. Characterisation of the skeletal damage

A. Head, neck, trunk, rump and tail

Lesion: tick detected (yes) or not detected (no) for presence of firearms injury. For multiple choices**, circle** as appropriate**. Characterisation:** S=sharp skeletal fragments, R=rounded skeletal fragments, C=remodelling and callus, U uncertain, x = complex. **Attributable to shot(s):** note the letter of the shot(s) which correspond to that used above. Use U for undetermined/uncertain.

	Lesion present				**Lesion characterisation**	**Attributable to shot(s)**
Facial bones	Yes	☐	No	☐	S / R / C / U / x	U / K / L / M / R / S / other specify
Cranium	Yes	☐	No	☐	S / R / C / U / x	U / K / L / M / R / S / other specify
Cervical spine	Yes	☐	No	☐	S / R / C / U / x	U / K / L / M / R / S / other specify
Thoracic spine	Yes	☐	No	☐	S / R / C / U / x	U / K / L / M / R / S / other specify
Lumbar spine	Yes	☐	No	☐	S / R / C / U / x	U / K / L / M / R / S / other specify
Sacrum/pelvis	Yes	☐	No	☐	S / R / C / U / x	U / K / L / M / R / S / other specify
Coccyx/tail	Yes	☐	No	☐	S / R / C / U / x	U / K / L / M / R / S / other specify
Ribs and sternum	Yes	☐	No	☐	S / R / C / U / x	U / K / L / M / R / S / other specify

1. EID Number ☐

B. Extremities

	Lesions present						Lesion characterisation	Attributable to shot(s)
Scapula, humerus, radius and ulna	Left	☐	Right	☐	No	☐	S / R / C / U / x	U / K / L / M / R / S / other specify
Carpi, metacarpi and phalanges	Left	☐	Right	☐	No	☐	S / R / C / U / x	U / K / L / M / R / S / other specify
Femur, tibia and fibula	Left	☐	Right	☐	No	☐	S / R / C / U / x	U / K / L / M / R / S / other specify
Tarsi, metatarsi and phalanges	Left	☐	Right	☐	No	☐	S / R / C / U / x	U / K / L / M / R / S / other specify

Lesion: tick if detected in one side (left or right), both sides (left and right) or not detected (no) for presence of firearms injury. **Characterisation:** S=sharp skeletal fragments, R=rounded skeletal fragments, C=remodelling and callus, U uncertain, x = complex. For multiple choices, **circle** as appropriate. **Attributable to shot(s):** note the letter of the shot(s) which correspond to that used above. Use U for undetermined/uncertain.

5. Comments

if insufficient space please use an additional sheet clearly marking the Badger EID or label Number

Signature			
Name of examining vet		Date Completed	
Signature of 'data supervisor'			
Name of 'data supervisor'		Date Checked	

Department for Environment, Food and Rural Affairs
Scottish Government, Welsh Government

'Scribe' initials	Weighed by (Initials)

AHVLA Animal Health and Veterinary Laboratories Agency

Restricted: Necropsy Data Capture Sheet for Project P10109OT-HUM

1. EID Number

Date of necropsy

2. Animal Details

Sex (√) Male ☐ Female ☐ Weight kg

3. Cutaneous/subcutaneous wounds

A. Rifle

Wound ID	(√)	**Entry/Exit** (**Circle** one answer only)	**Related to En**	**AU** (one unit only)	**Perforation** (**Circle** one answer only)	**Max. diameter**	**Appearance**	**Infected?** (**Circle** one answer only)
Wound A	ND ☐	En / Ex / U			N / P / T / U	mm	H / O / F / U / p	Y / N / U
Wound B	ND ☐	En / Ex / U			N / P / T / U	mm	H / O / F / U / p	Y / N / U
Wound C	ND ☐	En / Ex / U			N / P / T / U	mm	H / O / F / U / p	Y / N / U
Wound D	ND ☐	En / Ex / U			N / P / T / U	mm	H / O / F / U / p	Y / N / U
Wound E	ND ☐	En / Ex / U			N / P / T / U	mm	H / O / F / U / p	Y / N / U
Wound F	ND ☐	En / Ex / U			N / P / T / U	mm	H / O / F / U / p	Y / N / U

B. Shotgun

Wound ID	(√)	**Entry/Exit** (**Circle** one answer only)	**Related to En**	**AU** (one unit only)	**Perforation** (**Circle** one answer only)	**Appearance**	**Infected?** (**Circle** one answer only)
Cluster T	ND ☐	En / Ex / U			N / P / T / U	H / O / F / U / p	Y / N / U
Cluster W	ND ☐	En / Ex / U			N / P / T / U	H / O / F / U / p	Y / N / U
Cluster Y	ND ☐	En / Ex / U			N / P / T / U	H / O / F / U / p	Y / N / U
Cluster Z	ND ☐	En / Ex / U			N / P / T / U	H / O / F / U / p	Y / N / U

Wound ID: if possible, record entry wounds first. Consider a cluster of shotgun wounds as **one** unit.
ND: not detected – once all wounds have been identified and recorded, tick this box in any remaining unused rows in both tables.
Entry/Exit: if possible, determine if wound is an entry (En) or exit (Ex) wound. **Related to En**: if an exit wound is identified, if possible, record the related entry wound letter – if wound is an exit wound, but the related entry wound cannot be identified, record U.
AU: anatomical unit affected as shown on diagram in SOP5 Appendix 1; for shotgun wounds, record the AU in which the pellet density is highest. If the wound is in a transitional zone involving more than one AU, record the AU where there is most damage.
Perforation: N = Non-penetrating, P = Penetrating, no exit, T = Through.
Diameter: record maximum diameter of rifle wounds.
Appearance: H = Fresh frank haemorrhage and/or oedema, O = Organising blood clot/exudate, F = Fibrosis and scar formation, p = Post mortem
Infected?: Y = Yes, N = No.
For all columns where U is an option: U = Uncertain/Undetermined.
The **Entry/Exit**, **AU**, **Perforation**, **Maximum diameter**, **Appearance** and **Infected?** columns must be completed for all rifle wounds identified.
The **Entry/Exit**, **AU, Perforation**, **Appearance** and **Infected?** columns must be completed for all shotgun wounds identified.

Comments (skin/subcutaneous tissue)

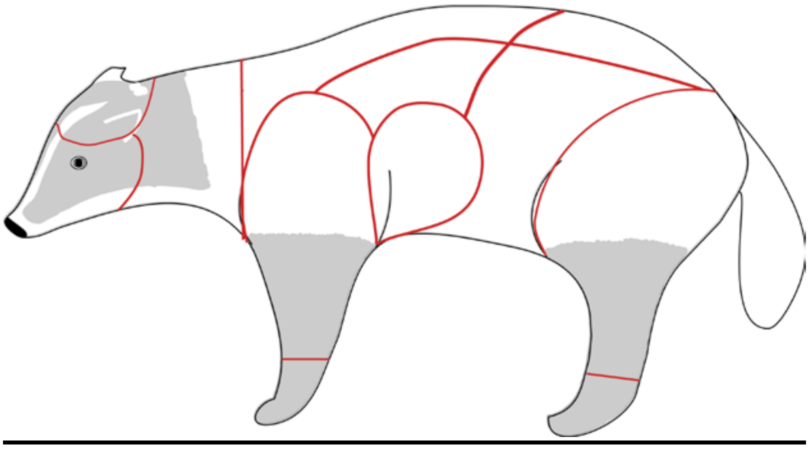
Continuation sheet used (√) ☐

EID Number

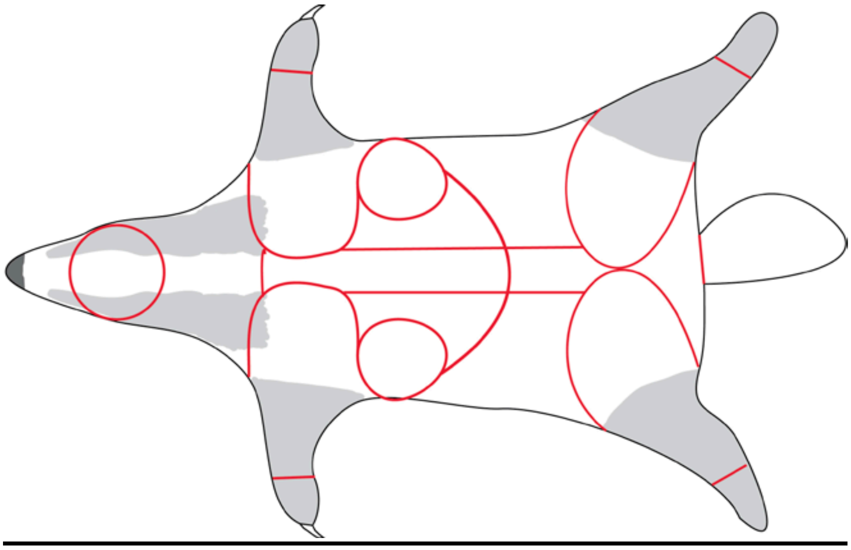
4. Plot of cutaneous/subcutaneous wounds

Plot the cutaneous/subcutaneous wounds on the diagram using the same nomenclature used in the table on the previous page (for example a cross labelled A to indicate where on the body rifle wound A was detected). **Give the location for each wound once only, and only on one of the three diagrams**. For rifle shots, note with a cross. For shotgun pellet clusters, shade the affected area and if possible give an approximate direction indicated by an arrow.

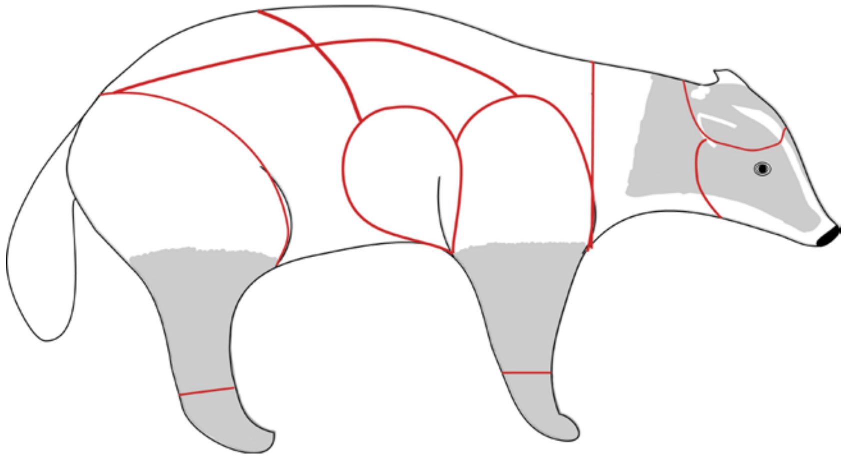
left



dorsal



right



EID Number

Firearms Injury: Y = Yes, N = No, U = Uncertain/Undetermined. If yes circled for heart, lung or liver, tick **(√)** one box to indicate approx. percentage of damaged tissue. For kidney, circle 'One' if unilateral lesion, 'Both' for bilateral lesion. For the legs, circle 'Left' or 'Right' if unilateral; circle left and right (one large circle) if bilateral. **Appearance**: H = Fresh frank haemorrhage and/or oedema, O = Organising blood clot/exudate, F = Fibrosis and scar formation, U = Uncertain/Undetermined, p = Post mortem, c = Complex. **Infected?**: Y = Yes, N = No, U = Uncertain/Undetermined. **Attributed to entry wound**: if possible, record the letter of the entry wound(s) that correspond to any firearms injury recorded in the row – if not possible to determine, record U. The **Firearms injury** column must be completed for all anatomical regions listed. If a firearms injury is identified, then the **Appearance, Infected? and Attributed to entry wound** columns must also be completed for that row .

5. Internal tissue damage attributable to firearms injury		**Firearms Injury** (**Circle** one answer only – except for legs; if both legs affected, circle left and right)	**Appearance**	**Infected?** (**Circle** one answer only)	**Attributed to entry wound(s)**
Head	Face	Y / N / U	H / O / F / U / p / c	Y / N / U	
	Cranium	Y / N / U	H / O / F / U / p / c	Y / N / U	
Neck	Muscles	Y / N / U	H / O / F / U / p / c	Y / N / U	
	Trachea/oesophagus	Y / N / U	H / O / F / U / p / c	Y / N / U	
	Major blood vessel	Y / N / U			
Thorax	Heart (√)	Y / N / U If yes, ≤ ~5% ☐ > ~5% to ≤ ~20% ☐ > ~20% to ≤ 100% ☐	H / O / F / U / p / c	Y / N / U	
	Lungs (√)	Y / N / U If yes, ≤ ~33% ☐ > ~33% to ≤ ~66% ☐ > ~66% to ≤ 100% ☐	H / O / F / U / p / c	Y / N / U	
	Diaphragm	Y / N / U	H / O / F / U / p / c	Y / N / U	
Abdomen/pelvis	Liver (√)	Y / N / U If yes, ≤ ~33% ☐ > ~33% to ≤ ~66% ☐ > ~66% to ≤ 100% ☐	H / O / F / U / p / c	Y / N / U	
	Spleen	Y / N / U	H / O / F / U / p / c	Y / N / U	
	Intestine (includes stomach)	Y / N / U	H / O / F / U / p / c	Y / N / U	
	Kidney	One / Both / N / U	H / O / F / U / p / c	Y / N / U	
Front leg	Muscles/tendons	Left / Right / N / U	H / O / F / U / p / c	Y / N / U	
	Major blood vessel	Left / Right / N / U			
Front foot	Foot	Left / Right / N / U	H / O / F / U / p / c	Y / N / U	
Hind leg	Muscles/tendons	Left / Right / N / U	H / O / F / U / p / c	Y / N / U	
	Major blood vessel	Left / Right / N / U			

Hind foot	Foot	Left / Right / N / U	H / O / F / U / p / c	Y / N / U	
Tail	Tail	Y / N / U	H / O / F / U / p / c	Y / N / U	
Additional findings	(Circle one answer only)				
Whole carcase	Extreme pallor	Y / N / U			
Thorax	Free blood in thoracic cavity (√)	Y / N / U If yes, ≤ ~25ml ☐ > ~25ml ☐			
	Pulmonary emphysema due to firearms injury	Y / N / U			
Abdomen/pelvis	Free blood in abdominal cavity (√)	Y / N / U If yes, ≤ ~25ml ☐ > ~25ml ☐			

EID Number ☐

Comments (internal tissue damage)

Continuation sheet used (√) ☐

6. Photography
(tick if photo taken)

Photo: Firearms injury (√) ☐

7. Is there evidence of significant post mortem change, to the degree that this necropsy was uninterpretable with respect to the aims of the study (tick one box) (√)

Yes ☐ No ☐

8. Are bullet fragments/shotgun pellets present on the radiographs, which are not associated with acute pathology? (tick one box) (√). If yes, please provide details in the 'tissue damage' comments section above.

Yes ☐ No ☐

9. Overall assessment

Cause of Death (CoD) (tick one box only) (√)

Fatal firearms injury ☐

Firearms injury with subsequent infection ☐

Firearms injury with major disablement ☐

Other cause with incidental firearms injury ☐

Other cause with no firearms injury ☐

Level of confidence of CoD (tick one box only) (√)

Very confident (no reasonable doubt about the CoD) ☐

Fairly confident (the CoD is likely to be correct, but there is some doubt) ☐

Not confident (the CoD recorded is considered the most likely of the 5 options, but there is significant doubt) ☐

Signature of examining vet ☐

Name of examining vet		Date	
Signature of 'data supervisor'			
Name of 'data supervisor'		Date	

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Annex D: Detailed Statistics

Three basic statistical tasks will be undertaken in this study which will be used to either assign resources to observations, and/or provide evidence about the humaneness of control, and to explore relations between some of the factors which describe how control is undertaken and our observations.

- Task 1) To estimate the frequency of occurrence of an outcome in a population (or in the long run) given our observations in a representative sample.
- Task 2) Statistical analysis associated with determining differences between observed and unobserved carcases.
- Task 3) To identify the factors that significantly influence the TTD.

Task 1: To estimate the frequency of occurrence of an undesirable outcome in a population (or in the long run) given our observations in a representative sample.

a) Confidence intervals for proportions
Estimates of confidence intervals for proportions will be produced using a “Modified Jeffries interval”(Brown and others 2001). These are Bayesian credible intervals which are calculated by finding quantiles x from the Beta Distribution such that:

$$\int_0^x \mathrm{B}\left(r+\frac{1}{2}, n-r+\frac{1}{2}\right) = 0.025 \text{ or } 0.0975$$

Where n = the sample size and r/n = the proportion.
With the modification that the quantile is calculated using:

$$x = 1 - 0.05^{1/n}$$

For r=0, and

$$x = 0.05^{1/n}$$

For r=n

b) Progress towards outcomes and further observations (Current estimate of outcome)
Given some observed outcomes and an expected number of further observations we can estimate the probability of observing a particular final outcome, or a range of final outcomes.
If we expect to be able to gain N observations in total and r incidents have been observed in the n observations conducted thus far, then the probability that by the end of the study (after conducting N-n further tests) there will be no more than R incidents in total (there will be no more than R-r further incidents) is given by the beta binomial distribution:

$$\sum_{i=0}^{i=R-r} p(i|r,n)$$

$$p(i|r,n) = exp\left(Ln\Gamma(N-n+1) - Ln\Gamma(i+1) - Ln\Gamma(N-n-i+1) + Ln\Gamma(r+0.5+i) + Ln\Gamma(-r+0.5+N-i) - Ln\Gamma(1+N) - Ln\Gamma(r+0.5) - Ln\Gamma(n-r+0.5) + Ln\Gamma(n+1)\right)$$

This approach can be used to determine the range of final outcomes that are likely given the results so far, and more importantly ranges of final outcome that are unlikely. This may have value in enabling us to direct resources away from groups where the outcome is not in doubt towards groups where more information may still change the final outcome.

Task 2: Statistical analysis associated with determining differences between observed and unobserved carcases.

As part of Objective 7, post-mortem data will be collected on two groups of carcases:

Group 1: carcases of badgers that were observed being shot.
Group 2: carcases of badgers that were not observed being shot.

Carcases in the two groups will be matched for at least shooter and ammunition type.

In these post mortem examinations, the frequency of certain kinds of outcomes will be recorded. Outcomes are for instance missing tail, off-target shots.We will use the observed frequencies of outcomes or clusters of outcomes (possibly non-independent outcomes) to determine whether the frequency of observations appears to be consistent between groups.

Group 1	true proportion=p_1 sample=n_1 observed number with outcome=r_1
Group 2	true proportion=p_2 sample=n_2 observed number with outcome=r_2

Evidence for a significant difference between p_1 and p_2 (p_2>p_1) is assessed by

$$P(Observed \geq r_2 | p_1 = p_2) = 1 - \sum_{i=0}^{i=r_2-1} p(i|r_1, n_1)$$

Significance is demonstrated when $P(Observed \geq r_2 | p_1 = p_2)$ is sufficiently low (Bonferroni corrected 0.05)

Where, from the beta binomial distribution with a Jeffreys prior (as in Task 1)

$$p(i|r_1,n_1) = exp(Ln\Gamma(n_2+1) - Ln\Gamma(i+1) - Ln\Gamma(n_2-i+1) + Ln\Gamma(r_1+0.5+i) + Ln\Gamma(n_1-r_1+0.5+n_2-i) - Ln\Gamma(n_1+1+n_2) - Ln\Gamma(r_1+0.5) - Ln\Gamma(n_1-r_1+0.5) + Ln\Gamma(n_1+1))$$

(Adapted from Little(Little 1989))

We have calculated the number of replicates required to enable us to detect differences between the two groups. Given two groups described above, a critical value for 'Observed' r_c is the lowest value for which $P(Observed \geq r_2 | p_1 = p_2)$ is sufficiently low to just demonstrate that p_2>p_1. The power to detect a difference between p_1 and p_2 is given by:

$$Power = \sum_{i=0}^{i=n_1} [p(r_1 = i|p_1, n_1) p(r_2 \geq r_c | p_2, n_2)]$$

Where $p(r_1 = i|p_1, n_1)$ and $p(r_2 \geq r_c|p_2, n_2)$ are binomial and cumulative binomial distribution functions.

The number of replicates required depends on the frequency of occurrence of the outcome of interest in the observed group of animals. For example, the number of replicates will be different for the following scenarios:

- An outcome that is never present in the Observed Group (p_1=0)
- An outcome that is rare in the Observed Group (p_1=0.1)
- An outcome that is common in the Observed Group (p_1=0.5)
-

For these three scenarios, the minimum sample sizes, i.e. replicates required, for each group to give a 90% probability of detecting a difference between 'Observed' and 'Unobserved' rates with a false positive probability of 5% are shown in Table 5 (next page).

Table 1 Minimum sample sizes for various combinations of observed and unobserved rates.

'Observed' Rate (p_1)	'Unobserved' Rate (p_2)	Number of outcomes examined 1	2	5	10	20	50
0	0.02	265	333	398	462	525	648
0	0.05	105	132	158	184	209	234
0	0.1	52	65	78	91	104	116
0	0.2	25	32	38	45	51	57
0	0.5	9	12	14	17	19	21
0	0.8	5	6	6	8	9	11
0	0.9	4	4	5	7	8	8
0	0.95	4	4	5	6	6	7
0.1	0.2	221	271	334	379	424	485
0.1	0.3	68	84	103	116	131	148
0.1	0.5	22	27	32	37	41	47
0.1	0.8	8	10	11	13	15	17
0.1	0.9	7	8	9	9	11	12
0.1	0.95	5	6	7	9	10	11
0.5	0.65	192	234	289	329	369	418
0.5	0.7	108	128	158	181	203	232
0.5	0.8	45	54	67	75	85	96
0.5	0.9	22	27	34	37	43	48
0.5	0.95	16	20	24	27	30	34

Task 3: Exploratory analysis for unexpected trends

A multi-factorial analysis of the TTD data will explore the impact of factors that may influence the TTD. Factors that we will explore include weather, range, experience of the shooter, time of night that shooting is undertaken, progression of the cull.

A survival analysis approach, consistent with the censored TTD observations will be employed, assuming proportional hazards between different levels of each factor. Significant differences between gradients (intercepts on the log scale) will be identified.

We do not propose to include the identity of the cull area as a covariate in the analysis because it is not likely to be ecologically meaningful. More local factors such as landscape type may be included.

If the cull progresses as expected, then TTD is expected to be similar across shooters, and landscape type because sufficiently experienced and briefed shooters will take shots when there is a sufficiently high probability of achieving a short TTD.

Annex E: Workshop

Title: Behavioural indicators to use during the monitoring of pilot badger culls.

Background: There is a paucity of literature on the behavioural responses of animals that have been chest shot. The brain is the target area when domestic animals are killed using a firearm. Three published studies on free shooting of wild animals all targeted the brain rather than the chest. These studies on whales, seals and impala indicated that death in many cases was instantaneous. In the case of whales and seals, a workshop was held to determine the most appropriate indicators of death to use in the field. However due to the mechanism of death being significantly different between head shot and chest shot animals, it is uncertain whether the outcome of that workshop is applicable in the proposed study. The behavioural responses of animals to destruction of the brain by a bullet have been documented, e.g. collapse and muscular contractions (Gregory, 2004) Behavioural responses to chest shots have been described by several hunting organisations, but no objective study of these has occurred.

Some anecdotal accounts suggest that deer can continue to graze after receiving a lethal chest shot, before dropping unconscious some time later. Could such behaviour be used to indicate that the animal was not experiencing pain and suffering during this time? There may be other behaviours that occur that could be used in a similar manor. Videos of chest shot foxes show them collapsing and muscular contractions occurring instantaneously.

Objectives: To identify indicators of a) death and b) intensity of pain before death in chest shot free living wild badgers.

To determine which of these indicators can be measured under the field conditions of the pilot badger culls, without interfering with the actions of the shooters.

Invited Participants:

- Chair of Independent Expert Panel
- University of Bristol, seal and whale killing expert
- Defra
- RVC
- RSPCA
- University of Bristol, slaughter research team.
- Deer Society
- BASC
- Badger expert
- Other people experienced in chest shooting wild animals.

References

AMANDA J, J. (2010) The role of computed tomography in adult post-mortem examinations: an overview. Diagnostic Histopathology 16, 546-551
BEVERLAND, D. E. & RUTHERFORD, W. H. (1983) An assessment of the validity of the injury severity score when applied to gunshot wounds. Injury 15, 19-22
BRADSHAW, E. L. & BATESON, P. (2000) Welfare Implications of Culling Red Deer (Cervus Elaphus). Animal Welfare 9, 3-24
BROWN, L. D., CAI, T. T. & DASGUPTA, A. (2001) Interval estimation for a binomial proportion. Statistical Science 16, 101-133
CAMPBELL, N. C., THOMSON, S. R., MUCKART, D. J. J., MEUMANN, C. M., VAN MIDDELKOOP, I. & BOTHA, J. B. C. (1997) Review of 1198 cases of penetrating cardiac trauma. British Journal of Surgery 84, 1737-1740
COCKRAM, M.S., SHAW, D.J., MILNE, E., BRYCE, R., MCCLEAN, C., & DANIELS, M.J. (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
DEFRA (2011) Annex G: Best Practice Guidance Controlled shooting in the field, and cage-trapping & despath of badgers, under licence to prevent the spread of bTB in cattle. July 2011 edn. on line
FERAL (2010a) Control method: Cage trapping of foxes followed by shooting. http://www.feral.org.au/wp-content/uploads/2011/04/fox_cage_trap_worksheet.pdf
FERAL (2010b) Control method: Ground shooting of foxes. http://www.feral.org.au/wp-content/uploads/2011/04/fox_ground_shooting_worksheet.pdf
FOX, N. C., BLAY, N., GREENWOOD, A. G., WISE, D. & POTAPOV, E. (2005) Wounding rates in shooting foxes (Vulpes vulpes). Animal Welfare 14, 93-102
GRANDIN, T. (1994) Euthanasia and slaughter of livestock. J Am Vet Med Assoc 204, 1354-1360
GREEN, P. D. (1980) Protocols in medicolegal veterinary medicine. II. Cases involving death due to gunshot and arrow wounds. Canadian Veterinary Journal 21, 343-346
GREGORY, N. (2004) Physiology and behaviour of animal suffering. Oxford, Blackwell
GREGORY, N. (2005) Bowhunting deer. Animal Welfare 14, 111-116
GUGALA, Z. & LINDSEY, R. W. (2003) Classification of Gunshot Injuries in Civilians. Clinical Orthopaedics and Related Research 408, 65-81
KEEP, J. M. (1970) Gunshot injuries to urban dogs and cats. Australian Veterinary Journal 46, 330-334
KIRKWOOD, J. K. (2000) Humaneness of MAFF's badger despatch procedures. London, MAFF
KNIGHT, B. & SAUKKO, P. (2004) Forensic Pathology, Hodder Arnold
KNUDSEN, S. K. (2005) A review of the criteria used to assess insensibility and death in hunted whales compared to other species. Veterinary Journal 169, 42-59
LEVY, A. D. & HARCKE, H. (2011) Essential of Forensic Imaging: a text-atlas, CRC Press
LEWIS, A. R., PINCHIN, A. M. & KESTIN, S. C. (1997) Welfare Implications of the Night Shooting of Wild Impala (Aepyceros Melampus). Animal Welfare 6, 123-131
LITTLE, R. J. A. (1989) Testing the equality of two independent binomial proportions. The American Statistician 43, 283-288
MUNRO, R. & MUNRO, H. (2011) Forensic veterinary medicine. In Practice 33, 262-270
MUNRO, R. & MUNRO, H. M. (2008) Fireamrs injuries. In Animal abuse and unlawful killing, Saunders Elsevier
PARMLEY, L. F., MANION, W. C. & MATTINGLY, T. W. (1958a) Nonpenetrating traumatic injury of the heart. Circulation 18, 371-396
PARMLEY, L. F., MATTINGLY, T. W., MANION, W. C. & JAHNKE, E. J., JR. (1958b) Nonpenetrating traumatic injury of the aorta. Circulation 17, 1086-1101
PSD (1997) Assessment of Humaneness of vertebrate control agents. York, MAFF
SVENDSEN, O., JENSEN, S. K., KARLSEN, L. V., SVALASTOGA, E. & JENSEN, H. E. (2008) Observations on newborn calves rendered unconscious with a captive bolt gun. Veterinary Record 162, 90-92
THALI, M. J., KNEUBUEHL, B. P., BOLLIGER, S. A., CHRISTE, A., KOENIGSDORFER, U., OZDOBA, C., SPIELVOGEL, E. & DIRNHOFER, R. (2007) Forensic veterinary radiology: ballistic-radiological 3D computertomographic reconstruction of an illegal lynx shooting in Switzerland. Forensic Science International 171, 63-66

URQUHART, K. A. & MCKENDRICK, I. J. (2003) Survey of permanent wound tracts in the carcases of culled wild red deer in Scotland. Veterinary Record 152, 497-501
URQUHART, K. A. & MCKENDRICK, I. J. (2006) Prevalence of 'head shooting' and the characteristics of the wounds in culled wild Scottish red deer. Veterinary Record 159, 75-79
YELVETON, J. T. (1996) Pathology scoring system for blast injuries. Journal of Trauma 40, S111-115