Bovine tuberculosis in England in 2016

Epidemiological analysis of the 2016 data and historical trends

September 2017

Incidence Rate Ratios (unadjusted & adjusted) for new TB incidents in herds of different size or type, and by risk area in 2016

Republished November 2017 with minor editorial corrections
Cover picture is Figure 4.2.1c
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HOW TO READ THIS REPORT: The detail in this report is tiered and readers are advised to read the Executive Summary first, followed by the bulleted text at the start of each section. If more detail is wished on any of the points described this can then be explored in the relevant section.
<table>
<thead>
<tr>
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This report was commissioned by Defra under Project SB4500 and through the TB Epidemiology Enhancement Project. It replaces the previous Annual Surveillance Reports for England¹. Analyses were conducted in this report at county level and by risk area for England. Wales continue to report surveillance² separately. TB data³ for all GB administrations for 2016 is published separately.

²http://gov.wales/topics/environmentcountryside/ahw/disease/bovinetuberculosis/bovinetberadication/?lang=en

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1. Executive summary

1. This Executive Summary introduces this report about the bovine tuberculosis (TB) epidemic in England and provides an overview.

2. The report describes the England control strategy and then presents separate chapters, with summary bullets, supported by detailed text on (i) the level of TB in England and changes over time, (ii) the characteristics of infected herds, (iii) the effectiveness of surveillance, (iv) the impact of TB and of the control measures, (v) the effectiveness of controls, and (vi) the detailed epidemiology of disease in each risk area. A glossary is also provided. The data that support this report are presented separately on line in the GB TB Data Report, and a link is provided.

3. Bovine TB in England is subject to statutory control based on the strategy published in 2014, which divides the country into three ‘risk’ areas determined by their level of disease. The High Risk Area (HRA), mainly in the west and south-west, had the great majority of new TB incidents in 2016. The Low Risk Area (LRA) in the north, east and south-east had very few TB incidents in 2016 and continued to fulfil the criteria for Officially TB Free (OTF) status designation set out in EU legislation. The Edge Area, which lies between the HRA and LRA, had 10% of the new TB incidents in 2016.

4. Control of TB is based on systematic testing of herds to identify and remove infected cattle, with restrictions and interventions applied during the removal process to prevent the spread of disease and reduce the risk of disease persistence. A range of new controls including new licenced badger cull areas came into effect during 2016.

5. The level of TB in England increased steadily from 1986 to 2010 and has since plateaued. This plateau hides a significant increase in incidence between 2015 and 2016 in the Edge Area, where a new endemic area has appeared in north Leicestershire. In 2016 TB incidence in the HRA fell slightly, to the level seen in 2014; the level of TB in the LRA remains very low.

6. Although the rate of new infections is no longer increasing in the HRA, over half the herds with new incidents in the HRA in 2016 had previously been infected with TB, confirming that recurrent infection is an important driver of the epidemic here. This is also highlighted by the frequency with which TB infection is revealed by check tests carried out 6 or 12 months after an incident has been resolved. Such ‘risk-based’ testing was more successful at finding infected herds in the HRA in 2016 than routine testing.

7. In the Edge Area the epidemic continues to propagate, driven mainly by the introduction of purchased cattle that have undisclosed TB infection, but also by the development of local areas of infection that in some cases may be driven by infection in the local badger population.
8. In 2016, as in previous years, herds located in the HRA (where there is high infection pressure from infected herds and from infection in badgers), herds with over 300 cattle (which have a greater tendency to be in the HRA) and herds that had previously been infected, were the most likely to be found infected with TB. Dairy herds were found to have an additional risk of TB infection that could not fully be explained by their size or location.

9. Key data for 2016 are presented in Table 1.1.

Table 1.1 Key bovine TB parameters in 2016 (selected 2015 values given in brackets)

<table>
<thead>
<tr>
<th>Overview</th>
<th>High Risk Area</th>
<th>Edge Area</th>
<th>Low Risk Area</th>
<th>England Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of herds detected as infected (total new herd incidents, 2015 values)</td>
<td>3,229 (3,401)</td>
<td>387 (339)</td>
<td>137 (156)</td>
<td>3,753 (3,896)</td>
</tr>
<tr>
<td>Number of open incidents at the end of 2016</td>
<td>2,536 (2,574)</td>
<td>207 (196)</td>
<td>45 (58)</td>
<td>2,788 (2,828)</td>
</tr>
<tr>
<td>Herd incidence per 100 herd-years at risk (2015 values in brackets)</td>
<td>17.9 (18.8)</td>
<td>6.7 (5.6)</td>
<td>1.0 (1.0)</td>
<td>10.2 (9.8)</td>
</tr>
<tr>
<td>Average monthly prevalence (%) (2015 values in brackets)</td>
<td>10.7 (10.5)</td>
<td>3.3 (2.7)</td>
<td>0.3 (0.3)</td>
<td>5.4 (5.2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Duration</th>
<th>Median duration of restrictions for all incidents(^3) (days) [25-75(^{th}) percentile]</th>
<th>185 [146 – 289]</th>
<th>166 [140 – 238]</th>
<th>126 [80 – 201]</th>
<th>182 [146 – 285]</th>
</tr>
</thead>
<tbody>
<tr>
<td>% persistently infected herds(^4) (2015 values in brackets)</td>
<td>6.6 (6.5)</td>
<td>4.3 (2.9)</td>
<td>0.7 (0.8)</td>
<td>6.1 (6.0)</td>
<td></td>
</tr>
<tr>
<td>Number of open cases at the end of 2016 with duration &gt;550 days</td>
<td>337</td>
<td>13</td>
<td>0</td>
<td>350</td>
<td></td>
</tr>
</tbody>
</table>

| Recurrence | % incidents involving previously infected herds, within last 36 months | 58.2 (58.0) | 29.2 (28.7) | 13.1 (7.1) | 53.4 (53.2) |

\(^1\) 44 (32\%) of TB cattle incidents in the LRA were lesion- and/or culture-positive (OTF herd status withdrawn)

\(^2\) Includes all suspect and confirmed incidents

\(^3\) That closed in 2016.

\(^4\) Incidents that had lasted >550 days that closed in 2016.
2. Preface

This report together with the concurrently published report titled ‘Bovine tuberculosis in Great Britain. Surveillance data for 2016 and historical trends’ (referred to hereafter as the ‘GB TB data report’) replace the previously published Annual Surveillance Report titled ‘Bovine tuberculosis: Infection status in cattle in England’ (last published in 2015, reporting the 2014 data). That report has been replaced to make its content more accessible, particularly for the lay reader, by presenting the descriptive epidemiology, analyses and discussion of the contributing factors for the epidemic in this separate report with selected graphics, including maps, and descriptive text.

The supporting detailed surveillance data tables, additional graphics and the majority of data published in previous annual reports are published separately, on line, in the ‘GB TB Data Report’ which presents all similar data for England, Scotland and Wales; the contents list and a link to that report are provided in Appendix 2. Note these data are derived from the same source as Defra’s ‘National Statistics’ on the incidence and prevalence of bovine tuberculosis (TB) in Great Britain. These include monthly statistical reports and other quarterly statistics on specific aspects of the TB surveillance regime⁴, such as pre-movement testing and TB in non-bovine species. However due to the timing of this report the data presented here are more complete for 2016, as results from investigations and testing that were completed in the first months of 2017 are included. This additional time has been used to good effect to remove duplication and correct other transactional errors, so data in this report will not exactly match those in the statistics notices.

This epidemiology report describes the bovine tuberculosis epidemic in cattle in England in 2016 and includes commentary and analyses in light of the associated intervention policies. The report has sections that separately present and discuss the level of disease and changes over time, our success in finding cases (surveillance), the impact of the disease and of control measures, and the effectiveness of controls in reducing transmission. Later sections describe the epidemic in each of the England risk areas.

A separate report will be published later in the year providing epidemiological parameters and observations for each county in the Edge and High Risk Areas. Bovine TB surveillance and control are complex processes and a wealth of jargon has developed, which has become common parlance to those closely engaged with the control programme. This report tries to limit its use and to include explanatory text. Esoteric language is explained when first used, and there is a glossary at Appendix 1.

An Explanatory Supplement⁵ is published concurrently with additional explanation about the disease, the data and methodologies used and the approach to control.

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3. Control of bovine tuberculosis (TB) in England

Bovine tuberculosis (TB) is the most pressing animal health problem in England. It is an infectious and contagious bacterial disease, with two main reservoirs here (cattle and badgers), that threatens our cattle industry and presents risks to other livestock, wildlife and domestic pets. The TB level in parts of England is the worst in the EU and probably the worst in the developed world, and poses an increasing risk to intra-EU and international trade of cattle and their products. TB can also threaten human health, and although widespread pasteurisation of milk largely protects the public from undisclosed cases of TB in cattle, the bovine epidemic and associated spill-over into other domestic species puts their keepers at risk.

In view of these impacts, bovine TB has been subject to statutory controls in England since the 1950s with substantial success over the years. More recently disease has spread, and in April 2014, Defra published its strategy for achieving Officially Bovine Tuberculosis Free Status (OTF) for England (Figure 3.1).

![Figure 3.1 Summary graphic of the England TB Eradication Strategy](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/300447/pb14088-bovine-tb-strategy-140328.pdf)
The Strategy defines disease control measures that aim to eradicate bovine TB by 2038, achieving OTF status for England incrementally, whilst maintaining trade, and an economically sustainable livestock industry. One of its key features is to divide the country into three ‘risk areas’ defined by the level of TB in them in 2014, each with bespoke controls. Compulsory TB controls in cattle are based on the regular testing of herds to detect disease, slaughter of positive animals and the imposition of movement restrictions following a failed test. The latter remain in place until there is sufficient evidence that TB infection has been removed from the herd. Such evidence will differ according to local circumstances, in particular the risk area in which the herd resides.

A range of new controls were introduced in 2016 including stricter testing protocols and seven new badger cull zones in the High Risk Area (HRA), additional options for testing in the Low Risk Area (LRA), and support for a herd accreditation scheme. Further details of these and a full description of the current approach are presented in the Explanatory Supplement7. A brief history of controls can be seen in the England TB Epidemiology Report for 20158.

Purpose of this report

This report aims to provide a better understanding of disease behaviour and the impact of the current strategy using epidemiological analyses of the available data, in conjunction with detailed information provided by colleagues working in the control programme.

The raw data can be misleading as the potential for finding herds that are infected with TB is directly related to (i) how hard we look – i.e. the design and effectiveness of the surveillance carried out (particularly the type and frequency of testing), and (ii) the level of disease, which differs by risk area. There are also factors that affect the probability of becoming infected that are unevenly distributed in the population, for example the differences in cattle demography, both the frequency of large herds and of dairy herds, in the different risk areas helps to explain some of the distribution of TB infection. Two other important factors affect the level of disease in the different risk areas in England; firstly the level of infection (prevalence) in the local cattle population which influences the chance of local transmission between cattle herds, and secondly the presence of TB (M. bovis) infection in other species to which cattle are exposed. The most important of these is the local badger population, which is endemically infected in the west and south of England.

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The analyses in this report take such factors into account to provide as accurate a measure as possible of the relative risk and frequency of TB in different herds. This enables more accurate assessment of the efficacy of applied control measures.

A key measure of the epidemic is herd incidence, which describes the rate at which new incidents (also called ‘breakdowns’) occur in herds over time. It is a measure of whether controls to prevent transmission of the disease and the propagation of the epidemic are working. This is complemented by the herd prevalence and the proportion of herds restricted due to TB infection at a point in time. The latter gives two useful indicators, firstly a guide to how long it takes to remove disease from infected farms (measured by the duration of restrictions in comparison to the annual incidence). Secondly, as it reflects both incidence and duration of restrictions, a measure of the impact of the disease, including impacts on farmers. More information on how these measures of disease frequency are calculated is presented in the [Explanatory Supplement](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/643586/tb-epidemiology-2016-suppl.pdf).
4. The TB epidemic in England

4.1 Incidence, geographic distribution and trends over time

- In 2016 there were 3,753 new TB incidents in England as a whole, which is similar to recent years; total numbers per annum have remained relatively stable between 3,700 and 3,900 since 2011. As in previous years, most incidents (86%) occurred in the High Risk Area (HRA), with 10% in the Edge and 4% in the Low Risk Area (LRA).

- The TB incidence rate in the HRA in 2016 was 17.9 incidents per 100 herd years at risk, and in the Edge and LRA was 6.7 and 1.0, respectively. This reflected a fluctuating plateau of disease over recent years in the HRA and LRA, but an increase in incidence in the Edge Area.

- This pattern was reflected in the actual number of incidents in 2016, with the number of herds newly infected with TB lower in the HRA, LRA and England overall when compared to 2015, but higher in the Edge area.

- Since the start of 2011 the epidemic across England as a whole has shown a slow and very slight declining trend overall. However the current quarterly number of incidents is still more than double the number before the UK outbreak of foot-and-mouth disease in 2001.

- Lesions typical of TB infection and/or positive culture for *Mycobacterium bovis* were detected in over three quarters of incidents in the HRA and just over half of those in the Edge, but in less than a third in the LRA.

- The spatial distribution of TB incidents remained much the same as in 2015; however there was both expansion and retraction of endemically infected areas in the Edge Area, with expansion exceeding retraction. A new endemic area appeared in the Edge in north Leicestershire.

- Much of the geographic distribution of TB is explained by the distribution of cattle herds, particularly large herds, and increases in herd size in the most infected areas over recent years may have contributed to maintaining the epidemic. However, there is a substantial population of cattle in the north of England that is not infected, showing that other factors are also important. These factors include the existing level of infection in the local cattle population and the presence of TB infection in other species and their environment, particularly badgers, to which cattle are exposed.
The number of herds newly infected with TB detected during the year reflects the control effort needed and the impact on individual farmers (but can be misleading in terms of comparisons between years\(^{10}\)). The vast majority of TB incidents occurred in the High Risk Area (HRA), with around 4\% in the Low Risk Area (LRA) and about 9\% in the Edge Area between the HRA and LRA (Table 4.1.1, Figure 4.1.4).

In 2016, the total number of TB infected herds was lower in England overall and also in both the HRA and LRA compared to 2015. The incidence rate was also slightly lower in the HRA (p=0.05), but remained the same in the LRA. However in the Edge Area, both the number of TB incidents and the incidence increased in 2016 compared to 2015, the latter increasing significantly.

The LRA had 137 TB incidents in 2016 which was a decrease from 2015 (n=156). A third of LRA TB incidents were confirmed (OTFW), with numbers decreasing from 51 in 2015 to 43 in 2016. The decreasing trend in 2016 in the LRA was not statistically significant (p=0.81). (Note that as the skin test is less accurate when there is very low level of disease, incidents that have been confirmed are a better measure of disease level in the LRA. In contrast the higher level of TB in both the Edge and HRA mean that a positive skin test is a very good indicator of infection, so all incidents are counted to measure the level. (See Explanatory Supplement\(^{11}\) for further detail.)

In summary, the highest levels of TB in England were found in the HRA where the number of new TB incidents in 2016 was eight times higher than in the Edge Area, and 24 times greater than in the LRA. TB incidents with confirmatory evidence of infection from post-mortem tests (including presence of tuberculous gross lesions and/or positive culture results) accounted for 71\% of TB incidents in the HRA, 51\% in the Edge Area and 32\% in the LRA (Table 4.1.1). Note that the LRA TB incidents are further assessed to see if infection was acquired locally; this further analysis and discussion is presented in Section 5.3.

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\(^{10}\)The number of herds and of herds that are tested, and choice of test and the way tests are interpreted, changes between years, and the majority of incidents are found by skin testing of cattle on farms, so the number of cases found only partly reflects the disease level.

Table 4.1.1 Number of TB infected herds and incidence rate\(^2\) in England, by risk region, 2015 & 2016

<table>
<thead>
<tr>
<th></th>
<th>High Risk Area (HRA)</th>
<th>Edge Area</th>
<th>Low Risk Area (LRA)</th>
<th>England</th>
</tr>
</thead>
<tbody>
<tr>
<td>New TB incidents in 2016 (% of total for England)</td>
<td>3,229 (86.0)</td>
<td>387 (10.3)</td>
<td>137 (3.7)</td>
<td>3,753</td>
</tr>
<tr>
<td>New TB incidents in 2015 (% of total for England)</td>
<td>3,401 (87.3)</td>
<td>339 (8.7)</td>
<td>156 (4.0)</td>
<td>3,896</td>
</tr>
<tr>
<td>TB infected herds that were lesion and/or culture positive in 2016 (% of total for risk area)</td>
<td>2,300 (71.2)</td>
<td>196 (50.6)</td>
<td>43 (31.3)</td>
<td>2,539</td>
</tr>
<tr>
<td>TB infected herds that were lesion and/or culture positive in 2015 (% of total for risk area)</td>
<td>2,614 (76.9)</td>
<td>178 (52.5)</td>
<td>51 (32.7)</td>
<td>2,843</td>
</tr>
<tr>
<td>TB incidence rate per 100 herd-years at risk in 2016</td>
<td>17.9</td>
<td>6.7</td>
<td>31.0</td>
<td>10.2</td>
</tr>
<tr>
<td>TB incidence rate per 100 herd-years at risk in 2015</td>
<td>18.8</td>
<td>5.6</td>
<td>1.0</td>
<td>9.8</td>
</tr>
</tbody>
</table>

1 Herds detected as infected with *Mycobacterium bovis* regardless of confirmation status (whether at least one animal was lesion and/or culture positive (OTF herd status withdrawn).

2 see Appendix 2 for further explanation regarding how incidence rates are calculated.

3 Calculated from all incidents including introduced and unconfirmed cases; incidence rate of confirmed cases was 0.3 per 100 herd years at risk, the same as in 2015 In the HRA and LRA of England, there was a decrease in the number of TB infected herds between 2015 and 2016, in incidents both with and without confirmatory evidence of *M. bovis* infection from post-mortem tests. However in the Edge, there was an increase in the total number of incidents, and in the number of TB infected herds with confirmation from post-mortem tests, although the proportion in that risk area decreased. This likely reflects earlier detection of disease, and is discussed further in Section 5.2.

**Temporal trends in the number of new TB infected herds detected in England**

From 1986 to 2000, before the Foot and Mouth Disease (FMD) outbreak in 2001, the number of herds newly infected with TB was rising at a year on year rate of over 14% and the time it would have taken for the epidemic to double in size was estimated at 5.3 years (Figure 4.1.1a).
The doubling time indicates the time it would take for incidents to double in number, given the trend of the data. $R^2$ indicates ‘goodness of fit’ of the superimposed trend line to the raw data (quarterly values) and here shows this is an accurate estimate. (An $R^2$ of 1 would indicate a perfect fit.)

Surveillance testing and control measures in cattle herds across GB were disrupted during the FMD epidemic in 2001, and numbers of TB infected herds increased rapidly over this period, leaping from 363 in the last quarter of 2000 to 662 in the last quarter of 2002 with an annual rate of increase of 25.3%.

The rate of increase in TB incidents reduced once controls were re-established after the FMD epidemic (Figure 4.1.1b). From 2003 to 2010 the epidemic continued a steady but significant ($p=0.005$) upward trend with an annual rate of increase for all incidents of 5.6% (doubling time of 12.8 years). Since the start of 2011 the epidemic appears to show a declining trend overall, with an estimated time taken for the epidemic to halve in size of 273 years. However this is not a statistically significant decline ($p=0.89$), so together with the poor fit of the trend line ($R^2=0.0009$) this indicates that the epidemic as a whole in England is plateauing (note that the current quarterly number of incidents is still more than double that before FMD).
The doubling time indicates the time it would take for incidents to double in number, given the trend of the data. Trend lines, doubling or halving times, and the statistical significance of the trend are shown for the two periods 2003-2010 and 2011-2016. The $R^2$ value indicates ‘goodness of fit’ of the superimposed trend line to the raw data, and here shows the trend was quite erratic in both time periods. An $R^2$ of 1 would indicate a perfect fit. The upward trend for 2003-10 was significant but the high $p$ values for the period 2011-16 shows the epidemic is now plateauing.

The total number of TB infected herds in England has remained fairly stable at between 3,700 and 3,900 since 2011 (Figure 4.1.2a). However the proportion found in the Edge Area has increased since 2013 when annual testing was introduced.
The total number of TB infected herds has ranged between 3,700 and 3,900 since 2011; the introduction of annual testing of herds in the Edge area in 2013 increased the proportion of TB incidents detected there. While the number of TB incidents in the HRA has decreased in 2016, the number in the Edge area has increased.

Figure 4.1.2b displays the total number of TB incidents in the LRA, by confirmation status (TB infected (OTF-W) and TB suspected (OTF-S)). The number of confirmed TB infected herds has not varied much over the past ten years, although it was highest in 2015 (n=51). The consistent historically low incidence in the LRA enabled an application for Officially Tuberculosis Free status for this area to be made in 2017.
The TB epidemic in England is best measured by the incidence rate, which reflects the rate at which herds become newly infected. The annual incidence rate of TB in England remained generally stable between 2011 and 2016, with between year fluctuations of one to two percent. The limited fluctuation between 2015 and 2016 masks the changes at risk area level, namely that TB incidence in the HRA decreased while that in the Edge area increased by nearly 20% from 5.6 in 2015 to 6.7 in 2016 (TB incidents per 100 herd-years at risk) (Figure 4.1.3). In the LRA, the incidence rate has remained stable and many of the new TB incidents were not confirmed by post-mortem tests of TB suspect animals.

In this report the incidence rate is calculated as number of new TB incidents per ‘100 herd-years at risk’ which compensates for changes in the number of herds over time, for differences in how often herds are tested between areas, and for delays in testing. This enables a more accurate comparison between areas and between years than the just the number of incidents that occur.
The increase in TB incidence in the Edge Area was statistically significant in 2016 (p=0.0125) and is a concern; this is discussed further in Section 4.2. In the HRA just under a sixth of herds experienced a new TB incident, similar to 2015.

There are substantial differences in TB incidence rates between the HRA, Edge and LRA (as well as wide variation between counties within the same risk area) (see Table 4.1.1, Figure 4.1.4 and the County Report Supplement\(^{13}\)). Historical trends in TB incidence rate (Figure 4.1.3) show overall incidence rates in the HRA and LRA have been relatively stable since 2011 as have the numbers of incidents, however there has been an increase in both in the Edge area over the same time period (Figure 4.1.2a). Further discussion of the incidence is presented in each risk area section (Sections 5.1, 5.2 and 5.3).

Figure 4.1.3 Annual incidence of new TB incidents (per 100 herd-years at risk (HYR)) by risk area, from 2007 to 2016.

- Incidence has been relatively stable in the LRA and HRA since 2011 but has increased in the Edge area over the same period. Note only a third of LRA incidents were confirmed.

Figure 4.1.4 County incidence of all TB incidents per 100 herd years at risk in England in 2016

- As expected, there is wide variation in incidence rates by county and risk area.
Spatial changes in the TB epidemic

Changes between 2015 and 2016 in the areas of England that can be defined as 'endemically infected' are shown in Figure 4.1.5, (see Appendix 1 for definition for endemic infection). The comparison shows that the majority of the HRA is, and remained, 'endemically' infected, and most of the rest of England is not. However there are small areas of the Edge that have 'endemic' TB and small areas of the HRA that do not. The most obvious changes were seen in the Edge Area where a clear 'endemic' area appeared in north Leicestershire, and there were areas of both expansion (spread) and retraction of the epidemic. Rates of spread and retraction in 2015-16 were similar to 2013-14, and 2014-15 (Table 4.1.2). However, there were anomalies in the data as can be seen by the erroneous presence of apparently endemic areas in the LRA (Figure 4.1.5).

Table 4.1.2 Rates of endemic spread and retraction of TB in England, 2013 to 2016

<table>
<thead>
<tr>
<th></th>
<th>2013-14</th>
<th>2014-15</th>
<th>2015-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spread [km/yr] Median (maximum)</td>
<td>4.7 (20.3)</td>
<td>4.7 (20.2)</td>
<td>4.5 (17.7)</td>
</tr>
<tr>
<td>Retraction [km/yr] Median (maximum)</td>
<td>3.6 (19.0)</td>
<td>3.5 (19.0)</td>
<td>4.1 (14.3)</td>
</tr>
</tbody>
</table>
Figure 4.1.5: Map of endemic TB spread and retraction in England between 2015 and 2016

- Rates of spread and retraction in 2015-16 were similar to 2014-15 however a new endemic area is now evident in the Edge in north Leicestershire.
Cattle demographics

Herd size and the local density of herds are closely associated with the risk for a particular herd to become infected with TB and these factors make a strong contribution to the spatial pattern of the TB epidemic in England (Fig 4.1.6).

![Herd Density and Incidence Maps](image)

**Figure 4.1.6 Herd density (a) and herd level incidence (b) of TB in England in 2016.**

Herd density is measured as the number of herds per square kilometre; herd incidence is the average incidence in the 100 closest herds to each herd location which ‘smooths’ the effect of political boundaries.

The highest numbers of cattle and density of herds are both found in the HRA and parts of the Edge Area (Fig 4.1.6). The sparsest population in terms of both holding and cattle numbers is found in Eastern England. However cattle demographics alone cannot explain the distribution of TB as can be seen by the differences between the maps, particularly in Northern England, and other factors are also important. This is discussed further in Section 4.2.

Figure 4.1.7 shows the proportional distribution of herds within each surveillance risk area by size and type. Herds with over 200 cattle, which have been shown to have a higher risk of infection with TB, form less than 15% of all herds in the LRA but over 20% in the HRA. This may account for some of the difference in disease level between the two areas.
The differences in cattle demographics, both the frequency of large herds and of dairy herds, in the different risk areas helps to explain some of the distribution of TB infection.

Two other important factors affect the level of disease in the different risk areas in England. These are:

1. the local level of TB infection (prevalence) already present in the cattle population, which influences the chance of local transmission between cattle herds, and

2. the presence of TB infection in other species to which cattle are exposed. The most important of these is the local badger population, which is endemically infected in the west and south of England.

The probability of finding cases (i.e. the sensitivity of the surveillance system) also has an effect on the level of disease disclosed and this differs due to differences in both policy and epidemic behaviour between risk areas. This is discussed further in Section 4.3.
4.2 Characteristics of herds found infected with TB in 2016

- The three key factors that increased the risk of becoming infected in England in 2016 were having over 300 cattle, being located in the HRA and being a dairy herd. These factors often co-exist, with herds in the HRA tending to be larger, and many dairy herds being large and located in the HRA. Nearly 30% of herds with over 300 cattle that were tested in 2016 were found to be infected, while around 17% of tested dairy herds and of those tested in the HRA were diagnosed with TB in 2016.

- Adjusting for both herd size and location (i.e. looking at any herd of a given size in a given location) shows that dairy herds had a nine per cent greater risk of infection than beef herds \((p=0.03)\). This is in contrast to previous years when the differences between beef and dairy risk could be explained by location and herd size, and warrants further investigation.

- Analysis also shows that the probability of a dairy herd being found to be infected was more than twice that of a beef herd, reflecting the large part of the burden and responsibility of TB that is carried by the dairy industry.

- A history of TB infection was an important risk factor in all risk areas, and across England over half the herds that were found infected in 2016 had had a previous TB incident within the last 3 years, with the proportion rising steadily over the last 10 years in both the HRA and the Edge. Conversely herds that had a TB incident in the last three years had a 25% chance of being found to be infected when tested compared to only a 4% chance for those with no history.

- This year, for the first time for all incidents, an analysis of new data that shows the route by which herds became infected has been introduced, however these data are complex, so the new analysis is limited while the processes bed in. This limited analysis shows that exposure to environmental sources (most likely infected badgers or their excreta) at pasture, which was most common in the HRA, followed by movements of infected cattle onto the holding (which clearly predominated in the Edge area), were the two most commonly recorded routes by which herds became infected with TB in 2016.

- Most TB incidents from which an isolate can be typed \((84\%)\) are attributed to the local genotype, i.e. they occur within the ‘home range’, showing the type is not unexpected in that area.

This section describes features of herds newly found to be infected with TB in England in 2016, including risk factors for herds becoming infected and likely source of infection.
Factors associated with the likelihood that a herd will become infected

The pathway by which TB infection gets into a herd differs between herds, but analysis shows that the herds most at risk of becoming infected with TB in England in 2016 were large herds located in the HRA (which tend to be dairy herds), and those that had previously been infected with TB (a ‘recurrent’ case).

Herd size and type

There are differences in both the number of TB infected herds and incidence rates (which reflect a herd’s likelihood of becoming infected), across herd types and herd size categories and this also varies across risk regions in England.

Figure 4.2.1a Incidence rates for new TB incidents in herds of different size or type, and in each risk area of England, in 2016

- Herd size was strongly associated with the likelihood of a herd becoming infected with TB; in initially uninfected herds with over 300 cattle, the incidence rate of TB in 2016 was 29%, while it was <4% in herds with 50 or fewer cattle.
- Dairy herds were more than twice as likely to be found infected in 2016, as beef herds.
- Herds in the HRA were almost three times as likely to be found infected with TB, as herds in the Edge.
4. The TB epidemic in England

Figure 4.2.1b Percentage of herds of each size, and percentage that experienced a new TB incident in 2016 (herds with undetermined herd size (not shown) form 2.9% of the population and had no TB incidents.)

- Two thirds of TB incidents occurred in herds with more than 100 cattle, although they make up only a third of herds in the whole population.

- In smaller herd sizes of 50 or fewer cattle, there are relatively few TB incidents even though herds of this size account for over 20% of all herds.

Incidence rates for new TB incidents starting in England in 2016, according to these demographics are shown in Figure 4.2.1a which shows that large herds and dairy herds are much more likely to be found infected, as are herds located in the HRA of England.

The disproportionate risk of infection in larger herds can be seen in Figure 4.2.1b, which shows that most herds are small, while most infection is found in larger herds.

Overall, the proportion of TB incidents that were disclosed in beef and dairy herds since 2007 has been fairly consistent at close to 60% in beef and 40% in dairy (less than 1% in herd types classed as 'Other'). However, there are many more beef than dairy herds, so this does not reflect their likelihood of becoming infected. Figure 4.2.1a shows that dairy herds had more than twice the risk of becoming infected (incidence) in 2016 than beef herds, however much of this can be explained by the fact that dairy herds also tend to be large herds, and are more commonly located in the HRA.
Figure 4.2.1c Incidence Rate Ratios (Unadjusted and Adjusted) for new TB incidents\textsuperscript{14} in herds of different size or type, and by risk area in 2016 (Poisson analysis, see Appendix 4, in 2015 report\textsuperscript{15})

- The denominator value (time at risk) is slightly higher in the aggregated data as this aggregates time at risk in herds that have had multiple whole herd tests in each year used in the Poisson regression which as a result reduces the incidence rate. Note, this will have a small effect on the incidence rate ratio.

- Herd size and location are the most important explanatory factors for the incidence rate.

- The unadjusted incidence rate in dairy herds was over three times greater than beef herds. However, dairy herds are consistently larger, and more concentrated in the HRA than beef herds.

- After adjusting for herd size and location, dairy herds were 9% more likely to have a TB infection than beef herds.

Exploring which potential risk factors are important in terms of the risk of infection is done by comparing the incidence rate ratio (IRR, i.e. the comparative proportion of herds in each category that become infected), and then taking the other factors into account which

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\textsuperscript{14} All TB infected herds – includes OTF-W and OTF-S

could affect the rate of infection. These comparative ratios are shown in Figure 4.2.1c which shows, for example, that if the location and herd type are taken into account when calculating the incidence rate in a herd of a particular size, the rate ratio hardly changes, so herd size may be the most important explanatory factor.

The IRR increased with herd size and was highest in herds with more than 300 cattle. This effect remained after adjusting for the effects of herd type and risk area, with herds of over 300 animals having a higher IRR than herds with 1-300 animals, and this has been consistently observed over several years. The high incidence rate in dairy herds is largely caused by the fact that they tend to be large herds and located in the HRA, and adjusting for both herd size and location in the 2016 data greatly reduces the estimated risk associated with being a dairy herd. However in contrast to previous years, it does not completely remove it, and shows dairy herds are at slightly higher risk of new infection than beef herds of the same size and in the same location (IRR=1.09, 95% CI 1.01; 1.17, p=0.03). As expected, the incidence rate was significantly lower in the Edge and LRA compared to HRA, even after adjusting for the effects of herd size and type, indicating that location is an important risk factor. (Data can be seen in table form in the GB data Report16).

**Herd Size**

For every category of increasing herd size, the risk of becoming infected increases as well and this has remained so over the last 10 years. Figure 4.2.2 displays the incidence of TB incidents (per 100 herd-years at risk) from 2007-2016, by herd size category. This figure clearly shows the strong relation between herd size and the incidence of TB (note these are unadjusted figures, however the Poisson analysis shows that herd type and location have little effect on these estimates). Figure 4.2.2 also shows a dip in incidence rates in 2010 and 2014 in all categories that are more pronounced as herd size increases, for which we do not have an explanation.

Figure 4.2.2: Incidence rate in different herd size categories over time

- For each category of increasing herd size, the risk of becoming infected increases (consistent over the past ten years).

- Smaller herds of less than 50 cattle (bottom line in Figure 4.2.2) show a much lower incidence compared to those with over 50 cattle, and has remained stable since 2007 at about 3%.

Changes in herd size may have contributed to the epidemic over recent years as there has been a steady increase in average herd size over the last ten years (See section 4.1). This has affected all areas, but is most pronounced in the HRA (Figure 4.2.3). The increasing numbers of very large herds (i.e. much larger than 300 cattle) may also be affecting the incidence rate.
Figure 4.2.3 Changes in mean herd size in the three surveillance risk areas over the last ten years

The reason for the increased risk of infection with increasing herd size is not well understood but likely to be associated with one or more of the following:

- A higher probability of buying-in cattle; each purchase carries a risk of introducing infection.

- A likely larger area of land use for grazing, increasing the risk of exposure to *M. bovis* in the farm environment, including wildlife; greater land use may also be associated with a greater probability of using fragmented land parcels potentially taking cattle to areas with greater environmental exposure.

- A higher risk of residual infection remaining in the herd after officially testing clear of infection at the end of a TB incident, due to the larger number of animals and the imperfect sensitivity of the TB tests.

More research is needed to assess which of the possible factors associated with herd size may be affecting incursion and/or retention of infection in larger herds.
**Herd Type**

Dairy herds in England are much more likely to become infected with TB than beef herds (Figure 4.2.4). As discussed above this increased risk is largely due to their size and location. When adjusting for herd size and location, the IRR reduces greatly, however the overall trend remained in that dairy herds had an increased risk of infection with TB.

![Figure 4.2.4: Incidence rate in different herd type categories over time](image)

- Incidence rates in dairy herds were over twice that in beef herds, and have increased in recent years.

Herd type can be seen as a proxy measure for a particular type of husbandry which could include management and other factors that increase or decrease the risk of TB infection. Therefore if true, these differences could be further investigated to identify these factors, which could lead to better insight into which interventions are most likely to be effective in herds of a particular type. Review of the possible reasons for these differences last year highlighted the difficulty in defining a ‘dairy’ herd, which will affect what is recorded in the database. Differences in how herds are defined (misclassification) could be part of the explanation of these differences, particularly as decisions on how to record are likely to be associated with region.

**Recurrent TB incidents**

Having had a previous infection with TB (an incident) increased the likelihood of a herd becoming infected in 2016. This is known as ‘recurrence’ and a recurrent TB incident is
defined in this report as: a TB incident disclosed in the reporting year (i.e. 2016) involving a herd that had also been under movement restrictions for a different TB incident in the previous 36 months.

![Graph showing the annual proportion of herds with recurrent TB incidents between 2007 and 2016, by surveillance risk area.]

**Figure 4.2.5: The annual proportion of herds with recurrent TB incidents between 2007 and 2016, by surveillance risk area.**

The proportion of TB infected herds with recurrent incidents in 2016 was highest in the HRA (Figure 4.2.5) and increased steadily from 2007 to a plateau of 58% since 2014. In the Edge area, the proportion of recurrent TB incidents has also risen since 2007, albeit with more fluctuation (reflecting lower numbers). In the LRA the proportion of recurrent TB incidents is lower and also variable (13% in 2016). The overall proportion of new TB incidents in England 2016 that were ‘recurrent’ was 53%.

Conversely, (starting with an individual herd and assessing how likely it was to be found to be infected in 2016), the much higher risk of another TB infection in herds with a history of TB that has been reported previously continued. A quarter of herds in England that had a history of a TB incident in the previous three years suffered a new TB incident in 2016. In contrast, only four per cent of herds with no history of TB had a TB incident in 2016. This increased risk of new infection in 2016 for previously infected herds is associated with location, herd size and herd type. Looked at individually, analysis shows the increased risk applied to all risk areas, though it was substantially higher in the LRA and among the smallest herds (Figure 4.2.6a). In the LRA, a herd with a history of TB was five times more likely to have a further TB incident than a herd with no TB history. Whereas, in both the
HRA and Edge Area, herds with a history of TB were twice as likely to have a TB incident in 2016 as herds with no TB history.

**Figure 4.2.6a.** The odds of recurrent infection in herds with a history of TB in the different risk areas, and different categories of herd type and herd size (inset lines show 95% confidence intervals)

Beef and dairy herds, and herds in the larger size categories that had a history of TB all had similar odds of recurrent infection (also about double).

Figure 4.2.6b displays the proportion of herds experiencing a new TB incident in 2016 by risk area, with a history of TB in the previous 36 months, and those with no TB history. The proportion of recurrent TB incidents was highest in the HRA. In all risk areas, dairy herds experienced the highest proportion of TB infection, whether or not the herd had a history of TB in the previous 36 months.

Recurrence may have a number of causes, likely relating to location, biosecurity, residual undetected infection, and/or buying or other management practices. The increased risk of recurrence for particular farms as described here will be used in ongoing work to develop more targeted interventions determined by farm characteristics. Further research to better understand the causes of recurrence is also planned.
Figure 4.2.6b: The proportion of herds by surveillance risk area and herd type, that experienced a TB incident in 2016, separated by previous history.

The knowledge of their increased risk may also help keepers with a history of TB infection make informed decisions about their management practices using advice from initiatives such as the TB Hub\textsuperscript{17} to help promote safer buying practices and improved biosecurity.

**Source of infection**

Assessing how a herd became infected with TB is very challenging, as TB is a chronic insidious infection, generally disclosed sometime after it arrives in a herd and there are usually several possible routes of introduction. Therefore, the evidence to establish retrospectively which route brought in the infection is often hard to reconstruct. In late 2015, a new approach was introduced that seeks to clarify both the source of the infection, i.e. which mammalian host *M. bovis* came from (almost invariably cattle or badgers), and the route by which it got into cattle on the infected farm (the ‘risk pathway’). Clarifying the full route of infection should enable more explicit use of targeted biosecurity measures to intervene at different points along the risk pathway.

In short, this new methodology asks the investigating veterinary surgeon to consider the evidence available and select up to three risk pathways that may have introduced

\textsuperscript{17} http://www.tbhub.co.uk/tb-facts/statistics/
infection, indicating their relative likelihood, and record specifically whether each is
definite, most likely, likely or possible. Risk pathways can also be excluded if there is
evidence to that effect. A more detailed description of this methodology is provided in the
Explanatory Supplement\textsuperscript{18} to this report. This approach became widely used during 2016,
though its novelty and relative complexity mean that the quality of the data captured is
uncertain, though it has improved during the year as familiarity and additional training
came to bear. This section presents an analysis of a subset of the data, selected as being
that which is most likely to reflect the true situation, given these caveats. Further
description of the methodology for this selection and analysis is given at the end of this
section.

All incidents in England for which the likely source and risk pathway had been recorded
using the new data fields, and which were resolved in 2016, were identified for analysis,
amounting to 4,832 of the 5,759 incidents resolved in 2016. These are described in Table
4.2.1.

Table 4.2.1 Number of incidents that started in each year that were resolved in 2016,
and number of these for which the hazard and risk pathway were recorded using the
new data capture form

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolved</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>8</td>
<td>16</td>
<td>41</td>
<td>242</td>
<td>2,394</td>
<td>3,042</td>
<td>5,759</td>
<td></td>
</tr>
<tr>
<td>Hazard &amp; risk pathway recorded</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>10</td>
<td>34</td>
<td>177</td>
<td>1,919</td>
<td>2,685</td>
<td>4,832</td>
</tr>
</tbody>
</table>

Incidents from earlier years are included as this is the first and only opportunity for these
older incidents to be considered in this type of analysis. Further analysis was limited to
those incidents where a ‘definite’ or ‘most likely’ hazard and risk pathway were identified
and for the latter only incidents where three possible combinations had been recorded.
The numbers are shown in Table 4.2.2.

2016-suppl.pdf
Table 4.2.2 Number of incidents contributing data to the analyses in Figures 4.2.7 and 4.2.8

<table>
<thead>
<tr>
<th>Probability of hazard/risk pathway combination</th>
<th>Field in which hazard and risk pathway data were recorded in resolved incidents</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Provisional</td>
<td>Final</td>
</tr>
<tr>
<td>Definite</td>
<td>165</td>
<td>266</td>
</tr>
<tr>
<td>Most likely</td>
<td>267</td>
<td>531</td>
</tr>
</tbody>
</table>

Incidents in which a ‘definite’ risk pathway for infection was attributed

Figure 4.2.7 shows the attributed risk pathway for the 431 incidents in which the investigator was sure enough of the evidence to record a ‘definite’ source.

In the HRA, where a ‘definite’ pathway was recorded, infection was most commonly attributed (by informed veterinary opinion following review of the evidence) to exposure to infected badgers at pasture followed by infected cattle movement onto the holding, while in the Edge and LRA the latter was the most common (as can be seen in Figure 4.2.7). However, the number of incidents with a ‘definite’ pathway recorded makes up less than 10% of those that were assessed. Approaches to analyse these complex data are still being developed, however as many incidents had a ‘most likely’ option chosen by preference over less certain options, these may provide insight as to likely risk pathways and were selected for further analysis.

The option ‘Other or unknown’ is provided for incidents where exploration of the evidence shows either that it cannot clearly support any risk pathway, or where a rare source that is not covered by any of the listed risk pathways is identified. This category is supported by free text that explains the reason for this selection and a full analysis of these cases will be included next year. Examination of three such incidents showed that two had a single reactor or IR with a negative culture result and no strong evidence for any particular risk pathway. The third had a single reactor from which *M. bovis* was cultured that was out of its home range, yet the herd had been closed for 20 years and was located in the Edge Area.
Figure 4.2.7 Hazard and risk pathway attributed in incidents that were resolved in 2016 where the probability of that risk pathway was assessed as ‘definite’ by informed veterinary opinion (n=431)

Incidents in which a ‘most likely’ risk pathway for infection was attributed

Figure 4.2.8 shows the ‘most likely’ risk pathway for incidents where three risk pathway options were selected of which one was ‘most likely’ and the others less probable. Note this has not been stratified further so includes incidents from all risk areas, however the vast majority of incidents are in the HRA.

Note there were nine incidents where two ‘most likely’ options were selected; eight of these chose the two options for exposure to infected badgers as ‘most likely’ (i.e. at pasture and while housed), and one showed both movements of infected cattle onto the holding and residual infection in the herd as ‘most likely’. These incidents are represented twice in Figure 4.2.8 and reflect the possibility that infection came via both these risk pathways.
### Methodology for selection and analysis of data

Initial analysis shows that where only one option for the source was chosen, the proportion of pathways stated only as ‘possible’ was much higher than when the investigator selected more options. Unsurprisingly, the least common option chosen was ‘definite’, as the investigator was required to have strong evidence to support this choice. The most frequently chosen probability option where more than one hazard/risk pathway was recorded was ‘most likely’, and the data could be interpreted as suggesting that where several risk pathways were chosen the investigator felt able to attribute more certainty, so these incidents were selected for further analysis. The pattern was similar for the options chosen both at the stage of allocating a ‘provisional’ risk pathway earlier in the incident, and when the final assessment was made; the latter accounted for 77% of incidents with such data, and is shown in Figure 4.2.9. Further analysis of the data used the ‘final’ risk pathway assessment for each incident unless this was missing (35% of incidents), in which case the provisional assessment was used, provided the incident was recorded as resolved/completed.
4. The TB epidemic in England

Molecular typing

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 typing. 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. Most isolates are recovered from premises located within the home range of the genotype identified. Specifically, of the 2,793 isolates with location and full genotype identified in 2016, 84% are in their home range (449 out-of-home range isolates). Further information about genotyping is given in the Explanatory Supplement\(^\text{20}\). The assessments described in the previous section on source of infection, and in the Edge Area and LRA epidemiology reports (see Sections 5.2 and 5.3) will have been informed by knowledge of the genotype where available. A full report on the outcomes of *M. bovis* genotyping carried out in 2016 is included in the GB Data Report\(^\text{21}\).

Molecular typing of this sort is likely to be replaced by whole genome sequencing (WGS) in the next year or two, if current research confirms earlier findings that it can provide much greater discrimination between strains of *M. bovis*. This could potentially allow explicit identification of transmission pathways between some farms, or confirm certain incidents have been caused by residual infection in the herd from a previous incident, rather than reintroduction.

\(^{19}\) vets select up to 3 options in all these incidents and were asked to indicate the level of probability which they gave to that hazard/risk pathway combination being the infection source


4.3 Finding Infected herds: Effectiveness of surveillance

- The vast majority of all incidents (3,747\textsuperscript{22}) were disclosed in the HRA, with less than 15\% found in Edge and LRA combined. There have been only minor variations in the success of different surveillance streams compared to 2015.

- Risk-based surveillance (Area and Herd Risk) tests in the HRA detected the most incidents (43\%), followed by routine tests in this same area, the two accounting for nearly 70\% of all incidents detected. The high proportion of incidents and reactors detected by post-incident tests in the HRA reflects the difficulty of clearing infection here, and confirms the value of enhancing stamping out procedures within incidents (two compulsory clear tests at severe interpretation for all incidents in the HRA was introduced from April 2016) and highlights the need for better understanding of the causes of recurrent infection.

- Routine surveillance was the most successful stream in the Edge area, detecting >60\% of Edge incidents, reflecting the heightened surveillance applied here. These tests also disclosed the majority of reactors due to the severe interpretation and minimum two clear tests requirement for lifting restrictions. In comparison, routine tests disclosed around a third of incidents in both the HRA and LRA. Risk based surveillance detected a much smaller proportion (20\%) of incidents in the Edge area than the HRA confirming the increased efficacy of within-incident testing procedures in the former.

- Risk-based surveillance detected 51\% of incidents in the LRA, within which radial tests were the most successful, detecting nearly three quarters of these, confirming their value in preventing disease taking a foothold in clean areas and informing on potential sources.

- Slaughterhouse surveillance disclosed a slightly lower proportion of incidents in 2016 than in 2015 in all risk areas. As previously, similar proportions of all TB incidents were detected at slaughter in the HRA and LRA (14\%) though the much higher disease level in the former means this similarity hides a 23 fold greater number of incidents detected by this surveillance in the HRA compared to the LRA (445 versus 19). This high number suggests enhancing routine surveillance in the HRA (as is being considered) would be beneficial. The lower proportion of incidents in the Edge detected by slaughterhouse surveillance (9\%) again confirms the efficacy of live animal testing here.

- Proactive tests detected less than 10\% of the TB incidents within each area, although the main test (Pre-movement test) is under-recorded. Some of these tests,

\textsuperscript{22} In this section, there are five TB incidents not accounted for as their disclosing test type was not available at the time of reporting.
like private tests and post-movement tests, are in used in notable proportion only in the LRA (the latter compulsory since April 2016 to mitigate the risk of disease incursion).

- The presence and challenge of inconclusive reactors (IRs) shows the sensitivity of surveillance continues to be constrained by test limitations. Nearly half of IR-only test herds went on to have an incident within the following 15 months in the HRA with substantial proportions similarly affected in the Edge and LRA. This indicates IRs are an important predictor of the presence of infection in all risk areas; this is particularly the case if the farm has a history of TB.

**Surveillance Overview**

Bovine tuberculosis (TB) is a slowly progressing insidious disease and affected animals usually appear healthy for some time after becoming infected, during which time they can potentially spread infection. Surveillance on apparently healthy animals therefore plays a key role in halting disease spread. The surveillance programme in the different surveillance risk areas (HRA, Edge area and LRA) involves both active surveillance, where live animals are tested, and passive surveillance, whereby animals suspected of being infected with TB are examined either clinically or at post-mortem.

As in 2015, TB surveillance activities in England are categorised into four different surveillance streams; this chapter assesses how well these work at finding infected herds. A detailed description of these streams and associated tests is provided in the TB Explanatory Supplement. In brief the four surveillance streams are:

- **Routine**: systematic testing of OTF herds at a pre-defined interval of one or four years.
- **Risk-based**: additional testing of herds or cattle because they are more likely to be infected.
- **Slaughterhouse**: post-mortem inspection of all cattle slaughtered commercially in abattoirs.
- **Pro-active**: where the presence of infection could have a greater impact on disease spread.

**Surveillance Streams**

In 2016, there was extensive TB surveillance in over 5 million cattle kept in approximately 50,500 active cattle holdings in England. As a result, 4.1 million cattle were tested in OTF herds; the majority of them in the HRA (63%), 21% in the Edge and 16% in the LRA. Over

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82,000 herd tests\textsuperscript{24} were carried out, detecting 3,747 TB incidents\textsuperscript{25} (86\% of them in the HRA). Five hundred new TB incidents were from SLH cases (leading to 491 confirmed new TB incidents); 89\% in the HRA, 7\% in the Edge and 4\% in the LRA.

Sixty eight per cent of new TB incidents in England were confirmed by post mortem tests, with a 71\% confirmation rate in the HRA vs 51\% in the Edge and 32\% in the LRA. No clinical cases, nor report cases, were detected in 2016 (two clinical cases and one report case were detected in 2015).

Figure 4.3.1 shows the relative proportions of individual cattle tests, herd tests, reactors and incidents for the four surveillance streams, though note that each test event is recorded as a test in the herd, even if it was an animal-level test (e.g. pre-movement or tracing tests), which accounts for the high proportion of herd tests recorded in the proactive surveillance stream.

With approximately equal share of the proportion of herd tests and 5\% less cattle tests, Area and Herd Risk tests picked up a higher proportion of reactors, TB incidents and confirmed TB incidents than the Routine surveillance stream. This highlights the value of targeting higher risk herds (e.g. post-incident herds); however, it also indicates there is scope to intensify routine surveillance.

![Figure 4.3.1. Surveillance Stream tests characterisation: proportion of cattle tests, reactors, herd tests, TB incidents and confirmed TB incidents.](image)

There was a 4\% reduction in the number of TB incidents detected in 2016, compared to 2015. Most (65\%) herd tests were carried out in the HRA, where 86\% of all TB incidents (and 91\% of confirmed ones) were detected, as well as 90\% of reactors.

\textsuperscript{24}Herd tests include both individual tests and whole herd tests carried out in farms, each accounting for one test carried out.

\textsuperscript{25}This figure excludes 5 TB incidents for which the test type was unknown at the time of reporting.
4. The TB epidemic in England

Table 4.3.1. Total Number of tests, reactors, breakdowns and confirmed (i.e. OTF-W) breakdowns by surveillance risk area and surveillance stream in 2016.*

This includes all tests applied to a herd, whether they are herd-level (e.g. whole herd test, routine herd test) or animal-level (e.g. tracing tests, pre-movement test) tests.

<table>
<thead>
<tr>
<th>Area</th>
<th>Surveillance Stream</th>
<th>Total Herd Tests (%)</th>
<th>Total TB Incidents (%)</th>
<th>TB Incidents per 100 Herd Tests</th>
<th>Total Confirmed TB Incidents (%)</th>
<th>Reactors per 1,000 cattle tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRA</td>
<td>Area &amp; Herd Risk</td>
<td>16,677 (20)</td>
<td>1,383 (37)</td>
<td>8.3</td>
<td>949 (37)</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>Proactive</td>
<td>24,209 (29)</td>
<td>287 (8)</td>
<td>1.2</td>
<td>199 (8)</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Routine</td>
<td>13,106 (16)</td>
<td>1,111 (30)</td>
<td>8.5</td>
<td>715 (28)</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>Slaughterhouse</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HRA Total</td>
<td></td>
<td>53,992 (65)</td>
<td>3,226 (86)</td>
<td>6.0</td>
<td>2299 (91)</td>
<td>3.2</td>
</tr>
<tr>
<td>Edge</td>
<td>Area &amp; Herd Risk</td>
<td>2,447 (3)</td>
<td>78 (2)</td>
<td>3.2</td>
<td>44 (2)</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Proactive</td>
<td>6,918 (8)</td>
<td>32 (1)</td>
<td>0.5</td>
<td>14 (1)</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Routine</td>
<td>6,405 (8)</td>
<td>239 (6)</td>
<td>3.7</td>
<td>102 (4)</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Slaughterhouse</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edge Total</td>
<td></td>
<td>15,770 (19)</td>
<td>385 (10)</td>
<td>2.4</td>
<td>196 (8)</td>
<td>0.9</td>
</tr>
<tr>
<td>LRA</td>
<td>Area &amp; Herd Risk</td>
<td>4,328 (5)</td>
<td>69 (2)</td>
<td>1.6</td>
<td>14 (1)</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Proactive</td>
<td>5,486 (7)</td>
<td>11 (0)</td>
<td>0.2</td>
<td>6 (0)</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Routine</td>
<td>3,160 (4)</td>
<td>37 (1)</td>
<td>1.2</td>
<td>4 (0)</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Slaughterhouse</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LRA Total</td>
<td></td>
<td>12,974 (16)</td>
<td>136 (4)</td>
<td>1.0</td>
<td>43 (2)</td>
<td>0.2</td>
</tr>
<tr>
<td>Grand Total</td>
<td></td>
<td>82,736</td>
<td>3,747</td>
<td>4.5</td>
<td>2,538</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Since the total number of herd tests comprises all tests applied to a herd, including animal-level tests (e.g. tracing tests, pre-movement tests), the area and herd risk and proactive surveillance streams have a relatively higher number of tests compared to other surveillance streams that mainly comprise herd-level tests (i.e. routine surveillance stream).

Within the HRA, the most successful surveillance stream is the Area and Herd risk, detecting 43% of incidents; followed by the routine surveillance stream (34%). This shows there is room for enhancing routine surveillance, as proposed in the current consultation suggesting rationalisation of testing in this area. The fact that 14% of incidents are detected by passive surveillance at the slaughterhouse reinforces this argument. In fact, the most successful tests in this area are post-incident tests, which suggest that enhancing within-incident procedures so as to clear disease more effectively would be beneficial, as recrudescence is one of the causes of recurrence. This is aided by the introduction of two clear tests at severe interpretation to clear any incident in April 2016.

Nearly two-thirds of incidents in the Edge area were detected by routine tests (WHT) (62%) vs only a fifth detected by area and herd risk tests, which shows that strong active surveillance (yearly whole herd testing and six-monthly in Cheshire Edge) is working in this area to find disease early and prevent geographic expansion. This is also supported by the
lowest levels of passive surveillance detection (9%) incidents in this area detected by slaughterhouse surveillance.

In the LRA, where disease is under control and meeting Officially TB Free status criteria, just over half of incidents were detected by targeted Area and Herd risk surveillance tests (radial tests, in particular), with 27% detected by routine surveillance. This applies at lower intensity than in the Edge and the HRA (four-yearly Routine Herd tests) and it is supplemented by 14% incidents detected at slaughterhouse.

Compared to 2015, the proportion of TB incidents detected by Area and Herd Risk tests has had a 1% decrease whereas the proportion detected by Routine tests had a 2% increase in HRA and Edge. Slaughterhouse detection has remained stable at 1% in the Edge and LRA with a 2% reduction in the HRA (14 to 12%).

Over the period 2012-2016, the relative proportions of TB incidents detected by Routine and Area and Herd Risk tests combined within each surveillance risk area have been between 71-82% (Figure 4.3.8). Slaughterhouse surveillance has represented 16% of the relative proportion of incidents detected in the HRA and LRA, on average (13% in the Edge). The Proactive surveillance stream relative incident detection proportion has been between 7 and 9% in all areas, on average.


Figure 4.3.2. Annual proportions of new TB incidents detected by different surveillance streams within each risk area from 2012 to 2016. (data in GB Data Report)

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• Risk based surveillance finds the most incidents in the HRA and LRA while routine testing is most effective in the Edge Area. Proportions have changed little over time in the HRA and LRA. Where risk is higher (HRA and Edge), effective minimising of transmission is best achieved by routine testing and the increasing efficacy of routine testing in the Edge Area since the introduction of the policy in 2013 can be seen from its increasing proportion.

Over the same period, the HRA has had the most stability in terms of the relative proportion of TB incidents disclosed by different surveillance streams (up to 5% variation since 2012). This is the surveillance risk area where policies have changed the least.

In the same period, the Edge Area showed more variability in the relative proportion of TB incidents detected by surveillance streams as per changing policies. Routine surveillance detected increasingly more incidents than Area and Herd surveillance across all years (62% in 2016 compared to 50% in 2015), reflecting the success of early detection brought about by routine yearly whole herd testing (WHT) since 2013 (six-monthly in Cheshire since January 2015). The relative proportion of TB incidents detected through slaughterhouse surveillance has halved over this period (20% in 2012 vs 9.3% in 2016), again suggesting this is due to early detection by increased testing. The proportion of TB incidents detected through Proactive surveillance has varied considerably, likely reflecting changes in pre-movement testing activities and their recording.

Since 2012, the biggest variations in the relative proportions of TB incidents detected by different surveillance streams within a surveillance risk area are seen in the LRA. As in the Edge, these were mainly in the Area and Herd risk and the Routine surveillance streams. This is due in part to the low number of TB incidents but also due to the major policy changes from 2013 (radial testing).

Area and Herd Risk Surveillance Stream

The Area and Herd Risk surveillance stream comprises tests carried out in higher risk situations, such as post-TB incident (post-breakdown tests), tests on premises contiguous to infected premises, tracing tests on cattle moved to or from infected premises. A higher proportion of incidents are disclosed by this stream, compared to the proportion of herd tests carried out. Its performance is summarised in Table 4.3.2:

Table 4.3.2. Number and percentage of cattle tests, reactors, herd tests, TB incidents and confirmed TB incidents by the Area and Herd Risk Surveillance Stream in each surveillance risk area in 2016.

<table>
<thead>
<tr>
<th>Surveillance Risk Area</th>
<th>Cattle Tests in thousands (%)</th>
<th>Reactors (%)</th>
<th>Herd Tests in (%)</th>
<th>TB Incidents (%)</th>
<th>Confirmed TB Incidents (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>England</td>
<td>1,713 (41%)</td>
<td>4,804 (53%)</td>
<td>23,452 (28%)</td>
<td>1,530 (41%)</td>
<td>1,007 (40%)</td>
</tr>
<tr>
<td>HRA</td>
<td>1,213 (47%)</td>
<td>4,536 (55%)</td>
<td>16,677 (31%)</td>
<td>1,383 (43%)</td>
<td>949 (41%)</td>
</tr>
<tr>
<td>Edge</td>
<td>135 (15%)</td>
<td>192 (24%)</td>
<td>2,447 (16%)</td>
<td>78 (20%)</td>
<td>44 (22%)</td>
</tr>
<tr>
<td>LRA</td>
<td>366 (54%)</td>
<td>76 (64%)</td>
<td>4,328 (33%)</td>
<td>69 (51%)</td>
<td>14 (33%)</td>
</tr>
</tbody>
</table>
In the HRA, the highest performing tests in terms of TB incident detection within this stream are post-incident tests: they represent 30% of Area and Herd Risk tests in the HRA (4,951), disclosing around three quarters of reactors and TB incidents (3,398 and 1,017 respectively), as discussed above. They are followed by contiguous tests and tracing tests.

In the Edge area, post-incident tests are also the highest performing within this surveillance stream. Representing 21% of Area and Herd Risk herd tests in the Edge, they disclosed 67% of incidents and 68% of reactors (52 TB incidents and 130 reactors). The next in performance are tracing tests.

In the LRA, the best Area and Herd Risk performing tests are radial tests (RAD, RAD6 and RAD12), which accounted for 51% herd tests within this area and surveillance stream (2,207 herd tests) and disclosed three quarters of incidents (51) and 70% of reactors (53). Only 11% of the incidents disclosed were confirmed (although not necessarily by the same M. bovis genotype as the index case). They provide information for case management of the index case and also serve to demonstrate absence of endemic pockets of disease around confirmed incidents in the LRA. Due to the low incidence, post-incident tests only represented 148 tests in herds, with 10 incidents and 13 reactors disclosed.

Particularly in yearly-tested areas, post-breakdown tests, radial tests, contiguous tests and tracing tests are under-recorded if carried out at the same time as another herd test (e.g. a Whole Herd Test), as only one test type is recorded in our system. The relative frequency of the different tests within this surveillance stream in the different risk areas is shown in Figure 4.3.3 a, b and c.

Further information on this surveillance stream can be found in section 4.5.

![Figure 4.3.3a. Percentage of main test types within the Area and Herd Risk surveillance stream by surveillance risk area in 2016: HRA](image)
Figure 4.3.3b. Percentage of main test types within the Area and Herd Risk surveillance stream by surveillance risk area in 2016: Edge Area

Figure 4.3.3c. Percentage of main test types within the Area and Herd Risk surveillance stream by surveillance risk area in 2016: LRA

Routine Surveillance Stream

Routine surveillance comprises tests carried out by default to maintain TB surveillance (routine herd tests, whole herd tests and new herd tests). Table 4.3.3 summarises the performance of this surveillance stream within each surveillance risk area:
Table 4.3.3. Number and percentage of tests, reactors, TB incidents, Confirmed TB incidents and Reactors by Routine Surveillance and by risk area in England in 2016.

<table>
<thead>
<tr>
<th>Surveillance Risk Area</th>
<th>Cattle Tests in Thousands (%)</th>
<th>Reactors (%)</th>
<th>Herd Tests (%)</th>
<th>TB Incidents (%)</th>
<th>Confirmed TB Incidents (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>England</td>
<td>1,909 (46%)</td>
<td>3,770 (41%)</td>
<td>22,671 (27%)</td>
<td>1,387 (37%)</td>
<td>821 (32%)</td>
</tr>
<tr>
<td>HRA</td>
<td>1,040 (40%)</td>
<td>3,200 (39%)</td>
<td>13,106 (24%)</td>
<td>1,111 (34%)</td>
<td>715 (31%)</td>
</tr>
<tr>
<td>Edge</td>
<td>645 (74%)</td>
<td>541 (69%)</td>
<td>6,405 (41%)</td>
<td>239 (62%)</td>
<td>102 (52%)</td>
</tr>
<tr>
<td>LRA</td>
<td>223 (33%)</td>
<td>29 (25%)</td>
<td>3,160 (24%)</td>
<td>37 (27%)</td>
<td>4 (9%)</td>
</tr>
</tbody>
</table>

The performance of routine testing in England is not comparable between HRA and Edge areas, where the main test, Whole Herd Test (WHT), is applied annually in all cattle over six weeks. This type of test only applies to the LRA in high risk herds and the main routine surveillance test is the Routine Herd Test (RHT), applied four-yearly and mainly to breeding stock. Proportionately, it had the best performance in the Edge, where more incidents are detected per herd tests carried out within this stream (62% of all incidents).

The vast majority of routine tests in the HRA and Edge are WHTs. In the HRA, they detected 1,091 TB incidents and 3,162 reactors. New herd tests (NH1 and NH2) detected 20 TB incidents (11 confirmed) and 38 reactors. In the Edge WHTs detected 238 TB incidents and 537 reactors. Only a single incident (confirmed) was detected within this area by New Herd Tests, with 4 reactors.

In the LRA, the vast majority of routine tests are RHTs, which detected 37 incidents and 29 reactors. WHTs in high risk herds in the LRA accounted for 218 herd tests and detected two TB incidents (none confirmed) and one reactor. The 288 New herd tests carried out detected one TB incident (not confirmed), with no reactors recorded.

Slaughterhouse Surveillance Stream

Slaughterhouse (SLH) surveillance utilises compulsory post-mortem inspection in all cattle slaughtered in commercial abattoirs, followed by confirmation by culture if typical TB
lesions are found. As such, is able to detect some infected cattle that may have been missed by active live animal surveillance.

The proportion of new TB incidents disclosed by meat inspection (SLH surveillance) depends on background force of infection and also on the frequency and efficacy of live animal surveillance tests that take place in cattle herds\(^{27}\). Herds are tested four times more frequently in the Edge and HRA compared to the LRA and with a stricter eligibility criteria. Therefore a higher proportion (but lower number) of TB incidents might be anticipated to be detected at slaughter in the LRA compared to the other risk areas.

Table 4.3.4. Slaughterhouse Surveillance Stream Performance within each surveillance risk area in England in 2016.

<table>
<thead>
<tr>
<th>Surveillance Risk Area*</th>
<th>Total Cattle Slaughtered (from unrestricted holdings)</th>
<th>Total SLH Confirmed (Suspects)</th>
<th>% SLH cases confirmed (suspects)</th>
<th>%TB Incidents (Total)</th>
<th>% Confirmed TB Incidents (Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>England</td>
<td>1,265,988</td>
<td>676 (931)</td>
<td>0.05 (0.07)</td>
<td>13% (500)</td>
<td>19% (491)</td>
</tr>
<tr>
<td>HRA</td>
<td>463,263</td>
<td>611 (790)</td>
<td>0.13 (0.17)</td>
<td>14% (445)</td>
<td>19% (436)</td>
</tr>
<tr>
<td>EDGE</td>
<td>215,971</td>
<td>44 (74)</td>
<td>0.02 (0.03)</td>
<td>9% (36)</td>
<td>18% (36)</td>
</tr>
<tr>
<td>LRA</td>
<td>585,281</td>
<td>21 (67)</td>
<td>0.004 (0.01)</td>
<td>14% (19)</td>
<td>44% (19)</td>
</tr>
</tbody>
</table>

* Two confirmed slaughterhouse (SLH) cases had an unknown originating location.

Nearly half the cattle from unrestricted herds slaughtered originated in the LRA (46%), followed by the HRA (37%) and the Edge (17%). A very small proportion of cattle slaughtered consisted of slaughterhouse case suspects or confirmed 85% of which originated in the HRA, 8% in the Edge and 7% in the LRA. Detection at slaughter in 2016 was lower compared to 2015. See below.

Table 4.3.5. Slaughterhouse Surveillance Stream Outcomes Comparison between 2016 and 2015.

<table>
<thead>
<tr>
<th>Origin</th>
<th>Total cattle slaughtered % change</th>
<th>Proportion of Cattle Slaughtered by Area % change</th>
<th>SLH Case Suspects % change</th>
<th>SLH Cases Confirmed % change</th>
<th>TB Incidents 2016 % change</th>
<th>Confirmed TB Incidents % change</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRA</td>
<td>4%</td>
<td>0%</td>
<td>-36%</td>
<td>-38%</td>
<td>-18%</td>
<td>-18%</td>
</tr>
<tr>
<td>Edge Area</td>
<td>-1%</td>
<td>-1%</td>
<td>-11%</td>
<td>-6%</td>
<td>-8%</td>
<td>-5%</td>
</tr>
<tr>
<td>LRA</td>
<td>4%</td>
<td>0%</td>
<td>-3%</td>
<td>-19%</td>
<td>-21%</td>
<td>-17%</td>
</tr>
<tr>
<td>Unknown</td>
<td>7%</td>
<td>0%</td>
<td>-80%</td>
<td>-33%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENGLAND</td>
<td>3%</td>
<td>-</td>
<td>-33%</td>
<td>-36%</td>
<td>-17%</td>
<td>-17%</td>
</tr>
</tbody>
</table>

Although the proportion of cattle slaughtered by area has increased slightly in all areas except the Edge (-1% reduction), the proportion of suspect SLH cases and confirmed ones has reduced, particularly in the HRA (-36% and -38% respectively). The proportions of

\(^{27}\) Further analysis of the efficacy of slaughterhouse surveillance and monitoring performance may be found in CDC slaughterhouse report: [www.gov.uk](http://www.gov.uk)
cattle sent to slaughter from unrestricted herds has not changed except for a 1% reduction in the Edge.

As in previous years, the proportion of TB incidents disclosed by SLH surveillance is virtually the same in the LRA and HRA (14% vs nearly 16% in 2015); likely reflecting that the background force of infection is higher in the latter. Hence, there is potential to consider enhancing active surveillance in the HRA. The Edge area has the same level of active surveillance as the HRA (except in Cheshire where it is higher due to six-monthly testing), but with a lower background force of infection and less incidents are detected by passive surveillance, as expected.

The proportion of confirmed TB incidents detected by this surveillance stream is very similar in HRA and Edge areas (nearly 20%) but higher in the LRA (44%), with a much lower number of cases. Nearly all incidents detected at the SLH are confirmed (culture positive). If culture is negative, the suspect slaughterhouse case is cleared and restrictions are lifted from the herd.

Since 2007, the proportion of confirmed TB incidents disclosed through SLH surveillance in the HRA has remained fairly consistent but there has been greater fluctuation in the Edge and LRA. The pronounced fall in Edge cases detected at slaughter in recent years probably reflects the success of the Edge Area policy in achieving earlier detection through increased live animal testing (Figure 4.3.5).

Figure 4.3.5. The proportion of new confirmed TB incidents that were disclosed by slaughterhouse surveillance from 2007 to 2016, by risk area
Proactive Surveillance Stream

Proactive surveillance includes international trade tests, private tests, tests at artificial insemination centres and pre- and post-movement testing. These are individual cattle tests so usually single animals or a batch are tested, therefore the number and percentage of cattle tests is more relevant than herd tests.

Tests such as pre-movement tests are not specifically recorded if taking place as part of another test (e.g. a WHT). Proactive tests detect the smallest proportion of TB incidents of all the surveillance streams (9%); however, this amounts to a significant number of TB incidents (330 in 2016) and it forms an important protective mechanism in preventing high impact disease spread (e.g. into the LRA).

Table 4.3.6. Number and percentage of tests, reactors, TB incidents and confirmed TB incidents by the Proactive Surveillance Stream within each surveillance risk area in England in 2016.

<table>
<thead>
<tr>
<th>Surveillance Risk Area</th>
<th>Cattle Tests in Thousands (%)</th>
<th>Reactors (%)</th>
<th>Herd Tests* (%)</th>
<th>TB Incidents (%)</th>
<th>Confirmed TB Incidents (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>England</td>
<td>519 (13%)</td>
<td>532 (6%)</td>
<td>36,613 (44%)</td>
<td>330 (9%)</td>
<td>219 (9%)</td>
</tr>
<tr>
<td>HRA</td>
<td>337 (13%)</td>
<td>464 (6%)</td>
<td>24,209 (45%)</td>
<td>287 (9%)</td>
<td>199 (9%)</td>
</tr>
<tr>
<td>Edge</td>
<td>98 (11%)</td>
<td>55 (7%)</td>
<td>6,918 (44%)</td>
<td>32 (8%)</td>
<td>14 (7%)</td>
</tr>
<tr>
<td>LRA</td>
<td>85 (13%)</td>
<td>13 (11%)</td>
<td>5,486 (42%)</td>
<td>11 (8%)</td>
<td>6 (14%)</td>
</tr>
</tbody>
</table>

*Proactive tests form a high proportion as they are mainly individual animal tests but each counts as a herd test (they all provide an opportunity to detect an incident). A holding is likely to have more pre-movement tests than herd tests.

The majority (65%) of proactive surveillance cattle tests were conducted in the HRA and nearly 20% were conducted in the Edge. Sixteen per cent were conducted in the LRA as the major test type (pre-movement testing) only applies to high risk herds in this area.

In the HRA and Edge areas virtually all proactive surveillance stream tests conducted in 2016 were pre-movement tests (PRMTs). Private and Irish post-import tests detected 1% of TB incidents (2 and 3 respectively in the HRA but none in the Edge.

In the LRA, the main test is also the PRMT (nearly 70% of cattle tests) detecting 55% of TB incidents in this area (6 incidents and 6 reactors); private tests represent over 15% of cattle tests and detected close to a fifth of TB incidents (and confirmed ones) although equivalent to just two incidents and two reactors. International trade tests (pre-export and Irish post-import tests) failed to detect confirmed TB incidents, but each disclosed 1 TB incident and 1 reactor from just over 3,000 cattle tested in around 200 herd tests.

Following the policies introduced in the LRA in April 2016, 11% of cattle tests (9,685) were post-movement cattle tests, which applies golden biosecurity rules28 and enhances the

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28 This advice currently forms part of the “Stop infected cattle entering the herd”, point 3 of the Five Point Plan biosecurity advice, recommends post-movement test cattle entering the herd. www.tbhub.co.uk
detection of infected cattle moved into the LRA. The voluntary pre-sale check test has not had such a big impact (0.5% or 398 cattle tests with no incidents detected).

Figure 4.3.6. Performance of main test types within the Proactive surveillance stream by surveillance risk area in 2016.

Pre-Movement Testing (PRMT)

Just over 2.5 million cattle moved within GB in 2016 (75,000 more than in 2015), excluding movements to a slaughterhouse directly and indirectly (e.g. via slaughter markets and authorised finishing units). Cattle have moved within and between the same areas in roughly the same proportions since 2014 (up to 2% variation in some cases). In the HRA and LRAs around 80% of cattle move within their area but only around or just under 50% of Edge area cattle stay there.

The lower number of intra-traded cattle in the Edge area reflects the relatively small number of holdings here, which promotes trading with other areas. The detailed aspects of cattle trade can be seen in the table below.

Table 4.3.7. Summary of number of cattle movements between risk areas and countries

<table>
<thead>
<tr>
<th>Cattle Moved in 2016</th>
<th>To HRA</th>
<th>To Edge</th>
<th>To LRA</th>
<th>To Scotland</th>
<th>To Wales</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>From HRA</td>
<td>675,613</td>
<td>91,760</td>
<td>51,355</td>
<td>660</td>
<td>32,247</td>
<td>851,635</td>
</tr>
<tr>
<td>From Edge</td>
<td>57,604</td>
<td>146,536</td>
<td>40,893</td>
<td>531</td>
<td>14,457</td>
<td>260,021</td>
</tr>
<tr>
<td>From LRA</td>
<td>23,484</td>
<td>46,559</td>
<td>596,460</td>
<td>20,648</td>
<td>5,989</td>
<td>693,140</td>
</tr>
<tr>
<td>From Scotland</td>
<td>2,501</td>
<td>4,749</td>
<td>51,883</td>
<td>423,027</td>
<td>1,315</td>
<td>483,475</td>
</tr>
<tr>
<td>From Wales</td>
<td>86,505</td>
<td>30,320</td>
<td>23,540</td>
<td>359</td>
<td>243,943</td>
<td>384,667</td>
</tr>
<tr>
<td>Total</td>
<td>845,707</td>
<td>319,924</td>
<td>764,131</td>
<td>445,225</td>
<td>297,951</td>
<td>2,672,938</td>
</tr>
</tbody>
</table>

The Edge has notable proportions of cattle being traded with the HRA; higher than with the LRA. Trade with Scotland and Wales is very limited; the LRA trades more with Scotland (increasing from 9% in 2014, 10% in 2015 and 11% in 2016) than with Wales. The HRA and the Edge have nearly no trade with Scotland.
Small percentages of cattle move from the HRA to the Edge (11%), as in 2015 and 2014, with 6% going to the LRA. This is declining from 7% in 2015 8% in 2014. Still, the Edge receives 29% of their cattle from the HRA and 15% from the LRA. Pre- and post-movement testing can reduce the risk of disease introduction through purchases although it will not eliminate it. Annually (or less frequently) tested herds are subject to Pre movement testing. A total of 1.1 million of cattle in 2016 were moved out of the yearly-tested HRA and Edge areas (up 24,000 from 2015, which had also increased by 52,000 cattle in 2014). However, only 486,676 cattle tests were recorded as PRMT (around 44%) as other tests can be used to provide the same evidence of infection status prior to movement.

An increased proportion of TB incidents were detected by PRMT in the Edge in 2013 following the introduction of county level yearly testing (Figure 4.3.5). The proportion has continued to fall since then; likely due to PRMT being masked by herd-level tests (WHT or clearing SI tests) in this area.

![Figure 4.3.7. The proportion of total TB incidents disclosed by pre-movement testing* between 2007 and 2016, by risk area. *These data refer to tests categorised as PRMT, but note other test codes can be used as a pre-movement test, but are not included here.](image)

The proportion of TB incidents disclosed by pre-movement tests in the HRA has remained fairly stable since 2007; there has been more variability in the Edge Area and LRA. An increased proportion of TB incidents were detected in the Edge Area in 2014 following the increase in the number of eligible herds due to the introduction of county level yearly testing in 2013. A total of 320 TB incidents were detected in 2016 by pre-movement tests.
(87% occurred in the HRA; 10% in the Edge Area and 3% in the LRA), although these are still under-recorded.

The proportion of TB incidents detected by PRMT in the LRA has fluctuated since 2006 and is based on very low numbers of incidents (see Figure 4.3.5). Furthermore the predictive value of tests is reduced in the low risk areas.

Figure 4.3.8. Total TB incidents disclosed by pre-movement testing* between 2006 and 2015, in the Edge Area and LRA. *These data refer to tests categorised as PRMT, but other test codes can be used as a pre-movement test which are not included here.

Inconclusive Reactors (IRs)

Inconclusive reactors (IRs) are cattle that have a reaction to the TB skin test29 which is not large enough to classify them as reactor/s. These animals remain isolated in the herd awaiting the results of a retest in 60 days' time with movement restrictions applied to the whole herd (i.e. whole herd restrictions30). These herd restrictions are replaced by individual restrictions only on the IR/s if the herd has not had a confirmed TB incident in the previous three years (three-year rule). If the IRs are reactors or IRs at the first retest (i.e. two-time IRs), the IRs are deemed to be reactors, starting a TB incident in the herd (whole herd restrictions, reactor removal and additional incident testing imposed).

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29 Single Intradermal Comparative Cervical Test or SICCT
30 Whole herd restrictions apply to all temporary CPHs (tCPHs) and permanent CPHs (pCPHs) where no IRs have been disclosed and associated to the premises where the IR(s) was disclosed.
As expected, around ¾ of IR-only tests and IRs disclosed in these tests are in the HRA, followed by the Edge and LRA areas. Between 2015 and 2016, there were increases in the number of IR-only herds and IRs disclosed (Table 4.3.8).

Table 4.3.8. Summary of number of IR-only tests and IRs disclosed, their percentages and percentage change between 2015 and 2016 by surveillance risk area.

<table>
<thead>
<tr>
<th>Region</th>
<th>IR-only tests (%) (% change 2015-16)</th>
<th>IRs disclosed (%) (% change 2015-16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRA</td>
<td>2053 (74%) (+3%)</td>
<td>4226 (76%) (+14%)</td>
</tr>
<tr>
<td>Edge Area</td>
<td>455 (16%) (+2%)</td>
<td>804 (15%) (+3%)</td>
</tr>
<tr>
<td>LRA</td>
<td>277 (10%) (+14%)</td>
<td>509 (9%) (+33%)</td>
</tr>
</tbody>
</table>

In the Edge and LRA, nearly all IR-only tests in 2016 took place in herds with no recent confirmed TB incidents. In the HRA, 69% of IR-only tests took place in herds which had had a confirmed TB incident in the previous three years. This follows from higher incidence in the later region.

An unrestricted herd with only IRs disclosed can have a TB incident disclosed either at the IRs retest or at a subsequent test, or not having a TB incident within a subsequent 15-month period.

![Figure 4.3.14. Fate of IR-only tests, following disclosure in 2016 by surveillance risk area.](image)

Nearly half of IR-only test herds went on to have an incident within the following 15 months in the HRA (31% in the Edge and just over a quarter in the LRA). More incidents were confirmed vs unconfirmed in the HRA, but in the LRA and Edge, the opposite is true. More incidents were disclosed at a subsequent test than at the IR retest in the HRA but again, the opposite is true in the Edge and LRA. The differences between the incident categories are much more marked in the LRA compared to the Edge.

Risk ratio analyses were carried out for various possible outcomes: having a confirmed TB incident at the IR retest, at a subsequent test, having TB incident at either of these tests. To test whether having had a confirmed TB incident within the last three years was
associated with any of the outcomes considered\textsuperscript{31}, we split the IR-only test herds by whether they had had a confirmed TB incident or not.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure.png}
\caption{Proportion of IR-only herds going on to have a TB incident in 2016 at either the IR retest or a subsequent test (within 15 months after IR test), by surveillance risk area and TB history. Totals above each column represent the number of herds with a TB incident.}
\end{figure}

IR-only test herds had statistically significant associations between their TB history and:

- having a confirmed incident disclosed at retest, at a subsequent test and having any TB incident disclosed at a subsequent test in the HRA.
- having a confirmed incident at the retest in Edge area herds.

Inconclusive reactors are being looked at in terms of disease control as evidence shows that herds in which only IRs are disclosed have a substantial risk of a near future TB incident. This knowledge is being used to inform policies to mitigate this risk, which are undergoing consultation.

\textsuperscript{31} The event of a herd being an IR-only herd more than once during the reporting period was not taken into account. The impact of confounders has not been assessed.
4.4 Impact of disease and control measures: prevalence, duration and persistence

- During 2016, at any point in time, about 2,700 herds (over 5% of the cattle herds in England), were under movement and other restrictions due to a TB incident. This national prevalence level is similar to previous years.

- Most of these herds are in the HRA where around 2,000 herds (nearly 11%) are under restriction at any one time; this level has been stable since 2011.

- Prevalence in the Edge Area has increased almost ten-fold since 2003, with a particular rise since the introduction of a stricter regime for returning a herd to OTF status with the new Edge area policy in 2013. Prevalence was over 3% (~140 herds) on average during 2016.

- TB infected herds remained under restriction for a median of about six months in the HRA and Edge, reducing to about three months in the LRA, however the range was wide. Removal of infection from large herds, and those with more than one reactor, proved more challenging and such herds tended to be restricted for longer, increasing the impact on the farmer.

- The proportion of TB incidents that closed in 2016 in the HRA that were ‘persistent’, i.e. with infection present for 18 months or longer, was lower than the previous year (8.3 down to 6.5%), though this was still a substantial number of herds (220). However it increased in the Edge, to 9% (16 incidents, up from 9), but reduced to <1% (1 incident) in the LRA.

- In December 2016, 237 herds had an open persistent incident, with the monthly number fluctuating around 250, as similar numbers of incidents become persistent and have their restrictions lifted month by month.

- Over 25,000 cattle were slaughtered for TB control in 2016 and half of all closed TB incidents across England in 2016 had only one or two reactors removed (median). However for some farmers the loss was much greater as this statistic hides substantial differences between incidents and risk areas with high numbers in some incidents pushing up the average values. In 2016 an average of seven reactors were removed per breakdown in the HRA, six in the Edge Area and four in the LRA.

**Level of disease: Prevalence**

Prevalence shows the proportion of herds classified as infected with TB at a given point in time and is measured by counting the number of herds under restrictions due to a TB incident at the mid-point of each month. This measurement is therefore affected by both the occurrence of new TB incidents and the control strategy. The latter is determined by the risk of leaving infection present if controls are removed too soon, and specifies the
extent of testing needed to provide sufficient evidence to declare a herd free of TB, which affects the duration of restrictions (see next sub-section). As the prevalence of TB depends on both how many herds are newly infected with TB (incidence) and how long restrictions are maintained (duration), it gives an indication of how much impact the epidemic is having on the cattle farming sector.

During 2016, an average of 5.4% of herds in England overall were restricted at any one time, equating to over 2,700 herds. However this overall figure masks substantial differences between risk areas as shown in Figure 4.4.1, which also shows a seasonal cycle, likely related to the timing of testing (which is planned to fit with the farming calendar when possible).

![Figure 4.4.1 Proportion of live English herds under TB movement restrictions (prevalence) as a result of any TB incident, by month, between January 2007 and December 2016](image)

- Prevalence in the HRA has plateaued since 2011, but risen over time in the Edge; it has remained consistently low in the LRA.

From 2006 to 2011, the prevalence in the HRA increased to 11%, but has since stabilised. Prevalence in the Edge Area has increased steadily since 2007 with a marked upward trend since testing was increased in this area in 2013, reflecting the earlier detection achieved, and the more stringent controls deployed. Prevalence in the LRA has remained consistently low for the past ten years.

In 2016, as in previous years, there was a wide variation in the prevalence of TB incidents in different counties (Figure 4.4.2), with the highest prevalence seen in Wiltshire in the
HRA, and the lowest in counties in the LRA. Further details about prevalence at county level within each risk area are presented later in this report (Sections 5.1 to 5.3).

Figure 4.4.2 County prevalence: percentage of herds in the county that were under restrictions due to a TB incident at the end of 2016 (15th December)

**Duration of TB incidents (period of movement restrictions)**

Herd infected with TB are prevented from moving cattle while infection is being removed, to limit the risk of spreading TB. The duration of such movement restriction affects both farmers and tax payers because restrictions constrain the management of the herd and longer duration is generally associated with more tests and so greater costs. Shorter periods of restrictions enable a farmer to get back to business as usual more quickly, so minimising their economic impact, but must be balanced against the risk of leaving infection on farm (and further spread of disease) if restrictions are removed too early.

The median length of time required to clear disease in a herd in 2016 differed slightly, but not significantly, between risk areas (Figure 4.4.3a), although both the HRA and Edge had a greater proportion of herds restricted for over 200 days (~7 months) than the LRA.
Figure 4.4.3a Median duration (and ‘interquartile range’, IQR) of all TB incidents that closed in 2016 by risk area

- Herds tend to be restricted due to TB for slightly longer in the HRA than in the Edge, and for shorter in the LRA than both, however there is wide variation within each risk area.

In the HRA, herds tended to be restricted for longer than the other risk areas, with a median duration of about six months, and half of herds under restriction for between five and nine-and-a-half months (the ‘interquartile range’, IQR). The Edge Area median duration was similar (about 5½ months, IQR ~ 4½ - 8 months). However, in the LRA, the median duration of TB incidents was noticeably shorter at about three months (IQR ~ 2½ - 6½ months), reflecting the high number of suspect cases (OTFS) which require only a single SIT to demonstrate infection is not present.

Factors that are associated with a significant increase in duration include large herd size and number of reactors found (perhaps reflecting the probability of more recently infected cattle that may test negative at the time infection is first disclosed).

The duration that a herd was under movement restrictions was associated with herd size in all risk areas (Figure 4.4.3b). It took longer for restrictions to be lifted in herds with more than 200 animals as can be seen by the increasing proportion of such herds (green shading) in the longer duration categories on the right of the chart. Medium and small herd sizes predominate among herds that are restricted for shorter periods (left side of the chart, orange and blue shading respectively). Median duration in smaller herds of up to 50 animals shows a linear decrease, and as duration of incidents increases, the proportion of small herds affected decreases.
4. The TB epidemic in England

Figure 4.4.3b Comparative duration of TB incidents that closed in 2016, by risk area and herd size (values show number of herds in each size category)

- Smaller herds of up to 50 animals came off movement restrictions more quickly than herds with 51-200, which resolved more quickly than those with over 200 animals, regardless of risk area.

Long restriction periods are the result of challenges in removing infection, or in demonstrating that this is the case. They may result from a number of factors that can interfere with efforts to remove infection, such as a poor response of one or more infected animal to the skin test, intense cattle-to-cattle transmission, continued re-infection (e.g. from wildlife or contiguous herds), or (less commonly) the potential for uninfected animals to show non-specific reactions to tests.

There were a total of 3,794 herds in England where movement restrictions were lifted in 2016. Figure 4.4.3c shows the number of Short Interval Tests (SITs) it took to clear a TB incident, comparing risk area and herd size. Overall in England, forty five per cent of herds (with TB incidents that closed in 2016) took two SITs to clear, and 90% of all herds had five or fewer SITs to clear a TB incident. Only 2% had more than ten SITs.

In the HRA and Edge area, most TB incidents took two or three SITs to clear; for the LRA this was one or two. As previously discussed, the HRA has TB infected herds under restrictions for longer, therefore more herds in this area received more than five SITs compared to the Edge and LRA.
Figure 4.4.3c Number of short interval tests (SITs) to clear a TB incident, by risk area and herd size (for TB incidents ending in 2016. Note: 34 herds were missing information on SITs)

In the HRA, generally larger herds required three or more SITs to clear a TB incident, however there were more herds of 51-200 cattle in the HRA requiring one or two SITs compared to smaller or larger herds. Interestingly, the number of larger herds (>200 cattle) in the HRA requiring three SITs to clear a TB incident was lower than the number requiring five or more (345 vs 372).

Changes in duration over time

Since 2007, TB incidents with more than one reactor have consistently been under restriction for longer, in all risk areas, compared to incidents with one reactor only, and the former tend to fluctuate more (Figure 4.4.4). Herds in the HRA generally had a longer duration of movement restrictions in both categories. Duration for single reactor herds is largely driven by the required number of SITs, which for the LRA is often only one as many cases are suspect rather than confirmed, hence the lower duration for such herds in this area.
4. The TB epidemic in England

Figure 4.4.4 Median duration of TB incidents that closed in each year, between 2007 and 2016

- Since 2007, TB incidents in the HRA and those with more than one reactor have consistently been under restriction for longer, compared to incidents in the Edge or LRA, or with one reactor only.

Since 2013 most single reactor herds in both the HRA and Edge have required two SITs, leading to a similar duration of about 150 days in both areas for such herds, reflecting the logistics of delivery.

Persistent TB incidents

If a TB infected herd is under movement restrictions for over 550 days (about 18 months), infection is considered to be ‘persistent’. The majority of these incidents are subject to enhanced management procedures (discussed further in Section 4.5).

Figures 4.4.5 show the number of persistent incidents that were resolved in each year since 2007; the vast majority are in the HRA (note y axis is scaled to a tenth true value for HRA so that values for Edge and LRA can be seen). The numbers in the HRA have been reducing in recent years, however in the Edge they have been increasing since 2013, and in 2016 reached 16 incidents, exceeding the previous peak of 13 in 2010. Further details of the Edge Area epidemic are given in Section 5.2.
The number of persistent TB incidents is consistently higher in the HRA; in 2013 peaked at 337 but has since declined to around 200 (216 in 2016).

In the Edge area, the number of persistent TB incidents was highest in 2016 (16) but shows a fluctuating trend.

In the LRA, the total number of persistent TB incidents has been between 0 and 3 since 2007. There was only one TB incident that was classed as persistent in the LRA in 2016.

In December 2016, 237 herds had a persistent incident that had not been resolved ('open'), with the number fluctuating monthly around 250, as similar numbers of herds become persistent as others have their restrictions lifted month by month. The majority of these incidents (65%) had been ongoing for between 18 months and 3 years and only 10 incidents started 10 or more years ago. Most (89%) of persistent incidents are in the West region of England.

Persistent TB incidents have a variety of causes including:

- The limitations of the test in finding all infected animals, particularly in large herds, including continued spread within the herd due to presence of animals that fail to react to the test.
Repeated re-infection from an unidentified source, possibly driven by management factors, for example the need to use particular fields with known badger activity.

New infection unknowingly introduced with purchased animals (under licence), or new exposure in the environment, including contiguous herd breakdowns or changes in management.

Figure 4.4.5b Proportion (HRA) and location (elsewhere) of all TB incidents that ended in 2016 that had lasted more than 550 days (persistent incidents)

- Most herds that have prolonged infection with TB are located in the HRA, particularly Cornwall, Wiltshire and Gloucestershire where they formed more than 7.5% of all TB incidents that closed in 2016.

- Very few TB incidents that closed in 2016 in the Edge or LRA had infection persisting for longer than 18 months, and so are shown by their location rather than as a proportion of all incidents.

Number of animals removed

In 2016, a total of 25,468 cattle were slaughtered for TB disease control. The median number of reactors removed per incident has remained at two for several years; however some incidents have large numbers which raises the mean. The mean number of reactors in the HRA per TB incident from 2007 to 2016 has shown a slight fluctuation (Figure 4.4.6) of between 6-8 reactors per TB incident, with a slightly increasing trend. There has been
greater fluctuation in the Edge which showed a peak in 2015 likely reflecting the impact of the more stringent controls introduced from 2013, but has since stabilised. There are very few incidents in the LRA so the mean shows greater variability.

In 40% of all TB incidents that closed in 2016, no more than two reactors (to the skin or the gamma interferon [IFN-γ] test) were removed and there were no changes in the overall number of reactors removed between 2015 and 2016 (median=2) in England overall or the HRA or Edge (the median in the LRA was 1). In the HRA and the Edge area, the IQR was the same (1 – 6) and was lower in the LRA (1 – 2). The proportion of closed breakdowns in England with two or more reactors increased significantly from 55.8% in 2015 to 60.5% in 2016 (p=0.000). This was driven by the HRA, where the proportion of TB incidents with two or more reactors also increased significantly in 2016 compared to 2015 (from 56.2% to 62.4%, p=0.000). The increased proportion with more reactors without overall increase in reactor numbers likely reflects reducing numbers of herds. In the Edge and LRA the proportion of TB incidents with 2 or more reactors decreased in 2016 compared to 2015 (-7.9% and -14.1%, respectively) but were not statistically significant (p=0.2 and 0.3, respectively).

**Figure 4.4.6 Rolling mean number of reactors taken per TB incident that closed between Jan '07 and Dec '16, by risk area** (12-month moving average)

The majority of the >25,000 cattle removed from herds in 2016 were reactors taken from the HRA, and this has been the pattern over the last ten years (Figure 4.4.7). However substantial numbers are also taken as inconclusive reactors (IRs, 1,155 in the HRA) and dangerous contacts (DCs, 482 in the HRA).
Figure 4.4.7 Number of reactors, inconclusive reactors and dangerous contacts removed from herds between 2007 and 2016, by risk area (note HRA reactors presented as a tenth their true value)

- Most cattle removed are reactors taken from the HRA (same pattern observed over the past ten years), with substantial numbers also removed as dangerous contacts or inconclusive reactors.
4.5 Reducing transmission of disease: effectiveness of different controls

- New controls introduced in 2016 included:

  o Stricter management of new TB incidents in the HRA, with all incidents requiring two clear severe interpretation tests as a minimum, before restrictions are lifted.
  
  o Compulsory post-movement testing of cattle moving from higher risk areas to the LRA.
  
  o Funded voluntary pre-sale TB check test in a herd-dispersal sale in the LRA.
  
  o Private Interferon-gamma test (IFN-γ) in certain circumstances subject to authorisation.
  
  o Extension of the delivery of information packages on area, farm and TB incidents to all farmers affected by TB incidents in the HRA.
  
  o Continued and new badger cull areas in defined HRA areas
  
  o TB prevalence survey of badgers found dead in the Edge area.

- As in previous years, the vast majority of cattle removed were skin-test reactors (93%). Most were identified by standard interpretation however a fifth were found following severe interpretation. Less than 7% were identified by IFN-gamma. As previously, bacterial culture effectively confirmed TB, with positive results in 95% of visibly-lesioned (VL) carcases.

- Most bacteriologically confirmed samples came from standard reactors (70-80%). Confirmation rates within each area were highest also among standard reactors (35-44%). The next highest confirmation rate was found in IFN-gamma reactors in the HRA (27%), which confirms the usefulness of its current targeted application in this area.

- Nearly 66% of reactors were removed within the 10 working-day target (slightly down from 2015); a ‘reactor removal’ project aims to improve the current situation.

- Infected herds had a larger median size than the national population (167 animals versus 54), and were more likely to be detected in winter than summer.

- Parallel IFN-γ tests in confirmed incidents in the Edge and LRA areas accounted for over three quarters of all IFN-γ samples received. 67% of herd submissions had IFN-γ reactors disclosed in them. Out of the IFN-γ reactors disclosed, 14% were confirmed as infected by post mortem tests in 2016.
• Only one IFN-γ submission came from an unconfirmed incident in the Edge area, despite the latter becoming more frequent. This limited use and changing epidemiology in the Edge suggests there is scope to consider its wider application.

• The best performing tests for finding subsequent infection when an incident is being controlled were post-incident tests, followed by contiguous tests.

• Three herd depopulations were authorised in England in 2016 (one total and two partial).

• Results from badger culls in 2016 indicate that all ten badger control companies have delivered the level of badger removal required and that the operations were carried out to a high standard of public safety.

Cattle Slaughtered for Disease Control Purposes

In line with previous years, the vast majority of cattle removed for disease control purposes were reactors (93%). The majority of them were standard-interpretation reactors\textsuperscript{32}; a fifth severe-interpretation reactors\textsuperscript{33} and less than 7% were IFN-gamma reactors.

Confirmation means the detection of typical lesions at post mortem (PM) examination (Visibly-lesioned or VL sample) or of \textit{Mycobacterium bovis} (\textit{M. bovis}) in culture. All cattle slaughtered for disease control purposes have a post mortem examination\textsuperscript{34} (PM) but samples are only sent for culture and isolation of \textit{M. bovis} where this is required for case management (e.g. where no visible lesions are observed in that herd during the incident).

In line with previous years, 95% of visibly-lesioned (VL) samples from cattle yielded a positive culture result, whereas only 5% of non-visibly-lesioned (NVL) samples did so. Details are shown in figure 4.5.2 below.

\textsuperscript{32} Reactors whose readings of increases in skinfold thickness for bovine site are over 4 mm bigger than those on the avian site (irrespective of whether the avian site reading is positive or negative)
\textsuperscript{33} Reactors whose readings of increases in skinfold thickness for bovine site are >3 mm bigger than those on the avian site or those with a positive bovine reading and negative avian reading.
\textsuperscript{34} Missing PM examination in 0.8% of reactors and 0.7% of IRs and DCs slaughtered.
Figure 4.5.2. Diagram showing the number of cattle that were slaughtered for TB control reasons in 2016 and the number in which infection with *Mycobacterium bovis* was confirmed.

Cattle slaughtered that had not reacted to the test but with strong epidemiological evidence of being infected (‘dangerous contacts’) are shown separately. Inconclusive reactors (IRs) include farmer as well as APHA-led slaughtered cattle.
Eighty per cent of samples taken in 2016 did not need a culture result (or had one pending at the time of report); 22% of these were VL samples and 58% were NVL samples. The latter, most likely from TB incidents already confirmed by other samples.

![Graph showing number of cattle slaughtered for TB control reasons in 2016 by type and surveillance risk area, including confirmation rates. Inconclusive reactors (IRs) include farmer as well as APHA-led slaughtered cattle.]

As expected, the vast majority of cattle slaughtered came from the HRA (over 85%) as well as over 90% of confirmed cattle.

IFN-gamma tests are compulsory in confirmed incidents in the Edge and LRA but discretionary in the HRA. IFN-gamma reactors represent around 45% of all cattle slaughtered in the Edge and LRAs (1,444 and 277 respectively), but just under 2% in the HRA (457 reactors).
Regarding the proportion of confirmed cattle within each surveillance risk area, close to or over three quarters of confirmed cattle slaughtered were standard-interpretation reactors. Standard reactors from the HRA had the highest confirmation rate, followed by standard reactors in the Edge and the LRA. These are followed by severe interpretation reactors in the HRA but by IFN-gamma reactors in Edge and LRA.

In the HRA, the confirmation rate of IFN-gamma reactors is higher than the confirmation rate of severe reactors (27% vs 21%), which proves its useful role at removing infected cattle using the current targeted approach. The extension of use of gamma-IFN test in the HRA is being consulted on.

Figure 4.5.4. Overview of the variation in numbers of cattle slaughtered for disease control purposes by category and surveillance risk area since 2007.

Over the years, there have been variations in the number of cattle removed. For example, there was a marked increase in the number of reactors in the Edge when the requirements to: a) have two clear tests at severe interpretation for all incidents before lifting restrictions and b) compulsory application of IFN-gamma test in all confirmed TB incidents, were rolled out from 2013 and 2014 respectively.

The measure requiring two clear tests at severe interpretation before restrictions are lifted from any incident applies since April 2016 in the HRA. This means that IRs disclosed at standard interpretation may be removed as reactors when reinterpretation at severe is applied, increasing the number of reactors and reducing the risk of leaving residual infection in the herd. Figure 4.5.4 below shows these effects, with increasing numbers of reactors taken, particularly in the Edge Area, in recent years.
APHA has a target removal interval of 10 working days from the disclosure of reactor and DC cattle. In England in 2016, nearly 66% of cattle were removed on target (slightly down from nearly three quarters in 2015). There were regional variations: from a maximum of 87% in the North region removed within target, to a minimum of 61% in the South East region.

The rollout of the reactor removal project in autumn 2017 expects to have a beneficial impact in these figures. Delayed removal has a negative economic (and potentially welfare) impact on the farm and can increase the risk of disease spread if the reactors/DCs are not kept in appropriate isolation conditions\(^{35}\).

**Characteristics of infected herds**

With herd size being a risk factor for having a TB incident\(^{36}\), it is no surprise that the median herd size of herds with a TB incident disclosed in 2016 is higher than the median herd size in the national herd. In 2016, the median herd size at incident disclosure was 167. The median herd size in all holdings in England was 54 (median of monthly averages through 2016).

TB incidents were detected throughout the year, with a minimum of 206 in June and a maximum of 398 in January. Fewer incidents were detected over the summer months: 6% in June, July and August compared to winter months (over 8% per month, with a maximum of 11% in January). This is most likely due to variations in number of tests performed per month, with less cattle tested in summer when cattle are at grass and farmers are busy with harvesting and silage making. Further analysis of the seasonality of testing will be considered for resource allocation next year.

All incidents where the causative organism of bovine tuberculosis (*Mycobacterium bovis*) is isolated undergo genetic testing to determine its genotype. This gives an indication of the typical location of particular types of bacteria or their home range, using historical sampling (2011-2016). In 2016 in England, the most frequent genotype was 11:a, found in just over a fifth of samples. This was followed by 17:a and 25:a (based on 2,307 samples from incidents starting in 2016). These three genotypes accounted for just over 50% of all genotypes disclosed.

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\(^{35}\) Isolation requirements set by a legal notice served on the owner/keeper of reactor/DC animal.

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Figure 4.5.5. Home range areas using 2011-2016 data for spoligotypes 11:a, 17:a and 25:a

These are the three most frequently found genotypes of each spoligotype (i.e. 11a, 17a and 25a) and cover extensive areas in the SW of England and Wales (Figure 4.5.5). They can help provide information on the causal pathways involved in incidents (e.g. a purchased confirmed animal is the index case of an incident and the home range of the genotype of this reactor’s sample matches the location of the originating farm). A pilot project is currently being conducted to improve genetic typing of samples using Whole Genome Sequencing, to provide more detailed information.

Dealing with infected herds

The main test used in surveillance for the detection of bovine TB, the skin test or SICCT is also the main test used in the control of TB incidents, once disclosed. The skin test is used during incidents at 60 day intervals and this is called a Short Interval Test (SI).
One way to enhance the detection of infected cattle that apply to all areas is to take additional cattle that we suspect are infected and have a link with infected cattle. They are removed as dangerous contacts, as discussed above.

All confirmed incidents in the LRA and Edge areas must use IFN-gamma to enhance the detection of reactors, whereas its application is discretionary in the HRA. Specific information on its use is provided below.

**Use of additional or “ancillary” tests for detection of infected cattle within a TB incident**

The gamma interferon blood test, (IFN-γ\(^{37}\)) is used to increase the probability of detecting infected cattle that may not have been detected by the skin test due to imperfect sensitivity. Its main use is to complement the skin test within confirmed incidents (i.e. used in parallel). This is mandatory in all confirmed incidents in Edge and LRA to take more proactive action in removing infected cattle, whereas in the HRA its use is discretionary.

A total of 73,268 cattle were tested with the IFN-γ test in 2016 in England (71% of total in GB); 3% of which were positive (2,529 IFN-γ reactors). In 660 submissions made, 440 had IFN-γ reactors disclosed (67%). Parallel tests in Edge and LRA confirmed incidents accounted for over three quarters of all samples. Of these 2,529 IFN-γ reactors were found, with 355 or 14% of them being confirmed (all were VL except one NVL reactor confirmed on culture).

Since 2010, the proportion of IFN-γ reactors detected from all samples taken has been stable at 4-5% (5% in 2016). Additional data since its rollout in 2006 is presented below. The proportion of IFN-γ reactors remains relatively low and stable at around 10% (this test identifies infected cattle up to two weeks post-infection i.e. very early, so the chance of having confirmed samples is lower than for skin tests as there has been little time for lesions to form).

\(^{37}\) Supplementary or ancillary test: Bovigam interferon-γ blood test (Prionics AG, Switzerland)
4. The TB epidemic in England

Figure 4.5.6. Number of samples tested, herds sampled and proportions of herds positive and IFN-γ confirmed.

As mentioned above, just over 100 samples have been taken using the new private scheme, introduced in April 2016.

Another discretionary use of the IFN-γ test in parallel use with the skin test is its application to unconfirmed incidents in the Edge area. Only 744 cattle as part of seven submissions have been tested under this policy in the years since the rollout of IFN-γ, up to 31 December 2016 (0.14% of the total). Only one of these submissions, from a single farm was in 2016, when 190 cattle were tested under this premise (0.18% of total). This suggests this policy option could usefully be used more widely, as shown by the evidence presented above where 67% of gamma tests revealed additional reactors. IFN-γ tests are also used in persistent incidents, as part of the enhanced incident management procedures: 58 submissions were received in 2016 with 6,608 cattle sampled and 487 reactors detected. It can also be used to inform depopulation procedures and it was used in one occasion for this purpose in England in 2016. See below for further information.

In terms of its use in serial application with the skin test, to confirm the presence of *M. bovis* infection, there were 14 submissions of this type (e.g. in suspect fraud cases).

**Persistent incidents and enhanced TB incident management procedures**

If a TB incident in a herd is persistent (duration over 550 days or 18 months) or if it is explosive (several reactors initially disclosed), it is eligible for enhanced incident management measures. Such procedures include tailored advice and support to the farmer and enhanced sensitivity of testing to increase the chance of detecting infected
cattle (stricter interpretation, use of additional testing, etc.). Persistent herds are described further in Section 4.4.

At the end of 2016 there were nearly 200 herds under restriction and registered for enhanced management procedures in the South West region, with under 100 in the Midlands and less than 10 in both the North and South East regions.

**Depopulation**

An extreme way of dealing with an infected herd is the removal of all cattle in the herd or in certain groups. This is an exceptional measure in severe incidents and subject to certain criteria being met, veterinary risk assessment carried out and approval granted. Usually the scenario involves a high number of cattle infected as well as additional suspects on farm.

As discussed above, additional testing (i.e. IFN-gamma) to gather more information can be carried out before this is undertaken. 3 depopulations for disease control purposes were carried out in 2016 (one total and two partial).

**Limiting spread and containing disease when found: efficacy of additional surveillance**

As discussed in Section 4.3, surveillance carried out due to an increased likelihood of infection being present (‘Area & Herd risk’ tests) is the most successful at finding infected herds, and in 2016 41% of all incidents and 40% of confirmed ones were so disclosed. This section describes the relative success of these tests. The data about all surveillance tests is presented in Table 4.3.1 in Section 4.3.

**Contiguous test efficacy.**

Contiguous’ tests (CON, CON12) are used to detect infection in herds in the vicinity of a herd with a confirmed TB incident in the HRA and Edge areas (except Derbyshire Edge and Cheshire Edge where more frequent testing of all herds is used instead) and are part of the ‘Area and Herd risk’ surveillance stream. The vast majority of contiguous tests were carried out in the HRA. They detected 14.1 incidents per 100 herd tests and 3.9 reactors per 1,000 cattle tests. The application of contiguous testing is decided on a case by case basis as part of case management.
4. The TB epidemic in England

Table 4.5.1. Contiguous tests: proportional distribution and reactors and TB incidents detected by risk area, as a proportion of the Area & Herd Risk surveillance stream, and of all surveillance streams

<table>
<thead>
<tr>
<th>CONTIGUOUS</th>
<th>Cattle Tests</th>
<th>Reactors</th>
<th>Herd Tests</th>
<th>Incidents</th>
<th>Confirmed Incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRA % (n)</td>
<td>97% (n= 225,277)</td>
<td>99% (n=907)</td>
<td>97% (n=1,818)</td>
<td>98% (n=260)</td>
<td>99% (n=175)</td>
</tr>
<tr>
<td>Edge % (n)</td>
<td>3% (n=7,865)</td>
<td>1% (n=8)</td>
<td>3% (n=49)</td>
<td>2% (n=4)</td>
<td>1% (n=2)</td>
</tr>
<tr>
<td>LRA % (n)</td>
<td>0% (n=5)</td>
<td>0% (n=0)</td>
<td>0% (n=1)</td>
<td>0% (n=0)</td>
<td>0% (n=0)</td>
</tr>
</tbody>
</table>

Proportion of Area & Herd risk surveillance stream
- 14% 19% 8% 17% 18%

Proportion of all surveillance
- 6% 10% 2% 7% 7%

Radial test efficacy

Radial tests (RAD, RAD6 and RAD12) have been used since 2013 to test herds within 3km of a confirmed incident in the LRA and in small parts of the Edge area (i.e. the east of Derbyshire and, until January 2015, the Ege area of Cheshire). Nearly all of them are carried out in the LRA. They detected 2.4 incidents per 100 herd tests and 0.2 reactors per 1,000 cattle tests.

Table 4.5.2. Radial tests: proportional distribution and reactors and TB incidents detected by risk area, as a proportion of the Area & Herd Risk surveillance stream, and of all surveillance streams

<table>
<thead>
<tr>
<th>RADIAL</th>
<th>Cattle Tests</th>
<th>Reactors</th>
<th>Herd Tests</th>
<th>Incidents</th>
<th>Confirmed Incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRA % (n)</td>
<td>1% (n= 3,641)</td>
<td>0% (n=0)</td>
<td>1% (n=25)</td>
<td>0% (n=0)</td>
<td>0% (n=0)</td>
</tr>
<tr>
<td>Edge % (n)</td>
<td>2% (n=7,382)</td>
<td>18% (n=12)</td>
<td>5% (n=122)</td>
<td>11% (n=6)</td>
<td>25% (n=2)</td>
</tr>
<tr>
<td>LRA % (n)</td>
<td>97% (n=313,836)</td>
<td>82% (n=53)</td>
<td>94% (n=2,207)</td>
<td>89% (n=51)</td>
<td>75% (n=6)</td>
</tr>
</tbody>
</table>

Proportion of Area & Herd risk surveillance stream
- 19% 1% 10% 4% 1%

Proportion of all surveillance
- 8% 1% 3% 2% 0%

Tracing test efficacy

Tracing tests (forward and backward tests) are triggered from a confirmed TB incident to check a possible source of infection or whether it had spread and are therefore very important to contain disease. Around 70% of these tests were carried out in the HRA, with the rest divided between the LRA (17%) and the Edge (13%). In 2016, these detected 0.8 incidents per 100 herd tests and 2.2 Reactors per 1,000 cattle tests.
These numbers are an underestimation, as if a tracing test is carried out at the same time as a surveillance herd test, only the latter would be recorded.

Table 4.5.3. Tracing tests: proportional distribution and reactors and TB incidents detected by risk area, as a proportion of the Area & Herd Risk surveillance stream, and of all surveillance streams

<table>
<thead>
<tr>
<th>TRACING</th>
<th>Cattle Tests</th>
<th>Reactors</th>
<th>Herd Tests</th>
<th>Incidents</th>
<th>Confirmed Incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRA % (n)</td>
<td>67% (n= 39,592)</td>
<td>87% (n=115)</td>
<td>71% (n=7,333)</td>
<td>80% (n=64)</td>
<td>79% (n=45)</td>
</tr>
<tr>
<td>Edge % (n)</td>
<td>10% (n=5,717)</td>
<td>8% (n=10)</td>
<td>13% (n=1,308)</td>
<td>11% (n=9)</td>
<td>11% (n=6)</td>
</tr>
<tr>
<td>LRA % (n)</td>
<td>24% (n=14,088)</td>
<td>5% (n=7)</td>
<td>17% (n=1,719)</td>
<td>9% (n=7)</td>
<td>11% (n=6)</td>
</tr>
</tbody>
</table>

Proportion of Area & Herd risk surveillance stream

<table>
<thead>
<tr>
<th>Proportion of Area &amp; Herd risk surveillance stream</th>
<th>3%</th>
<th>3%</th>
<th>44%</th>
<th>5%</th>
<th>6%</th>
</tr>
</thead>
</table>

Proportion of all surveillance

<table>
<thead>
<tr>
<th>Proportion of all surveillance</th>
<th>1%</th>
<th>1%</th>
<th>13%</th>
<th>2%</th>
<th>2%</th>
</tr>
</thead>
</table>

Over 95% of all herds that had a tracing test had a forward tracing test in all risk areas. The vast majority of incidents detected by tracing tests in the Edge and LRA and of all incidents in the HRA were detected by forward tracing tests. However, in terms of individual cattle tests, slightly more cattle had a backward tracing test than a forward one in the LRA (in the HRA and Edge area, more cattle had a forward tracing test).

In terms of performance, the backward tracing tests detected more incidents (9 per 100 herd tests) and reactors (3 per 1,000 cattle tests) than the forward tracing tests (1 incident per 100 herd tests and 2 reactors per 1,000), which reflects their importance in value if not in volume.

**Post-TB incident test efficacy**

As discussed above, the diagnostic tests are imperfect and may miss infected cattle. There are area variations but in general, after a TB incident is resolved and trading restrictions have been lifted, post-incident tests are conducted at six months and twelve months intervals in order to detect any residual infection in the herd. However, if a new incident is detected, it is sometimes difficult to say if this is due to residual infection or to a new infection with the same or a different source and risk pathway, so measures to tackle both are necessary to prevent recurrence.

Irrespective of this, although they only represent a quarter of herd tests, they detect over 70% of incidents and reactors disclosed within this surveillance stream. They represent 7% of herd tests in England but detect nearly 30% of all incidents and nearly 40% of all reactors.

They are particularly important in the HRA, where 6 and 12 month tests disclosed 19 incidents per 100 herd tests and 4 reactors per 1,000 cattle tested.
Table 4.5.4. Post-TB incident tests: proportional distribution and reactors and TB incidents detected by risk area, as a proportion of the Area & Herd Risk surveillance stream, and of all surveillance streams

<table>
<thead>
<tr>
<th>POST-INCIDENT</th>
<th>Cattle Tests</th>
<th>Reactors</th>
<th>Herd Tests</th>
<th>Incidents</th>
<th>Confirmed Incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRA % (n)</td>
<td>87% (n= 875,052)</td>
<td>96% (n=3,398)</td>
<td>88%(n=4,951)</td>
<td>94% (n=1,017)</td>
<td>96% (n=709)</td>
</tr>
<tr>
<td>Edge % (n)</td>
<td>10% (n=102,249)</td>
<td>4% (n=130)</td>
<td>9% (n=519)</td>
<td>5% (n=52)</td>
<td>4% (n=31)</td>
</tr>
<tr>
<td>LRA % (n)</td>
<td>3% (n=29,143)</td>
<td>0% (n=13)</td>
<td>3% (n=148)</td>
<td>1% (n=10)</td>
<td>0% (n=2)</td>
</tr>
</tbody>
</table>

Proportion of Area & Herd risk surveillance stream

|                | 59% | 74% | 24% | 71% | 74% |

Proportion of all surveillance

|                | 24% | 39% | 7%  | 29% | 29% |

Altogether, the tests mentioned above account for the vast majority of cattle tests carried out under the Area & Herd risk surveillance stream (94%) and 39% of all cattle tests done. In terms of herd tests, they are 86% of the Area and Herd risk surveillance stream and 24% of the total; outside an incident herd.

Hotspot procedures

There are other test types also used to mitigate the potential effect of infection once detected, as well as providing information on its origin. These tests are used in low incidence areas, in response to an incident of unclear origin. Hotspot tests apply to herds identified within 3km of the index herd.

Only 2 herds, one in the LRA and one in the Edge had hotspot tests applied in 2016. No incidents were disclosed as a result.

Summary of Area and Herd Risk tests’ performance

Table 4.5.5 summarises the performance of all Area and Herd Risk tests mentioned, in terms of incident and reactor detection as a proportion of tests in herds and cattle tested.

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38 Low incidence areas refer to the four-yearly testing area of England or the low incidence area in Wales.
Table 4.5.5. Summary of performance of Area and Herd Risk tests in unrestricted herds, regarding incident and reactor detection

<table>
<thead>
<tr>
<th>Area and Herd Risk Tests</th>
<th>Incidents (per 100 herd tests)</th>
<th>Reactors (per 1000 cattle tests)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-incident</td>
<td>19</td>
<td>4</td>
</tr>
<tr>
<td>Contiguous</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Backward tracing</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Radial</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Forward tracing</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

The best performing tests in terms of incident disclosure are post-incident tests, although they are meant to be a check to make sure no infection is left behind following incident resolution. They detect the majority of incidents in the HRA, where the recurrence rate is higher. Further analysis is required to explain recurrence causes but this suggests routine surveillance could be ramped up in this area as well as enhancing disease stamping out policies during incidents (recrudescence is a cause of recurrence). As discussed, the stricter requirements for lifting restrictions in all incidents in the HRA since April 2016 will contribute to this. The next tests in terms of performance are contiguous tests.

Five tests that had incorrect test codes have not been taken into account in this section.

Bovine tuberculosis in species other than cattle

TB in badgers

Although bovine TB can infect any warm-blooded mammal, the main wildlife reservoir in England is the European badger (*Meles meles*). In the HRA of England, where the influence of badgers in the epidemic is suspected to be stronger, licensed badger culling has been in progress for the last four years in selected areas. Culling has been conducted each autumn since 2013 in areas of Gloucestershire and Somerset and since 2015 in Dorset. Seven new areas were added in 2016. The numbers of badgers culled in 2016 in each area are shown below.

Table 4.5.6. Table showing number of badgers removed in licensed cull areas in 2016

<table>
<thead>
<tr>
<th>Cull Area</th>
<th>Number of badgers removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1-Gloucestershire (4th year; 2013 start)</td>
<td>252</td>
</tr>
<tr>
<td>Area 2-Somerset (4th year; 2013 start)</td>
<td>217</td>
</tr>
<tr>
<td>Area 3-Dorset (2nd year; 2015 start)</td>
<td>502</td>
</tr>
<tr>
<td>Area 4-Cornwall (1st year)</td>
<td>711</td>
</tr>
<tr>
<td>Area 5-Cornwall (1st year)</td>
<td>851</td>
</tr>
<tr>
<td>Area 6-Devon (1st year)</td>
<td>2,038</td>
</tr>
<tr>
<td>Area 7-Devon (1st year)</td>
<td>833</td>
</tr>
<tr>
<td>Area 8-Dorset (1st year)</td>
<td>3,000</td>
</tr>
<tr>
<td>Area 9-Gloucestershire (1st year)</td>
<td>1,858</td>
</tr>
<tr>
<td>Area 10-Herefordshire (1st year)</td>
<td>624</td>
</tr>
</tbody>
</table>
Results from 2016 indicate that all ten badger control companies have delivered the level of badger removal required and that the operations were carried out to a high standard of public safety. Further information can be found at the Summary of badger control monitoring during 2016\textsuperscript{39}. It is too soon to draw firm conclusions about the effect of the industry-led badger culls on the disease incidence in cattle. However Brunton et al. (2017)\textsuperscript{40} recently published an ‘adjusted’ (multivariable) analysis using the first two years of available data, and a descriptive analysis of data captured to date is due for publication concurrently with this report, at the same location\textsuperscript{41}. TB in badgers is also controlled through the licensed use of injectable BCG vaccine (when available) in the HRA and Edge areas.

**TB in other animals**

Specific procedures are in place to deal with TB incidents in species other than cattle. In England in 2016, the highest proportion of premises with non-bovine species under movement restrictions due to suspect or confirmed bovine TB were South American (SA) camelid premises (39%), followed by pig premises. However, the highest proportion of TB confirmed premises were in the “Other” species category\textsuperscript{42}, followed by pigs (20%) and SA camelid premises (16%). Individual pig samples made up the highest proportion of submissions (28%), followed by SA camelid submissions. However, the highest number of samples positive for *M. bovis* was deer and “Other” samples with 29 each, followed by goat samples. These three groups made up for 65% of all *M. bovis* positive samples. The impact of TB incidents can be considerable in some cases, with 755 goats removed as test reactors in 2016 from three premises with a new confirmed TB incident. This is dependent on the number of animals in the premises and the extent of infection. Regarding infected wildlife other than badgers, wild deer accounted for 44 individual samples submitted of which 25 were confirmed. Table 4.5.7 summarises samples and results by species.

\textsuperscript{39}www.gov.uk
\textsuperscript{40}Ecology and Evolution. 2017;1–18
\textsuperscript{42}The “Other” species category refers to both domestic pets and zoo animals not covered by more specific categories detailed within the report.
### Table 4.5.7. Data on bovine TB in species other than cattle in England in 2016

<table>
<thead>
<tr>
<th>Reporting period:</th>
<th>S A Camelids</th>
<th>Sheep</th>
<th>Goats</th>
<th>Pigs</th>
<th>Deer</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Jan 2016 - 31 Dec 2016</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **No. of premises placed under movement restrictions in 2016 due to suspected TB or a confirmed incident of *M. bovis* infection (1)**
  - 46
  - 5
  - 23
  - 33
  - 5
  - 5

- **No. of premises with a new TB incident which was confirmed by culture of *M. bovis***
  - 8
  - 2
  - 3
  - 10
  - 6
  - 22

- **No. of animals removed as TB test reactors.**
  - 37
  - 1
  - 755
  - 16
  - 6
  - 0

- **Total no. of premises under movement restrictions at the end of the reporting period due to suspected TB or a confirmed incident of *M. bovis* infection (2)**
  - 65
  - 6
  - 30
  - 34
  - 21
  - 26

- **No. of individual animal specimens submitted for post-mortem examination at APHA laboratories due to suspected TB (3)**
  - 106
  - 7
  - 38
  - 117
  - 52
  - 91

- **Of those, the number that was positive for *M. bovis*. (Note that lack of a positive culture does not mean disease was not present in the animal) (4)**
  - 20
  - 2
  - 27
  - 23
  - 29
  - 29

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(1) 7 holdings listed here contained multiple species; (2) 14 holdings listed here contained multiple species; (3) The “Deer” category includes 44 wild deer; (4) The “Deer” category includes 25 wild deer

Most cases appear to be an overspill from infection in cattle or main reservoirs. More analysis is needed to ascertain their contribution to the epidemic, although their role appears to be small at the moment. Additional information can be found at the [Bovine TB in non-bovine species – Combined 2016 report](https://www.gov.uk/government/statistical-data-sets/other-tb-statistics).
5. Epidemiology of TB in each Surveillance Risk Area

5.1 High Risk Area

- In the HRA as a whole, there was a marginally significant small reduction in TB incidence in 2016 compared to 2015 (-4.3%). The increase in incidence in 2015 compared to 2014 was not statistically significant and the level of incidence in 2014 was the same as 2016 (17.9 incidents per 100 herd-years at risk). This suggests that disease may be plateauing rather than declining.

- The incidence per 100 herd-years at risk increased in seven HRA areas from 2015 to 2016. Wiltshire, Devon and Oxfordshire HRA continue to be the top HRA areas for incidence with minor changes in their ranking. Oxfordshire HRA had the highest TB incidence in both 2015 and 2016 (26 and 27 incidents per 100 herd-years at risk respectively). Derbyshire HRA, East Sussex HRA and West Midlands have had the lowest incidence rates in all HRA areas since 2014.

- Oxfordshire also registered the highest prevalence in 2016 (17% herds under restriction due to a TB incident at year end), followed by Devon and Wiltshire with 15%.

- Devon and Cornwall have the highest population of herds in the HRA, with 33% of unrestricted herds, and account for around 40% of TB incidents (and of confirmed ones). The higher proportion of incidents compared to herds reflects increased risk due to other factors (e.g. Devon also has a high percentage of large herds of over 300 cattle).

- However, within each county, Cheshire HRA has the highest proportion of herds of over 300 cattle (19%) and incidentally the highest percentage of dairy cattle (77%); but it is the fourth lowest area in terms of incidence, which shows the multifactorial aspect of the disease.

- Looking at TB incidents that closed in 2016, Wiltshire and Dorset had had herds under movement restrictions due to a TB incident for the longest period (over 200 days in both cases). Of the TB incidents that closed in 2016, none of them had lasted over 18 months ('persistent') in Cheshire HRA, East Sussex HRA and West Midlands. This suggests that the impact of the disease in terms of duration of restrictions is felt differently across the HRA.

- Tests in the HRA accounted for 10% of all IFN-gamma tests carried out in 2016. Over 50% of these IFN-gamma tests were carried out in Devon, Avon and Somerset.
The HRA extends from the western areas of the Midlands to the South and West of England (excluding the Isles of Scilly) and part of East Sussex. It has 16 counties, five of which are mixed HRA/Edge areas. Defra’s overall objective for the HRA is to reduce TB, seeking initially to stabilise incidence and then to start to reduce it. Local and national bespoke initiatives are being implemented; with challenges coming from the high volume of cases.

Figure 5.1.1. HRA county map showing also Edge areas in blue

In this chapter, TB infected herds are reported with no distinction between status (confirmed or suspected), due to the high positive predictive value of the skin test in HRA, meaning very close to 100% of all TB test positive herds are infected.

Overall in the HRA there was a significant decrease in incidence per 100 herd years at risk (HYR) in 2016 compared to 2015 (p=0.049). The ‘spike’ in incidence in 2015 in several areas (Figure 5.1.2) may have been at least partly due to the efforts to reduce the number

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44 The counties with mixed HRA and Edge Area status are Cheshire, Derbyshire, East Sussex, Oxfordshire and Warwickshire. Data reported is for the HRA portion of these counties unless otherwise stated.

45 PPV in high incidence areas if severe interpretation used only in confirmed incidents (95%CI): 92.3% (91.1-93.7%). Goodchild, A. V., et al. (2015). “Specificity of the comparative skin test for bovine tuberculosis in Great Britain.” 177(10): 258
of herds with overdue tests in 2015, which will have had the effect of finding additional cases that should have been disclosed in 2014 or earlier. The incidence in the HRA as a whole in 2014 was 17.9 incidents per 100 HYR, i.e. the same value as 2016; so it is more likely that the HRA incidence is plateauing rather than declining.

Table 5.1.1 Table of headline figures for the High Risk Area for TB in England

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of TB infected herds</th>
<th>Incidence rate¹</th>
<th>Median duration of TB incident (days) (interquartile range)</th>
<th>Prevalence² (average monthly)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>3,229</td>
<td>17.9</td>
<td>185 (146 to 289)</td>
<td>10.7</td>
</tr>
<tr>
<td>2015</td>
<td>3,401</td>
<td>18.7</td>
<td>179 (143 to 272)</td>
<td>10.5</td>
</tr>
<tr>
<td>Change (%)*</td>
<td>-3.7% (p=0.024)</td>
<td>-4.3% (p=0.049)</td>
<td>+3.4% (p=0.117)</td>
<td>+1.9% (p=0.791)</td>
</tr>
</tbody>
</table>

The z-test was used to compare incidence rates and prevalence between 2015 and 2016. The changes in total number of breakdowns and breakdown duration were compared using a chi-squared test.

¹ TB infected herds per 100 herd-years at risk
² The percentage of herds under restriction due to a TB incident on average per month

County level risk for new infection with TB

The preferred measure of disease occurrence is incidence per 100 herd-years at risk (per 100 HYR), which reflects the rate at which new TB incidents are occurring and is a proxy for risk. Figure 5.1.2 ranks counties and part-counties in the HRA by their incidence rate (per 100 HYR) since 2014.

Figure 5.1.2. Incidence rate (per 100 herd-years at risk) per year since 2014, by HRA county (or HRA portion of mixed HRA/Edge area county if *). Areas ranked by incidence in 2016.
The incidence increased in 7 HRA areas from 2015 to 2016 (it had increased in 9 areas in 2015 compared to 2014). Oxfordshire HRA had the highest county incidence over the last two years with 26 and 27 incidents per 100 HYR in 2015 and 2016 respectively. This was followed by Devon in 2016 (22 incidents per 100 HYR) and by Wiltshire in 2015 (25 incidents per 100 HYR).

The majority of HRA areas had an increase in incidence in 2015, to which the reduction in the number of overdue tests could have contributed. Thus it is possible that the decrease in incidence between 2015 and 2016 seen in Devon, Avon, Warwickshire, Somerset and West Midlands is an artefact caused by the 2015 ‘peak’, as incidence in 2016 was higher than in 2014 in all these counties (Figure 5.1.2). Oxfordshire HRA and Cornwall have had an increasing incidence trend since 2014, whereas Shropshire (and less markedly in Gloucestershire and Hereford and Worcester) have had a decreasing trend. In terms of the lowest incidence areas, Derbyshire HRA, East Sussex HRA and West Midlands have had the lowest incidence rates in all HRA areas since 2014.

As mentioned, there was a marked reduction in overdue tests in 2015\textsuperscript{46}, with the HRA and HRA/Edge area full counties going from having 294 in January 2015 to 13 in January 2016 and 17 in January 2017 (total number in England for 2016: 37). This could have contributed to the increase in the number of cases in some areas.

Demographics and influence on TB

The risk of TB is shown consistently to increase with the number of cattle in a herd and other factors, like the level of fragmentation of the farm land (Broughan et al., 2016\textsuperscript{47}). The total number of cattle is a crude demographic measure as the cattle distribution and management within herds can influence the risk of disease. The more cattle, the more TB incidents but the extent of the proportional relationship varies between areas (see figure below).

\textsuperscript{46} Overdue tests linked to a reduction in Common Agriculture Payments since January 2015.
Unsurprisingly there was a statistically significant positive strong association between the total number cattle and total number of incidents as well as between the total number of herds and total number of incidents in HRA areas in 2016\(^48\). So areas with more herds and cattle had more incidents. This is most evident in Devon which has 21% of all the herds in the HRA and 23% of larger herds (over 300 cattle) in the HRA. However, within each area, Cheshire HRA has the highest proportion of herds of over 300 cattle (19%), followed by Dorset (17%). Cheshire HRA and Oxfordshire HRA have the highest percentage of 301-500 cattle herds (11%). Cheshire HRA also has the highest proportion of herds with over 500 animals (9%), with Oxfordshire HRA having 2% of those herds within its area (3 herds) (see figure below). However, they have stark differences in their incidence rate: Cheshire HRA with 13 and Oxfordshire HRA 27 incidents per 100 herd-years at risk.

The different pattern seen between Figures 5.1.2 and 5.1.3, which are both presented with counties ranked in order of incidence in 2016, shows that although the more cattle and herds that are present, the more TB incidents will occur, the risk for an individual farm to have a TB breakdown is only partly associated with this. Consideration of the incidence rate at which new cases are detected, rather than the total number of incidents, helps to highlight other risk factors for infection. Thus despite these areas having lower numbers of both herds and cattle compared to other areas in the HRA, herds located in Oxfordshire...

\(^{48}\) Spearman’s rho=0.95 P-value<0.0000
HRA, Wiltshire, Gloucestershire, Avon and Warwickshire have a high risk of becoming infected, as shown by their incidence rate (Figure 5.1.2).

Figure 5.1.4. Total number of herds in the HRA, with the comparative proportion of large herds. Areas ranked by incidence in 2016. HRA-portion of mixed HRA/Edge area counties (*) represented in this figure.

Figure 5.1.4 shows the relative numbers of herds, and proportions of large herds in the different areas of the HRA, arranged in order of TB incidence in 2016. The pattern reveals that although analyses confirm that larger herds are more at risk of disease, the presence of more large herds alone cannot explain the area’s incidence rate. Many areas with a high proportion of large herds have a relatively low incidence rate.
Figure 5.1.5a Demographic indicators at herd level by county in the High Risk Area (whole HRA counties). Ranked in order of 2016 incidence (for whole counties)

HRA areas are heterogeneous in terms of the abundance of dairy and beef cattle (see Figure 5.1.5a). Nine counties have higher numbers of dairy cattle and seven counties have higher numbers of beef cattle. Over 20% of dairy and of beef cattle in the HRA are in Devon, followed by Somerset with 13% dairy cattle and Cornwall with 13% of beef cattle in the HRA.

By county, the highest percentage of dairy cattle was found in Cheshire HRA (77%), followed by Dorset (67%) and Staffordshire (64%). The counties with the highest percentage of beef cattle were Hereford and Worcester (71%), Warwickshire HRA (69%) and East Sussex HRA (63%)\(^49\).

More than half of beef cattle are beef finishing in all except 5 counties or part-counties. The counties with the highest proportion of beef suckler cattle are Oxfordshire HRA (68% of all beef cattle were suckler cattle), followed by Derbyshire HRA and East Sussex HRA.

Figure 5.1.5b Demographic indicators at herd level by counties in the mixed HRA/Edge area counties (data showing HRA portion only). Ranked in order of 2016 incidence (for mixed counties)

The vast majority of cattle in small herds (1-50 cattle) are beef, ranging from a minimum of 81% of cattle in small herds in Cheshire HRA to 98% of cattle in small herds in Warwickshire HRA. Within the intermediate herd size category (51-200 cattle), except in Cheshire HRA with 47%, over half the cattle were beef (55% to 92%).

There are large numbers of dairy cattle in the HRA and these tend to be in large herds - half or more herds in the HRA with >200 cattle are dairy herds. However the high numbers of cattle per se are not usually associated with a higher risk of infection, as shown by the patterns seen in Figures 5.1.5a and b, where only Devon has both higher numbers of cattle and higher incidence. Only Hereford & Worcester have less than 50% (45%). There is a tendency for larger herds to be dairy and intermediate herds to be beef but small herds tend much more strongly to be beef herds.

Similar statistically significant strong positive correlations were found between total incidents and total cattle of each herd type; however, current herd type records are reported not to be as reliable as herd size ones. The analysis of these demographic characteristics suggests that it is the amount of cattle under surveillance that is positively correlated with the total number of TB incidents, rather than the characteristics of the cattle population.
Characteristics of TB in the High Risk Area and differences between counties

Number of new TB infected herds

The number of TB infected herds is important in terms of resource planning and number of businesses impacted. Up to April 2016, the management of confirmed and unconfirmed TB incidents differed in the HRA, unconfirmed incidents needing fewer tests prior to lifting restrictions leading to a shorter duration.

![Figure 5.1.6. Comparison between the number of TB incidents (confirmed and unconfirmed) and number of unrestricted herds in HRA areas (only HRA portion in mixed HRA/Edge counties (*)](image)

Overall, there was a 4% reduction in the number of total incidents in the HRA in 2016, compared to 2015. The biggest reduction was in West Midlands (but only from 7 to 5 incidents in 2016), followed by Somerset (18% reduction).

The proportion of TB incidents that were confirmed ranged from 50% in East Sussex HRA to 80% in West Midlands (the counties with the least number of TB incidents and incidence in 2016). The median confirmation was 73% in the HRA (Figure 5.1.6).

Nearly 90% of all herds in the HRA were tested in 2016, although only Whole Herd Tests (WHT) are taken into account so the amount of herd tests is underestimated. Most of the testing and TB incident control effort in terms of volume goes into Devon, followed by Cornwall. These two counties together comprise 33% of unrestricted herds in the HRA and account for around 40% of TB incidents (and confirmed ones).

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50 See section 4.3, for discussion on coverage
Incidence and prevalence

In previous reports, we have considered incidence per 100 live herds. This does not account for the different frequencies of testing carried out nor for the proportion of these herds that are actually at risk of having a new incident (i.e. herds tested that year). This can lead to the levels of disease being underestimated.

Reports to EU Commission follow the incidence per 100 herds tested values and this is important for Officially Tuberculosis Free (OTF) status declarations. Only herds, actually tested and therefore at risk of having an incident, were included so, there is less potential for underestimating the levels of disease. However, this measure does not account for differences of testing frequency and slaughterhouse cases only contribute to the numerator. Therefore, this measure tends to give the highest values of incidence.

Our preferred measure is incidence per 100 herd-years at risk, as discussed at the beginning of the section. This reflects the rate at which new cases occur and accounts for differences in testing frequency, so shows more accurately and timely the disease situation and effect of controls. The methodology is described in the Explanatory Supplement\(^{51}\). This measure is also used in Defra’s Official TB statistics reported at Quarterly publication of National Statistics on the incidence and prevalence of tuberculosis (TB) in Cattle in Great Britain – to end December 2016\(^{52}\).

Differences between incidence measures as well as prevalence are presented in Figure 5.1.7, and show the two measures are similar and tend to give the same county ranking, but incidence per 100 herds tested is slightly lower (as restricted herds are included in the denominator). Differences in prevalence reflect both incidence and variations in the duration of the TB incident (see below) as well as the timing of the start of the incident, as prevalence is measured at the year end. Oxfordshire HRA had the highest levels of incidence and prevalence in 2016.

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Figure 5.1.7. Incidence measures and total prevalence of TB in High Risk Area counties and HRA portion of part counties (*) in 2016, ranked by incidence per 100 herd-years at risk.

Nearly 20% of TB incidents starting in 2016 were disclosed in November and December (nearly 30% if October is included). Therefore, a fifth of TB incidents are under restriction as of December 2016 due to timing of start, leading to a slightly higher prevalence estimate than if incidents were disclosed evenly through the year.

Devon had the highest number of herds restricted for the whole of 2016 (156). Some HRA areas did not have any such herds: Cheshire HRA, East Sussex HRA and West Midlands; so the impact of disease is different across the HRA.

TB incident duration and persistence

Looking at the 3,255 TB incidents that closed in 2016 in the HRA, forty per cent of them were located in Devon and Cornwall (26% and 14% respectively). Wiltshire and Dorset had had herds under movement restrictions due to a TB incident for the longest period, according to their median duration (over 200 days in both cases).

Confirmed incidents had longer median duration than unconfirmed ones or total incidents in all HRA areas. This reflects the requirement for additional tests in confirmed incidents. The requirement for two clear tests at severe interpretation in all HRA incidents introduced in April 2016 is expected to increase the duration of restrictions. However, the high
accuracy (PPV) of tests in the HRA\textsuperscript{53} together with the need to intensify the efforts to tackle disease in this area and reduce recurrence (58\% in the HRA in 2016), justifies this. This measure will help reduce recurrence due to recrudescence and may also reduce the severity of incidents. Other measures implemented in the HRA also contribute to reducing recurrence, for example encouraging good biosecurity and badger culling both target recurrence due to reinfection.

![Figure 5.1.8. Total number of incidents that closed in 2016 and their median duration (days) by total, confirmed and unconfirmed incidents in the HRA counties or part-counties (*). Ranking by total number of incidents closing in 2016.](image)

TB incidents that last over 550 days are deemed to be persistent and are subject to enhanced management procedures (see figure below). None of the TB incidents that closed in 2016 were persistent in Cheshire HRA, East Sussex HRA and West Midlands. In the rest of the HRA areas, the percentage of TB incidents that were persistent ranged from 2\% in Derbyshire to 10\% in Wiltshire. See Figure 5.1.9 below.

\textsuperscript{53} PPV in high incidence areas if severe interpretation used only in confirmed incidents (95\%CI): 92.3\% (91.1-93.7\%). Goodchild, A. V., et al. (2015). \textquotedblright Specificity of the comparative skin test for bovine tuberculosis in Great Britain.\textquotedblright 177(10): 258
Figure 5.1.9. Total number and percentage of persistent TB incidents (duration over 550 days) that closed in 2016 by HRA county or part-county (*)

With regards to incidents that were persistent as of December 2016, see section 4.4.

**TB surveillance and incident detection**

In addition to active surveillance, on average, 15% of all TB incidents in the HRA were disclosed by Slaughterhouse (SLH) surveillance, with variations between areas (see Figure 5.1.10). All areas had similar high levels of live herd testing suggesting this is not the reason for substantial differences in proportion of incidents detected at slaughter.

Figure 5.1.10 shows areas in order of incidence in 2016, and shows the greatest proportion of TB incidents detected through SLH surveillance tended to be located in areas with the lowest incidence and lowest number of incidents (West Midlands and East Sussex HRA), but note there were very few incidents reported in these areas.

Devon and Cornwall, counties with high incidence, had similar proportions of incidents detected at slaughter as in the Low Risk Area (LRA) (14%), which has less active surveillance effort (i.e. Routine surveillance mainly by using Routine Herd tests every four years). This suggests live animal surveillance could be improved to enhance early detection of infected herds; as it is currently being considered under the rationalisation of testing in the HRA.
The limitations of live animal testing are also demonstrated by the fact that SLH cases were detected during TB incidents across the HRA, where there is enhanced field surveillance. This shows the limitations of skin or SICCT test when there is a high background force of infection.

The proportion of TB incidents detected by different surveillance streams in the HRA over time is shown in Figure 5.1.11 (Routine, Area and Herd Risk, Proactive and Slaughterhouse).

Since 2010, over 85% of TB incidents in England have occurred in the HRA. The relative continuity in HRA disease control policies during this period (until April 2016) accounts for the relative stability in the proportions of TB incidents disclosed through different surveillance streams. For more information on surveillance streams see the figure below as well as section 4.3.
Figure 5.1.11. Proportion of TB infected herds disclosed by surveillance stream in the HRA by year

The highest proportion of incidents disclosed by Area & Herd Risk tests were in Warwickshire HRA (53%) followed by Gloucestershire (49%). In all mixed HRA/Edge area counties except for East Sussex HRA, higher proportions of TB incidents were disclosed by Area & Herd risk tests than by routine tests (see figure below). No incidents were disclosed by Area & Herd Risk surveillance tests in West Midlands in 2016; probably due to the low number of incidents in the county.

In terms of routine surveillance, eighty per cent of incidents in the West Midlands were disclosed by routine tests, followed by Derbyshire HRA and Oxfordshire HRA (48%).

The highest proportion of TB incidents disclosed by Proactive tests was in Gloucestershire (13%), although this surveillance stream’s detection is underestimated.

Oxfordshire HRA has the lowest proportion of incidents disclosed by SLH surveillance, whereas East Sussex HRA had the highest proportion.
Dealing with infected herds in the HRA

Since April 2016, all incidents in the HRA will need two clear severe interpretation skin tests before restrictions are lifted. As a result, 160 more incidents followed this type of management in 2016 compared to 2015\(^5\)\(^4\), with 477 additional reactors disclosed from those. The most efficient tests at detecting incidents within the Area and Herd Risk surveillance stream in the HRA were the post-incident tests (21 incidents per 100 herds tested).

As of December 2016, the vast majority of open persistent incidents were in the HRA (229 out of 237); these are eligible for enhanced management procedures, which includes the use of IFN-gamma tests (see below). Two partial herd depopulations were authorised in the HRA to deal with infected herds in 2016.

Use of IFN-gamma test in HRA

The IFN-gamma blood test is used as a supplementary test to the tuberculin skin test during TB incidents, which is the primary screening test. The total number of IFN-gamma tests carried out in the HRA remains over 6,000 since 2012.

This number is quite small, given the discretionary application of g-IFN in HRA, compared to the compulsory application in all confirmed TB incidents in the Edge and the LRA. Tests

\(^{54}\) Before 6th April 2016, this type of incident management was followed due to epidemiological reasons.
in the HRA represent only 14% of all IFN-gamma tests carried out since 2009 and 10% of the 72,854 carried out in 2016. In 2016, the majority of IFN-gamma tests were carried out in Devon (23% of total).

![Graph showing the number of g-IFN samples per HRA portion of mixed HRA/Edge Area County since 2009]

**Figure 5.1.13. Number of g-IFN samples per HRA portion of mixed HRA/Edge Area County since 2009**

There is great variability between counties and years not only due to the discretionary application to TB incidents of the tests, but also to the fact that the number of samples taken in each TB incident depends on the number of cattle over six months present in the herd. While the HRA IFN-gamma reactors only represented 21% of all IFN-gamma reactors in England, their confirmation rate much higher (27%) compared to the confirmation rate in Edge and HRA (5%). This justifies the current targeted approach in the HRA and potential expansion of use.

**TB control in wildlife**

Seven new badger cull areas were authorised in the HRA in 2016, making it a total of 10 badger cull areas authorised as of the end of 2016. Further information can be found in section 4.5.
5.2 Edge Area

- The Edge is the buffer zone between the HRA and the LRA and is subject to stricter disease control measures than the HRA. A detailed report of TB in the Edge Area in 2016 was produced earlier in 2017. This section presents key points from that report; additional detail about each county or part-county (denoted by an asterisk prefix) can be seen in the County Report supplement.

- The TB epidemic continued to increase in the Edge Area in 2016 with the annual incidence across the whole Edge Area up from 5.6% to 6.7%. This was driven by increases in *Oxfordshire, which now has the highest risk in the Edge Area, as well as *Cheshire, Leicestershire, Hampshire and Nottinghamshire. In *East Sussex there was a notable reduction in incidence, while the remaining counties or part-counties have shown slight increases or a plateau.

- In all counties, but particularly *Oxfordshire and Hampshire, infection was introduced to many of the affected herds as a result of purchase of (undisclosed) infected cattle, usually from the High Risk Area (HRA), but also other parts of the Edge Area. Exposure to infected badgers or contamination from them, was also believed to play a role in eight of the 11 counties, particularly *Cheshire and Leicestershire.

- Overall numbers of incidents remained low in most counties/part counties in the Edge Area compared to the HRA, with most having less than 25 in 2016.

- Possible candidate counties for OTF status in the foreseeable future are Buckinghamshire and *East Sussex. Those with longer term potential for OTF status include Nottinghamshire and Northamptonshire, though both need to improve buying practices to reduce the threat from undisclosed infection in purchased cattle. The latter also has areas of higher incidence, likely associated with infection in badgers, which must be reversed.

- In most counties there is evidence that infected herds are being discovered sooner after infection is introduced than in the past, indicating some success in control measures. However the increasing incidence and specific evidence in this report (e.g. the importance of inconclusive reactors) confirms the need for additional controls, including those planned to be introduced in 2017.

- The particular challenges noted in the Edge Area include:

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- Purchase of infected animals as a substantial contributor to the epidemic
- Endemic areas reflecting local spread of TB and likely wildlife infection are emerging in Warwickshire, north east Leicestershire, and the Hampshire/Berkshire border, and continue to cause concern in Cheshire, Derbyshire and Oxfordshire.
- Inconclusive reactors as an important predictor of TB infection in most counties.
- Clusters of cases in several localities are likely to be driven by badger infection, but may have multiple sources and need better exclusion of a cattle source risk pathway

**Introduction**

The ‘Edge Area’, one of the three management areas for TB in England, was established in January 2013 and was later incorporated into the Government’s strategy to achieve Officially Bovine Tuberculosis Free (OTF) status for England by 2038. It sits within the annual testing area of England, creating a zone of increased surveillance between the HRA which has a much higher incidence of TB and the LRA where TB is close to eradication. Edge area control efforts seek to slow down and reverse geographic spread, and reduce the incidence rate, with the aim of obtaining OTF status for this area as soon as possible.

The epidemiology of the **Edge Area in 2016** was analysed and reported earlier in 2017 and this section of the England report summarises the key findings, derived from that report.

Note that due to the timing of these reports, all data are derived directly from the transactional database ‘Sam’ and so may differ slightly from similar data quoted in other sections of this report which was downloaded later in the year so is more complete, and has had additional review to remove duplicates and correct errors.

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Figure 5.2.1 Counties and part-counties in the Edge Area

The Edge Area consists of six whole counties and 5 part-counties (identified by an asterisk prefix) as shown in Figure 5.2.1 below; it extends up the middle of England from Hampshire to Cheshire. Its extent was defined in 2013, at county level where possible, but where there were substantial differences across a county, only the relevant part of the county was selected by defining the area at parish level, with the aim of setting the inner boundary at the outer edge of known endemic disease and the outer boundary to include areas where the incidence of TB was currently low, but that were at risk of the geographic spread of disease in the short to medium term.

Beef herds predominate in all counties in the Edge Area except the part of Cheshire that is in the Edge Area, where dairy herds predominate; however Leicestershire and Hampshire have substantial numbers of dairy herds. In all counties, dairy herds tend to be large while beef herds are small to medium, though there are some large beef finishing units.
Level of TB in the Edge Area

Across the whole Edge Area the 2016 incidence rate was 6.7%, up from 5.6% in 2015, however there was wide variation between counties. The rate in each county or part county is shown in Figure 5.2.2, and ranged from a high of 16% in *Oxfordshire down to under 3% in *East Sussex.

![Figure 5.2.2. Edge county annual incidence rate 2014 - 16 & 2016 end-year prevalence](image)

(Counties shown in order of highest to lowest incidence in 2016; *part county. Given current policy and effective removal of infection, the end-year prevalence value should ideally be less than half the annual incidence value for each county/part county).

The incidence rate in all counties remains above the level defined by the EU for OTF status, namely <0.1% annual fully confirmed (‘OTFW’) incidence (note this target relates to the simpler measure of number of cases per 100 OTF herds tested which is presented in the Edge Area report published earlier this year and is usually slightly lower in value than the rate presented here. The EU definition also requires 99.9% of herds to have remained OTF for at least six consecutive years (equates to a point prevalence of <0.1%).

57 In this report the incidence rate and the final estimate of prevalence are presented as the data are now available. Note these are more accurate and differ slightly from the values presented in the earlier published 2016 Edge Report which is prepared from a less complete dataset available earlier in the year. Although the numbers differ slightly the trends and comparative relationship between counties and years are largely unaffected.
The incidence rate has increased in eight of the 11 counties/part-counties in the Edge compared to 2015, in three counties (Berkshire, Northamptonshire and Buckinghamshire) only slightly and likely to reflect a plateau. However in *Oxfordshire the incidence has increased from just over 8% to 16% and there have been notable increases in *Cheshire, Leicestershire, Nottinghamshire and Hampshire. In the earlier report the simpler incidence calculation suggested there was little change in *Cheshire, but the more refined calculation that adjusts for the frequency of testing and other factors shows that the rate of new disease increased in *Cheshire. However *Oxfordshire has replaced *Cheshire as the county/part county in the Edge with the highest incidence. The likely source of infection that has contributed to these increases is discussed below.

The prevalence at the end of 2016 in each county or part-county is also shown in Figure 5.2.2. Prevalence\(^{58}\) reflects both the incidence of new disease and the duration of restrictions, and so to some extent reflects the requirements for lifting restrictions. The duration of restrictions reflects the level of evidence required to give confidence that infection has been removed. A new policy in the Edge Area (and High Risk Area) was introduced in April 2016, requiring all incidents to have two herd tests prior to lifting of restrictions. This inevitably takes over 4 months\(^{59}\), so at any one time prevalence will have a minimum value over one third of the annual (12 month) incidence, with increasing values above this suggesting a longer average duration of restrictions. This is the case with Berkshire in particular, where low incident numbers and the few persistently infected herds have a visible impact on the prevalence calculation. (Note prevalence values also differ slightly but not materially between this and the earlier report as the data presented here are more complete, having been downloaded later in the year).

The number of incidents in each Edge county/part county each year for the last 10 years is shown in Figure 5.2.3. Most have had fewer than 25 incidents a year in this period, though some have an increasing trend. In terms burden of disease the number of incidents in the *Cheshire Edge is significantly greater than other Edge area counties.

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\(^{58}\) Prevalence is calculated as the percentage of live herds under restriction due to a TB incident at the end of the year

\(^{59}\) Two clear tests at 60 day intervals are required to raise restrictions so all incidents inevitably have a duration of >120 days plus time for reactor removal, disinfection, administrative requirements, etc.
Figure 5.2.3 Number of TB incidents in each Edge county/part county, 2007-16

Source of infection

Sources of infection are assessed as part of the disease investigation visit into each incident by local APHA vets. Purchase of (undisclosed) infected cattle was the main source of infection for incidents in *Oxfordshire, Hampshire, Nottinghamshire and *East Sussex, and an important source for all counties except *Derbyshire. There is evidence of wildlife involvement (almost invariably badgers) in most counties and this was the predominant attributed source for *Cheshire, Leicestershire and *Derbyshire (Figure 5.2.4).

There is no evidence of wildlife infection contributing to bovine incidents in either Nottinghamshire or Buckinghamshire, and wildlife appeared to play little role in the epidemic in 2016 in *East Sussex, having been a significant factor historically.

In general purchased cattle tend to be the source of infection in beef fattener herds, while wildlife exposure is more often associated with cases in dairy and suckler herds.

Endemic areas reflecting local spread of TB and likely wildlife infection are emerging in *Warwickshire, north east Leicestershire, and the Hampshire/Berkshire border, and continue to cause concern in *Cheshire, *Derbyshire and *Oxfordshire.

The Defra-funded TB prevalence survey of badgers found dead in the Edge area initiated in 2016 and should help to shed light on the prevalence and geographic distribution of TB in badgers in the Edge area and its role in the development of these areas of local spread. It involves a network of farmers, wildlife groups and other stakeholder organisations established to collect badger carcasses for examination at the collaborating universities.60

60 Nottingham, Surrey and Liverpool
Figure 5.2.4. Source of infection by county/part county (Ordered by decreasing numbers due to purchase; note only OTFW for *Cheshire, n=67; *indicates part county)

Prospects for progress towards OTF status

The paragraphs below discuss the potential for OTF status of each county/part county in the Edge Area; however note this potential depends absolutely on improvements in the management of the risk of introduction of TB through purchase of cattle with undisclosed infection. In some counties it is also dependent on limiting and reversing the development of endemic areas of infection, which are likely related to developing endemic infection in local badger populations.

Possible candidate counties for OTF status in the near future are:

- **Buckinghamshire**, where the incidence is plateauing at a low level and the epidemic is apparently maintained by purchase of (undisclosed) infected cattle

- **East Sussex**, where there was only one fully confirmed case (OTFW) in 2016 and this was in an AFU, and attributed to purchase of restricted cattle with undisclosed infection from the HRA. All other cases were OTFS, so evidence for their source is more limited, however only one was suspected possibly to be due to wildlife infection.

Counties showing an epidemic pattern that might enable achievement of OTF status, but on a longer timescale, are:

- **Nottinghamshire** (despite increase in incidence), if improvements can be made to buying practices, and to the live animal detection rate so that cases detected at
slaughter reduce, as there is no evidence of wildlife infection as a source for cattle incidents.

- **Northamptonshire** could fall into this category as it has a low incidence, however buying practices need to be improved, and the apparent development of endemically infected areas needs to be reversed.

Counties with little prospect of OTF status in the near or medium term due to a moderate or high incidence, likely more widespread badger infection and/or a substantial contribution from the purchase of undisclosed infected cattle.

5.3 Low Risk Area

- The herd incidence and prevalence of TB in the LRA remained much the same between 2015 and 2016, with the flat rates and sporadic patterns of disease of previous years continuing one more year. As a result, the LRA as a whole continued to fulfil the criteria for Officially Tuberculosis Free (OTF) status designation set out in the EU legislation.

- The current controls and surveillance regime, enhanced by the implementation of compulsory post-movement TB testing in April 2016, appear to be effective in keeping the incidence and prevalence of TB in the LRA very low, despite the ongoing TB epidemic in other parts of the country.

- As in previous years, substantial proportion (almost 60%) of all the new lesion- or culture-positive (OTFW) incidents detected in 2016 were, once again, attributed to the introduction of infected cattle from higher risk areas of GB, confirming the need to remain vigilant and maintain the existing cattle movement controls.

The Low Risk Area of England (LRA) was established on 1st January 2013, and is part of the Strategy for achieving Officially TB Free (OTF) status for England by 2038. The specific objectives for the LRA within that Strategy are to maintain or reduce the very low and sporadic incidence of TB and deal effectively with any incursions of the disease, with a specific target of securing OTF status for all the counties of the LRA by 2025. By strengthening the existing risk-based TB surveillance and control measures in the LRA as part of the UK’s TB Eradication Programme approved and co-financed by the EU since 2010, it may now be possible to achieve this target ahead of schedule.

This section of the England report summarises the annual review of TB in the LRA that is provided to the European Commission. Regional field epidemiology reports\(^61\) for the LRA from which the annual reviews are derived were published in July this year. Due to the timing of these reports, all data are extracted directly from the transactional database ‘Sam’ and so differ slightly from similar data quoted in other sections of this report for which the data have been reviewed to remove any duplicates and correct errors.

Description of the LRA

The LRA comprises 24 contiguous counties in the North and East of England, as well as the Isle of Wight and the Isles of Scilly, all managed as one epidemiological unit for TB control and reporting purposes. The LRA is bound by Scotland to the north and by the Edge Area of England to the south and west. It represents approximately 72,600 km\(^2\) (55%) of England’s land area and nearly 21,000 (41%) of its cattle herds. Cattle densities

in the LRA are generally lower than those in the rest of England, although parts of Cumbria, Co. Durham, Lancashire and Yorkshire sustain substantial cattle populations.

The default routine TB testing interval of cattle herds in the LRA is four years, so that approximately one quarter of the herds are tested each year. Additionally, some 10% of all herds in this area underwent annual or more frequent testing in 2016 because they were deemed to be at a higher risk of infection (e.g. 2,012 herds in 2016 compared with 1,845 in 2016). The number of TB herd tests carried out in the LRA in 2016 (8,445) was lower than in 2015 (10,338), but similar to the figure for 2013 (8,568), when enhanced targeted surveillance around infected cattle herds (‘radial’ testing) was first introduced in the LRA.

Like other parts of England, routine testing of herds in the LRA is supplemented by mandatory pre-movement testing of cattle moving out of annually tested herds. Additionally, since April 2016 post-movement testing has also been required for all cattle entering the LRA (to live) from higher risk areas of England and from Wales. Post-mortem meat inspection (slaughter surveillance) of all cattle commercially slaughtered for human consumption is a particularly important component of the TB surveillance system in the LRA, accounting for 35% to 55% of the small number of new OTFW incidents detected in this area each year.

**Level of bovine TB in the LRA**

The incidence of TB in the LRA remained very low and stable in 2016. A total of 3,748 new TB incidents (‘breakdowns’) were reported in cattle herds across England in 2016 compared with 3,964 the previous year, 3,890 in 2013 and 3,919 in 2012. As in previous years, the geographic distribution of breakdowns in 2016 was not uniform: although the LRA contains 41% of England’s total cattle holdings, it only accounted for 133 (3.5%) of the 3,750 total new TB herd incidents identified in England in 2016, a slightly lower proportion than in 2015 (4%). This represented a herd incidence rate of 1 new herd incident per 100 herd-years at risk, the same as in 2015.

The number of cattle herds in the LRA under movement restrictions (i.e. OTF status suspended or withdrawn) at the end of 2016 due to an ongoing TB breakdown was 48 (62 herds at the end of 2015). That figure was equivalent to a herd prevalence of 0.2% (0.3% at the end of the previous year).

However, in the LRA, like Scotland, due to the very low prevalence of *M. bovis* infection in cattle, the positive predictive value of the comparative intradermal tuberculin test is lower than in the rest of GB, if still high. This means that test reactors with no visible lesions and negative culture results in the LRA are more likely to represent false positive test results than in the HRA and Edge Area. Consequently, it is important to also consider the number and incidence of new herd incidents that have been confirmed by post mortem

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62 See Goodchild et al. (2015), Veterinary Record: [http://veterinaryrecord.bmj.com/content/177/10/258](http://veterinaryrecord.bmj.com/content/177/10/258)
tests (‘OTF status withdrawn’, OTFW) detected in the LRA. Only 44 OTFW incidents were in the LRA, compared with 52 in 2015 (both forming a similar very small proportion of the total, see section 4.1). The OTFW herd incidence rate in the LRA in both 2016 and 2015 was 0.3 incidents per 100 herd-years at risk.

In 26 (59%) of the 44 herds sustaining OTFW incidents in the LRA last year there was conclusive evidence (from molecular and field epidemiological analyses) to show that TB was definitely introduced via movements of infected cattle from farms in higher incidence areas of England and Wales, without subsequent secondary spread to other herds in the LRA. This is a similar number to previous years (Table 5.3.1). So, as in previous years, more than half of all the new OTFW incidents in the LRA continued to be caused by ‘non-indigenous’ or ‘imported’ infection.

We can then use this information to re-calculate the ‘crude’ annual percentage of active cattle herds with new OTFW incidents and the percentage of OTF herds at year end in the LRA, which are the two epidemiological parameters used in the EU TB legislation to assess regional or national OTF status. If OTFW breakdowns of a non-indigenous origin are excluded from the numerators of the crude TB herd incidence and prevalence calculations, the LRA of England as a whole continued to fulfil the criteria for regional OTF status in 2016 because the adjusted percentages were below the thresholds set by the EU.

County-by-county analyses continued to show a sporadic occurrence of TB in 2016, with no evidence of spatial clustering of cases or M. bovis genotypes. The vast majority of OTFW herd incidents in the LRA were quickly resolved through the application of standard control measures, mainly short-interval skin testing at severe interpretation supplemented by interferon-γ blood parallel testing and, exceptionally, partial depopulation of infected farms in a few extreme instances. The regional reports from APHA field teams did not highlight any particular concerns about local spread or endemic infection in cattle or wildlife, apart from a cluster of 17 incidents on 16 separate cattle holdings identified between November 2014 and the end of 2016 near the village of Shap in East-Central Cumbria. All the OTFW cases in this cluster were caused by a unique genotype of M. bovis found in Northern Ireland, but not previously isolated in GB. Herds in this small part of the LRA are undergoing targeted TB surveillance and enhanced control measures to eradicate the infection.

As in previous years, the proportion of herds sustaining recurrent TB incidents was much lower than in the rest of England, so that typically around 10% of all herds experiencing a new OTFW incident during the year had a history of TB in the preceding 36 months. When recurrent herd incidents happen in the LRA, they are usually associated with large beef finishing units that regularly bring in cattle from the HRA, Edge Area, Wales, or from Northern Ireland for fattening before slaughter.

In conclusion, there was no material change in the overall incidence and prevalence of TB in the LRA between 2016 and 2015, with the flat trend and sporadic pattern of breakdowns continuing for another year. The improvements made to the sensitivity of TB surveillance regime in 2016 (chiefly through the implementation of mandatory post-movement TB testing) have not led so far to an increase in the number of new OTFW cases detected. The current controls appear to be effective in keeping the incidence and prevalence of TB in the LRA very low, despite the ongoing epidemic in other parts of the country.

**Table 5.3.1 Outcome of detailed epidemiological investigations into the origin of OTFW breakdowns in the LRA of England (2010-2016)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of new TB breakdowns in the LRA (OTFW herd status)</th>
<th>Breakdowns considered to have been introduced, based on a combination of molecular epidemiology and CTS data analysis</th>
<th>Additional breakdowns regarded as introduced, based on further scrutiny by the APHA regional offices</th>
<th>Breakdowns listed under (B), but not validated by the regional offices (D)</th>
<th>Breakdowns retained in the annual herd incidence calculations (not clearly introduced)</th>
<th>Breakdowns judged as being clearly introduced from outside the LRA and dropped from the annual bTB herd incidence calculations (B+C-D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre 2011 (active in period 2010-2016)</td>
<td>28</td>
<td>8</td>
<td>10</td>
<td>0</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>2011 (revised 2014)</td>
<td>37</td>
<td>12</td>
<td>6</td>
<td>1</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>2012 (revised 2014)</td>
<td>41</td>
<td>11</td>
<td>8</td>
<td>0</td>
<td>22</td>
<td>19</td>
</tr>
<tr>
<td>2013 (revised 2015)</td>
<td>41</td>
<td>10</td>
<td>11</td>
<td>0</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>2014 (revised 2016)</td>
<td>38</td>
<td>7</td>
<td>13</td>
<td>0</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>2015 (revised 2017)</td>
<td>52</td>
<td>10</td>
<td>25</td>
<td>0</td>
<td>17</td>
<td>35</td>
</tr>
<tr>
<td>2016</td>
<td>44</td>
<td>8*</td>
<td>18</td>
<td>0</td>
<td>18</td>
<td>26</td>
</tr>
</tbody>
</table>

**OTFW breakdowns in the LRA of England (2010-2016)**

* Analysis still pending for isolates/samples from 12 OTFW incidents in the LRA
## Appendix 1: Glossary and Definitions used for TB control

<table>
<thead>
<tr>
<th>Detail</th>
<th>Abbreviation</th>
<th>Definition or description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal and Plant Health Agency</td>
<td>APHA</td>
<td>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.</td>
</tr>
<tr>
<td>Annualised</td>
<td></td>
<td>Conversion of a variable into a yearly sum (e.g. by multiplying a quarterly incidence by 4).</td>
</tr>
<tr>
<td>Bovine tuberculosis</td>
<td>TB</td>
<td>Disease of cattle and other mammals caused by infection with <em>Mycobacterium bovis</em></td>
</tr>
<tr>
<td>Breakdown</td>
<td></td>
<td>See ‘TB incident’</td>
</tr>
<tr>
<td>Case</td>
<td></td>
<td>See ‘TB incident’</td>
</tr>
<tr>
<td>Co-financing/ed</td>
<td></td>
<td>Co-funding/financing is the financial contribution of the Commission to EU Member States for control and eradication of certain animal diseases and zoonosis.</td>
</tr>
<tr>
<td>Compensation</td>
<td></td>
<td>The financial contribution from the competent authority to the owner of the animals that have been culled in the course of controlling or eradication of a particular disease. There are different statutory compensation systems for cattle slaughtered in England, Scotland and Wales.</td>
</tr>
<tr>
<td>Contiguous herd</td>
<td></td>
<td>Strictly speaking, a herd that has a common boundary with the herd 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.</td>
</tr>
<tr>
<td>Dangerous contact</td>
<td>DC</td>
<td>A non-reactor animal in an OTF-W TB incident herd considered to be at such high risk of being infected that is compulsorily slaughtered for disease control purposes.</td>
</tr>
<tr>
<td>Disclosing test</td>
<td></td>
<td>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).</td>
</tr>
<tr>
<td>Eradication Programme</td>
<td></td>
<td>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</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Gamma interferon test</td>
<td>Laboratory-based blood test approved as an ancillary diagnostic tool that measures the amount of the cytokine (immunological messenger molecule) IFN-(\gamma) 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.</td>
<td></td>
</tr>
<tr>
<td>Genotype</td>
<td>A unique DNA type or ‘strain’ of <em>Mycobacterium bovis</em>, defined by a combination of spoligotype (expressed as a number) and VNTR type (expressed as a letter). This information is used for the molecular epidemiology of TB bacteria in GB.</td>
<td></td>
</tr>
<tr>
<td>Herd</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>Herd size</td>
<td>For a TB incident, herd size is the largest number entered in SAM at any time during the incident. For Officially TB Free (OTF) herds, herd size is generally that recorded at the most recent whole herd test. All cattle need to be accounted for at the time of submitting the test chart on SAM (tested or not).</td>
<td></td>
</tr>
<tr>
<td>Herd test</td>
<td>A surveillance or control test triggered by a herd level event, rather than a test triggered for an individual animal.</td>
<td></td>
</tr>
<tr>
<td>Herd types</td>
<td>‘Beef’ includes Beef, Suckler, Beef Heifer Rearer, Beef Bull Hirer, Stores herds and Meat Buffalo herds; ‘Beef fattener’/’Beef finisher’ includes beef finishing herds ‘Dairy’ includes Dairy, Dairy Dealer, Dairy Bull Hirer, Dairy Producer, Dairy Heifer Rearer and Domestic herds; ‘Other’ includes Calf Rearers, unspecified Dealer Herds, AI, and herds described on SAM as ‘Other herds’.</td>
<td></td>
</tr>
<tr>
<td>Herd-years at risk</td>
<td>The sum of the time (days, months or years) herds in the population 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.</td>
<td></td>
</tr>
<tr>
<td>Holding</td>
<td>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 one or more herds.</td>
<td></td>
</tr>
</tbody>
</table>
| Homerange                    | The geographical area in which a particular genotype of *M. bovis* 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.

### Incidence

The incidence of a disease is the occurrence of new cases 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 75th and 25th 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 31st December, 2016. This gives different values from the Agricultural Census, which is at holding level.

### 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 suspicion of the presence, of *M. bovis* infection or because statutory tests are overdue leading to the loss of Officially TB Free herd status (see below). Herd restrictions due to overdue tests are excluded from analyses in this report to avoid overestimates of disease.

### Mycobacterium avium

The causative organism of avian tuberculosis, which occasionally infects cattle.
<table>
<thead>
<tr>
<th><strong>Mycobacterium bovis</strong></th>
<th><strong>M. bovis</strong></th>
<th>The causative organism of bovine tuberculosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New TB incident</strong></td>
<td></td>
<td>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 restriction, 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 disclosed (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)</td>
</tr>
<tr>
<td><strong>Non-visible lesions</strong></td>
<td>NVL</td>
<td>No lesions typical of bovine TB detected in the carcass at post mortem examination</td>
</tr>
<tr>
<td><strong>Officially bovine tuberculosis free (OTF) status</strong></td>
<td><strong>OTF</strong></td>
<td>A Member State or part of a Member State may be declared officially tuberculosis-free according to the procedure laid down in Annex I to Council Directive 64/432/EEC if it meets the following conditions: (a) the percentage of bovine herds confirmed as infected with tuberculosis has not exceeded 0.1 % per year of all herds for six consecutive years and at least 99.9 % of herds have achieved officially tuberculosis-free status each year for six consecutive years, the calculation of this latter percentage to take place on 31 December each calendar year; (b) each bovine animal is identified in accordance with Community legislation; (c) all bovine animals slaughtered are subjected to an official post-mortem examination; (d) the procedures for suspension and withdrawal of officially tuberculosis-free status are complied with.</td>
</tr>
<tr>
<td><strong>Officially bovine tuberculosis free status suspended</strong></td>
<td><strong>OTF-S</strong></td>
<td>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. This report does not distinguish between OTF-S-1 and OTF-S-2 restrictions, which are determined by epidemiological risk or case management policies.</td>
</tr>
<tr>
<td><strong>Officially bovine tuberculosis free status withdrawn</strong></td>
<td><strong>OTF-W</strong></td>
<td>TB incident in which additional evidence of <em>M. bovis</em> infection has been identified in at least one bovine animal slaughtered for disease control purposes, i.e. <em>M. bovis</em> identified in a cultured tissue sample and/or typical gross lesions of TB detected in the carcass. It also includes other incidents upgraded to OTF-W for epidemiological reasons and slaughterhouse case-disclosed incidents that are confirmed on culture.</td>
</tr>
<tr>
<td><strong>Persistent herd</strong></td>
<td></td>
<td>Refers to a TB infected herd that has been under TB</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>or persistent TB incident herd</td>
<td>restrictions for at least 550 days (about 18 months).</td>
<td></td>
</tr>
<tr>
<td>Poisson regression</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>Post-mortem or post mortem examination</td>
<td>Examination (to various extents) of the carcass and organs of slaughtered cattle for lesions typical of bovine TB.</td>
<td></td>
</tr>
<tr>
<td>Pre-movement testing</td>
<td>Mandatory testing for cattle over 42 days moving out of an at least annually tested herd to live in 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.</td>
<td></td>
</tr>
<tr>
<td>Prevalence</td>
<td>The prevalence of a disease is the proportion of a defined population (at the animal or herd level) affected by that disease in a designated time.</td>
<td></td>
</tr>
<tr>
<td>Reactor</td>
<td>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 <em>M. bovis</em>. 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.</td>
<td></td>
</tr>
<tr>
<td>Recurrent herd incident</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>Reference category</td>
<td>In regression analyses the reference group acts as a baseline against which we compare other groups of interest.</td>
<td></td>
</tr>
<tr>
<td>Reservoir</td>
<td>The reservoir is the animal where the infectious pathogen normally resides, and therefore is the common source of infection to other animals or humans.</td>
<td></td>
</tr>
<tr>
<td>Risk Area or Surveillance Risk Area or Surveillance Area</td>
<td>Since 1 January 2013, TB testing intervals for bovines are annual or four-yearly at county level. The Strategy for achieving Officially Bovine Tuberculosis 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 testing), Edge area (annual testing) and Low Risk area (LRA – 4-yearly testing).</td>
<td></td>
</tr>
<tr>
<td>SAM database</td>
<td>APHA’s TB control and surveillance system, which records for example, details of herds, TB tests, TB incidents and the details of any slaughtered (reactors, slaughterhouse cases and direct contacts) and inconclusive reactor cattle.</td>
<td></td>
</tr>
<tr>
<td>Term</td>
<td>Abbreviation</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>--------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Sensitivity (of a test)</td>
<td>Se</td>
<td>The proportion of truly infected individuals in the screened population who are identified as infected (positive) by the test.</td>
</tr>
<tr>
<td>Severe interpretation</td>
<td></td>
<td>The positive cut-off criterion normally 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.</td>
</tr>
<tr>
<td>Short Interval Test</td>
<td>SIT</td>
<td>See ‘Test code definitions’</td>
</tr>
<tr>
<td>Single intradermal comparative cervical test</td>
<td>SICCT</td>
<td>Also commonly referred to as the ‘skin test’ or ‘tuberculin skin test’. The testing procedure involves the simultaneous injection of a small amount of <em>M. bovis</em> and <em>M. avium</em> 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.</td>
</tr>
<tr>
<td>Slaughterhouse case</td>
<td>SLH</td>
<td>This refers to an animal that had lesions consistent with TB during routine post-mortem meat inspection in an abattoir. For the slaughterhouse case to trigger an OTF-W incident, <em>M. bovis</em> must be isolated on culture from samples of the lesions. Until <em>M. bovis</em> 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.</td>
</tr>
<tr>
<td>‘Smoothed’ and/or ‘12-month moving average’</td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>Specificity (of a test)</td>
<td>Sp</td>
<td>The proportion of truly uninfected individuals in the screened population who are identified as uninfected (negative) by the test.</td>
</tr>
<tr>
<td>Spoligotype</td>
<td></td>
<td>The result of one molecular technique used for genomic typing of organisms of the <em>Mycobacterium tuberculosis</em> complex, known as Spacer Oligonucleotide typing.</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>SD</td>
<td>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.</td>
</tr>
<tr>
<td>Standard interpretation</td>
<td></td>
<td>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</td>
</tr>
<tr>
<td><strong>Surveillance Streams Definitions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------------------------------</td>
<td>---</td>
</tr>
<tr>
<td><strong>Area &amp; Herd Risk</strong>: Disease first disclosed as a result of tests carried out due to history or other epidemiological evidence that there is a higher probability of disease in the animal or herd.</td>
<td><strong>Pro-active</strong>: 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).</td>
<td></td>
</tr>
<tr>
<td><strong>Routine</strong>: 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.</td>
<td><strong>Slaughterhouse (SLH) Surveillance</strong>: 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).</td>
<td></td>
</tr>
</tbody>
</table>

| **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’ below. |
| **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)** | **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. 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 bTB | |
- 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 RAD12 test 12 months after the RAD6 test in the LRA only.
- 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 every 12 months in annual testing areas and 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.

<table>
<thead>
<tr>
<th>Testing interval</th>
<th>Testing interval for TB surveillance purposes, 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.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time at risk</td>
<td>TAR 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.</td>
</tr>
<tr>
<td>Tracing tests</td>
<td>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).</td>
</tr>
<tr>
<td>VetNet database</td>
<td>VetNet</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Visible lesions</td>
<td>VL</td>
</tr>
<tr>
<td>VNTR type</td>
<td>VNTR</td>
</tr>
</tbody>
</table>
Appendix 2: Contents of the GB TB Data Report

Surveillance data, charts and tables that were previously published in the GB and England Annual Surveillance Reports are now published in a separate report called ‘Bovine tuberculosis in Great Britain. ‘Surveillance data for 2016 and historical trends’, referred to for convenience as the GB TD Data report.

The underlying data for all the figures in this England Epidemiology Report can be seen and accessed in the GB Data report, which also presents substantial additional data. The report is provided in Excel format and is designed for electronic use. The contents list is shown below.

Bovine tuberculosis in Great Britain. Surveillance data for 2016 and historical trends

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