



Department
for Environment
Food & Rural Affairs

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Bovine TB in non-bovine farmed animals: call for views

August 2015



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The deadline for responding to this call for views is Friday, 20th November 2015. Responses can be made by:

1. Completing the survey on the 'Citizen Space' on-line portal
<https://consult.defra.gov.uk/bovine-tb/bovine-tb-in-non-bovine-animals-call-for-views>
2. Sending an e-mail to btbengage@defra.gsi.gov.uk
3. Writing to –:

Non Bovine Call For views,
TB Programme,
Defra,
Area 5D, Nobel House
17 Smith Square
London SW1P 3JR

Any enquiries regarding this publication should also be sent to the bTB Engage e-mail address.

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Part one: Introduction

Purpose

1. The purpose of this call for views is to gather evidence to inform future decisions that will:
 - Ensure that proportionate measures are in place to address the risk posed by TB in non-bovine species.
 - Enhance the sensitivity of TB surveillance in non-bovines.
 - Introduce stricter measures for TB breakdowns non-bovines

Non bovine animals: the disease risk

2. There are around 20 million farmed non-bovines in England, the vast majority being pigs and sheep. All are susceptible to *Mycobacterium bovis* (*M. bovis*) infection but the risk of infection - and of them passing infection to cattle, wildlife or humans in England - is generally considered to be low, as shown in the following table.

Table 1 Summary of disease risk for the main farmed non-bovine species in GB.

Species	Disease risk (for full Veterinary Risk Assessments and explanation of technical terms see Annex)
Captive Deer	In GB captive deer are generally considered to be spill-over end hosts, i.e. they are unlikely to sustain the infection within their own population in the absence of infected cattle or a wildlife reservoir.
Goats	Goats are considered to be spill-over hosts, contracting infection sporadically from wildlife, cattle or co-habited non-bovine species in areas of GB where <i>M. bovis</i> is known to be endemic in cattle. Goats are able to spread to other members of their population and potentially to susceptible co-habiting species.
Pigs	Pigs are generally considered to be spill-over hosts but is not particularly contagious amongst pigs. There is evidence in other EU countries that can be a reservoir of TB and can transmit TB both to other pigs, and to cattle.
Sheep/Lambs	Sheep are susceptible to TB, but maybe less so than other species. They are considered to be spill-over hosts but as they develop lesions in the respiratory tract it is possible that infected sheep could act as a reservoir of infection.
South American Camelids (SAC)	SAC can be considered to be incidental, spill-over hosts to <i>M. bovis</i> and are not a significant amplifier (vector) of TB for cattle, other domestic animals or wildlife. Nevertheless, there have been instances of TB transmission between camelid herds. Therefore, SAC can behave as vectors of <i>M. bovis</i> infection for other animals with which they came into contact, usually other camelids.

3. The risks of TB infection in companion animals (e.g. cats, dogs and ferrets) and of them spreading infection to farmed animals, wildlife and humans are assumed to be very low. The same is thought to be the case with zoo animals.
4. Many species of non-bovine farmed animals e.g. captive deer, goats, pigs, sheep and SAC are susceptible to *M. bovis* infection but only a relatively small number of animals are identified as infected each year¹.

Table 2 Non-bovine farmed animal numbers, TB skin tests and reactors removed in England

	Numbers (million) 2013 ²	TB skin tests (numbers) 2014	Skin test %	Numbers Removed ^{3, 4} 2014
Farmed Deer ⁵	0.02	441	1.22	3
Goats	0.08	3433	1.05	871
Pigs	4.1	237	0.00	3
Sheep/Lambs	14.9	105	0.00	0
SAC	0.03	1359	1.46	117
Total Farmed	19.13	5575	0.01	994

5. The current surveillance arrangements for TB in non-bovine farmed animals comprise:
 - A statutory duty on persons to report suspicion of TB in carcasses and the identification of *M. bovis* by laboratory examination of a sample taken from a live animal or carcass.
 - A statutory duty to report suspicion of TB in live deer.
 - Abattoir surveillance, the detailed EU arrangements for which are being reviewed on a species by species basis.
 - Targeted non-bovine farm animal testing where they are contiguous to or co-located with a cattle herd breakdown.
6. For most non-bovine species there are no officially validated ante-mortem TB diagnostic tests. Suspicion of bovine TB in farmed non-bovine animals is normally a result of reporting by private veterinary surgeons (as required by law), post-mortem abattoir surveillance and some TB testing of non-bovines which are contiguous to, or co-located with, a cattle TB breakdown.

¹ Voluntary surveillance arrangements mean we cannot say for sure that these numbers reflect true incidence of TB in these populations

² For deer, goats, pigs and sheep see pp 13 and 14 of https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/355868/structure-jun2014final-eng-18sep14.pdf The SAC figures are based on an industry estimate

³ Includes direct contacts as well as suspected clinical cases.

⁴ Excludes carcasses with possible TB lesions found at meat inspection in abattoirs

⁵ Figures for other captive deer (i.e. deer managed in a park setting) are not available

7. *Diagnosis of M. bovis* infection in companion and zoo mammals is normally a result of reporting by private veterinary surgeons. Such cases are rare and often occur in high bovine TB incidence areas. More complex incidents are occasionally disclosed such as the cluster of seven confirmed and two suspected cats with *M bovis* TB in different households near Newbury in 2012-13, which led to the diagnosis of active *M bovis* infection in two people who had contact with one of the cats.

Table 3 Non-bovine companion animals

	Numbers (million) 2013	Diagnosed with TB (numbers) 2014
Cat	8.5	20
Dog	8.5	1
Ferret	N/K	0
Total Companion	17	21

8. APHA carries out epidemiological investigations into all companion animal cases to assess any connection with local cattle epidemics. Currently APHA and Public Health England monitor the results of scanning surveillance and work with the sectors to raise awareness of the risks and of the measures that can be taken to reduce these risks.

Table 4 Selected non-bovine zoo animals

	Numbers 2014	Diagnosed with TB (numbers) 2014
Antelope	N/K	0
Total	N/K	0

TB Diagnostics in non-bovines

9. The tuberculin skin test is the international standard for ante-mortem diagnosis of TB in non-bovine farmed animals, pets and zoo animals even though for most non-bovine species there is no validated evidence of the sensitivity and specificity of this test under UK conditions.
10. Concerns about the limited sensitivity of the test in camelids prompted representative organisations in that sector to commission and pay for APHA research to validate blood tests to supplement the skin test. One result of that has been the launch of a private sector voluntary surveillance scheme, aiding camelid owners' efforts to protect their animals and businesses. Subject to available resources and industry funding, APHA would be able to work with other non-bovine sectors on validation of TB tests, including supplementary blood (antibody) tests.
11. For most non-bovine farmed species the tuberculin skin test in its various forms is and is likely to continue to be the primary TB screening and control tool, whether in statutory TB breakdown situations or voluntary surveillance and pre-movement testing. Evidence from several studies conducted in different animal species also

shows that serological tests for TB only have a moderate sensitivity unless primed by a tuberculin skin test.

Disease control: what happens when TB is identified on a farm

12. For non-bovines in cases where there is a reasonable suspicion of bovine TB in a herd or flock restrictions will be served to control the movement of the animals. For milking animals these restrictions also require the owner to ensure that milk from TB reactors is not used for human consumption and milk from non-reactors is pasteurised before sale for human consumption.
13. Restrictions are only lifted when there is sufficient evidence that the remaining animals are not infected. For some animals, this may be obtained by skin testing (augmented in camelids by serological tests). But where skin testing is impractical (in slaughter pigs, for example) it may be necessary to consider detailed statistical evidence from ongoing abattoir surveillance.

Maintaining a strong evidence base.

14. In order to ensure disease control in non-bovines is evidence-based, transparent and up to date, we will publish and regularly review our veterinary risk assessments on the TB risks to farmed non-bovine animals. We will also continue to regularly publish some key statistics about the results of TB surveillance in non-bovines.
15. We believe the TB statistics published by APHA provide the necessary clarity on identification, investigation and outcome of TB incidents in all non-bovine species⁶. These will continue. At the same time we will continue to work with and encourage other stakeholders to develop their own evidence sources. An example of a current initiative is SAVSNET.

SAVSNET already collects companion animal data from labs and vets in practice.

SAVSNET are in discussions with APHA about including their companion animal test results, including TB, on the SAVSNET web site to sit alongside existing data already analysed at <http://www.savsnet.co.uk/lab-report/>

Using this approach SAVSNET can address issues of space and time.

A second approach that is being considered is looking to expand the nature of the tests requested from labs to include histopathology. These data are not structured or coded but they do use very precise language making them accessible to free text mining by computers.

⁶ <https://www.gov.uk/government/statistical-data-sets/other-tb-statistics>

SAVSNET are now collecting some 2000 consults a day from across the UK, with now almost 400,000 consults in our databases. This allows SASNET to use the same approaches of free text mining to identify those rare cases where vets are considering TB as part of the diagnosis.

16. Currently the post-mortem and culture of results for suspected bovine TB index cases are paid for by APHA. These results contribute to the APHA evidence base and aid efforts to prevent the spread of the infection.

Part two: Controlling bovine TB in non-bovine animals: a call for your views

Policy principles

17. The Government's response to *M. bovis* infection in non-bovine species will be evidence-driven and proportionate to the risk, in order to target efforts in areas where risk management will make a real impact on reducing bTB incidence and spread. Based on those precepts, we set out below our proposed principles for intervention in the case of farmed non-bovine animals. They are:

- Primary responsibility for TB surveillance in live non-bovines should rest with the keepers of the animals.
- The current means of surveillance should continue, which for most species means TB reporting by private veterinarians and animal owners, supplemented for meat producing animals by statutory post-mortem examination.
- Where TB is suspected, APHA should apply movement restrictions, implement herd/flock testing where this is practically possible and, as necessary, cull reactor animals and dangerous contacts to clear infection and mitigate risk to other animals.
- Statutory provisions should be used to compulsorily slaughter non-bovine farmed animals in which bovine TB is believed to be present.
- Species-specific statutory compensation arrangements should exist for all non-bovine farmed species which are compulsorily slaughtered.
- In order to ensure good value for public money, compensation amounts should be designed to ensure all of the following: high levels of compliance with disease control measures; incentivisation of owners to manage their own disease risks; and protection of the economic sustainability of animal keepers' businesses.
- Maintenance of the evidence base on bovine TB in non-bovine species is the job of Government – Government should be responsible for the first cases (index case) identified in individual TB outbreaks, statistical reporting, and provision of information to animal keepers and private veterinarians.
- The burden of regulation on non-bovine farm businesses and allied sectors should be kept to the minimum necessary to still achieve the Government's long-term aim of completely eradicating bovine TB.

Question 1: Are these the right principles?

Identifying disease in non-bovine animals

18. There is no statutory duty (except in captive deer⁷) to report suspicion of disease in live non-bovine animals. For cattle, The Tuberculosis (England) Order 2014⁸ states:

Notification of suspected disease in a bovine animal

5. (1) *Any person who—*

(a) *is the keeper of a bovine animal which the keeper suspects of having tuberculosis or suspects may be an affected animal,*

(b) *in the course of practice as a veterinary surgeon, examines or inspects a bovine animal which the veterinary surgeon suspects of having tuberculosis, or may be an affected animal,*

(c) *in the course of that person's duty, inspects, for any purpose, a bovine animal which that person suspects of having tuberculosis or suspects may be an affected animal, must give immediate notice of such suspicion to the Secretary of State.*

Question 2: Do you think the duty to report suspicion of TB in a bovine animal should also apply to non-bovine animals?

19. For farmed non-bovine animals, the means of detecting disease may include testing of herds or flocks which are contiguous to a cattle herd breakdown. Very few cases are identified in this way and experience to date suggests that the resources allocated to delivering such testing could be used more effectively. We therefore intend to review the effectiveness of such testing to ensure we have an approach which works and delivers best value for money.

TB surveillance testing

20. Bovine TB infection of non-bovine animals, though still rare, can result in significant losses to affected farm businesses and to address this risk the camelid sector has introduced voluntary TB surveillance arrangements. We understand that some other sectors are considering similar voluntary schemes.

21. Government has no current plans to introduce statutory surveillance for TB in non-bovine species. But we are keen to work with those organisations that wish to develop their own voluntary TB surveillance and testing arrangements. That may include arrangements for investigation work such as private post-mortem and/or culture of disease, through APHA's commercial services.

⁷ The only exception is deer, in which clinical cases are also notifiable under The Tuberculosis (Deer and Camelid) (England) Order 2014 SI 2014 2337.

⁸ <http://www.legislation.gov.uk/uksi/2014/2383/made>

Question 3: How could Defra facilitate the development of voluntary surveillance and testing schemes for non-bovine animals?

Authorising voluntary TB testing and notification of results

22. To aid national disease control, it is important that Government is aware of plans for non-statutory TB testing, including in non-bovine species, and is informed of the results. The statutory provisions already in place for camelids⁹ are set out below:

Tuberculosis testing of camelids

12. (5) A person must not perform a test for tuberculosis on a camelid except with the written consent of the Secretary of State, and a person to whom such consent is given must, as soon as any positive tuberculosis result of such test is known, report such result to the Secretary of State.

Question 4: Should the provisions introduced in October 2014 for camelids requiring consent for TB testing and notification of results apply to all farmed non-bovine species?

Paying for statutory TB surveillance testing

23. For captive deer, statutory TB testing is undertaken and paid for by keepers. The Tuberculosis (Deer and Camelid) (England) Order 2014, states:

Testing of deer

*6. An appropriate officer may by notice require a keeper of deer to—
(a) arrange for specified deer to be tested for tuberculosis with a relevant test at the keeper's own expense by a specified date;*

24. For bovines and camelids – and, in practice, all other non-bovine species – statutory surveillance testing is paid for by Government. For camelids, the 2014 Order referred to above states:

Tuberculosis testing of camelids

12.(1) The Secretary of State may by notice served on a camelid keeper require specified camelids to be tested by the Secretary of State for tuberculosis by a specified date

25. From the Government's perspective, it would be sensible to rationalise the situation. The simplest solution would be to bring statutory testing of deer into line with other species. But there is an opportunity cost consideration – i.e. if such tests are paid for by owners rather than Government there would be an

⁹ The Tuberculosis (Deer and Camelid) (England) Order 2014 SI 2014 2337.

opportunity to recycle the savings into other important TB controls. So we would welcome your views on the options.

Question 5: Who should pay for statutory TB surveillance testing of non-bovine animals, and why?

Compensation arrangements

26. Where TB infection is confirmed or strongly suspected in a herd or flock of farmed animals (whether cattle or non-bovines) it is important to quickly remove the affected animal(s). In the case of cattle, deer and camelids specific statutory compensation schemes enable this to happen without delays caused by independent valuation being required prior to culling.
27. For all other farmed non-bovine animals the default statutory basis for compensating owners for compulsory slaughter is The Diseases of Animals (Ascertainment of Compensation) Order 1959. This Order requires the Minister to provide a valuation for the animals. In cases where the valuation is disputed, a statutory arbitration process applies. This is a burdensome process for both the keeper and the Department.
28. The amount of compensation payable will be informed by decisions on the policy principles set out above, on which we are also calling for your views. For ease of reference:
- In order to ensure good value for public money, compensation amounts should be designed to ensure all of the following: high levels of compliance with disease control measures; incentivisation of owners to manage their own disease risks; and protection of the economic sustainability of animal keepers' businesses.

Question 6: Should statutory compensation for compulsory slaughter be extended to all non-bovine farmed animals and, if so, how should the amounts be set?

29. There may be circumstances where owners of animals to be compulsorily slaughtered can secure more in salvage following negotiations with a slaughterhouse that is prepared to take such TB affected animals. Cattle owners are already able to benefit from this alternative to receiving the compensation fixed in legislation.

Question 7: Should keepers of meat producing non-bovine farmed animals have the opportunity to secure for themselves a salvage value individually negotiated with a slaughterhouse operator for compulsorily slaughtered animals?

30. Cattle farmers may be subject to reductions to TB compensation if the TB testing of their herd is overdue. We would like your views on how compensation arrangements may be used for non-bovine species to drive good behaviours and drive out bad practices that put other herds or flocks at risk.

Question 8: Should Government vary compensation for compulsorily slaughtered non-bovines, to reward good behaviours or penalise bad practices? If so, how?

Other non-bovine (companion and zoo) animals

31. *M. bovis* infection in companion and zoo mammals is a relatively rare occurrence but can happen. In 2013 a cluster of 9 cats in the Newbury area living close to one another were confirmed or suspected to have been infected. Infection from small mammals in the area was the most likely source. Four people tested as a result of being in contact with the cats were diagnosed as infected with TB (2 active and 2 latent). As a result of those cases Public Health England re-evaluated the risk of human infection from cats with TB from negligible to very low.
32. APHA and Public Health England will continue to monitor the results of scanning surveillance for TB in companion animals and work with the sectors to raise awareness of the risks and of the measures that can be taken to reduce these risks. APHA will continue to provide advice to owners and private vets for all culture-confirmed incidents of *M. bovis* infection in companion animals and only carry out epidemiological investigations if the pets are kept on the same premises as susceptible farmed species or to support investigations by the public health authorities. Any zoos and exotic animal collections with confirmed incidents of TB caused by *M. bovis* will continue to be placed under movement restrictions until considered free of disease.

Question 9: Do stakeholders agree that this approach is proportionate and targeted to the risk? If not, what more needs to be done?

Annex : Veterinary Risk Assessments

This Annex sets out **latest drafts** of the veterinary risk assessments for TB in:

- Camelids
- Captive Deer
- Goats
- Pigs; and
- Sheep

Question 10: Do you have further information/evidence that can help inform the development of any/all of these veterinary risk assessments?

Following analysis of your comments we aim to publish the veterinary risk assessment and from then on to update them as 'living documents'

Terms used in the VRAs:

It is well recognised that *M. bovis* can contemporaneously infect multiple species, which together constitute a 'multi-host complex'¹⁰. Within such a complex, host species may be 'maintenance' (infection persists without input from other sources), or 'spill-over' (infection persists as long as there is input from an external source) type. Spill-over hosts may be further categorised into 'dead-end' (no evidence of significant onward transmission) and 'amplifier' (where they increase the prevalence of disease within their own or other populations) forms¹¹. Consequently, successful eradication of TB from cattle requires identification and characterisation of the other members of the multi-host complex, particularly those which are able to act as a source of infection.

Coleman and Cooke (2001) have classified the species that can act as hosts to *M. bovis* as follows:

- maintenance hosts (e.g. bovines, badgers and, occasionally, farmed and wild deer), where the infection persists by vertical, pseudo-vertical or horizontal transmission within the species, without the need for input from other species
- spillover hosts, where TB occurs within the species only as long as there is input from an external source (maintenance host). Spillover hosts may in turn be either 'dead-end' hosts (if the incidence and pathology of the disease

¹⁰ (O'Reilly and Daborn, 1995; Delahay et al., 2002; Buick, 2006; Gortazar et al., 2011)

¹¹ (Morris et al., 1994; Buick, 2006; Corner, 2006)

indicates they play no significant role in its onward transmission) or 'amplifier' hosts (if they appear capable of transmitting *M. bovis* to other species).

Qualitative veterinary assessment of the risk associated with the movement of South American camelids from TB-infected premises in England

Summary

The TB Programme of Defra has commissioned formal veterinary advice to help inform policy decisions regarding the control of TB (*Mycobacterium bovis* infection) in South American camelids (SAC) in England. The following questions were of particular interest:

(a) What is the overall risk of spread of *M. bovis* infection associated with British SAC?

The veterinary advice is that:

- i. SAC are clearly susceptible to infection with *M. bovis* and other mycobacteria that cause TB in animals.
- ii. In an unknown proportion of *M. bovis*-infected SAC, the bacterium can give rise to tuberculous disease. Although clinical signs are not specific, clinical disease presents with very extensive and severe pathology and affected animals can be highly infectious.
- iii. Even so, based on the currently available information from GB and other countries, SAC can still be considered incidental, spillover hosts to *M. bovis*. In most cases these animals become infected through contact with one of the maintenance hosts and vectors of the infection in GB (i.e. badgers and cattle, or environment contaminated by their secretions and excreta). In other words, SAC normally act as sentinels of endemic infection in local badger populations and cattle herds.
- iv. Therefore, SAC are not currently considered a significant vector of TB for cattle, other domestic animals or wildlife. However, this is not a static situation and new factors may come into play that could alter this risk assessment.
- v. Due to their relatively small numbers and likely overall low prevalence of *M. bovis* infection, the weight of infection in the British SAC population is far lower than that in the two recognised maintenance hosts of the disease in England and Wales, namely domestic cattle and the Eurasian badger. Additionally, SAC tend to be bred, reared and kept on dedicated holdings as an alternative livestock enterprise, rather than on traditional livestock farms. They are often shown at specialist events. This means that SAC are generally segregated from cattle, pigs and other livestock, thus reducing the opportunities for direct (airborne) and indirect inter-species transmission.

- vi. In light of all the above, there is little justification for a programme of mandatory, regular, proactive TB testing of British camelid herds as part of the national bovine TB eradication plan paid by the government. Sporadic TB incidents involving SAC can be managed on a case-by-case basis using the general legal provisions for the diagnosis and control of TB in species other than cattle, laid down in the Tuberculosis (England) Order 2007 (as amended) and the Animal Health Act 1981.
- vii. Nevertheless, there have been instances of TB transmission between camelid herds. Therefore, SAC can behave as amplifiers (vectors) of *M. bovis* infection for other animals with which they came into contact, usually other camelids. Natural transmission of the bacterium has been documented between tuberculous alpacas and close human in-contacts.
- viii. There is an unquantifiable (but probably low to medium) risk of translocation of TB into naïve camelid herds via uncontrolled movements of untested camelids between farms (e.g. sales, movement of animals for breeding), especially if those animals originate in herds with a history of confirmed *M. bovis* infection, or have been reared in endemic bovine TB areas of England and Wales. Although the probability of an event of that nature may be low, its animal health consequences could be potentially quite serious, particularly if infected camelids were unwittingly moved to low incidence regions of the country and there was a long delay in identifying those animals.
- ix. There is no evidence to date of any incidents of TB in cattle, sheep, goats, pigs or captive deer being attributed to transmission from infected SAC. Despite some recent large outbreaks of TB in SAC, the overall risk of TB transmission posed by SAC to other domestic animals (particularly to cattle) remains generally very low, but it is not negligible.
- x. *M. bovis* infection in British SAC does not materially affect the background level of risk of TB spreading to cattle, sheep, goat, pig and deer farms. The greatest risk to those livestock sectors continues to stem not from tuberculous SAC, but from exposure to infectious local wildlife (mainly badgers), from contact with undisclosed infected cattle on the same or contiguous farms, or from movements of other infected, undetected livestock (cattle, pigs, sheep, goats) between farms within the same species 'compartment'.
- xi. The APHA guidance on TB in camelids should be revised to include explicit advice to potential purchasers about the risks of TB and the standards/assurances they should ask for from breeders.
- xii. Additionally, the camelid breeding societies and the British Veterinary Camelid Society should continue to highlight among their members the importance of conducting routine postmortem examinations on all unexplained casualties on farm and the need to submit tissue samples from suspect TB cases for differential/confirmatory diagnosis.
- xiii. The current voluntary passive surveillance regime for TB in camelids could be strengthened to mitigate the risk of spreading *M. bovis* infection between camelid herds and to protect the high-value pedigree breeding stock of some commercial herds. The camelid breeding societies and show organisers should be encouraged to adopt a policy of voluntary private pre- and/or post

movement TB testing of SAC intended for trade, entering shows and markets, moved for mating or offered for sale, as a recommended good-practice standard for the SAC industry.

- xiv. For additional protection, any new camelids introduced into a SAC holding should be kept in isolation and tested for TB at least 60 days after arrival (and 90 days or more after their last tuberculin skin test, if any) before joining the resident herd.
- xv. Since the tuberculin skin test has been shown to have a very limited sensitivity in camelids (the probability of false negative results is high and the predictive value of a negative result in GB is low), this test should *not* be used on its own as a pre- or post- movement screening tool for TB. Skin-test negative SAC should be tested 10-30 days later with one or two serological (antibody) tests. To allay any concerns about 'false positive' results in herds not affected by TB restrictions, two antibody tests could be combined in 'serial' interpretation, whereby only those animals reacting to both serological tests would be considered suspect, re-tested and only culled if positive for a second time.
- xvi. In order to safeguard the reputation of the British SAC industry and the integrity of the UK's bovine TB eradication plan, *mandatory* TB blood testing for SAC moved domestically and those intended for export may be necessary if the practice is not voluntarily adopted by the industry within a reasonable timeframe.

(b) What would be the veterinary risks associated with the uncontrolled/unrestricted movement of animals out of SAC holdings in which *M. bovis* infection has been diagnosed

The veterinary advice is that:

- i. unrestricted movements of SAC from known TB-infected holdings (other than directly to slaughter under licence) would result in a substantially increased risk of *M. bovis* spread to other farms and areas of the country. The current system of herd movement restrictions pending the completion of repeat skin tests with negative results and supplemented by parallel antibody testing and tracings should be maintained, mainly to protect other TB-free SAC herds.
- ii. A combination of *mandatory* skin and antibody tests used in parallel interpretation (to maximise diagnostic sensitivity) should be a prerequisite for lifting restrictions from all SAC herds diagnosed with culture-confirmed *M. bovis* infection, as well as any forward tracings thereof.
- iii. Additionally, given the moderate sensitivity of TB antibody testing, SAC herds experiencing a confirmed *M. bovis* TB breakdown should undergo skin and antibody testing again six to twelve months after movement restrictions are lifted (except perhaps those holdings with introduced singleton infected animals and no evidence of secondary intra-herd spread). This measure would help to identify and reduce the risk of undisclosed residual herd infection.

Introduction and background

1. Tuberculosis (TB) is a major infectious disease of mammals caused by infection with one of the mycobacteria of the *Mycobacterium tuberculosis* complex (MTBC) (Smith et al. 2009). The disease is characterised by the formation of granulomas, primarily in the respiratory system and associated lymph nodes, from which mycobacteria are excreted and infect other individuals.

2. Most cases of TB in farm animals are caused by infection with *Mycobacterium bovis* (*M. bovis*) a member of the MTBC. *M. bovis* infection of cattle (bovine TB) is endemic in large parts of England, in Wales and on the island of Ireland. *M. bovis* has a wide host range and can infect (and cause TB) in virtually all mammalian species, including other farmed animals (such as camelids), companion animals and wildlife. Badgers in particular are an important reservoir for the bacterium in large tracts of the UK and Ireland. *M. bovis* is zoonotic, i.e. it can cause TB in humans naturally, although the risk of contracting the disease for the human population in the UK is very low as a result of milk pasteurisation and other controls.

Frequency and distribution of TB in South American camelids

3. The *Camelidae* family of the *Artiodactyla* order comprises the ‘Old World’ (dromedary and Bactrian camels) and the South American or ‘New World’ camelids (llamas, alpacas, vicuñas and guanacos, collectively referred to in this paper as “SAC”). Of all camelids, alpacas, followed by llamas, are the most numerous in Great Britain (GB).

4. Both New and Old World camelids are known to be susceptible to infections with *M. bovis*, *M. tuberculosis* and related mycobacteria, which can cause TB in these species (O’Reilly and Daborn 1995, Fowler 2010). Tuberculosis was first reported in dromedaries in Egypt (Littlewood, 1888) and in India (Lingard, 1905 and Leese, 1908), although traditionally it has not been regarded as a major disease of camelids (Fowler 1996, 2010). Indeed, there are only rare reports of infections in their natural habitats in Northern Africa, Central Asia and South America (Fowler 2010).

5. However, the disease has gained greater relevance in Europe over the last two decades, because the growing number of alpacas and llamas being imported and bred in several European countries to serve as pets, ornamental animals or for production purposes (breeding, fibre production, pack animals and, more recently, meat production). Sporadic incidents of TB caused by *M. bovis* have now been diagnosed in captive llamas and alpacas in The Netherlands, Ireland, Spain, New Zealand and the US, as well as in Great Britain (Table 1). Some of these episodes were characterised by a high morbidity and severe clinical disease (Dinkla et al. 1991, Twomey et al. 2007).

Table 1 – Reports of natural *Mycobacterium bovis* infection in South American camelids outside the UK.

Country	Year of disclosure	Species affected	Comments
Holland	1988	Alpaca	Dinkla et al. (1991) - imported stock. 12/13 alpacas in a holding affected with extensive pulmonary TB.
RoI	2004	Alpaca	Ryan et al. (2008) - Local strain of <i>M. bovis</i> . Infected cattle and badgers in the locality (high bTB incidence area).
Spain	2009	Alpaca	García-Bocanegra et al. (2010) Index herd in an endemic bTB area of Andalucía. Several animals were affected, with secondary spread to another alpaca herd. Alpacas infected with a strain of <i>M. bovis</i> commonly found in the local cattle herds and wildlife.
USA	1970s to date	Alpacas, llamas	Bleem et al. (1993), Fowler (2010) – isolated sporadic incidents in zoos and on private farms.
Argentina	?	Alpaca	Argentinean animal health authorities (pers. comm.) Animals co-grazing with infected cattle herds
NZ	2000, 2004	Alpaca	P. Livingstone, NZ Animal Health Board (pers. comm.) Probably wildlife vector-related (ferrets or possums).

6. TB in camelids caused by infection with *M. microti* (another member of the *M. tuberculosis* complex, like *M. bovis*), *M. avium* complex and *M. kansasii* has also been reported in GB and other countries (Johnson et al. 1993, Oevermann et al. 2004, Lyashchenko et al. 2007, Braun et al. 2009, Zanolari et al. 2009).

7. Historical APHA/Defra records indicate *M. bovis* was first isolated in 1994 from two alpacas in a private wildlife collection near Henley-on-Thames (Oxfordshire), although the case was never written up for publication.

8. The first fully documented episode of TB in British SAC caused by *M. bovis* infection was diagnosed by a team of APHA and private veterinarians in 1999, when a llama from a small pet/showing herd in Southeast Wales died with TB lesions. The disease was caused by the predominant strain of *M. bovis* found in cattle and badgers in the surrounding area. Another female llama that had been sold within the previous year as a pet from this herd to another premises situated five miles away died at the same time and was also found to be infected with *M. bovis* (Barlow et al., 1999).

9. Since then, the number of new incidents of *M. bovis* TB infection officially confirmed by culture on SAC premises has gradually risen year on year until it reached a peak in 2010 (Table 2). This coincided with an expansion in the population (and popularity) of these species in the UK, an increase in the incidence of TB in cattle, greater awareness of the disease among veterinary practitioners and herd owners and the introduction of new legislation that made TB a notifiable disease in camelids and other non-bovine domestic animals in 2006. However, this rising trend was interrupted in 2011, when the total number of TB incidents recorded in SAC

holdings fell suddenly. Despite this increase in documented cases, relatively few confirmed incidents of TB caused by *M. bovis* are being diagnosed in SAC herds in GB (3 in 2007, 11 in 2008, 12 in 2009, 15 in 2010, 6 in 2011, 14 in 2012, 10 in 2013 and 7 in 2014).

Table 2 – Annual number and location of new incidents of TB in camelid herds caused by *M. bovis* infection in GB, as confirmed by laboratory culture¹².

Year of disclosure	Infected herds (with > 1 dead or culled animal)	Type of herd infected (herd with > 1 culled animal)	Location of affected herds
1999-2003	5	2x alpaca 3x llama	Gwent (2 llama holdings), Gloucestershire (alpaca), Herefordshire (llama), Somerset (alpaca)
2004	1*	alpaca	Devon
2005	1	llama	Avon
2006	2 (1)	1x alpaca 1x llama (1)	Sussex (alpaca), Devon (llama)
2007	3 (3)	2x alpaca (2) 1x llama (1)	Carmarthenshire (llama), Powys (alpaca), Dorset (alpaca)
2008	11 (6)	9x alpaca (4) 2x llama (2)	Carmarthenshire (llama), Devon (1 llama, 1 alpaca), Avon (2), Cornwall, Gloucestershire (3), Herefordshire, Worcestershire
2009	12 (6)	all alpacas	Devon (3), Derbyshire, Gloucestershire (2), Shropshire, Somerset (2), Staffordshire, Worcestershire (2)
2010	15 (6)	all alpacas	Devon (4)****, Cornwall (3), Gloucestershire, Hampshire, Monmouthshire, Staffordshire (2), Warwickshire, Worcestershire (2)
2011	6 (4) **	all alpacas	Cornwall, Dorset, Gloucestershire (2), South Gloucestershire (near Bristol)****, Warwickshire
2012	14(5) **	11x alpacas (4) 2x llama 1x 'mixed' (1) ***	Carmarthenshire, Cheshire, Devon (4), Somerset(2), Staffordshire, Warwickshire***, West Midlands, West Sussex, Wiltshire, Worcestershire
2013	10(6)	9x alpacas (5), 1 x 'mixed' (1)	Ceredigion, Cornwall, Devon, Gloucestershire (3)***, North Somerset (2), Shropshire, Vale of Glamorgan.
2014	7(6)	all alpacas	Devon, Gloucestershire, Herefordshire, Monmouthshire, Powys, Staffordshire, Wiltshire

(*) No culture possible, but typical histopathology and PCR positive for MTB complex.

(**) The figure in parentheses may increase as some of those incidents have not been closed and

¹² These statistics are updated quarterly by Defra and are available online at: <https://www.gov.uk/government/statistical-data-sets/other-tb-statistics> ['Incidents of confirmed *M. bovis* infection in domestic and companion animals and wild deer in GB']

ongoing live testing may identify further cases.

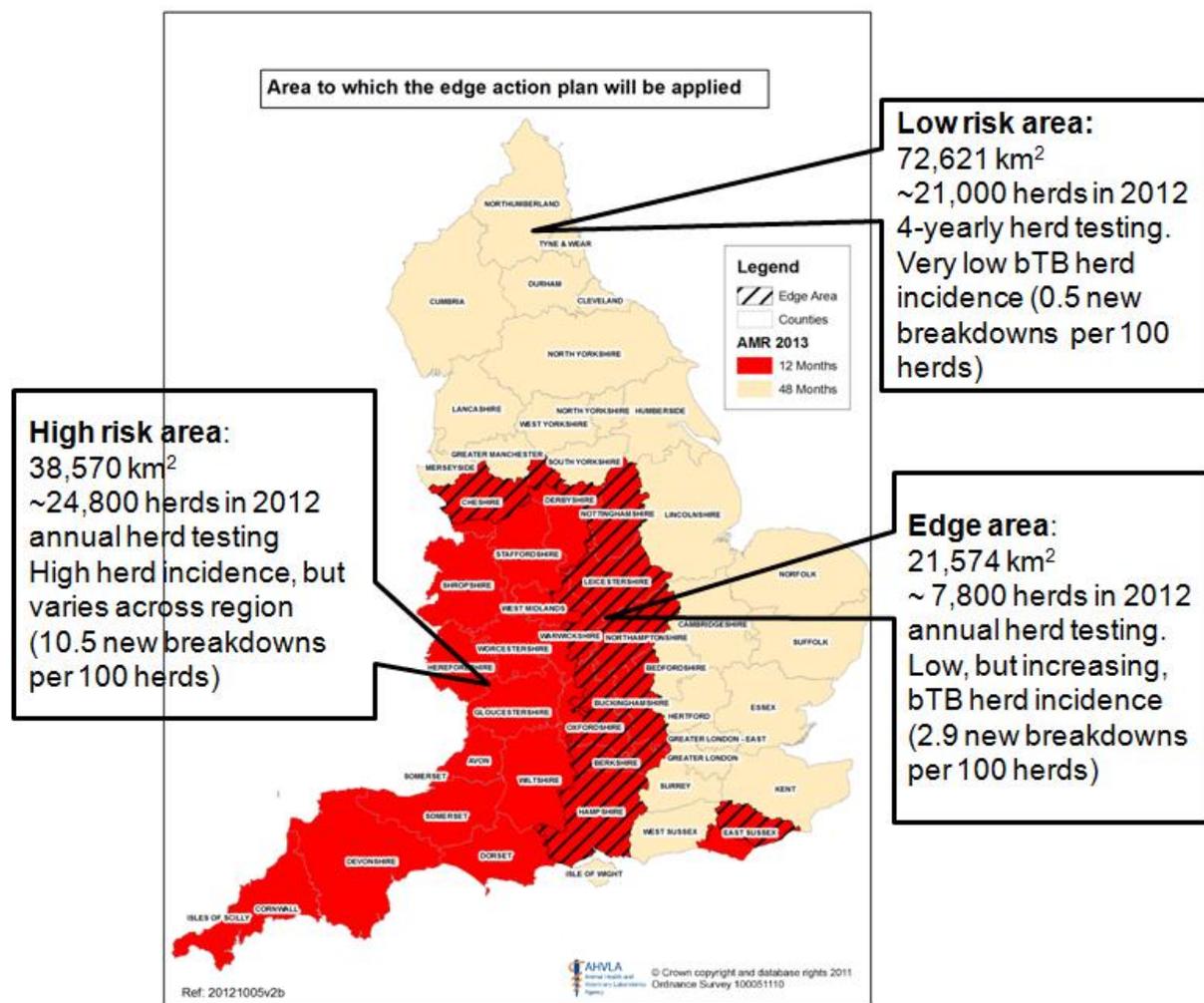
(**) A premises on which both alpacas and llamas were kept.

(***) Three of those were epidemiologically linked via movements/purchases of infected animals and could therefore be considered one TB incident.

(****) Location was incorrectly referred to as Avon in previous updates.

10. A total of 14 new incidents of *M. bovis* TB were confirmed in GB during 2012 (Table 2). These included two serious TB outbreak in a large alpaca breeding herd on the East-West Sussex border and a smaller alpaca herd in Warwickshire, respectively (both of which ended in depopulation of the affected premises). All of the SAC herds affected in 2012 were reared in counties where bovine TB is endemic and cattle herds are tested for the disease annually (Figure 1).

Figure 1 – Current cattle TB testing interval map of England showing the high risk, (solid red), edge (hatched red) and low risk surveillance areas (counties in cream). SICCT test = single intradermal comparative cervical tuberculin test.

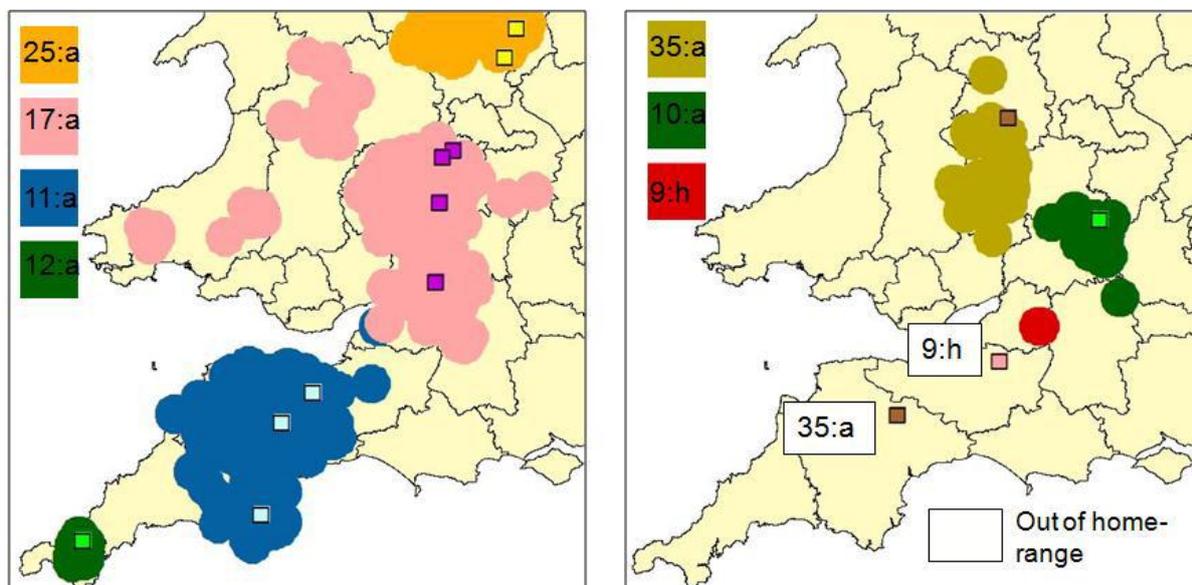


11. To put these figures in perspective, in 2011 a total of 4,843 new TB herd breakdowns in cattle were detected in GB, of which 3,036 were confirmed by evidence of infection at postmortem examination or culture (OTF status withdrawn).

Over 34,000 cattle were compulsorily removed in the same year for TB control reasons, with an additional 1,100 bovine carcasses yielding *M. bovis* after detection of suspect TB lesions during postmortem inspection at commercial slaughter.

12. Virtually all of the incidents of TB in SAC caused by *M. bovis* listed above in Table 2 have emerged in regions of GB where this infection is endemic in cattle and wildlife (the SW of England, the West Midlands and South and Mid Wales). Most incidents have been caused by the locally prevalent molecular type of the bacterium (i.e. they were ‘within home-range’), indicating that SAC herds are normally contracting TB from local reservoirs of infection, rather than from contact with camelids from other herds (Figure 2 and Appendix 1). A similar pattern has been observed in tuberculous alpacas in Ireland (Connolly et al. 2008). However, epidemiological evidence from alpaca TB outbreaks in the UK and abroad has also demonstrated that, on some occasions, uncontrolled movements of infected SAC can unintentionally spread *M. bovis* between herds and generate new (secondary) outbreaks (Barlow et al. 1999; Twomey et al. 2009; García-Bocanegra et al. 2010).

Figure 2 – Location of camelid (alpaca) herds with *M. bovis* infections diagnosed in 2009, mapped against the ‘home-range’ of the main molecular types (genotypes) of *M. bovis* present in GB. (source: Dr Noel Smith, TB genotyping group, APHA Weybridge).



13. Although there is little specific knowledge of the pathogenesis of TB in camelids, epidemiological investigations by APHA vets and the geographical distribution of outbreaks of TB in SAC in GB suggest that these are generally initiated by spill-over of infection from infectious cattle or badgers. In other words, these species become infected only when the challenge level is relatively high and, in the long term, cannot sustain the infection within their own populations in the absence of a cattle or wildlife reservoir.

14. However, once infected with *M. bovis*, SAC can infect other camelids, animals and humans on the same premises, as well as other livestock on contiguous holdings and other SAC herds via movements of infected animals. The scale, seriousness and protracted course of some of the TB outbreaks involving SAC premises in GB illustrates the potential for onward transmission of *M. bovis* from infectious camelids under favourable conditions, such as: severe pathology, delayed reporting and/or diagnosis, high on-farm stocking densities, multiple animal

movements between herds and poor biosecurity. Thus, from an epidemiological point of view, SAC can behave as amplifier hosts (or vectors) of *M. bovis* (Bleem et al. 1993).

Diagnosis of tuberculosis in SAC

15. TB is a chronic, insidious infectious disease and clinical signs are only evident in the advanced stages of infection. The incubation period of the disease is probably variable and cannot be estimated with certainty because it is difficult to establish the exact time of infection in most field cases (Fowler 2010). Clinical signs of TB in SAC are not specific and may include progressive wasting, lethargy, loss of appetite, respiratory distress with occasional coughing. Sudden death of apparently healthy animals with extensive TB lesions has also been described (Barlow et al.; Zanolari et al. 2009; Twomey et al. 2010 & 2012). Therefore, ante mortem diagnosis of TB based on clinical examination alone is insensitive, has low specificity and cannot be used on its own to provide assurances of TB freedom in SAC. TB has to be considered in the differential diagnosis of all cases of debilitating disease in these species, with or without obvious respiratory signs and particularly in regions where bovine TB is endemic (Barlow et al. 1999, Oevermann et al. 2004, Twomey et al 2007, Fowler 2010).

16. Ante mortem diagnosis of TB in camelids by immunological methods is challenging, with none of the currently available tests being able to detect infected and uninfected animals with complete accuracy (Wernery and Kaaden, 2002, Alvarez et al. 2011). The tuberculin skin test is the traditional diagnostic approach in cattle and other animal species, but it is unreliable and has a low sensitivity in camelids (Ryan et al. 2008, Dean et al. 2009). Although progress has been made in recent years to develop alternative in vitro tests, there are no internationally accepted standards for TB screening tests. The ante mortem tests currently available in SAC are based on the detection of cell-mediated (tuberculin skin tests, interferon-gamma release assay) and antibody (serological tests) immune responses in infected animals (Bleem et al. 1993, Cousins and Florisson 2005, Ryan et al 2008, Dean et al. 2009, Twomey et al. 2009, 2010 & 2012, Alvarez et al. 2011).

17. The tuberculin skin test has been the method traditionally used for pre-movement TB screening of camelids intended for international trade. In GB and many other countries (e.g. Argentina, Canada, Ireland, NZ, Switzerland, Sweden, USA) tuberculin skin testing of SAC is by the single intradermal comparative technique in the post-axillary site (i.e. the fibreless area behind the elbow) (O'Reilly and Daborn 1995, Ryan 2008, Twomey et al. 2010, Fowler 2010). This is the recommended site for the skin test in SAC, although the mid-lateral cervical area and the caudal aspect of the pinna (base of the ear) have also been used (Fowler 2010).

18. Except for the site of injection, both the single and comparative tuberculin skin tests are performed in camelids following the protocols in use in cattle, but at minimum testing intervals of 90 days. Neither test has been optimised and validated in large numbers of SAC of known infection status. Furthermore, skin tests are time consuming, require two visits to the farm 72 hrs apart, their accuracy is highly dependent on a meticulous technique (which can be difficult to adhere to in difficult field testing conditions), they cannot be repeated on short succession (due to the risk of de-sensitisation of the skin) and, as shown by several case reports and APHA's field experience, have a low sensitivity in naturally infected camelids (Twomey et al.

2007, Ryan et al. 2008, Dean et al. 2009, García-Bocanegra 2010, Twomey et al. 2012).

19. With support from the British camelid industry, APHA has recently completed a study to optimise and evaluate the sensitivity and specificity of a new SAC-specific interferon-gamma (IFN- γ) assay for TB, two lateral flow rapid antibody tests (STAT-PAK and DPP) and two ELISA-based antibody tests (IDEXX and ENFERplex), using respectively diseased alpacas from *M. bovis*-infected herds and alpacas from presumed TB-free in geographical areas with no history of bovine TB. The results of this research carried out under GB field conditions show that, while the sensitivities of the IFN- γ and antibody tests were similar (range of 57.7% - 69.2%), the specificity of the IFN- γ test (89.1%) in *M. bovis*-free herds was lower than any of the antibody tests (range of 96.4% - 97.4%) (Rhodes et al. 2012). The sensitivity of testing can be increased by combining two antibody tests (Lyashchenko et al. 2011, Rhodes et al. 2012) or the IFN- γ test with two antibody tests in parallel interpretation, although this resulted in decreased specificity (Rhodes et al. 2012). The data from this and similar evaluations in other countries opens up new opportunities for practical and reliable ante mortem TB screening of SAC in herd breakdown situations, pre-movement testing and tracing investigations (Lyashchenko et al. 2011, Rhodes et al. 2012).

20. As in other animals, a definitive diagnosis of TB in SAC caused by *M. bovis* infection requires the isolation of the organism from pathological (or clinical) specimens using laboratory culture in selective media. Once *M. bovis* infection has been confirmed in a camelid herd by laboratory culture, APHA will not normally submit further samples for culture from other suspect animals in the same herd (APHA 2013).

Current surveillance and outbreak control regime for TB SAC in England

21. One of the selling points of SAC to potential new owners is the lack of regulation required to keep these animals. Camelids currently fall outside of livestock legislation – there are no statutory requirements for animal identification or movement recording, but most (perhaps 95%) breeders keep records. The British Alpaca and Llama Societies (BAS & BLS) distribute a shared Camelid Movement Record Book to all members. All alpacas (~28,000) and llamas (~3,500) registered with the societies are micro chipped and have ear tags, although the latter are not always inserted.

22. Detection of TB lesions in carcasses and isolation of the organism in tissue samples of SAC and other non-bovine domestic animals has been notifiable in England since 2006, under Articles 6 and 20 of the Tuberculosis (England) Order 2007 (as amended) respectively. Where tuberculous lesions are detected postmortem, APHA will arrange for a representative sample of the affected tissue(s) to be submitted for laboratory culture for isolation and molecular typing of *M. bovis* free of charge to the submitter. For many years, Defra and the Devolved Administrations have subsidised the scanning surveillance and subsequent confirmatory diagnosis of TB in SAC at APHA laboratories and the Scottish Agricultural Colleges (Dr A Foster, APHA, pers. comm.).

23. Although TB is notifiable in camelids, there is no compulsory scheme for regular TB testing of camelid herds in GB. In the absence of a proactive ante mortem surveillance regime, initial detection of TB in infected SAC herds relies primarily on the submission by private veterinary surgeons of carcasses or tissue samples for

postmortem examination at APHA regional laboratories, either as routine casework or as suspected clinical cases of TB that die on farm or are euthanased due to a deteriorating body condition.

24. SAC owners are encouraged to have sudden, unexplained deaths of animals on their premises investigated, as well as other conditions that may be related to TB infection, but there are reasons to believe that this advice is not consistently heeded and an unknown degree of under-reporting of suspect cases of TB may be taking place. There may be a number of reasons for this, including inexperience of some camelid keepers, depressed camelid prices leading to less demand for veterinary services and the commercial breeders' concerns that a diagnosis of TB could have a serious impact on their business as a result of herd movement restrictions.

25. Very few alpacas are currently slaughtered for human consumption in the UK and there are only three abattoirs licensed to accept llamas and alpacas in GB (FSA, pers. comm.). Therefore, unlike other non-bovine farmed animals, ante- and postmortem surveillance by FSA veterinarians and meat inspectors in the slaughterhouse does not yet offer a meaningful alternative system for detection of TB in SAC.

26. In light of all the above, it is not possible to estimate the true prevalence of *M. bovis* infection in the SAC population. However, over the last 5 to 10 years there has been a substantial improvement in the degree of awareness of TB and its risk factors among owners of SAC and their veterinarians, which probably contributed to the rise in reported cases of TB in alpacas and, to a lesser degree, llamas.

27. Where typical lesions of TB have been identified by postmortem examination in SAC, APHA will usually place the holding of origin under movement restrictions pending the results of confirmatory laboratory tests. If the laboratory confirms the isolation of *M. bovis* in laboratory culture, the herd will remain under movement restrictions until all the remaining animals on the premises have received two successive tuberculin skin tests with negative results at 90-day intervals¹³. Since October 2014 mandatory TB testing of infected SAC herds has comprised an initial (bovine only) tuberculin skin test followed for non-reactors with the Chembio TB StatPak/IDEXX antibody tests in parallel interpretation for improved testing sensitivity.

28. The Secretary of State has statutory powers to enter premises to test and take samples and since October 2014 there has been a statutory compensation scheme in place under which APHA can slaughter TB test-positive animals in return for compensation of £750 per animal. APHA currently offers TB testing of affected herds in England at Government expense, along with free disposal and postmortem examination and culture (where required). There is a statutory compensation

¹³ Until recently, the tuberculin skin test format used in known infected SAC herds in GB was the comparative intradermal test with a severe interpretation (positive bovine tuberculin reaction greater than a negative or positive avian reaction). However, we started to use single intradermal tuberculin testing (with bovine tuberculin only) in some severe TB breakdowns detected in 2012 for better sensitivity, including tracings thereof. Single intradermal testing will shortly become the default screening method for all culture-confirmed TB incidents in SAC herds and high-risk tracings

scheme in Wales under which keepers receive £1,500 for mature breeding animals and £750 each for all other SAC.

29. It is also Defra policy to skin test any SAC that are contiguous to (or co-located with) infected cattle herds. Only one comparative intradermal tuberculin test with negative results is normally required in such circumstances.

30. APHA will also report any confirmed cases of *M. bovis* infection in camelids in England to the local Consultant in Communicable Disease Control of the Health Protection Agency.

31. The current Defra policy for APHA's intervention in the control of TB on SAC premises under various possible scenarios has been summarised in Appendix 2. Differences in case management can appear as discrepancies to external stakeholders, but are essential to ensure that the response is commensurate with the risk of spreading infection in each situation and the particular premises affected.

The risk questions

32. The aim of this paper is to answer the following disease questions:

- What is the overall risk of transmission of *Mycobacterium bovis* infection associated with South American camelids in GB?
- What would be the veterinary (disease) risks associated with the uncontrolled/unrestricted movement of animals out of camelid holdings in which *M. bovis* infection has been diagnosed?

33. The hazard of interest is *M. bovis*, the zoonotic bacterium of the MTB complex primarily responsible for TB in animals, which is endemic in large parts of GB.

34. The risk of interest is the secondary spread of *M. bovis* beyond the index infected SAC premises. The TB transmission risks from infected camelids fall into one of the following four categories, with the first two currently being the most important for overall TB disease control in England:

- a. Risk of transmission to cattle;
- b. Risks to local wildlife;
- c. Risks to other camelids; and
- d. Risks to other non-bovine domestic species (pigs, sheep, goats, etc.)

35. The risks to these four categories of animals are relative between different types of movements and relative to SAC holdings in which *M. bovis* infection may be present but has not been detected. The comparative baseline is thus not risk-free. This is due to many factors including –

- a. The reliance on postmortem surveillance for TB in SAC is insensitive as *M. bovis* infection is often chronic with a long incubation period;
- b. Ante-mortem tests for TB, like all biological tests, are not perfect;
- c. Not all infected animals are readily identifiable or traceable (as there is no legal obligation to uniquely identify camelids and record their movements in GB).
- d. Infection of local wildlife and intra-herd spread of infection can still take place while a SAC holding is under TB-related movement restrictions.

36. For the purpose of the assessment, the following terminology will apply (OIE, 2004; EFSA, 2006):

- Negligible - So rare that it does not merit to be considered
- Very low - Very rare but cannot be excluded
- Low - Rare but does occur
- Medium - Occurs regularly
- High - Occurs very often
- Very high - Events occur almost certainly

37. So – in the context of this veterinary risk assessment, the following definitions are applicable when estimating risks:

- Negligible – not worth considering; insignificant.
- Very Low – very unlikely to contribute to disease transmission, but cannot be excluded.
- Low – more than negligible. A situation comparable to the level of risk of TB transmission occurring within low prevalence areas.
- Medium – bovine TB transmission occurs regularly. A situation comparable to the level of risk of TB transmission occurring within TB endemic areas.
- High – Spread of disease is probable. Comparable to situations such as calves fed unpasteurised milk containing *M. bovis* or cattle coming into direct contact with an infected badger carcass.
- Very High – almost certain that bovine TB transmission takes place. Similar to experimental infection of cattle via the intra-tracheal route using large doses of *M. bovis*.

38. Animal TB represents a risk to the public and in the last nine years there have been two recorded instances of human *M. bovis* infection in GB attributed to close contact between tuberculous camelids and their carers (Twomey et al. 2010b). However, this assessment is not concerned with the risk of natural transmission of *M. bovis* from camelids to people (zoonotic TB), which is the remit of the Health Protection Agency and the equivalent public health protection bodies in Scotland and Wales.

Summary of risk factors

Structure of the SAC sector / industry

39. South American camelids are not native to the British Isles. They are relatively new to the UK. The exact population of SAC in the UK is not known, as there is no official register for these species, but their numbers are currently estimated at 30,000

- 35,000 alpacas¹⁴, 3,000 - 4,000 llamas, a few guanacos (the wild relative of the llama) in a couple of holdings and very small numbers of vicuñas (the wild relative of the alpaca)¹⁵. Although the population of SAC in the UK has increased over the last two decades (Davis et al. 1998, D'Alterio et al. 2006), it is still small by comparison with a cattle population of around 9 million. In England, the population of alpacas and llamas was estimated to be 11,000 in 2013:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/355868/structure-jun2014final-eng-18sep14.pdf

40. Similarly, the current number of imports of SACs into GB is small relative to the predominant livestock species. The first ever commercial importation of alpacas into the UK was from Chile in 1995¹⁶. Imports are continuing to this day (mainly from Australia, New Zealand, Chile, USA, Canada and other EU Member States), albeit on a much reduced scale and with higher individual values, thus limiting the potential for introduction of *M. bovis*-infected animals from abroad. A total of 857 SAC in 25 consignments were imported in 2005, compared with only 89 animals in 20 consignments (mostly alpacas) in 2010¹⁷.

41. The UK exports SAC to other EU Member States, although we understand that the export market has been somewhat depressed over the last two years due to concerns about TB. One consignment went to Qatar in 2008.

42. SAC can be found throughout GB and may share the same premises with other domestic (farmed) species. They also undertake movements particularly for showing, sales, breeding and (in the case of llamas) trekking, which can increase the likelihood of contact between herds and transmission of *M. bovis* among SAC and between species. Experience from the FMD outbreak of 2001 suggested that SAC contacts with other livestock species at shows, livestock markets and trekking events may be limited, but it is unknown if practices have changed.

43. The BAS has 1,120 registered herds, ranging from keepers of two to four 'ornamental' or 'pet' alpacas (usually gelded males) to serious commercial pedigree breeders in the classical sense, who breed alpacas for genetic improvement and whose herds comprise several hundred animals (the largest alpaca herd in GB has an estimated 1,000 animals). There are a large number of part-time 'hobby' alpaca owners who keep from two to fifty animals. Alpaca herds are distributed throughout the country, but their densities appear to be highest in the Home Counties and the South and West of England. Alpacas are relatively rare in Scotland (Appendix 3).

44. Llamas are used for a wide range of purposes. The British Llama Society (BLS) estimates that 95% of llamas in the UK are kept as field pets by their owners, who enjoy the pleasure of breeding young animals and occasionally selling any surplus ones on. A small proportion of llama owners breed them on a somewhat larger scale and the sales of the progeny may generate a small income, although the

¹⁴ As of 31 December 2012 the BAS registry stood at 31,088 live animals (source: BAS), compared with 11,000 alpacas registered in 2006.

¹⁵ Source: British Alpaca Society (BAS) and British Llama Society (BLS).

¹⁶ Richard Beale (BAS) and Liz Butler (BLS), paper to TBEG (March 2010).

¹⁷ Data obtained from the TRACES system on 2 & 3 November 2011.

BLS claims that nobody makes a living from breeding llamas in this country. There are also about twenty llama trekking businesses in the UK offering various length treks in areas that attract tourists. Around four to six llamas are generally needed for this type of activity. The BLS has a code of conduct for llama trekking.

45. On dozens of sheep farms camelids are kept to ward off attacks from dogs and foxes. Castrated male llamas are said to make excellent flock guards as it is in their nature to protect their group. This instinct can be transferred to guarding field stock such as sheep, goats, free-range poultry and ducks. Groups of up to three castrated male alpacas can also be used for this purpose. The value of the fleece from these animals helps offset some of the costs of keeping them¹⁸.

On-farm animal management, husbandry and movements

46. Camelid owners tend not to come from a livestock background, few are agriculturalists. The main activity on holdings with SAC (particularly those with alpacas) is breeding. Fibre production is an important subsidiary activity on some holdings. All SAC species have non-allergenic fleeces. Llama fibre goes into carpet production whereas alpaca fibre is turned into high-value products for the clothing industry. Tonnage is growing with direct sales to mills for processing and to small scale knitters.

47. Other uses of SAC include llama trekking, exhibition at open farms and zoological collections or simply as companion/ornamental/status animals (pets). Some free-range chicken producers, sheep farmers and owners of outdoor pig units use alpacas and llamas as guard animals to keep foxes and dogs away.

48. A small number of surplus alpacas are being slaughtered for meat production, as in Australia. The niche market for alpaca meat in the UK is still in an embryonic stage, with only three abattoirs in GB approved by the FSA for the slaughter of such animals. Llamas are not killed for human consumption in the UK at present.

49. Showing of SAC is very popular and is considered the breeders' shop window. Shows will have from 200 to 500 animals. Some shows are dedicated SAC-only events, whereas others take place as part of wider agricultural shows. The main shows are for alpacas, namely: the National show held at the East of England showground, the British Alpaca Futurity Show held each year in February at Stoneleigh Park, the Bath and West, the Three Counties, the South of England, as well as a number of smaller county shows. Some owners take camelids to shows in other EU countries, but some national alpaca breeding societies have recently started to ban UK alpacas from shows in the Continent because of concerns relating to TB.

50. Semen extension, preservation and artificial insemination in alpacas and llamas are developing technologies and progress in this field is slow (reviewed by Bravo et al. 2013). Consequently, movements of SAC for breeding purposes (mating) are a common practice within this sector. These 'breeding movements' are

¹⁸ ADAS report to Defra on the UK camelid industry

in the form of so-called 'drive-by mating' (whereby stud males are transported to one or several farms for one day or a succession of days to breed with one or more females) and 'bed and breakfasting' (whereby breeding females go out and stay on another camelid farm for a few days to mate with a stud male). Some sales of SAC also take place at livestock markets.

51. Co-habiting, co-grazing and, to a lesser extent, contiguous grazing with cattle especially in endemic TB areas, increase the risk of transmission between cattle and camelids. It is not clear how many premises in GB have llamas and alpacas in addition to cattle, but this is more likely to involve small holdings as commercial SAC units generally operate as separate enterprises. Every year approximately twenty cattle premises affected by OTFW breakdowns are identified by APHA as having co-located or contiguous camelid herds which are eligible for TB testing under current policy.

52. Awareness of the role that good biosecurity plays in controlling / restricting the spread of infectious diseases in the camelid industry is still lower than in other farming sectors, such as the commercial pig and poultry sectors. Specific concerns have been expressed by some sectors of the camelid industry regarding the biosecurity risks associated with stud males moving around the country with no mandatory official movement recording or quarantine. The camelid breed societies have recognised this and produced a number of training events and guidelines since 2010, but the extent of their impact and adoption by SAC keepers is unclear.

Pathogenesis, routes of infection and ability to shed the bacterium

53. SAC, like other mammals, are susceptible to infection with *M. bovis* and other mycobacteria. Based on the distribution of tuberculous lesions most commonly observed in TB cases diagnosed in British SAC (i.e. the lungs, pleura and associated thoracic lymph nodes), the main mechanism of infection in these species is likely to be the respiratory route, through the inhalation of infectious aerosols generated by infected SAC, cattle or badgers coming into close contact with susceptible animals (Barlow et al. 1999, Twomey et al 2007). This effect may be enhanced when some of the lesions in infected SAC show pulmonary cavitation (Twomey et al. 2009; Crawshaw et al. 2013).

54. *M. bovis* DNA has been detected by PCR assay in nasal swab samples taken from known tuberculous alpacas during postmortem examinations conducted at APHA laboratories. This finding confirms the potential for infected SAC to shed the bacterium, generate infectious aerosols and infect other animals via the respiratory route.

55. A secondary route of infection is the oral route, through ingestion of pasture and animal feedstuffs contaminated with the bacterium. Lesions of TB have been found in the retropharyngeal lymph nodes, liver, omentum and mesenteric lymph nodes of infected SAC in GB (Crawshaw et al. 2013). *M. bovis* DNA has also been detected in postmortem faecal samples from infected alpacas with variable degrees

of TB pathology, demonstrating again the ability of these animals to act as vectors of infection¹⁹.

56. Pseudo-vertical transmission to the 'crias' of dams with *M. bovis* infection through grooming and lactation (oro-nasal route), is another potential, if less likely, mechanism of transmission. Tuberculous granulomata have been described in the mammary gland and supramammary lymph nodes of an eight-year-old female alpaca from the West Midlands that was euthanased and presented to APHA Shrewsbury after a period of ill thrift with respiratory distress. The pathologists concluded that the considerable number of bacilli in the mammary gland in this case strongly suggested that milk from that alpaca would have contained sufficient numbers of the bacterium to cause infection in the offspring (Richey et al. 2011).

57. The identification at APHA of mycobacterial granulomas in the kidneys of alpacas with confirmed *M. bovis* infection also raises the possibility of transmission via infected urine (Twomey et al. 2009; Richey et al. 2011).

58. Finally, in view of the severe pathology found in some llamas and alpacas slaughtered due to TB, vertical transmission of *M. bovis* from dam to foetus *in utero* cannot be ruled out as another potential transmission route.

59. There is little published research regarding the pathogenesis of *M. bovis* infection in camelids, the association between virulence and duration of the incubation period (time from infection to onset of clinical signs), or the impact of concurrent infections, stress and nutritional status on the progression of infection. In a Canadian experimental study in which six llamas were experimentally infected with high doses of *M. bovis*, the earliest death occurred at 68 days post-exposure (Stevens et al., 1998). The findings of that study, however, cannot be used as direct reference for situations where natural exposure to an unknown challenge dose of *M. bovis* is suspected.

60. The sporadic and spatially clustered presentation of TB incidents in SAC in areas of endemic cattle and wildlife infection, combined with evidence from other countries, suggests that SAC are essentially spill-over hosts to *M. bovis*. However, because the gross pathology of TB observed in SAC is frequently more extensive than that seen in other species and *M. bovis* DNA has been found in a range of excretions (clinical samples) of tuberculous camelids, it is clear that these species do have the potential to propagate the infection within as well as between herds (via movements of subclinically infected animals).

Summary of mitigating factors

Geographic location

61. In general, SAC reared for commercial purposes tend to be kept on dedicated holdings rather than on mixed farms. This separation of the camelid and more traditional livestock industries in GB may help limit the spread of *M. bovis* infection between these sectors. However, SACs reared in regions where bTB is endemic will be under a constant threat of infection from local badger populations and

¹⁹ Crawshaw T. Personal communication and manuscript in preparation.

contiguous/co-located cattle herds for the foreseeable future. Additionally, the relatively uncontrolled movements of SAC throughout the country without any form of pre- or post-movement testing poses a risk of seeding ('translocating') the infection over long distances to low bTB incidence parts of the country, thus placing other livestock and wildlife populations at risk.

Surveillance and control

62. Tuberculosis has been a notifiable disease of non-bovine farmed and pet mammals in GB since 2006. There is a statutory requirement to notify APHA on the detection of any suspect tuberculous lesions in camelid carcasses through PME and the isolation of *M. bovis* in clinical samples. Rapid compulsory notification of TB suspect cases enables rapid disease detection and control, mitigating the risk of *M. bovis* transmission between SAC holdings, but this assumes that camelid keepers will arrange and pay for veterinary postmortem examination of all (or most) animals suffering unexplained deaths. The long productive lives of SAC relative to other livestock and the small numbers of camelids slaughtered for meat production militates against the use of slaughterhouse surveillance for TB monitoring and control.

63. Under-reporting of cases may arise through reduced awareness of the signs and impacts of TB in SAC herds among private veterinary surgeons and keepers. This may result in infected animals remaining in the herd for prolonged periods before being euthanased without PME for tuberculous lesions. Improving the awareness of private veterinary surgeons on the importance of PME in the case of any suspect signs or lesions could also help to improve case detection and mitigate spread.

64. The true uptake of private testing in camelids is unknown, but it is thought to be very low although there is anecdotal evidence that demand for private blood testing appears to be increasing. Improving private herd testing and pre/post-movement testing frequency could supplement postmortem TB surveillance and aid early TB detection and removal of infected animals, preventing unnecessary TB spread. It would also be a way of adding value to animals marketed for sale and breeding herds. However, the British SAC industry is currently divided as to the value of this measure.

TB breakdown management

65. When *M. bovis* infection is strongly suspected or confirmed on a SAC holding (usually in the form of TB lesions detected during postmortem examination of found-dead or euthanased animals), APHA will impose movement restrictions to prevent the spread of the infection to other premises (APHA notice TN02). If the suspicion of *M. bovis* TB can be confirmed by culture of the organism in the laboratory, the restrictions will remain in place until all the remaining camelids on the premises have undergone two consecutive tuberculin tests in the skin of the post-axillary region with negative results (at a minimum interval of 90 days) and as long as no clinical suspect animals are identified in the intervening period (APHA 2013).

66. Because of the low sensitivity of the tuberculin skin test in SAC, APHA have been deploying an ancillary antibody (Chembio StatPak) test on an experimental voluntary basis since 2006 to speed up the resolution of TB breakdowns and reduce the risk of residual *M. bovis* infection when movement restrictions are lifted. The

blood test is routinely offered to keepers of SAC herds sustaining culture-confirmed *M. bovis* TB breakdowns and owners of high-risk spread tracings. However, although virtually all affected SAC owners give permission to have their animals skin tested, a small proportion of them decline the voluntary blood test, or do so only after evidence of widespread infection emerges in their herds in the form of further clinical cases.

67. More rarely suspicion of TB infection in SAC arises through tracings undertaken from known infected premises, or skin check testing of camelids co-located with (or contiguous to) cattle herds that have had its OTF status withdrawn due to a confirmed TB breakdown. In these circumstances, if skin testing of camelids reveals reactors with no visible lesions (NVL) and negative culture results, all the remaining camelids on the affected premises are required to pass only one skin test with negative results. Such restrictions help prevent the spread of infection to other premises (APHA 2013).

68. For owners of TB affected SAC herds Defra compensates keepers £750 for each reactor removed. The Welsh Government's statutory scheme pays £1,500 for adult pedigree breeding animals and £750 for the rest. When owners decline to have their animals TB tested, movement restrictions are applied indefinitely.

69. All reactor animals and any direct contacts identified by APHA are slaughtered as soon as possible with the owner's agreement to remove infection from the herd and mitigate any further spread. Slaughter usually takes place on farm, and carcasses are disposed of at APHA regional labs or animal by-product plants depending on whether postmortem examination and tissue samples are necessary to inform the next steps in the management of the TB incident.

70. Any cattle herds with an epidemiological link (co-located or contiguous) to an infected SAC premises are also subjected to an APHA veterinary risk assessment and skin tested, unless recently TB tested for other reasons (APHA 2013).

71. Splitting large herds into smaller management groups with dedicated facilities and equipment following testing in the face of an outbreak (based on infection risk through contact with reactor animals and clinical cases, etc.) can improve biosecurity and limit intra-herd spread.

72. Unlike the situation in cattle herds, SAC herds experiencing TB breakdowns do not currently undergo follow-up tests 6 and 18 months after de-restriction. This increases the risk of residual herd infection causing recurrent TB breakdowns and dissemination of infection to other herds through movements of infected animals not detected in the course of the original incident.

Summary of the likelihood of spread of *M. bovis* infection

73. This paper explores the need for movement restrictions in SAC herds whenever *M. bovis* infection is suspected or confirmed and provides a qualitative assessment of the risks of allowing the movements of animals out of such herds.

74. Based on the currently available information from GB and other countries, SAC can be considered incidental, spillover hosts for *M. bovis* that act as sentinels of infection in the local badger populations and cattle herds. The risk (transmission) pathways are represented schematically in Figure 2.

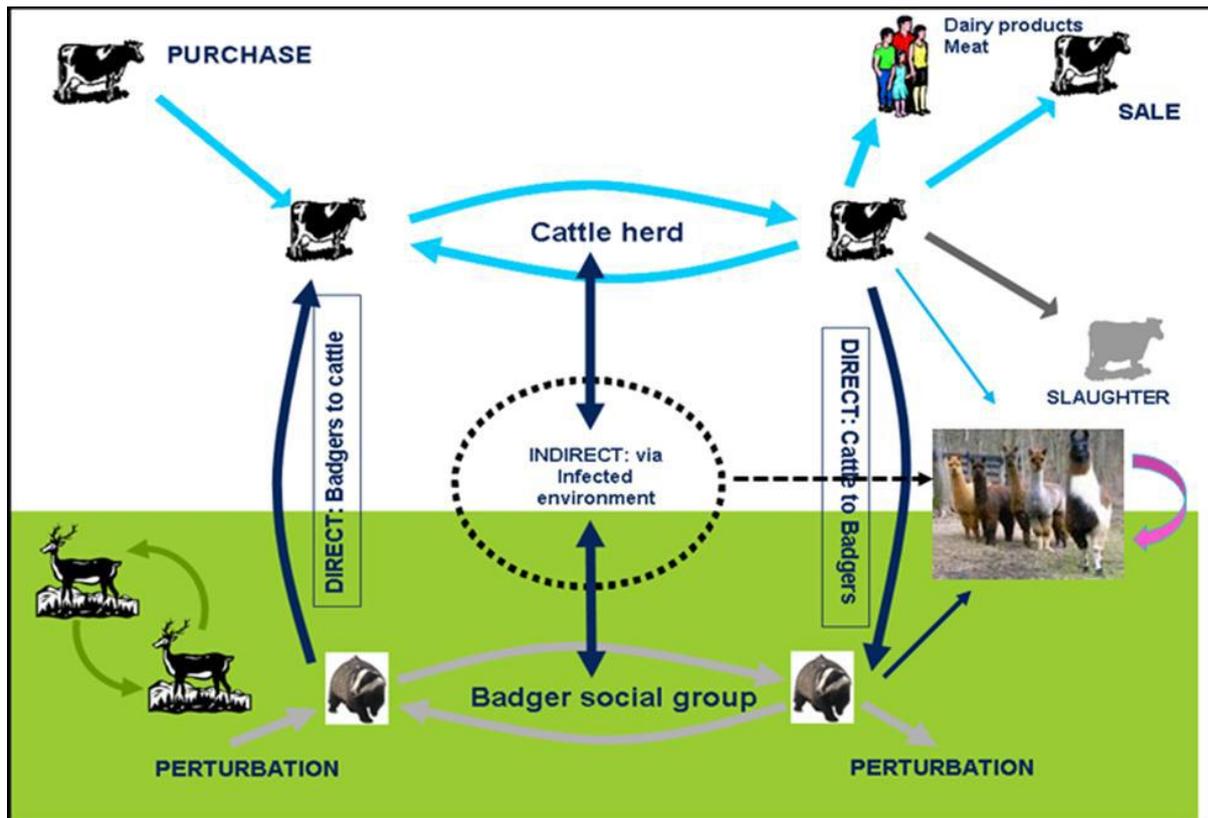
75. There is no evidence yet that camelid populations can act as maintenance hosts of *M. bovis* infection in the absence of a local cattle or wildlife reservoir.

76. Cases of presumed natural transmission of *M. bovis* between alpacas and from alpaca to their keepers have been documented in the veterinary literature (Twomey et al. 2010, Di Summers personal communication). Therefore, it is possible that under the right conditions a subclinically infected llama or alpaca shedding the bacterium could infect other domestic animals coming into direct or indirect contact with them. However, there is no firm evidence to date that any incidents of TB in cattle, pigs, sheep, goats or captive deer have been acquired through interspecies spread of *M. bovis* from infected SAC.

77. The current available evidence suggests that there is a risk of TB transmission between SAC, and potentially from SAC to other species. It is hard to quantify these risks, which arise from the movement of subclinically infected animals and subsequent direct or indirect contact. Due to the nature of the industry, the risk of transmission between camelids seems to be higher than from camelids to other species.

78. Despite the large outbreak of TB in alpacas in East Sussex, the risk posed by camelids to other species (particularly to cattle) is probably quite low, but not negligible, so that it does not warrant a change in current voluntary passive surveillance arrangements. However, this is not a static situation and transmission risks may change over time. Monitoring of new cases of TB in SAC must continue, as well as field epidemiological investigations into the origin of TB breakdowns in cattle herds.

Figure 2 – Diagram representing the role of SAC as spillover hosts in the transmission cycle of *M. bovis* in GB. Camelids can contract the infection through direct or indirect contact with the maintenance hosts (cattle and badgers and their excretions), or through close contact with other (infected) camelids.



Summary of the veterinary consequences of spread of *M. bovis* infection

79. *M. bovis* infection in SAC and its spread through the uncontrolled movement of animals can have an impact on:

a) Animal welfare (within sector, and /or to other species including cattle and wildlife). Clinical signs of TB have been reported in SAC of all ages and are a relatively common occurrence in infected SAC herds. In the absence of systematic TB surveillance in SAC by routine ante-mortem testing or slaughterhouse meat inspection, clinical cases are often the first indication of the presence of TB in a herd. Adverse animal welfare consequences may arise from delayed diagnosis or reporting of a TB suspect index case, from an owner's decision to 'treat' exposed and suspect animals with anti-TB drugs or herd owners' reluctance to deploy more sensitive TB blood-based tests to speed up the identification of subclinically infected animals. Adverse welfare consequences can also arise from the imposition of movement restrictions through the inability to move animals and over-stocking of SAC premises, although this is only likely to be a significant issue in commercial breeding herds.

b) International trade and reputation. The number of GB exports of live SAC to other EU Member States and to third countries is understood to be low (around 80 in 2009), although big commercial breeders are looking to expand this market. Considering the overall low prevalence of *M. bovis* infection in the British SAC population and the low numbers of camelid exports, there is a low probability of exporting *M. bovis* infected SAC to other Member States. However, the consequences of such an event for the reputation of the British camelid industry could be very serious. The current TB screening method for exported camelids, which is based on skin testing in the 30 days before the intended movement, has a

very low sensitivity and could easily miss an infected animal (low predictive value of a negative test result). Therefore, the risk of 'exporting' TB in SAC from GB should be regarded as medium (low probability of the event, but high impact if it occurred).

c) Economic losses in infected herds

i. Commercial losses may not be important for small holders and owners of alpacas and llamas kept as pets or for ornamental purposes.

ii. Economic losses will be greatest for pedigree breeding and showing herds that rely on movement of live animals, showing, sales and exports for the viability of their business.

d) The risk of zoonotic TB from *M. bovis* infection in SAC is considered very low as these are not milk-producing animals. Only those persons with direct, prolonged contact with live infectious animals and during postmortem inspection should normally be considered at risk of zoonotic infection. However, any public health risks are for the relevant bodies to assess and manage. APHA reports all cases of culture-confirmed *M. bovis* infection in SAC in England to the Consultant in Communicable Disease Control (CCDC) of the relevant Health Protection Unit.

Summary of the uncertainties and assumptions

80. It is important to note the limited evidence available with which to consider the objectives of this paper and the substantial uncertainties that remain. Much of the published information that is available is based on passive TB surveillance and small numbers of animals, making it difficult to transpose to the general population. It is also often based on experience in other countries, which again may not be applicable to the GB situation.

81. There is also limited specific knowledge of the pathogenesis of *M. bovis* infections in SAC compared with cattle, badgers or deer.

82. The poor sensitivity of the tuberculin skin in camelids and the lack of a routine TB herd testing programme in SAC contribute to our incomplete knowledge of the underlying immunology and basic transmission processes of TB in these species. The relationship between infectiousness of *M. bovis*-infected animals and the ability to detect them is not well understood either, although it is assumed that the more advanced the TB infection process, the more infectious an animal becomes and the easier it is to detect it through ante-mortem immunological tests, clinical or postmortem examinations.

83. The main uncertainty revolves around the true herd and animal prevalence of *M. bovis* infection in the British SAC population. The prevalence of infected herds appears to be low and concentrated in the areas of GB where bovine TB is endemic, but this is based only on findings of postmortem surveillance and limited risk-based ante mortem testing of herds. Despite the low apparent prevalence of infected herds, TB outbreak investigations in GB have demonstrated that the prevalence of infected animals in some herds can be high.

Conclusions (and summary of veterinary advice)

Overall risk of spread of *M. bovis* infection associated with British SAC

84. The veterinary advice is that:

a. SAC are susceptible to infection with *M. bovis* and other mycobacteria that cause TB in animals.

b. In an unknown proportion of *M. bovis*-infected SAC, the bacterium can give rise to TB. Although clinical signs are not specific, clinical disease presents with very extensive and severe pathology and affected animals can be highly infectious.

c. Even so, based on the currently available information from GB and other countries, SAC can still be considered incidental, spillover hosts to *M. bovis*. In most cases these animals become infected through contact with one of the maintenance hosts and vectors of the infection in GB (i.e. badgers and cattle, or environment contaminated by their secretions and excreta). In other words, SAC normally act as sentinels of endemic infection in local badger populations and cattle herds.

d. Therefore, SAC are not currently considered a significant vector of TB for cattle, other domestic animals or wildlife. However, this is not a static situation and new factors may come into play that could alter this risk assessment.

e. Due to their relatively small numbers and likely low prevalence of *M. bovis* infection, the weight of infection in the British SAC population is far lower than that in the two recognised maintenance hosts of the disease in England and Wales, namely domestic cattle and the Eurasian badger. Additionally, SAC tend to be bred, reared and kept on dedicated holdings as an alternative livestock enterprise, rather than on traditional livestock farms. They are often shown at specialist events. This means that SAC are generally segregated from cattle, pigs and other livestock, thus reducing the opportunities for direct (airborne) and indirect inter-species transmission.

f. In light of all the above, there is little justification for a programme of mandatory, regular, proactive TB testing of British camelid herds as part of the national bovine TB eradication plan paid by the government. Sporadic TB incidents involving SAC can be managed on a case-by-case basis using the general legal provisions for the diagnosis and control of TB in species other than cattle, laid down in the Animal Health Act 1981 and subsequent regulations made under that Act..

g. Nevertheless, there have been instances of TB transmission between camelid herds. Therefore, SAC can behave as amplifiers (vectors) of *M. bovis* infection for other animals with which they came into contact, usually other camelids. Although there is no evidence to date of any incidents of TB in cattle, sheep, goats, pigs or captive deer being attributed to transmission from infected SAC, the risk of such events is not negligible.

h. There is an unquantifiable (but probably low) risk of translocation of TB into naïve SAC herds and the TB-free regions of GB via uncontrolled movements (e.g. sales) of camelids, particularly from premises with a history of confirmed *M. bovis* infection and herds reared in areas of England and Wales where bovine TB is endemic.

i. The overall risk of TB transmission posed by SAC to other domestic animals (particularly to cattle) remains generally very low, despite some recent large outbreaks of TB in SAC.

j. *M. bovis* infection in British SAC does not materially affect the background level of risk of TB spreading to cattle, sheep, goat, pig and deer farms. The greatest risk to those livestock sectors continues to stem not from tuberculous SAC, but from exposure to infectious local wildlife (mainly badgers), from contact with undisclosed infected cattle on the same or contiguous farms, or from movements of other infected, undetected livestock (cattle, pigs, sheep, goats) between farms within the same species 'compartment'.

k. The APHA guidance on TB in camelids should be revised to include explicit advice to potential purchasers about the risks of TB and the standards/assurances they should ask for from breeders.

l. Additionally, the camelid breeding societies and the British Veterinary Camelid Society should continue to highlight among their members the importance of conducting routine postmortem examinations on all unexplained casualties on farm and the need to submit tissue samples from suspect TB cases for differential/confirmatory diagnosis.

m. The current voluntary passive surveillance regime for TB in camelids could be strengthened to mitigate the risk of spreading *M. bovis* infection between camelid herds and to protect the high-value pedigree breeding stock of some commercial herds. The camelid breeding societies and show organisers should be encouraged to adopt a policy of private pre- and/or post-movement TB testing of SAC intended for trade, entering shows and markets, moved for mating or offered for sale, as a recommended good-practice standard for the SAC industry.

n. For additional protection, any new camelids introduced into a SAC holding should be kept in isolation and tested for TB at least 60 days after arrival (and 90 days or more after their last tuberculin skin test, if any) before joining the resident herd.

o. Since the tuberculin skin test has been shown to have a very limited sensitivity in camelids (the probability of false negative results is high and the predictive value of a negative result in GB is low), this test should *not* be used on its own as a pre- or post- movement screening tool for TB. Skin-test negative SAC should be tested 10-30 days later with one or two serological (antibody) tests. To allay any concerns about 'false positive' results in herds not affected by TB restrictions, two antibody tests could be combined in 'serial' interpretation, whereby only those animals reacting to both tests would be considered suspect, re-tested and only culled if positive for a second time.

p. In order to safeguard the reputation of the British SAC industry and the integrity of the UK's bovine TB eradication plan, *mandatory* TB blood testing for SAC moved domestically and those intended for export from the UK may be necessary if the practice is not voluntarily adopted by the industry within a reasonable timeframe.

Risks associated with the uncontrolled/unrestricted movement of animals out of SAC holdings in which *M. bovis* infection has been diagnosed

85. The veterinary advice is that:

q. unrestricted movements of SAC from known TB-infected holdings (other than directly to slaughter under licence) would result in a substantially increased risk of *M.*

bovis spread to other farms. The current system of herd movement restrictions pending the completion of repeat skin tests with negative results and supplemented by parallel antibody testing and tracings should be maintained, mainly to protect other TB-free SAC herds.

r. A combination of mandatory skin and antibody tests used in parallel interpretation (to maximise diagnostic sensitivity) should become a prerequisite to lift restrictions from all SAC herds diagnosed with culture-confirmed *M. bovis* infection, as well as any forward tracings thereof.

s. Additionally, given the moderate sensitivity of TB antibody testing, SAC herds experiencing a confirmed *M. bovis* TB breakdown should undergo skin and antibody testing again six to twelve months after movement restrictions are lifted (except perhaps those holdings with introduced singleton infected animals and no evidence of secondary intra-herd spread). This measure would help to identify and reduce the risk of undisclosed residual herd infection.

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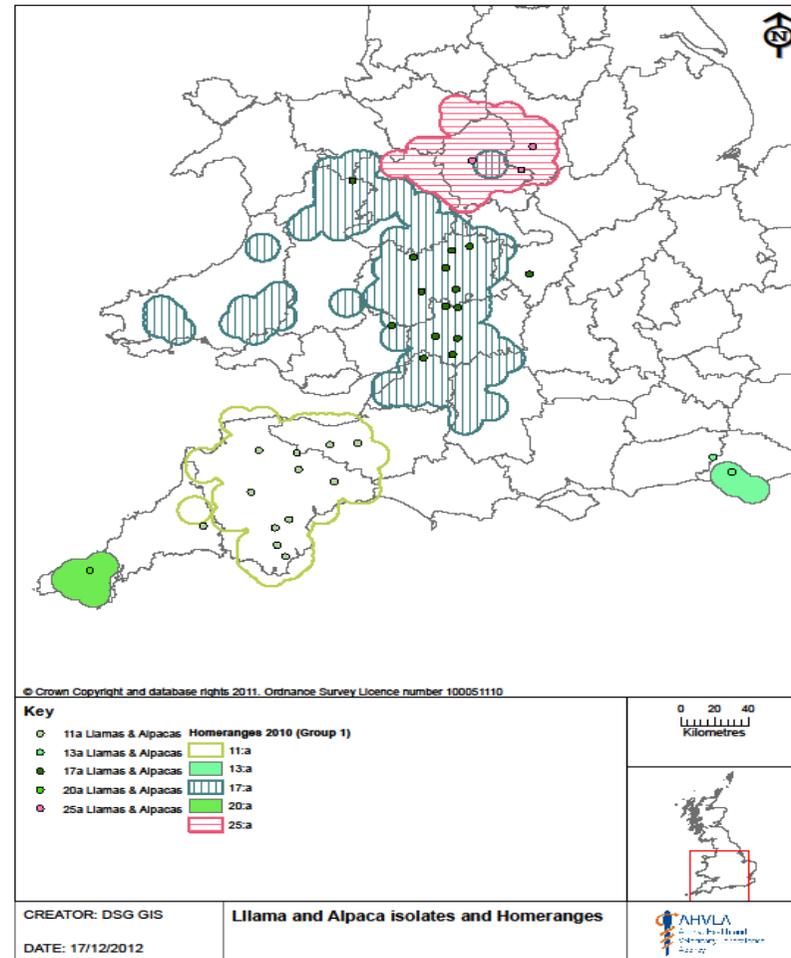
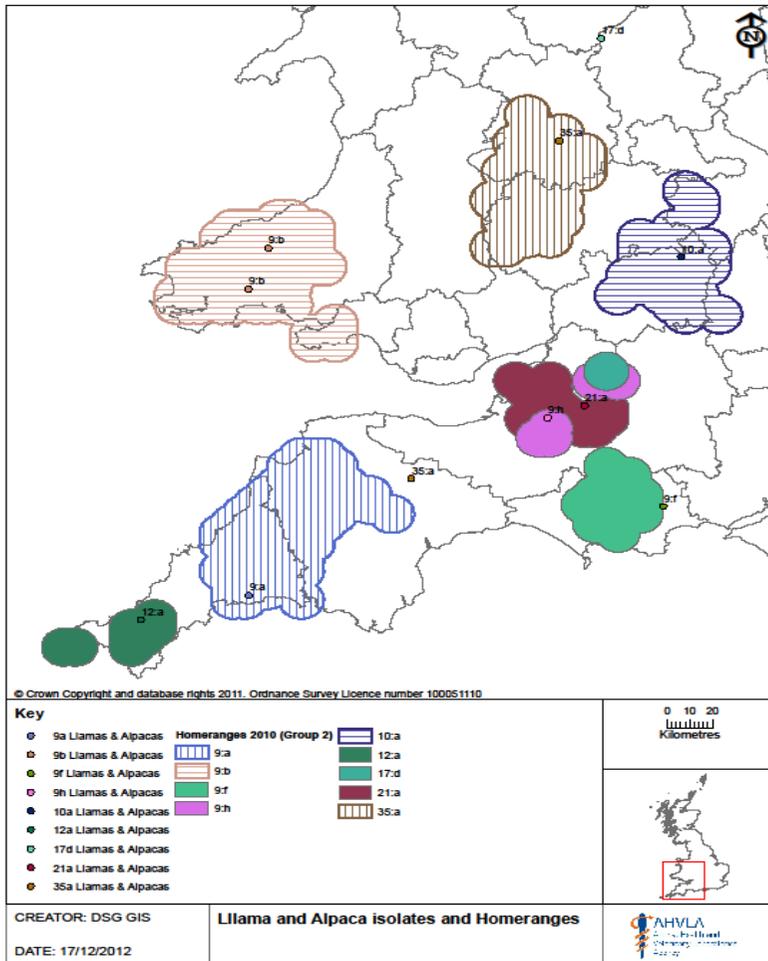
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Appendix 1 - Location of alpaca and llama premises that experienced culture-confirmed breakdowns of *M. bovis* TB in GB 2006 - 2012. The point locations of infected premises are shown against the 'home ranges' of the most common genotypes of the bacterium in GB (2010 home range map). Only 5 of the 46 isolates mapped were out of their expected range. Source: N. Smith, T. Crawshaw, R. Nicholson (APHA).



Appendix 2 – Current Defra (England) policy for the control of TB incidents on SAC premises

Scenario

APHA response

Comments

1. TB strongly suspected at PM

examination of diseased/dead camelid

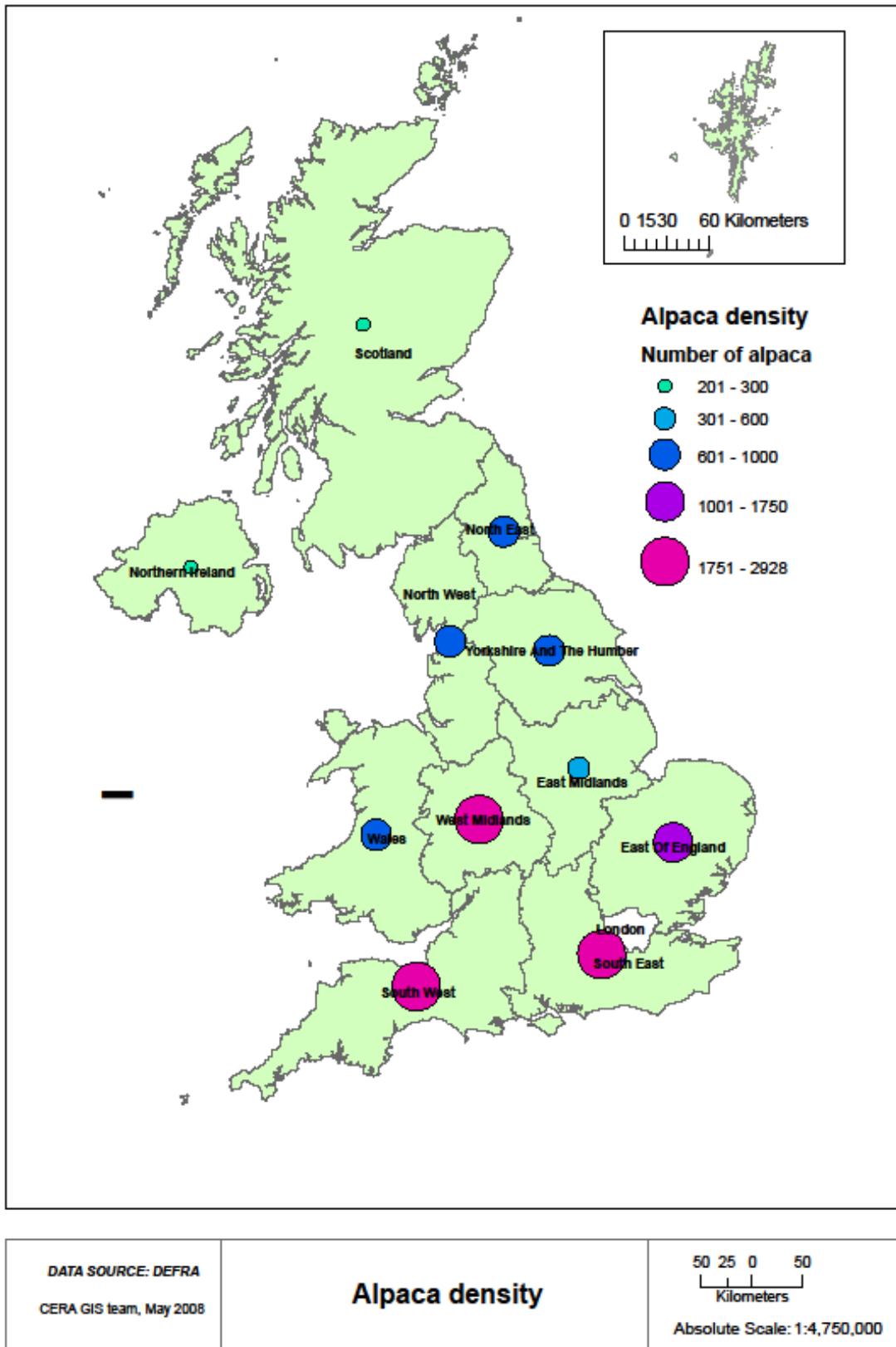
- veterinary risk assessment

- all private skin testing must be authorised

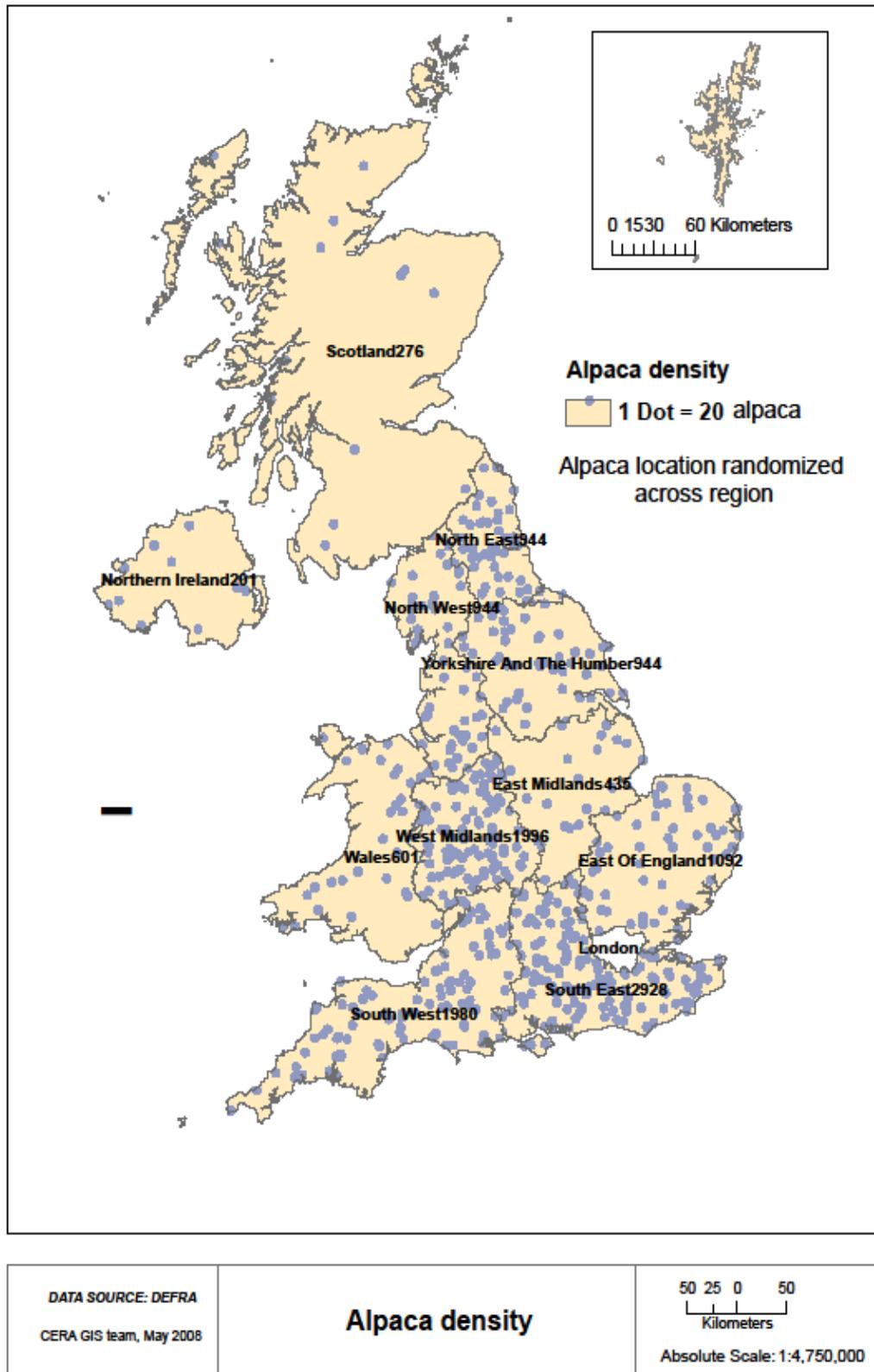
- | | | |
|---|---|---|
| 2. <i>M. bovis</i> positively identified in laboratory cultures of suspect postmortem cases | <ul style="list-style-type: none"> • herd restriction is default position • await culture result • consider immediate (private?) skin test • (confirm) herd restrictions • two skin herd tests with negative results at 90-day intervals • supplementary serological testing 10-30 days later on all skin test-negative animals • cull any test reactors, clinical suspects and contacts • request movement/sales records • notify CCDC (Health Protection Agency) | <p>by (and results notified to) APHA</p> <ul style="list-style-type: none"> • testing and slaughter of reactors is voluntary: requires prior written consent & agreement to surrender any reactors in exchange for a fixed ex gratia payment • blood test strongly advised for enhanced sensitivity (mandatory from 2012) • indefinite movement restrictions if herd owner refuses to test or remove all reactor animals |
| 3. Tracings from <i>M. bovis</i> - infected herds | <ul style="list-style-type: none"> • identify & contact current owner • skin test of individual animals (forward-tracings) or herd (back-tracings) (x1) • possibility of combining with serological testing if "hot" tracing | <ul style="list-style-type: none"> • indefinite movement restrictions if animal owner refuses to test or remove all reactor animals |
| 4. Camelids co-located with infected (OTF status withdrawn) cattle herds | <ul style="list-style-type: none"> • assess degree and duration of contact • issue restrictions & skin test (x1) | |
| 5. Camelid holdings adjoining infected cattle (OTF-W) herds | <ul style="list-style-type: none"> • risk assessment • skin herd test (x1) | |
-

Appendix 3

a. Alpaca regional population map of the UK (2008)



b. Regional alpaca population density map of the UK (2008)



Appendix 4 – Outcome of spread tracing inquiries from two severe TB outbreaks identified in SAC holdings in England in 2012

	Camelid premises containing TB tracings moved/purchased from infected premises in Sussex	Camelid premises containing TB tracings moved/purchased from infected premises in Warwickshire	Total	Individual animals (alpacas) traced infected premises in Sussex	Individual animals (alpacas) traced infected premises in Warwickshire	Total
1. Total number of (spread) tracings initially identified by APHA	54	26	80	144	71	215
2. Number that could be located by APHA	32	26	58	73	71	144
3. Number of those at (2) that have been skin and blood tested so far	29	14	43	66	45	111
4. Number of those at (2) where the owner has not agreed to test,	3	12	3	--	26	26
5. Of those at (3), no. reacting to the tuberculin skin test	1	1	2	1	1	2
6. Of those at (3), no. that were seropositive (StatPak test)	11	12	23	18	17	35
7. Number of skin test reactors or seropositive tracings slaughtered	12	12	24	19	17	36
8. Of those at (7), how many were VL and/or culture +ve	2	1	3	2	2	4
9. Among those herds with TB test positive tracings, how many herds/animals have so far tested positive at the follow-up whole-herd test.	0	0	0	0	0	0

Veterinary risk assessment of the spread of TB from the movement of captive deer from known TB-infected groups

Executive summary

1. Deer are highly susceptible to TB and infection has been detected in captive (farmed and park) deer and wild deer in Great Britain (GB). In GB they are generally considered to be spill-over end hosts, i.e. they are unlikely to sustain the infection within their own population in the absence of infected cattle or a wildlife reservoir. However there is evidence that wild deer can be a reservoir of TB and can transmit TB both to other deer, and to cattle.
2. The incidence of cases of TB in captive deer has remained at a steady low level over recent years. The incidence in wild deer is usually higher, possibly reflecting a much larger population, with large numbers of culls, compared to captive deer.
3. There is no statutory TB testing programme for deer herds in GB and surveillance is reliant on compulsory notification of suspect clinical cases, lesions found at postmortem and isolation of *Mycobacterium bovis* (*M bovis*) and on abattoir surveillance. The prevalence of TB in deer is not known but appears to be very low based on the surveillance systems in place (however, individual herds may contain high numbers of infected animals).
4. Currently, APHA places movement restrictions on holdings where disease has been confirmed or is strongly suspected with the aim of preventing disease spread. Restricted herds require tuberculin skin testing or depopulation of the remaining animals on the infected premises in order to lift the restrictions. If skin testing is not possible e.g. with some park deer, a surveillance programme at the slaughterhouse may be considered.
5. APHA also instigates spread and source tracings, as well as testing of any cattle herds that may be co-located with (or contiguous to) the infected premises.
6. Small numbers of TB breakdowns occur almost every year in captive deer. There are relatively few movements of deer in England when compared with other species but more than half are from farm to farm so there is a risk of spread of TB (and other diseases) via this route.

Introduction and background

Structure of the industry

7. Deer farming is a relatively recent enterprise in GB. Captive deer are managed in either park or farm systems. In 2011, according to the June Agricultural Census, there were approximately 21,000 farmed deer on commercial agricultural holdings in England and, according to the Economic Report on Scottish Agriculture, there were 31,000 in the UK. The total park deer population in GB is unknown. However, in 2005, based on annual population control culling of about 8,000

animals, it was estimated that there were approximately 40,000 park deer. These deer are distributed across several parks (some of which are famous tourist sites) where wild and/or exotic species of deer can roam and be viewed (Defra 2012).

8. By contrast wild deer in GB are estimated at well over two million with an annual cull of over 300,000 (FAWC 2013). Captive deer therefore represent the minority of the deer population across the country.

On-farm management and husbandry

9. In the park system, deer are raised in a park setting, are allowed to roam freely and may be provided with some supplemental feed.

10. Farmed deer systems follow conventional agricultural practices. There are several categories including calf rearers, calf finishers, breeder finishers and producer/processors (www.bdfpa.org). Adult deer do not usually require housing but they need protection from adverse weather conditions. Adults (and particularly calves) may therefore be housed during the winter.

11. For weaning, farmed hinds and calves are normally gathered in September or November, before or after the autumn rut. Farmed hinds should have finished calving by the end of June and so calves are three to five months old at weaning. Normally calves are weaned into buildings where they can be protected from inclement weather and fed over winter. Hinds are turned back out onto grass to improve body condition before the onset of winter.

12. Deer farms usually have perimeter fencing that is two metres high to prevent deer escaping.

Tuberculosis in deer

13. Tuberculosis (TB) caused by *M. bovis* is primarily a disease of cattle but can infect any mammalian species. *M. bovis* was first diagnosed in farmed deer in England in 1985 and involved a consignment of red deer imported from Hungary (Stuart et al. 1988, Delahay et al. 2002). The index case, a red deer stag in Gloucestershire, had generalised lesions of TB. Subsequent tracings revealed two other consignments from Hungary kept at two premises in East Sussex, from which 106 were examined at postmortem; 26 were infected and 19 had lesions.

14. The next outbreak was in 1988, when two deer died on a farm in Northamptonshire (Bode 1995). Following skin tests, 119 deer were culled. *M. bovis* was confirmed in 32 deer and 21 had visible lesions. These were traced back to a farm in Essex, which had a dispersal sale in 1987. Eleven farms had received deer and TB was confirmed on four of these; disease was also confirmed in another herd that had received deer from one of these four farms. These early outbreaks were also associated with transmission of disease to deer herds in Sweden through export of British deer.

15. The incidence of TB in captive/farmed deer has remained at a steady low level over recent years. By comparison, the incidence in wild deer is usually higher (table 1). This probably reflects the higher population of wild deer in the UK. The exact size of populations of captive and wild deer are not known; however, the number of wild deer in GB is approximately two million with an annual cull of over 300,000 (FAWC 2013), providing greater opportunity for detection of cases, compared with the estimated UK populations of farmed deer (approximately 31,000)

and park deer (approximately 40,000) (Defra 2012). The population of farmed deer in England is recorded as 22,000 in 2013:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/355868/structure-jun2014final-eng-18sep14.pdf

16. TB in deer is often detected at postmortem either for diagnostic purposes (scanning surveillance) or meat inspection, followed by bacterial culture, which is the gold standard for establishing a diagnosis. The prevalence of TB in deer is not known but appears to be very low based on the surveillance systems in place. AHLVA usually only culture visible lesions found during the course of diagnostic postmortems or from lesions submitted from abattoirs. However, *M. bovis* can also be isolated from deer where visible lesions have not been identified (Bode et al. 1995). Therefore a surveillance system that only cultures from visible lesions will underestimate the true prevalence.

17. Deer are generally considered to be spill-over hosts and therefore usually require exposure to other infected animals (e.g. cattle and badgers) for infection to persist. In support of their status as a spill-over host, the *M. bovis* genotypes from most cases correspond with the predominant genotypes found in the cattle and wildlife from the same geographical area.

18. There is some evidence that deer can act as a reservoir host for *M. bovis*, (able to maintain infection in their populations) where wild deer live or congregate at high population density and commonly interact with cattle e.g. in SW England and the northern USA (Delahay et al. 2007, Ward and Smith 2012, Sorensen et al. 2014). Infection in wild deer has also been reported in a number of countries where bovine TB is considered to be eliminated. However, in some cases it is not clear if infection would be maintained in deer in the absence of another wildlife reservoir, e.g. wild boar in Spain (EFSA 2008).

Table 1: Numbers of infected deer found each year in GB

<https://www.gov.uk/government/statistical-data-sets/other-tb-statistics>

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Farmed deer	0	1	5	1	1	1	1	6	2	11	6
Park deer	2	1	17	4	2	0	6	0	0	0	1
Wild deer	42	31	29	20	31	18	15	17	12	8	15

19. Animal Health Veterinary Laboratories Agency (APHA) field staff normally place movement restrictions on captive deer herds when suspect lesions of TB are detected in the course of postmortem meat inspection, pending laboratory culture results. If *M. bovis* infection is confirmed by laboratory culture, live testing of the affected herd is then carried out using the single intradermal comparative cervical tuberculin (SICCT) test. This test appears to work well in deer, with a sensitivity of 85.8% and specificity of 97.7% (EFSA, 2008, tables 10 and 11).

20. There is limited use of Johne's disease vaccine on deer farms (according to the last available VMD data, less than 1,000 doses were used in 2011) but infection

with *Mycobacterium avium* subspecies *paratuberculosis* (MAP – the causative agent of Johne’s disease), or vaccination against the disease can affect the performance of the SICCT. In TB-free herds, Johne’s infection/vaccination can lead to a decrease in specificity of the SICCT test (although this should be less marked than in the case of the single intradermal mid-cervical test with bovine tuberculin only). Conversely, in a herd infected with TB, there is a potential decrease in sensitivity caused by non-specific sensitisation of vaccinated animals against avian tuberculin which may mask the increase to the bovine tuberculin.

21. The SICCT test has been used in deer for many years and is accepted internationally. Nevertheless, this test is not perfect and it is difficult to perform in deer under field conditions. There has been interest recently in the use of antibody tests for deer. However, there is no harmonised EU legislation at present regulating the use of TB tests in captive deer across Europe or defining the criteria for OTF status accreditation of deer herds, so national governments are relatively free to set the TB test rules based on the available tests. Antibody tests may have the potential to supplement/enhance, but not replace, tuberculin skin testing in deer in certain situations e.g. in identifying additional infected animals during culture confirmed TB breakdowns and pre- and post-movement testing.

The risk question

What is the risk of *M bovis* spreading to bovines, non-bovines and wildlife from the movement of farmed deer from holdings where *M bovis* infection has been diagnosed in previously co-located farmed deer? What are the consequences?

22. The hazard in this situation is the *M. bovis* bacterium. The risk is the spread of *M. bovis* beyond the initial infected premises (release, exposure and consequence, including impacts on animal welfare).

23. The risk of TB transmission from infected deer to other animals falls into the following four risk groups, with the first two currently being most important for overall TB disease control in England:

- i) Risks to cattle;
- ii) Risks to badgers;
- iii) Risks to other members of same species (compartment); and
- iv) Risks to other non-bovine species.

24. The risks are difficult to quantify and are probably best expressed as relative to the comparative baseline which is not risk-free as no routine testing is carried out in deer herds to establish their TB status.

Summary of the risk factors

Pathogenesis of TB in deer

25. Deer are highly susceptible to TB. Infection has been detected in farmed, park and wild deer in GB. Lesions frequently involve the tonsils, retropharyngeal lymph nodes, thoracic lymph nodes and lungs - in some cases only mesenteric lymph nodes are affected. The distribution of lesions associated with *M. bovis* infection

indicates that inhalation and ingestion may be the most common routes of infection (Delahay et al. 2002, EFSA 2008).

26. The time course of infection is generally slow. In experimental infection of the tonsils of white-tailed deer, the first gross lesions were observed in the lungs at day 42 post infection (PI) and consisted of necrosis and mineralization. At day 56 PI the lesions had a thin capsule of peripheral fibrosis. At day 328 PI there was liquefaction of the necrotic centres, giving the gross appearance of an abscess (Palmer et al. 2002).

27. The gross findings can range from no visible lesions, to single or multiple lesions of variable size, to severe generalized disease. The development of lesions has been attributed to immunocompetence associated with social group structure. Changes to social structure have been associated with larger abscesses and social stability has been associated with discrete lesions. Other factors that may affect the development of disease include nutritional status, stocking density and size of challenge.

28. The rate of disease progression is variable, with some animals being severely affected within months of infection and others surviving for years with no obvious clinical signs of disease. In fact, most *M. bovis* infected deer do not show any clinical signs because of the absence of severe pathological changes. In advanced disease, emaciation is the most typical sign. Lethargy and retarded antler growth may occur. Enlargement of superficial lymph nodes may be observed, accompanied by discharging sinus tracts.

29. Experimental studies show that *M. bovis* can successfully be transmitted from deer to cattle and free ranging and captive deer have been implicated in the spread of tuberculosis in cattle in the USA, Canada, Ireland and New Zealand (EFSA 2008). Transmission of *M. bovis* from infected deer is more likely from those that have clinical disease. Abscesses often contain large numbers of mycobacteria and are considered to be important in the dissemination of infection, especially if they open into an airway or have sinus tracts discharging from the skin. Infections that do not result in clinical disease probably do not represent a significant threat to other animals; however, a large outbreak affecting 10 herds of farmed deer in Sweden, disclosed in 1991, was traced back to deer imported from GB in 1987 (that presumably appeared healthy when exported) (Bolske 1995). The original export consignment of 168 deer had been skin tested with a negative result prior to export and it was suspected that subsequent transport in overcrowded conditions facilitated dissemination of infection within the group. The risk associated with moving animals was also highlighted by cases in GB in the 1980s and more recently in 2013.

30. Based on the English Agricultural Survey 2012 and on data held on cattle populations in 2012 by APHA in the Rapid Analysis and Detection of Animal-related Risks (RADAR) information management system, it has been estimated that 35 holdings in England were likely to have had both cattle and deer at some point in 2012. This may be an underestimate as not all deer or cattle farms would have recorded their County Parish Holding number (CPH) in 2012 but the overall number of holdings with co-located cattle and deer is probably low. As the species are also usually managed separately, the risk of spread of TB through direct contact between cattle and captive deer is low. There may be a risk of deer carcasses being a source

of infection for wildlife through scavenging if infected carcasses are not disposed of correctly.

Movement of deer

31. Deer are transported for the following reasons, from farms to abattoirs for slaughter, from parks and farms to provide breeding stock for new or existing herds or for finishing. There are now approximately 55 slaughterhouses approved to kill deer in Great Britain although only two or three exercise this licence.

32. Routine deer movements are permitted in England under a general licence. All deer moved under this licence must be uniquely identified and the movements must be reported to the Animal Reporting and Movements Service (ARAMS) which is being replaced the Animal Movement Licensing System (AMLS).

33. There are relatively few movements of deer in England compared with other species (see table 2) but more than half are from farm to farm so there is a risk of spread of TB (and other diseases) via this route. This is illustrated by a large herd dispersal in 1987 which resulted in disease being confirmed in four premises and by a breakdown in a herd in 2013 in a low risk TB area that acquired deer from a farm in a high-risk area.

Table 2: England – deer movements

Destination	Deer	
	Number of Batches	Number of Deer
2011 Movements		
Farm to Farm	388	2,287
Farm to Market	2	28
Farm to Abattoir	128	1,707
Market to Farm	1	2
Market to Abattoir	0	0
Other *	13	25
TOTAL 2011	532	4,049
TOTAL 2010	733	5,399
TOTAL 2009	498	3,166

Data source: movements entered onto AMLS in England 2009, 2010 and 2011

*Other - includes, show grounds, export/import, vets, zoos.

34. Because of the suspected low prevalence of TB in farmed deer herds, the movement of deer from known TB-infected holdings to slaughter would not result in a substantially increased risk of *M. bovis* spreading to cattle or other non-bovine holdings. However, individual herds can contain high numbers of infected animals and these herds potentially represent a risk for transmission to other animals.

Geographical location

35. The density of farmed deer populations is illustrated in Appendix 1. There are significant populations of deer in the SW of England, the Welsh borders and the Midlands which coincide with the 'high' risk and 'edge' areas as described in the new bovine TB strategy (Defra 2014) (see Appendix 2).

Management factors

36. The management of farmed deer in GB, which are predominantly kept outdoors, potentially allows access to reservoir hosts, e.g. badgers.

Summary of mitigating factors

Surveillance and control

37. There is no routine statutory TB testing programme for live deer in GB. However, APHA has powers to enforce TB testing of any deer for disease control purposes. Apart from testing of imported animals, all testing is a private matter and arrangements for testing are at the discretion of and cost to herd owners.

38. When live TB testing of deer is required, this is by the tuberculin skin test and is at the owner's expense; however, APHA will supply the tuberculin free of charge. The test may only be carried out with prior authorisation from (and by Official Veterinarians appointed by) APHA. In practice, this could take place for one of the following reasons:

- i) Application for (or renewal of) Deer Health Scheme membership. The Deer Health Scheme is a voluntary scheme that enables deer farmers to get their animals certified as officially free from bTB by having them voluntarily TB tested at annual or two-yearly intervals, depending on the location of the herd. Membership has gradually declined over the years and there are currently very few active members.
- ii) "Diagnostic" purposes, e.g. when suspect TB lesions have been found on postmortem examination of captive deer, in order to check test the herd of origin, or when TB is confirmed in cattle herds adjoining (or co-located with) deer herds;
- iii) To allow removal of movement restrictions on deer farms following disclosure of TB test reactors, clinical cases or confirmed slaughterhouse cases;
- iv) For health certification of deer for export;
- v) Check testing of imported animals; or
- vi) Private testing, e.g. prior to movements or sale with the permission of APHA.

39. Under the Tuberculosis Orders for England and Scotland, there is a statutory requirement to notify the suspected presence of TB in the carcase of any bovine or farmed or companion (pet) mammal or when *M bovis* is isolated. Additionally, the Tuberculosis (Deer) Order 1989, as amended, requires the notification of suspect clinical cases in Scotland and England. It also provides the statutory powers to require testing of deer to be undertaken at the owner's expense in order to ascertain freedom from disease. If TB is confirmed, or if there is a strong suspicion of TB infection, i.e. suspect clinical cases reported or suspect lesions found at postmortem examination, movement restrictions will be imposed with the aim of preventing the spread of disease and will remain in place until appropriate testing or other means of surveillance have satisfied APHA there is freedom from TB. Tracings of movements on and off the premises are also carried out.

40. TB control in captive deer relies on a test and slaughter policy based on the SICCT test and the application of movement restrictions. Where TB testing is used to allow removal of movement restrictions following disclosure and confirmation of TB in the herd/group, two clear consecutive tests will be required at 120 day intervals. If infected deer are identified on a farm, APHA may apply skin testing to any cattle, camelids or goats present on the breakdown premises and neighbouring premises pending a veterinary assessment. Movement restrictions are only lifted when all reactors have been slaughtered and the herd has passed two consecutive skin tests.

41. Animals can be licenced to move direct to slaughter to alleviate overstocking issues and maintain viable businesses for the commercial sector whilst not increasing the disease spread risk.

42. In the low risk area, any incidents of TB in non-bovine species caused by *M. bovis* infection result in enhanced TB surveillance (targeted testing) of cattle herds situated within a 3km radius of the index premises.

43. When *M. bovis* has been detected on a holding, movement restrictions are used to prevent the spread of disease to other premises through the movement of potentially infected animals. The restrictions remain in place until the risk of further spread by animal movements can be assessed to be negligible.

Identification of deer

44. Deer must be marked or identified in the appropriate manner, before owners are permitted to:

- move live deer on to or off any premises;
- move any carcasses; or
- test them for TB.

Summary of the veterinary and other consequences

45. *M. bovis* in deer and its spread through the movement of infected deer could have an impact on –

- i) Animal welfare (within sector, and /or to other species including cattle and wildlife)

Disease with clinical signs is very rare in deer. Conversely, adverse welfare consequences may arise from movement restrictions through over-stocking, particularly if movements off cannot be licensed in a timely manner due to disease risk.

ii) International trade and reputation

Considering the high incidence of TB in cattle in GB and the potential for spill over to deer, coupled with the low sensitivity of surveillance, there is a risk of exporting infected animals (see table 3). In 2014, two consignments of deer semen were sent to New Zealand. No semen was despatched from GB in 2012 or 2013.

Table 3 Number of live deer moved from GB (Source APHA)

Year	Austria	France	Northern Ireland	Republic of Ireland	Italy	Russia
2013		4(2)*	16 (4)	9(3)	10(2)	
2014	5(1)		11(2)	7(1)		60(2)

*number of consignments in parenthesis

iii) Economic losses in infected herds

Although incidence of TB in deer herds is low, commercial losses may be significant for some herds where a large number of infected animals/reactors are detected.

iv) Public health

The impact of TB in deer will be very low as they are not milk-producing animals. Only those with direct contact with live animals and at slaughter will be at risk of zoonotic infection. This risk is assumed to be very low but has not been assessed in detail here.

Summary of the likelihood of disease spread

46. The risk of TB spread from one commercial deer herd to another is likely to be very low, given that the incidence of disease is low in deer and there are relatively few movements of deer in England. As there are significant populations of deer in the 'high risk' and 'edge' TB areas and the sensitivity of surveillance is likely to be low, the risk of spread is not negligible and spread has occurred in England in 1985, 1987 and again more recently in 2013. There is also the potential for spread to wildlife, cattle and other non-bovine species on the unit of destination.

Summary of the uncertainties and assumptions

47. The main uncertainty is the true prevalence of *M. bovis* in the GB deer population as there is no ante-mortem surveillance for TB in deer and the slaughterhouse and scanning surveillance are likely to have a low sensitivity.

Conclusions (and summary of veterinary advice)

48. Movement of farmed deer from known TB-infected holdings **to slaughter** would not result in a substantially increased risk of *M. bovis* spread to wildlife, cattle or other non-bovine holdings.
49. The current system of licensing animals to move to slaughter enables commercial deer farmers to maintain viable businesses, as well as control disease risks.
50. The risk of TB spread from farmed deer to cattle is likely to have a very limited impact on the current epidemic given the apparent low prevalence of TB in deer and their limited contact with cattle. Although theoretically possible, there is limited evidence of spread to cattle from deer.
51. There is the potential risk that moving finishing stock from infected herds into less bio-secure units in the low-incidence areas of the country could spread the disease into wildlife there. Restricting these movements may be appropriate given the consequences to TB spread into these areas.
52. The lack of live animal testing is an evidence gap.

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Appendices e.g. summary of responses in different scenarios (see camelid VRA)

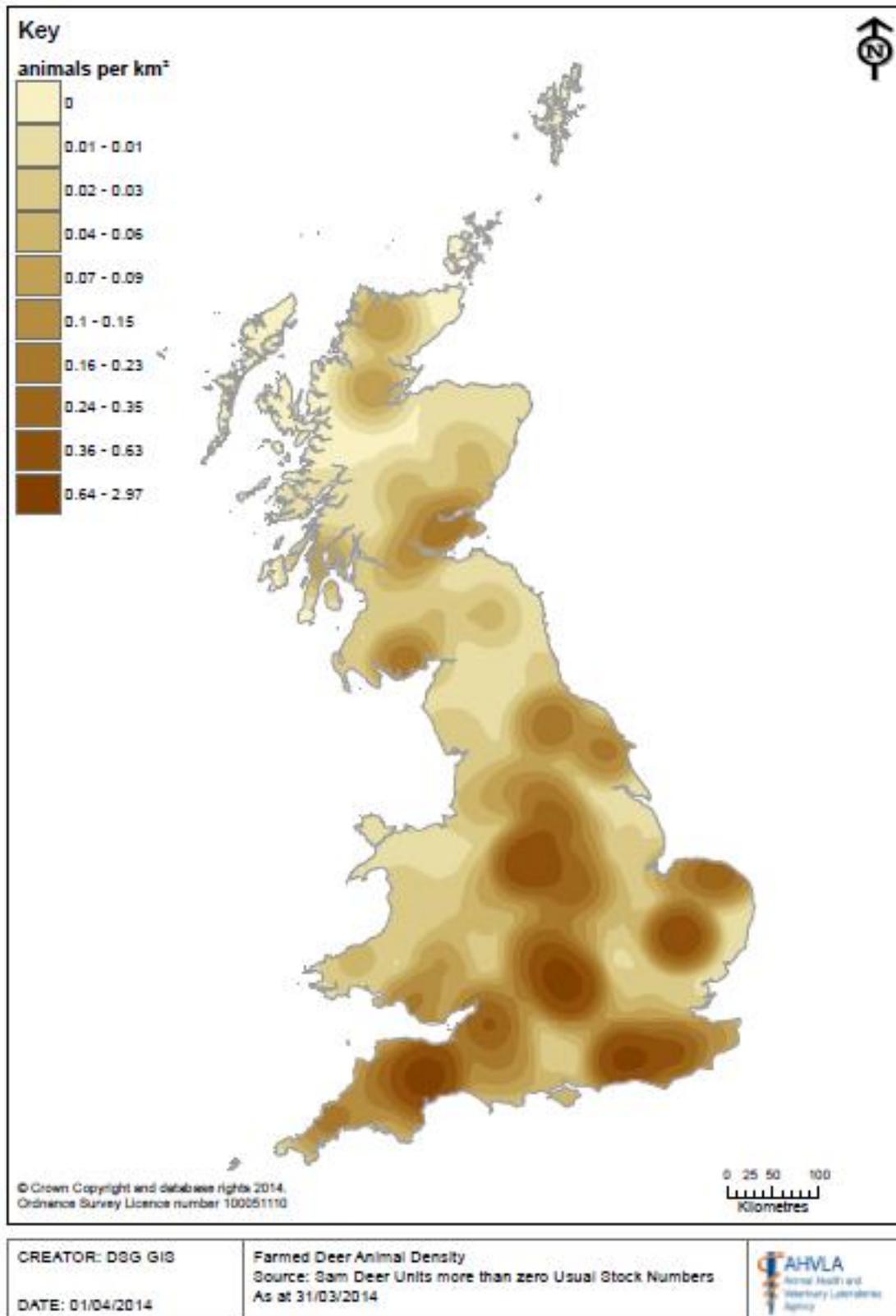
Useful websites:

<http://www.bds.org.uk/>

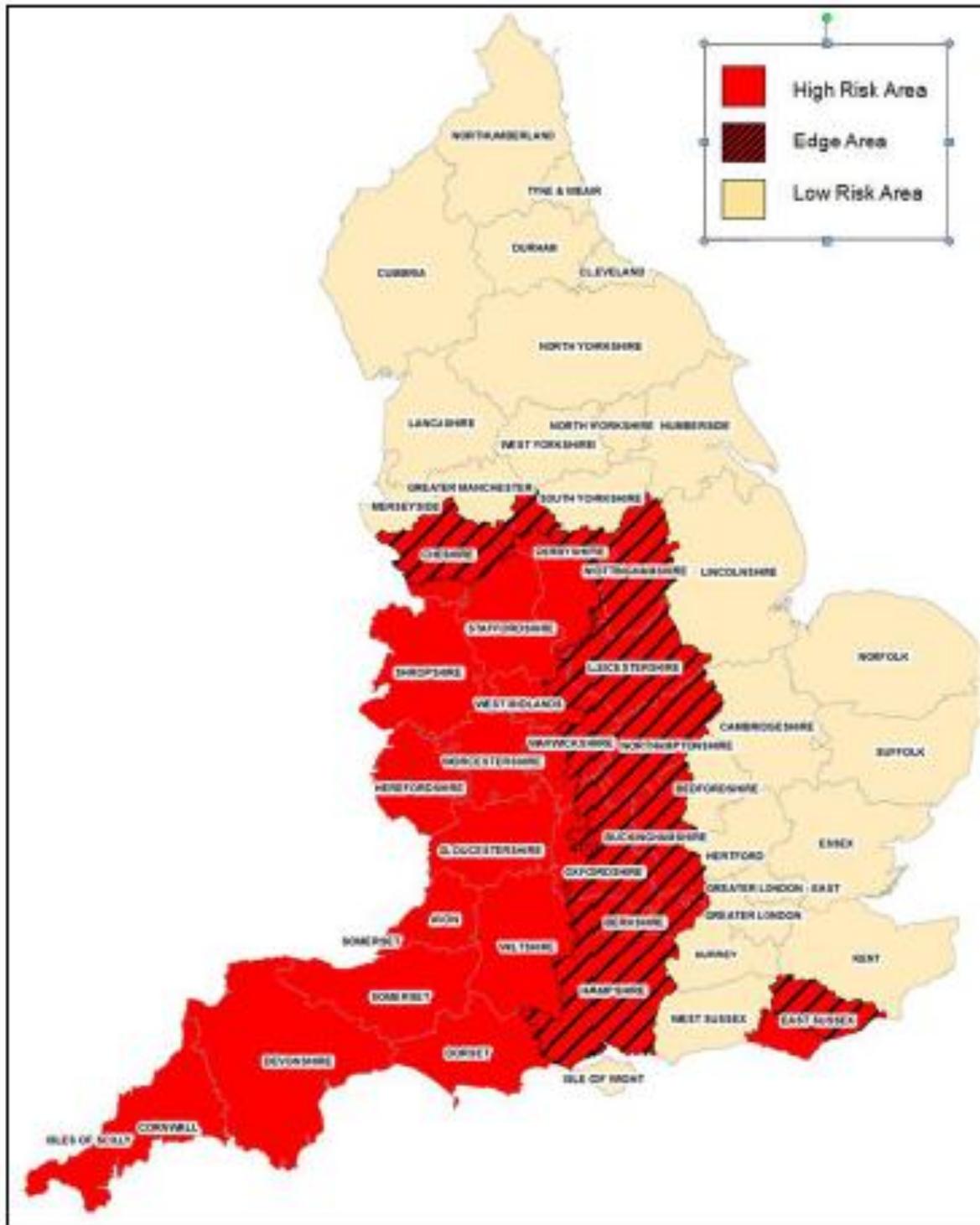
<http://www.bdfpa.org/> - includes links to Defra sites

<http://www.vetdeersociety.com/>

Appendix 1 Farmed deer density in GB



Appendix 2 Geographical location of the three risk areas in 2013



Veterinary assessment of the risk factors associated with the movement of domestic goats from known TB-infected groups.

Executive summary

1. Despite the ongoing increase in prevalence of *Mycobacterium bovis* (*M. bovis*) in the English bovine populations, the apparent prevalence in the UK goat population appears to be consistently low with occasional outbreaks. At present, goats appear to be spill-over hosts, contracting infection sporadically from wildlife, cattle or co-located non-bovine species in areas of the UK where *M. bovis* is known to be endemic in cattle. Goats are able to spread the disease to other members of their population and potentially to susceptible co-located species.
2. In England, there are no statutory compensation arrangements and TB controls remain voluntary. Case identification and surveillance remains reliant on lesion detection and culture through routine meat inspection or postmortem examinations by private veterinary surgeons or at APHA laboratories. Current control measures include movement restrictions, and subsequent skin testing to clear infection from the herd. Removal of any animals in the face of a positive tuberculin reaction must be in agreement with the livestock owner.
3. The structure of the goat industry appears novel, relative to other UK agricultural industries, with the large influence of a 'pet' population. This segregation into commercial and hobby farming appears to act as a contributing risk factor. Although the consequences of an outbreak are much greater in large commercial units, smaller holdings pose a much greater risk to disease transmission through varied management and biosecurity practices. Such transmission includes potential zoonotic implications through close contact and consumption of unpasteurised products. The presence of goats of open farms and petting zoos poses a similar zoonotic risk, highlighting the variation in risk type from commercial and hobby farms.
4. This paper outlines the risk factors that would need to be considered when assessing the risk TB in goats could pose to cattle, wildlife and other non-bovines.
5. In conclusion, although the risk of TB getting into a goat herd appears to be small, the risk of spread within the herd or to other species once infection is in goats appears to be moderate to high.

Introduction and Background

6. Tuberculosis (TB) in cattle is primarily caused by *Mycobacterium bovis*. Sporadic cases are however reported in many non-bovine species, including goats. To date, all reported cases have arisen in areas where TB is known to be endemic in cattle and wildlife.
7. The evidence available demonstrates that goats act as a reservoir for infection in many countries, including; Spain, France, Austria and Germany (Gutiérrez, Tellechea et al. 1998, O'Reilly, Daborn 1995). The epidemiological picture of disease in these countries however, appears to be considerably different to

that of the UK. New Zealand have reported a high prevalence of infection in feral goat populations located in areas where TB was endemic with a high prevalence in cattle and farmed deer, potentially implicating goats in transmission with these species (Sanson 1988, Broughan, Downs et al. 2013, Part 1,).

8. At present, Animal Health and the Veterinary Laboratories Agency (APHA) field staff usually place movement restrictions on a holding when lesions suspicious of TB are detected in goats through postmortem inspection at slaughter or when goats are co-located on a cattle breakdown herd. Such restrictions remain in place until all the suspect animals, and direct contacts, have been removed and the remaining herd have passed sufficient ante-mortem tests to rule out infection. There is no routine ante-mortem testing in goats.

9. When infection is detected in an animal, the primary concern is that it may be present in other animals on that holding, posing a risk to other co-located animals. APHA therefore work with owners to test the remaining animals to remove any infected cases through ante-mortem test using diagnostics such as the Single Intradermal Cervical Comparative Tuberculin (SICCT) test. Unlike many UK industries, this is more problematic with goats due to the lack of compensation available, making all slaughter decisions voluntary.

10. The combination of movement restrictions and ante-mortem test use allows segregation of the goat herd that poses a transmission risk until their potential to transmit disease can be considered negligible. This minimises the risk to disease spread and allows the application of additional actions if required.

The goat industry

11. The structure of the goat industry in England is very different from many other commercial sectors. It is split into pet and commercial units, within which there are multiple different enterprise types (e.g. milk, meat, fibre, breeding). There is a level of integration between all different enterprises, particularly between those that are relatively smaller holdings (Figure 1).

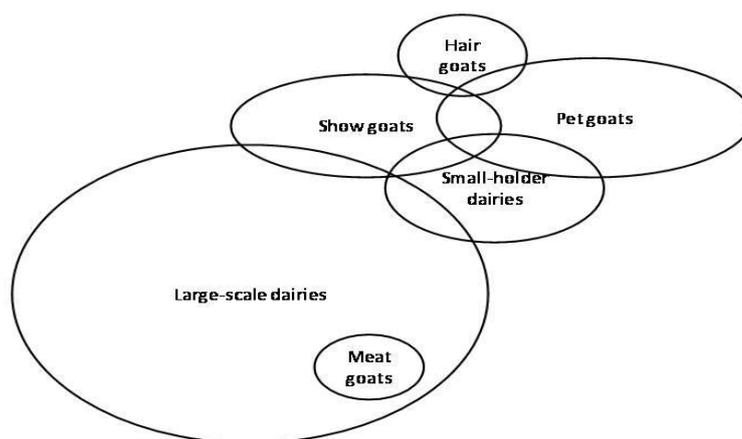


Figure 1. Representation of the relationships between the different sub-groups of the goat industry (APHA survey).

Such relationships may be of importance with regards to disease introduction and spread. The split of the national herd into these sub-populations is unusual, with a small number of large commercial herds representing a large proportion of the national herd, but a very large number of small holdings representing a small proportion of the national herd.

12. The commercial nature of these larger holdings means the consequences of introducing infectious diseases, including TB, are very great and so increased biosecurity measures are taken to prevent the introduction of such pathogens. The biosecurity practices associated with goats kept on smaller holdings are likely to be more inconsistently implemented, and animals are much more likely to be grazed at pasture, increasing the likelihood of contact with wildlife. More commonly on smaller holdings, goats are kept with cattle and other at-risk species, potentially introducing a transmission risk between species groups.

13. This paper will explore the risks of moving goats from holdings where *M. bovis* infection has been diagnosed in previously co-located goats to other holdings.

The Risk Question

What are the veterinary risks and consequences of moving goats from holdings where *M. bovis* infection has been diagnosed in previously co-located goats?

14. The hazard in this situation is the *M. bovis* bacterium. The risks examined will include spread of *M. bovis* beyond the infected premises (if not placed under some form of movement restriction) and risks to animal welfare.

15. The TB transmission risks from non-bovine farmed species to other animals fall into the following four categories, with the first two currently being most important for overall TB disease control in England:

- i) Risk to cattle
- ii) Risk to wildlife (e.g. badgers)
- iii) Risk to other members of the same species (compartment)
- iv) Risk to other non-bovine species

16. The risks to these four categories are relative between different types of movements and relative to holdings where disease has not been confirmed. The comparative baseline is therefore not risk-free. Although we recognise the presence of a zoonotic risk from specific goat products, they are touched on, but are largely outside the scope of this paper.

Summary of the Risk Factors

Pathogenesis

17. Goats are susceptible to *M. bovis* infection. They are also susceptible to infection with *M. avium* and *M. tuberculosis*, increasing the potential public health risk associated with their infection. A goat-specific mycobacterium (*M. bovis* subsp. *caprae*) has been recognised in Spain (Broughan, Downs et al. 2013, Part 1). The main transmission route appears to be through inhalation of bacilli from respiratory

secretions of infected goats when in close contact with susceptible animals, for example through nose-to-nose contact at feed/water troughs. The occurrence of lymphohaematogenous spread appears to be reduced compared to cattle, however spread to the udder does occur through the development of open tuberculous lesions (Bernabé, Gómez et al. 1991). Lesions development in the udder enables bacterial shedding in colostrum or milk, resulting in pseudovertical oral transmission to young kids. Similar to explosive outbreaks seen in cattle, the pooling of colostrum from mastitic does can lead to rapid within herd spread. Bacterial shedding in milk also holds the potential for zoonotic transmission to humans, in the absence of pasteurisation (Bernabé, Gómez et al. 1991, Shanahan, Good et al. 2011). Lesions are typically described in pulmonary tissues resulting in bronchopneumonia, however intestinal ulceration and lymph node (typically; bronchial, retropharyngeal and mediastinal) involvement is also recognised (Bernabé, Gómez et al. 1991, Radostits, Gay et al. 2000, Crawshaw, Daniel et al. 2008). *M. bovis* has been isolated from clinically mastitic does and cultured from bulk tank samples from an infected herd, suggesting a high level of infection in that herd (Shanahan, Good et al. 2011).

18. The most recent outbreaks in goat herds in GB have originated in areas associated with endemic disease in cattle and badgers, and therefore are likely to have been caused from contact with infected bovines and wildlife, implicating goats as spill-over hosts, backed up by the results of *M bovis* genotyping. The available evidence suggests they can spread infection within their cohort and could, in theory, spread disease to other susceptible species. Goats should therefore also be considered amplifier hosts for TB. The largest recent GB outbreaks involved milking goat holdings in Gloucestershire and Staffordshire. Strain typing suggests the initial source of the disease in Staffordshire was acquired locally. Other non-bovine species have been implicated in TB transmission to goats. The most recent case in England involved suspected infection in co-located alpaca and goat herds. Lesions were detected in an alpaca and two reactors were subsequently detected in the goat population. The rest of the goat population subsequently tested clear on an SICCT test. The widespread distribution of infection within the alpaca population resulted in slaughter of the entire population, through risks posed from dangerous contacts. It is unclear if one species transmitted disease to another, but the widespread distribution of infection in the alpaca cohort would suggest them to be the infection source. Goats have also been identified as a maintenance host of infection in several Mediterranean countries including; Spain, France and Italy implicating the effects of different epidemiological situations on infection transmission (Broughan, Downs et al. 2013, Part 1).²⁰

19. Primary surveillance in GB relies on lesion detection at routine postmortem examination (PME) at slaughterhouses, by private veterinary surgeons or at disease investigation centres – there is no routine skin testing. TB is notifiable when suspected in carcasses of all mammals (except humans) and suspect lesions are sent away for confirmatory culture. Slaughterhouse awareness of associated lesions

²⁰ Involvement of goats as a maintenance host also recognised in; Germany, USA, Africa, India and Australia (Broughan, Downs et al. 2013, Part 1).

appears to be good with recent improvements being made to improve PM detection in goats and avoid confusion due to lesion similarities with Caseous Lymphadenitis (CLA) (Bernabé, Gómez et al. 1991). Non-bovine companion and farmed animals comprise less than 1% of all cultured *M. bovis* samples, which probably indicates a lower prevalence in these species in GB. Infection prevalence in the English goat population has always been low, with infrequent sporadic outbreaks. The introduction of compulsory testing of cattle in the 1950's has helped to maintain this low prevalence (O'Reilly, Daborn 1995, Daniel, Evans et al. 2009). However, statutory notification of any suspected caprine TB lesions has only been mandatory since 2006, therefore it is likely the prevalence estimates before this time were underestimated (Daniel, Evans et al. 2009). Despite the low national prevalence, within herd prevalence can rise rapidly following an outbreak (Crawshaw, Daniel et al. 2008).

20. The SICCT test can be performed on goats using modified cattle techniques, typically involving injection of individual tuberculins on opposite sides of the neck. The test has been shown to have good sensitivity (83.7%), specificity (100%) and positive predictive values (Daniel, Evans et al. 2009, Broughan, Downs et al. 2013, Part 2). Execution of the test is however more difficult due to the fine nature of goat skin and so additional application techniques should be adopted to ensure diagnostic accuracy (Shanahan, Good et al. 2011). Goats show a marked response to tuberculin. Standard interpretation is used when there have been no recent cases and no lesions or positive cultures at PME (for example in co-located goats on a cattle breakdown farm). Severe interpretation is then adopted to re-test a herd following lesion detection at PME or a positive culture (APHA 2012). A recent paper suggested that, to maximise sensitivity, any reaction at the bovine site should be interpreted as a positive reactor. The paper failed to comment on the impact on test specificity, but it could be expected to fall due to the effects of co-infection with *M. avium*, increasing the number of false positives. Further work would be required in this area to confirm such interpretative techniques (Shanahan, Good et al. 2011). Test sensitivity was seen to fall when co-infected with Paratuberculosis (*Mycobacterium avium* subsp. *Paratuberculosis*) or CLA (*Corynebacterium pseudotuberculosis*) or vaccinated against Paratuberculosis (Gudair – Pfizer Animal Health) (Shanahan, Good et al. 2011, Bezos, Álvarez et al. 2011, Broughan, Downs et al. 2013, Part 2). The levels of Gudair usage in goats appears to fluctuate annually, with variations from 0.4-18.6% of the national herd being vaccinated²¹. Vaccination against Paratuberculosis has the potential to influence TB detection, however the relatively low uptake of vaccination combined with the low prevalence of disease means the involved risk is likely to be low.

21. The gamma-interferon assay (g-IFN) as used in cattle demonstrates good sensitivity (83.7%) in goats (Broughan, Downs et al. 2013, Part 2). As expected sensitivity can be improved further by using the SICCT and g-IFN in combination. A multiplex immunoassay originally developed for use in cattle was tried in one outbreak in Ireland and appeared to be reliable (Shanahan, Good et al. 2011,

²¹ Data taken from 2006-2010 VMD data on Gudair usage in goat populations in the UK.

Broughan, Downs et al. 2013, Part 2). A different study in Spain looked at the effect of using a non-commercial standard and anamnestic ELISA. Although the standard ELISA had relatively poor sensitivity/specificity, when used after the administration of bovine tuberculin to increase the production of specific antibodies via the anamnestic response, improved sensitivity/specificity values were seen (Gutiérrez, Tellechea et al. 1998).

22. There is no harmonised EU legislation at present regulating the use of TB tests in goats across Europe or defining the criteria for OTF status accreditation of goat herds, so national governments are relatively free to set the TB test rules based on the available tests. Antibody tests may have the potential to supplement/enhance, but not replace, tuberculin skin testing in goats in certain situations e.g. in identifying additional infected animals during culture confirmed TB breakdowns and pre- and post-movement testing. Any antibody tests will have to be validated in goats kept under UK conditions before wider use.

On-farm animal management and husbandry

23. Most commercial dairy and many meat herds tend to operate a zero-grazing policy. Although primarily to combat the inability of goats to produce immunity against parasitic challenge, it minimises contact with wild or co-located cattle or non-bovine species, therefore minimising the potential for disease transmission. The use and reliance on outdoor grazing is increased in other production systems, reducing biosecurity. Movements and the degree of mixing within the goat industry are dependent upon the type of enterprise. Movements for breeding and shows are negligible in larger commercial enterprises where replacements are generally home bred. Smaller holdings undergo a higher degree of movements and herd mixing for breeding/replacements or shows and so the risk of infection transmission is increased (see Appendix 1 for full details of enterprise-specific mixing). The development of stud farms and “travelling bucks” within affiliated goat groups potentially increases the transmission risks associated with breeding.

24. Commercial milking does are generally kept for six, ten month lactations before being removed from the herd at an average of 5-6 years, indicating relatively rapid herd turnover rates (British Goat Society 2008). Productivity and longevity is reduced through perpetual breeding and so pet animals will often live for considerably longer. Around 7,000-8,000 goats are slaughtered for human consumption annually in the UK (due to limited demand and the relatively small national herd). There appears not to be a predisposition for slaughter to take place at specific slaughterhouses, with most mixed slaughterhouses slaughtering goats. These animals originate from specially bred, and fattened, Boer meat animals (usually for gourmet markets), fattened surplus male kids or cull dairy/fibre animals that have reached the end of their productive life (often for local ethnic community sales). Purpose bred meat goats are raised and fattened at one unit before slaughter at 6-18 months, and so pose a minimal transmission risk (goat-meat.co.uk 2011). Although the majority of dairy males are destroyed at birth, there is a developing market to purchase and fatten males at one site until slaughter at around 6-18 months. The risk of disease introduction is potentially high, but the risk of subsequent spread is minimal. Such animals are usually reared indoors due to lack of immune responses to parasitic challenges, and therefore likely spread to other

populations is low. The increased age at which pet animals live to, combined with the reliance on surveillance through slaughterhouse detection of lesions, could potentially result in infected animals remaining in the herd for prolonged periods.

25. Setting up any new herd relies on the purchase of new stock, and the potential to introduce infection. Subsequent replenishment is enterprise dependent. Large scale commercial enterprises generally rely on home-bred replacements, minimising introduction risks. This is potentially of greater importance due to the increased herd turnover rates. Smaller scale enterprises generally purchase stock from within local affiliated groups (see Appendix 1 for full indications of movements on to different units). The buying in of new stock exposes these smaller herds to greater levels of transmission risk. There is potential for breeding between low-producing dairy animals and beef breeds to maximise outputs.

26. Across the commercial dairy sector goats are primarily fed a total mixed ration of maize silage with protein and clover additives. Minimal transmission risks exists from crude foodstuffs, however storage methods potentially expose the feed stuffs to urination/defecation from wild animals (see biosecurity paragraph 38 below). Apparent minimal oral transmission and deep bedding systems minimise the risk of bacilli spread from waste.

27. Co-location, or to a lesser extent contiguous grazing with, cattle, especially in endemic areas, increases the risk of transmission between cattle and goats (Shanahan, Good et al. 2011). Evidence shows that 34% of goat herds in the UK are co-located with cattle, indicating the risk of transmission may be high, especially in endemic areas²². However Defra received notification of few OTFW breakdowns in cattle with co-located goats (estimated to be around 20 per year). This is more likely to implicate small holdings as commercial units generally operate as separate enterprises. The natural implication of goats as 'browsing' animals means they are more likely to wander into woodlands/hedgerows in search of plants/shrubs, potentially increasing the risk of direct or indirect contact with badgers.

28. Feral goat populations have been recognised in the UK and have been recorded in endemic areas including Wales and Exmoor. Although such populations could potentially be involved in bacterial spread, they appear well locally managed and are recognised to have only a small roaming area. Surveillance was carried out on a sample of culled goat carcasses from the North Snowdonia population. None were found to be infected with *M. bovis* (Welsh Assembly Government 2010). When moving from high risk areas APHA may require private testing be carried out. The epidemiological significance of feral populations elsewhere (e.g. New Zealand) is considered minimal, with goats acting more as a spill-over population than active source of infection spread (O'Reilly, Daborn 1995). The overall risk to domestic goats from these populations is therefore likely to be low.

²² Data taken from APHA 2009 data from CPH Programme on co-habitation. Included all co-located goats and cattle, even when other species were found on the holding too. Did not include co-location of goats with Buffalo/Bison as deemed unlikely these were to be agricultural holdings and therefore impact is likely to be minimal.

Structure of the sector/industry.

29. The national herd in England as at June 1st 2013 is comprised of approximately 80,000 individual goats, half of which are breeding adults: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/355868/structure-jun2014final-eng-18sep14.pdf. Approximately half of the total English goat herd is evenly split between South West England and Yorkshire (DEFRA 2004), see Appendix 2. Herds located in the SW of England would be at greatest risk of TB, due to the state of endemicity of the cattle and badger populations in this region. The presence of a large, grazed commercial unit and many smaller goat herds in the Midlands could also be at risk from TB as it continues to spread at these border regions. Small goat holdings are seen throughout the country (see Appendix 2 for density map). The predominant herd size in England is 0-5 goats/holding, indicating the majority of the industry is comprised of pet farmers. Although there are less than 100 holdings with over 100 goats, they contribute 58% of the national herd (Figure 2).

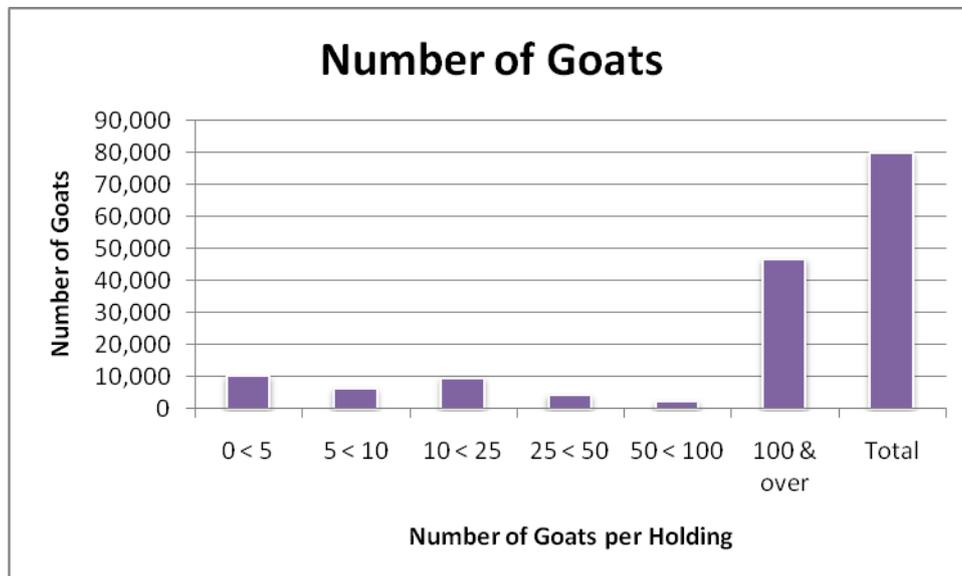


Figure 2. Distribution of the national goat herd dependant on herd size ²³.

30. The goat industry is stratified into 6 integrated sub-groups (Figure 3.) These include:

- Large scale, commercial dairy goats
- Small-scale dairy goats
- Goats for meat
- Goats for fibre (Mohair/Cashmere)
- Goats for breeding/showing
- Goats for pets

²³ Data taken from APHA Draft Protocol for survey of *M. bovis* in Goats in England and Wales.

Although the majority of herds, but minority of individuals, are kept as pets (Figure 3), milk production is the biggest commercial use of goats in the UK (approx. 30% of the total UK goat population) (Harwood 2012). Milk and milk products are predominantly processed on farm before being sold commercially. Although the majority of milk products sold are pasteurised, the production of non-pasteurised products implicates the potential for zoonotic transmission of bacilli (See surveillance and control paragraph 41). There are over 800 milk producing herds, but less than 30 registered holdings selling unpasteurised products (Broughan, Downs et al. 2013, Part 1). There will be an unquantifiable amount of home consumption and farm-gate purchase of unpasteurised milk.

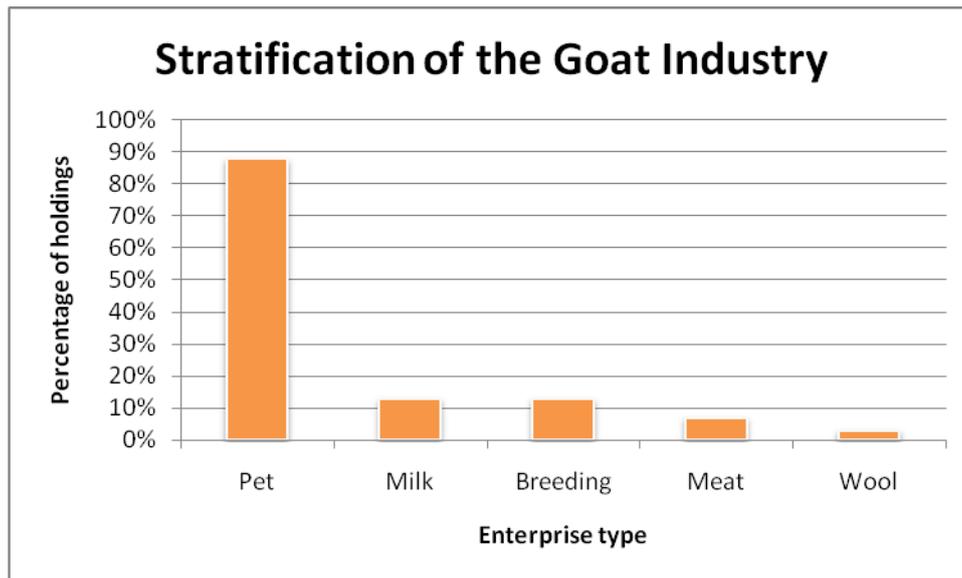


Figure 3. Stratification of the goat industry represented as percentages of the total herds.²⁴

31. Movements between herds are highly enterprise dependant (Figure 4). The increased integration of smaller holdings increases the risk for infection introduction and spread. This has been evident from the recent large outbreak (2008) which occurred due to the dispersion of infected animals to various small holdings. Any situation where goats come together, such as shows or markets, could pose a risk to transmission. This risk is however hard to quantify. Goats potentially travel to several shows annually, each of which is likely to employ different bio-security measures. Although the animals remain at shows for very short periods of time, the likelihood that they would receive the level of exposure required to result in the development of infection is low. However, animals are often housed together in poorly ventilated temporary structures, often with nose-to-nose contact, thereby increasing the risk associated with disease transmission.

²⁴ Data taken from APHA Draft Protocol for survey of *M. bovis* in Goats in England and Wales.

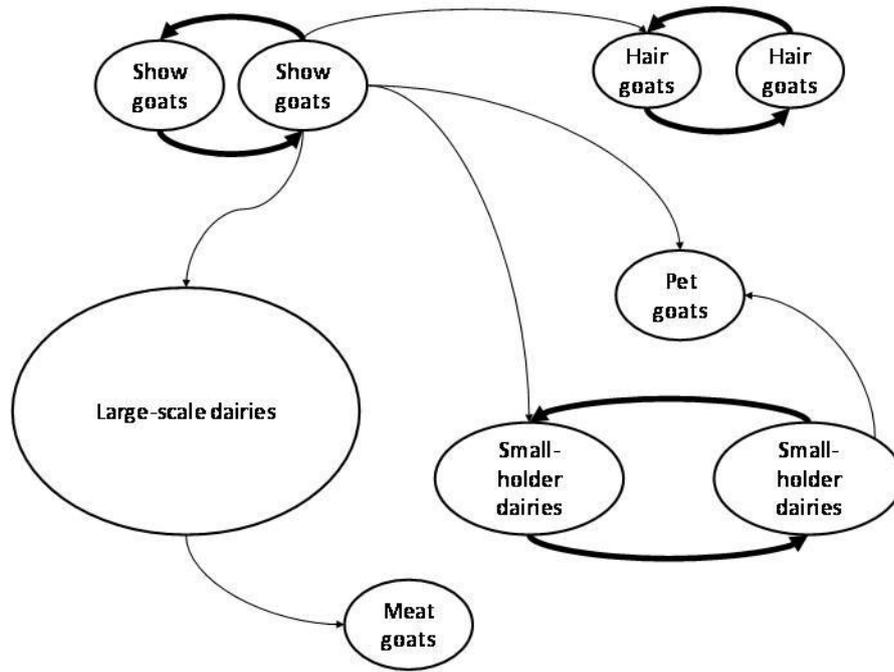


Figure 4. Movement of stock between the goat sub-populations. Where thick arrows represent high levels of movements and thin arrows represent low levels of movement.

32. The degree of biosecurity implemented on different holdings appears to be enterprise dependant and relies on personal experience and views. Lack of consistency increases the transmission risk through stock movements between herds. The risk appears to be greatest on smaller holdings where increased movements and wildlife interactions are observed. .

33. All goats in England require registration and identification under EU legislation. All goats must be registered and tagged within nine months of birth, or sooner if leaving the site of birth. Electronic Identification (EID) tags are available for goats, but as the size of the national herd falls below the EU threshold, EID's are not compulsory in England.

34. All goat reactors and/or direct contacts are removed through slaughter on farm, by a licensed slaughter man, sent to red meat processing plants or be transported to APHA laboratories for PME. In the case of pets, euthanasia by injection may be most appropriate. The slaughter must take place at a time that allows for full PME and sample collection for culture. Ensuring correct proceedings in such a situation is vital for accurate disease surveillance through PME and in ensuring infected animals are removed rapidly, reducing the risk of disease transmission.

Summary of Mitigating Factors

35. Tuberculosis remains a notifiable disease in non-bovine species, including goats. There is a statutory requirement to notify APHA on the detection of any lesions detected in a carcass through PME, suspicious of TB. Such notification enables rapid disease detection, preventing unnecessary spread.

Geographic location

36. The distribution and structure of the national herd employs different challenges to mitigate spread to other agricultural industries. The presence of few large commercial units, holding the majority of the national herd, present a low infection risk, but the consequences of an outbreak at such units is much greater. Smaller holdings potentially pose a much greater risk to infection spread. Their widespread distribution throughout the UK and predisposition to trade live animals between each other implicates them much more in infection spread and makes introduction of preventative measures much harder.

37. Specific records must be completed whenever an animal moves for new ownership; to a different county parish holding (CPH) within 5 miles of the main holding; or to any holding over 5 miles away from the main holding. The use of statutory identification and tracing records enable accurate identification of animal movements. This data can then be used to trace an infection back to its origin in the face of an outbreak, preventing propagation (DEFRA 2009).

Surveillance and control

38. Structure and separation of groups within herds is often limited to non-existent in smaller holdings, whereas large commercial units form production-specific subgroups to ensure appropriate management (Daniel, Evans et al. 2009). This segregation of the herd into distinct epidemiological groups potentially reduces disease transmission within the overall herd. When implicated alongside good biosecurity practices, such measures could massively reduce spread.

39. Improving biosecurity can limit disease transmission onto and off holdings. Such measures are increasingly important in endemically infected areas. Zero grazing policies adopted on commercial units generally restrict wildlife contact; however restricting access of wildlife into goat housing should be a priority. Minimising access of wildlife to food stores through use of staggered electric fencing and designing/placing feed and water troughs appropriately, in housing, to minimise badger contact can also help minimise the transmission risk. Where animals are grazed, restricting wildlife interactions become more problematic, hindered further by the natural browsing and inquisitive nature of goats. Fencing off known latrines and preventing grazing on pasture with known active latrines and setts can help to minimise transmission risks. The purchase and movements of animals between holdings poses a large risk, especially when purchasing from an endemic area. Industry recommends having animals tested prior to movement and then isolating animals before re-testing 60 days later to prevent introduction into the herd. The degree of uptake of private testing is unknown and presumed limited (The Goat Veterinary Society 2008). The production of Defra documents and industry held advice meetings can help to improve awareness of goat owners of the risks associated with disease spread, the importance of TB testing and the application of appropriate controls to minimise the risk of spread.

40. Due to the lack of reactors detected, routine testing of goats ceased around 1978 (The Goat Veterinary Society 2008). Since then, surveillance has relied on

slaughterhouse case detection, which suggests a very low prevalence. Testing at the Government's expense can occur when;

- A goat with PM lesions and/or that is a culture positive reactor is found, with the aim to remove movement restrictions
- There is an epidemiological link to another goat breakdown herd
- The goats are co-located on a cattle breakdown herd
- The goats are co-located on a holding where TB is detected in other species

Voluntary testing in any other situation is carried out at the expense of the farmer by an APHA approved private veterinary surgeon. Although the government has the power to test any animal suspected of infection with TB, due to the lack of financial compensation, slaughter is voluntary. The lack of financial incentive means testing of the UK herd is potentially problematic, possibly resulting in infected animals remaining, undetected, in the national herd.

41. Farms involved in the production of raw milk/milk products have a legal obligation under the Dairy Hygiene regulations to regularly test animals to confirm TB-free status, minimising the zoonotic transmission risk. The testing interval and funding remains at the farmer's discretion, potentially limiting compliance. The Food Standards Agency has been consulting informally on options for a control plan for TB in milking goats. Those consultations are ongoing and Defra's current view is that there is limited evidence of TB in milking goats in England to support the case for a statutory control plan based on skin testing.

42. Under-reporting of cases may arise through reduced awareness of private veterinary surgeons on the symptoms and impacts of TB in goat herds. This may result in infected animals remaining in the herd for prolonged periods before being euthanased without PME for tuberculous lesions. Improving the awareness of private veterinary surgeons on the importance of PME in the case of any suspect symptoms or lesions could also help to improve case detection and mitigate spread.

43. Although the true uptake of regular skin testing in goats is unknown, it is thought to be low. Improving testing frequency could aid early detection and removal of reactor animals, preventing unnecessary disease spread. The goat industry advocates testing a proportion of a herd to reduce costs, but increase surveillance.

Breakdown Management

44. Movement restrictions are served following the identification of tuberculous lesions, or when goats are co-located on a cattle breakdown herd. These restrictions remain in place until APHA are confident that disease is no longer present on the holding. In practice this usually means that all reactor animals are removed and the remaining herd tests clear on two subsequent SICCT tests at severe interpretation. If the initial reactors were NVL and culture negative, the remaining herd only required to pass one clear SICCT test. Any co-located or contiguous cattle holdings and other non-bovines, on a veterinary risk assessed basis, are also subjected to testing. Such restrictions minimise spread on the breakdown holding and help prevent the spread of disease to other premises (APHA 2012).

45. All reactor animals are slaughtered, either on farm or at a processing plant, to remove infection from the herd and mitigate any further spread. Slaughter at a processing plant must be accompanied by the appropriate Food Chain Information declaration form. Meat and milk from reactor animals can enter the food chain, as long as pasteurisation of milk takes place to minimise the zoonotic transmission risk.

46. The breakdown of large herds into sub-populations potentially limits spread, when combined with good farm practices. Re-structuring of within-herd subgroups following testing, in the face of an outbreak, based on infection risk through contact with reactor animals improves biosecurity and limits spread within the herd.

Summary of Likelihood

How likely is it that the disease will spread due to the movement of infected goats?

47. The cornerstone to controlling TB is the accurate detection and removal of infected animals before they pose an infection risk to others (Daniel, Evans et al. 2009). The lack of routine testing in goats and the reliance on slaughter house detection combined with the longevity of some goats suggests infected animals could potentially remain in the national herd for prolonged periods of time, posing an infection risk. It is well recognised that pet goat herds pose the greatest risk to animal and human health due to their management techniques.

48. Although infection may self-sustain itself within a specific cohort, at present goats don't appear to be involved in spread to the wider bovine and non-bovine (including wildlife) population in the UK. Therefore the risk posed by the national goat herd to the national epidemiology of TB appears to be very low. However when an infected animal is detected on a holding, there is strong evidence that goats are able to maintain and spread infection within their specific cohort and thus potentially to other in-contact, susceptible species. The relative risk also appears to differ between holding size, with small holdings posing a much greater risk to disease transmission than larger commercial herds as they are more likely to become infected.

Summary of Veterinary Consequences

Disease consequences

49. The consequence of uncontrolled movement or sale of untested and potentially infected animals is the transmission of *M. bovis* to naive goats, and potentially cattle and other non-bovine, populations.

Animal welfare

50. Clinical disease could be more likely to be detected in goats, relative to other farming sectors, due to the increased longevity of commercial animals and the large proportion of animals kept for long durations as pets. When detected and left untreated, clinical disease can result in high morbidity or chronic respiratory problems, implicating serious welfare concerns. Animal welfare concerns also arise through the application of movement restrictions resulting in overstocking, especially if restrictions coincide with kidding periods.

Public Health

51. Zoonotic transmission through consumption of unpasteurised milk/milk products is of public health concern. Regular TB testing of milking goats is a legal requirement under the Dairy Hygiene regulations. Enforcement of the legislation is a matter for local authorities (The Goat Veterinary Society 2008). The lack of fixed statutory amounts of compensation for TB affected animals removed is thought to minimise the incentive to test and remove potentially infected animals that could pose a risk to disease transmission.

52. Although large commercial units generally sell pasteurised products, excess milk is sometimes sold at the farm gate unpasteurised, and so could present a risk to public health. The greatest risk to public health however, probably originates from small herds where unpasteurised products are consumed by owners/friends and/or sold at the farm gate.

53. Due to the docile and gregarious characters of goats, they are commonly found in petting farms and zoo's throughout the UK²⁵. Although APHA annual checks are made on all holdings, TB testing of goats is not legally required and so a potential zoonotic transmission route may exist. Indeed, the 2012 outbreak of co-located goats and alpacas was situated on an open farm with regular public access.

Economic losses

54. Commercial losses may affect both dairy and meat producing goats when clinically infected through reduced milk yields and body condition. Movement restrictions are likely to have greatest impact on pedigree and rare breed populations who rely on live animal movements to maintain a viable business. Segregation of herds into subgroups helps to minimise disease spread and therefore economic losses.

International trade/reputation risks

55. International trade is likely to involve small numbers of pedigree animals, associated with the hobby sector, rather than commercial trade. The associated risks to international reputation are therefore likely to be low. In 2011, 356 goats were exported from the UK, 75% of which were to EU countries²⁶. This very small proportion of the national agricultural trade means the risk to overall trade from TB in goats is low.

Summary of uncertainties and assumptions

²⁵ Information is available through APHA regional offices if required.

²⁶ Data taken from export records of APHA Agricultural Livestock & Germplasm exports group data.

56. The main uncertainty remains the true prevalence of *M. bovis* in the GB goat population, as primary surveillance relies on slaughter house detection, potentially infected animals may remain in the herd for long periods. The level of uptake of voluntary ante-mortem testing also remains ambiguous, making understanding of the true prevalence difficult.

57. The degree and purpose of movements between herds also remains vague. A better understanding of such information could provide better epidemiological evidence for the apparently increased risk smaller holding place on TB transmission.

58. Feral goat populations have been recognised on Exmoor and in Snowdonia. Although these populations are feral, their roaming area is thought to be small and a certain degree of management is usually undertaken, for example thinning out of the herd. The actual impact of such populations however remains poorly understood. Feral herds are thought to have minimal epidemiological impact in other countries (e.g. Spain, New Zealand), despite having relatively high cohort prevalence.

Conclusions (and summary of Veterinary Advice)

59. Contact with infected co-located, cattle or other non-bovines, or wildlife species appears to be the greatest risk in terms of infection source. This could be managed by maximising biosecurity measures to prevent contact between goats and other populations. Breaking down large groups into smaller populations also appears to be effective in minimising disease spread. Close nose-to-nose contact appears the greatest risk leading to within herd transmission. Ensuring adequate space and appropriate feeding and drinking facilities, and splitting up larger groups, could reduce this close contact. Shedding of bacilli in milk also contributes to increased within-herd prevalence in the face of an outbreak through pseudovertical transmission to young stock. Better milk management, such as not pooling colostrum or feeding kids waste mastitic milk could help minimise this transmission route. Buying in of new stock appears to pose a large risk of disease introduction when stock originates from an undetected breakdown herd. This is primarily of concern to smaller flocks where larger trading networks are apparent. Promoting industry suggestions, such as, pre- and post-movement testing suggestions could help to reduce this risk.

60. The reliance on postmortem surveillance combined with the increased longevity of pet goats appears to potentially hinder the ability to rapidly detect and remove infected individuals. The lack of financial support for farmers with regards to testing and compensation could be an influential factor in ensuring surveillance testing takes place, especially with regards to the production of raw milk/raw milk products and the risk they pose to public health. Promoting industry suggestions such as testing a proportion of a herd to minimise costs could allow for better ongoing surveillance. Following reports of good diagnostic parameters of the SICCT and g-IFN tests, increased promotion of the importance of ante-mortem testing in situations likely to pose a high transmission risk could be effective.

61. The structure of the national goat herd means that large commercial units pose the smallest risk to transmission, due to the management and bio-security practices enforced, but the consequences of a breakdown on such units is much greater. Smaller holdings appear to pose the greatest risk to disease spread, largely due to variations in management/bio-security practices. This suggests that these

holdings may be the most appropriate target for increased control attempts, such as biosecurity awareness.

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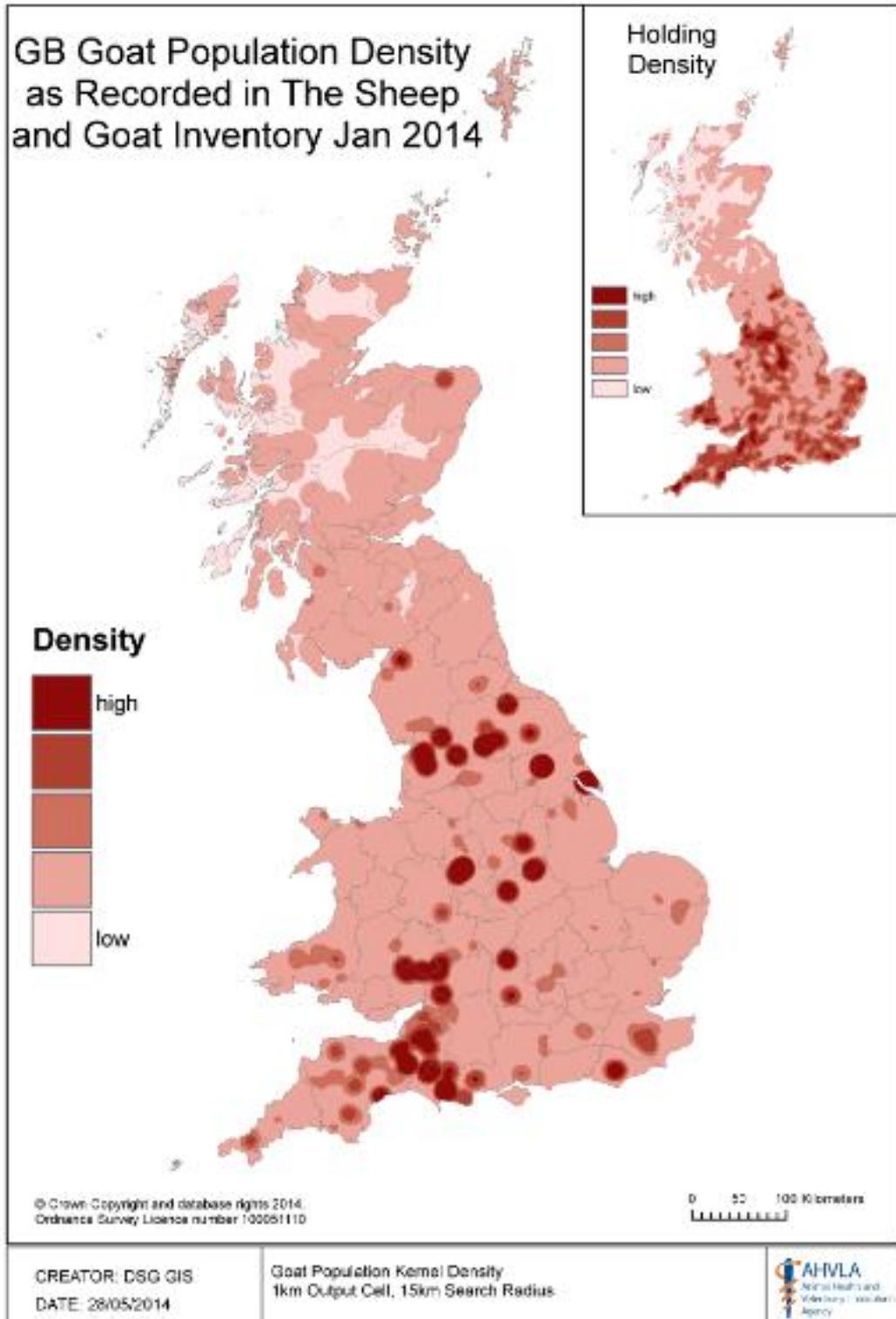
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Appendix 1. Table to demonstrate the degree of movements and mixing between different enterprises within the goat industry, and the consequences for the epidemiology of *M. bovis*.

Population	Movements on	Movements off	Consequences for <i>M. bovis</i> epidemiology
Large-scale commercial dairy	<ul style="list-style-type: none"> Initial purchase of goats to establish the herd. After the initial set-up period, herds are generally self-contained units. Occasional purchase of high quality bucks and some does from showing stock to improve breeding standards. 	<ul style="list-style-type: none"> Male kids are sold for meat. A limited number of surplus female kids may be sold to small-scale dairies. Limited market for milking goats at the end of productive life – those not culled on farm are sent for the processed meat trade e.g. Midlands' kebab trade. 	<ul style="list-style-type: none"> Little scope for introduction or exchange of disease between large-scale dairies, except at the time of establishment. Individual surveillance of each dairy will be important. May be co-located show herds.
Small-scale dairy	<ul style="list-style-type: none"> Generally self-contained. Replacement stock generally comes from other small-scale dairies. Occasional purchase of high quality bucks and some does from showing stock through local goat groups to improve breeding standards. 	<ul style="list-style-type: none"> Sale of young stock to other small-holders. Generally not a large number of sales/purchases – tend to be farm-to-farm. Old stock generally culled on farm and sent for rendering. 	<ul style="list-style-type: none"> Greater potential for disease exchange than with large-scale dairies through activities including: <ul style="list-style-type: none"> Sales Purchases Attendance at shows.
Meat goats	<ul style="list-style-type: none"> Purchase of male kids from large-scale commercial dairies. Fattening only units, no on-farm breeding. 	<ul style="list-style-type: none"> To slaughter 	<ul style="list-style-type: none"> Likelihood of infection will reflect the likelihood in the herd of purchase origin. Little risk of onward spread. Slaughterhouse surveillance is of increased value.

Population	Movements on	Movements off	Consequences for <i>M. bovis</i> epidemiology
Hair goats	<ul style="list-style-type: none"> • Initial purchase of goats to establish the herd. • After the initial set-up period, these herds are generally self-contained units. • Occasional purchase of high quality bucks and some does from showing stock through local goat groups to improve breeding standards. 	<ul style="list-style-type: none"> • Very limited movements off, generally to other hair goat producers, often via shows. 	<ul style="list-style-type: none"> • Likelihood of disease exchange and mechanisms similar to small-scale dairy • Increased risk due to more frequent attendance at shows.
Show goats	<ul style="list-style-type: none"> • Generally breed own replacements. • Sale and purchase self-contained within a narrow range of breeders within the showing community. 	<ul style="list-style-type: none"> • Sales to other showing goat herds, commercial dairies or hair goat enterprises. 	<ul style="list-style-type: none"> • Likelihood of disease exchange and mechanisms similar to small-scale dairy. • Increased risk due to more frequent attendance at shows.
Pet goats	<ul style="list-style-type: none"> • Very limited purchases from small scale dairies and show goats through local goat clubs. 	<ul style="list-style-type: none"> • Very limited movements off – tend to be young stock to other pet goat owners. 	<ul style="list-style-type: none"> • Low likelihood of introducing or encountering infection, unless from wildlife.

Appendix 2. Density of the UK national goat population.



This map is a simplified WIP version from the APHA Livestock Data Demographic Group (LDDG), and is therefore subject to change. It portrays population density information for England, Wales and Scotland and has been created using the Kernel Density tool within ArcGIS. It is suitable for determining relative areas of higher and lower population density at national scales only. Dark shades represent areas of higher population density than light shades. The tool used does not correct for edge effects associated with kernel density estimation and therefore values close to the land boundary are lower than reality.

Veterinary risk assessment of the spread of bovine TB from movement of domestic pigs from groups known to be infected with *Mycobacterium bovis*

Executive summary

1. Pigs are susceptible to infection with *Mycobacterium bovis* (*M. bovis*). In GB they are generally considered to be spill-over hosts, i.e. they are unlikely to sustain the infection within their own population in the absence of infected cattle or a wildlife reservoir. There is evidence in other countries that suidae can in certain circumstances be a reservoir of tuberculosis (TB) (maintenance hosts) and can transmit TB both to other pigs and to cattle. Case identification and surveillance is reliant on lesion detection and culture through routine meat inspection or postmortem examination (PME) by private veterinary surgeons or at Animal Health and Veterinary Laboratories Agency (APHA) laboratories.
2. Currently APHA place movement restrictions on holdings where disease has been confirmed by culture or where there is a reasonable suspicion of *M. bovis* infection in an unrestricted herd following disclosure of characteristic TB lesions at PME, with the aim of preventing disease spread. APHA can licence animal movements direct to slaughter to alleviate overstocking and maintain viable businesses for the commercial sector whilst not increasing the disease spread risk.
3. There are no validated tests for TB in pigs and APHA currently require the single intradermal comparative cervical test (SICCT) which is recognised for international trade. A programme of surveillance at the slaughterhouse may be considered as an adjunct to this test.
4. The incidence of cases of TB in pigs has been rising over recent years. Given that pigs in GB are spill-over hosts, it seems likely that this increase in disease in pigs is only a reflection of the ongoing upward trend of TB in GB cattle. The risk of disease entering the pig population is greatest for pigs raised in outdoor systems, where there may be greater opportunity for contact with *M. bovis* wildlife vectors, or those kept on farms with limited biosecurity (Bailey et al. 2012).
5. The main risk of spreading TB through movement of domestic pigs is from pedigree animals from infected herds that are moved to shows, markets and for breeding purposes. Maintaining movement restrictions on breeding stock with known infection is therefore appropriate. Movement of commercial pigs is usually through pyramids for fattening. As the pigs don't live long enough to become very infectious and are managed in all-in-all-out system, they represent a low risk of spreading TB but there is a potential risk that moving fattening stock from infected herds into units with poor biosecurity in the low-incidence areas of the country could spread the disease into wildlife or cattle there.

Introduction and background

6. Tuberculosis (TB) caused by *M. bovis* is primarily a disease of cattle but can infect any mammalian species. Submissions to APHA laboratories of suspect TB

lesions from pigs have increased over recent years; almost all are located in the west and south west England reflecting the level of infection in cattle and wildlife. Since 2004, they have become the third most frequent non-bovine domestic species from which *M. bovis* has been isolated in GB (Broughan et al. 2013). Although submissions have been increasing, there hasn't been a proportionate rise in culture confirmed cases – only 10% of samples were positive at the peak. The reason for the increased submission rate is unclear but may be due to increased awareness in the abattoirs of TB in pigs following training by the Food Standards Agency (FSA). The majority of cases originate from one abattoir in the south west of England.

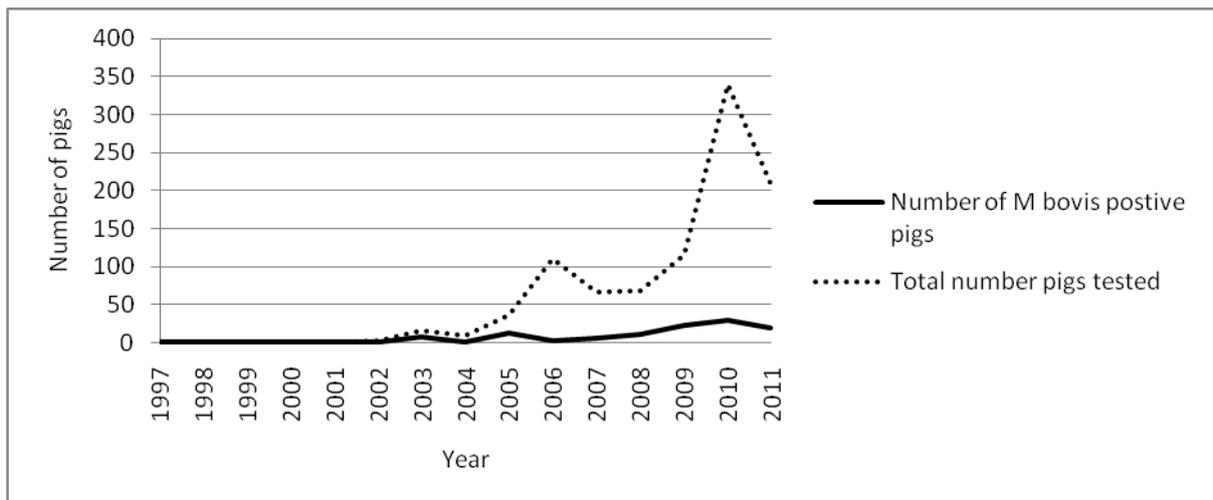


Figure 1: The number of confirmed cases of TB in pigs, compared to the number of individual animals submissions. A case is an individual animal confirmed positive by *M. bovis* culture; it is not at the holding level.

7. There is some evidence that suidae can be a reservoir of disease (maintenance host) and act as a source of TB infection to cattle, for instance the European wild boar (*Sus scrofa*) in Mediterranean Spain (Naranjo et al. 2008). There are reports from Spain and Portugal that the same *M bovis* spoligotypes were circulating in pigs, wild boar and cattle suggesting a multi-directional interspecies transmission of *M bovis* (Pesciaroli et al. 2014). In New Zealand, *Sus scrofa* are used as sentinel animals to detect infection in the local wildlife population (Nugent et al. 2011a). Unlike Spain, *Sus scrofa* in New Zealand are not thought to play a significant role in the epidemiology of disease, as the rate of transmission between pigs appears very low (Nugent et al. 2011b).

8. At present, APHA field staff normally place movement restrictions on pig herds where TB has been confirmed at postmortem examination (PME), through culture or following disclosure of characteristic TB lesions. In cases where the infected epidemiological group has been removed, APHA may, on the basis of a veterinary risk assessment, decide not to place movement restrictions on the holding. If APHA are concerned that infection may be present in other groups on the holding, they will work with the owner to determine the TB status of the remaining animals. There are no validated tests for TB in pigs and APHA currently require that this be achieved by use of the single intradermal comparative cervical test (SICCT).

A programme of surveillance at the slaughterhouse may be considered as an adjunct.

9. Validation of TB tests for pigs is not currently a Government priority but it is possible for private groups to lead and fund this work as demonstrated recently by the camelid industry. Whilst it is unlikely that such tests would be used for general surveillance of non-restricted herds given the low level of disease in these animals, validated tests would assist in determining the TB status of herds that have fallen under movement restrictions, provide a more consistent approach for removing restrictions and might also be used in voluntary schemes for pre and post-movement testing.

10. This paper will explore the risks of moving pigs, previously co-located with confirmed infected pigs, to other holdings.

The risk question

What is the risk of *M. bovis* spreading to bovines, non-bovines and wildlife from the movement of pigs from holdings where *M. bovis* infection has been diagnosed in previously co-located pigs? What are the consequences?

11. The hazard in this situation is the *M. bovis* bacterium. The risk is the spread of *M. bovis* beyond the initial infected premises (release, exposure and consequence, including impacts on animal welfare). A schematic of the risk pathway is shown in figure 2.

12. The risk of TB transmission from infected pigs to other animals fall into the following four risk groups, with the first two currently being most important for overall TB disease control in England -

- i) Risks to cattle
- ii) Risks to badgers
- iii) Risks to other pigs; and
- iv) Risks to other non-bovine species.

13. The risks are difficult to quantify and are probably best expressed as relative to the comparative baseline which is not risk-free as no routine testing is carried out in pig herds to establish their TB status.

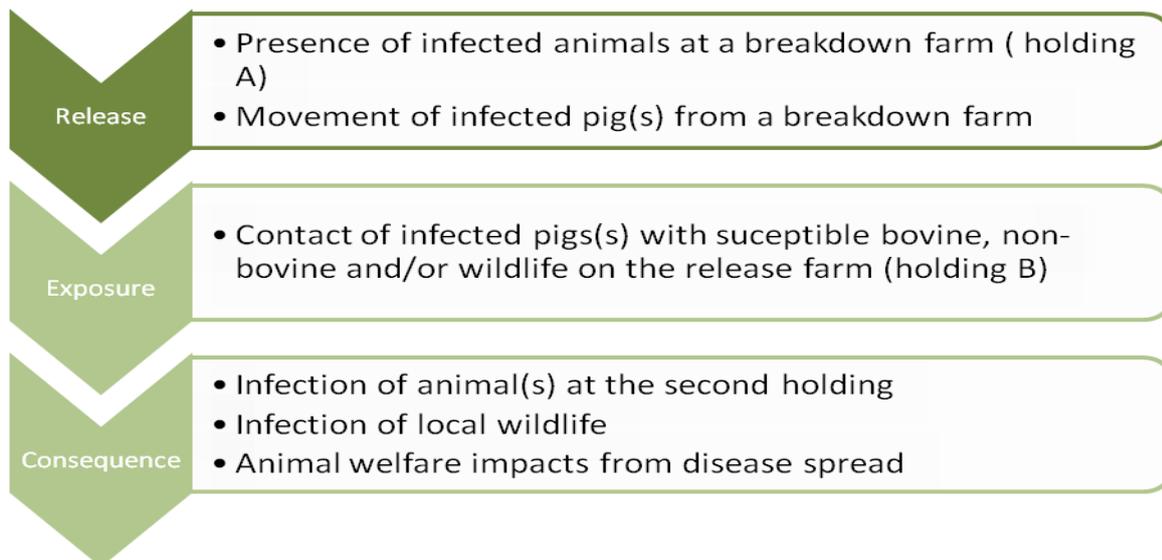


Figure 2: Risk pathway.

Summary of the risk factors

Structure of the sector / industry

14. The national pig herd in England as at 1st June 2014 is approximately 3.95 million²⁷. The pig population density is highest in the East of England (see Appendix 1 for a density map); however there are pockets of moderately dense pig populations in Devon, Dorset and Somerset which are in the high risk TB area as described in the new bovine TB strategy (Defra 2014). There is a localised high density spot of pigs in Oxfordshire which lies in the edge area and is therefore at risk of disease incursion (see Appendix 2). The bulk of the industry operates in a pyramidal structure (figure 3). One breeding nucleus herd can supply breeding stock and/or sperm to multiple premises. Due to the value of the stock at the top of the pyramids, units are highly bio-secure and animals on them are regularly tested for infectious diseases, although not for *M. bovis*. Animals (and personnel) tend to move one way through the pyramid. At the lower levels of the pyramid, animals may be managed outside. In recent years, there has been a move to farrow and rear commercial pigs outside, then bringing them back inside to fatten. Approximately 40% of commercial breeding sows are kept outdoors and a large proportion of their progeny move indoors at weaning to finish²⁸. Animals in the slaughter generation may move between a number of fattening units before slaughter. There is therefore the potential for contact with wildlife in these outdoor units but a similar risk also exists for indoor

²⁷ Figure for 2014 taken from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/355868/structure-jun2014final-eng-18sep14.pdf

²⁸ Defra Pigs and Poultry Farm Practices Survey 2009

herds if the biosecurity of their buildings is poor. The proportion of holdings with both pigs and cattle was approximately 50% in 2009²⁹.

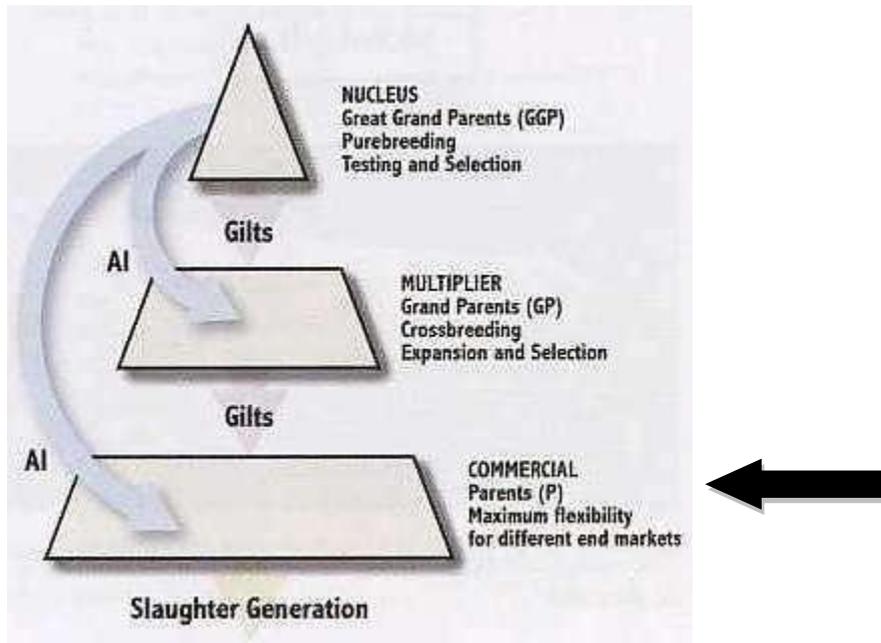


Figure 3: Figure showing the pyramidal structure of the commercial pig industry. Taken from <http://www.britishpigs.org.uk/modern2.htm>. The black arrow indicates where animals may be managed outside. The figure is not to scale: the size of the slaughter generation is much larger than the size of nucleus high health herds.

15. In addition to the large commercial herds, there are smaller scale hobby farmers, small holding owners, and owners and breeders of rare breeds. Such holdings make up the minority of pig numbers, but are likely to be relatively more at risk of exposure to TB than the commercial units, as their animals are more likely to be kept outside and have contact with wildlife. According to Bailey et al. (2012), the majority of porcine TB breakdowns in GB between 2007 and 2011 fell within the equivalent genotype home-range of cattle but as direct contact between cattle and pigs was rarely reported it suggests that the pigs were mainly infected by wildlife.

16. There is likely to be a spectrum of the bio-security of pig holdings in GB, but in general the pigs at the top of the commercial pyramids will have the highest bio-security standards. Those at the bottom, particularly when kept outdoors and therefore exposed to other species, tend to be the least biosecure.

17. Pigs over 12 months old need to be permanently identified back to the holding of origin, or individually (depending on the type of movement)³⁰.

²⁹ APHA data based on farm type recorded.

³⁰ Ref <http://www.defra.gov.uk/publications/files/pb13647-pig-keepers-guide.pdf>

On-farm animal management and husbandry

18. There is a high level of herd turnover in breeding sows (40 - 50% per year) in commercial units and all fatteners pass through meat inspection. Commercial herds often operate (although not always) an all-in, all-out batch management system potentially enabling cleansing and disinfection to occur between groups. Movements for breeding, markets and shows are negligible for commercial herds, e.g. artificial insemination (AI) is now widely used for breeding, but movements between holdings for fattening occur.

19. Genotyping of the *M. bovis* isolate and thorough veterinary disease investigation help identify the farm on which an animal became infected. APHA are likely to back-trace infected animals to the likely place of infection.

20. Biosecurity awareness and practices could be more advanced in the commercial pig industry than some other farming sectors, such as the cattle and sheep sectors. This is because many units are housed and can therefore be made bio-secure. Such levels of biosecurity are harder to achieve with outdoor animals.

21. Following the Foot and Mouth Disease outbreak in 2001 the feeding of materials of animal origin to pigs was banned under animal by-products legislation. There is an exemption on feeding unprocessed milk and colostrum to pigs if it originates from animals on the same holding as the pig; therefore, where milking animals (cattle, goats, and sheep) are co-located with pigs, these pigs could be fed potentially infected milk.

22. With smaller scale farming such as of rare breed pedigree stock, there will be greater movement of animals to shows, markets and for breeding. All movements of pigs are required to be licensed and recorded³¹. Movements to shows are important for pedigree keepers, and there are two to three main shows for such pigs per year. AI is not used in pedigree animals and, therefore, the survival of these breeds relies on movements of animals, both sows and boars, between premises. It is likely that the biosecurity of such holdings will not be as high as in the larger, high health herds and in pyramid breeding systems where shows do not feature, as, in addition to animal movements between herds, these animals are likely to be kept outdoors. For these reasons, there may be scope for the development and use of validated tests for pre and post-movement testing (see paragraph 10).

Pathogenesis

23. Pigs are susceptible to *M. bovis* infection (hence their use as sentinels in New Zealand). The main route of infection is through ingestion of infected food stuffs, either scavenging infected carcasses or eating infected milk products. As a result, lesions are often found in the retropharyngeal and mandibular lymph nodes (Nugent et al. 2002). While in some cases lesions are limited to these nodes recent work suggests lesions are often found in other tissues at slaughter (see Table 1).

³¹ Further information at <http://www.defra.gov.uk/food-farm/animals/movements/pigs/>

Pigs with head lesions only	Head lesions with lesions in the thorax	Head lesions with lesions in the abdomen	Head lesions with lesions in the thorax <i>and</i> abdomen	Thorax lesions only	Lesions in thorax <i>and</i> abdomen	'Generalised' lesions
32	7	1	4	1	4	6

Table 1; Location of *M. bovis* lesions in pigs 2007-2011 (Bailey et al. 2012). The location of *M. bovis* lesions was described in 55 pigs, from 2007 to 2011. 'Head lesions only' include pigs with lesions only in the mandibular, parotid and retropharyngeal lymph nodes (LN). Thoracic lesions include those in the mediastinal LN, bronchial LN, pleura, pericardium and lungs. Abdominal lesions include those in the mesenteric LN, spleen, liver and supramammary LN.

24. Tuberculosis is not particularly contagious amongst pigs and in most cases is self-limiting (Pesciaroli et al. 2014). There was a recent case in Wales of a breeding boar with orchitis caused by *M. bovis* where there was spread of infection to gilts he had served (unpublished case report). This, combined with the evidence from Spain and Portugal, suggests that pigs are likely to be spill-over hosts with the potential to be amplifier hosts in GB.

25. There is no legal requirement to test pigs on breakdown OTFW holdings. The single intradermal comparative cervical test (SICCT) can be performed in pigs at the base of the pinnae. The sensitivity and specificity of the skin test have been reported to be both 100% in pigs but these estimates are based on a small number of animals tested and the skin test has not been validated in pigs. Furthermore, evidence on its positive predictive value is limited in GB. Despite this, the skin test is used as a research tool for investigating TB in suidae (it has been used in New Zealand and Spain for example).

26. Postmortem awareness of TB in pigs appears to be variable across slaughterhouses, with high submission rates from individual slaughterhouses. The majority of pigs in GB are slaughtered in a small number of plants. Meat inspector awareness seems to be increasing, following a training drive by the FSA of its inspectorate in 2009-2010. However, slaughterhouse surveillance is likely to have a low sensitivity, estimated to be 25-30% (de la Rua, personal communication), and is likely to be lower than that of the SICCT.

27. Infection prevalence in pigs in GB appears to be very low, based on slaughterhouse surveillance. Most but not all confirmed cases involve the detection of only one or two infected animals in the herd of origin.

28. From June 2014, directly applicable EU legislation (Regulation (EU) 219/2014) introduces changes to the meat inspection regime with increased reliance

on visual inspection of pig carcasses and offal by government officials with incision and palpation used only in cases where the Official Veterinarian is of the opinion that there is a possible risk to public health, animal health or animal welfare. This 'visual-only' regime for pigs may result in a reduction in the already low apparent incidence of TB in pigs.

Summary of mitigating factors

Geographic location

29. The major high density pig populations in the UK (Humberside, East Anglia and the north east of Scotland) are not within the TB high risk or edge areas and this will provide some protection to the pig sector from disease incursion, but does not affect the risk of TB spread once in the pig population.

Management

30. Current bio-security practices in indoor commercial units and pyramid structures will prevent infection from entering the chain or being moved from one holding to another within the pyramid especially if attention is paid to wildlife proofing. However, this mitigation measure is less effective where part of the chain (e.g. breeding and rearing) takes place outdoors as there is a greater risk of exposure to infected wildlife and/or cattle.

31. When *M. bovis* has been detected on a holding, movement restrictions are used to prevent the spread of disease to other premises through the movement of potentially infected animals. The restrictions remain in place until the risk of further spread by animal movements can be assessed to be negligible.

Surveillance and control

32. The high turnover of stock in commercial pig production enables slaughterhouse surveillance for disease monitoring and control. The all-in, all-out process helps in removing infected animals and provides the opportunity for effective cleansing and disinfection between groups. When newly purchased or reared replacement animals are kept separate from the older stock from a known infected epidemiological group, disease impact on farm can also be limited.

33. Slaughter of pigs occurs in a few specialist abattoirs, which can be targeted for TB awareness training (see above comments on low, perceived sensitivity of this surveillance). One abattoir has recently increased sample submission, and *M. bovis* positive cases have increased slightly as a result, although not in scale with the submission rate, indicating that the positive predictive value of visible lesions has decreased.

34. Where slaughterhouse surveillance is not appropriate, testing of individual, live pigs for TB is used occasionally to survey herds that have had a culture-confirmed case of *M. bovis* identified, despite the limited test characteristic data available.

35. The industry, led by BPEX, has been increasing pig keeper awareness of TB, and educating farmers how to reduce their risks e.g. by taking appropriate on-farm biosecurity measures (BPEX knowledge transfer bulletins).

Summary of the veterinary consequences

36. *M. bovis* in pigs and its spread through the movement of infected pigs could have an impact on:

i) Animal welfare

Disease with clinical symptoms is very rare in pigs, probably due to the short lifespan of commercial pigs. There may be a greater risk of clinical disease in pedigree and breeding animals, which have longer life spans. Conversely, adverse welfare consequences may arise from movement restrictions through over-stocking, particularly if movements off cannot be licensed in a timely manner due to disease risk.

ii) International trade and reputation

GB moves live pigs to other EU Member States and exports to third countries. Considering the high incidence of TB in cattle in GB and the potential for spill-over to pigs, coupled with the low sensitivity of slaughterhouse surveillance, there is a risk of exporting infected animals.

iii) Economic losses in infected herds

Commercial losses may not be important for finishing herds that can operate under movement restrictions as animal movements can be licensed to slaughter, however carcass condemnation might be important if infection persists in the herd. Economic losses from movement restrictions will be greatest at the top of the pyramids and in smaller holdings such as rare breed pedigree herds that require movement of live animals to maintain business viability.

37. Impacts on public health from TB in pigs will be very low as pigs are not milk-producing animals. Only people who have direct contact with live animals and who work at slaughterhouses will be at risk of zoonotic infection. This risk is assumed to be very low but has not been assessed in detail here.

Summary of the likelihood of disease spread

38. The risk that TB spreads from one commercial pig pyramid to another is likely to be negligible to very low, given that movements tend to occur within one chain to slaughter. However, fattening pigs moving from outdoor rearing units to fattening units within a pyramid can transfer infection from one location and one herd to another. However, given that the majority of commercial pig movements will be ultimately to slaughter and that turnover in commercial herds is high, the consequences of spreading *M. bovis* infection in this way are likely to be limited.

39. If an unrestricted and undetected *M. bovis* infected pig moves from an area of high TB incidence in cattle to an area of low incidence, into an indoor unit, it will contact other pigs, but exposure to wildlife, cattle and other non-bovine species on the unit of destination is likely to be very low or negligible.

40. There is the potential risk that moving fattening stock from infected herds into units with poor bio-security in the low-incidence areas of the country could spread the disease into wildlife there.

41. In smaller, extensively managed pig holdings, the risk of TB spread through movement is higher as pigs on these herds often live longer, tend to move more often between herds with more opportunity to come into contact with other animals and are more likely to be bred and reared outdoors.

Summary of the uncertainties and assumptions

42. The main uncertainty is the true prevalence of *M. bovis* in the GB pig population as there is no ante mortem surveillance for TB in pigs and the slaughterhouse surveillance is likely to have a low sensitivity (and may be reduced further by recent changes to the meat inspection regime).

Conclusions (and summary of veterinary advice)

43. Given the integrated and controlled structure of the commercial pig industry, the veterinary advice is that movement of commercial pigs from known TB-infected holdings through known high biosecurity indoor pyramidal structures to slaughter would not result in a substantially increased risk of *M. bovis* spread to wildlife, cattle or other non-bovine holdings.

44. The current system of licensing animals to move to slaughter enables commercial pig farmers to maintain viable businesses, as well as control disease risks.

45. The risk of TB spread from pigs to cattle is likely to have a very limited impact on the current epidemic given the apparent low prevalence of TB in pigs and their limited contact to cattle. There is no evidence of spread to cattle from pigs.

46. There is a risk that moving fattening stock from infected herds into units with poor bio-security in the low-incidence areas of the country could spread the disease into wildlife there. Restricting these movements is therefore appropriate given the consequences to TB spread into these areas.

47. The main disease spread risk appears to occur with the movement of pedigree animals from infected herds for breeding purposes, and there is some evidence for such transmission. Maintaining movement restrictions on breeding stock with known infection is therefore appropriate.

48. The lack of a validated test and the limited, available information about test performance characteristics in pigs is an evidence gap.

49. Industry should consider whether to validate TB tests for pigs. Whilst it is unlikely that such tests would be used in the surveillance of non-restricted herds given the low level of disease in these animals, validated tests would assist in assessing the health status of herds that have fallen under movement restrictions due to a TB case detected at slaughter, and could give increased compliance with testing in these herds.

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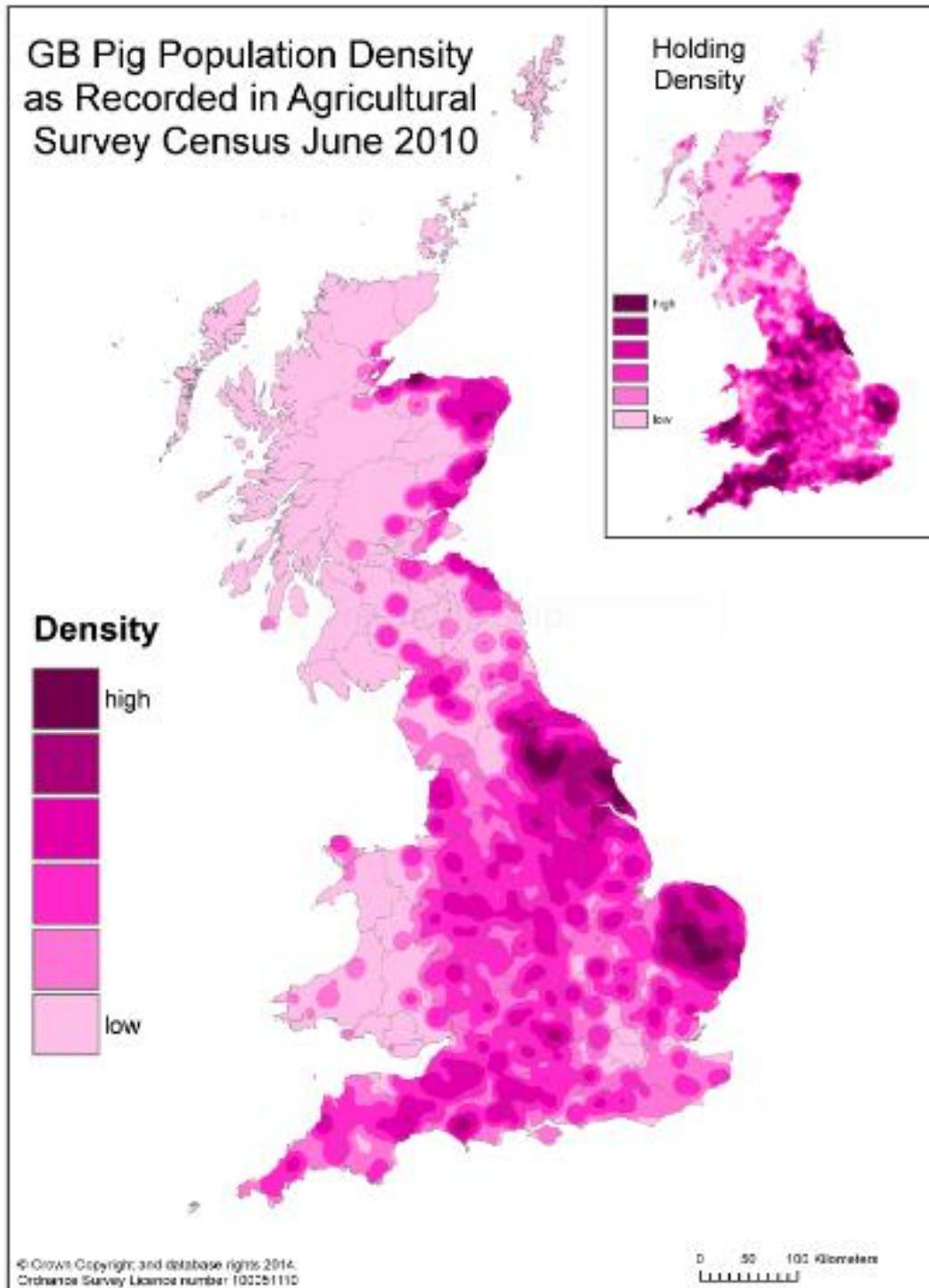
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Appendix 1 Density map of the GB pig population



This map is a simplified WIP version from the APHA Livestock Data Demographic Group (LDDG), and is therefore subject to change. It portrays population density information for England, Wales and Scotland and has been created using the Kernel Density tool within ArcGIS. It is suitable for determining relative areas of higher and lower population density at national scales only. Dark shades represent areas of higher population density than light shades. The tool used does not correct for edge effects associated with kernel density estimation and therefore values close to the land boundary are lower than reality.

Veterinary risk assessment of the spread of TB from the movement of farmed sheep from known TB-infected groups

Executive summary

1. Sheep are susceptible to TB but the incidence in farmed sheep in Great Britain (GB) appears to be low.
2. They are considered to be spill-over hosts but as they develop lesions in the respiratory tract it is possible that infected sheep could potentially act as a source of infection for other animals.
3. There is no statutory TB testing programme for farmed sheep in GB and surveillance is reliant on compulsory notification of lesions found at postmortem, isolation of *Mycobacterium bovis* (*M. bovis*) and on abattoir surveillance. The prevalence of TB in sheep is not known but appears to be very low based on the surveillance systems in place. Therefore, the movement of sheep from known TB-infected holdings would not result in a substantially increased risk of *M. bovis* spreading to cattle or other non-bovine holdings.
4. When a TB positive flock is identified, AHPA usually place movement restrictions on the holding. Restrictions can also be put in place when sheep are co-located on a cattle breakdown herd. Such restrictions remain in place until all the suspect infected animals, and direct contacts, have been removed and the remainder of the flock have passed sufficient ante-mortem tests to rule out infection. The test usually employed is the Single Intradermal Cervical Comparative Tuberculin (SICCT) test.
5. Due to the structure of the industry in the UK (stratification), there are a large number of sheep movements which increases the risk of spreading disease, including TB. Sheep are usually managed extensively with a risk of contact with wildlife and co-located livestock, such as cattle.

Introduction and background

6. Tuberculosis (TB) in cattle is primarily caused by *M. bovis* but sporadic cases are reported in many non-bovine species, including sheep. In GB and elsewhere TB in sheep is uncommon (see table 1). Cases generally originate from farms where sheep have close contact with tuberculous cattle or wildlife (Broughan et al. 2013).
7. The increase in the number of breakdowns in GB after 2009 may have been due to the transfer in responsibility for the collection and submission of TB

lesions in sheep at slaughter from the Animal Health Agency to the Food Standards Agency (FSA) with a resulting increase in awareness in FSA (Van der Burgt et al. 2013). There was no change in the diagnosis of TB breakdowns from submissions to Government diagnostic laboratories during this period (up to two per year).

8. The recorded decline in breakdowns in 2012 and 2013 may be due to under-reporting as a response to concerns raised at a national level about the inability to trace suspects in mixed groups of sheep on the slaughter line if tags and heads are removed after slaughter and before the carcasses are dressed.

Table 1 Frequency of breakdowns due to *M. bovis* in sheep incidents in GB 2000-2012 (APHA 2012 - Bovine tuberculosis: infection status in cattle in GB, Annual Surveillance Report <http://www.defra.gov.uk/APHA-en/files/pub-survreport-tb12.pdf>)

Year	Number of new breakdowns
2000	0
2001	0
2002	1
2003	0
2004	0
2005	2
2006	0
2007	0
2008	1
2009	5
2010	8
2011	17
2012	9*
2013	3**

* Figure revised downwards in July 2014

** New data not included in Annual Surveillance Report (source APHA)

9. There is speculation as to why there are limited reports of TB in sheep. The evidence clearly shows that sheep are naturally susceptible to infection with *M. bovis* (Cordes et al. 1981, Cousins 2001) but even in areas of GB where the prevalence of bovine TB is high, it seems that few sheep become infected, based at least on the frequency of cases detected at slaughter. In New Zealand, there were no isolations of *M. bovis* during a survey of 12 million sheep and lamb carcasses in 1986/87, although the nationwide incidence of infection in cattle was low at the time (0.05%) (Allen 1988).
10. Management and behavioural factors could contribute to the seemingly low incidence of TB in sheep by limiting exposure to infection. They are generally managed extensively, tend to graze during daylight and have cautious

behaviour, thus reducing potential contact with tuberculous cattle and wildlife (Marianelli et al. 2010). The influence of management factors is supported by data from housed sheep in Germany. The incidence of ovine TB in Germany between 1904 and 1918 was relatively high (0.14%-0.22%) compared with only 8 confirmed cases in GB, where sheep were not routinely housed (Cousins 2001).

11. Detection of TB in sheep is also limited by the lack of statutory surveillance, the low sensitivity of abattoir surveillance and the absence of specific clinical signs in sheep (Van der Burgt et al. 2013).
12. Whatever the reasons, sheep are considered to be spillover and dead-end hosts to *M. bovis*, rather than true maintenance hosts
13. They are only likely to become infected when the challenge level is relatively high and unlikely to sustain infection within the flock without contact with a local cattle or wildlife reservoir (Cousins 2001, Marianelli et al. 2010).
14. There is no routine ante-mortem testing for TB in sheep in GB. If TB is confirmed or if there is a strong suspicion of TB infection in sheep e.g. when lesions suspicious of TB are detected through postmortem inspection at the abattoir, movement restrictions are imposed by AHPA. Restrictions can also be put in place when sheep are co-located on a cattle breakdown herd. Restrictions usually remain in place until all the suspect infected animals, and direct contacts, have been removed and the remainder of the flock have passed sufficient ante-mortem tests to rule out infection.
15. When infection is detected in an animal, the primary concern is that other animals on the holding may be infected, posing a risk to other co-located animals. AHPA therefore work with owners to test the remaining animals to remove any infected cases through ante-mortem test using diagnostics such as the Single Intradermal Cervical Comparative Tuberculin (SICCT) test. There is no compensation available for sheep identified as reactors or direct contacts making all slaughter decisions voluntary.
16. The combination of movement restrictions and use of ante-mortem tests allows segregation of any sheep flock that poses a transmission risk to other flocks/herds until the potential to transmit disease can be considered negligible. Other actions such as animal movement tracings can also be carried out.

The risk question

What is the risk of *M. bovis* spreading to bovines, non-bovines and wildlife from the movement of farmed sheep from holdings where *M. bovis* infection has been diagnosed in previously co-located farmed sheep? What are the consequences?

17. The hazard in this situation is the *M. bovis* bacterium. The risks examined will include spread of *M. bovis* beyond the infected premises (if not placed under some form of movement restriction) and risks to animal welfare.
18. The TB transmission risks from non-bovine farmed species to other animals fall into the following four categories, with the first two currently being most important for overall TB disease control in England:
- i) Risk to cattle;
 - ii) Risk to wildlife (e.g. badgers);
 - iii) Risk to other members of the same species (compartment); and
 - iv) Risk to other non-bovine species.
19. The risks are difficult to quantify and are probably best expressed as relative to the comparative baseline which is not risk-free as no routine testing is carried out in sheep flocks to establish their TB status.

Summary of the risk factors

Geographic location

20. The density of farmed sheep populations in GB is illustrated in Appendix 1. There are significant populations of sheep in the SW of England, Wales and the Midlands which coincide with the 'high' risk and 'edge' areas as described in the new bovine TB strategy (Defra 2014) (see Appendix 2).

Structure of the UK sheep industry

21. The UK national sheep flock in 2013 was approximately 22.6 million (Table 2) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/293717/structure-dec2013-uk-19mar14.pdf . In England, the sheep and lamb population was approximately 15.3 million in 2014 and 14.9 million in 2013 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/355868/structure-jun2014final-eng-18sep14.pdf.
22. The sheep population peaks during the summer after lambing and reaches a minimum over the winter as lambs are slaughtered and breeding stock is culled.
23. Annual ewe natural mortality rates in the UK are estimated to range between 3 - 8% representing a loss of between half and one million ewes per year. In addition, estimated ewe replacement rates, at 20 per cent (approximately 3 million ewes per year), are influenced by longevity and may be compromised by diseases causing premature death or involuntary culling (Lovatt and Strugnell 2013).

Table 2 Sheep and lambs on UK agricultural holdings on 1 December (thousands)

Year	2008	2009	2010	2011	2012	2013
TOTAL SHEEP AND LAMBS	22 010	21 340	21 347	22 007	22 991	22 624
Female breeding flock	14 059	13 842	13 843	14 199	14 278	14 849
Other sheep and lambs	7 951	7 497	7 504	7 808	8 714	7 774

24. The UK sheep industry is stratified with specific breeds occupying habitats and management systems to which they are suited. These include hill, upland and lowland environments (Sargison 2012, UK Agriculture: http://www.ukagriculture.com/livestock/sheep_industry.cfm).

i) The hills (40% of the national flock)

Pure bred hill and mountain sheep produce lambs as flock replacements with excess lambs moved for fattening in the lowlands. Older ewes that have lambed several times are sent to less harsh upland conditions to be crossed with longwool breeds.

ii) The uplands (19%)

Draft hill ewes and ewes from specific upland breeds are crossed with longwool breeds to produce halfbred or mule lambs. Male lambs are sold for fattening in the lowlands and ewe lambs are transferred to the lowlands to be crossed with lowland breeds.

iii) The lowlands (41%)

The upland halfbred and mule ewes are crossed with lowland breeds to produce lambs for fattening on grass. Lambs from the hill and upland areas are fattened on root crops over the autumn and winter.

Feral sheep

25. Populations of feral sheep are limited to the St Kilda group of Islands off the Western Islands of Scotland (Soay and Boreray) and a small group of Soay sheep at Cheddar Gorge. As the focus of this assessment is on farmed sheep, they will not be considered further.

Dairy sheep

26. There is a small dairy sheep sector in GB with approximately 20,000 sheep milked in 40 to 50 flocks. Most flocks have between 250 and 500 milking sheep with the largest milking 1,000 sheep and the smallest under 100 (Source: British Sheep Dairying Association).

On-farm management and husbandry

27. Most lambs are born in late winter or spring. Sheep are generally managed extensively but lowland flocks may be housed over the winter and lamb indoors. In the hills and uplands, lambing is generally outdoor with the ewes moved to more sheltered areas.
28. There is thus considerable scope for contact with wildlife and cattle, especially in the upland and lowland areas where sheep are frequently kept on the same holdings as cattle and may share grazing.
29. Stratification results in a considerable number of sheep movements in the UK (see table 3). All sheep movements must be reported to the Animal Reporting and Movements Service (ARAMS). Data on batch movements is downloaded from ARAMS to the Animal Movement Licensing System (AMLS). All sheep must be appropriately identified:
<https://www.gov.uk/government/publications/guidance-for-keepers-in-england-rules-for-identifying-sheep-and-goats>

Table 3 Movement of sheep in the UK, 2009-2011 (Source Defra)

Destination	Sheep	
	Number of Batches	Number of Sheep
Farm to Farm	78,578	4,045,726
Farm to Market	235,365	6,434,435
Farm to Abattoir	105,573	3,959,318
Market to Farm	71,608	2,807,122
Market to Abattoir	53,055	3,514,384
Other *	33,847	847,187
TOTAL 2011	578,026	21,608,172
TOTAL 2010	582,314	22,086,803
TOTAL 2009	588,754	22,349,643

*Other: includes, show grounds, export/import, vets, zoos

Biosecurity

30. Biosecurity in the beef and sheep sectors is less well developed than in other sectors, such as pigs and poultry. There are intrinsic barriers to biosecurity in the UK sheep industry, including the extensive husbandry systems in the UK and the large number of sheep movements. A report on best practice in disease prevention by the livestock industry in the UK (Hovi 2005) identified other potential barriers including lack of penetration of quality assurance (QA) schemes in the sheep sector, lack of cohesion and collaboration within the sector, farmers' attitudes to biosecurity and lack of buy-in from veterinarians and /or lack of veterinary services.

Pathogenesis, pathology and clinical signs

31. There are few reports of sheep with TB exhibiting clinical signs. In the first reported outbreak with clinical signs in England and Wales, the predominant clinical sign was general ill-thrift (Van der Burgt et al. 2013). In Spain, coughing and dyspnoea were reported in two flocks with confirmed TB (Munoz Mendosa et al. 2012).
32. Evidence from postmortem examination suggests ovine infection can occur by both ingestion and inhalation routes. In Northern Ireland, lesions were identified in the respiratory system of four sheep, but in these cases gastrointestinal lesions were not present (Malone et al. 2003). However, Cordes et al. (1981) and Davidson et al. (1981) examined greater numbers of sheep in New Zealand and observed extensive lesions in the lungs, intestine, liver and lymph nodes. Italian authors also reported gross caseous lesions in the submandibular nodes and the liver of a slaughtered ewe with generalised *M. bovis* infection, in addition to the lungs and mediastinal lymph nodes (Marianelli et al. 2010). Lesions in the respiratory system imply that infected sheep could potentially act as a source of infection for other animals (Broughan et al. 2013).
33. Skin testing is carried out using the single intradermal comparative tuberculin (SICTT) test. Tuberculin is administered either into the inner thighs or each side of the neck. The SICTT test is the internationally accepted test for TB in sheep but there has been limited use of the test in sheep. It has not been fully validated and there are no reliable estimates of test sensitivity and specificity. The test seems to have been effective in eradicating disease in a recent breakdown in England (Van der Burgt et al. 2013).
34. In some circumstances, a programme of slaughterhouse monitoring may be used as an adjunct or in place of skin testing to determine the TB status of the flock.
35. The only conclusive way of confirming *M. bovis* infection in sheep is by bacteriological culture of the organism in selective media from fresh tissue or clinical samples, a procedure that typically takes 6 to 8 weeks. A negative culture result does not completely rule out infection with *M. bovis*.

Summary of mitigating factors

Surveillance and control

36. Surveillance in sheep is mainly through postmortem examinations carried out as part of statutory slaughterhouse meat inspection. Slaughterhouse surveillance is relatively insensitive as routine inspection will not include examination of all the sites where lesions occur (e.g. mesenteric lymph nodes). Lesions due to *M. bovis* may be mistaken for lesions caused by other

diseases e.g. Caseous Lymphadenitis or abscesses caused by other bacteria; these are common incidental findings in sheep and are often not examined further to determine their aetiology. Sheep may also occasionally be infected with *M. avium* (Kummenje and Fodstad 1976).

37. Determining the farm of origin is difficult if sheep from various farms are mixed after purchase at the market for transport to the slaughterhouse and/or the tags and heads are removed before carcasses are dressed after slaughter.
38. Under the Tuberculosis Orders for England and Scotland, there is a statutory requirement to notify the suspected presence of TB in the carcass of any bovine or farmed or companion (pet) mammal or when *M. bovis* is isolated. There is no routine statutory TB testing programme for live sheep in GB.
39. TB testing is carried out using the SICCT and is a private matter with arrangements for testing at the discretion of and cost to flock owners. AHPA will supply the tuberculin free of charge. The test may only be carried out with prior authorisation from (and by Official Veterinarians appointed by) AHPA. In practice, this could take place for one of the following reasons:
 - i) “Diagnostic” purposes, e.g. when suspect TB lesions have been found at postmortem examination of sheep, in order to check the flock of origin, or when TB is confirmed in cattle herds adjoining (or co-located with) sheep flocks;
 - ii) To allow removal of movement restrictions on sheep farms following disclosure of TB test reactors, clinical cases or confirmed slaughterhouse cases;
 - iii) For health certification of sheep for export;
 - iv) Check testing of imported animals; or
 - v) Testing prior to movement or sale.

Breakdown management

40. TB control in sheep relies on a test and slaughter (or slaughter only) policy based on the SICCT test and the application of movement restrictions.
41. If TB is confirmed, or if there is a strong suspicion of TB infection, e.g. suspect lesions found at postmortem examination, movement restrictions will be imposed by AHPA with the aim of preventing the onward spread of disease from the farm. Restrictions will remain in place until appropriate testing or other means of surveillance have satisfied AHPA there is freedom from TB. Tracings of movements on and off the premises are also carried out.
42. Under the Animal Health Act, Veterinary Inspectors have the power to test any animals (not just cattle) for TB. However, in the absence of a specific compensation order for sheep, the current TB legislation affords no legal powers to enforce the slaughter of reactors or contacts. Any testing must be therefore be done on a voluntary basis.

43. TB testing can be carried out at the expense of Defra when there is good evidence of disease e.g. when visible lesions are seen at postmortem examination and where the owner has signed a voluntary agreement to release any test reactors for postmortem prior to testing.
44. Where TB testing (SICCT test) is used to allow removal of movement restrictions following disclosure and confirmation of TB in the flock/group, two clear consecutive tests will be required at 60 day intervals. If infected sheep are identified on a farm, AHPA may apply skin testing to any cattle, camelids or goats present on the breakdown premises and neighbouring premises pending a veterinary assessment. Movement restrictions are only lifted when all reactors have been slaughtered and the flock has passed two consecutive skin tests.
45. In certain circumstances, parallel skin and blood testing, may be used to identify additional infected animals e.g. if many sheep react to the skin test and are found to have visible lesions or are culture positive, or if skin test negative clinical cases are identified in the flock. In Northern Ireland, the interferon-gamma test gave positive responses to sheep that reacted to the tuberculin test (Malone et al. 2003). Parallel testing would only be on a voluntary, ad hoc and semi-experimental basis.
46. AHPA may also agree to the use of a programme of slaughterhouse surveillance in order to lift TB restrictions.
47. Animals can be licenced to move direct to slaughter to alleviate overstocking and maintain viable businesses for the commercial sector whilst not increasing the disease spread risk.

Summary of the veterinary and other consequences

Animal welfare

48. Disease with clinical signs is very rare in sheep. The major impact on animal welfare would be the imposition of movement restrictions (except direct to slaughter) and the possibility of overcrowding or shortage of feed or grazing.

International trade and reputation

49. Due to high incidence of TB in cattle and the potential spill-over to sheep, coupled with the low sensitivity of slaughterhouse surveillance, there is risk of exporting infected animals. Table 4 show the numbers of live sheep exported from GB for breeding. Sheep are also moved to the EU for fattening and slaughter, mainly to Belgium, France, Ireland and the Netherlands (Ares et al. 2013). Currently there is no active direct trade in live sheep to third countries for fattening and slaughter.

Table 4 - Movement of live sheep from GB for breeding (Source AHPA)

Year	EU	Northern Ireland	United Arab Emirates	Serbia	Guernsey	Isle of Man
2012	203 (163)	8,438 (472)				220 (36)
2013	297 (165)	5,790 (408)	124 (2)	37 (2)	16(1)	670 (37)
2014	5,200 (37)	3,214 (104)				205 (7)

(Number of consignments in parenthesis)

Economic losses

50. For infected flocks this is mainly due to imposition of movement restrictions but animals can be moved under licence direct to slaughter. For dairy herds, all milk from restricted herds must be pasteurised for human consumption. All milk from reactor animals must be completely excluded from the human food chain.

Impact on public health

51. Impact on public health from TB in sheep will be very low as sheep are not a major milk-producing animal in the UK. As only those with direct contact with live animals and at slaughter will be at risk of zoonotic infection, the risk to human health has not been assessed in detail in this document.

Summary of the likelihood of disease spread

52. The risk of TB spread from one commercial sheep flock to another is likely to be very low as despite the large number of movements in the sector, the incidence of disease in sheep in GB is extremely low. As sheep can develop lung lesions there is the potential for spread to other sheep at the flock of destination especially if the sheep are housed over the winter. There have been no reported incidents where TB has spread from sheep to other livestock. It is unlikely that there is spread from sheep to wildlife but there is no evidence available to confirm this.

Summary of the uncertainties and assumptions

53. The main uncertainty remains the true prevalence of *M. bovis* in the GB sheep population as there is no statutory surveillance for TB in sheep and surveillance depends primarily on slaughterhouse inspections which are likely to have a low sensitivity.

Conclusions (and summary of veterinary advice)

54. The movement of sheep from known TB-infected holdings would not substantially increase the risk of *M. bovis* spreading to cattle or other non-bovine holdings.

55. There is the potential risk that moving finishing stock from infected herds into the low-incidence areas of the country could spread the disease there. Restricting these movements may be appropriate given the consequences of TB spreading into these areas.

56. The lack of validated antemortem tests in sheep is an evidence gap.

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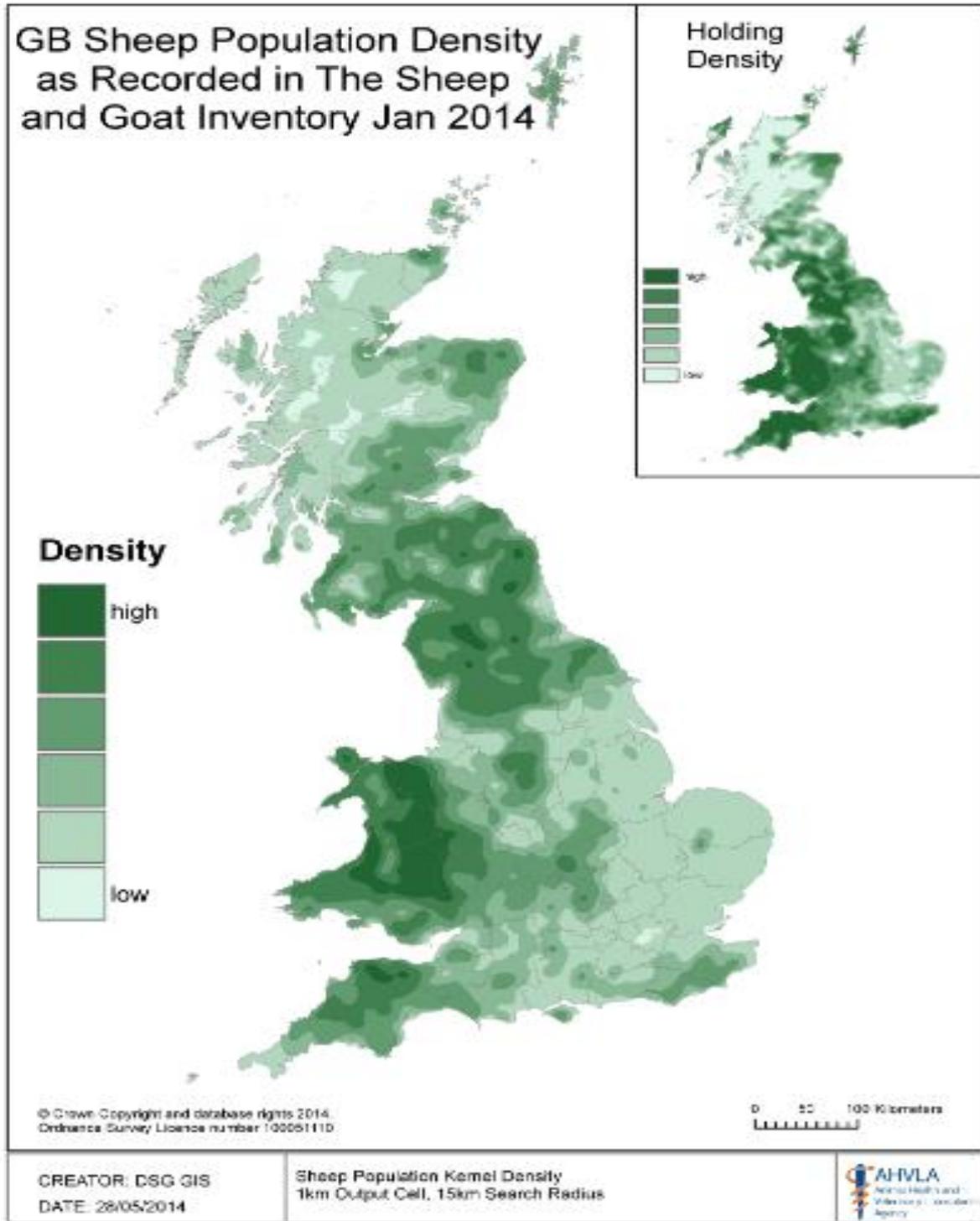
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Appendix 1 Density of farmed sheep in GB



This map is a simplified WIP version from the AHPA Livestock Data Demographic Group (LDDG), and is therefore subject to change. It portrays population density information for England, Wales and Scotland and has been created using the Kernel Density tool within ArcGIS. It is suitable for determining relative areas of higher and lower population density at national scales only. Dark shades represent areas of higher population density than light shades. The tool used does not correct for edge effects associated with kernel density estimation and therefore values close to the land boundary are lower than reality.

Appendix 2 Geographical location of the three risk areas in 2013

