

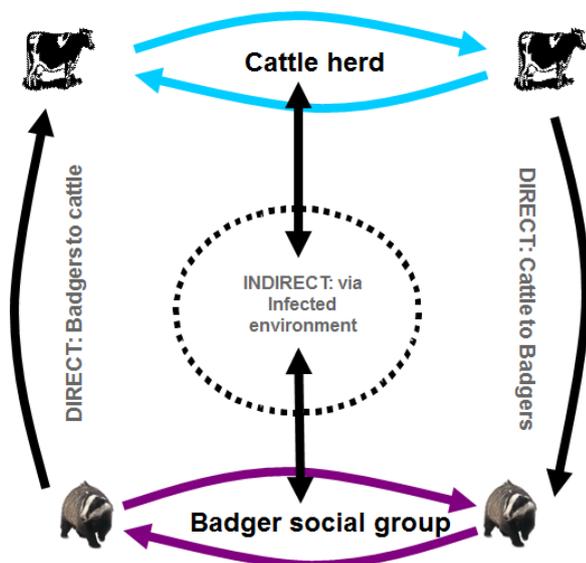


Animal &
Plant Health
Agency

Bovine tuberculosis in Great Britain in 2018

Explanatory supplement to the annual reports

September 2018





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Preface

This Explanatory Supplement is produced in support of the annual reports that describe the surveillance data and epidemiology of bovine tuberculosis (TB) in Great Britain, specifically the reports titled '[Bovine tuberculosis in Great Britain-Surveillance data for 2017 and historical trends](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/739906/GBDataReport.ods)'¹ (referred to in short as the '2017 GB TB data report') and 'Bovine tuberculosis in England 2017-Epidemiological analysis of the 2017 data and historical trends'² (referred to in short as the 2017 England TB Epi report).

The content is derived from explanatory text provided in previous annual reports to describe data, methodology and definitions, updated where appropriate.

A description of the policy for control of bovine TB in each of the three Administrations of Great Britain is also included.

¹ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/739906/GBDataReport.ods

² https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/739935/tb-epidemiology-england-2016.pdf

1. Overview of TB transmission pathways

In Great Britain the main species infected with *Mycobacterium bovis*, the bacterium that causes bovine tuberculosis (TB), are domestic cattle and wild badgers. The figure below shows simplified TB transmission pathways and the relationship between and within cattle and badger populations in terms of the spread of the disease.

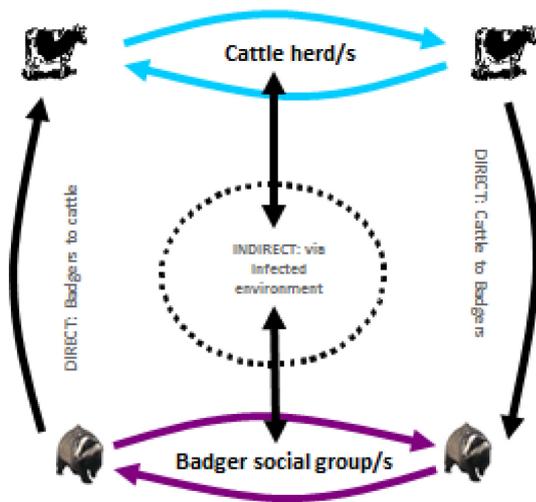


Figure 1.1 Simplified potential TB transmission pathways involving cattle and badgers.

However there is a wide variety of ways the organism can pass between the two main host species, aided by the ability of *M. bovis* to survive well in the environment in certain conditions, e.g. damp, warm soil shaded from direct sunlight, for many months. Figure 1.2 below shows the wide range of risk factors and pathways by which cattle can become infected with TB. We have, more or less, the knowledge of the variables that are involved in each pathway.

Most of the variables in brown boxes can be determined remotely from government datasets, e.g. we can assess cattle movements using the Cattle Tracing System (CTS); however, we would need to access farmer's records for non-reported movements (e.g. movements within 10 miles between premises under the same ownership, or, if prior to July 2017, between CTS-linked premises which allowed keepers to link holdings if they frequently moved cattle between them). The numbers of cattle in the herd are variable and herd size is affected by changing management practices during the year, with changes arising from expansion, loss to disease or maintaining a varied genetic pool, alongside adhoc management practices which are not captured by remote systems such as varying

the composition of the different epidemiological groups. Herd and enterprise types and concurrent disease can be difficult to establish remotely and also subject to change. Test performance depends on characteristics of the tests (i.e. individual vs group level), but also on its correct application and interpretation. History of TB and testing records are readily available at central level (reliability is dependent on the quality of data entry). The presence of contiguous neighbours can be assessed using land ownership data, but this can obscure differences between the ownership of the land and the use of the land.

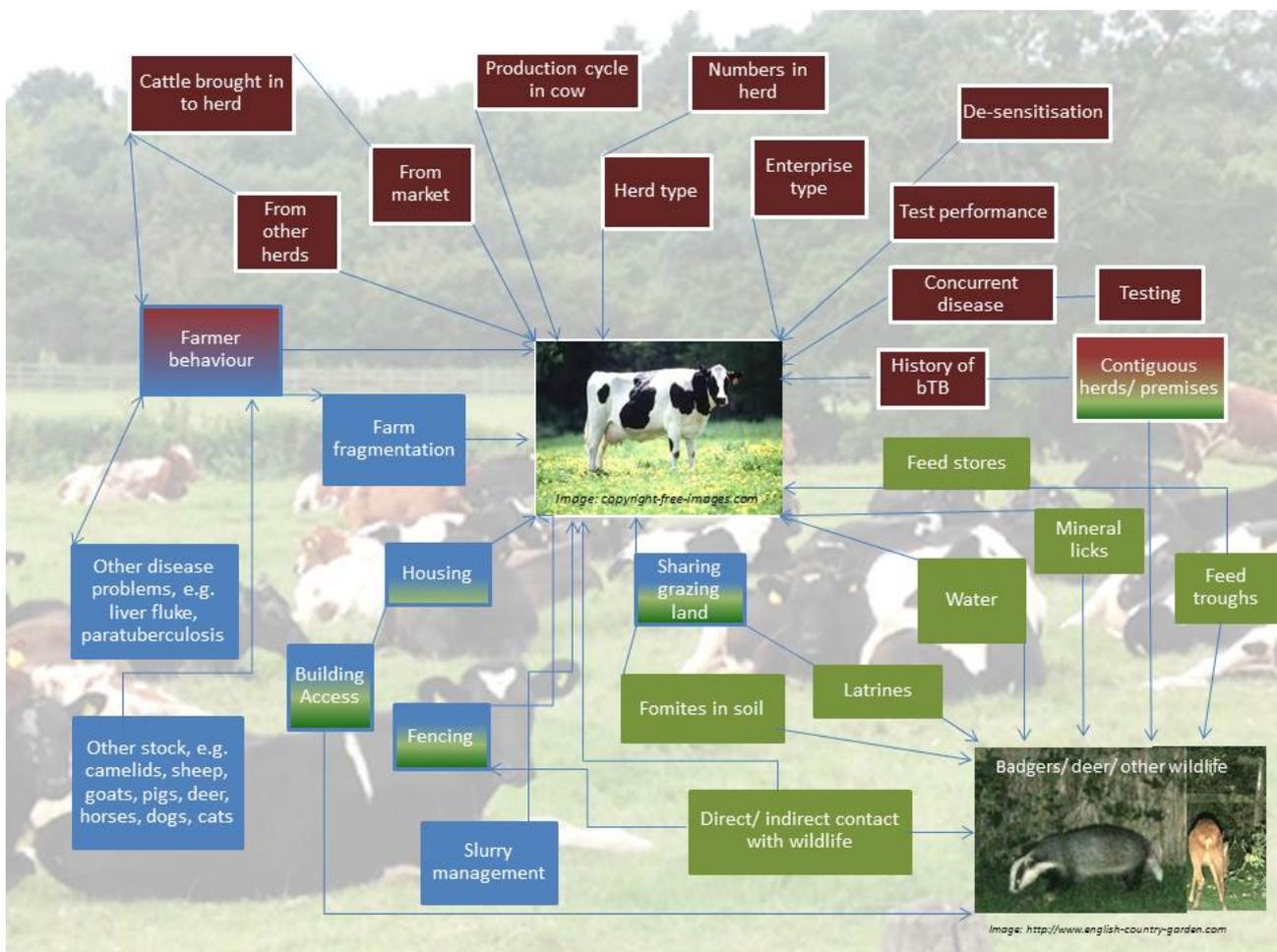


Figure 1.2 Detailed diagram showing TB potential risk pathways

The variables in green and blue boxes depend on knowledge of farm management practices, which often can only be established through farm visits and by direct contact with the farmer. Geographic Information Systems (GIS) have been used in an attempt to define the extent of farm fragmentation, but there are problems with the data and the methodology applied to a large number of herds. Alternative novel methodologies to assess it are being pursued currently.

All these are potential risk pathways which may or not materialise depending on whether there is a level of exposure to the hazard (e.g. an infected cow or badger; infected material in the environment, etc.) and the degree of it on a particular farm.

2. Glossary and definitions used for TB control

Detail	Abbreviation	Definition or description
Animal and Plant Health Agency	APHA	The Animal and Plant Health Agency (APHA) was launched on the 1st October 2014. It merged the former Animal Health and Veterinary Laboratories Agency with the Plant and Bee Health and GM Inspectorates and the Plant Varieties and Seeds Office (previously based in FERA), creating a single agency responsible for animal, plant and bee health.
Annualised		Conversion of a variable into a yearly sum (e.g. by multiplying a quarterly incidence by 4).
Bovine tuberculosis	TB	Disease of cattle and other mammals caused by infection with <i>Mycobacterium bovis</i>
Breakdown		See 'TB incident'
Case		See 'TB incident'
Co-financing/ed		Co-funding/financing is the financial contribution of the EU to certain national animal disease surveillance, control and eradication programmes approved by the European Commission.
Compensation		The statutory payment made by the competent authority to the owner of the animals that have been culled for TB eradication purposes. There are different statutory compensation systems for cattle slaughtered in England, Scotland and Wales.
Contiguous herd		Strictly speaking, a holding that has a common boundary with the TB incident holding of interest, but includes herds separated only by a short distance e.g. across a road or river, or where an epidemiological assessment indicates they are likely to be at risk of exposure to infection.
Dangerous contact	DC	A non-reactor animal in an OTF-W TB incident herd considered to be at such high risk of being infected that slaughter is justified, usually for the reason of contact with infected cattle.
Disclosing test		The test that triggers the start of a new TB incident which in turn marks the start of movement restrictions. (Includes TB incidents disclosed through a confirmed slaughterhouse case).

Eradication Programme		Programme aimed at achieving in biological extinction of an animal disease or zoonosis and-or to obtain the free or officially free-status of the territory according to EU legislation, where such possibility exists.
Gamma interferon test	IFN- γ or gIFN or IFN-gamma	Laboratory-based blood test approved as an ancillary diagnostic tool that measures the amount of the cytokine (immunological messenger molecule) IFN- γ released in whole blood cultures stimulated with tuberculin. It is used to supplement the skin test in certain TB incident herds, rather than as a standalone test.
Genotype		A unique DNA type or 'strain' of <i>Mycobacterium bovis</i> , defined by a combination of spoligotype (expressed as a number) and VNTR type (expressed as a letter). This information is used to characterise the molecular epidemiology of the TB bacterium in GB and support APHA epidemiological investigations into the origin of individual TB incidents.
Herd		An animal or group of animals kept on a holding as an epidemiological unit. In GB they are identified with a County Parish Holding Herd (CPHH) number.
Herd size		For a TB incident, herd size is the largest size entered in SAM for a test conducted at any time during the incident. For officially TB free herds, herd size has been changed in 2017 to take a median size recorded on the BCMS Cattle Tracing Scheme for the holding over the most recent 12 months with a recorded size, and this has been supplemented for those holding with more than one herd in existence at the same time or not present in BCMS with the herd size recorded at the most recent whole herd test. Where no size is retrievable from either source the typical number of animals indicated on SAM has been used. The change to using CTS was largely driven with the aim of reducing the numbers without a retrievable size from the testing history and where recent tests presented no eligible stock.
Herd test		A surveillance or control test triggered by a herd-level event, rather than a test triggered for an individual animal or a small group of animals within a herd.
Herd types		'Beef' includes Beef, Suckler, Beef Heifer Rearer, Beef Bull Hirer, Beef dealer, Stores herds and Meat Buffalo herds; 'Beef fattener'/ 'Beef finisher' includes beef finishing

		<p>herds</p> <p>'Dairy' includes Dairy, Dairy Dealer, Dairy Bull Hirer, Dairy Producer, Dairy Heifer Rearer, Producer Buffalo and Domestic herds;</p> <p>'Other' includes Calf Rearers, unspecified Dealer Herds, Artificial Insemination (AI), Bison and herds described on SAM as 'Other herds'.</p>
Herd-years at risk	HYR	The sum of the time (days, months or years) that herds in the geographical area of interest are unrestricted and are therefore at risk of a new incident, among the group of herds that have had a herd-level test during the period of interest.
Holding		A holding is a place where livestock, including cattle, are kept or handled in pursuit of an agricultural activity. It may be a farm, or other premises such as a market, lairage, abattoir or showground. Some keepers may have more than 1 holding and some holdings may be used by more than one keeper. A holding is not the same as a business. It is expressed as a County Parish Holding (CPH number) and a single holding may comprise of one or more herds.
Homerange		<p>The geographical area in which a particular genotype of <i>M. bovis</i> is typically recovered from infected cattle herds. A 5 km square is considered as part of a certain homerange if there have been three different incidents of that genotype, on at least 2 holdings, within a 5 year window. In order to create coherent area for each genotype, a 10km buffer is then drawn around each of the homerange so defined.</p> <p>Following a noted reduction in area size the methodology was revisited in 2018, identifying an issue in the assignment of herd locations with truncated map references that fall on grid cell boundaries. This issue has now been corrected.</p> <p>Another issue was identified regarding rows of data with incomplete or missing CPHs that were incorrectly processed resulting in some breakdowns not contributing to the algorithm. Hence the tool was not buffering some grid squares that should have been buffered and thus</p>

		<p>was underestimating the overall size of some home ranges. In 2017 the correction to this method resulted in 5 Homeranges having a size increase above 20%, with 29 having a correction of 5% or less.</p> <p>These issues have been corrected for the 2017 report, but previous years outputs are affected, and some Homerange polygons are impacted by amounts greater than in 2017.</p>
Incidence		The incidence of a disease is the rate at which new cases occur in a defined population over a designated time period.
Inconclusive reactor	IR	An animal showing a particular pattern of reactions to a comparative intradermal tuberculin test, where the difference in size of reactions to bovine and avian tuberculin is not large enough to cause it to be described as a reactor. Such animals are usually isolated and subjected to a second skin test after 60 days, unless removed earlier as DCs or IFN- γ test reactors (see above), or voluntarily slaughtered by their owner.
Inter-quartile range	IQR	A measure of statistical dispersion equal to the difference between the upper and lower quartiles: (i.e. the 75 th and 25 th percentiles of the distribution's values).
Linear regression		A statistical approach for modelling the relationship between a continuous outcome variable (e.g. duration of restrictions, which can take any value) and one or more 'predictor' variables (e.g. herd size, herd type or county).
Live herd or Active herd		A herd of cattle, farmed buffalo or farmed bison defined in the County/Parish/Holding/Herd (CPHH) notation which was "live" (i.e. not archived), flagged as active on SAM on 31 st December, 2018. This gives different values from the Agricultural Census, which is at holding level and updated at a different point in time.
Logistic regression		A statistical approach for modelling the relationship between a binary outcome variable (e.g. positive or negative result) and one or more 'predictor' variables (e.g. herd size, herd type or county).
Monitoring (programme)		Programme to investigate an animal population or subpopulation, and/or its environment (including wild reservoir and vectors), to detect changes in the occurrence and infection patterns of an animal disease or zoonosis.

Movement restrictions / restrictions		Legal prohibitions or restrictions on the free movement of animals into and out of a herd. Movement restrictions may be imposed on a herd because of the presence, or the suspected presence, of <i>M. bovis</i> infection, or because statutory tests are overdue leading to the loss of Officially TB Free herd status (see below) or because IRs have been disclosed in a herd with a history of OTF-W incidents in the previous three years. Herd restrictions triggered by overdue tests are excluded from analyses in this report to avoid overestimates of disease.
<i>Mycobacterium avium</i>	<i>M. avium</i>	The causative organism of avian tuberculosis, which occasionally infects cattle
<i>Mycobacterium bovis</i>	<i>M. bovis</i>	The causative organism of bovine tuberculosis
New TB incident		A herd newly found to be infected with TB. Defined as a herd previously OTF in which at least one test reactor, IR taken as a reactor, or a culture-positive slaughterhouse case has been found. The <i>restriction</i> , and thus the incident, starts on the disclosing test date (or date of slaughter of the slaughterhouse case). To qualify as being “new”, the incident must have been <i>disclosed</i> (i.e. discovered) in the period specified in the report. The incident ends on the date the TB10 form is served and restrictions are lifted. (see also ‘TB incident’ below)
Non-visible lesions	NVL	No lesions typical of bovine TB could be detected in the carcass at <i>post mortem</i> examination or meat inspection
Officially bovine tuberculosis free status	OTF	See Appendix 3 for Extract from European Union (1998), Council Directive 98/46/EC for full definition of the officially TB free status
Officially bovine tuberculosis free status suspended	OTF-S	For the purposes of this report OTF-S is the status of a herd with a TB incident where there is a suspicion of infection being present. A TB incident that did not meet the conditions for an OTF-W incident (see below) is classified as an OTF-S incident.
Officially bovine tuberculosis free status withdrawn	OTF-W	This term refers to a herd with a TB incident in which additional evidence of <i>M. bovis</i> infection has been identified in at least one slaughtered bovine animal, i.e. <i>M. bovis identified</i> in a cultured tissue sample and/or lesions detected in the carcass of a SICCT or IFN- γ test reactor. It also includes other incidents upgraded to OTF-W for epidemiological reasons.
Persistent herd		Refers to a TB incident herd that has been under

or persistent TB incident herd		restrictions for at least 550 days (approximately 18 months).
Poisson regression		A type of statistical modelling based on a particular type of numerical distribution that is used to compare rates of rare occurrences between different population groups, different areas, or different times.
Post-mortem or <i>post mortem</i> examination	PME	Examination (to various extents) of the carcass and organs of slaughtered cattle for lesions typical of bovine TB undertaken at an APHA Regional Laboratory, at the slaughterhouse following in vivo suspicion of infection (e.g. reactors, IRs and DCs), or as part of routine meat inspection.
Pre-movement testing	PrMT or PRMT	Mandatory testing for cattle over 42 days moving out of an at least annually tested herd into other herds and for cattle moved out of herds in the LRA to Scotland, unless the animal had spent its entire life in the LRA.
Prevalence		The prevalence of a disease is the proportion of a defined population (at the animal or herd level) affected by that disease at a designated point in time.
Reactor	R	An animal showing a positive reaction result to a single intradermal tuberculin comparative cervical (SICCT) test (a.k.a. the skin test), or to a gamma interferon (IFN- γ) assay consistent with it being infected with <i>M. bovis</i> . This does not include an animal first suspected to have TB at the slaughterhouse. An animal that tests twice as inconclusive reactor to the SICCT test is automatically classified as a reactor, but will not count towards statistics for reactors throughout these reports.
Recurrent herd incident		A herd that had a TB incident disclosed in the reporting year (i.e. 2016) that had also been under movement restrictions for a different bTB incident in the previous 36 months.
Reference category	Ref	In regression analyses the reference group acts as a baseline against which we compare other groups of interest.
Reservoir		The reservoir is the animal where the infectious pathogen normally resides, and therefore is the common source of infection to other animals or humans.
Risk Area or Surveillance Risk Area or		Since 1 January 2013, TB testing intervals for bovines in England are annual or four-yearly at county level. The Strategy for achieving Officially Bovine Tuberculosis

Surveillance Area or TB Area		Free status for England published in April 2014 set out three risk surveillance areas, which are followed in this report: High Risk area (HRA – annual routine surveillance testing), Edge area (annual or six-monthly testing) and Low Risk area (LRA – 4-yearly testing for most herds). In 2017 Wales adopted a regionalised approach to TB distinguishing five TB areas (Low TB Area, Intermediate TB Area North, Intermediate TB Area Mid, High TB Area West and High TB Area East) ³
SAM database	Sam	APHA's IT system, which records, for example, details of herds, TB tests, TB incidents and the details and results of any tested and slaughtered cattle.
Sensitivity (of a test)	Se	The proportion of truly infected individuals in the screened population that are identified as infected (positive) by the test.
Severe interpretation		The positive cut-off criterion used to interpret the results of a skin test in TB incident herds in order to achieve a greater sensitivity. Using this interpretation of the single intradermal comparative cervical tuberculin test, animals showing either i) a positive bovine reaction and negative avian reaction or ii) a positive bovine reaction more than 2mm greater than a positive avian reaction are deemed reactors.
Short Interval Test	SIT	See 'Test code definitions'
Single intradermal comparative cervical test	SICCT	Also commonly referred to as the 'skin test' or 'tuberculin skin test'. The testing procedure involves the simultaneous injection of a small amount of <i>M. bovis</i> and <i>M. avium</i> tuberculins (purified protein derivative (PPD); a crude extract of bacterial cell wall antigens), into two sites of the skin of the animal's neck, followed by a comparative measurement of any swelling (delayed-type hypersensitivity reaction) which develops at the two injection sites after 72 hours.
Slaughterhouse case	SLH	This refers to an incident (rather than an animal) that is triggered by the disclosure of an animal from an OTF herd that had lesions consistent with TB during routine post-mortem meat inspection. In order that the case

³ <https://gov.wales/sites/default/files/publications/2017-11/wales-bovine-tb-eradication-programme.pdf>

		becomes an OTF-W incident, <i>M. bovis</i> must be isolated on culture from samples of the lesions. Until <i>M. bovis</i> is isolated at culture, a slaughterhouse case remains suspect and does not contribute to incident figures within this report, unless any subsequent skin check test performed in the herd of origin identifies reactors.
‘Smoothed’ and/or ‘12-month moving average’		A 12-month moving average is the average of the values for the current month and the previous 11 months. Moving averages can be any length. But, in general, shorter lengths will be best at identifying turning points and longer lengths best at identifying trends.
Specificity (of a test)	Sp	The proportion of truly uninfected individuals in the screened population that are identified as uninfected (negative) by the test.
Spoligotype		The result of one molecular technique used for genomic typing of organisms of the <i>Mycobacterium tuberculosis</i> complex, known as Spacer Oligonucleotide typing.
Standard deviation	SD	The standard deviation measures the spread of the data around the mean value. It is useful in comparing sets of data which may have the same mean but a different degree of variability in raw values.
Standard interpretation		The positive cut-off criterion normally used to interpret the results of a skin test. Using this interpretation of the comparative intradermal tuberculin test, animals showing a positive bovine reaction more than 4mm greater than a negative or positive avian reaction are deemed reactors.
Surveillance		Surveillance refers to activities to collect and record data on specific diseases in defined populations over a period of time, in order to assess the epidemiological evolution of the diseases and the ability to take targeted measures for control and eradication.
Surveillance Streams Definitions		<ul style="list-style-type: none"> • Area & Herd Risk: Disease first disclosed as a result of targeted tests carried out due to history or other epidemiological evidence that there is a higher probability of disease in the animal or herd. • Trade and Other: Disease first disclosed as a result of testing scheduled due to the high impact of disease if present, in the destination herd / premises (includes tests on animals where the presence of some epidemiological risk factors may increase disease probability but this is not the primary reason for testing).

		<ul style="list-style-type: none"> • Routine: Disease first disclosed as a result of tests scheduled as part of routine surveillance (i.e. by default), with no expectation of increased or decreased probability of disclosing infection. • Slaughterhouse (SLH) Surveillance: Disease first disclosed as a result of routine SLH surveillance of animals not believed at higher likelihood of being diseased (excludes results of inspection of reactor cattle).
TB area		Three TB areas (High risk area, Edge area and Low risk area) in England based on the distribution of TB within England.
TB Incident		A herd that has been categorised as infected with bovine tuberculosis is called a TB infected herd, and the event is called a 'TB incident'. Also referred to as a 'breakdown' or 'case'. The criteria that determine this are given under the definition of a 'new TB incident' above.
TB10 form or notice	TB10	Notice served at the end of a TB incident to lift the restrictions imposed on cattle movements onto and off the holding and thus restoring the OTF status of the herd.
Test code definitions (some of them)		<ul style="list-style-type: none"> • Hotspot Test (HS): Test carried out at herd level in low incidence areas if a holding is within a 3km radius of an incident, which triggers a potential hotspot area (potential hotspot area is an area in England or Wales of enhanced surveillance around TB incidents with confirmed disease of uncertain origin emerging in a region of historically low TB incidence). All bovines except calves under six weeks of age included. An HS1 test is triggered usually 2-3 months from identification, followed by a HS, 12 months later. • Private Test (PRI): A test carried out on individual animals, commissioned and paid for by the owner and carried out by an OV with the Regional Veterinary Lead (RVL) agreement. E.g. extra TB test in a breeding bull. • Radial Test (RAD): Carried out on herds within a 3km radius of a herd with its Officially TB Free status withdrawn in the Low Incidence Area or in the Cheshire and Derbyshire Edge Area. All bovines except calves under six weeks of age included. This is followed by a RAD6 test six months later and by a

		<p>RAD12 test 12 months after the RAD6 test in the LRA only,</p> <ul style="list-style-type: none"> • Routine Herd Test (RHT): Routine surveillance herd test carried out in parishes with a 48 month testing interval. It must include: breeding bulls (i.e. entire male animals over 12 months of age); females which have calved; young bovines which will be used for breeding whether they are home-bred or purchased (except calves under six weeks old); pet cows and other non-commercial cattle resident on the holding. • Short Interval Test (SI Test or SIT): Herd test carried out 60 days after removal (or effective isolation) of the last reactor, or following confirmation of disease whilst the herd is under TB movement restriction. It includes all bovines except calves under six weeks old but this exemption will exclude herds where there is an epidemiological risk of infection within this group. • Whole Herd Test (WHT): Routine surveillance herd test carried out every 6 months in annual testing areas and elsewhere in individual herds requiring annual testing, e.g. producer-retailer dairy herds, bull hirers, heifer rearers, city/open farms, AI centres, etc. (unless specifically exempted by the RVL). It can also be carried out via RVL discretion in 48 month testing areas. It includes all bovines except calves under six weeks old.
Testing interval		<p>Testing interval for routine TB surveillance purposes. In England the interval is either every six months, 1 or 4 years depending on the policy applied to the risk area. In Scotland it has always been 4 years and annual in Wales since 2010. Given by the Area Testing Interval or Area Monitoring Regime (ATI or AMR) or the Unit Monitoring Regime (UMR) to which individual herds are allocated by APHA. In Wales, the ATI is recorded for the third quarter of the year in question, whether or not the herd was tested in that year. Any shorter interval assigned specifically to an individual herd within a parish has not been used.</p>
Time at risk	TAR	<p>Time spent not under restriction since the most recent herd-level test or end of incident and at risk of being diagnosed with TB during the observation period.</p>

Tracing tests		Tests carried out to 'trace' the potential source or spread of infection. 'Backward' tracings investigate where infection may have come from, e.g. the herd of origin of purchased cattle suspected of being infected when they arrived. 'Forward' tracings check individual animals that have left the herd when infection was believed to be present to see if they are infected and may have carried infection to their destination herd(s).
VetNet database	VetNet	VetNet is the predecessor of SAM, APHA's bTB control and surveillance system. Data was migrated into SAM from VetNet when SAM was launched in 2011.
Visible lesions	VL	Lesions typical of bovine TB detected in the carcass of a SICCT or IFN- γ test reactor at post-mortem examination or meat inspection.
VNTR type	VNTR	The result of a form of genomic typing based on repeated sequences of genomic DNA described as Variable Number Tandem Repeat typing.

3. Data sources and processing

Source of data

- The data on herds, animals, bovine tuberculosis (TB) incidents and tests applied to the British cattle population were downloaded from the Animal and Plant Health Agency's (APHA) SAM RADAR TB reception database on 29th March 2018 and includes skin tests entered on to Sam and completed on or before the 24th. Data prior to late September 2011 derives from the old VetNet system, which was decommissioned and migrated into Sam at the end of September 2011. Information relating to culture results of all TB suspect samples exists on Sam, but is derived from the APHA's LIMS system for samples from around the time of Sam TB going live, and prior to that from the APHA TB Culture System (TBCS), plus a short cross-over period when both were in use. Apparent missing results on Sam have been retrieved directly from LIMS where possible, in particular for samples from around the time of SAM TB going live.
- Data are downloaded three months after the reporting year in order to capture as many laboratory culture results for incidents commencing in the reporting year as possible. This date is, however, too early to capture all events during most of these incidents, for example the dates of removal of movement restrictions, from which the duration of incidents is calculated. Therefore, incidents that *ended* during the reporting year are used to calculate the duration of incidents and the total number of reactors in an incident.
- As in previous reports, the old county boundaries that were set in 1974 are used throughout.
- In England, outputs are for the most part broken down by the new TB risk and surveillance areas introduced in 2013. From January 2018 part Edge, part HRA split counties were re-classified as fully in the Edge area. These include Cheshire, Derbyshire, East Sussex, Oxfordshire and Warwickshire. Herds in these counties are subject to mandatory interferon gamma blood testing in TB breakdowns with lesion and/or culture positive animals. Herds in some parts of the Edge Area are subject to six-monthly routine surveillance testing, while others remain on annual testing supplemented with 3km radial testing around TB breakdown herds with lesion and/or culture positive animals (see [Appendix Figure 5.1](#)).
- Considerable effort has been made to correct as many of the data inconsistencies observed in Sam as possible, and we are confident we have used a dataset that is broadly correct. However, this 'data cleansing' effort will

inevitably result in small differences in incident numbers with the National bTB Statistics published every month by the Defra statistics team in York. The APHA TB Epidemiology and GB Data Reports and the National Statistics are produced and published in different ways. The National Statistics are published much more frequently than the APHA Reports (monthly versus annually) and the data carries less of a lag (National Statistics are published three months after data becomes available as opposed to later the following calendar year). A consequence of this prompt publication is that there is less scope to thoroughly check and clean the data in the National Statistics before they are published.

- In most cases, discrepancies between the APHA reports and the National Statistics are a result of the following issues:
 - Some TB incidents do have a start date in Sam that lags behind the true disclosing test date, which may result in placing it in a different period in Sam to the APHA reports.
 - Inaccurate or missing TB10 information, which mark the end of restrictions, has also been a serious issue within SAM and one addressed since the 2012 report. Revisions in SAM, policy changes and user training have reduced many errors in this respect and the situation is now greatly improved, although there are still a very small number of incidents with obviously incorrect or missing TB10 dates which have been may still be corrected. It should be noted that management of the closure of incidents involves the receipt of a BT5 form which provides evidence of cleansing and disinfection on the incident premises. This is required before a TB10 can be issued to formally close the incident. Non-receipt or delays in the receipt of the BT5 form will artificially prolong the duration of incidents, which in effect should last until the final clearing skin test. Policy introduced late in 2015 has attempted to penalise non-returners of the BT5 and the situation appears to be much improved, although slow returns will artificially lengthen the incident duration. A similar delay can also be due to noted discrepancies within the BCMS Cattle Tracing System, whereby animals observed on the farm do not all match those reported in BCMS and which have to be corrected prior to the lifting of restrictions. There are occasionally administrative errors where incidents do not appear on Sam, despite evidence of reactors and short-interval tests occurring in those holdings. These are true new incidents and are counted in the APHA reports, but are few.
 - There are also additional incidents that are counted by National Statistics, but are removed during data cleansing and not represented in the APHA Reports. For example, administrative errors where multiple incidents are

created simultaneously under the same herd can occur. Herds with culture-negative slaughterhouse cases in which no test reactors are found and herds with NVL 1xIRs only (rare) do not constitute new incidents for the purposes of these Reports.

- Work is continually conducted to harmonise reporting between APHA Reports and the National TB Statistics, in the aim of establishing as similar an underlying dataset as possible.

Data processing and analysis

The number of statistical comparisons between the reporting and previous year has been reduced to avoid giving undue emphasis to short-term fluctuations between years. Where a statistical difference is quoted, in tables of frequencies in 2 x 2 tables, we used Fisher's Exact Test. In tables with more than two rows or two columns we used the chi-squared (χ^2) test where the expected frequency for each cell is at least 1.0, and 80% or more of the expected frequencies should be at least 5 (Petrie & Watson, 1999).

Where not otherwise specified, data analysis was performed using Stata v14.0.

Classification of incidents

Since January 2011, cattle herds in GB have been described by their Official Tuberculosis Free (OTF) status. This can be OTF-W (OTF withdrawn), OTF-S (OTF suspended), or if free from any restrictions, OTF. This terminology is used in the surveillance reports.

OTF-S incidents describe herds in which all test reactors failed to disclose visible lesions or positive culture results. Other herds without a TB incident can have their OTF status temporarily suspended after suspect lesions of TB have been observed in a slaughterhouse during routine post-mortem meat inspection and pending a culture result, due to overdue tests, or when IRs only are found within three years of a previous OTF-W incident in the same herd. However, such herds do not contribute to OTF-S incident totals in this report. In some figures differentiation is made between OTF-S incidents with 0-1 or >1 one reactor. Few are classed as 'unclassified', where no post mortem results are available.

For the purpose of this report OTF-W status refers to a herd with a TB incident in which the presence of tuberculosis is confirmed in at least one animal by the isolation of *M. bovis* infection, or classical lesions of tuberculosis are seen at post mortem examination in the carcass of at least one test reactor animal from the herd. Additionally TB incidents in Wales where an epidemiological assessment establishes

the likelihood of infection in the absence of post-mortem evidence of infection can be classified as OTF-W (termed OTF-W-2, but not differentiated from OTF-W within these reports).

To qualify as being “new” within the specified period, a TB herd incident must have been disclosed and restrictions imposed within that period.

4. Methodology

4.1 Incidence

Incidence is the rate of new cases that occur in a population of interest over a specified period of time. Successful control of an epidemic should be reflected by a reduction in the probability that new cases will occur. This can be difficult to measure, particularly where the disease of interest is often chronic and subclinical and detection of infection is dependent on proactive testing of herds at different frequencies. Different approaches will give slightly different values, so when comparing between areas or over time, it is important to understand the characteristics of the measure being used and use the same measures.

The **incidence rate** which is expressed as the number of new incidents per 100 herd-years at risk (HYR) measures the number of new cases of disease that occur in a given time period in the population at risk, whilst taking account of historical testing frequency and the periods that a herd is classified as un-restricted and at risk of infection. **Only herds that have a test during the reporting period contribute to the measure.** This index is generally considered more accurate for comparing incidence between areas than other incidence measures because it accounts for different intervals between tests in herds that other measures such as new TB incidents per number of herds or tests do not.

The number of new incidents per 100 HYR is the measure of TB incidence that is used in the National Statistics for Great Britain. The method has been modified from that described by Downs et al. (2012). The numerator is the number of new TB incidents detected in the year in the area of interest. The denominator is calculated by summing the time that all herds in the same area are considered at risk of a TB incident. A herd was considered to be at risk of a TB incident between a) negative herd tests (herd tests clear of infection), b) a negative herd test and the disclosure of a TB incident and c) from the end of movement restrictions (date of TB10) after a TB incident to the next herd test. The time at risk is calculated at each test or TB incident as the total time the herd was not under restriction since the most recent test (or end of restrictions) before or at the beginning of the year. Only periods of risk that

end in the time period for which the rate is being estimated contribute to the denominator. Expressing incidence as TB incidents per 100 herd-years at risk aims to take better account of the opportunity for infection to be detected.

Different incidence measures

Two other incidence measures have commonly been used to determine incidence of TB: and are also presented in the annual reports new incidents detected 'per 100 unrestricted herds tested' and 'per 100 live herds'. Historically and elsewhere the simpler approach of looking at the proportion of all herds that had a TB incident in the year (incidents per 100 live herds) has been widely used. International notifications of disease status, including to the European Commission often require a measure of incidence derived from the number of new infected herd incidents per 100 herds tested during the period, which excludes herds that were not tested, and so in which TB is very unlikely to be found. The number of new TB incidents per 100 live (i.e. active) herds is the simplest way to calculate incidence, but it does not account for the different frequency of testing in each area of England and the proportion of unrestricted herds that are at risk of a new TB incident. **Thus all herds are in the denominator**, but only those tested can be in the numerator; the effect of testing some herds less than once a year means they have less potential to contribute cases to annual incidence calculation and so bias the calculation towards being an underestimate of the rate at which new cases occur. Using the number of unrestricted herds tested in a year as a denominator addresses this issue to some extent, but it is dependent on the proportion of the herd tested. TB incidents detected through slaughterhouse surveillance also contribute to the numerator, but not to the denominator. As a result, TB incidents per 100 unrestricted herds tested tend to give the highest values of herd incidence compared with the other two methods. The three different incidence measures tend to give similar temporal patterns, however the rate (per 100 herd-years at risk) is usually higher due to the smaller denominator.

Incidence rate ratios

Incidence rate ratios (IRR) indicate the size of the difference in disease incidence between different categories of animal or herd, e.g. of herd size, herd type and risk area, relative to a reference category (see Section 5 for an explanation of the choice of reference category). For example, if a category had an IRR of 2.0, this means that the incidence rate of TB in herds within that category was twice as high as that of the reference category. An IRR of less than 1 represents categories where the incidence rate is lower than that of the reference category.

To investigate the effect of herd type, Poisson regression was used to produce IRRs that adjusted for the effects of herd size and risk area. The adjusted IRRs for the

herd size categories and risk regions were very similar to the unadjusted IRRs. As expected, the incidence rate was significantly lower in the Edge Area and LRA compared to HRA, even after adjusting for the effects of herd size and type.

4.2 Prevalence

Prevalence describes the proportion of herds in an area that are infected at a given point in time. This report presents point prevalence, measured by calculating the proportion of herds under restriction (due to a TB incident) at a given moment. Monthly point prevalence is calculated as the number of live (active) herds under restriction as a result of a TB incident at the mid-point of each month, divided by the reported number of live herds in existence in the middle of each month. Annual average prevalence is the average of the 12 months within the year. At a county level, the prevalence reported represents the number of herds under restrictions at the end of the year, divided by the number of herds in existence **at the end of each year**, in line with TB official statistics and EU definitions.

Herds restricted due to an overdue test rather than a bTB incident are not classified as 'restricted' in this report and therefore estimates of the proportion of herds under restriction will be lower in this report than in the official TB statistics.

4.3 Recurrent TB incidents

A recurrent incident is defined in the GB Data report and the England epidemiology report as: a herd that had a TB incident disclosed in the reporting year (i.e. 2017) that had also been under movement restrictions for a different TB incident in the previous 36 months. Recurrence can result from a general increase in incidence (a herd would have a greater probability of a past TB incident if the past incidence were high), but can be increased if some herds are more likely to have repeated TB incidents than others for particular reasons relating to these herds.

The 'current period' refers to the reporting year (2017). The 'history period' is the 36 months preceding the start date of the incident in the current period or, where no recurrent incident has occurred in a herd, is the 36 months prior to the mid-point of the current period. Analyses included all herds that were considered 'live' in the current period (2017), i.e. active at the end of it. Whether the herd was live in the history period (preceding 36 months) was not checked.

Herds that were under restriction for four months or more in the current period resulting from a TB incident that started in the history period were excluded from analyses. It was considered that such herds had limited opportunity to become TB incidents since there may have been no further testing in the period following the

close of the incident. Setting a threshold of four months allowed for the detection of possible recurrence at the next test scheduled after lifting of restrictions in herds where restrictions were lifted within the first four months of the current year.

In recent years, recurrence has been described in terms of the relative risk (RR) that herds under movement restrictions in the 36-month history period had a new TB incident in the current year when compared with herds with no history of restrictions, and stratified this by risk area, herd type and herd size. Thus the 'relative risk' (RR) was calculated by dividing the proportion of herds with a recent history of TB that had a TB incident in the current year, by the proportion of herds without a recent history of TB that had a TB incident in the current year.

Using this method invites comparisons between the relative risks, but given that for each level of each factor the risk to the denominator population is quite different, comparisons are not strictly valid. This is particularly true for the differences across risk regions, but is also likely to be the case with respect to herd size categories and herd types, as well as the potential that each of these factors are confounded with another.

Based on these assumptions, it was agreed to recalculate this table using a logistic regression where the outcome would be the odds ratio. The odds ratio (OR) represent the odds of a herd having a TB incident in the current year, where the herd has a history of TB incident in the previous 36 months, compared to the odds of a TB incident occurring where there is no history of TB incident. The odds ratio (OR) is a measure of association between an exposure and an outcome. The logistic regression was run on each variable, with 'previous TB incident' as an interaction term to determine if the odds of having a TB incident in the current year were increased where a herd had a history of TB incidents.

Although recurrence is calculable from TB incident data, its cause in any given TB incident is difficult to discern. With surveillance data it is difficult to distinguish between persistent undisclosed ('residual') cattle infection from a previous TB incident and a newly introduced infection event.

4.4 Spatial extent of endemic TB

In order to identify the area of England and Wales affected by endemic TB, a definition of endemicity was developed under the Defra-funded research project SE3045. This enables the expansion and retraction of the endemic TB area of GB to be measured over time and provides a useful tool for decision makers when reviewing the efficacy and implementation of local TB control measures. A geographical unit is considered endemic if there are at least three OTF-W TB

incidents⁴ within a 7km radius of the unit within a two year period. The geographical unit used to map the expansion and retraction of the endemic area in a 500x500m grid cell.

This definition was developed through analysis of TB surveillance data and with input from APHA veterinary field staff and is the best-fitting definition that can be applied on a national level. It is not perfect and will apply better in some areas than in others. For example, small 'endemic' TB areas can appear which could be temporary artefacts due to the chosen definition of endemicity. Whilst acknowledging the limitations of this definition, it does provide a generally applicable and reproducible approach for determining the endemic area. The definition may need to be refined in future to reflect any changes in the epidemiology of TB over time as well as changes to surveillance regimes.

4.5 Further notes on statistical methods

- All statistical calculations were performed in Stata v14.0.
- A chi-squared test was performed for comparing years, e.g. number of TB incidents in 2016 and 2017. A Fishers Exact test was used if a cell value was less than five.
- The estimated significance probability for the Fisher's Exact test for 2 x 2 tables with large numbers is taken from Pezzullo (2010), generally as a two-tailed value.
- A z-test was used to compare prevalence between 2017 and 2018.
- Incidents rates were compared by analysing the deviation of the incidence rate ratio from 1, using the two tailed significance value.
- The reference category chosen for categorical predictors in regression analyses varied. Ideally the reference category was both biologically relevant and had a sufficient number of observations or cases to be statistically sound. However, if the most biologically relevant category had insufficient observations/cases or there was no clear biological advantage in selecting a reference category, then the category with the most observations/cases was chosen.

⁴ This includes OTF-W-2 TB incidents in Wales within the cohort of OTF-W TB incidents. These are herds which have their OTF status withdrawn for epidemiological reasons, without confirmation via post-mortem examination or bacteriological culture.

- In some of the analyses performed, the number of TB incidents may vary depending on when data extraction and analysis were carried out. These variations are generally minor.

4.6 Risk pathway assessment

Investigations of TB incidents to assess the hazard (source of infection) and risk pathway (route by which infection entered the herd) follow the set protocol described below. An assessment is made early on during the investigation and management of the incident, to help guide and prioritise immediate actions; this is the 'provisional assessment'. It is then repeated when all evidence has been gathered/received including e.g. post mortem, tracing and culture results; this is the 'final' assessment. The same protocol is used for both provisional and final assessments. However, the final assessment has two added categories, for the rare cases where infection was ultimately judged not to have been present, namely 'non-specific reaction' and 'anomalous result'. In 2017 refresher training was provided to investigating officers to ensure that, as far as possible, the protocol for risk pathway assessment is applied consistently.

Protocol for risk pathway assessment

The investigating officer is asked to assess all the evidence available to identify the route by which TB infection entered the holding. As there are usually several plausible possibilities, the protocol asks the investigator to use all available evidence plus veterinary judgement to describe how likely the various possibilities are. Up to three risk pathways can be recorded, and each must be given a probability value, choosing from the options 'definite', 'most likely', 'likely' and 'possible'. The investigator must summarise the evidence in support of their selection(s) and is advised that 'Although it will often not be possible on a particular farm to say for certain how the cattle got infected, consideration of how this may have happened in light of the husbandry practised, biosecurity measures in place, and other findings in the investigation will make some pathways more likely than others.'

Each assessment is comprised of a 'hazard' which is the original source of infection, for example infected cattle, infected badgers, other infected domestic or wild animals, and a risk pathway, for example cattle movements from a defined risk area, exposure during housing or at pasture, etc. Additionally investigators are asked to record risk pathways that have been excluded e.g. movements on a completely closed farm or contiguous contact when there are no neighbouring cattle.

5. Discussion of methods to measure test accuracy

Sensitivity and specificity are useful for describing respectively, how likely a test will be to find all the infected animals or herds, and how likely it is that some of the animals that are infected will test negative and so be missed. So knowing the test's sensitivity means you can work out how many animals or herds that are infected are likely to be missed, and knowing the specificity you can work out how many animals or herds that test positive are not actually infected. The ability to identify diseased animals (sensitivity) or to correctly measure that an animal is not infected (specificity), directly affect how well controls that seek to remove infected animals for the herd (e.g. removal of reactors), or to allow only uninfected animals to be moved (e.g. pre-movement tests) will work.

Ideally tests should have both high sensitivity and specificity as effective disease eradication depends on finding and removing all infected animals. Of particular note is that there is a trade-off between sensitivity, i.e. ensuring that all infected animals will give a positive result to the test, and specificity, i.e. ensuring that uninfected animals give a negative result. Thus if we lower the threshold of a positive result (e.g. how much the skin thickness has to increase to call the animal 'positive') to increase sensitivity, we increase the chances of wrongly categorising an *uninfected* animal as infected, a 'false positive' result (i.e. a reduction in specificity). Therefore, different test interpretation policies are applied according to the area, herd history and other factors to make the best compromise for the circumstances. In TB most tests have more of a problem with sensitivity, so they fail to find all infected animals (i.e. infected animals may give a negative test result) but tend to have a high specificity, so it is very unlikely that an uninfected animal will give a positive test result.

An important use of sensitivity and specificity values is to estimate a test's predictive values – that is if you get a positive or negative test result for an animal, how well does that predict whether the animal is infected or not.

The **positive predictive value (PPV)** of a test is defined as the probability that a positive testing animal is truly infected. Conversely, **the negative predictive value (NPV)** is the probability that an animal with a negative test result is truly free from infection. Both of these measures depend on the proportion of the population that is infected (the prevalence of infection) as well as the sensitivity and specificity of the test.

As a general rule, the higher the prevalence of infection in a population, the higher the PPV and the lower the NPV of a diagnostic test. In other words, the same

diagnostic test for *M. bovis* infection in cattle will not have the same predictive value when used in different infection risk or prevalence areas. Due to effect of stage of infection on sensitivity, and the differing prevalence of disease in different parts of the country, it is not easy to calculate 'average' predictive values for the available TB tests, although their values in areas of different prevalence are useful for planning how tests should be interpreted.

The main detection test used for surveillance in UK, the single intradermal comparative cervical test (SICCT) is very good when it gives a positive result (i.e. if cattle test positive, they almost certainly have TB), but can miss infected cattle. When this happens some cattle may have no reaction, while others will not give a big enough reaction to be classified as positive. These are called 'inconclusive reactors' and will require an additional test to decide their true disease status. If they retest as inconclusive or positive, they are classified as infected and are slaughtered, and incident procedures are triggered.

The limitations of the SICCT can be addressed by changing the way its results are interpreted, as is done with 'standard' or 'severe' interpretation, which changes the threshold of a positive result. It can also be improved by using an understanding of how likely IRs are to be truly infected, from statistics such as presented in this report, and by the use of the more sensitive supplementary gamma interferon test. These options are explored below.

The specificity of the SICCT test at different interpretations in GB was recently estimated⁵. This was found to vary not only with the different positive cut-off points for standard and severe interpretation, but also across regions within GB. The table below shows how likely a test positive animal is to truly be infected (i.e. the PPV) if the test is read at different levels of severe interpretation, and depending on where the animal is, reflecting the likelihood that it has been exposed to infection.

According to the calculated PPV of the SICCT test, 91.8 per cent of reactors in GB are infected, varying between 92.3% in the high-prevalence counties and 76.9% in the low-prevalence counties. This study indicates that the SICCT test, as used in GB, has a very high specificity, meaning that at standard interpretation it will give rise to one false positive animal for every 4760-7690 animals tested. Conversely, the findings suggest that over 90 per cent of reactor cattle identified only by skin test in GB between 2002 and 2008 were infected and endorse the compulsory slaughter of all SICCT test reactor cattle for effective disease control.

⁵ Goodchild, A. V., et al. (2016). "Specificity of the comparative skin test for bovine tuberculosis in Great Britain." 177(10): 258

Table 4.1. Selected data from Table 6 in Goodchild et al (2016):

Calculation of the positive predictive value (PPV) for the Single Intra-dermal Comparative Cervical Tuberculin (SICCT) test in three groups of Great Britain (GB) counties that vary in bovine tuberculosis (TB) prevalence, with 95% confidence intervals based on the confidence intervals of specificity

Group of counties and description	High prevalence GB High-Risk Area+4 Welsh counties	Medium prevalence GB Edge Area +3 Welsh counties	Low prevalence GB Low-Risk Area +Gwynedd +Anglesey +Scotland	All of GB
PPV if the interpretation was severe only for OTF-W incidents (with 95% confidence interval)	92.3% (91.1 to 93.7%)	88.6% (86.4 to 90.9%)	76.9% (72.1 to 82.0%)	91.8% (90.5 to 93.3%)
PPV if all tests had been at severe interpretation (with 95% confidence interval)	89.5% (88.2 to 91.3%)	74.8% (71.6 to 79.0%)	46.6 (39.7 to 55.4%)	87.7 (86.1 to 89.7%)
PPV if all tests had been at ultra-severe interpretation (with 95% confidence interval)‡	88.9% (87.4 to 90.3%)	74.3 (70.7 to 77.5%)	43.2 (35.3 to 50.3%)	86.9 (85.1 to 88.6%)

In summary, in high or intermediate prevalence situations, nearly every single reactor detected by the comparative skin test is truly infected, especially in the HRA and in short interval and herd risk tests. Thus a positive SICCT test provides strong evidence of infection in TB incidents in these risk areas independent of post-mortem confirmatory evidence. As expected, PPV increases with the test Se, Sp and animal prevalence.

However, the lower predictive value of the skin test in lower incidence areas such as the LRA, parts of Wales and in Scotland, suggests that some test positive animals

without post-mortem evidence of disease in these areas are not truly infected with TB.

Note that measurement of all test characteristics depends on knowing the true status of the animal, which should be measured using a 'gold standard' test. However, such a test is lacking for cattle in the early stages of TB infection. The difficulty in knowing whether an animal is truly uninfected (or actually in the early stages of disease) means that estimating specificity and negative predictive value is particularly challenging. Careful use of test application or interpretation to improve predictive values, and consideration of other evidence when deciding whether a test negative animal is truly uninfected, can improve accuracy and enable the heterogeneity of the epidemic to be taken into account when designing control measures.

Actions to increase detection of infected cattle in a TB infected herd

Surveillance tests are imperfect, so when there is some evidence of infection with *M. bovis*, in a herd, options have been developed to enhance the chance of detecting all infected cattle. These include:

Increasing the number of herd SICCT tests (so called short-interval (SI) tests) that the herd must pass to regain OTF status following disclosure of one or more reactors.

Severe interpretation of skin test: Increasing the sensitivity in this way will reduce the specificity of the skin test with 1 in 1,111 cattle potentially being a false positive reactor, instead of 1 in 5,000 at standard reading⁶. However, note these values apply to individual animals and test sensitivity is higher at the herd level and classification of a herd as infected is more accurate, particularly when more than one reactor is detected.

Consider removal of non-reactor cattle as DCs: this relates to cattle that have been in contact with other infected cattle but can also be based on test history e.g. One or more previous classification as an IR (that may have resolved), or belonging to a cohort in which there has been a high percentage of reactors detected.

Supplementing the skin test with the interferon-gamma blood test, applying a parallel interpretation of the results so that animals reacting to either or both tests are regarded as infected and removed from the herd.

⁶ The Strategy for achieving Officially Bovine Tuberculosis Free status for England:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/300447/pb14088-bovine-tb-strategy-140328.pdf

6. Surveillance

6.1 Surveillance overview

Bovine tuberculosis is a slowly progressing insidious disease that is not clinically apparent for some time after infection, but which can spread during this time. This means that surveillance on apparently healthy animals is needed in addition to investigating apparent clinical cases of TB, to get ahead of disease spread. Surveillance involves both active surveillance where live animals are tested and passive surveillance whereby there is a requirement for the government to be notified if anyone suspects TB. The latter occurs mainly from cattle being processed through slaughterhouses. Active surveillance can be modified in the different parts of the country to reflect the different likelihood of TB either being present or being detected.

The ability to detect TB using a particular test depends on how likely disease is to be present and how good the test is. The likelihood of infection with TB is associated with location, herd type and herd size, as well as whether the herd has previously been infected. These important differences in likelihood of disease presence in herds, regardless of whether it is detected or not, affect how surveillance is best carried out and how effective it is at finding infected herds and animals.

6.2 Surveillance Streams definitions

The term 'Surveillance Stream' was coined in 2016 to classify bovine TB surveillance systems in the England Epidemiology Report according to the intention behind the activities carried out to detect disease. Broadly speaking, there are two types of activities among the four streams defined below: slaughterhouse surveillance and application of the TB skin test (SICCT). The definitions for the surveillance streams encompassing these are below. Tests carried out as part of the Area & Herd risk surveillance stream have been further divided by purpose: primarily aiming to detect disease (surveillance) or aiming also to stamp it out (control).

Routine live animal testing and slaughterhouse surveillance are used to detect TB in herds or animals not expected to be at any increased likelihood of being infected, while 'Area and Herd Risk' surveillance, and 'Proactive surveillance' are targeted at herds or animals thought to be at higher risk of being infected, and/or where there would be a higher impact if they were infected (e.g. pre- and post-movement testing before moving to a lower risk area).

SURVEILLANCE STREAMS DEFINITIONS	
ROUTINE	Disease first disclosed as a result of tests scheduled as part of routine surveillance with no expectation of increased or decreased probability of disclosing infection
AREA & HERD RISK	Disease first disclosed as a result of targeted tests carried out due to history or other epidemiological evidence that there is a higher probability of disease in the animal or herd
SLAUGHTERHOUSE SURVEILLANCE	Disease first disclosed as a result of routine post-mortem meat inspection during commercial slaughter of animals not believed at higher likelihood of being diseased (excludes results of inspection of test reactor cattle and DCs removed by APHA)
TRADE & OTHER SURVEILLANCE	Disease first disclosed as a result of testing scheduled due to the high impact of disease if present, in the destination herd / premises (includes tests on animals where the presence of some epidemiological risk factors may increase disease probability but this is not the primary reason for testing). Referred to as Proactive surveillance in earlier reports.

6.3 Surveillance Streams classification table

TEST CODE	NAME	ENGLAND SURVEILLANCE REPORT (2018) CATEGORIES	SURVEILLANCE STREAMS (2016 onwards)	SURVEILLANCE PURPOSE
CON, CON6, CON12	Contiguous Test	Area & Herd Risk Contiguous tests	Area & Herd Risk	Control
CT(RTA)	Check Test (Road Traffic Accident)	N/A	Area & Herd Risk	Surveillance
CT-HS1, CT-HS2	Check Test (Hotspot)	Area & Herd Risk Hotspot tests	Area & Herd Risk	Surveillance
RAD,RAD6, RAD12	Radial Test	Area & Herd Risk Radial test	Area & Herd Risk	Control
90D	See TBU test	N/A	Area & Herd Risk	Surveillance
CT	Check Test	N/A	Area & Herd Risk	Surveillance
CT(EM)	Check Test (Exposure Mitigation) (Backward tracing herd test)	Area & Herd Risk Backward tracing test	Area & Herd Risk	Control

CT(I-I)	Check Test (Investigation and Intervention)	Area & Herd Risk Check test	Area & Herd Risk	Surveillance
DTG	Delayed Testing Group	N/A	Area & Herd Risk	Control
IFN, IFN LOW IN, IFN PERSI, IFN NSR, IFN SLHERD, IFN ANOM, IFN NBCP/PBCP, IFN OTH_SP, IFN PRI	Gamma Interferon Test (OTF-W LRA, OTF-W persistent TB incidents, non-specific reactor herd, whole or partial reactor herd slaughter, anomalous reactions procedure, badger culling area tests, disease in other species present, private	Area and Herd Risk Not typically disclosing tests	Area & Herd Risk	Control
PSI	Partial Short Interval Test	N/A	Area & Herd Risk	Control
SI	Short Interval Test	Area and Herd Risk Not typically a disclosing test	Area & Herd Risk	Control
IASI	SI test in OTF-S herds in Wales Intensive Action Area only	N/A	Area & Herd Risk	Control
TBU (former 90D)	TB Unit Test (AFUs)	Area and Herd Risk AFU test	Area & Herd Risk	Surveillance
12M	Twelve Month (Post-TB incident) Test	Area and Herd Risk Post-incident tests	Area & Herd Risk	Control
6M	Six Month (Post-TB incident)Test	Area and Herd Risk Post-incident tests	Area & Herd Risk	Control
IR/IFN 2xIR	Inconclusive Reactor Test / Gamma Interferon Test severe 2xIRs (Wales only)	Area and Herd Risk Not typically a disclosing test	Area & Herd Risk	Surveillance
TR	Traced Bovine Test	Area and Herd Risk Forward tracing tests	Area & Herd Risk	Control
Old RH*	Reformed Herd Test	N/A	Area & Herd Risk	Surveillance
ASG	Approved Segregated Group Test	Area and Herd Risk Not typically a disclosing test	Area & Herd Risk	Control (if on TB incident herd)
AI	Artificial Insemination Centre Test	Trade and Other Pre-movement testing	Trade & other	Surveillance

BHH	Bull Hirer Test (Scotland only)	N/A	Trade & other	Surveillance
CT-LRA-SA	LRA Pre-Sale Check Test	Trade and Other Pre-sale check LRA	Trade & other	Surveillance
EX	Export Test	Trade and Other Pre-export	Trade & other	Surveillance
PII	Post-Irish Import Test	Trade and Other Post-export	Trade & other	Surveillance
PIO	Post-Import Test	Trade and Other Post-export	Trade & other	Surveillance
POSTMT/ POSTMOVNC/ POSTMOVOV	Post-Movement Tests	Trade and Other Post-movement	Trade & other	Surveillance
PRI	Private Test	Trade and Other Private tests	Trade & other	Surveillance
PRMT	Pre-Movement Test	Trade and Other Pre-movement testing	Trade & other	Surveillance
CT-NH1/2/3	New Herd Test	Routine New Herd tests	Routine	Surveillance
OT	Other	N/A	Routine	Surveillance
RHT/RHT48	Routine Herd Test	Routine Routine Herd tests	Routine	Surveillance
WHT	Whole Herd Test	Routine Whole Herd tests	Routine	Surveillance
IA6/IA12	Routine 6M/12M test within the Welsh Intensive Action Area area only	N/A	Routine	Surveillance
SL	Slaughterhouse	Slaughterhouse Surveillance Stream		
* No distinction in the system between Reformed Herd tests and New Herd tests.				

7. Genotyping

Attempts are made to recover the *M. bovis* organism from all TB incidents and to subject at least one isolate per TB incident to molecular (DNA) typing. This identifies the 'genotype' (a sequence of numbers and letters) of the *M. bovis* isolate recovered by analysing its spoligotype and VNTR (Variable Number Tandem Repeat), a means of identifying particular sequences in the genome of the bacterium. This knowledge is used to describe areas where particular genotypes are common, so called 'home ranges' and then to compare isolates from new TB incidents with the previous known distribution, including the home range, of the particular genotype identified.

Explanatory notes and summary of insights from TB genotyping in GB (2000 to 2014)

- Homorange maps are an attempt to capture the geographical localisation (endemic regions) of the various strains (genotypes) of *M. bovis* found in GB. They have proved extremely useful for identifying the expected genotype at a given location and thus support epidemiological investigations at the national, regional and individual incident level. The homorange maps display the 27 genotypes for which enough data exist, representing >96% of GB isolates.
- The genotype of any given *M. bovis* isolate is defined by a combination of its spoligotype and VNTR type. These are two different DNA fingerprinting techniques targeting different segments of the *M. bovis* genome.
- At least one *M. bovis* isolate for every new (OTFW) incident undergoes genotyping at APHA, to support outbreak investigations by field veterinary officers. In combination with Cattle Tracing System movement records, this is a powerful tool to establish the likely source of new bTB incidents. This also helps build up a picture of the molecular epidemiology of bTB in GB, which is characterised by several "mini-epidemics".
- A homorange defines a geographical area in which a certain genotype of *M. bovis* is not unexpected. A simple algorithm to define homorange area for the common genotypes of *M. bovis* was developed as part of Defra research project SE3257. This is the same criterion as that used in previous reports to the Commission, i.e. a 5 km square is considered as part of a certain homorange if there have been three different incidents of that genotype, on at least 2 holdings, within a 5 year window. In order to create coherent area for each genotype, a 10km buffer is then drawn around each of the homoranges so defined.

- The frequency of each genotype found in GB cattle has not varied significantly over a decade of monitoring in spite of an increase in the number of incidents (Annual TB Surveillance Reports, 2001-2018).
- The genotypes of bTB found in companion animals, domesticated animals and other farmed species apart from bovines are, in general, identical to those found in neighbouring cattle herds. There are not host-specific genotypes of bTB in GB.
- Specific genotypes of *M. bovis* are geographically localised in GB leading to the development of the 'homerange' concept for 97% of TB isolates (Project SE3257). The relatively stable homeranges for *M. bovis* in GB are incompatible with cattle movement patterns, which suggest that the geographical localisation of genotype homeranges is caused by wildlife reservoirs of infection.
- Over 80% of cattle incidents are within homerange and over 95% of cattle incidents are in-homerange or within 50km of homerange. For the limited badger isolates that we have, 96% of genotyped isolates from badgers are in, or within 50Km of the equivalent cattle homerange (Project SE3257).
- Roughly half of the cattle TB incidents that are 'out-of-homerange' can be explained by inward movement of an infected animal from a holding located in the homerange of the genotype of *M. bovis* responsible for the incident on the destination farm (Project SE3257 and LRA Annual Reviews 2012 / 13).
- The analysis in Project SE3257 suggests that TB incidents caused by the long-distance movement of infected cattle out of homerange represent at most 7.5% of the total number of incidents in GB per year and, more likely, 3% of incidents and that 70% of these out-of-homerange infected animals are detected within three years.

8. Additional TB controls in Great Britain in 2018

8.1 TB control in England

Bovine TB is subject to statutory control in England following as set out in [The Strategy for achieving Officially Bovine Tuberculosis Free status for England](#)⁷ published in 2014 and the [Bovine TB Strategy Review](#)⁸ published in 2018. The aim of the Strategy is to eradicate TB by 2038 while maintaining an economically sustainable cattle industry. Under the Strategy England is divided into three areas reflecting the level of disease in each and controls differ accordingly. Control in all areas is based on a range of surveillance and control measures, which were described in detail in the England Epidemiology Report of the 2016⁹ data published in 2017 (Sections 3.5 and 3.7 and Appendices 1b and 6). Up to date information on current policies can be found at www.tbhub.co.uk.

Table 8.1.1 New TB control measures introduced in England in 2018

<p>Annual surveillance TB testing for lower risk herds in the six-monthly testing parts of the Edge Area</p> <p>All cattle herds in the high bovine TB incidence counties of Cheshire, Oxfordshire, and Warwickshire and in parts of Berkshire, Hampshire and Derbyshire are subject to routine six-monthly surveillance testing. From May 2019 cattle herds in these parts of the Edge Area will be eligible for annual surveillance testing if they meet either of the following criteria:</p> <ul style="list-style-type: none">• the herd has been in existence for at least six years and has not had a TB breakdown in that six year period. A single break from keeping cattle of less than four months during the six year period is permitted• the herd is registered to a bovine TB health scheme accredited under the Cattle Health Certification Standards (CHeCS) at level 1 or above

⁷ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/300447/pb14088-bovine-tb-strategy-140328.pdf

⁸ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/756942/tb-review-final-report-corrected.pdf

⁹ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/593226/tb-epidemiology-england-2015.pdf

Changes to compensation paid for cattle compulsorily slaughtered for bovine TB control

There will be a reduction in compensation for the following.

Unclean cattle:

- Cattle producers in England are required to ensure the cleanliness of animals presented for slaughter under the clean livestock policy.
- TB affected animals removed for TB control purposes must meet the same standards of cleanliness that are applied to all other animals sent for slaughter.
- Food Business Operators (FBO), including slaughterhouses have a responsibility under the legislation to produce food safely by applying robust hygienic practices.
- At the slaughterhouse animals are checked by Food Standards Agency (FSA) staff before slaughter for cleanliness and dryness. To prevent the contamination of meat and reduce risks to public health, the Official Veterinarian (OV) at the slaughterhouse may reject for slaughter any animal that does not meet the required standard of cleanliness.
- To protect public health and the welfare of cattle, since 1 November 2018, a 50% reduction in compensation is applied for cattle that cannot be processed for human consumption at a slaughterhouse because they are unclean. Only a very small proportion of the TB infected cattle sent to slaughter will be affected.

Cattle moved into a TB breakdown herd and subsequently removed for TB control purposes:

- There are a number of reasons why owners of TB-restricted herds may need to bring cattle onto their holding, however these cattle are at greater risk of becoming infected than cattle moved into OTF herds.
- Owners of TB-restricted herds can move cattle onto their holding in defined circumstances, under licence and subject to a favourable veterinary risk assessment by APHA. In this situation, the taxpayer takes a disproportionate share of the financial risks associated with introducing cattle into TB breakdown herds, in particular the cost of compensation if those animals become reactors.
- For this reason, Defra has followed the example of the Welsh Government and applies a 50% reduction in compensation for animals moved into a TB breakdown herd that are subsequently removed as TB reactors (or direct contacts) before the herd regains OTF status.
- The 50% reduction in compensation payment does not apply where the herd is registered to a bovine TB health scheme accredited under the Cattle Health Certification Standards (CHeCS), provided that accreditation was gained prior to the herd losing its OTF status.
- The 50% reduction in compensation payment also does not apply to Approved Finishing Units (AFU), Licensed Finishing Units (LFU) and TB Isolation Units.

Enhancing private slaughter arrangements for cattle compulsorily slaughtered for bovine TB control

It has been recognised that some owners could benefit from the private slaughter option, for example beef finishers that have a good working relationship with their slaughterhouse operator and can negotiate higher salvage payments than the rates of compensation payable by Defra. For this reason, Defra is incentivising the option of private slaughter so that owners can realise this benefit where possible.

Defra will pay full compensation for cattle compulsorily removed for TB control purposes that are privately slaughtered but the carcase is totally condemned by the slaughterhouse operator due to TB.

Removal of the animal must take place within ten working days of it being identified as a TB reactor or DC. If the animal is not removed within the specified time period, APHA will organise removal to one of their contracted slaughterhouses and the owner will receive compensation as per normal arrangements.

Expansion of the Edge Area and cattle testing arrangements

In most Edge Area counties there is evidence that infected herds are being discovered sooner after infection is introduced than in the past, indicating some success in control measures¹. However, it is essential that cattle measures are strengthened to reverse the trend of rising levels of bovine TB, and halt the spread of disease.

The following changes were implemented from January 2018.

Re-classification of Edge Area counties

The following part Edge, part HRA split counties were re-classified as fully in the Edge Area:

- Cheshire
- Derbyshire
- East Sussex
- Oxfordshire
- Warwickshire

Cattle testing arrangements in the Edge Area

Herds in some parts of the Edge Area are subject to six-monthly routine surveillance testing, while others remain on annual testing supplemented with 3km radial testing around TB breakdown herds with lesion and/or culture positive animals.

Routine six-monthly herd testing in Warwickshire, Oxfordshire, Cheshire, the west of Berkshire, northwest Hampshire and west Derbyshire – i.e. where the level of disease is highest and where radial testing may be impractical or administratively complex

Radial testing around TB breakdowns with lesion and/or culture positive animals in all other parts of the Edge Area, as currently happens in the LRA

Information showing the previous surveillance testing regime and current testing regime for each Edge Area county can be found at www.tbhub.co.uk

8.2 TB control in Scotland

Scotland has been officially bovine TB (TB) free (OTF) since 2009 and the Scottish Government is committed to a comprehensive, practical and proportionate programme of actions in order to maintain current low levels of TB and to safeguard OTF status.

TB controls in Scotland are underpinned by the provisions of the Tuberculosis (Scotland) Order 2007 and by the risk based routine herd testing policy introduced in 2012, whereby “low risk” herds became exempt from the four yearly routine herd testing programme.

Further information on [TB in Scotland](#) can be found on the Scottish Government website¹⁰.

Table 8.2.1 - TB cattle measures in Scotland introduced in 2018

On 12 December 2018 [The Tuberculosis \(Miscellaneous Amendments\) \(No 2\) Order 2018](#) came into force.

These new rules include changes to disease control measures and compensation arrangements

8.3 TB control in Wales

Bovine tuberculosis (TB) is subject to statutory control in Wales and is directed by the principles set out in the Bovine TB eradication programme. TB controls are underpinned by the Tuberculosis (Wales) Order 2010. Details about TB in Wales and the surveillance and control measures associated with the eradication programme can be found on the [Welsh Government website](#)¹¹.

¹⁰ <http://www.gov.scot/Topics/farmingrural/Agriculture/animal-welfare/Diseases/disease/tuberculosis>

¹¹ <http://gov.wales/topics/environmentcountryside/ahw/disease/bovinetuberculosis/bovinetberadication/?lang=en>

Table 8.3.1 - TB policy measures introduced in Wales in 2018

<p>The Wales TB Eradication Programme Delivery Plan was published in 2017.</p> <p>As part of this plan a new regionalised approach to TB eradication was launched and a number of region-specific measures outlined</p> <p>Key changes include:</p> <ul style="list-style-type: none">• Introduction of Wales TB areas (High West, High East, Intermediate North, Intermediate Mid and Low)• Post-Movement Testing is required for all cattle moved into the Low TB Area• Pre-Movement Testing is longer required for cattle moved within or from the Low TB Area <p>In the intermediate and high TB areas key changes include:</p> <ul style="list-style-type: none">• Biosecurity Requirements Notices (BRNs) will be issued as necessary to OTFW chronic breakdown herds• Clearing tests will not be allowed as Pre movement tests from 1 October 2017• Slaughter of all inconclusive reactors (IRs) in chronic herd breakdowns. <p>Wales-wide measures include the phasing out of Exempt Finishing Units (EFUs) by 1 January 2018, a compensation cap applied from 1 October 2017 and the continuation of a badger found dead survey</p> <p>For the full details of the delivery plan please Welsh Government website (link below). https://gov.wales/sites/default/files/publications/2017-11/wales-bovine-tb-eradication-programme-delivery-plan.pdf</p>
<p>Enhanced surveillance in Intermediate TB Area North (ITBAN):</p> <p>From November 2018, enhanced surveillance in herds which are contiguous to a TB breakdown was introduced in ITBAN</p>