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Plant Health
Agency

Bovine tuberculosis in England in 2019

Epidemiological analysis of the 2019 data and historical trends

September 2020

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HOW TO READ THIS REPORT: Readers are advised to read the Executive Summary first, followed by the bulleted text at the start of each section. If more detail is required on any of the points described this can be explored in the relevant section.

1. Executive summary

1. Bovine TB in England is subject to a statutory eradication programme based on the government's strategy published in April 2014. Within the strategy England is divided into three 'risk' areas as determined by the level of disease. The High Risk Area (HRA), mainly in the west and south-west, disclosed over three quarters of new TB incidents in 2019. As in previous years, the Low Risk Area (LRA) in the north, east and south-east disclosed very few TB incidents in 2019. Less than a quarter of LRA incidents were fully confirmed by the presence of test reactors with typical TB lesions and/or one or more animals with positive bacteriological results (OTF status withdrawn – OTF-W incidents). Twenty per cent of new TB incidents in 2019 were found in the Edge Area, which lies between the HRA and LRA.
2. Eradication of bovine TB is based on controlling the disease in both cattle and the wildlife reservoir. In cattle, systematic skin testing of herds supplemented by routine slaughterhouse surveillance aims to quickly identify and remove infected animals. This is coupled with pre- and post-movement testing to curb the spread of disease. Infected cattle herds are subjected to movement restrictions and incident management procedures (e.g. more sensitive testing). These measures aim to reduce the risk of disease persistence in the herd and allow the herd to regain their OTF status. Within the higher incidence portions of the Edge Area, annual routine surveillance TB testing was replaced by six-monthly testing in January 2018. Up to 44% of herds in these areas reverted to annual testing through 'earned recognition' in 2019. Bovine TB is controlled in the wildlife reservoir through licensed badger culling and vaccination. Additional licensed badger control areas were introduced in the HRA and Edge Area in 2019.
3. The incidence rate of bovine TB in England increased steadily from 1986 to 2010 and has since plateaued. In 2019, incidence per 100 herd-years at risk (100 HYR) decreased significantly in the HRA for the second year running and remained very low in the LRA. TB incidence per 100 HYR has been increasing in the Edge Area since 2013. This trend continued in 2019, however incidence per 100 unrestricted herds tested and end-of-year herd prevalence decreased in 2019 compared to 2018. The number of new TB incidents also decreased in the Edge Area for the first time in four years.
4. Over half of herds with new TB incidents in the HRA had suffered another TB incident in the previous three years, confirming that recurrent infection remains an important driver of the epidemic in this risk area. A greater proportion of HRA herds were found to be infected in the six to 12 month period after regaining OTF status, compared to post-incident herds in other risk areas.
5. In 2019, as in previous years, herds located in the HRA (where there is high infection pressure from cattle and 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 sustain a new TB incident. Dairy herds were found to have an additional

risk of infection that could not be fully explained by their herd size, testing history or location.

6. There was an increase in the number of interferon gamma (IFN-γ) blood tests completed in 2019. These tests are used in parallel with the tuberculin skin test (SICCT) to increase the probability of detecting and removing infected cattle from herds with OTF status withdrawn. In addition to other criteria, mandatory IFN-γ tests are carried out in the HRA for OTF-W herds located in licensed badger control areas where at least two seasons of effective control have been completed. As more badger control areas fulfilled this requirement in 2019, the number of herds subject to IFN-γ testing increased and will rise further in the coming years.

Table 1.1 Key bovine TB epidemiological parameters[1] in 2019, with selected 2018 values given in brackets

	HRA	Edge Area	LRA	England
Overview				
Number of new TB herd incidents detected	2,501 (2,761)	640 (717)	148[2] (129)	3,289 (3,607)
Number of open (continuing) TB incidents at the end of the year[3]	1,848 (2,126)	434 (516)	57 (59)	2,339 (2,701)
Herd incidence per 100 herd-years at risk	16.9 (18.5)	9.9 (9.1)	1.1 (0.8)	9.3 (9.3)
Average monthly prevalence (%)	10.5 (11.5)	5.9 (5.6)	0.4 (0.3)	5.5 (5.9)
Duration				
Median duration of restrictions for incidents (days) (25-75th percentile) that closed in 2019	205 (166-306)	197 (168-278)	163.5 (102-216)	200 (165-293)
Median duration of restrictions for incidents (days) (25-75th percentile) that closed in 2018	202 (166-320)	200 (167-284)	146 (97-189)	199 (165-307)
% persistent incidents (duration >550 days) that ended during the year	7.9 (7.8)	4.6 (4.8)	2.0 (1.7)	7.0 (7.1)
Number of persistent incidents (duration >550 days) ongoing at the end of the year	192 (242)	29 (24)	1 (0)	222 (266)
Recurrence				
% new TB incidents in the year in herds that suffered another TB incident in the preceding 36 months	56.5 (57.7)	46.5 (38.1)	10.8 (6.3)	52.4 (51.8)

[1] Includes all TB incidents (including OTF herd status suspended (OTF-S) and OTF herd status withdrawn (OTF-W))
[2] Only 36 (24%) of TB cattle incidents in the LRA were lesion- and/or culture-positive (OTF-W)
[3] The number of herds open at the end of 2018 is lower in this report than was published in Bovine tuberculosis in England report for 2018. This is because Approved and Licenced Finishing Units have been removed from both the 2018 and 2019 figures in this report.

2. Preface

2.1 Intended audience

This report describes the level of bovine tuberculosis infection in cattle herds in England in 2019. Bovine tuberculosis is caused by the bacterium *Mycobacterium bovis* (*M. bovis*) and is referred to hereafter as TB. This report is intended for those involved in the eradication of TB in cattle, both nationally and locally. This includes, but is not limited to: farmers, veterinarians, policy makers and the scientific community.

This England level report is part of a suite of annual reports providing data and epidemiological analysis of TB in Great Britain. Other publically available reports in the series include

1. **Bovine tuberculosis in Great Britain: Surveillance data for 2019 and historical trends** (referred to hereafter as the 'GB TB data report'). This data report is published as an ODS file and provides supporting material in the form of detailed data tables and additional graphics. It presents all similar data for England, Scotland and Wales.
2. **Year End Descriptive Epidemiology Reports** for counties in the Edge Area and Low Risk Area of England. These reports provide a detailed epidemiological assessment of TB at a local level.
3. **Bovine tuberculosis in Great Britain in 2019: Explanatory Supplement to the annual reports**. This document provides more in-depth explanations about the data handling methodologies, terminology, surveillance and control measures used within Great Britain.

Data presented in these reports are derived from the same source as Defra's 'National Statistics' on the incidence and prevalence of TB in Great Britain. These include monthly statistical reports and other quarterly statistics on specific aspects of the TB surveillance regime, such as pre-movement testing. Whilst the data source is the same, additional time has been spent removing duplication and correcting other transactional data errors before compiling this report. As such, the data in this report may not exactly match the national statistics.

2.2 Purpose of this report

This epidemiology report includes commentary and analyses of TB statistics in England, in light of disease control and eradication policies. It reports both the frequency and geographic distribution of the disease in England in 2019 and changes over time. It also explores the different TB surveillance methodologies employed in cattle herds and the impact of the disease and its control measures.

Bovine TB surveillance and control is a complex process and a wealth of jargon has emerged over time amongst those who seek to control and eradicate the disease. This report tries to limit the use of jargon, and to include explanatory text where required. Technical

language is explained when first used, and there is a glossary within the Explanatory Supplement.

2.3 Interpretation of the data

The potential for finding herds infected with TB is directly related to (a) how hard we look (the type and frequency of surveillance), and (b) the underlying level of disease (prevalence of infection) in the cattle population, both of which differ by risk area.

Several factors also affect the probability of a herd becoming infected with TB, which are unevenly distributed in the cattle population. For example,

(i) Herd size; large herds have an increased risk of infection
(ii) Herd type; dairy herds have an increased risk of infection
(iii) Presence of infection in the local cattle population, which increases the chance of local transmission between neighbouring cattle herds
(iv) Presence of TB (*M. bovis*) infection in other species to which cattle are exposed. The most important being the local badger population, which is endemically infected in much of the South West and West Midlands of England.

Furthermore, changes in surveillance intensity and control measures over time exert their own effects on the measures used to track changes in the epidemic.

This report aims to take such factors into account when measuring the relative risk and frequency of TB in different herds. This enables more accurate assessment of the efficacy of applied control measures.

2.4 Eradication of bovine tuberculosis (TB) in England

Bovine tuberculosis (TB) is an infectious and contagious bacterial disease. Its wildlife reservoir (badgers) is present in much of England, which complicates the eradication of the disease in its natural host (cattle). TB threatens the cattle industry and presents risks to other susceptible livestock, wildlife, zoological collections and domestic pets. TB in animals can also threaten human health, although the widespread pasteurisation of cows' milk largely protects the public from undisclosed cases of TB in cattle. Nevertheless, the TB epidemic in cattle and badgers, with occasional spill-over into other wild and domestic species, represents a low but ongoing public health risk.

In view of these impacts, TB has been subject to a statutory eradication programme in England since the 1950s. Substantial progress was made over the first three decades of the programme. However, progress stalled in the late 1980s and the incidence and range of endemic areas of disease increased steadily until 2010-11. In April 2014, the government published its Strategy for achieving Officially Bovine Tuberculosis Free Status (OTF) for England (summarised in Figure 2.1).

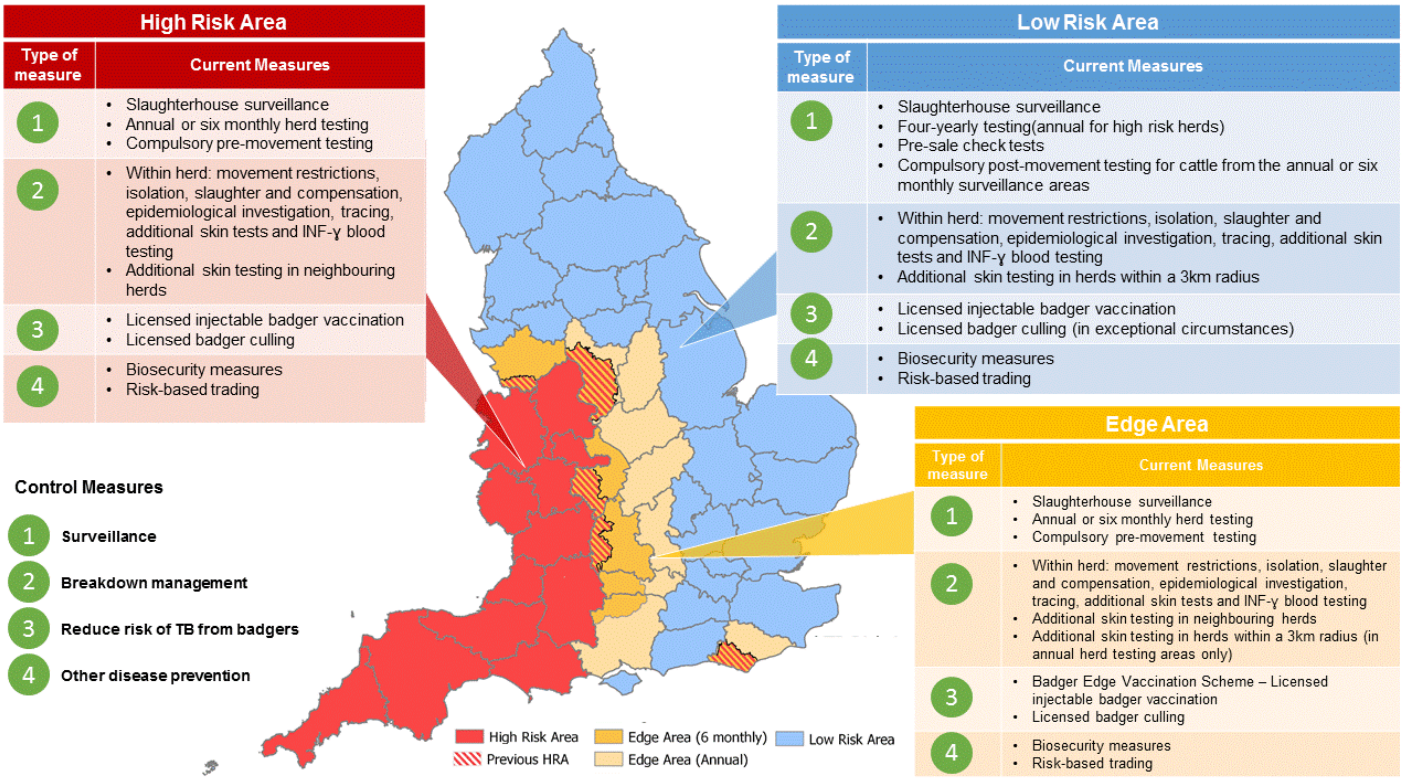


Figure 2.1 Summary graphic of the England TB Eradication Strategy

The Strategy defines disease control measures that aim to achieve officially TB Free (OTF) status for England incrementally by 2038. These measures are designed to be effective, whilst maintaining trade and an economically sustainable livestock industry. One of the key features of the current strategy is the division of the country into three 'risk areas'. These risk areas are defined by the level of TB, with bespoke control measures. Compulsory TB controls are based on the regular testing of herds, slaughter of positive animals and the imposition of movement restrictions following a failed test. Movement restrictions 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.

2.5 New TB surveillance and control measures introduced in England in 2019

Earned Recognition scheme: implemented in May 2019 for low-risk herds in the six-monthly testing parts of the Edge Area. This scheme allows eligible herds to move back to annual testing where they have:

- TB accreditation under the Cattle Health Certification Scheme (CHeCS) to level 1 or above, or
- Have been in existence for at least six years and have not had a TB incident during that six year period.

Approved Finishing Unit (Enhanced) with Grazing: a new type of finishing unit was introduced in the HRA to replace AFUs with grazing in badger control areas. The new type of unit operates under stricter biosecurity requirements than the previous AFUs with grazing.

Licensed badger culling: eleven new Badger Control Programme (BCP) areas were licensed by Natural England. Ten of those areas were introduced in the HRA, and one in the Edge Area, bringing the total number of BCP areas to 43, including three areas that have moved into a phase of licensed Supplementary Badger Control after four successive annual cycles of intensive culling (See Chapter 4, TB control in wildlife).

Badger vaccination: a further call for applications under the Badger Edge Vaccination Scheme 2 (BEVS2) was open between 20 June 2019 and 10 August 2019.

Successful completion of a pilot to explore the use of lay approved TB testers in private veterinary practices, thus paving the way for practices in England to employ these para-professionals from late 2020 subject to specific requirements.

3. The TB epidemic in England

3.1 Incidence, geographic distribution and trends over time

- In 2019, there were 3,289 new TB incidents in England. This was the second consecutive year the number of new TB incidents has fallen in England, and the lowest number disclosed since 2007. Between 2010 and 2018, the total number of new incidents per annum had been relatively stable, between 3,600 and 4,000. As in previous years, most new incidents in 2019 occurred in the High Risk Area (HRA) (76.0%), with 19.5% in the Edge Area and 4.5% in the Low Risk Area (LRA).
- Lower numbers of new TB incidents disclosed in England in 2019 compared to 2018, were observed in both the HRA and the Edge Area. The number of incidents increased very marginally in the LRA.
- Since the start of 2011, the epidemic appears to have slowed suggesting that the epidemic as a whole in England is plateauing. However, the 2019 quarterly incident totals are still more than double the quarterly totals before the UK outbreak of foot-and-mouth disease in 2001.
- Within the HRA, the TB incidence rate has fluctuated between 18 and 20 incidents per 100 herd years at risk (100 HYR) since 2011 up to 2018, but fell to 16.9 incidents per 100 HYR in 2019. Since 2010, there has been a continued increase in TB incidence within the Edge Area to 9.9 incidents per 100 HYR in 2019, whilst incidence has remained very low and stable during the same period in the LRA (1.1 TB incident per 100 HYR).
- Lesions typical of TB and/or positive culture results for *Mycobacterium bovis* were detected in cattle removed from 65% of all new incidents in the HRA, 58% in the Edge Area and 24% in the LRA.
- There was a net retraction of 426 km2 of the areas considered to harbour endemic *M. bovis* infection in England overall (2018-19), i.e. retraction of certain parts of the ‘endemic TB area’ exceeded expansion elsewhere.

Changes to the HRA and Edge Area boundary

In 2018, there was a change to the boundary separating the HRA and Edge Area. Previously split counties that used to straddle the HRA and the Edge Area (Cheshire, Derbyshire, East Sussex, Oxfordshire and Warwickshire) fully moved into the Edge Area. This caused an increase in the size of the Edge Area and a decrease in the size of the HRA, relative to previous years. To allow for a coherent temporal comparison of TB across multiple years, the 2018 spatial boundaries have been applied to all data in this report. Figures presenting pre-2018 HRA and Edge Area data are therefore not comparable to those published in previous reports. As a result of the boundary change, some herds that were in the HRA before 2018 moved into the Edge Area and became subject to more stringent control measures. These included six monthly surveillance testing and mandatory interferon gamma testing of herds sustaining OTF-W breakdowns. This will exert an additional influence on the number of new TB cases disclosed after 2018 compared to previous years.

Number of TB infected herds

The number of Officially Tuberculosis Free (OTF) herds in which a TB incident was detected in 2019 is referred to as the number of new herd incidents. The absolute number of new herd incidents is compared to previous years and between areas. However, the number of cattle herds in existence, herds that are tested, herds already under TB restrictions (non-OTF) and the types of test used change between years and TB risk areas. All this affects the number of new TB incidents detected and, consequently, the herd incidence rate is a better way of assessing temporal trends in the epidemic and differences between regions.

The number of new herd incidents decreased in England in 2019 (3,289) compared to 2018 (3,607). This was driven by a marked drop in the number of new herd incidents in both the HRA (9.4% reduction) and the Edge Area (10.7% reduction) compared to 2018. By contrast there was an increase in the number of TB incidents detected in the LRA in 2019 (148) compared with 2018 (129) (Table 3.1.1). In the LRA, the skin test has a lower positive predictive value than in the rest of the country, due to the very low prevalence of disease. Therefore, the number of OTF-W incidents is a better measure of disease in this area. The number of new OTF-W herds decreased by one in 2019, from 37 to 36. OTF-W incidents account for just 24% of all LRA TB incidents in 2019. This was the lowest number of OTF-W incidents in the LRA since 2014 (n=35).

Both the HRA and the LRA contain 41% of cattle herds (each) registered in England, while 18% of cattle herds are registered in the Edge Area. Approximately one in eight herds had a new TB incident in the HRA in 2019, compared to one in 13 in the Edge Area. For both areas this proportion decreased compared to 2018. In the LRA, one in 127 herds had a new TB incident in 2019 and one in 520 herds had an new TB incident that was lesion and/or culture positive (OTF status withdrawn (OTF-W)). However, it is important to note that only one in four herds are routinely tested in the LRA each year.

The higher prevalence of TB in both the Edge Area and HRA means that a positive skin test result (i.e. a test reactor) is a very good indicator of infection irrespective of *post mortem* and laboratory results (see Explanatory Supplement for further details). The proportion of TB incidents that were OTF-W in the HRA and Edge Area was 65% and 58%, respectively in 2019. Overall, the proportion of new herd incidents that were OTF-W decreased in England in 2019, compared to 2018. This trend was observed in the HRA and LRA, however the proportion of OTF-W herds in the Edge Area increased (Table 3.1.1).

Table 3.1.1 Number of all new TB incidents and herd incidence rate in England, by risk area, during 2018 and 2019

	HRA	Edge Area	LRA	England
All new TB incidents in 2019 (Percentage of total for England)	**2,501 (76.0)**	**640 (19.5)**	**148 (4.5)**	**3,289**
All new TB incidents in 2018 (Percentage of total for England)	2,761 (76.5)	717 (19.9)	129 (3.6)	3,607
New TB incidents in 2019 that were lesion and/or culture positive (OTF-W incidents) (Percentage of total incidents for risk area)	**1,613 (64.5)**	**374 (58.4)**	**36 (24.3)**	**2,023 (61.5)**
New TB incidents in 2018 that were lesion and/or culture positive (OTF-W incidents) (Percentage of total incidents for risk area)	1,868 (67.7)	405 (56.5)	37 (28.7)	2,310 (64.0)
TB incidence rate (OTF-W and OTF-S) per 100 HYR in 2019	**16.9**	**9.9**	**1.1**	**9.3**
TB incidence rate **(OTF-W and OTF-S)** per 100 HYR in 2018	18.5	9.1	0.8	9.3
Percentage change in TB incidence rate per 100 HYR from 2018 to 2019	**-8.8**	**+8.9**	**+29.5**	**-0.2**

Note: In the LRA the incidence rate of OTF-W only cases was 0.3 per 100 HYR, an increase from 0.2 in 2018.

The incidence figures per 100 HYR presented in this report have undergone a minor correction since the publication of the 2018 report. The correction accounts for the change in testing interval from annual to six-monthly testing in some parts of the Edge Area. For this reason, new TB incidents per 100 HYR disclosed in the Edge Area during 2018 was published as 9.2 in the 2018 report, but in this report has been corrected to 9.1. Similarly, for England as a whole, the number of new incidents per 100 HYR during 2018 has been updated from 9.4 in the 2018 report, to 9.3 in the current figures. Incidence in the HRA and LRA in 2018 is unchanged (Table 3.1.1).

Temporal trends in the number of new herd incidents in England

From 1986 to 2000, before the foot and mouth disease (FMD) outbreak in 2001, the number of new herd incidents was rising at an annual rate of over 14%. The time it was taking for the epidemic to double in size was estimated at 5.3 years (see Figure 3.1.1a in Bovine tuberculosis in England in 2018).

Surveillance testing, control measures and movement patterns in cattle herds across GB were disrupted during and immediately after the FMD epidemic in 2001. The number of new herd incidents increased rapidly over this period; leaping from 363 in the last quarter of 2000 to 662 in the last quarter of 2002, with a 25.3% annual rate of increase.

The rate of increase in TB incidents reduced once controls were re-established after the FMD epidemic (Figure 3.1.1). From 2003 to 2010 the epidemic continued a steady but significant (p=0.005) upward trend. The annual rate of increase for all incidents at this time was 5.6% (doubling time of 12.8 years). Since the start of 2011 the epidemic appears to have slowed, indicating 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.

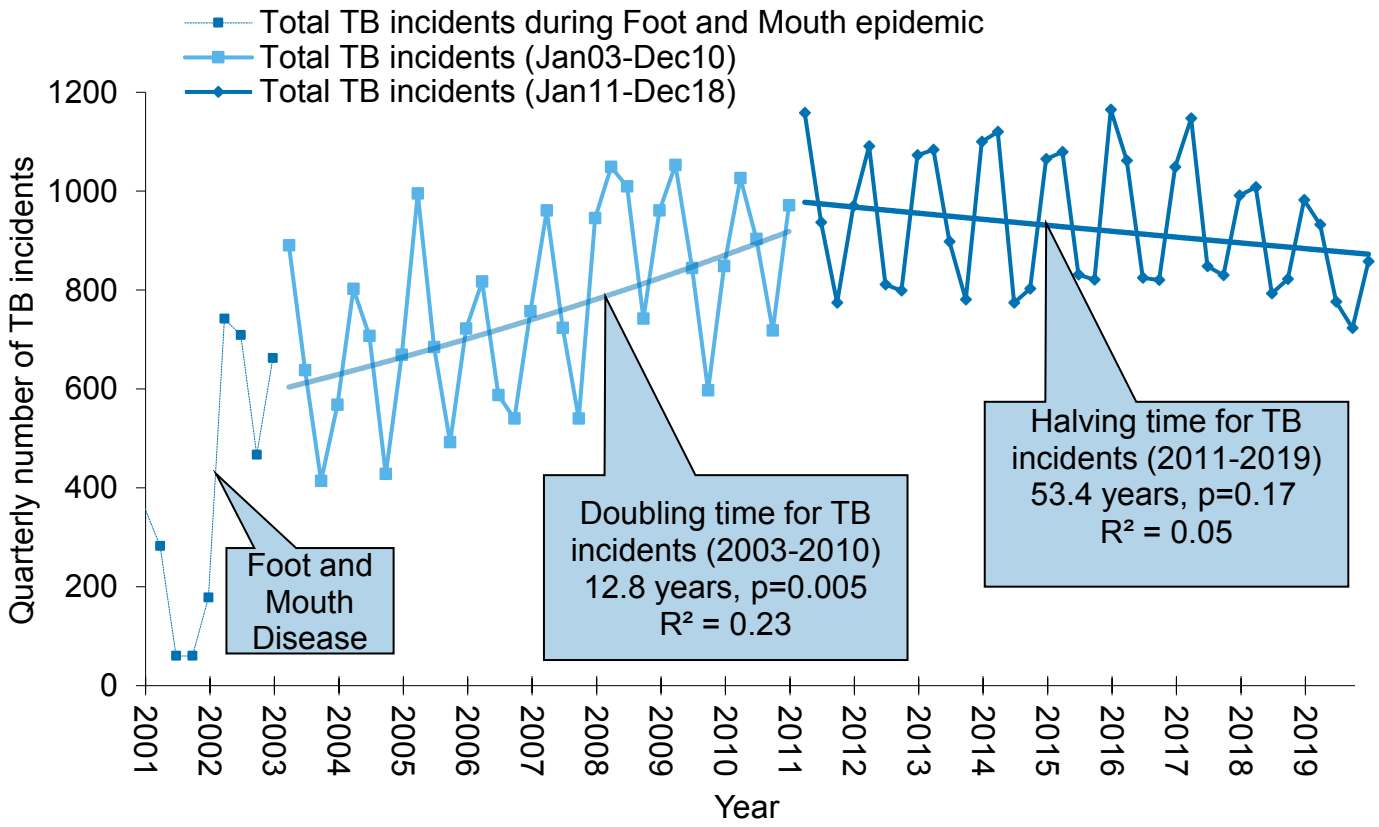


Figure 3.1.1 Quarterly totals for new TB incidents detected in England between January 2001 and December 2019

- Trend lines are shown for the two periods 2003-2010 and 2011-2019. The doubling time for the period 2003-2010 indicates the time it would take for incidents to double in number, given the trend of the data. The R^2 value indicates 'goodness of fit' of the superimposed trend line to the raw data. The trend was quite erratic in both time periods, largely due to seasonal trends (an R^2 of 1 would indicate a perfect fit).
- The upward trend observed between 2003 and 2010 was significant (p=0.005). The slightly decreasing trend for the period 2011-2019 was not significant (53.4 years, p=0.17), and the epidemic now appears to be plateauing.

The total number of new TB herd incidents in England decreased in 2019 to 3,289. This is the lowest number of new herd incidents reported in a year since 2007 (3,169). Generally the level of TB has been fairly stable in recent years at between 3,600 and 4,000 from 2010 to 2018 (Figure 3.1.2). In the Edge Area, the number of new herd incidents fell in 2019 compared to 2018, from 717 to 640. This is the first annual reduction since 2013, when the three TB risk regions of England were formally established and annual surveillance was uniformly adopted for all herds in the Edge Area. This was followed by six-monthly testing in the Edge Area portion of Cheshire in 2015, which was expanded to include the whole of Cheshire, Oxfordshire, Warwickshire and parts of Berkshire, Derbyshire and Hampshire in January 2018. Although the reduction in new TB incidents disclosed in the Edge Area is a welcome development, single inter-year changes should be interpreted with caution. Furthermore, multiple measures are used to explore TB trends and should not be considered in isolation.

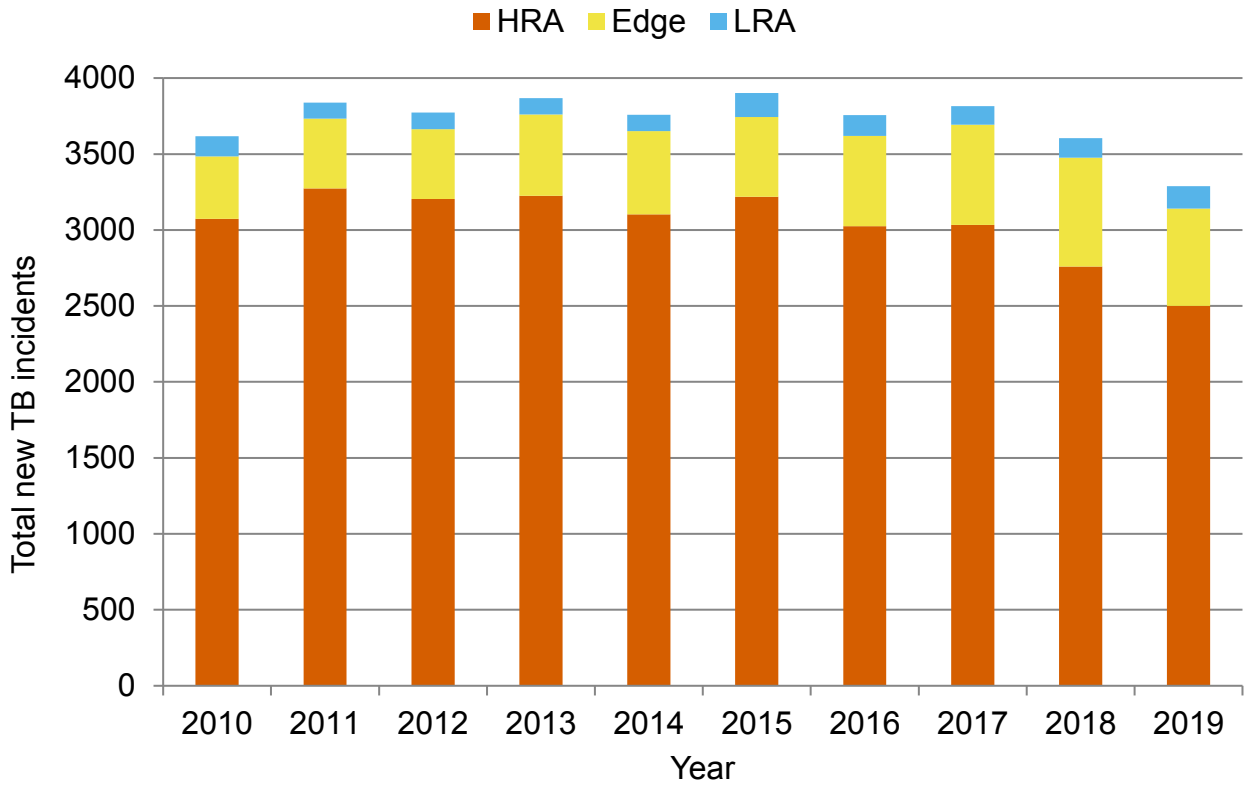


Figure 3.1.2 Annual trends in the total number of new TB infected herds, by risk area

- The total number of new TB incidents in England overall decreased for the second year running.
- The number of new TB incidents in the HRA also decreased in 2019 for the second year running.
- The number of new TB incidents in the Edge Area fell in 2019 compared to the preceding year for the first time since 2013.

In the LRA the number of new TB incidents increased in 2019 compared to 2018. This was due to an increase in the number of Officially Tuberculosis Free status suspended incidents, which increased by 19. The number of Officially Tuberculosis Free status withdrawn incidents was similar in 2018 (n=37) and 2019 (n=36) (Figure 3.1.3).

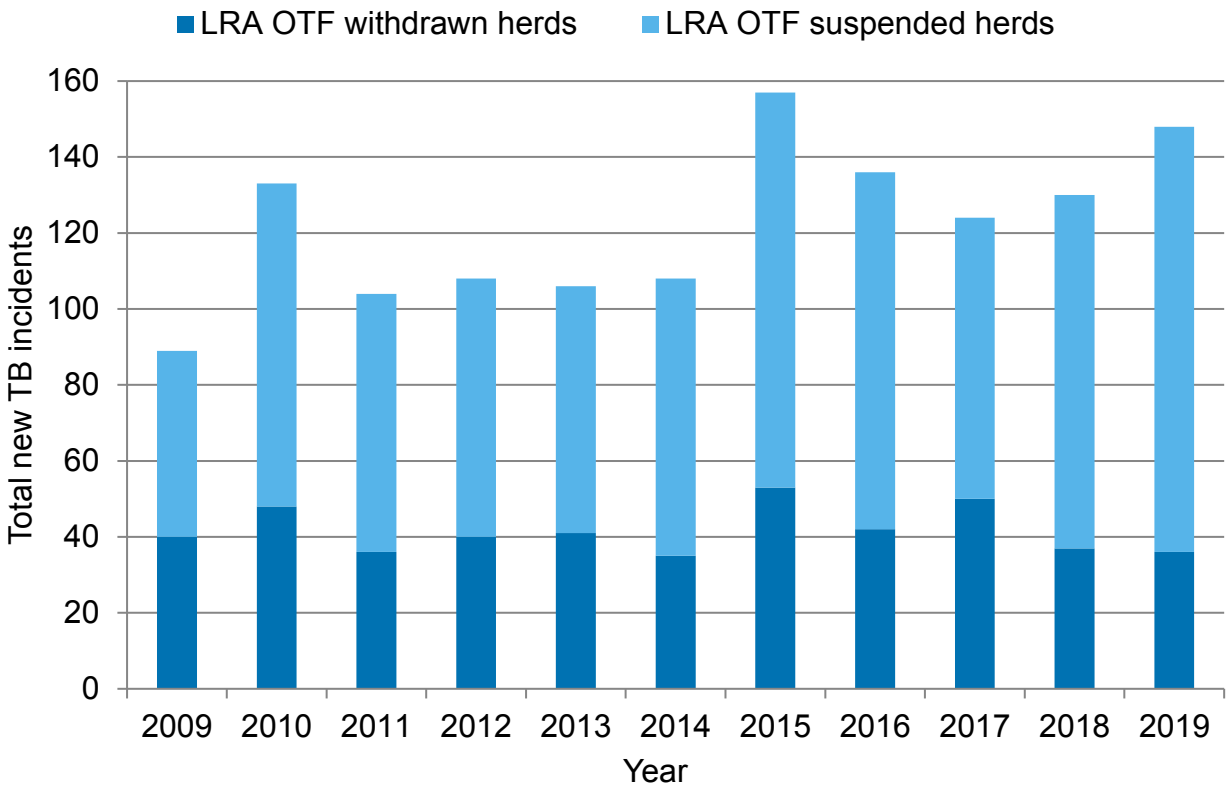


Figure 3.1.3 Annual total number of TB incidents in the LRA, by post mortem result status (OTF-W and OTF-S).

- The number of herds in the LRA with fully confirmed *M. bovis* infection at *post mortem* and/or bacteriological culture (new OTF-W incidents) has not varied much over the past ten years. Although it was highest in 2015 (n=53), there is no obvious temporal trend.
- The proportion of new TB incidents in the LRA that were OTF-W decreased to the lowest level in over 10 years (24%).

Annual herd incidence rate and geographical distribution of new TB incidents

The TB epidemic in England is also measured by the herd incidence rate. This is the rate at which herds become newly infected with TB. The incidence rate in this report is calculated as the number of new TB incidents per '100 herd-years at risk' (100 HYR). This measure adjusts for differences in the time that herds are at risk of infection. Herd-years at risk takes into account the number of herds tested, when and how often herds are tested and also periods when herds are under restriction due to test reactors or culture-positive slaughterhouse cases (and therefore not at risk of a new incident). While this statistic

enables a more accurate comparison between areas than the number of new incidents that occur, it is sensitive to changes in testing intervals within an area. This should be borne in mind when considering incidence rate trends in some parts of the Edge Area that moved from annual to six-monthly testing in 2018. A detailed description of the methodology used to calculate incidence per 100 HYR is available in the Explanatory Supplement.

The annual incidence rate of TB in England in 2019 was 9.3 TB incidents per 100 HYR. This rate has fluctuated by one or two percent over the past decade and has been following a slightly increasing trend overall, with a drop every fourth year (2010, 2014, 2018) (Figure 3.1.4). In accordance with this pattern, an increase in 2019 compared to 2018 would be expected, however the incidence rate did not change (also 9.3 in 2018). This is a positive observation, however inter-year changes should not be examined in isolation without considering longer-term trends. The incidence rate in 2019 is still higher than the rate reported in 2014 (8.6 TB incidents per 100 HYR), the previous low-point (Figure 3.1.4).

The level and trend in TB incidence varies between risk areas in England. In the Edge Area, the TB incidence rate has been increasing every year since 2013. This trend continued in 2019, despite a decrease in the number of new TB incidents. The number of herd-years at risk (denominator) fell in 2019 at a greater rate than the number of new TB incidents (numerator). TB incidence per 100 HYR increased by 8.9%, from 9.1 in 2018 to 9.9 in 2019 (Table 3.1.1 and Figure 3.1.4), but this increase was not statistically significant ($p= 0.118$).

Enhanced TB surveillance and case management policies aim to support timely detection of infected herds in the Edge Area. Changing surveillance strategies can impact the periods at which a herd is calculated to be at risk of new infection, the denominator to the incidence rate. These changes are thought to be at least partially responsible for the increased incidence reported in the Edge Area in 2019 compared to 2018. For more details see ‘Effect of routine TB surveillance changes in the Edge Area in 2018 on the herd incidence rate’ below. Incidence per 100 HYR remains the best measure of incidence long term because it takes into account differences in surveillance strategies between areas and over time. However, simpler measures of incidence can help to provide additional clarity with regard to overall TB trends in areas. For example, the trend in incidence per 100 unrestricted herds tested shows a steady increase in annual incidence in the Edge Area from 7.2 in 2016 to 8.9 in 2018, before falling to 8.2 in 2019 (Figure 4.2.4, Epidemiology of TB in the Edge Area).

Incidence per 100 HYR in the HRA decreased by 8.8%, from 18.5 in 2018 to 16.9 in 2019, a statistically significant drop ($p<0.001$). Both the denominator (herd-years at risk), and the numerator (number of TB incidents) declined in the HRA in 2019.

In the LRA, the incidence rate for all TB incidents increased significantly in 2019 compared to 2018 (0.8 to 1.1, $p=0.032$). However, over three quarters of the new TB incidents were not confirmed by *post mortem* tests of TB suspect animals (Figure 3.1.3). When considering the incidence rate for OTF-W herds only, the increase between 2018 and

2019 was barely noticeable and not statistically significant (0.2. to 0.3 incidents per 100 HYR, respectively (p=0.690)).

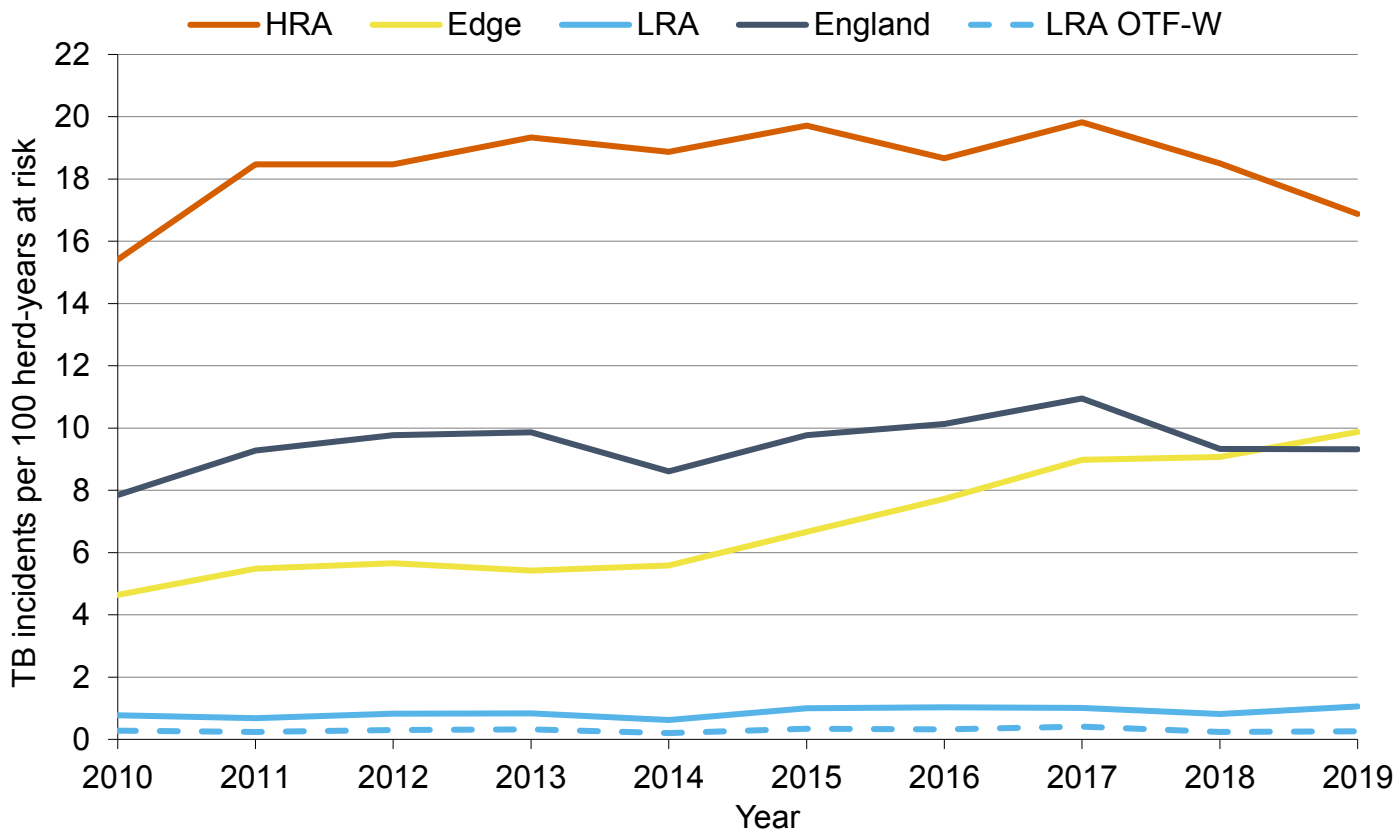


Figure 3.1.4 Annual incidence rate (per 100 HYR) for England and by risk area, from 2010 to 2019.

- The decrease in incidence rate in England as a whole was not significant in 2019 compared to 2018 (p=0.931).
- The incidence rate decreased significantly for the second consecutive year in the HRA (2019 compared to 2018, p<0.001).
- The incidence rate continued to rise in the Edge Area, however the difference between the overall incidence rate in 2019 compared to 2018 was not significant (p= 0.118).
- In the LRA, the incidence rate remained very low. A small significant increase was seen in 2019 compared to 2018 (p=0.032), while for OTF-W only incidents a very small non-significant increase was observed (p=0.690).

Figure 3.1.5 shows the incidence rate per 100 HYR for individual counties in England during 2019. The highest incidence rates were recorded in the Edge Area county of Oxfordshire (23.8), followed by the HRA counties of Wiltshire (21.7) and Avon (20.4). These three counties also had the highest incidence in England when considering the incidence measure ‘per 100 unrestricted herds’. However, Wiltshire had the highest incidence with 18.6 incidents per 100 unrestricted herds tested, followed by Avon (18.3)

and Oxfordshire (17.3). For HRA counties in the south-west, Cornwall, Devon, Somerset, Dorset, Gloucestershire and Hereford & Worcester, the incidence rate per 100 HYR was at its lowest level since pre-2013. In the Edge Area, the incidence rate increased in 2019 for all counties where six-monthly testing was fully or partially adopted in 2019 Berkshire, Cheshire, Derbyshire, Hampshire, Oxfordshire and Warwickshire. This is despite a reduction in the number of TB incidents reported in those counties. Incidence also increased in Northamptonshire, but fell in the remaining Edge Area counties in 2019. When considering incidence per 100 unrestricted herds in Edge Area counties, incidence fell or remained the same in every county of the Edge Area in 2019 compared to 2018, with the exception of Northamptonshire.

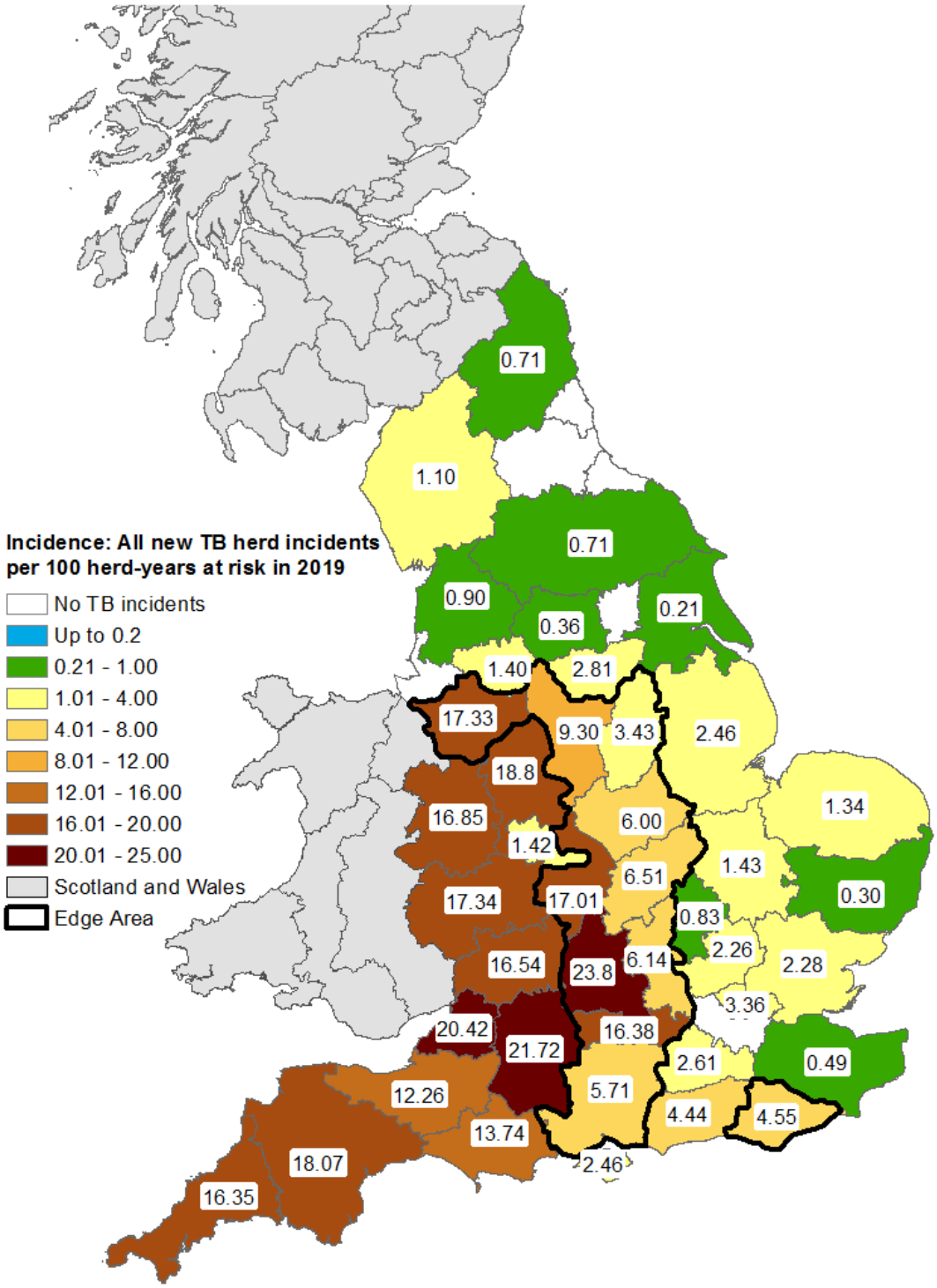


Figure 3.1.5 County herd incidence (all new TB incidents per 100 HYR) in England in 2019

- There is wide variation in incidence rates by county and risk area. Incidence was highest overall in the Edge Area county of Oxfordshire, followed by HRA counties Wiltshire and Avon.

Effect of routine TB surveillance changes in the Edge Area in 2018 on the herd incidence rate

Several factors have contributed towards the increased incidence within some parts of the Edge Area in 2019. Here we explore the impact of six-monthly testing and the earned recognition scheme.

Figure 3.1.5 shows the incidence rate within individual counties. The largest rises in incidence were seen in Oxfordshire, Warwickshire, Cheshire, Derbyshire, Berkshire and Northamptonshire. Excluding Northamptonshire, these are all counties where six-monthly surveillance testing was introduced in 2018 (2015 for parts of Cheshire). In these counties, six-monthly testing has decreased the overall time-at-risk herds contributed in 2019 compared to 2018. This is because when six-monthly testing was introduced in 2018, herds each contributed approximately 12 months of time for their first test, and a further six months of time at the second test. This inflated the time-at-risk in 2018 overall. Under normal circumstances time-at-risk would be closer to one year per herd, with both the first and second six-monthly tests contributing approximately six months of time for each herd.

This has however been impacted in 2019 by the Earned Recognition scheme implemented in May 2019. This scheme allows certain herds in the six-monthly testing parts of the Edge Area to move back to annual testing if they are:

1. TB accredited under the Cattle Health Certification Scheme (CHeCS) to level 1 or above, or
2. have been in existence for at least six years and have not had a TB incident in that six year period.

These conditions were met for between 23-44% of herds in 2019. This deflated the denominator (HYR) of the incidence rate for the Edge Area as those herds only accumulated six months of time at risk. Although herds in these areas may continue to gain or lose eligibility for the earned recognition scheme in the future, the number of herds changing their testing frequency is expected to be minimal.

Spatial changes in the TB epidemic

Changes between 2018 and 2019 in the areas of England that can be defined as ‘endemically infected’ have been assessed (see Explanatory supplement for definition and methodology for endemic infection). The results of this methodology can be influenced by areas of low cattle density and local purchasing behaviour, which in isolated cases may give the appearance of spread or retraction as the result of these factors, and not the endemicity of TB in cattle populations. Overall, the comparison shows that the majority of the HRA is, and remained, ‘endemically’ infected, along with areas in the Edge, particularly where they border the HRA. Most of the rest of England, particularly the LRA, is not ‘endemically’ infected. Veterinary assessment has highlighted that most of the changes in the South West of England are associated with low herd densities, while the endemicity

identified in West Sussex is most likely purchase driven. Elsewhere spread and retraction observations broadly reflect the situation observed locally.

In England there was calculated to be approximately 2,585km² of spread in some parts of this endemically infected area and 3,011km^2 of retraction in other parts, resulting in a net change of -426.25 km^2 from 2018-2019 (overall retraction). The net change refers to the area for which rate of spread was able to be calculated, which does not include a few isolated areas that have appeared but not joined up with previous endemic areas yet.

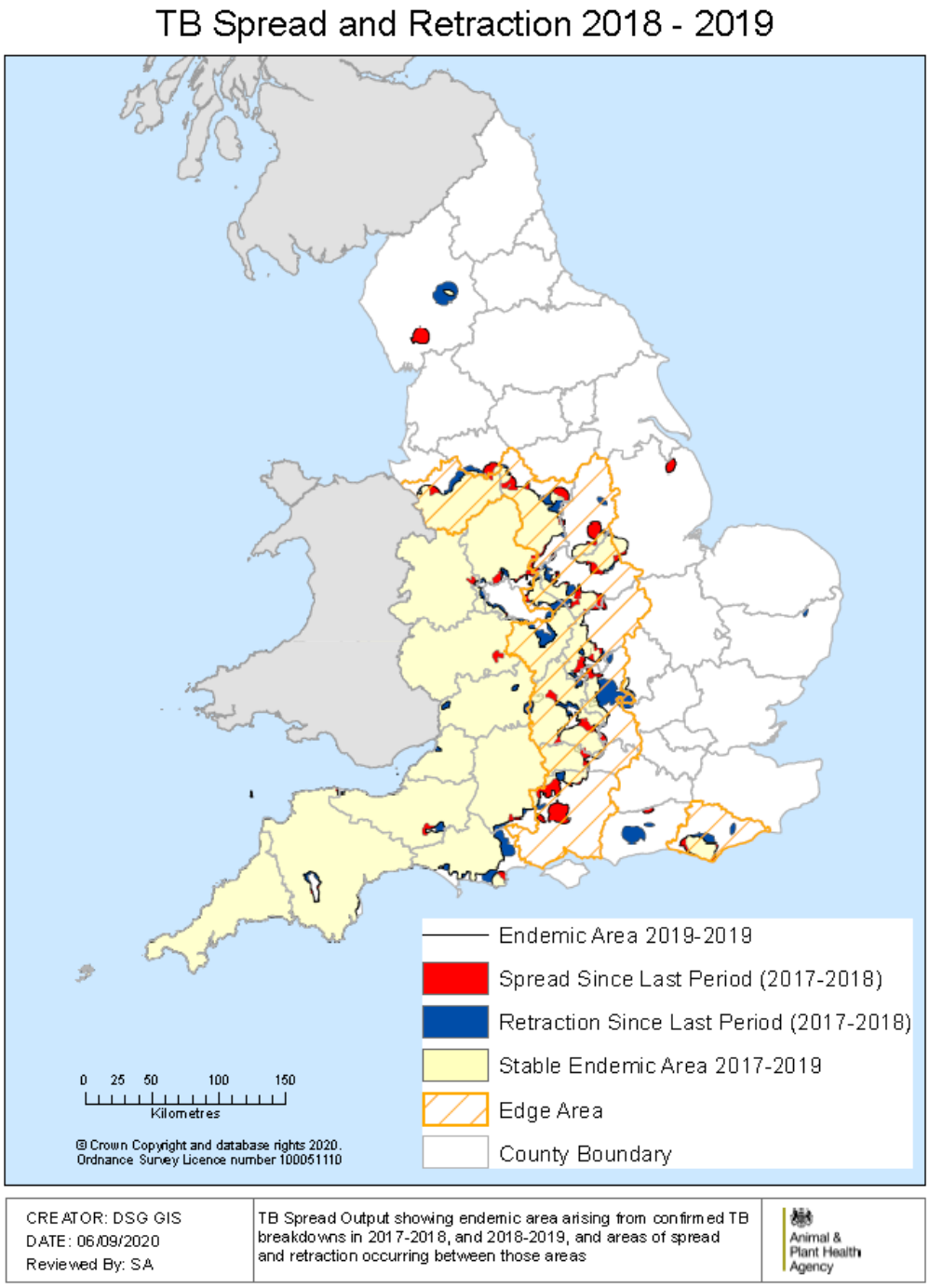


Figure 3.1.6 Spread and retraction of endemic TB areas in 2019 compared to 2018

3.2 Characteristics of herds found infected with TB

- Four key factors increased the risk of a herd having a new TB incident in England in 2019; having over 300 cattle, being located in the HRA, being a dairy herd and having experienced a TB incident in the past three years. These factors often co-exist, with herds in the HRA tending to be larger, and many dairy herds being large, located in the HRA and having a history of TB.
- 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 wildlife (particularly badgers) and their environment, to which cattle are exposed.
- Analysis shows that the probability of TB being found in a dairy herd was more than three times that of a beef herd, reflecting the large part of the burden of TB that is carried by the dairy industry.
- Even after adjusting for both herd size and location (i.e. looking at any herd of a given size in a given TB risk area), dairy herds had a twenty one per cent greater risk of infection than beef herds ($p<0.001$). This is in contrast to previous years (prior to 2016) when the differences in risk between beef and dairy herds could be explained by their location and size.
- A history of TB infection was also an important risk factor in all risk areas, and across England over half the herds that were found infected in 2019 had a previous TB incident within the last three years. Recurrence was highest in the HRA (57% of herds with new incidents in 2019) followed by the Edge Area (46%) and LRA (11%).
- The most likely source of infection, assessed for each new TB incident in 2019 by epidemiological veterinary assessment, varied by region. Within the HRA, badgers constituted 59% of the attributed sources, weighted by the level of veterinary certainty. In the Edge Area, new TB incidents were still most strongly ascribed to badgers (48%), but cattle movements (21%) were also identified as a common source of infection. In the LRA there as a high degree of uncertainty around the source of infection, however incidents were most strongly attributed to cattle movements (38%).
- Most TB incidents (83%) from which *M. bovis* was recovered and typed were attributed to a locally prevalent genotype of the bacterium. In other words, they occurred within the ‘home range’, indicating that the detected genotype was not unexpected in that area.

Factors associated with the likelihood that a herd will become infected

Many factors are associated with the risk of a herd becoming infected with TB. These include local herd density, herd size and type, TB history and the geographical location of a herd. Other factors that can contribute towards the distribution of TB include contiguous herds (and their TB history), herd management (such as cattle purchasing) and local environmental/wildlife factors.

Local herd density

Herd size and the local density of herds are closely associated with the risk for a particular herd to become infected with TB. These factors make a strong contribution to the spatial pattern of the TB epidemic in England (Figs 3.2.1a and b).

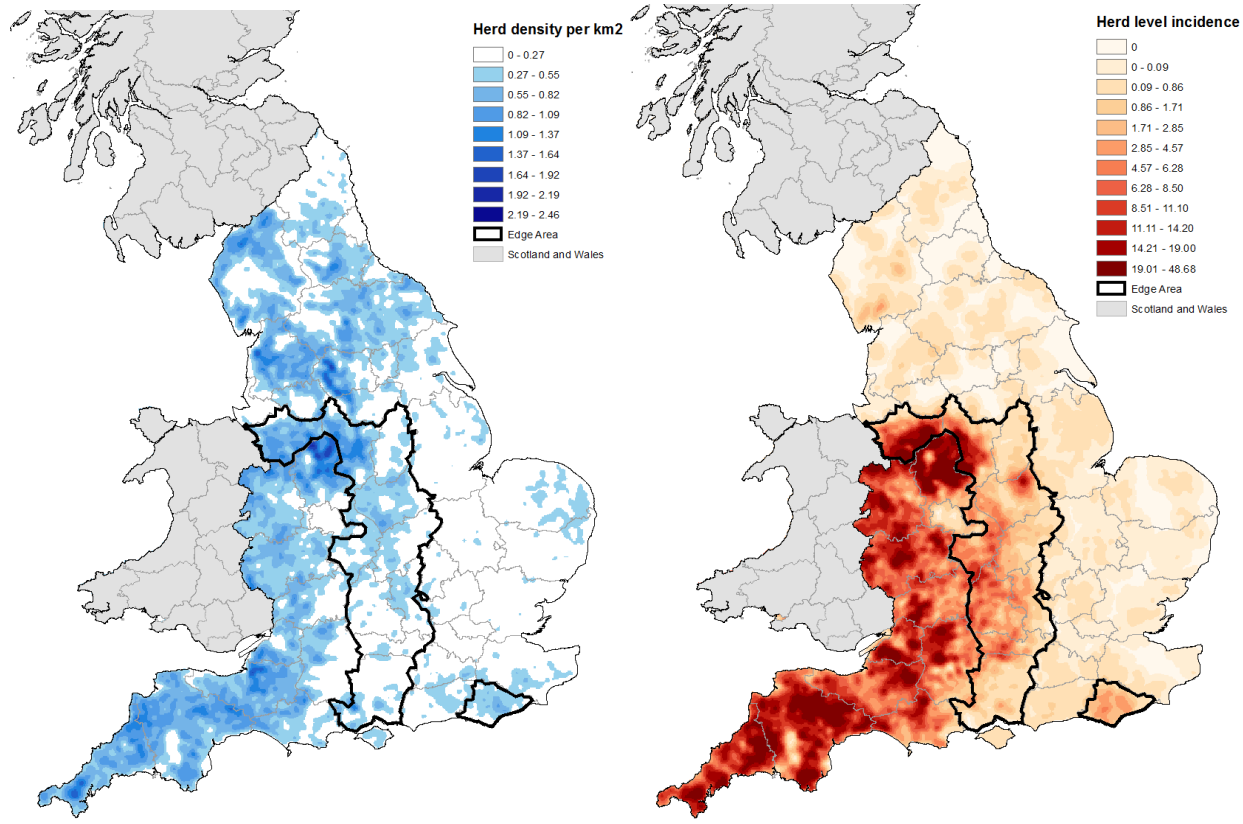


Figure 3.2.1(a) Herd density and (b) herd level incidence of TB in England in 2019. Herd density is measured as the number of herds per square kilometre; herd incidence is the average incidence in the 100 closest herds to each herd location which 'smooths' the effect of political boundaries

- Cattle demographics alone cannot explain the distribution of TB, as cattle density is high in parts of Northern England, where TB incidence is low.
- The highest numbers of cattle and the highest density of herds are mostly found in the HRA and parts of the Edge Area. The sparsest population in terms of both holding and cattle numbers is found in Eastern England.

Other factors important in explaining the distribution of TB, including herd size, type and TB history, will be explored in greater detail.

Herd size and type

Figure 3.2.2 shows the distribution of herds within each surveillance risk area by size and type. This has remained similar in recent years. Large herds with over 300 cattle have been shown to have a higher risk of infection with TB. These large herds represent fewer than 15% of all herds in the LRA, but 19% in the HRA (16% in the Edge Area).

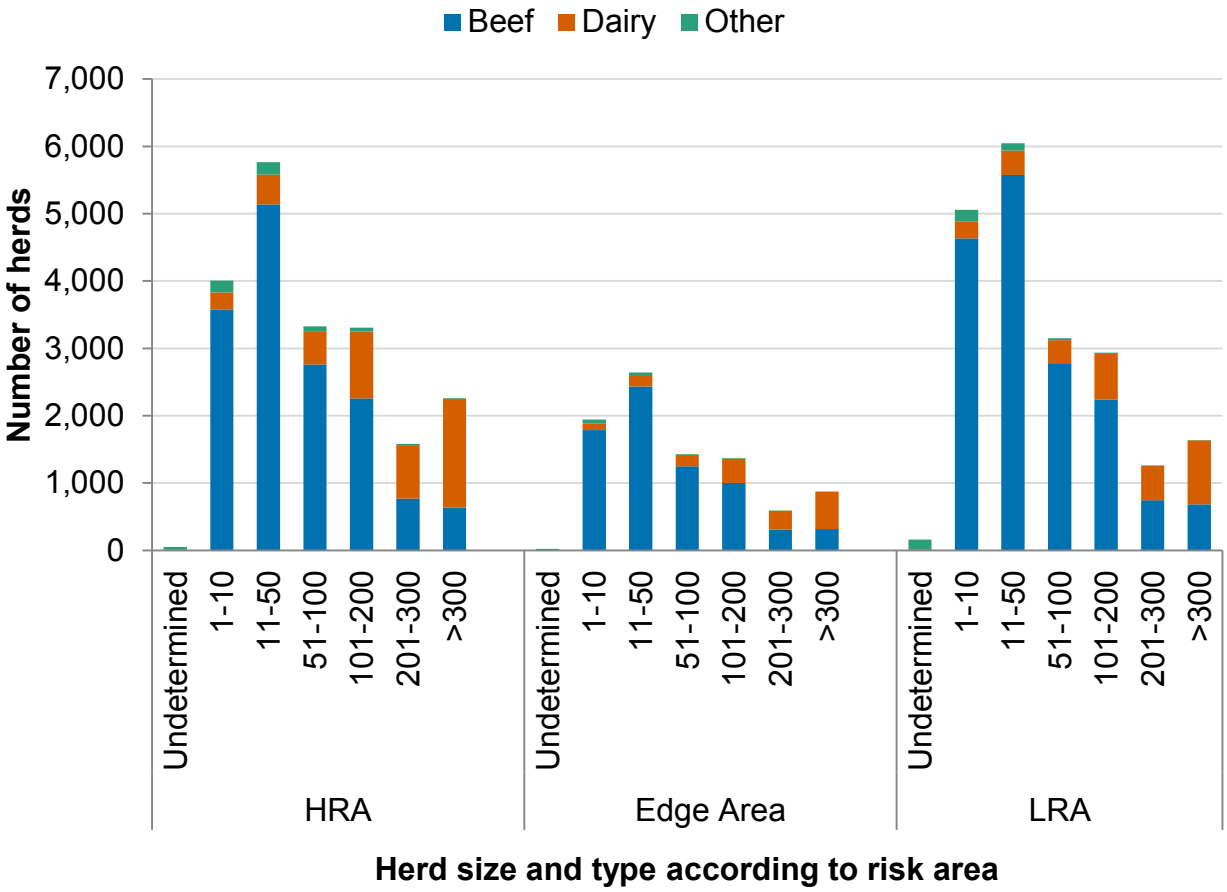


Figure 3.2.2 Number of herds by herd size and type in each risk area of England in 2019

- A greater number of large herds, and dairy herds are located in the HRA. This may explain some of the spatial distribution of TB infection.

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 (one percent or fewer 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 3.2.3a shows the incidence rate according to different characteristics (size, production type and location) of herds in England. This demonstrates that dairy herds were nearly three times more likely to become infected with TB than beef herds in 2019. However, dairy herds also tend to be larger herds and are more commonly located in the HRA, both of which are risk factors for TB infection (3.2.2).

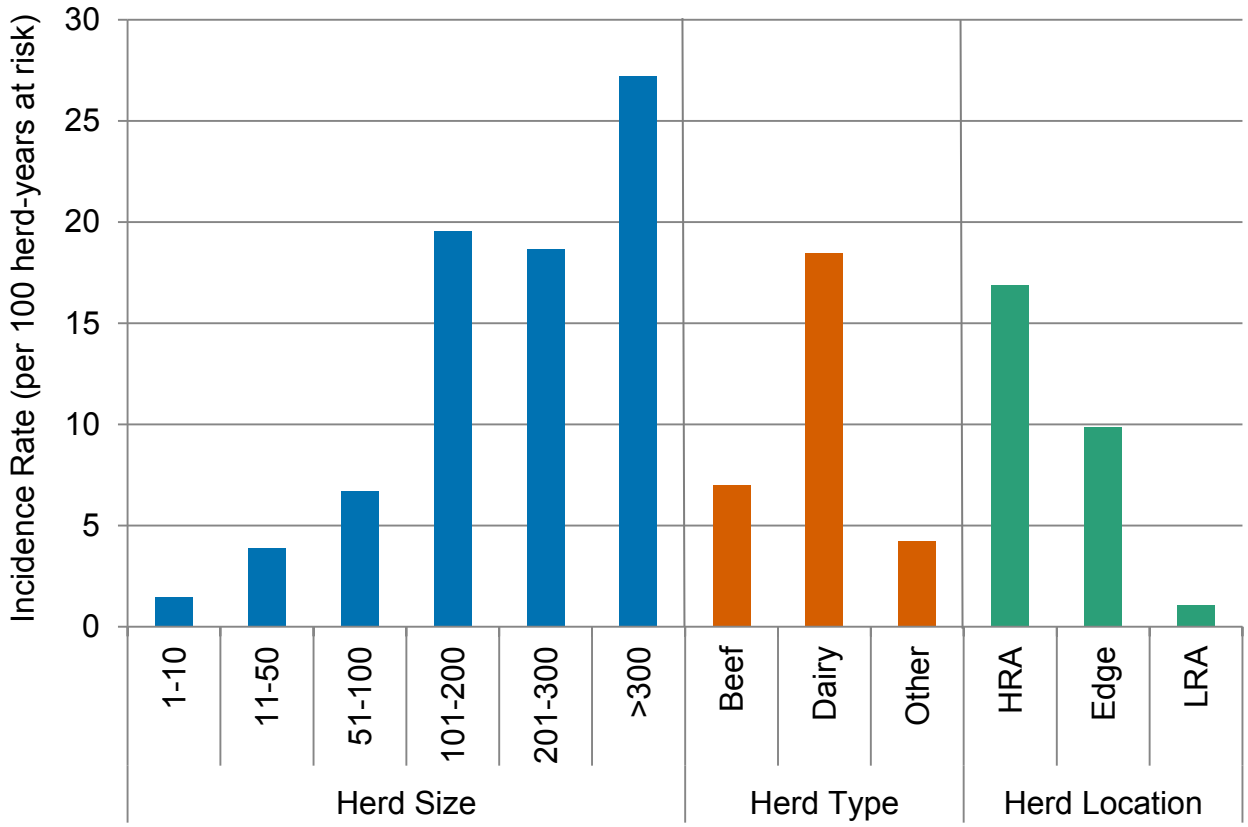


Figure 3.2.3a Incidence rates for new TB incidents in herds of different size or type, and in each risk area of England, in 2019

- All three factors appear to be strongly linked to the risk of TB infection.
- Herd size was strongly associated with the likelihood of a herd becoming infected with TB; in officially TB free herds with over 300 cattle, the incidence rate of TB in 2019 was 27%, while it was <4% in herds with 50 or fewer cattle.
- Dairy herds were 2.6 times more likely to be found infected in 2019 than beef herds.
- Herds in the HRA were over 1.7 times as likely to be found infected with TB than herds in the Edge Area and approximately 16? Times as likely as those in the LRA.

Potential risk factors are explored further by comparing incidence rate ratios (IRR). This is the comparative proportion of herds in each category that become infected. Other factors that could affect the rate of infection can then be taken into account. These comparative ratios are shown in Figure 3.2.3b. The Adjusted IRR shows that if location and herd type are taken into account when calculating the incidence rate ratios for herd size, the rate ratio hardly changes compared to the unadjusted IRR. This indicates that herd size may be a more important explanatory factor than herd type.

The IRR for herd size ranged from 0.05 to 0.7 times the rate of TB infection in herds with over 300 animals. As seen in previous years, the rate ratios increased with herd size, however in 2019, herds with between 100 and 200 animals were an exception to this

pattern. Herds with between 100 and 200 animals had a higher unadjusted IRR than herds with 200-300 animals, although the 95% confidence intervals around the IRRs overlap. After adjusting for the effects of herd type and risk area, the incidence rate ratio for herds with 100-200 animals fell below that for herds with 200-300 animals.

The high incidence rate in dairy herds is largely caused by the fact that they are disproportionately large herds and located in the HRA. Adjusting for both herd size and location greatly reduced the estimated risk associated with being a dairy herd. Even so, as in 2018, dairy herds were at higher risk of new infection in 2019 than beef herds of the same size and in the same risk area (IRR=1.21, 95% CI 1.12-1.31, $p<0.001$).

The incidence rate was significantly lower in the Edge and LRA compared to the HRA, even after adjusting for the effects of herd size and type. This indicates that location remains an important risk factor. In 2019, the adjusted IRR for herds in the Edge Area compared with herds in the HRA was 0.6 (95% CI 0.55-0.66). In recent years there has been an increase in the estimated risk for herds in the Edge Area compared to the HRA. In 2017 the adjusted IRR was 0.41 (95% CI 0.37-0.46), increasing to 0.49 (95% CI 0.45-0.54) in 2018 and 0.6 (95% CI 0.55-0.66) in 2019.

It is important to note that the Poisson analysis used to calculate the IRRs uses aggregated time at risk data. This aggregates the risk for herds that have had multiple whole herd tests in each year. The denominator value (time at risk) is slightly higher overall for the aggregated dataset (Figure 3.2.3b) than the non-aggregated dataset (Figure 3.2.3a). This results in slightly lower incidence rates. For more details about the Poisson analysis, see Appendix 4c in the 2015 report. Tabulated data can be seen in the GB data Report.

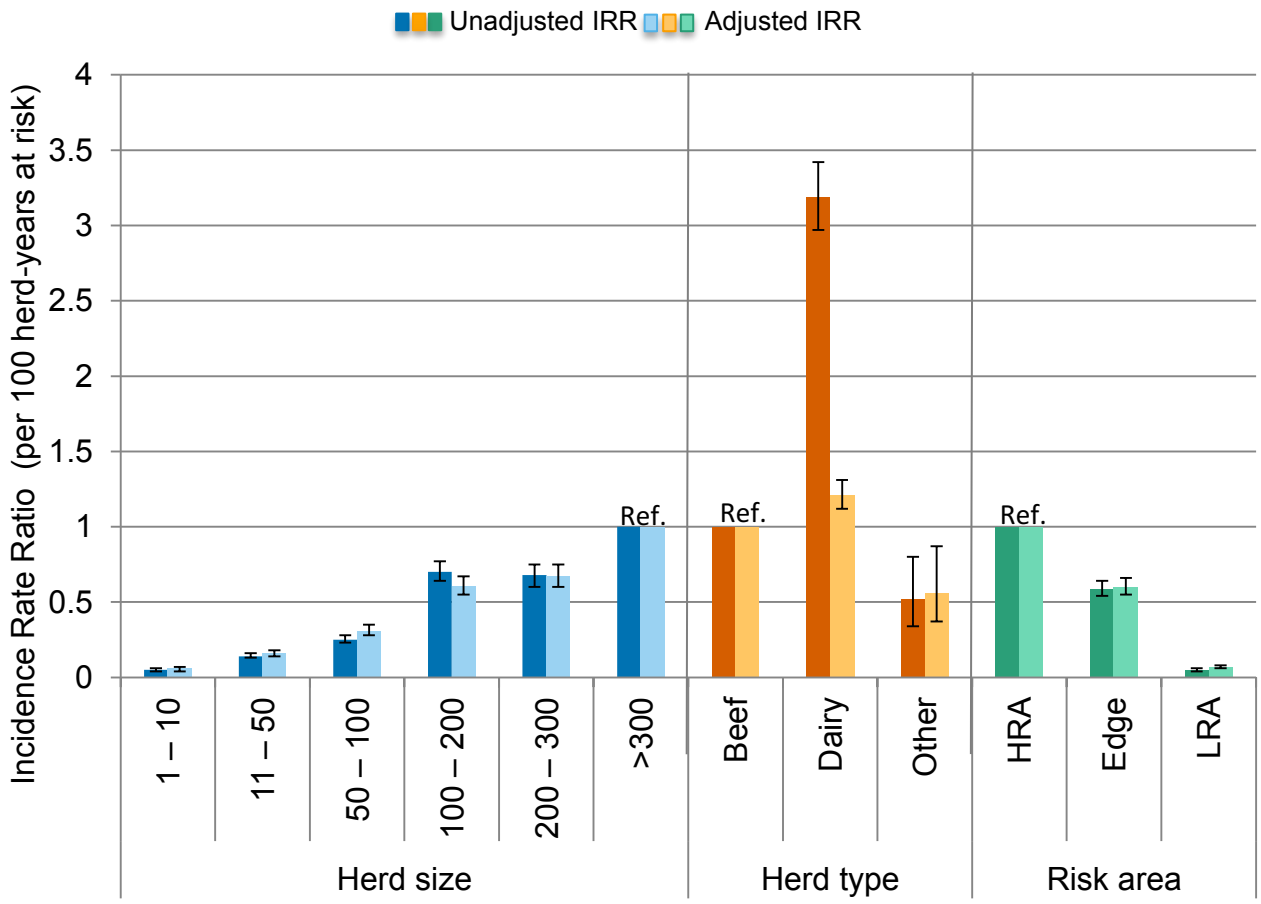


Figure 3.2.3b Incidence Rate Ratios (Unadjusted and Adjusted) for new TB incidents (OTF-W and OTF-S) in herds of different size, type and risk area in 2019

- Herd size and location are the most important explanatory factors for the incidence rate.
- The incidence rate for herds in the Edge Area was just over half the rate for herds in the HRA.
- The unadjusted incidence rate in dairy herds was 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 21% more likely to have a TB incident than beef herds.

Recurrent TB incidents

A herd's history of TB is linked to increased odds of infection occurring in any given year. A new TB incident in a herd that had a TB incident in the past three years is called a recurrent incident. In 2019, the odds ratio for recurrent incidents compared to new incidents in herds with no history of TB (recurrence odds ratio) was lowest in the HRA (OR 1.8, 95% CI 1.6-1.9). For the Edge Area, the recurrence odds ratio was higher at 3.5 (95%

CI 2.9-4.2). In the LRA the recurrence odds ratio was higher still, albeit with wide confidence intervals (OR 4.5, 95% CI 2.6-7.6).

The recurrence odds ratio has been relatively stable in the HRA in recent years (close to 2), but more variable in the Edge Area. In 2019, the Edge Area recurrence odds ratio increased for the second consecutive year (2017 OR 1.7, 95% CI 1.9-2.9 and 2018 OR 2.6 95% CI 2.2-3.1).

In the Edge Area, some locations have endemic infection, while some areas have a low incidence of TB. When recurrence is calculated for the area as a whole, the odds of herds with a TB history having a new incident in 2019 is high (similar to the odds in the HRA). However the odds of TB in herds with no TB history is very low (lower than the HRA). This causes a higher odds ratio for the Edge Area.

When the same analyses were run for previous OTF-W incidents only, the odds of a recurrent incident increased in the LRA. Having any TB incident in 2019 was over six times more likely in herds with a history of OTF-W incidents, compared to herds with an OTF-S or no TB history (OR 6.6 95% CI 3.2-13.4).

For herd size, the odds of having a TB incident in herds with a TB history compared to herds with no TB history was nearly five times higher in small herds (10 cattle or less) (OR 4.8 95% CI 2.9-7.9). For all remaining herd sizes, the odds of recurrence in herds with TB history compared to no TB history were close to double (Figure 3.2.4).

When comparing herd type, the odds of having TB was roughly two times higher in both beef and dairy herds with a TB history, compared to herds with no TB history. The ‘other’ category was much lower (OR 0.4 95% CI 0.06-3.3), although it has a very wide confidence interval.

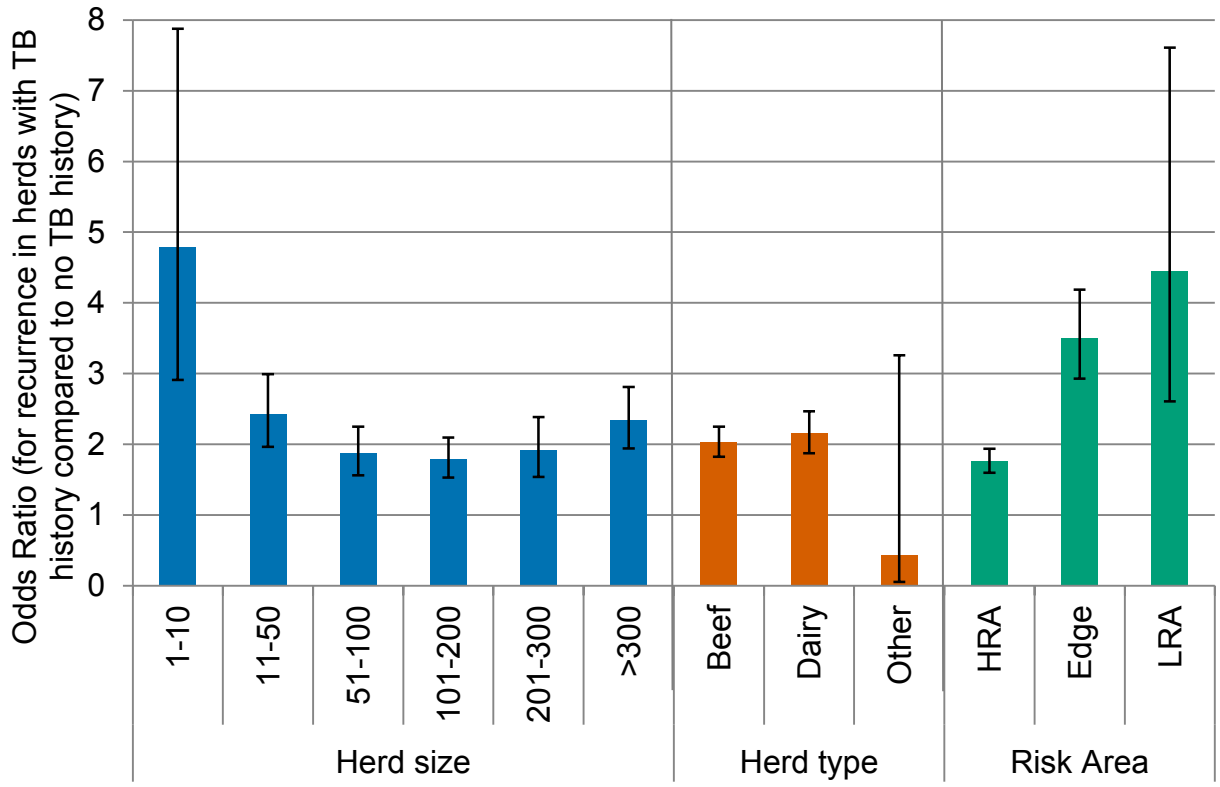


Figure 3.2.4. The odds of recurrent infection in herds with a history of TB compared to herds with no TB history, by herd size, herd type and risk area (error bars show 95% confidence intervals)

- Beef and dairy herds, and herds in most size categories that had a history of TB all had similar odds of recurrent infection (around double). The odds were higher in small herds and lower for other herd types, however there is a high level of uncertainty around the odds ratios for these categories (both have wide confidence intervals).
- In the HRA, the odds of recurrent infection in herds with a history of TB compared to herds with no TB history was just under double. In the Edge Area the odds were higher, at around three and half times for herds with a history of TB compared to herds with no TB history. In the LRA the odds were higher still, at over four, however the confidence intervals were wide.

The proportion of recurrent herds are explored in two ways. Firstly, by looking at the proportion of all herds with a history of TB that went on to experience a TB incident in 2019 compared to the proportion of all herds without a history of TB that went on to have a TB incident in 2019 (forward looking recurrence). Secondly, recurrence is explored within TB positive herds in 2019 only. Those herds with an incident were examined to see what proportion had previously had a TB incident in the past three years (backward looking recurrence).

Recurrence as a proportion of all herds was examined within each risk area and herd type category separately (Figure 3.2.5a). In all three risk areas, the proportion of recurrent TB incidents was highest in dairy herds, with around half the proportion of beef herds enduring a recurrent infection.

Recurrence may have a number of causes, likely relating to location, biosecurity, residual undetected herd infection, exposure to local wildlife reservoirs, and/or cattle 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. Farmers' knowledge of their herds' increased risk, may also help those keepers with a history of TB infection make informed decisions about their management practices using advice from initiatives such as the TB Hub to help promote safer buying practices and improved biosecurity.

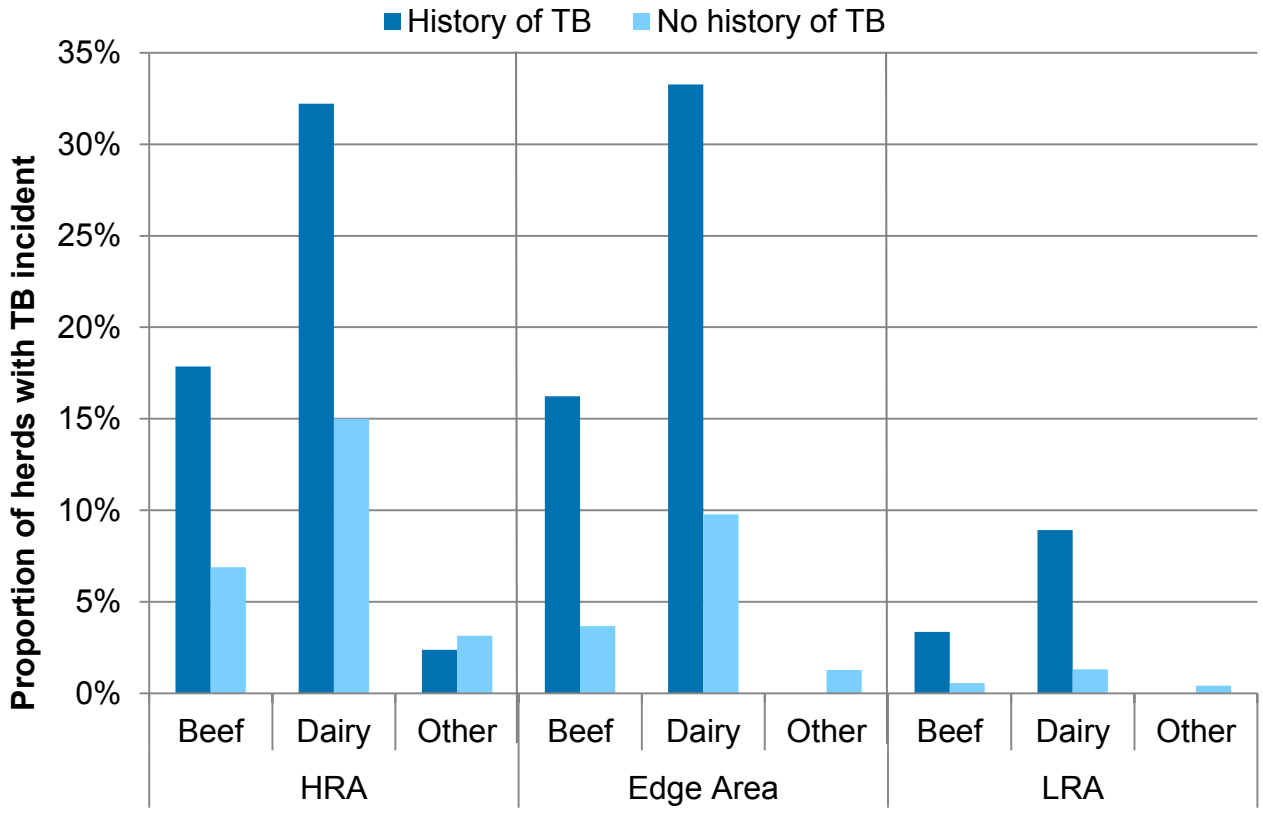


Figure 3.2.5a. The proportion of herds with and without a history of TB in the previous three years, that went on to experience a TB incident in 2019, by risk area and herd type

- The proportion of beef and dairy herds with a TB incident in 2019 was higher among herds with a TB history in the previous three years than those without, for all risk areas.
- In all risk areas, dairy herds with a history of TB had the highest proportion of TB recurring TB incidents, compared to beef and 'other' herds.

Figure 3.2.5b shows the annual trend in the proportion of TB incidents in 2019 that had a history of TB. Recurrence was consistently highest in the HRA, and lowest in the LRA. Within the HRA, 57.7% of herds that had a TB incident in 2019 also had at least one other TB incident in the past three years. In the Edge Area, the proportion of recurrent incidents was lower (46.5%), however this level has been increasing in recent years. In the LRA, the proportion of herds with a TB incident that had a history of TB was much lower, at 10.8% (Figure 3.2.5b).

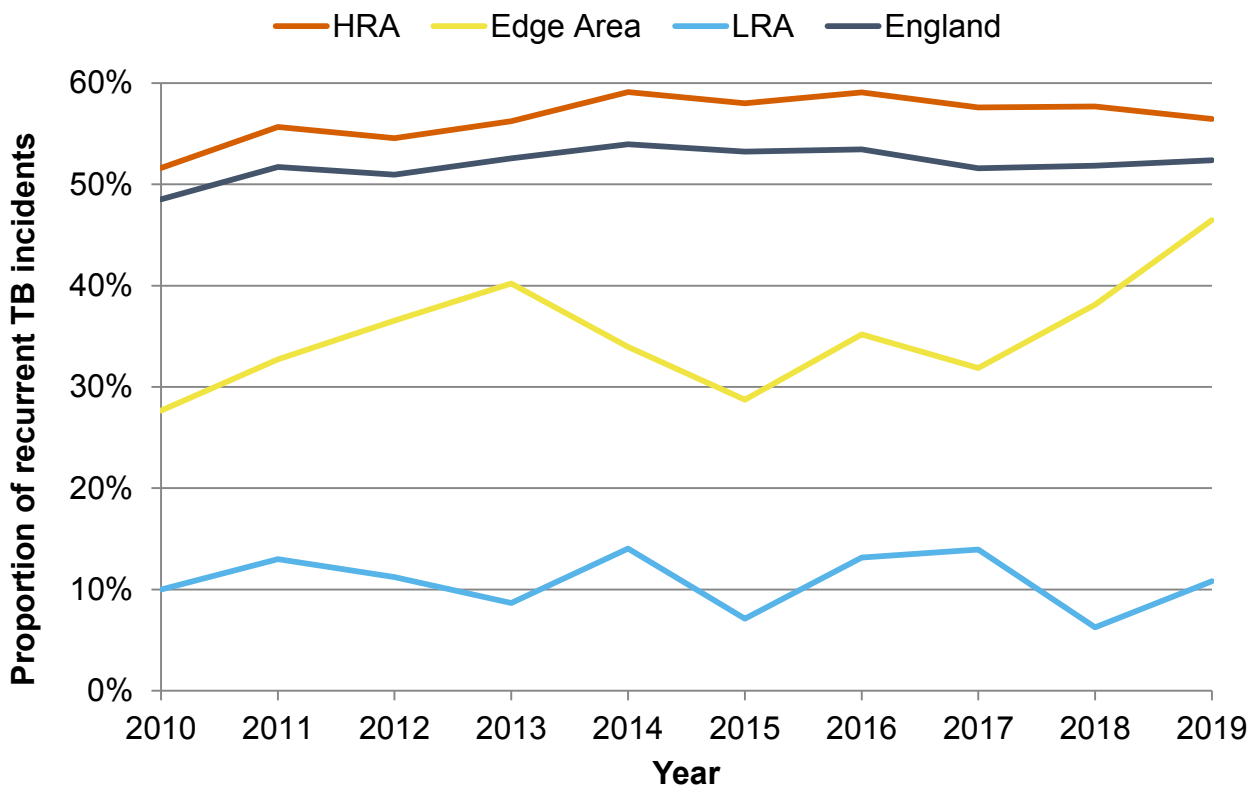


Figure 3.2.5b Annual proportion of TB incidents with a history of TB in the past three years, by risk area, from 2010 to 2019

- The proportion of recurrent TB incidents has remained relatively stable in the HRA and LRA over the past ten years.
- The proportion of recurrent TB incidents increased in the Edge Area in 2019, from 38% to 46%. This may reflect increasing endemicity within a portion of the Edge Area.

Molecular typing

Attempts are made to recover *M. bovis* from all TB incidents and to subject at least one isolate per TB incident to a combination of spoligotyping and Variable Number Tandem Repeat (VNTR) typing in order to identify its molecular type (genotype). 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.

Of the 2,221 isolates with location and a full genotype that had a calculated home range identified in 2019, 1,846 (83%) were in their home range (375 out-of-home range isolates). The most frequent genotype found in England in 2019 was 17:a, in which accounted for 22% of the *M. bovis* isolates subjected to genotyping. This was followed by 25:a (15%) and 11:a (13%), based on 2,365 incidents starting in 2019 with a genotype identified. These three genotypes accounted for 49% of all genotypes disclosed and cover extensive areas in the South West and West of England and Wales (Figure 3.2.6). Further information about genotyping is given in the Explanatory Supplement. The assessments described in the next section on source of infection have been informed by knowledge of the genotype where available. Further statistics on the outcomes of *M. bovis* genotyping carried out in 2019 is included in the GB Data Report.

Molecular typing through analysis of the entire sequence of the bacterium's DNA, known as Whole Genome Sequencing (WGS), can provide greater discrimination between strains of *M. bovis* than genotyping, which analyses only specific regions of the bacterial genome. This will be particularly important in the HRA where it is generally not possible to distinguish local sources of infection because they are defined by the same genotype using the current methodology. This could potentially allow explicit identification of transmission pathways between some farms, or confirm whether recurrent incidents have been caused by residual infection in the herd from a previous incident, or from a new introduction. Isolates sent for genotyping at APHA have also been sequenced since mid-2017 and the APHA now has ISO accreditation for high-throughput sequencing, although WGS from non-bovine species is very limited due to the availability of submissions. Work is currently ongoing to facilitate replacement of genotyping with WGS in routine TB control and surveillance operations.

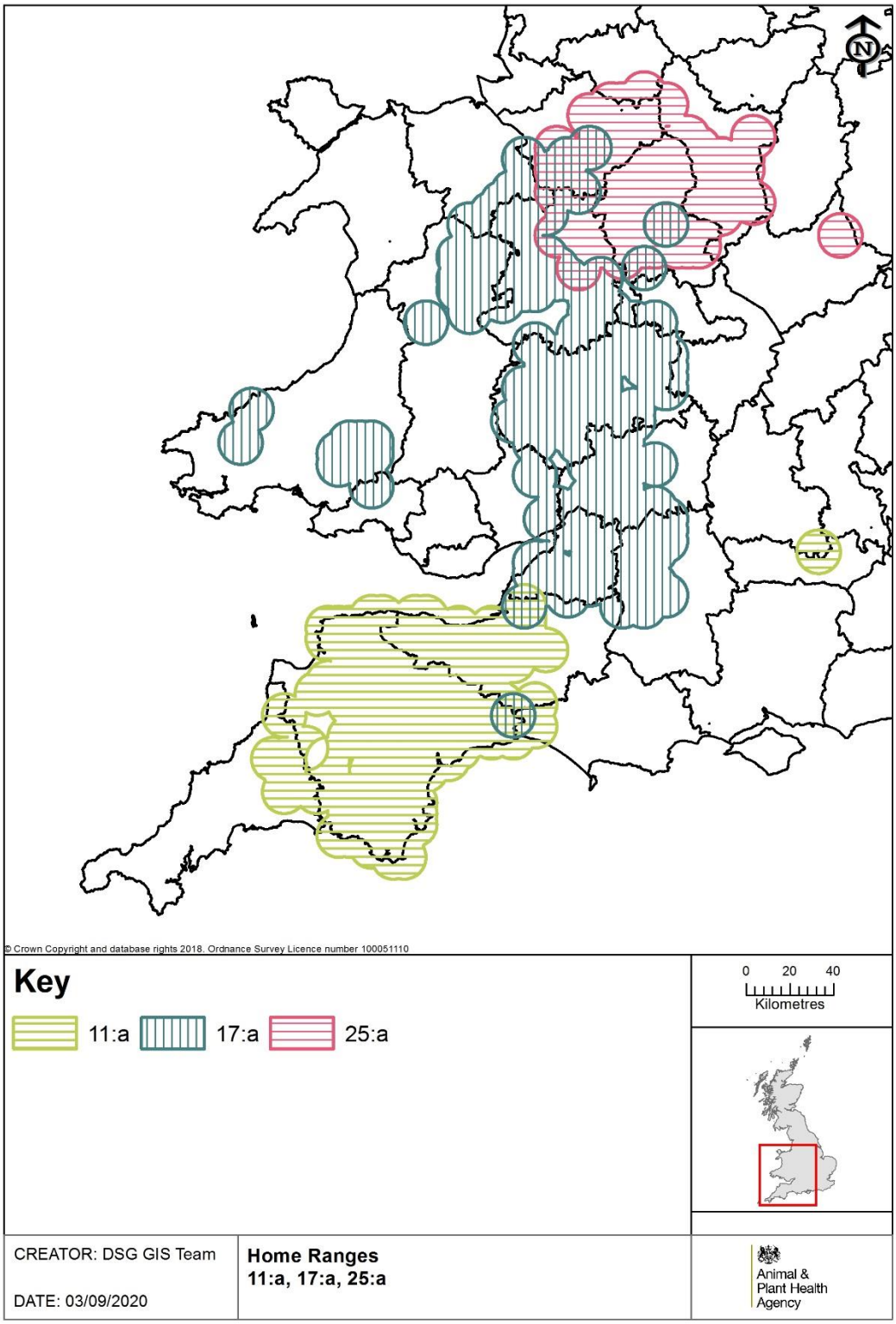


Figure 3.2.6. Home ranges of genotypes 11:a, 17:a and 25:a

Source of infection by veterinary assessment

Assessing how a herd became infected with TB can be challenging. TB is a chronic insidious infection, usually with a long incubation period. This means that in most animals

clinical signs are only apparent when the disease is fairly advanced. TB is generally disclosed through skin testing (proactive surveillance), on farm or *post mortem* surveillance at the slaughterhouse. The detection of TB may occur sometime after it arrives in a herd. As such, the evidence to retrospectively establish the source and route(s) of infection for an affected herd (the 'risk pathway') can be difficult to reconstruct. However, clarifying the risk pathway facilitates the use of targeted on-farm biosecurity measures to reduce the risk of reinfection for that herd.

Selecting and conducting investigations

Currently, a proportion of new TB incidents are fully investigated by the APHA. The aim is to complete an epidemiological assessment for all TB incidents in the Edge Area and LRA (both OTF-W and OTF-S). However, where resource constraints exist, it may not be possible to investigate all incidents and as many as possible are randomly selected or 'triaged' for a visit. Additionally, one third of new incidents in the HRA are randomly selected, as well as those that meet specified criteria (e.g. those with more than 15% of the herd or 20 cattle removed as test reactors in a single round of testing). For incidents selected for assessment, an APHA case veterinarian conducts a thorough on-farm investigation. This includes scrutiny of routinely collected data, such as cattle movement records, and the results of molecular analyses of the causative bacterium (where available). Intelligence gathered from genotyping *M. bovis* isolates can be a powerful tool in identifying a likely source of infection. This is limited, however, to OTF-W incidents where *M. bovis* has been cultured in the laboratory from TB lesions or other tissue samples. Due to the importance of controlling the spread of TB within the Edge Area, more time was spent validating the risk pathways for incidents in that area.

Combining risk pathways and certainty

During the assessment, the APHA case veterinarian selects up to three possible risk pathways of infection for each TB incident herd. Each risk pathway is given a score that reflects the likelihood of that pathway being the true one. The scores assigned have been updated this year to best characterise the uncertainty that exists around the identified pathways. They reflect the developing understanding of how likelihood is being assessed in practice. The selected risk pathways are recorded as either definite (score 8), most likely (score 6), likely (score 4) or possible (score 1). The source(s) for each incident are weighted by the certainty ascribed. Any combination of definite, most likely, likely or possible can contribute towards the overall picture for possible routes of introduction into a herd (Example A).

If the overall score for a herd is less than six, then the score is made up to six using the 'Other or Unknown Source' option (Example B). Buffering up to six in this way helps to reflect the uncertainty in assessments where only 'likely' or 'possible' sources are identified.

Example A: A single TB incident may have the following source and risk pathway profile, the total weighting is eight and so no buffering is required:

Source	Likelihood	Weighting	Proportion
Badgers	Most Likely	6	0.75
Cattle Movement (HRA)	Possible	1	0.125
Cattle Movement (Edge)	Possible	1	0.125
Total for incident A	-	**8**	**1**

Example B: A single TB incident may have the following source and risk pathway profile, the total weighting is below six and so an additional uncertainty buffer is applied:

Source	Likelihood	Weighting	Proportion
Badgers	Possible	1	0.167
Cattle Movement (HRA)	Possible	1	0.167
Cattle Movement (Edge)	Possible	1	0.167
Other or Unknown	Additional buffer	3	0.5
Total for incident B	-	**6**	**1**

Interpreting the source of infection

Source of infection outputs presented in this report combine the data from multiple herds. They provide the proportion of pathways in which each source was identified, weighted by certainty that each source caused the introduction of TB. The outputs do not show the proportion of herds where each pathway was identified (this is skewed by the certainty calculation). The inclusion of OTF-S herds in these calculations increase the uncertainty in the outputs. As a result, the relative proportions of each risk pathway are approximate and only broad generalisations should be made from these results. A more detailed description of this methodology is provided in the Explanatory Supplement.

All TB incidents that underwent a risk pathway investigation in England were identified for analysis, amounting to 1,844 of 3,289 new TB incidents in 2019. For the purposes of this analysis, the 38 possible risk pathways have been aggregated into nine hazards. Where aggregated, no data has been removed i.e. if an investigation identifies multiple risk pathways relating to infected cattle movement, they are all included in the analysis.

Figure 3.2.7 shows the proportion of risk pathway investigations that had a high degree of uncertainty in the selected risk pathway(s). Both the proportion of investigations with sufficient evidence, and those where additional 'other or unknown' source was applied are shown. For OTF-W incidents in the HRA that were selected for an investigation, 85% had sufficient evidence, and only 15% required some additional uncertainty buffering. In the LRA, there was less certainty around the OTF-W risk pathways; 31% did not have sufficient evidence and additional uncertainty was applied. For OTF-S investigations, where genotyping or WGS evidence is not available, the proportion of investigations that had insufficient evidence was higher. Thirty one percent of OTF-S investigations carried out in the HRA had uncertainty applied, compared to 39% in the Edge Area and 66% in the LRA. Overall, this demonstrates that the confidence in the veterinary assessments is

highest in the HRA, followed by the Edge Area and lowest in the LRA. It is important to keep this in mind when interpreting the aggregated outputs in this section.

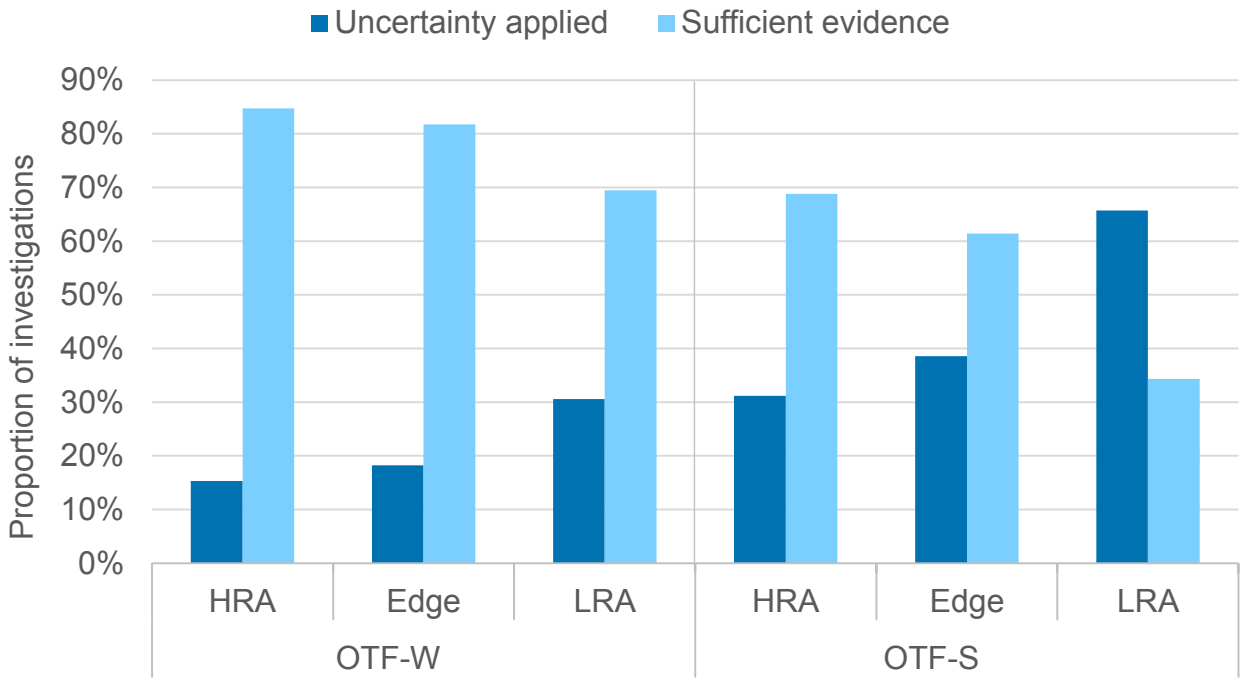


Figure 3.2.7. Proportion of risk pathway investigations (OTF-W and OTF-S incidents) that had sufficient evidence or required additional uncertainty to be applied in the LRA, Edge Area and HRA

At county level, the most common source of infection attributed within the HRA was badgers, with over 70% in Cornwall (78.0%), Staffordshire (71.5%) and Shropshire (70.1%) (Table 3.2.1).

Within the Edge Area, the source of infection with the highest contribution varied between counties. Derbyshire (61.4%), Cheshire (60.7%), Oxfordshire (55.2%), Northamptonshire (51.9%) and Warwickshire (50.3%) all had more than half of the weighted source attributed to badgers. While in some other counties, most notably Buckinghamshire (47.9%), the largest proportion of the weighted source was attributed to cattle movements (Table 3.2.1).

Investigations for the LRA are not aggregated to county level because of the low number of incidents and the high degree of uncertainty in each county.

Table 3.2.1 Number of incidents that started in 2019, and the weighted contribution each source of infection made to those incidents, by Risk Area and HRA and Edge Area county

County	Badgers	Cattle movement	Contiguous infection	Residual infection	Domestic animals	Non-specific reactor	Fomite source	Other wildlife	Other or unknown	Number of investigations
Cornwall	78.0%	5.3%	0.4%	4.5%	0.4%	0.0%	0.0%	5.3%	6.0%	163
Devon	54.0%	12.0%	1.3%	9.5%	0.0%	0.2%	0.5%	12.8%	9.7%	290
Dorset	46.3%	7.6%	2.0%	5.4%	0.0%	0.0%	0.7%	7.5%	30.4%	68
Gloucestershire	56.3%	13.1%	3.7%	6.3%	0.3%	0.9%	0.2%	5.7%	13.3%	50
Hereford & Worcester	45.5%	18.4%	2.5%	8.9%	0.0%	0.4%	0.6%	10.1%	13.7%	103
Avon	59.0%	8.4%	3.3%	6.0%	0.8%	0.6%	0.7%	5.5%	15.7%	56
Shropshire	70.1%	11.6%	0.9%	7.0%	0.3%	0.3%	0.0%	2.2%	7.6%	94
Somerset	44.5%	14.8%	1.8%	12.2%	0.0%	0.0%	0.1%	8.9%	17.7%	113
Staffordshire	71.5%	10.2%	4.5%	5.0%	0.0%	2.3%	0.1%	5.9%	0.5%	127
Wiltshire	50.2%	7.0%	2.1%	11.2%	0.0%	2.8%	0.3%	7.5%	18.9%	82
West Midlands	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1
HRA Overall	**58.6%**	**10.9%**	**2.0%**	**7.8%**	**0.1%**	**0.6%**	**0.3%**	**8.1%**	**11.5%**	**1,147**
Berkshire	23.0%	19.7%	0.7%	9.4%	0.0%	0.0%	0.0%	11.7%	35.4%	25
Buckinghamshire	6.3%	47.9%	3.5%	9.0%	0.0%	0.0%	0.7%	1.4%	31.3%	24
Cheshire	60.7%	14.7%	2.4%	9.0%	0.0%	0.0%	1.4%	0.5%	11.2%	110
Derbyshire	61.4%	16.7%	3.3%	10.3%	0.0%	0.0%	0.5%	2.4%	5.5%	106
Hampshire	16.8%	25.9%	0.9%	9.0%	0.0%	0.0%	0.0%	4.3%	43.1%	37
Leicestershire	45.4%	27.3%	2.8%	4.8%	0.0%	0.7%	1.2%	1.5%	16.4%	49
Northamptonshire	51.9%	23.4%	0.5%	4.4%	0.0%	0.0%	0.9%	4.3%	14.7%	34
Nottinghamshire	8.3%	27.4%	0.0%	0.0%	0.0%	6.0%	0.0%	1.2%	57.1%	14
Oxfordshire	55.2%	21.9%	0.5%	17.7%	0.0%	0.2%	0.4%	0.6%	3.7%	73
East Sussex	45.6%	14.0%	4.2%	4.7%	0.0%	10.1%	3.2%	0.0%	18.1%	23
Warwickshire	50.3%	17.6%	0.7%	3.8%	0.0%	0.0%	0.5%	11.1%	16.1%	64
Edge Area Overall	**48.2%**	**20.6%**	**1.9%**	**8.7%**	**0.0%**	**0.7%**	**0.8%**	**3.2%**	**15.9%**	**559**
LRA Overall	**10.2%**	**37.6%**	**3.6%**	**2.3%**	**0.0%**	**6.8%**	**2.0%**	**1.9%**	**35.5%**	**138**
England Overall	**51.8%**	**15.9%**	**2.1%**	**7.7%**	**0.1%**	**1.1%**	**0.6%**	**6.2%**	**14.6%**	**1,844**

The calculated contributions of each source of infection for the HRA, Edge Area and LRA TB incidents are depicted in Figures 3.2.8 to 3.2.10 respectively. Within the HRA, badgers constituted 59% of the weighted opinion, while cattle movements accounted for 11% of the weighted opinion (Figure 3.2.8). In the Edge Area, the source was still most strongly ascribed to badgers (48%), but cattle movements (21%) were also identified as posing a high risk of introduction (Figure 3.2.9). Conversely, in the LRA the contribution of badgers was much lower at only 10% (and incidents with more than 50% certainty for the badger source were limited to Cumbria, where infection in badgers has been confirmed). Overall, TB incidents in the LRA were most strongly attributed to cattle movements (38%). However, in the LRA 'Other or Unknown' sources were highest, at 36% compared to 12% in the HRA and 16% the Edge Area (Figures 3.2.8 to 3.2.10).

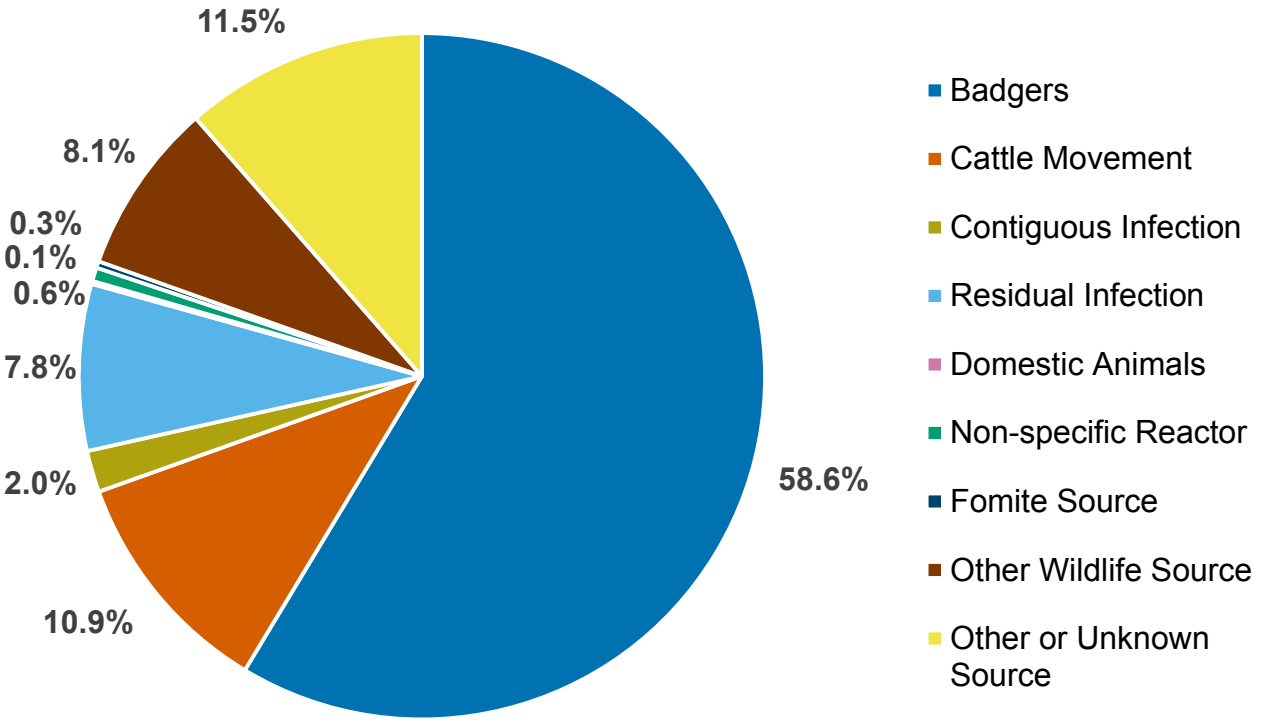


Figure 3.2.8 Summary of the weighted source of infection attributed for all TB incidents (both OTF-W and OTF-S with a provisional or final pathway) that started in 2019, in the HRA (n=1,147)

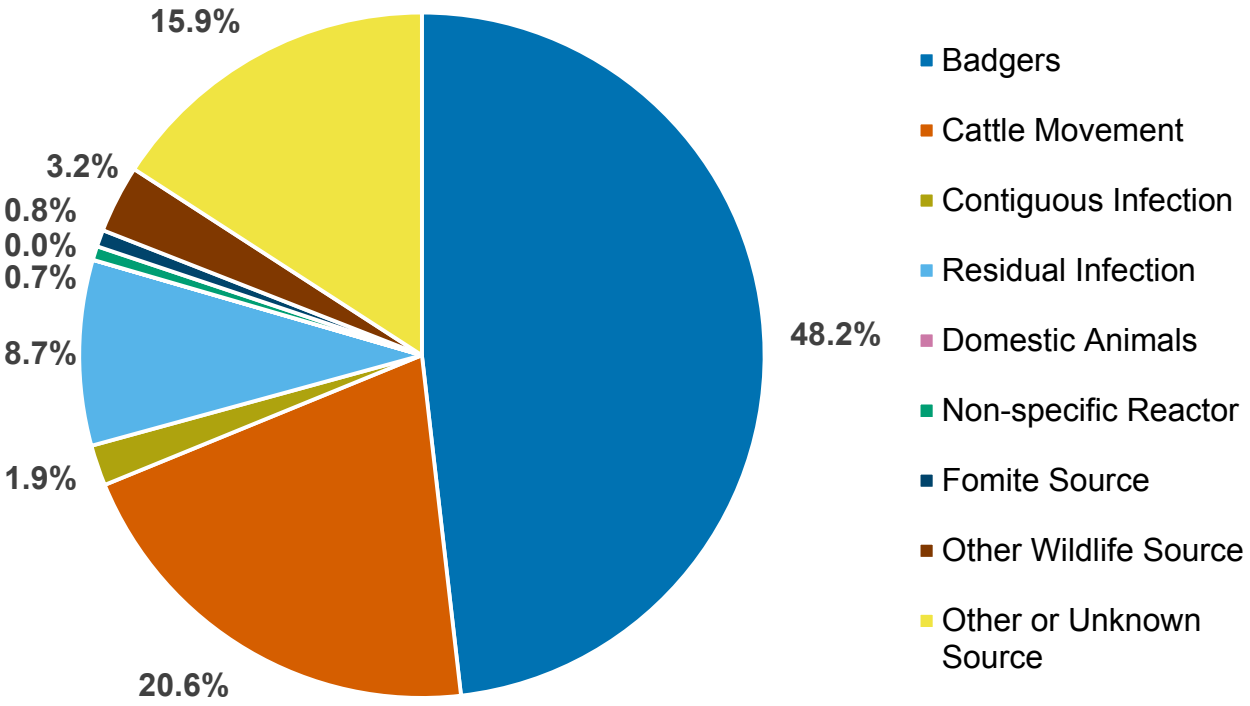


Figure 3.2.9 Summary of the weighted source of infection attributed for all TB incidents (both OTF-W and OTF-S with a provisional or final pathway) that started in 2019, in the Edge Area (n=559)

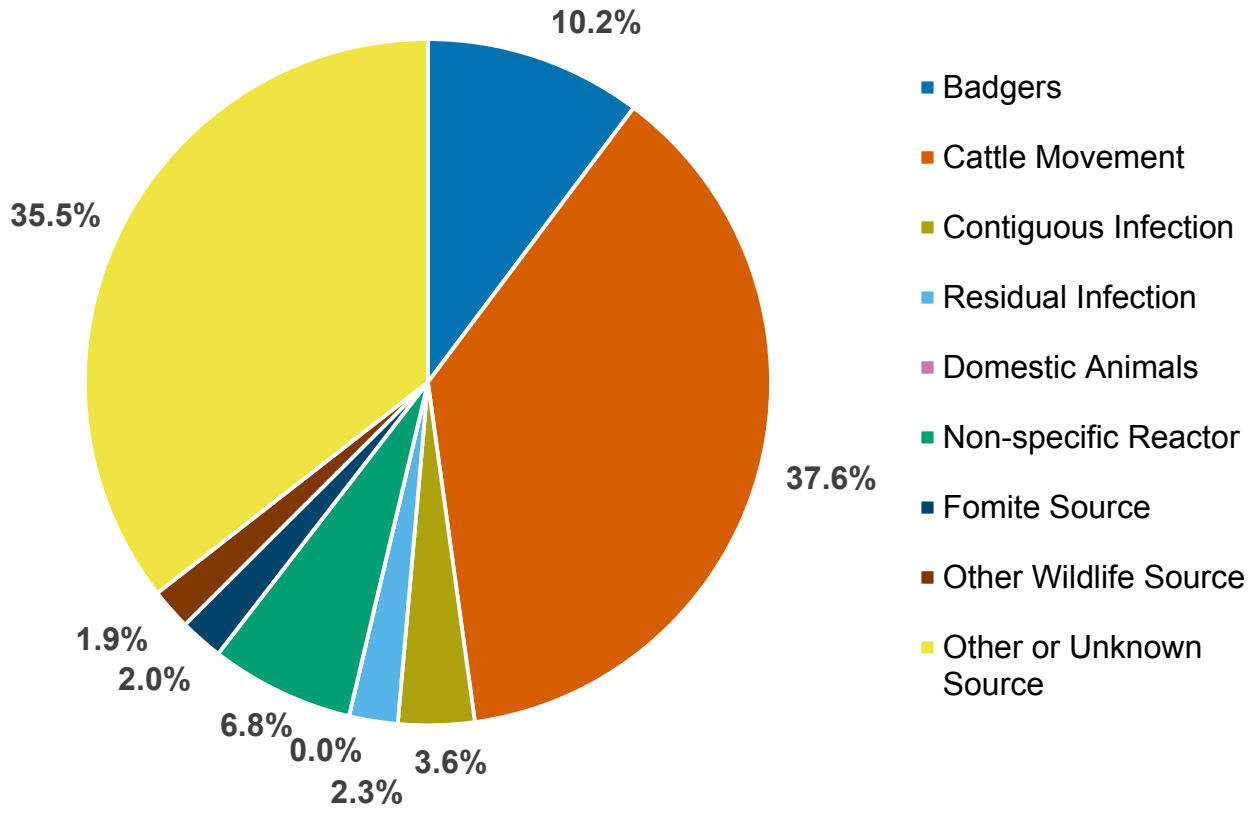


Figure 3.2.10 Summary of the weighted source of infection attributed for all TB incidents (both OTF-W and OTF-S with a provisional or final pathway) that started in 2019, in the LRA (n=138)

Spatial differences in the most likely source of infection for new TB herd incidents in 2019 are examined in Figure 3.2.11. Only TB incidents where a source was identified with more than 50% of the weighted certainty are shown on the map. TB incidents within the HRA were most often attributed to badgers. In the LRA, cattle movements were the most significant source of infection. Although in the LRA the proportion of incidents with an unclear source is high. This is not surprising as the majority of TB incidents in the LRA are OTF-S where no *M. bovis* isolates are available for genetic analysis. The only clusters of incidents with a likely wildlife source in the LRA are found in Cumbria. These are in the badger control area of East Cumbria (TB hotspot area HS21) and a new potential hotspot area initiated in South Cumbria in 2019 (potential HS26).

Within the Edge Area, TB incidents bordering the HRA, and in the north of the area were more often ascribed to badgers, while those towards the LRA, and in the south and east were more commonly linked to the movement of cattle. In contrast to this trend, notable clusters of badger attributed infection persist close to the LRA border in Leicestershire and Northamptonshire. Further details on the relevant risk pathways for each county within the Edge Area and LRA can be found in the 2019 Edge Area and LRA year-end reports.

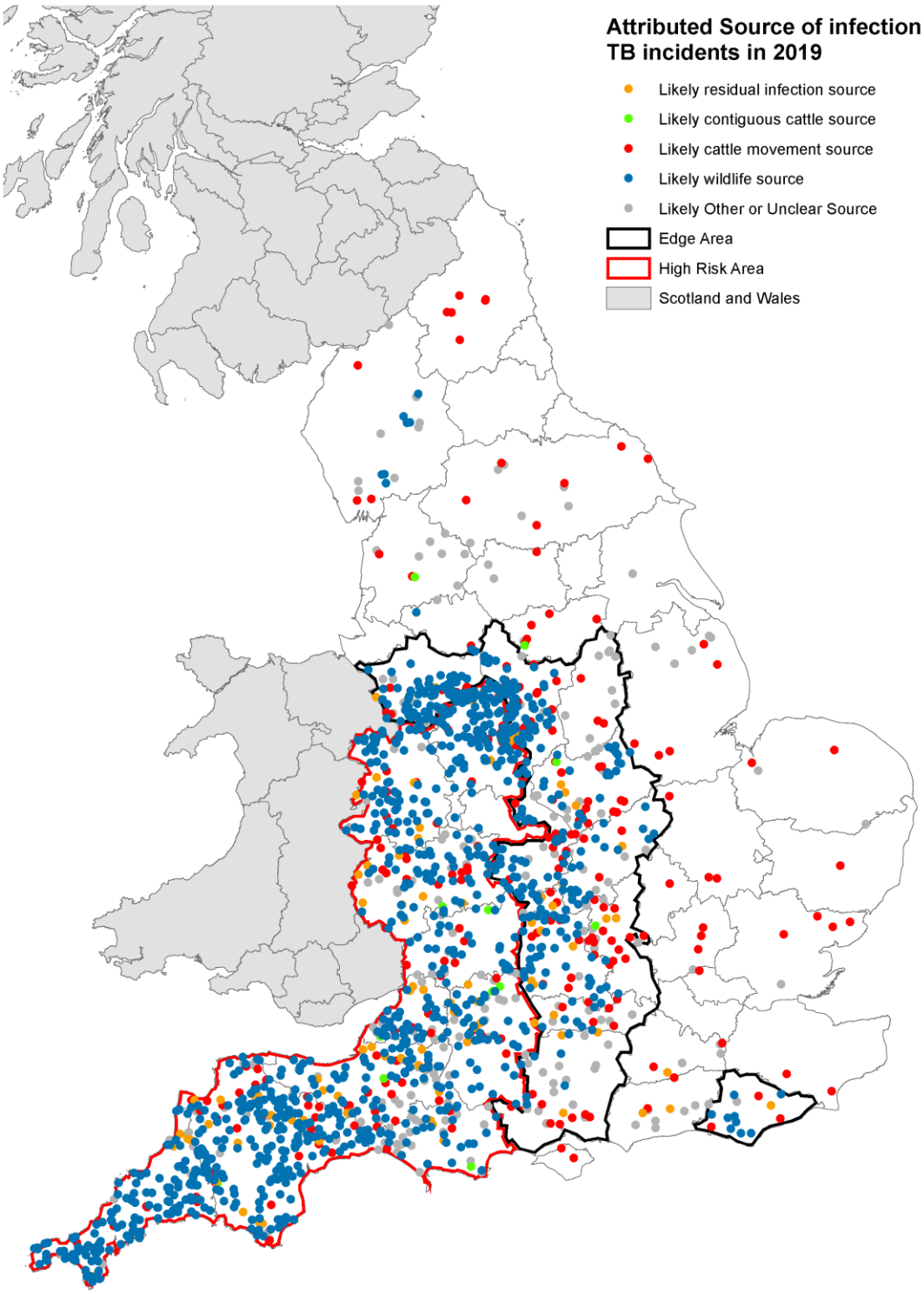


Figure 3.2.11. The source of infection recorded with the highest level of certainty, selected by informed veterinary opinion, for all TB incidents (both OTF-W and OTF-S) that started in 2019

- Within the Edge Area, TB incidents close to the HRA were more commonly attributed to badgers. Those in the Edge Area that border the LRA, in the east and further south, were more commonly ascribed to the movement of cattle or residual infection.

3.3 Finding infected herds: Effectiveness of different TB surveillance streams

- In 2019, a total of 5.5 million TB tests (live animal or *post mortem* examination) were carried out in bovine animals in England; half of which were in the HRA.
- In the HRA, TB incidents were most commonly detected through Area and Herd Risk surveillance tests (44%), while in the Edge Area, Routine surveillance detected most new TB incidents (56%). In the LRA, almost half of TB incidents were detected through Area and Herd Risk surveillance (45%) and over a third by Routine surveillance (36%).
- In England overall, the total number of incidents disclosed by Slaughterhouse (SLH) surveillance decreased in 2019 compared to 2018. The proportion of TB incidents disclosed through SLH surveillance was lower in the LRA in 2019 compared to 2018. In the HRA and Edge Area, the proportion of all TB incidents that were disclosed through SLH surveillance increased in 2019 compared to 2018.
- Higher proportions of TB incidents disclosed by SLH surveillance compared to other surveillance types in the HRA probably reflects the higher force of infection in this area compared to other risk areas.
- Within the Area and Herd Risk surveillance stream, 75% and 66% of TB incidents in the HRA and Edge Area, respectively, were detected by post-incident tests compared to 12% in the LRA. This reflects the difficulty of clearing infection from incident herds (and avoiding re-infection from environmental sources) in the HRA and Edge Area. It also highlights the need for better understanding of the factors that lead to recrudescence on farms.
- Radial tests detected the majority (71%) of TB incidents from Area and Herd risk tests in the LRA. Some of the incidents detected this way are likely to be the result of lateral spread. As such, reducing transmission from local cattle movements and contact with contiguous cattle could reduce TB incidence in the LRA.
- In the HRA, over 40% of herds with only Inconclusive Reactor (IR) test results went on to have an incident within the following 15 months. A substantial proportion was similarly affected in the Edge Area (33%). This indicates that IRs are an important predictor of the presence of infection and supports the policy to restrict IRs to the herd in which they are disclosed for life.
- Trade & other surveillance tests disclosed less than 10% of the TB incidents in the HRA and Edge Area (mainly pre-movement tests), but a higher proportion of incidents in the LRA (12%, although representing only 18 TB incidents).
- Cattle in all risk areas are predominantly moved within, rather than between, risk areas. A total of 240 new TB incidents were detected in 2019 by pre-movement tests (83% occurred in the HRA; 13% in the Edge Area and 4% in the LRA).

Surveillance overview

Bovine tuberculosis (TB) is usually a slowly progressing disease in which infected individuals rarely display clinical signs, although they can spread infection during that time. Surveillance for TB is based on detecting changes that occur before clinical signs become evident. This includes immunological markers of infection in live cattle and pathology (lesions) characteristic of *M. bovis* infection. The TB surveillance programme involves both active and passive surveillance. Active surveillance is comprised of live animal tests carried out on the farm. Passive surveillance occurs in the slaughterhouse, where commercially slaughtered non-reactor animals undergo routine *post mortem* meat inspection for TB and other notifiable diseases. Slaughterhouse inspection is carried out by the Food Standards Agency (FSA) meat inspectors and veterinarians. On-farm testing is generally carried out by an Official Veterinarian appointed by the APHA or, more rarely, by an APHA vet or Animal Health Officer. The main screening test for TB is the Single Intradermal Comparative Cervical Tuberculin test (SICCT). This test measures the animals' immune response to an injection of bovine tuberculin into the skin compared to another injection of avian tuberculin.

TB surveillance activities in England have been categorised into four different surveillance streams for the purposes of this report, since 2015 (see detailed description of the surveillance streams and associated tests in the TB Explanatory Supplement). In brief, the four surveillance streams are:

- **Routine:** active surveillance through systematic field (skin) testing of OTF herds at a pre-defined interval of six, 12 or 48 months.
- **Area and Herd Risk:** active surveillance with additional field (skin) testing of OTF herds or individual cattle because of evidence that they are at greater risk of being infected; including contiguous herd tests, radial tests, hotspot tests, tracing tests and check tests after a TB incident.
- **Slaughterhouse:** *post mortem* inspection of all cattle slaughtered for human consumption.
- **Trade and Other:** active surveillance through skin tests of individual animals moved between OTF herds. Generally conducted for the purposes of trade such as: private tests requested by farmers, compulsory pre- and post-movement testing of individual cattle and tests at artificial insemination centres. This surveillance stream was referred to as proactive surveillance in earlier reports.

Over 5 million cattle were kept in nearly 47,000 active cattle holdings in England in 2019. A total of 4.2 million individual TB skin tests were carried out on live animals in OTF herds. Furthermore, 1.3 million cattle were inspected at *post mortem*. Overall, this equated to over 75,000 OTF herds tested in 2019, which resulted in the detection of 3,264 TB incidents. Table 3.3.1 displays the number of tests performed and TB incidents disclosed through surveillance of OTF herds.

Figure 3.3.1 and Table 3.3.1 show the relative proportions of individual cattle tests, herd tests, reactors and incidents for the four surveillance streams. For the purposes of this

analysis, each test has been recorded as a test in the herd, even if it was an animal-level test, e.g. tracing tests (Area and Herd Risk surveillance stream) or pre-movement tests (Trade & other surveillance stream).

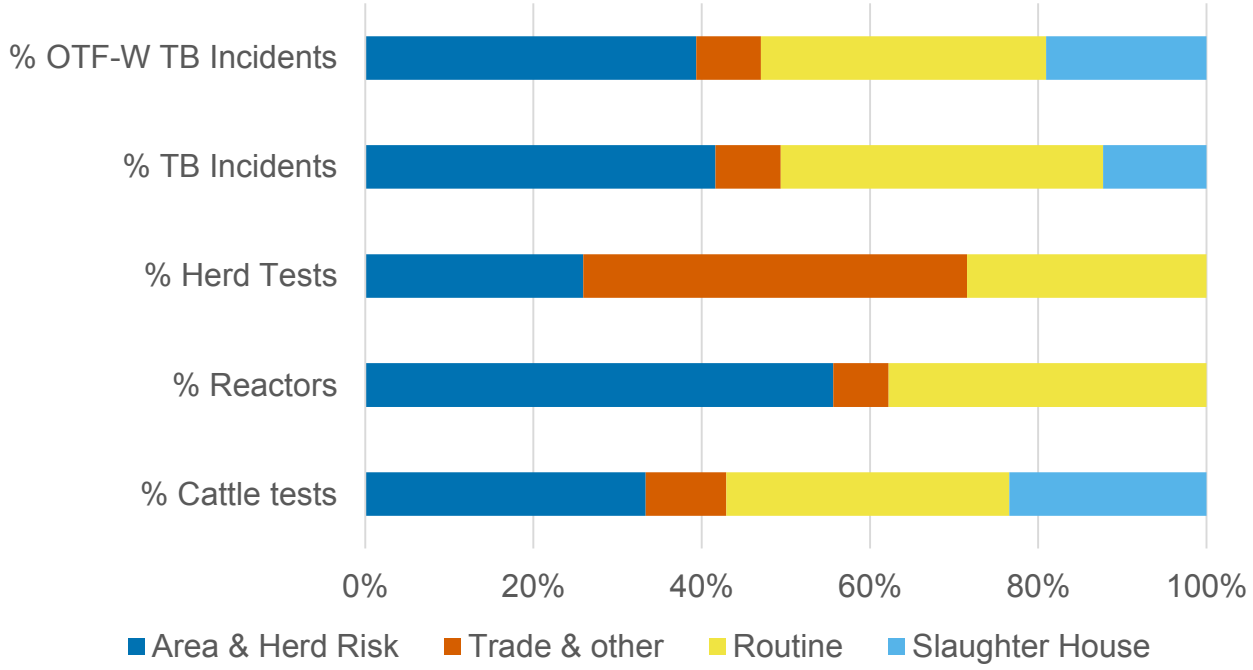


Figure 3.3.1. Proportion of herd and cattle tests, TB incidents in herds and individual reactors detected through each surveillance stream

In addition to the tests reported in Table 3.3.1, a further 2,539 herds received tests while under movement restrictions due to a TB incident, or in parallel to routine surveillance and control tests (for example interferon gamma (IFN-γ) testing). These have been excluded from Tables 3.3.1-3.3.4 as they are not generally used to detect new infection in OTF herds. Excluded test types include: short interval (SI) tests used to eradicate infection from a TB incident herd, inconclusive reactor (IR) tests, IFN-γ tests, and tests occasionally used on an approved segregated group (ASG) of a herd, often during a TB incident. Twenty five new TB incidents were disclosed by these test types, mostly through the testing of cattle at epidemiologically-linked premises during SI testing (n=11).

Table 3.3.1 shows all tests and herd tests, whether they are:

- herd-level and conducted on all or the majority of animals in a herd e.g. whole herd test (WHT) or routine herd tests (RHT) conducted as part of Routine Surveillance
- animal-level, e.g. tracing tests conducted as part of Area and Herd Risk Surveillance
- pre-movement tests conducted as part of Trade & Other Surveillance
- slaughterhouse *post mortem* inspection of all cattle slaughtered for human consumption.

In England overall, Area and Herd Risk surveillance tests detected more reactors, TB incidents and OTF-W incidents than Routine surveillance, in 2019 (Figure 3.3.1). This highlights the value of targeting higher risk herds through specific tests e.g. tracing tests

(Table 3.3.1). In the HRA, almost half (44%) of all incidents were detected by Area and Herd Risk surveillance and just over one third of incidents by Routine surveillance, in contrast to the Edge Area, where most (56%) TB incidents were detected by Routine surveillance. In the LRA, almost half of all incidents were detected by Area and Herd Risk surveillance. Over a third of incidents were detected by Routine surveillance. This is only conducted every four years in the majority of LRA herds because of the lower force of infection compared to elsewhere. The proportion of incidents detected through Trade & other surveillance was higher in the LRA than in the other TB risk areas. This highlights the importance of pre and post-movement testing of cattle moving into the LRA from areas with a higher TB risk. The proportion of TB incidents disclosed by Slaughterhouse surveillance was just under 7%, however this type of surveillance is more important in the LRA than in the other risk areas, because of the lower frequency of Routine surveillance (Table 3.3.1).

Table 3.3.1.Total number of tests, reactors, and TB incidents by risk area and surveillance stream in 2019.

Area	Surveillance Stream	Herd Tests N (%)	TB Incidents N (%)	OTF-W TB Incidents N (%)	TB Incidents per 100 herd tests	Reactors per 1,000 cattle tested
HRA	Routine	10,628 (24.9)	846 (34.1)	486 (30.3)	8.0	2.4
HRA	Area & Herd Risk	12,015 (28.1)	1,100 (44.3)	668 (41.6)	9.2	3.3
HRA	Slaughterhouse	N.A.	335 (13.5)	324 (20.2)	N.A.	N.A.
HRA	Trade & other	20,069 (47.0)	203 (8.2)	127 (7.9)	1.0	1.3
HRA	**Total**	**42,712 (56.6)**	**2,484 (76.1)**	**1,605 (79.8)**	**6 (Average)**	**1.8**
Edge	Routine	7,162 (38.4)	351 (55.4)	185 (49.9)	4.9	1.1
Edge	Area & Herd Risk	3,977 (21.3)	194 (30.6)	112 (30.2)	4.9	1.7
Edge	Slaughterhouse	N.A.	56 (8.8)	52 (14)	N.A.	N.A.
Edge	Trade & other	7,500 (40.2)	33 (5.2)	22 (5.9)	0.4	0.4
Edge	**Total**	**18,639 (24.7)**	**634 (19.4)**	**371 (18.4)**	**3.4 (Average)**	**0.8**
LRA	Routine	3,702 (26.2)	53 (36.3)	11 (30.6)	0.4	0.2
LRA	Area & Herd Risk	3,576 (25.3)	65 (44.5)	12 (33.3)	1.8	0.2
LRA	Slaughterhouse	N.A.	10 (6.8)	8 (22.2)	N.A.	N.A.
LRA	Trade & other	6,829 (48.4)	18 (12.3)	5 (13.9)	0.2	0.6

Area	Surveillance Stream	Herd Tests N (%)	TB Incidents N (%)	OTF-W TB Incidents N (%)	TB Incidents per 100 herd tests	Reactors per 1,000 cattle tested
LRA	**Total**	**14,107 (18.7)**	**146 (4.5)**	**36 (1.8)**	**0.8 (Average)**	**0.2**
England	**Total**	**75,458**	**3,264**	**2,012**	**4.1**	**1.4**

Over the past five years, the relative proportion of new TB incidents detected by different surveillance streams has varied more in the LRA and Edge Area compared to the HRA. This is due in part to statistical instability due the relatively low number of TB incidents, especially in the LRA. In the Edge Area, surveillance policy changes are also likely to be a contributing factor.

The proportion of new incidents detected by Routine surveillance in the Edge Area increased annually between 2015 and 2017. This rise followed the introduction of routine annual surveillance testing in the area in 2013. In 2018 and 2019, following the introduction of six-monthly testing in parts of the Edge Area, the proportion of new incidents detected by Routine surveillance fell slightly. The proportion of incidents detected through Trade & other surveillance in the LRA doubled in 2017 compared to 2016, before decreasing slightly in 2018 and again in 2019. This may be a positive effect of post movement testing cattle from other risk areas, introduced in April 2016.

In the LRA, the proportion of new TB incidents detected through Slaughterhouse surveillance decreased in 2019 compared to 2018, continuing the downward trend since 2015. In England overall, the proportion of TB incidents detected by Slaughterhouse surveillance has dropped by more than a quarter over the past five years (15.7% in 2015 vs 12.2% in 2019). This could be explained by enhanced surveillance and control regimes, adopted in 2013/14, detecting infected cattle on farm at earlier stages of infection on farm.

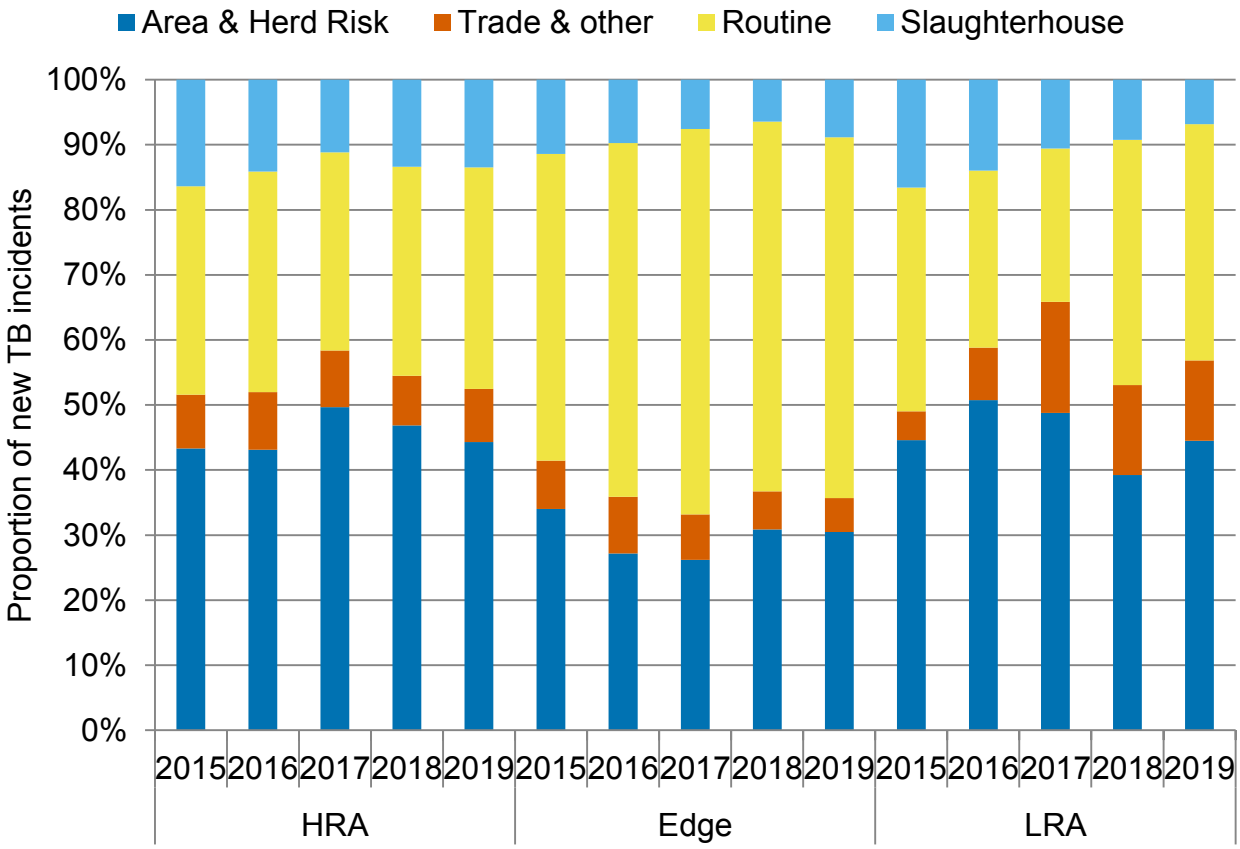


Figure 3.3.2 Annual proportions of new TB incidents detected by different surveillance streams within each risk area from 2015 to 2019

Routine surveillance stream

The Routine surveillance stream includes WHTs and RHTs conducted in OTF herds and tests conducted in new herds (NH). WHTs and RHTs are performed at scheduled intervals of six months or one year (WHTs) and four years (RHTs). WHTs are conducted in all cattle over six weeks old in the HRA and Edge Area; and in high risk herds in the LRA. RHTs in the LRA are conducted mainly in breeding stock.

Proportionally more TB incidents were disclosed per herd test in the HRA than the Edge Area, by both WHT and NH tests. This is likely to be due to a higher background force of infection in the HRA (Tables 3.3.1 and 3.3.2a and b). In the LRA, most herds receive RHTs tests at four-yearly intervals. Only slightly more TB incidents per 100 herd tests were detected by WHTs (1.7) compared to RHTs (1.4), despite herds receiving WHTs in the LRA being higher risk (Table 3.3.2c).

Table 3.3.2.a Performance of main test types within the Routine surveillance stream in the HRA in 2019

Test type	Test events N (%)	TB Incidents N (%)	OTF-W TB Incidents N (%)	Reactors N (%)	TB Incidents per 100 test events	Reactors per 1,000 cattle tested
New Herd Tests	515 (4.8)	21 (2.5)	10 (2.1)	42 (2.0)	4.1	2.4
Whole Herd Tests	10,113 (95.2)	825 (97.5)	476 (97.9)	2,026 (98.0)	8.2	2.4
HRA Routine total	**10,628**	**846**	**486**	**2,068**	**8.0**	**2.4**

Table 3.3.2.b Performance of main test types within the Routine surveillance stream in the Edge Area in 2019

Test type	Test events N (%)	TB Incidents N (%)	OTF-W TB Incidents N (%)	Reactors N (%)	TB Incidents per 100 test events	Reactors per 1,000 cattle tested
New Herd Tests	221 (3.1)	6 (1.7)	4 (2.2)	12 (1.5)	2.7	1.6
Whole Herd Tests	6,941 (96.9)	345 (98.3)	181 (97.8)	811 (98.5)	5.0	1.1
Edge Area Routine total	**7,162**	**351**	**185**	**823**	**4.9**	**1.1**

Table 3.3.2.c Performance of main test types within the Routine surveillance stream in the LRA in 2019

Test type	Test events N (%)	TB Incidents N (%)	OTF-W TB Incidents N (%)	Reactors N (%)	TB Incidents per 100 test events	Reactors per 1,000 cattle tested
New Herd Tests	464 (12.5)	6 (11.3)	1 (9.1)	3 (7.3)	1.3	0.2
Whole Herd Tests	230 (6.2)	4 (7.5)	0 (0)	3 (7.3)	1.7	0.1
Routine Herd Tests	3,008 (81.3)	43 (81.1)	10 (90.9)	35 (85.4)	1.4	0.2
LRA Routine total	**3,702**	**53**	**11**	**41**	**0.4**	**0.2**

Note: Test types in Table 3.3.2 include: New Herd Tests (VE-CT-NH1, VE-CT-NH2), Whole Herd Tests (VE-WHT, VE-WHT2), Routine Herd Tests (VE-RHT24/36, VE-RHT48).

Area and Herd Risk surveillance stream

The Area and Herd Risk surveillance stream comprises tests carried out in higher risk situations. This surveillance stream includes tests in unrestricted herds defined as higher risk such as herds subject to post-incident testing and in permanently restricted herds (Approved Finishing Units - AFUs); as well as tests for assessing potential source and spread following the detection of a TB incident, for example tracing, contiguous herds,

hotspot, and radial tests. Only post-incident tests at six and 12 months are included here, short interval tests are excluded.

In the HRA, most Area and Herd Risk TB incidents were detected by post-incident tests, followed by contiguous herd tests (Table 3.3.3). Relatively few source tracing tests were carried out in the HRA (less than two per cent of the Area and Herd risk surveillance stream). However, these tests detected 30 TB incidents per 100 herd tests, and had the highest detection rate for reactors, with nine positive reactors disclosed for every 1,000 cattle tested (Table 3.3.3).

Similar detection rates are seen in the Edge Area. Post-incident tests detected the highest proportion of TB incidents in this surveillance stream, followed by radial tests (Figure 3.3.3).

In the LRA, more than half of Area and Herd Risk herd tests carried out were radial tests, and they disclosed nearly three quarters of TB incidents. Only 17% of TB incidents disclosed in the LRA by radial testing were OTF-W (although not necessarily confirmed as the same *M. bovis* genotype as the index case). Radial tests enable the early detection of any lateral spread of infection from the index herd. They also provide evidence of the presence or absence of endemic disease around OTF-W incidents in the LRA.

Post-incident tests, radial tests, contiguous herd tests and tracing tests will not be recorded as such if conducted at the same time as another herd test (e.g. a WHT). Potential underreporting of these test types should be borne in mind when interpreting the results.

Potential TB Hotspot tests are used in the LRA, in response to an OTF-W incident (or cluster of incidents) of unclear origin. These tests apply to herds identified in an area delineated by APHA, commonly within 3 km of the index herd. A total of 323 herd hotspot tests were carried out in the LRA in 2019 (totalling 55,921 cattle tests) with four reactors disclosed from four TB incidents, none of which was OTF-W).

Table 3.3.3.a Percentage of main test types within the Area and Herd Risk surveillance stream in the HRA in 2019

Test type	Test events N (%)	TB Incidents N (%)	OTF-W TB Incidents N (%)	Reactors N %	TB Incidents per 100 test events	Reactors per 1,000 cattle tested
Contiguous herd tests	1,643 (13.7)	212 (19.3)	125 (18.7)	658 (18.1)	12.9	3.3
Spread Tracing animal tests	5,778 (48.1)	33 (3.0)	23 (3.4)	49 (1.4)	0.6	1.9
Source Tracing herd tests	57 (0.5)	17 (1.5)	15 (2.2)	105 (2.9)	29.8	9.8
Post-incident tests	4,373 (36.4)	824 (74.9)	497 (74.4)	2,778 (76.6)	18.8	3.4
Check tests	134 (1.1)	10 (0.9)	6 (0.9)	25 (0.7)	7.5	0.8
AFU tests	28 (0.2)	4 (0.4)	2 (0.3)	11 (0.3)	14.3	2.5

Test type	Test events N (%)	TB Incidents N (%)	OTF-W TB Incidents N (%)	Reactors N %	TB Incidents per 100 test events	Reactors per 1,000 cattle tested
HRA Area and Herd Risk total	**12,015**	**1,100**	**668**	**3,625**	**9.2**	**3.3**

Table 3.3.3.b Percentage of main test types within the Area and Herd Risk surveillance stream in the Edge Area in 2019

Test type	Test events N (%)	TB Incidents N (%)	OTF-W TB Incidents N (%)	Reactors N %	TB Incidents per 100 test events	Reactors per 1,000 cattle tested
Contiguous herd tests	41 (1.0)	2 (1.0)	1 (0.9)	2 (0.3)	4.9	0.4
Radial tests	1,557 (38.9)	55 (27.8)	26 (22.8)	97 (16)	3.5	0.6
Spread Tracing animal tests	1,575 (39.3)	4 (2)	3 (2.6)	10 (1.7)	0.3	1.4
Source Tracing herd tests	10 (0.2)	1 (0.5)	1 (0.9)	1 (0.2)	10.0	0.6
Post-incident tests	754 (18.8)	131 (66.2)	80 (70.2)	492 (81.3)	17.4	3.2
Check tests	40 (1.0)	1 (0.5)	1 (0.9)	3 (0.5)	2.5	0.3
Edge Area and Herd Risk total	**3,977**	**194**	**112**	**605**	**4.9**	**1.7**

Table 3.3.3.c Percentage of main test types within the Area and Herd Risk surveillance stream in the LRA in 2019

Test type	Test events N (%)	TB Incidents N (%)	OTF-W TB Incidents N (%)	Reactors N %	TB Incidents per 100 test events	Reactors per 1,000 cattle tested
Radial tests	2,029 (56.7)	46 (70.8)	8 (66.7)	56 (63.6)	2.3	0.2
Hotspot tests	323 (9.0)	4 (6.2)	0 (0)	4 (4.5)	1.2	0.1
Spread Tracing animal tests	1,057 (29.6)	5 (7.7)	3 (25.0)	5 (5.7)	0.5	1.2
Source Tracing herd tests	9 (0.3)	0 (0)	0 (0)	0 (0)	0.0	0.0
Post-incident tests	123 (3.4)	8 (12.3)	0 (0)	22 (25.0)	6.5	0.7
Check tests	35 (1.0)	2 (3.1)	1 (8.3)	1 (1.1)	5.7	0.1
LRA Area and Herd Risk total	**3,576**	**65**	**12**	**88**	**1.8**	**0.2**

Note: Table 3.3.3 test types include: Contiguous tests (VE-CON, VE-CON12), Radial tests (VE-RAD, VE-RAD6, VE-RAD12), Hotspot tests (VE-HS1, VE-HS2), Spread Tracing tests (VE-TR), Source tracing tests (VE-CT(EM)), Post-incident tests (VE-6M, VE-12M), Check tests (VE-CT(I-I)), AFU tests (VE-TBU).

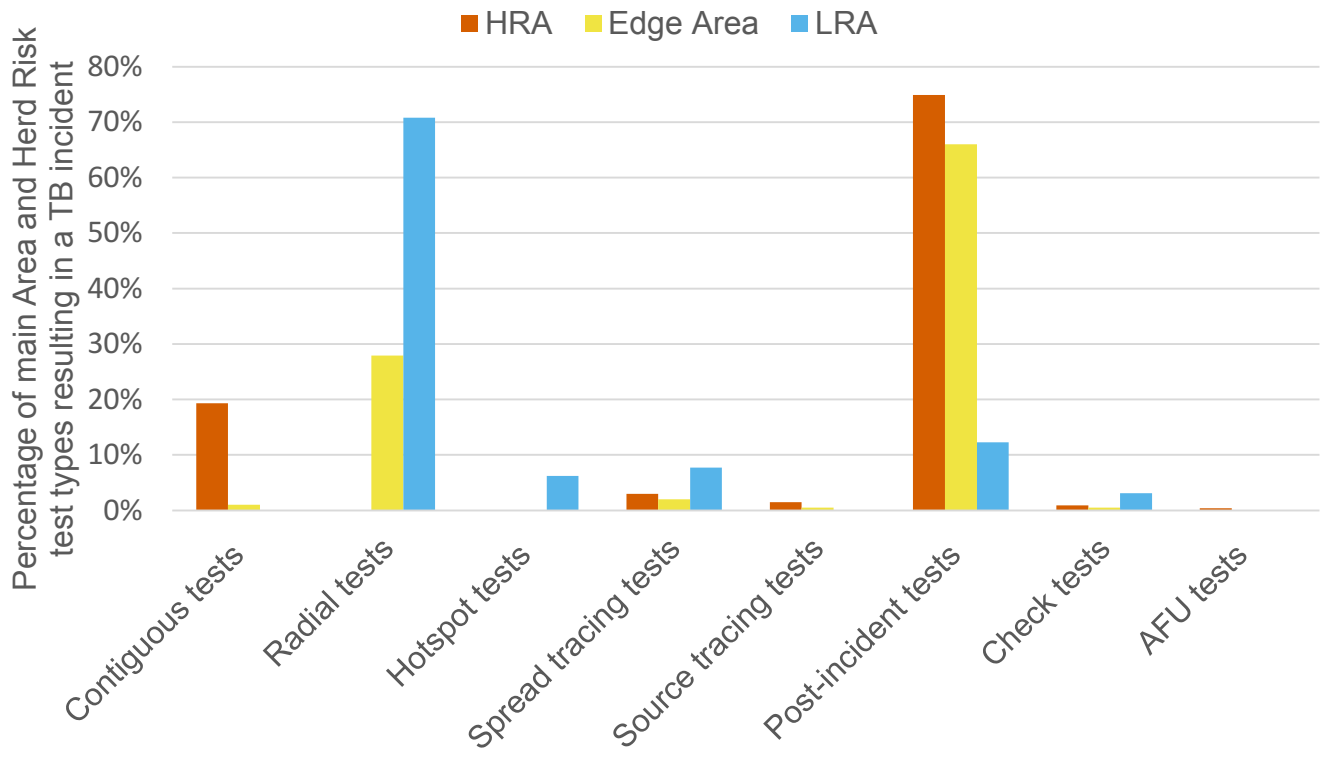


Figure 3.3.3 Percentage of main test types resulting in a TB incident within the Area and Herd Risk surveillance stream by surveillance risk area in 2019

Slaughterhouse surveillance stream

Slaughterhouse (SLH) surveillance utilises compulsory *post mortem* inspection (visual inspection of carcases with palpation and incision of lymph nodes) of all cattle slaughtered for human consumption, followed by isolation of *M. bovis* in bacteriological culture from the suspected tuberculous lesions. It is an ongoing, supplementary surveillance stream that may detect infected cattle missed by active live animal surveillance.

The proportion of new TB incidents disclosed by SLH surveillance depends on the background force of infection and also on the frequency and efficacy of live animal surveillance tests that take place in cattle herds. Further analysis of the efficacy of slaughterhouse surveillance and monitoring performance may be found in the Slaughterhouse report. Herds are tuberculin tested at least four times more frequently in the Edge Area and HRA compared to the LRA. Therefore, a higher proportion (but lower number) of TB incidents might be expected to be detected at slaughter in the LRA due to undisclosed infection in the live animal. However, this was not the case in 2019. The proportion of *all* TB incidents disclosed by SLH surveillance was highest in the HRA (14%), followed by the Edge Area (9%) and LRA (7%); likely reflecting the high background force of infection in the HRA. The proportion of OTF-W incidents detected by SLH surveillance, however, was highest in the LRA (22%) compared to the HRA and Edge Area (20% and 14%, respectively).

SLH surveillance predominantly detects OTF-W cases, due to the nature of the event being disclosed by the identification of visible lesions at slaughter. Every year, a small number of OTF-S incidents are also reported, that were initially triggered in the slaughterhouse. These are cases where visible lesions are subsequently culture negative, but a check test was performed in the herd and identified reactors, which do not themselves have visible lesions.

Since 2010, the proportion of OTF-W TB incidents disclosed through SLH surveillance in the HRA has remained fairly consistent. In the Edge Area and LRA, by contrast, there has been greater fluctuation. The proportion of OTF-W TB incidents disclosed through SLH surveillance in the Edge Area increased from 11% in 2018 to 14% in 2019. The Edge Area proportion in 2019 however, is still lower than the HRA and LRA and under half the proportion disclosed in 2011 (29%). The fall in Edge Area cases detected at slaughter since 2011 is most likely due to the increased frequency of routine surveillance in this area (Figure 3.3.4).

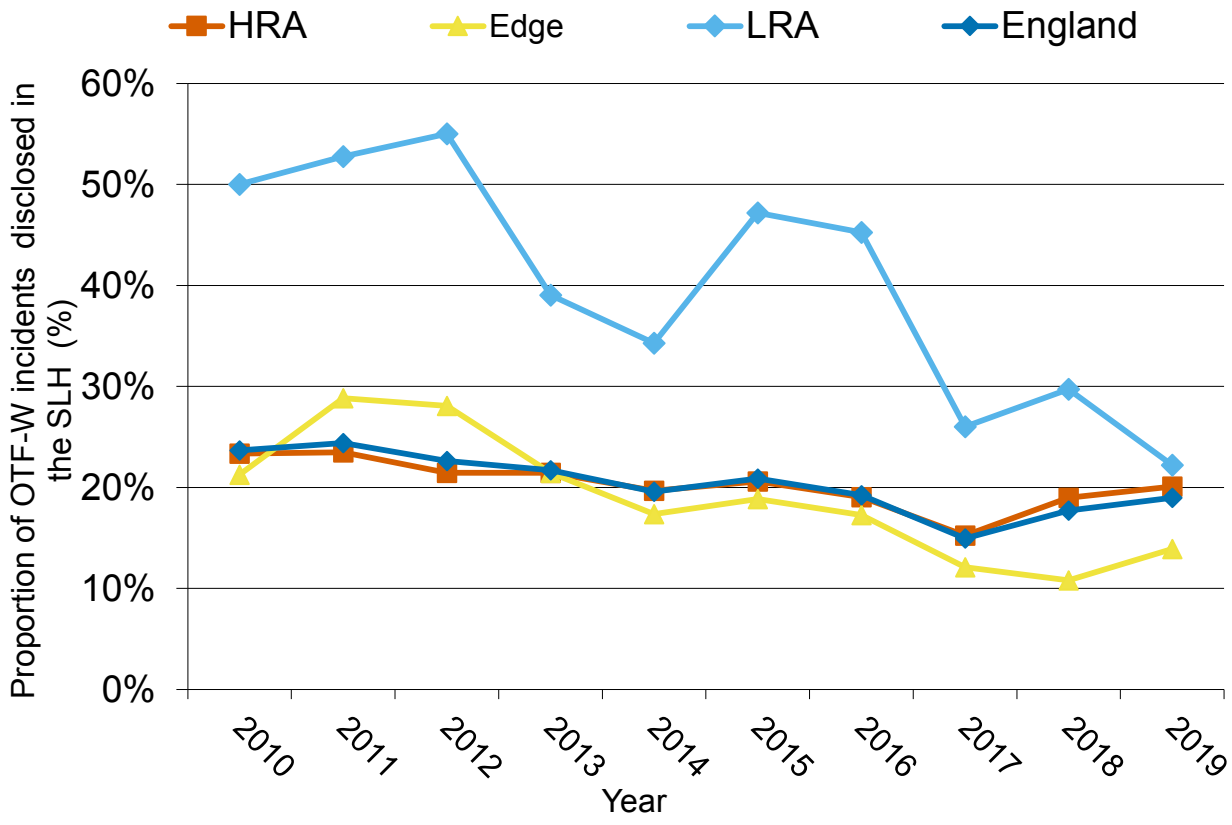


Figure 3.3.4 The proportion of new OTF-W TB incidents that were disclosed by slaughterhouse surveillance from 2010 to 2019, by risk area

Trade & Other surveillance stream

Trade surveillance includes international trade tests, private tests, tests at artificial insemination centres and pre- and post-movement testing. They are referred to as animal tests rather than herd tests. Only single animals or a batch of animals are generally tested.

Large numbers of cattle movements take place across the country, but not all cattle require bespoke pre-movement testing (PrMT). If the animal has been subject to a government-funded herd test within the required timeframe, a further bespoke PrMT funded by farmers is not required. This means that the total number of animal tests conducted prior to a movement cannot be counted within the surveillance data. Trade & other tests detect the smallest proportion of TB incidents of all the surveillance streams (7.9%). However, this amounts to a relatively high rate of reactors detected per 1,000 tests (1.3 in the HRA, where most tests in this stream are conducted). The main purpose of Trade & other tests is to reduce the risk of high impact disease spread, for example into the LRA.

As expected, the majority of Trade & other surveillance cattle tests were conducted in the HRA (53%) compared to 20% in the Edge and 27% in the LRA (Table 3.3.1). In the HRA and Edge Area, virtually all Trade & other surveillance stream tests in 2019 were PrMTs (Table 3.3.4), whereas post-movement tests and PrMTs comprised the majority of Trade & other surveillance stream tests in the LRA. In April 2016, a change in policy made post-movement testing of cattle entering the LRA from annual or more frequently tested areas of GB compulsory.

Private tests represented 1% of cattle tests in 2019 (which is the same as in 2018) and disclosed just three TB incidents (one OTF-W). International trade tests (pre-export and post-import tests) and voluntary pre-sale check tests resulted in the disclosure of just one OTF-W incident, from post-import testing into the HRA (Table 3.3.4).

Table 3.3.4.a Performance of main test types within the Trade & other surveillance stream in the HRA in 2019

Test type	Test events N (%)	TB Incidents N (%)	OTF-W TB Incidents N (%)	Reactors N (%)	TB Incidents per 100 test events	Reactors per 1,000 cattle tested
Pre-export	6 (0)	0 (0)	0 (0)	0 (0)	NA	NA
Post-import	50 (0.2)	0 (0)	0 (0)	0 (0)	NA	NA
Post-movement	79 (0.4)	1 (0.5)	1 (0.8)	4 (1.0)	1.3	11.9
Pre-movement	19,885 (99.1)	200 (98.5)	124 (97.6)	386 (97.0)	1.0	1.3
Private	49 (0.2)	2 (1.0)	2 (1.6)	8 (2.0)	4.1	6.9
HRA Trade & other total	**20,069**	**203**	**127**	**398**	**1.0**	**1.3**

Table 3.3.4.b Performance of main test types within the Trade & other surveillance stream in the Edge Area in 2019

Test type	Test events N (%)	TB Incidents N (%)	OTF-W TB Incidents N (%)	Reactors N (%)	TB Incidents per 100 test events	Reactors per 1,000 cattle tested
Pre-export	13 (0.2)	0 (0)	0 (0)	0 (0)	0.0	0.0
Post-import	37 (0.5)	1 (3.0)	1 (4.5)	4 (8.5)	2.7	7.7
Post-movement	48 (0.6)	0 (0)	0 (0)	0 (0)	0.0	0.0
Pre-movement	7,323 (97.6)	31 (93.9)	21 (95.5)	42 (89.4)	0.4	0.4
Private	79 (1.1)	1 (3.0)	0 (0)	1 (2.1)	1.3	1.4
Edge Area Trade & other total	**7,500**	**33**	**22**	**47**	**0.4**	**0.4**

Table 3.3.4c Performance of main test types within the Trade & other surveillance stream in the LRA in 2019

Test type	Test events N (%)	TB Incidents N (%)	OTF-W TB Incidents N (%)	Reactors N (%)	TB Incidents per 100 test events	Reactors per 1,000 cattle tested
Pre-export	76 (1.1)	0 (0)	0 (0)	0 (0)	0.0	0.0
Post-import	106 (1.6)	0 (0)	0 (0)	0 (0)	0.0	0.0
Post-movement	2,627 (38.5)	9 (50.0)	3 (60.0)	54 (83.1)	0.3	1.0
Pre-movement	3,770 (55.2)	9 (50.0)	2 (40.0)	11 (16.9)	0.2	0.2
Pre-sale check LRA	1 (0)	0 (0)	0 (0)	0 (0)	0.0	0.0
Private	249 (3.6)	0 (0)	0 (0)	0 (0)	0.0	0.0
LRA Trade & other total	**6,829**	**18**	**5**	**65**	**0.2**	**0.6**

Note: Table 3.3.4 test types include: Pre-export (VE-EX), Post-import (VE-PII, VE-PIO), Post-movement (VE-POSTMT, POSTMOVNC, VE-POSTMOVOV), Pre-movement (VE-PRMT, VE-AI), Pre-sale check LRA (VE-CT-LRA-SA), Private (VE-PRI).

Pre-Movement Testing (PrMT)

There were just over 2.7 million cattle movements within GB in 2019, excluding movements to a slaughterhouse, directly and indirectly (e.g. via slaughter markets and approved finishing units). This was 63,000 fewer movements than in 2018. Farms in all risk areas move more cattle within their area than to and from other areas. Furthermore, there is more cattle movement between areas most similar in terms of TB risk (Table 3.3.5). In the HRA and LRA around 80% of cattle move within their area compared to 55% of Edge Area cattle.

Table 3.3.5 Summary of number of cattle movements between risk areas and countries, 2019

Cattle movements in 2018	To HRA	To Edge Area	To LRA	To Scotland	To Wales	Total
From HRA	614,705	84,467	40,116	1,136	32,603	773,027
From Edge Area	56,095	210,241	41,892	501	18,286	327,015
From LRA	15,413	48,002	641,917	24,592	8,075	737,999
From Scotland	1,582	4,236	56,812	409,126	1,638	473,394
From Wales	81,767	35,609	22,505	395	274,920	415,196
Total	769,562	382,555	803,242	435,750	335,522	2,726,631

A total of 1.1 million cattle in 2019 were moved out of the annual or six monthly-tested HRA and Edge Area. This was the same in 2018, but down 60,000 from 2017. However, only 459,289 bespoke PrMTs were recorded (around 42%). This is probably because government-funded herd tests were used to provide the same evidence of infection status prior to movement.

The proportion of TB incidents disclosed by PrMTs in the HRA has remained fairly stable since 2010. There has been more variability in the Edge Area and LRA over this time period (Figure 3.3.5). A notable increased proportion of TB incidents were detected by PrMTs in the Edge Area in 2013. This was due to the introduction of annual testing, which increased the number of herds eligible for this test. The proportion has continued to fall since then; likely due to herd-level tests (WHT or clearing SI tests) being conducted in place of PrMTs and the increased frequency of testing.

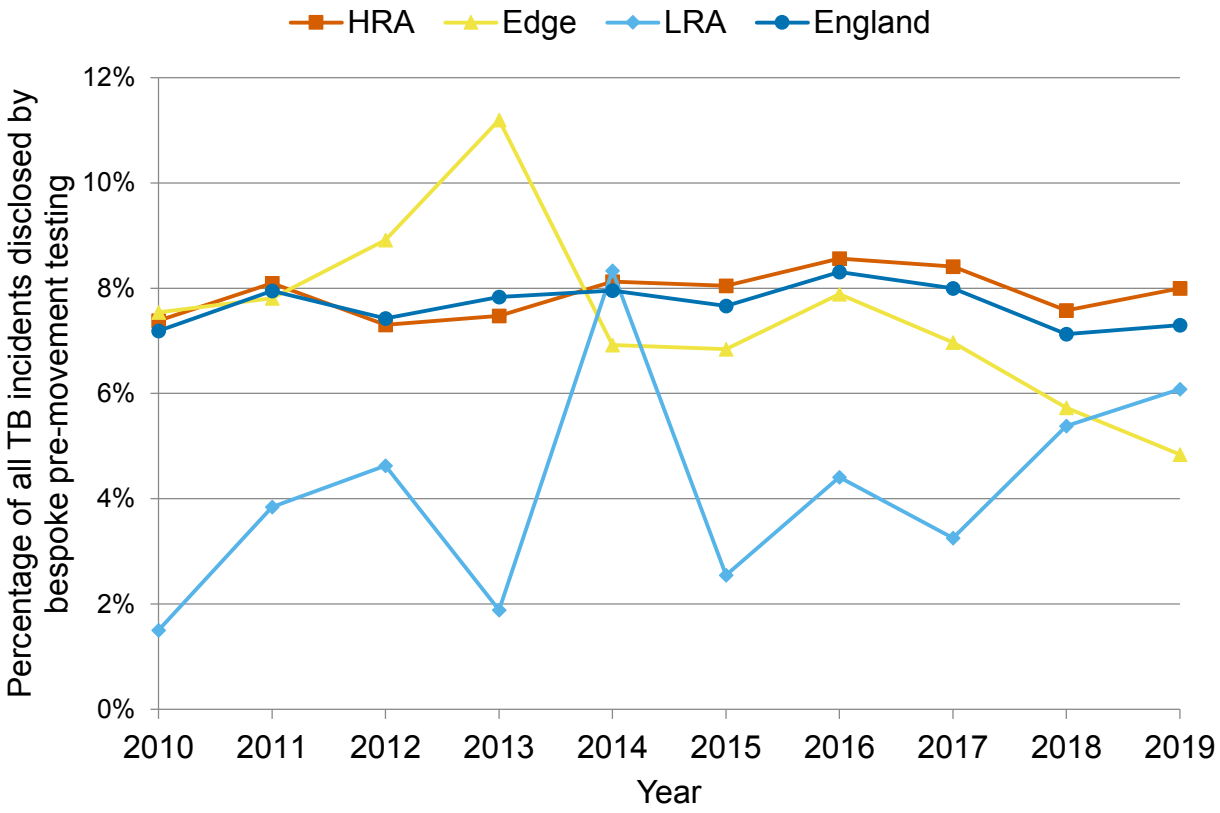


Figure 3.3.5 The proportion of total TB incidents disclosed by bespoke pre-movement testing between 2010 and 2019, by risk area.

- Figure 3.3.5 includes tests categorised as PrMT, but does not include other tests that can be used as a PrMT.

Inconclusive Reactors (IRs)

Inconclusive reactors (IRs) are cattle that have a differential bovine-avian reaction to the SICCT test that is not strong enough to classify them as reactors. These animals remain isolated from their herd while awaiting the results of a retest in 60 days' time. If the IRs fail to clear the first retest (i.e. 2x IRs or become straight reactors), they are deemed to be reactors. In that case a TB incident is declared in the herd, resulting in whole herd restrictions, reactor removal and additional incident testing.

As expected, most IR-only herds (herds that had only IRs disclosed and no reactors at the initial test) are detected in the HRA (63%). Similarly, most IRs are identified in the HRA (68%). Between 2018 and 2019, there was a decrease in the number of IR-only herds and IRs disclosed in the HRA, but increases in both the Edge Area and LRA (Table 3.3.6).

Table 3.3.6 Summary of number of IR-only herds and IRs disclosed, their percentages and percentage change between 2018 and 2019 by surveillance risk area.

Region	IR-only herds (% of all IR-only herds) (% change 2018-19)	IRs disclosed (% of all IRs disclosed) (% change 2018-19)
HRA	1,541 (63%) (-6%)	3,184 (68%) (-5%)
Edge Area	621 (26%) (+5%)	1,109 (24%) (+5%)
LRA	269 (11%) (+1%)	422 (9%) (+1%)

In 2019, 40% of IR-only herds in the HRA went on to have a TB incident within the following 15 months. In the Edge Area, 33% went on to have a TB incident, and 23% in the LRA (Figure 3.3.6). Around half of the IRs in IR-only herds where TB infection went on to be detected (OTF-S or OTF-W) were detected by the IR-only herd retests in the HRA (54%) and Edge Area (57%). In the LRA, the proportion was 82%, respectively.

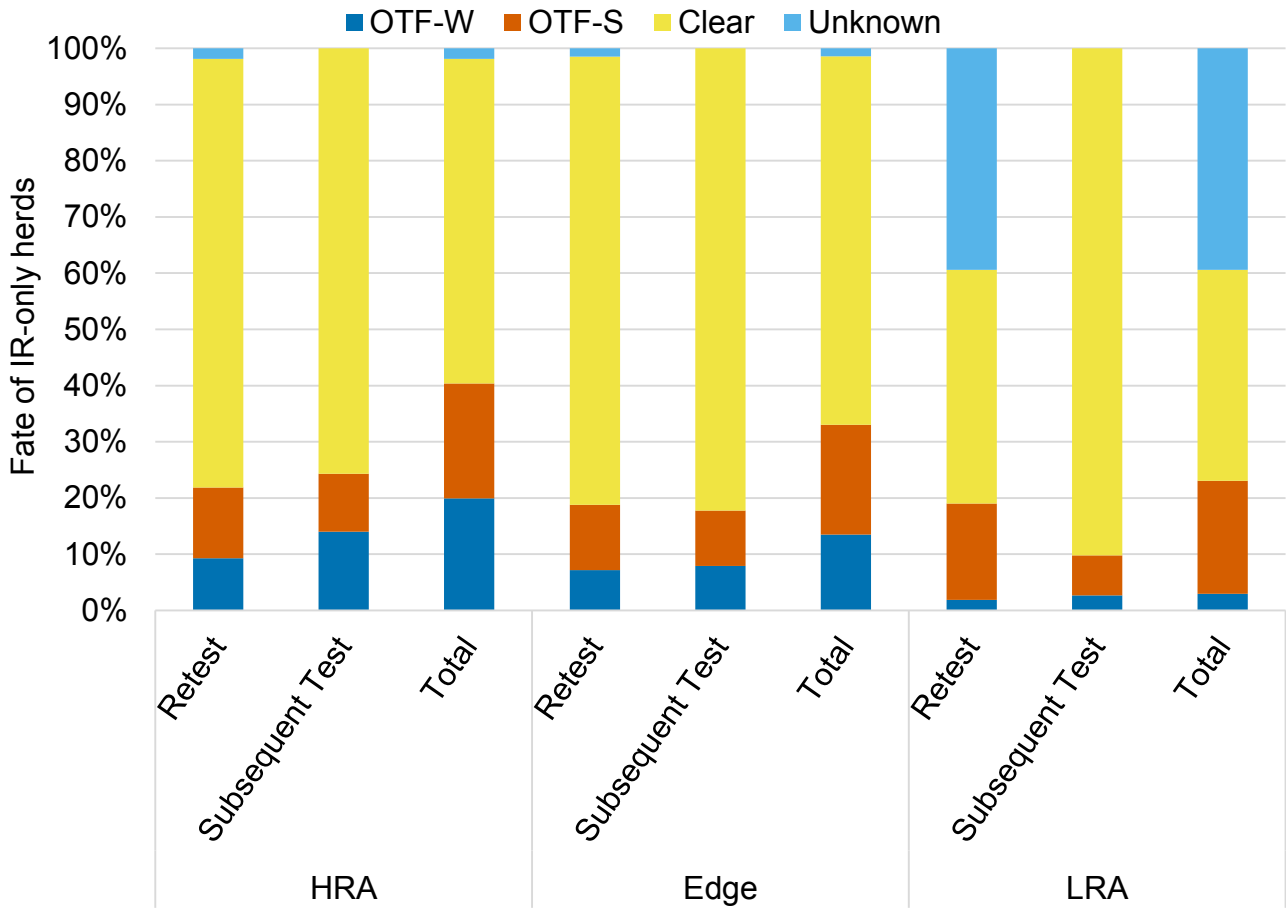


Figure 3.3.6 Fate of IR-only herds, following disclosure in 2019, by risk area. The fate of some herds is recorded as unknown due to reasons such as ceasing trading and not having a retest.

In 2019, in the Edge Area and LRA, nearly all IR-only tests took place in herds with no recent history of an OTF-W incident (90% and 97% respectively). The HRA had the lowest proportion of IR-only herds with no OTF-W incident in the previous three years (69%). This follows from the higher incidence observed within this region.

Figure 3.3.7 suggests that IR-only herds in all risk areas have an increased risk of a TB incident at a subsequent test if they have a history of TB. A multivariable analysis by Brunton et al[1] shows that the risk posed by IRs in the HRA and Edge Area is substantially reduced by those animals becoming reactors or 2xIRs at the retest 60 days later and being removed from herds. However, IRs that pass the retest can pose a TB risk for around 2.5 years from first disclosure. This indicates that IRs are an important predictor of the presence of infection. Although the retest eliminates most of the risk, the policy to restrict IRs to the herd in which they are disclosed for life should reduce the risk further.

[1] Brunton LA, Prosser A, Downs SH, Pfeiffer DU. Exploring the fate of cattle herds with inconclusive reactors to the tuberculin skin test. Frontiers in veterinary science. 2018;5:228.

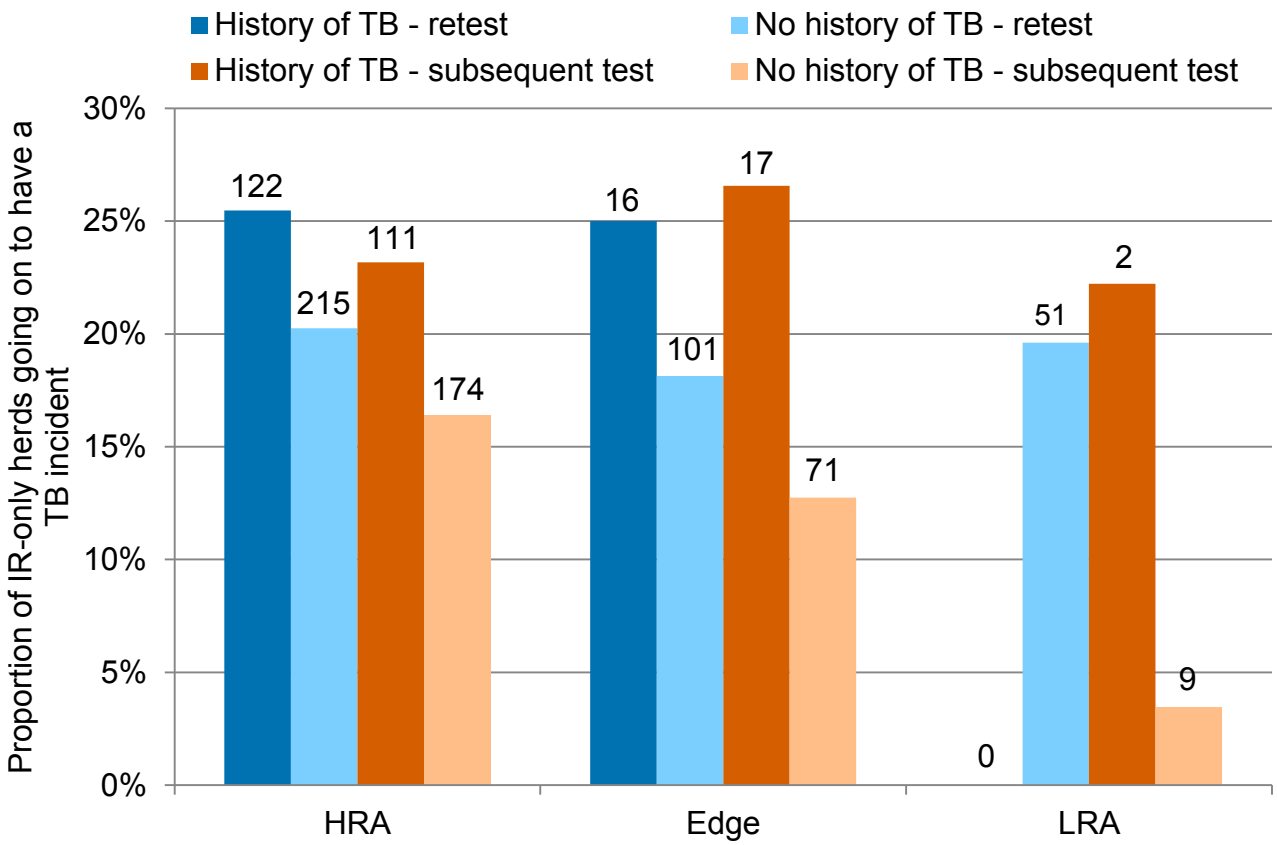


Figure 3.3.7 Proportion of IR-only herds going on to have a TB incident in 2019 at either the IR retest or a subsequent test (within 15 months after IR test), by surveillance risk area and TB history. Totals above each column represent the number of herds with a TB incident

Interferon gamma tests for detection of additional infected cattle within TB incident herds

The interferon gamma (IFN-γ) blood test is generally used in England as a parallel test in conjunction with the skin test to boost the overall sensitivity of testing in certain TB incident herds with *post mortem* evidence of infection. All herds experiencing fully confirmed (OTF-W) TB incidents in the LRA and Edge Area and in badger control areas (BCP Areas) of the HRA that have completed at least two culling seasons, must be subjected to supplementary IFN-γ blood testing, to enhance the detection of reactors. Mandatory IFN-γ tests are also used in persistent incidents where herds have been under restriction for more than 18 months, as well as in explosive breakdown herds and those being considered for whole or partial slaughter. Outside these scenarios, the deployment of the IFN-γ blood test in 2019 was discretionary.

Table 3.3.7 Animals (herds) receiving an IFN- γ test in 2019, by risk area

Risk Area	Chronic Breakdown Management	Miscellaneous	New OTF-W incidents in BCP Areas	OTF-W incidents outside HRA	Persistent OTF-W incidents	Persistent OTF-W incidents in BCP Areas
HRA	31 (4)	4,528 (80)	67,304 (608)	0 (0)	37,020 (215)	8,498 (53)
Edge Area	0 (0)	1,247 (12)	5,186 (25)	108,737 (901)	2,010 (11)	350 (3)
LRA	22 (2)	49 (2)	78 (1)	9,063 (83)	586 (5)	0 (0)

1. Test types included: Chronic breakdown management (VE-IFN_SLHERD), Miscellaneous (VE-IFN, VE-IFN_ANOM, VE-IFN_BOV_OTH, VE-IFN_FLEX, VE-IFN_NSR, VE-IFN_OTH_SP, and VE-IFN_PRI), New OTF-W in BCP Areas (VE-IFN_NBCP), OTF-W outside HRA (VE-IFN_LOW_IN), Persistent OTF-W (VE-IFN_PERSI), and Persistent OTF-W in BCP Areas (VE-IFN_PBCP).
2. Herds tested in parentheses.

A total of 244,709 cattle were IFN-γ tested in England in 2019 and 4.1% were positive (10,034 IFN-γ test positives). A total of 2,005 herds were tested and 1,296 had at least one IFN-γ test positive animal disclosed (65%).

Since 2010, the overall IFN-γ test positive rate in animals has varied between 4-6%. Historically there have been differences in the positive rate between risk areas, with higher rates in HRA herds (13% in 2015, 8% in 2016 and 11% in 2017). However, in 2019, the rate in the HRA dropped to 5% compared to 3% in the Edge Area and LRA (Figure 3.3.8). This is likely to be due to the sharp increase in compulsory IFN-γ testing in BCP areas, which particularly affects the HRA. This trend is likely to continue whilst BCP areas are eligible for IFN-γ testing. Previously many of the IFN-y tests were applied to persistent and ‘explosive breakdown’ herds where a higher positive rate is expected.

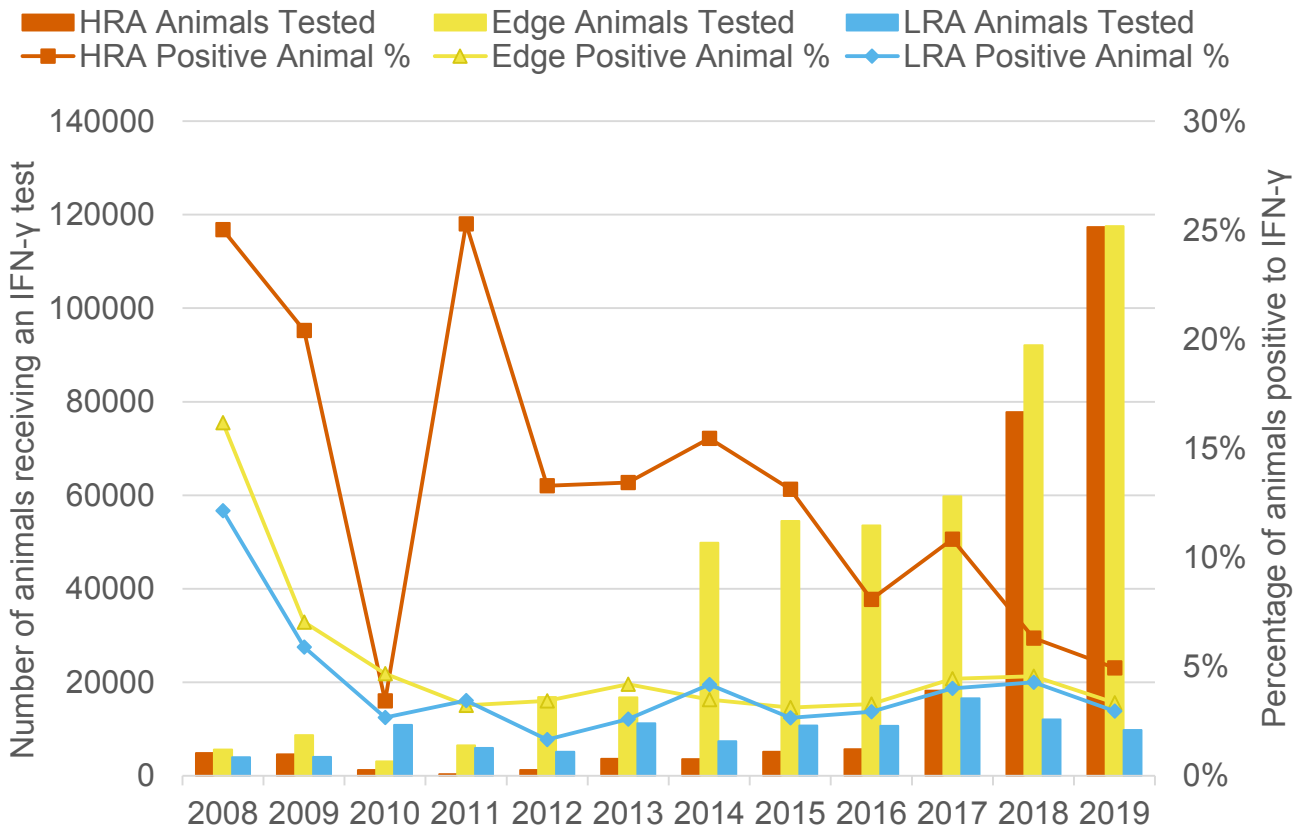


Figure 3.3.8. Number of animals tested and proportions of animals IFN-γ test positive by risk area, 2008 to 2019

The use of IFN-γ tests at the herd level has evolved over time. Due to a pilot of IFN-γ testing, many herds in 2008 and 2009 had a test (Figure 3.3.9), but the number of animals tested were low (Figure 3.3.8). In 2019, additional IFN-γ testing continues to be deployed subject to veterinary discretion, such as in complex TB incidents. In the Edge Area, the proportion of herds in which reactors were detected using IFN- γ testing has stayed broadly consistent across years and between risk areas at 60-80%. There has been wider variation in the HRA and LRA, possibly due to fewer herds receiving IFN-γ testing in previous years (Figure 3.3.9).

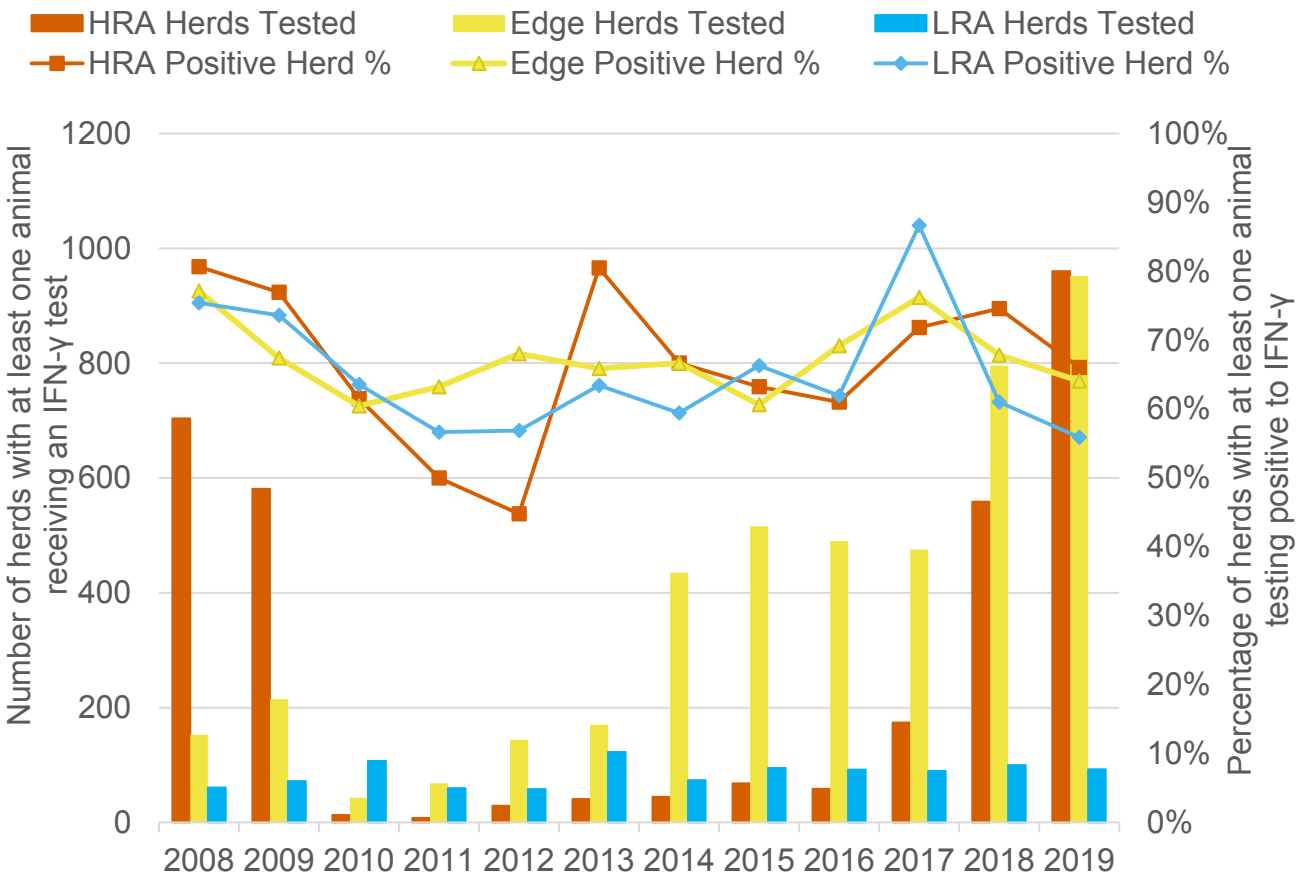


Figure 3.3.9. Number of herds tested and proportions of herds with at least one IFN-γ test positive animal by risk area, 2008 to 2019.

3.4 Impact of disease and control measures: prevalence, duration and persistence

- During 2019, at any point in time, about 2,700 herds (5.5% of the cattle herds in England) were under movement restrictions due to a TB incident. In other words, about 94% of all the cattle herds in England were Officially TB Free (OTF). This national prevalence level is similar to previous years.
- Most herds under movement restrictions are in the HRA. In 2019, the monthly average herd level prevalence in the HRA decreased compared to 2018. However, this level has been relatively stable since 2011. Prevalence in the HRA was highest in the counties of Avon (12.2%) and Wiltshire (12.0%).
- Prevalence in the Edge Area has continued to increase since 2003, with a particular rise from 2013 following the introduction of a stricter regime for returning a herd to OTF status after suffering a TB incident. Prevalence in 2019 was highest in the counties of Oxfordshire (12.1%) and Berkshire (9.9%).
- TB infected herds remained under restriction for a median of around six and a half months in the HRA and Edge Area, and just under five and a half months in the LRA, although the range was wide. Herds were under movement restrictions for longer periods in larger herds (>200 animals) and in TB incidents with more than one reactor.
- The number of TB incidents classed as ‘persistent’ (i.e. movement restrictions lasting for 18 months or longer) that were still ongoing at the end of 2019 decreased in the HRA (242 to 192), but increased in the Edge Area (24 to 29) compared to 2018. One persistent incident was ongoing in the LRA (in Cumbria) at the end of 2019.
- Overall, 255 persistent TB incidents were resolved in England, 86% of which were located in the HRA.
- In 2019, 31,582 cattle were slaughtered for TB control reasons, with a median of three reactors removed per TB incident. The mean number of reactors removed has fluctuated over time and between risk areas. On average, approximately ten reactors were removed per TB incident in the HRA and Edge Area, and five in the LRA in 2019. The fluctuation and high numbers of reactors in some incidents will mean the loss is much greater for some farmers.

Herd prevalence

Herd prevalence shows the proportion of herds classified as infected with TB at a given point in time. It is measured by counting herds under restriction due to a TB incident at the mid-point of each month, divided by the number of active herds in a geographical area. This measurement depends on both how many herds are newly infected with TB (incidence) and how long restrictions are maintained (incident duration). Stricter controls, in particular the extent of testing needed to provide sufficient evidence to declare a herd OTF, can increase the duration of restrictions. Less stringent controls may lead to a swifter resolution of the TB incident, but risks leaving undetected infection if controls are removed too soon. Prevalence provides an indication of how much impact the epidemic is having on the cattle farming sector.

During 2019, an average of 5.5% of herds in England overall were restricted at any one time, equating to around 2,700 herds. However, this overall figure masks substantial differences between risk areas and counties within those areas, as shown in Figures 3.4.1 and 3.4.2, respectively. Figure 3.4.1 also shows a seasonal cycle, likely related to the time of the year when most TB surveillance testing is undertaken. TB testing is planned to fit with the farming calendar when possible. Herd prevalence in the HRA decreased slightly in 2019 compared to 2018. In the Edge Area, herd prevalence has increased steadily since 2007 with a marked upward trend since 2013, when all herds in the area were placed on routine annual testing. This reflects both the earlier detection achieved and the more stringent controls deployed. In the LRA, prevalence has remained consistently low for the past ten years.

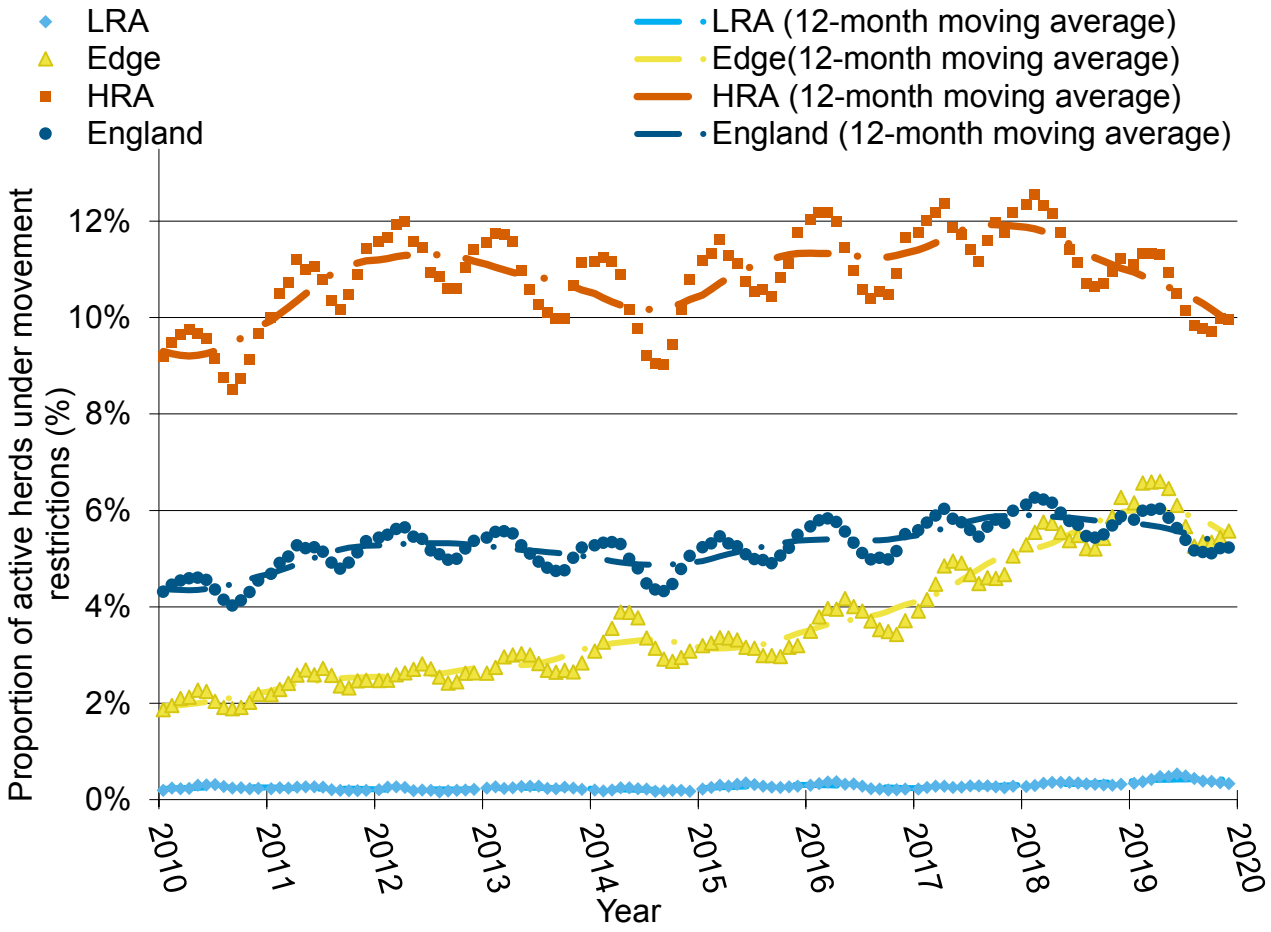


Figure 3.4.1 Proportion of active herds in England herds under TB movement restrictions (prevalence) as a result of any TB incident, by month, between January 2010 and December 2019

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

In 2019, as in previous years, there was wide variation in the herd prevalence of TB between counties (Figure 3.4.2). The highest prevalence was seen in Avon, Oxfordshire and Wiltshire (12%) and the lowest prevalence was in the LRA counties. Further details about prevalence at county level within the HRA are presented in Section 4.1. Prevalence levels and trends in individual counties of the Edge Area and LRA are presented in the Year End Descriptive Epidemiology Reports.

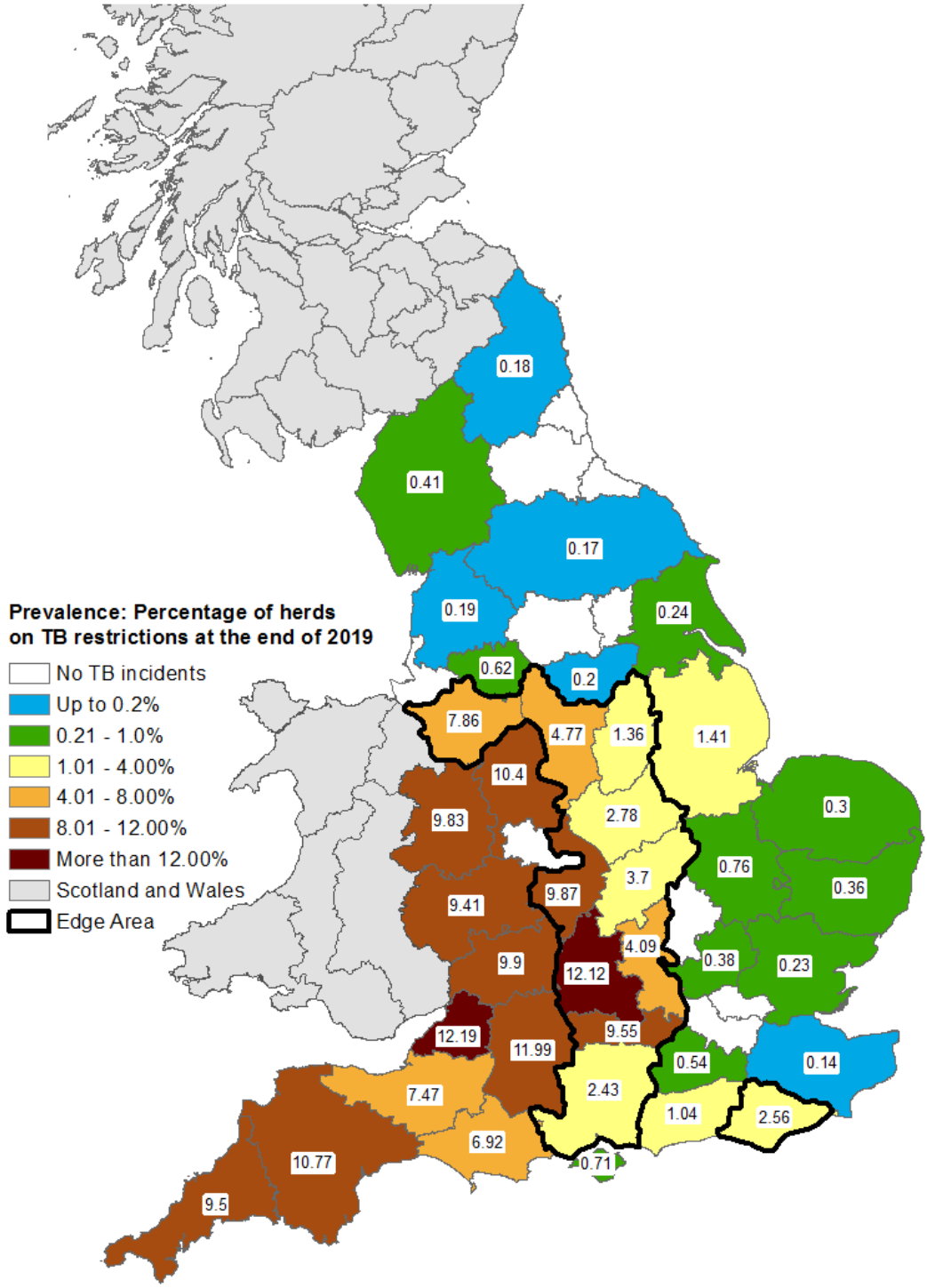


Figure 3.4.2 County prevalence: percentage of herds in each county that were under restrictions due to a TB incident at the end of 2019 (15th December)

- Prevalence is generally greatest in the HRA. However, as in previous years, high levels of prevalence were also found in some Edge Area counties, including Oxfordshire, Berkshire and Warwickshire.

Duration of TB incidents

Herds infected with TB are prevented from moving cattle while the incident control measures are in place, to limit the risk of spreading TB. Limited exceptions, including direct movements to slaughter, slaughter markets or finishing units approved by APHA (AFUs), are permitted under licence. The duration of these movement restrictions affects both farmers and tax payers because restrictions constrain the management of the herd. Longer durations are generally associated with more tests and more animals removed, and thus greater costs. Shorter periods of restrictions enable a farmer to get back to business as usual more quickly, so minimising their economic impact. However, this must be balanced against the risk of leaving undetected infection in the herd (and further spread of disease) if restrictions are removed too early.

A total of 3,652 herds in England had movement restrictions lifted in 2019. Of those, 17 were non-grazing AFUs (15 in the HRA and 2 in the Edge Area). Due to differences in the management of TB in such herds, they have been excluded from the following duration figures.

Herds with a TB incident were under restriction for longer in the HRA and Edge Area, compared to the LRA, with a median duration of approximately six-and-a-half months. The interquartile range (IQR) for herds in the HRA indicates that half were under restriction for between five-and-a-half and ten months. In the LRA, the median duration of TB incidents was just under five-and-a-half months (IQR 3.5 - 7 months). This reflects the higher proportion of herds with OTF-S cases in the LRA, most of which require only a single short interval test (SIT) with negative results to regain OTF status.

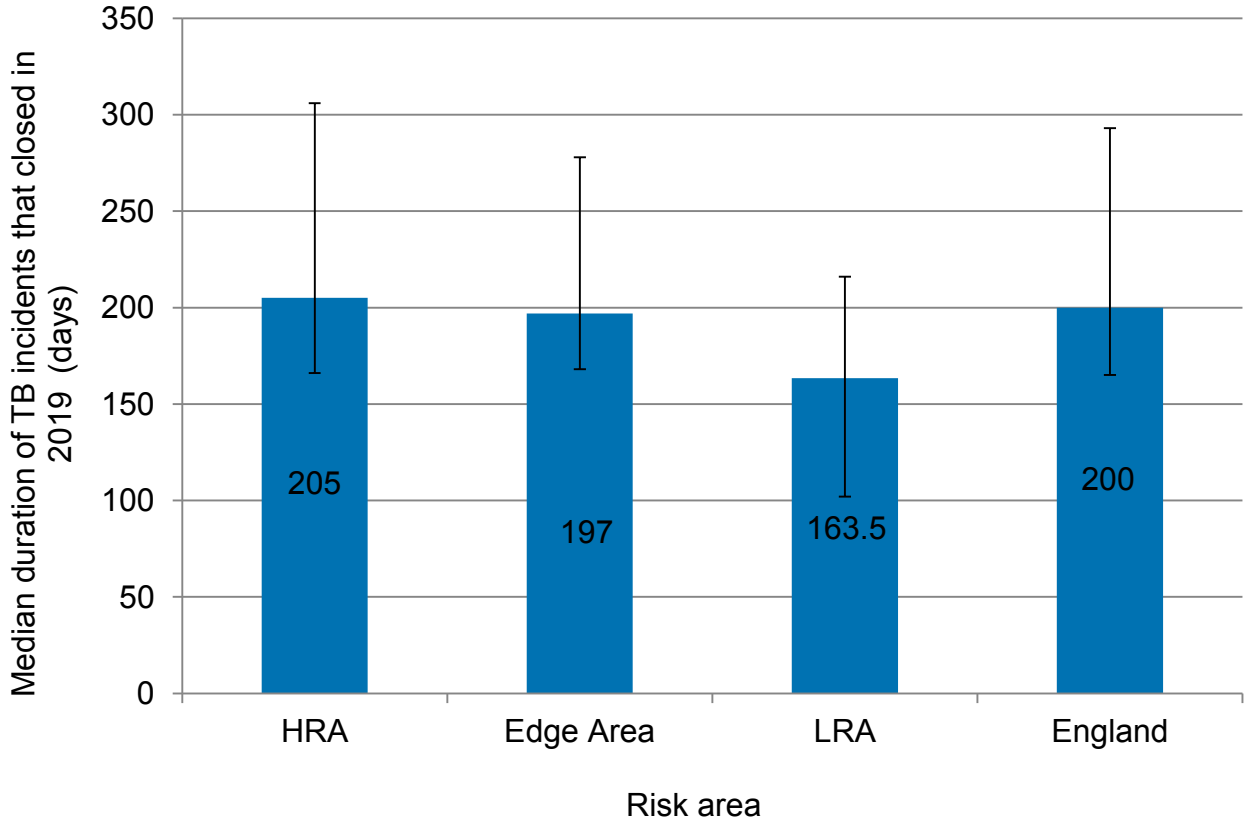


Figure 3.4.3 Median duration and interquartile range of all TB incidents that closed in 2019, by risk area

- Herds were under restriction due to TB for similar lengths of time (median) in the HRA and Edge Area, but the duration was shorter in the LRA, however there is wide variation within each risk area.

Factors that are associated with a significant increase in duration include large herd size and the number of reactors found. The latter can stem from case management processes, such as supplementary IFN-γ blood testing.

The duration of herd movement restrictions was associated with herd size in all risk areas (Figure 3.4.4). It took longer for restrictions to be lifted in herds with more than 200 animals. This can be seen by the increasing proportion of such herds (green shading) in the longer duration categories. A greater proportion of medium and small herds are restricted for shorter periods in all risk areas (movement restrictions of less than 240 days). As the duration of TB incidents increases, the proportion of small herds affected decreases.

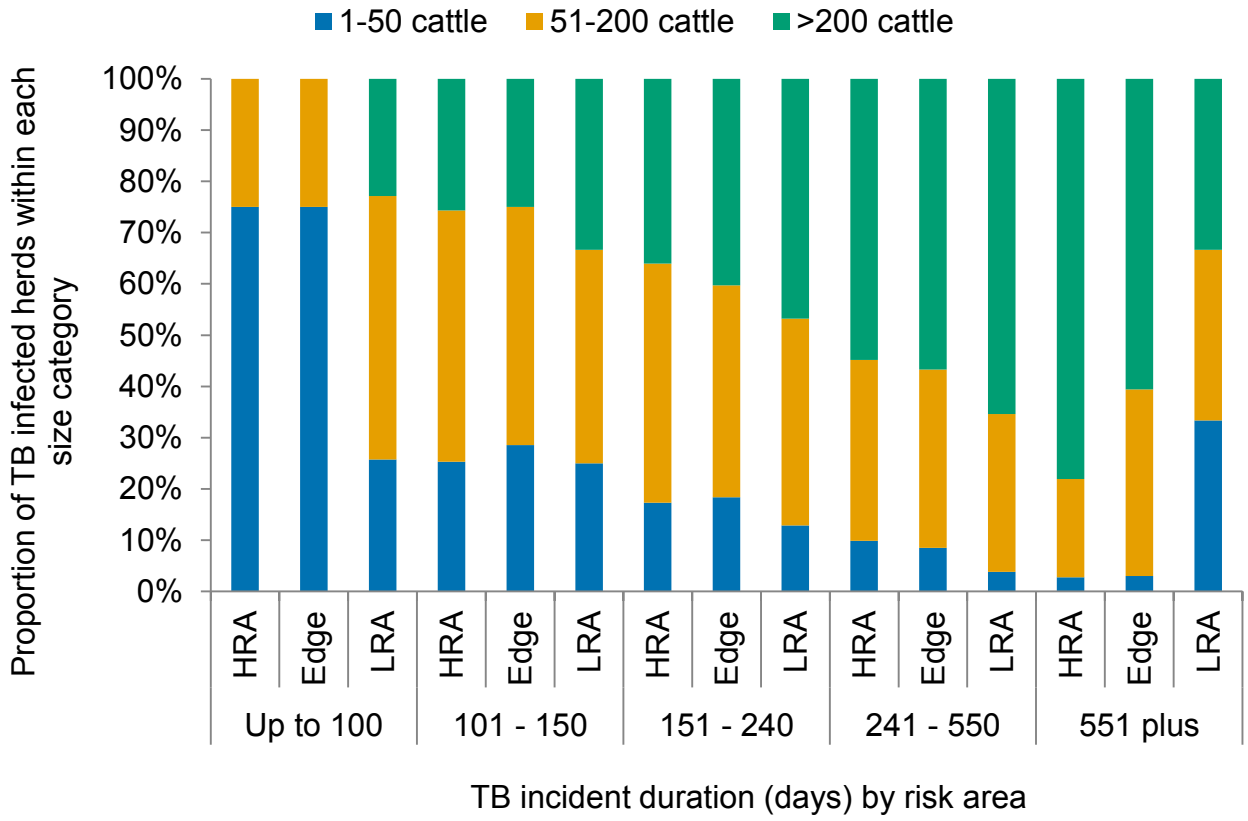


Figure 3.4.4 Comparative duration of TB incidents that closed in 2019, by risk area and herd size

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

Long duration of movement restrictions is the result of challenges in removing infection, or in demonstrating freedom of infection. They may result from a number of factors that can interfere with efforts to remove infection, such as

- imperfect sensitivity of the skin and interferon-gamma tests
- a poor response of one or more infected animals to the skin test
- intense cattle-to-cattle transmission (high within-herd infection prevalence)
- continued re-infection (e.g. from local wildlife reservoirs of TB, or contiguous herds)
- uninfected animals showing non-specific reactions to tests (less common).

Figure 3.4.5 shows the number of SITs it took to clear a TB incident, comparing risk area and herd size. Overall in England, 48% of herds (with TB incidents that closed in 2019) took two SITs to clear, and 86% took fewer than five 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. The HRA had herds under restriction for longer, with 15% of herds receiving more than five SITs in 2019. In the Edge Area only 11% of herds received more than five SITs, and in the LRA just three per cent (four herds).

In the HRA, 60% of small herds (1-50 cattle) required two SITs to clear a TB incident, while 34% required three or more. Fewer medium size herds (51-200 cattle) cleared a TB incident with two SITS (52%) and just under half required three or more SITs (47%). Most large herds (>200 cattle) required three or more SITs (64%).

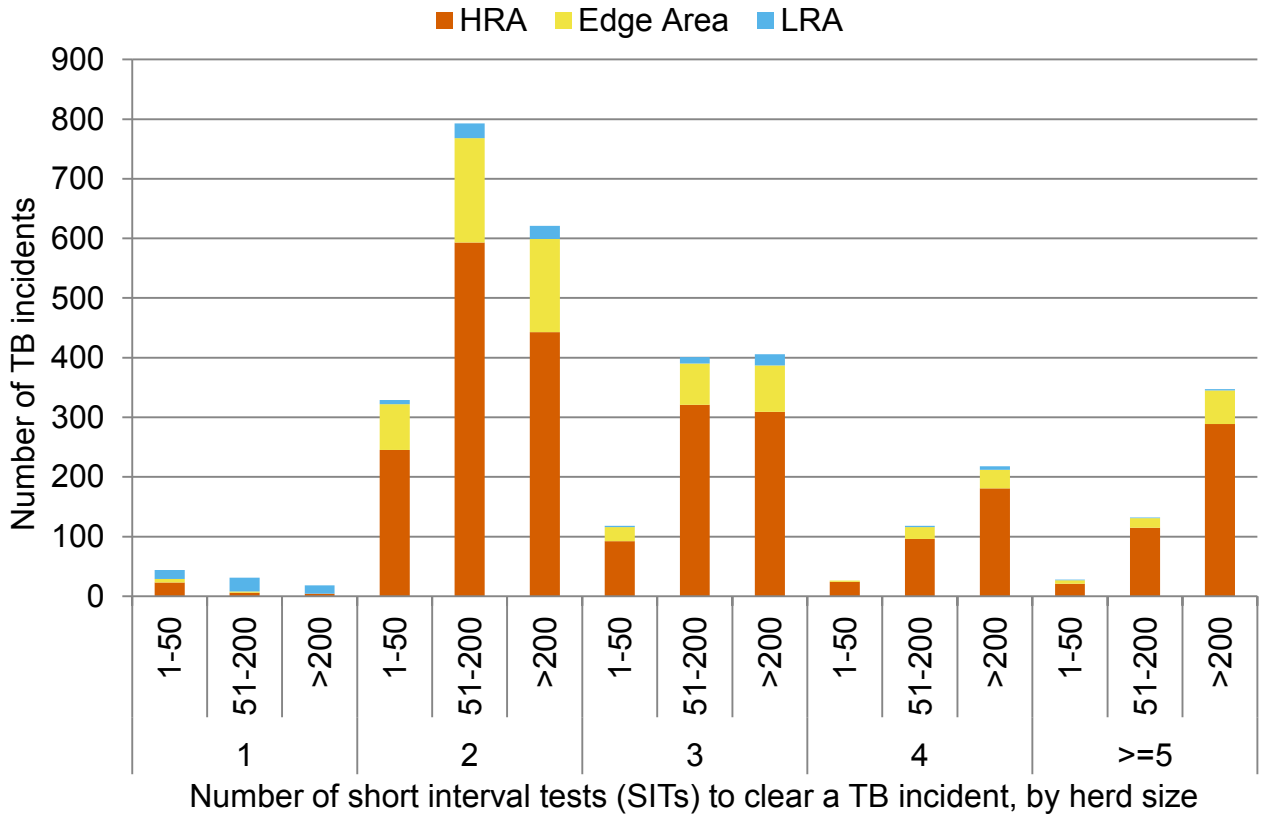


Figure 3.4.5 Number of short interval tests (SITs) to clear a TB incident, by risk area and herd size (for TB incidents ending in 2019)

- In the HRA and Edge Area, most herds required two or three SITs to clear a TB incident. In the LRA, most herds required one or two SITs.

Changes in duration over time

Since 2010, TB incidents with more than one reactor have consistently been under restriction for longer than those with only one reactor, across all risk areas (Figure 3.4.6). TB incidents with more than one reactor generally have a longer duration of movement restrictions in the HRA, compared to herds in the Edge Area and LRA. For TB incidents with 0-1 reactors, the duration of TB incidents has been similar between the HRA and Edge Area since 2014. The duration of TB incidents for single reactor herds is largely driven by the required number of SITs. In the LRA, this is often only one as many cases are suspect (OTF-S) rather than confirmed (OTF-W), hence the lower duration in the LRA.

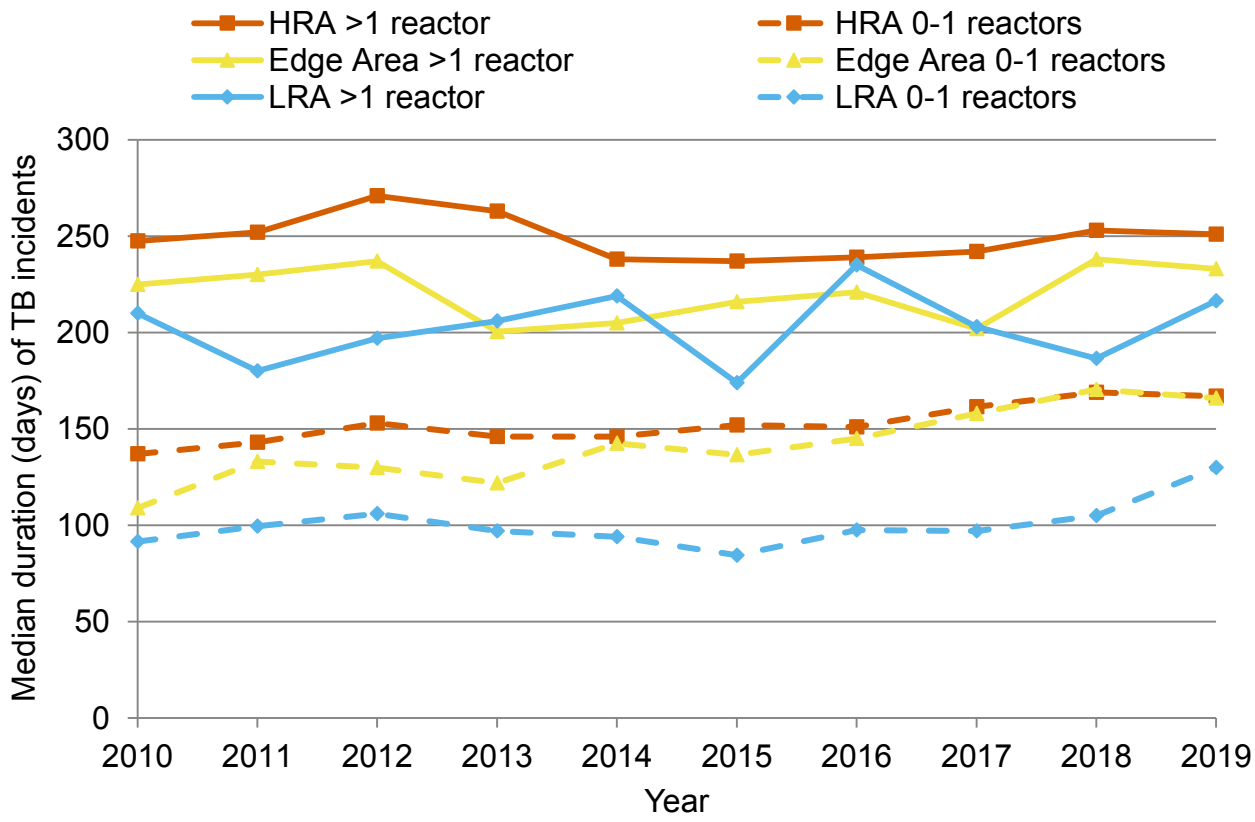


Figure 3.4.6 Median duration of TB incidents that closed in each year, between 2009 and 2019

- TB incidents in the HRA with more than one reactor have consistently been under restriction for longer than incidents in the Edge Area or LRA.
- Since 2013, most single reactor herds in both the HRA and Edge Area have required two SITs to clear a TB incident, leading to a similar duration.

Persistent TB incidents

If a TB infected herd is under movement restrictions for over 550 days (about 18 months), the incident is considered to be ‘persistent’. These affected herds are eligible for enhanced management procedures, based on a series of prioritisation criteria.

The causes of persistent TB incidents include:

- The limitations of the test in finding all infected animals, particularly in large herds, due to the presence of animals that fail to react to the test, leading to continued spread within the herd.
- 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 3.4.7 shows the number of persistent TB incidents that remained open at the end of each year, since 2010, by risk area. The vast majority (86%) are in the HRA (note y-axis is scaled to a tenth true value for the HRA so that values for the Edge Area and LRA can be seen).

The number of persistent incidents still open at the end of 2019 (n=222) was the lowest number since 2015 (n=220). In the Edge Area, the number of persistent incidents has been increasing annually, from 12 in 2016 to 29 in 2019. In the HRA the number of persistent TB incidents increased from 205 in 2015 to 242 in 2018, however it fell to 192 in 2019. One persistent incident remained open in the LRA (Cumbria) at the end of 2019 (Figure 3.4.7).

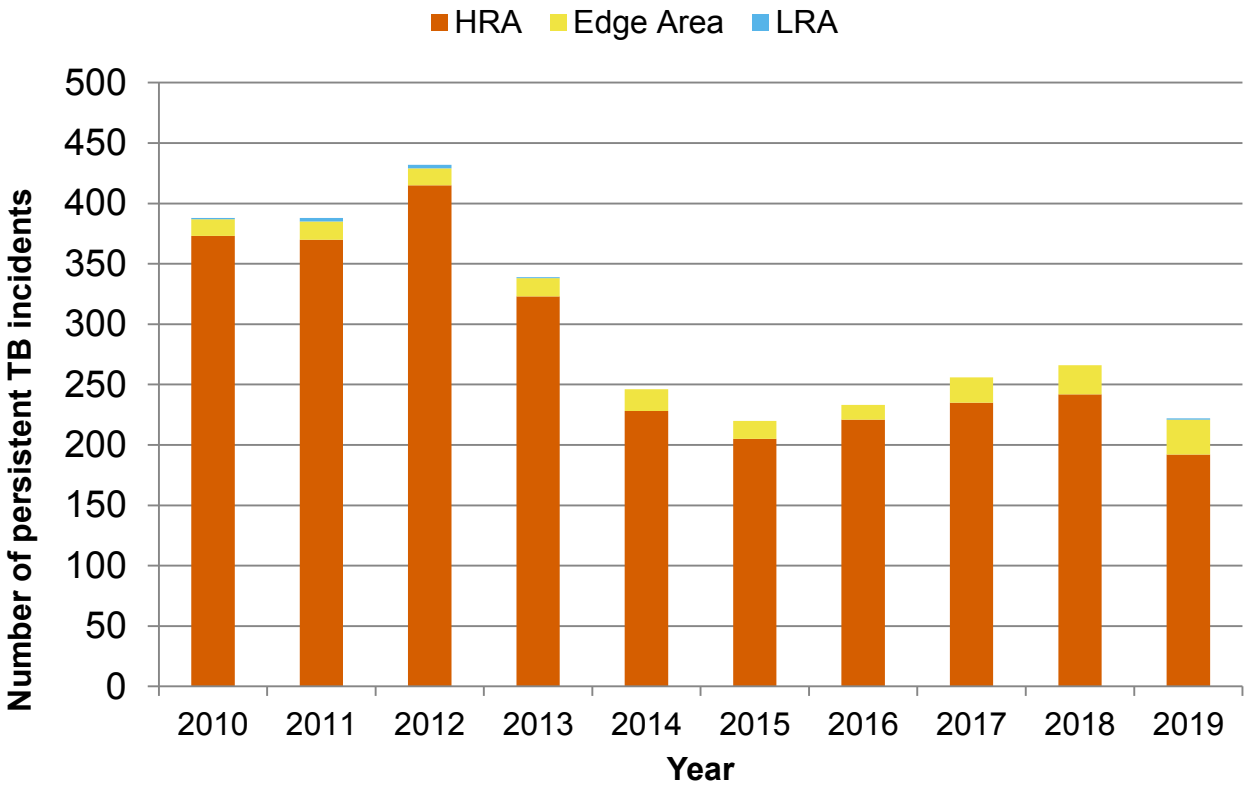


Figure 3.4.7 Number of TB incidents ongoing at the end of each year that had lasted more than 550 days ('persistent' TB incidents). (Note HRA values presented as a tenth their true value for clarity)

During 2019, 255 persistent TB incidents were resolved in England overall (219 in the HRA, 33 in the Edge Area and three in the LRA).

Most herds that have prolonged infection with TB are located in the HRA (86%), however there is variation in the burden of persistent incidents between counties.

Within each county, the highest proportion of persistent TB incidents open (out of all TB incidents) in the HRA at the end of 2019 were located in Dorset (18.1%), followed by Gloucestershire (14.4%). In the Edge Area, Berkshire had the highest proportion of persistent incidents (20.0%, n=4), followed by Oxfordshire (14.3%). Figure 3.4.8 shows that the burden of persistent incidents disproportionately affects counties in the south and east of the HRA and central Edge Area.

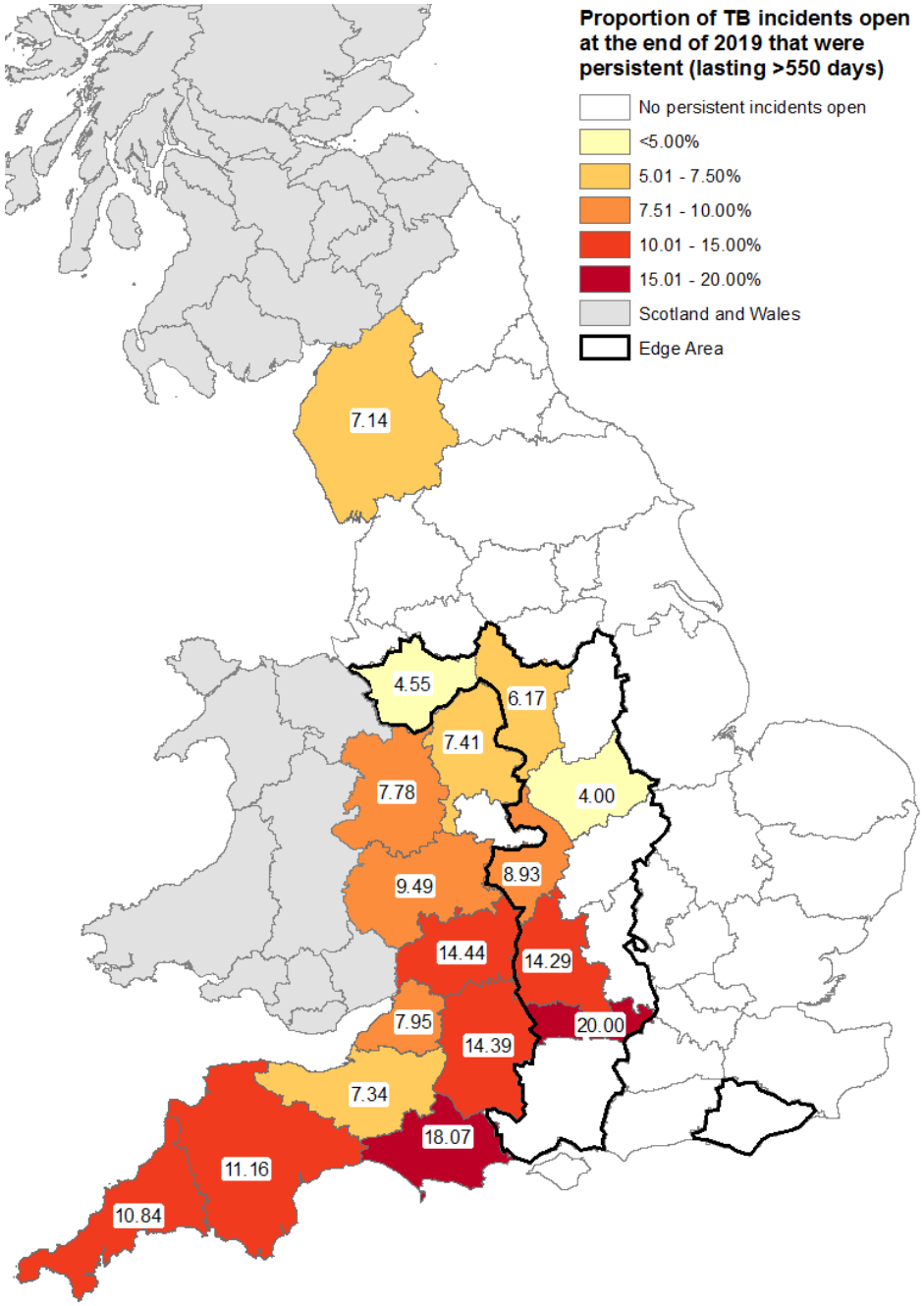


Figure 3.4.8 Proportion of all TB incidents in each county, open at the end of 2019 that had lasted more than 550 days (persistent incidents)

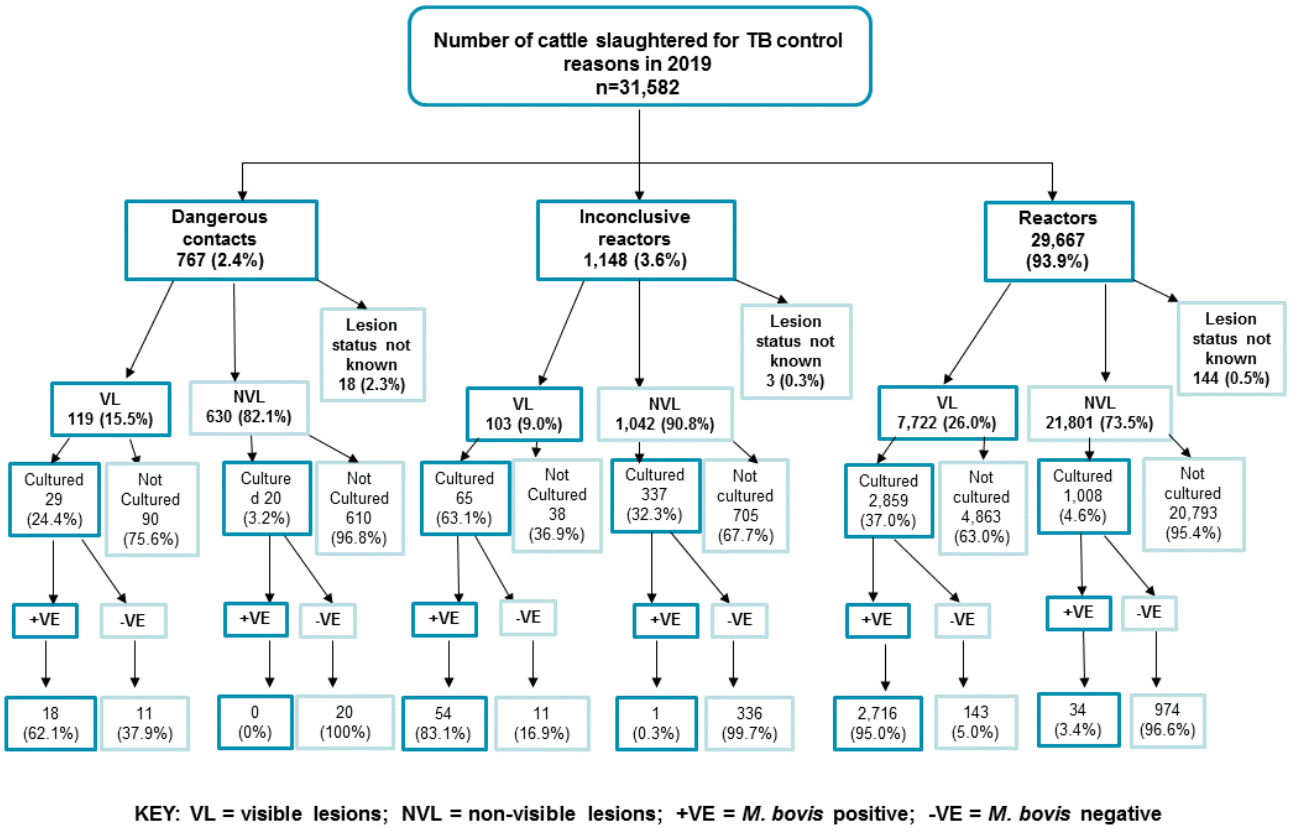
Number of animals removed from TB incident herds

Cattle that test positive for TB must be isolated from the herd and rapidly removed. In 2019, a total of 31,582 cattle were slaughtered for TB disease control purposes, with the vast majority of them being test reactors (93.9%). The remaining 6.1% were removed as inconclusive reactors (IRs) before they could be re-tested, or as dangerous contacts (Figure 3.4.9a).

Virtually all cattle slaughtered for disease control purposes have a *post mortem* examination, but not every TB-affected animal is sampled for laboratory culture and isolation of *M. bovis*. Confirmation of TB infection means the detection of typical lesions at

post mortem examination (visibly-lesioned or VL sample) in a slaughtered test reactor, or identification of *M. bovis* in culture.

In line with previous years, 94% of VL samples from cattle yielded a positive culture result, whereas only 3% of non-visibly-lesioned (NVL) samples did so (Figure 3.4.9a).



KEY: VL = visible lesions; NVL = non-visible lesions; +VE = *M. bovis* positive; -VE = *M. bovis* negative

Figure 3.4.9a Diagram showing the number of cattle that were slaughtered for TB control reasons in 2019 and the number in which infection with *M. bovis* was confirmed

The results of the SICCT skin test can be read at standard (ST) or severe (SEV) interpretation, depending on the circumstances in which the test is being performed. Severe interpretation is used in the vast majority of SITs carried out in TB incident herds. It is designed to identify more positive animals, thus reducing the risk of leaving undisclosed infection in the herd.

Most test reactors were standard-interpretation reactors (50%), while 16% were severe-interpretation reactors and 34% were IFN-γ test positives. IFN-γ tests are compulsory in OTF-W incidents in the Edge Area, LRA and within the HRA where badger control is in operation. A quarter of all cattle slaughtered for TB control reasons in the HRA were IFN-γ test positive animals (26%). In the Edge Area and LRA, IFN-γ test positive animals accounted for over half of all cattle slaughtered (55% and 58%, respectively - Figure 3.4.9b).

Slaughtered cattle that went on to be confirmed at *post mortem* (VL reactors or *M. bovis* positive animals) originated as standard-interpretation reactors in 80% of cases.

In England overall, 42% of standard-interpretation reactors were confirmed by visible lesions and/or *M. bovis* culture positive results. For severe-interpretation reactors, the proportion confirmed as *M. bovis* positive was 14%, and 9% for IFN-γ test positive animals.

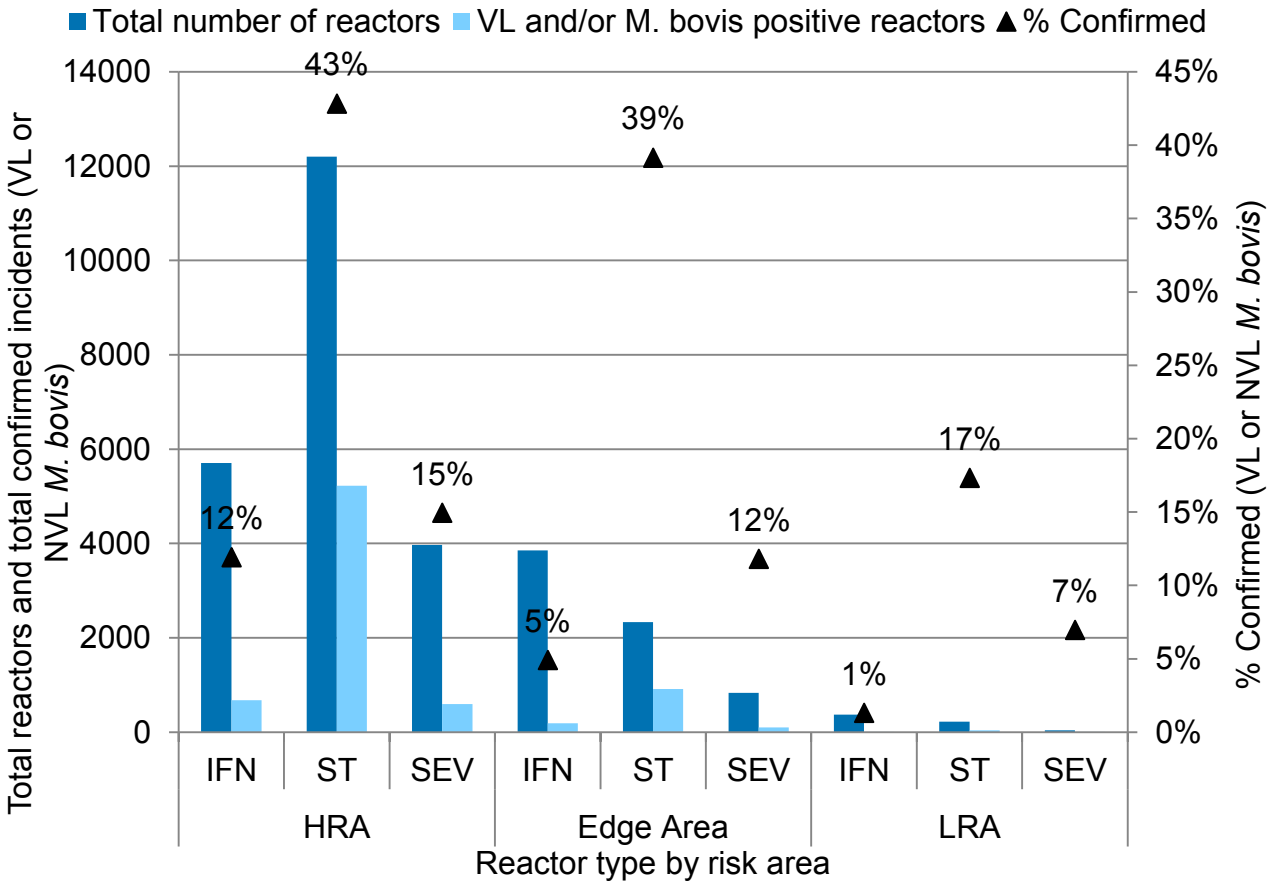


Figure 3.4.9b Number of reactors and total animals removed with *post mortem* evidence of *M. bovis* infection (VL reactors and/or culture-positive animals), by reactor type (IFN-γ, standard and severe interpretation) and risk area

In 2019, the median number of reactors removed per incident was three, an increase on 2018 (two). The mean number of test reactors removed (including IFN-γ test positive animals) in the HRA per TB incident was around six from 2009 to 2014. It has since increased to almost 10, by the end of 2019. Figure 3.4.10a shows the moving average (mean) number of reactors removed in each risk area. There has been greater fluctuation in the Edge Area, which showed a peak in 2015 and has since risen to over 10 since 2018. There are very few incidents in the LRA so the mean shows greater variability.

Of the TB incidents that closed in 2019, 312 had no reactors (Figure 3.4.10b). These were either incidents identified at the slaughter house, or by two or more inconclusive reactors, where subsequent testing in the herd revealed no further reactors Sixty-seven percent of TB incidents in England had two or more reactors, largely driven by the Edge Area, but

also the HRA (71% and 67% respectively). In the LRA, the proportion was 40% (Figure 3.4.10b).

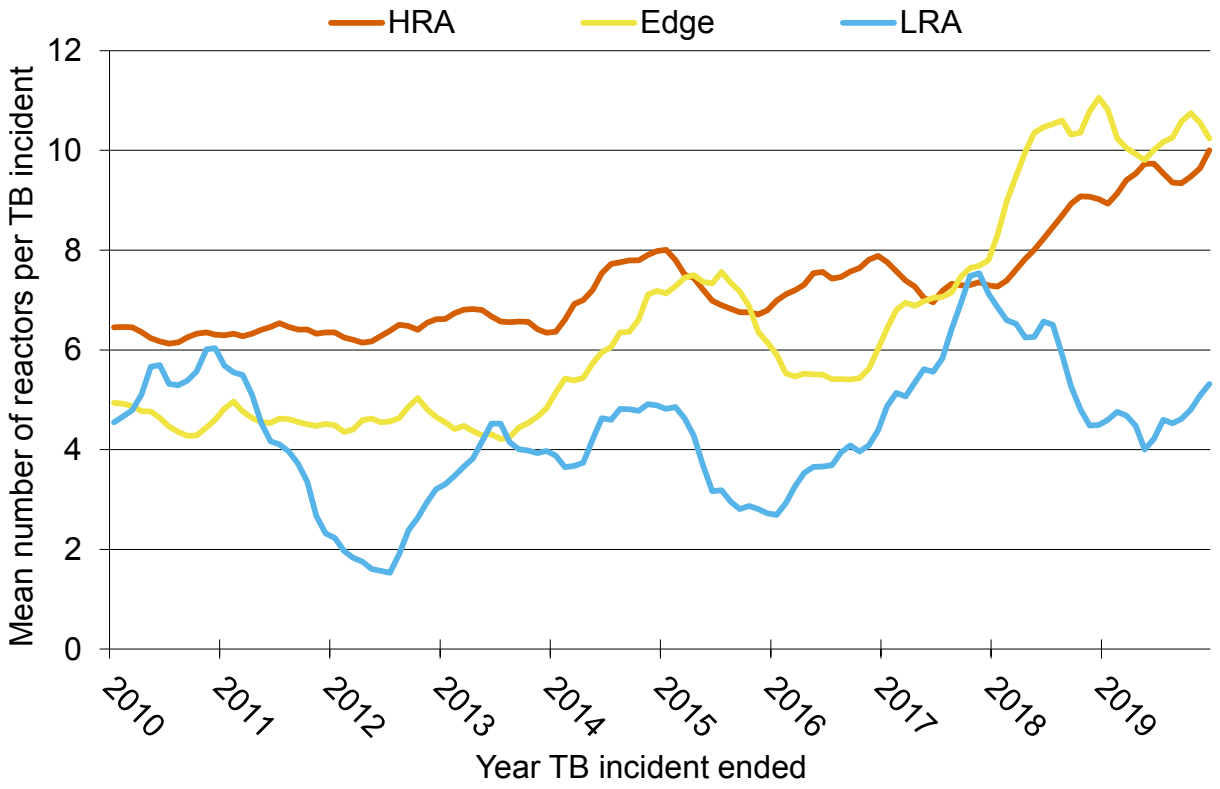


Figure 3.4.10a Rolling mean total number of test reactors taken per TB incident that closed between January 2010 and December 2019, by risk area (12-month moving average)

- The mean total number of test reactors removed in the HRA per TB incident was around six from 2009 to 2014 and has since risen to close to 10 reactors.
- There has been greater fluctuation in the Edge area, which showed a peak in 2015 and has since risen to over 10 since 2018.
- There are very few incidents in the LRA, so the mean shows greater variability (between 4 and 5 in 2019).

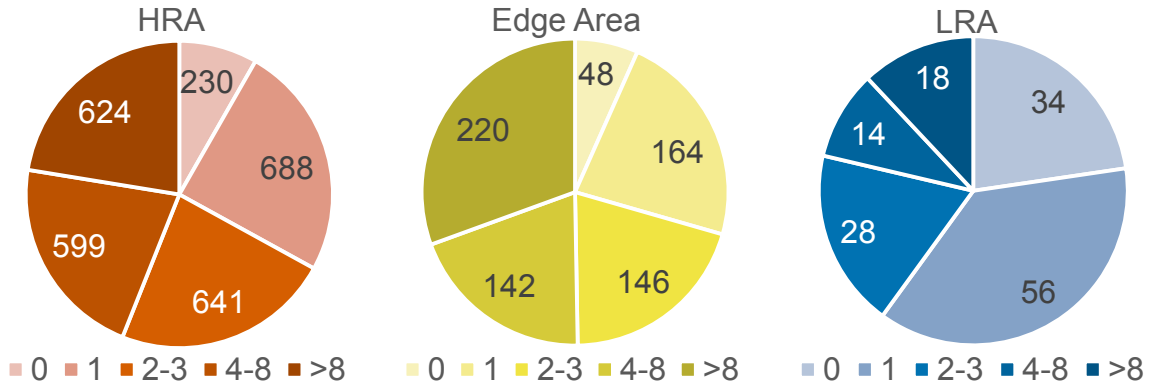


Figure 3.4.10b Number of reactors per TB incident that closed in 2019, by risk area

The frequency of TB incidents for each category of reactor numbers is specified in each pie

- In the HRA, incidents are spread fairly evenly between all reactor categories, with the exception of 0 reactors, which has fewer incidents.
- In the Edge Area, incidents with more than eight reactors were most common.
- In the LRA, incidents with just one reactor were most common.

In 2019, there was a 5% decrease in the number of cattle removed from herds across England compared to 2018. The majority of the 31,582 cattle removed from herds were reactors taken from the HRA (n=21,997, 74%), which has been the pattern over the last ten years (Figure 3.4.11). However substantial numbers are also taken as 1xIRs or DC s (815 in the HRA) and 2xIR or 3xIRs (568 in the HRA). There has also been a steep increase in the number of reactors removed from herds in the Edge Area, jumping from 2,609 in 2013 to over 7,000 in 2019, reflecting the impact of more stringent controls in this area.

Two consecutive skin herd tests with negative results at severe interpretation are required before restrictions can be lifted from any incident herd in the HRA (since April 2016) and the Edge Area (since 2013). This means that some IRs disclosed at standard interpretation may be removed as reactors when severe reinterpretation is applied. This increases the number of reactors, reducing the risk of leaving residual infection in the herd. Furthermore, compulsory application of IFN-γ test in all OTF-W incidents in the Edge Area was rolled out from 2014.

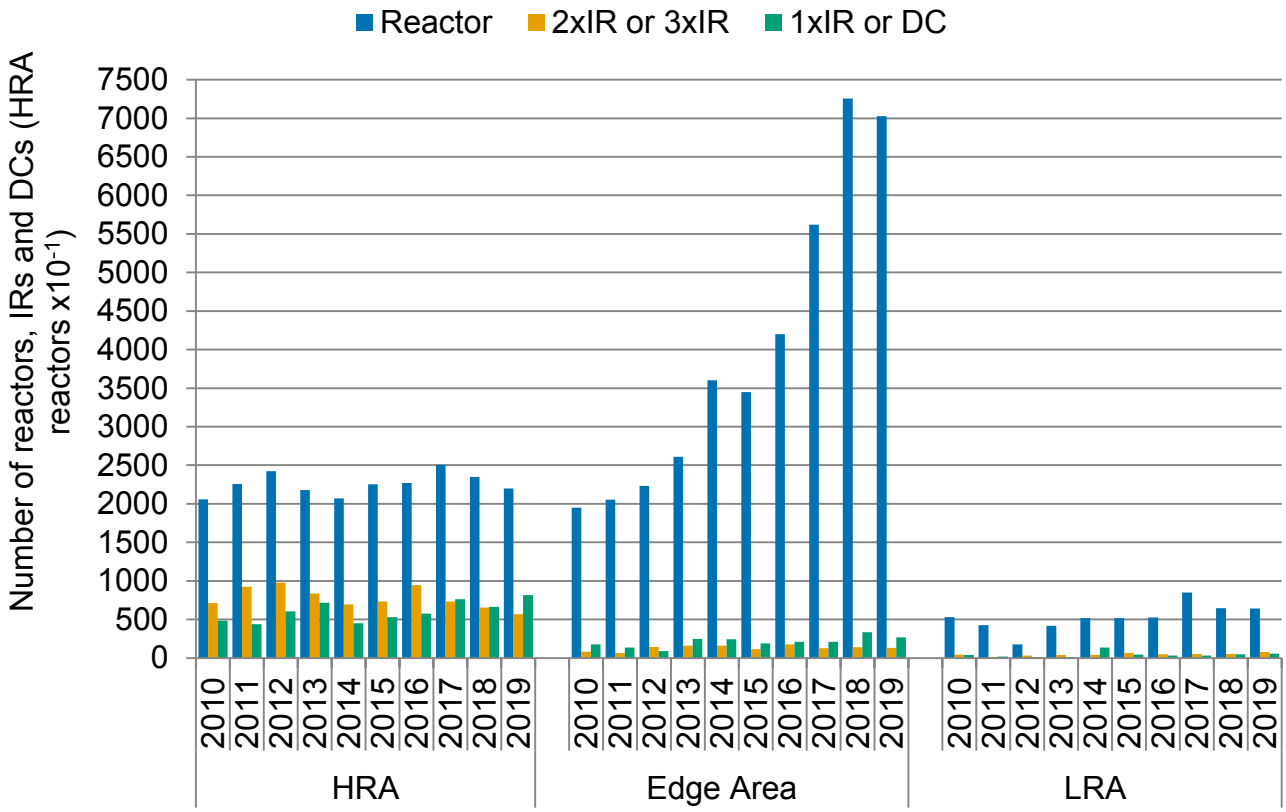


Figure 3.4.11 Number of reactors, inconclusive reactors and direct contacts removed from herds between 2010 and 2019, by risk area (note HRA reactors presented as a tenth of their true value)

- Most cattle removed over the past ten years are reactors taken from the HRA, with substantial numbers also removed as DCs or IRs.
- The number of cattle removed as reactors in the Edge Area has increased substantially since 2013, when more stringent controls were introduced.

4. The TB epidemic in England's risk areas

4.1 Epidemiology of TB in the High Risk Area

- Within the HRA, there was a significant reduction in TB herd incidence in 2019 compared to 2018 (16.9 TB incidents per 100 herd years at risk in 2019, 18.5 in 2018, $p<0.001$).
- The total number of TB incidents in 2019 (2,501) also decreased significantly compared to 2018 (2,761, $p=0.006$).
- TB incidence per 100 herd-years at risk decreased in almost all HRA counties in 2019, however the level of incidence varied considerably between counties. Wiltshire and Avon had the highest incidence of 22 and 20 incidents per 100 herd years at risk, respectively. The lowest incidence rates were observed in Dorset, Somerset and the West Midlands.
- The overall average monthly prevalence for the HRA decreased from 11.5% in 2018 to 10.5% in 2019, however this was not statistically significant ($p=0.287$). As with incidence, prevalence rates varied between counties. The highest herd prevalence rates in 2019 were seen in Wiltshire and Devon, both with 12% of herds restricted due to a TB incident at the end of the year. The lowest prevalence rate was seen in the West Midlands (1%).
- Devon and Cornwall had the highest population of herds in the HRA and accounted for around 38% of all new TB incidents in 2019.
- The duration of TB herd incidents varied between counties. Counties experiencing on average the longest TB incidents (for incidents that ended in 2019) included Wiltshire (median duration of 230 days), Dorset (226 days) and Devon (222 days).
- For persistent TB incidents still ongoing at the end of 2019 (duration >550 days), most were located in Devon and Cornwall. The highest proportion of cattle herds with ongoing persistent incidents was in Dorset (18%).
- The HRA (n=117,381) accounted for 48% of all IFN-γ tests carried out in England in 2019, an increase from 43% in 2018. Over 35% (n=41,480) of these IFN-γ tests were carried out in Devon alone.
- Ten new Badger Control Programme areas were authorised in the HRA in 2019. Overall, 40 areas underwent intensive or supplementary licensed badger culling in the HRA in 2019. Furthermore 448 badgers received the licensed injectable BCG vaccine in 2019.

Geographical coverage of the HRA

The HRA extends from the western areas of the Midlands to the south and west of England (excluding the Isles of Scilly) (Figure 4.1.1). In January 2018, the boundary of the HRA was redefined to exclude five counties that were previously divided between the HRA and Edge areas. All of these counties (Cheshire, Derbyshire, East Sussex, Oxfordshire and Warwickshire) were moved fully into the Edge Area, reducing the size of the HRA. Data reported in this chapter is for the 12 counties that constituted the HRA from 2018 onwards, unless otherwise stated. TB trends over time compare TB incidents in the post-2018 HRA counties only, and do not include incidents from part-counties that are now Edge Area.

Defra's overall objective for the HRA is to gradually reduce TB incidence following a period of stabilisation.

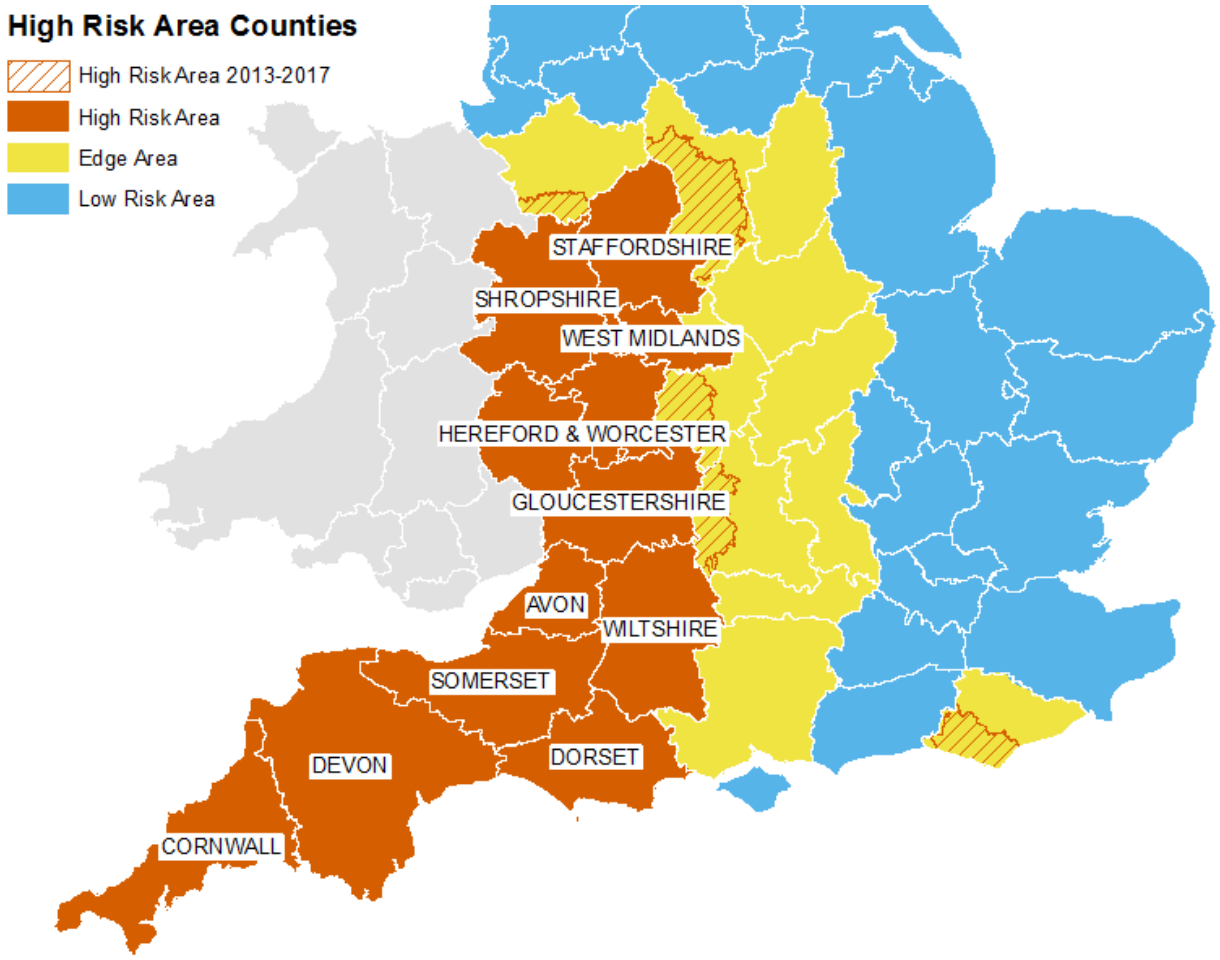


Figure 4.1.1 HRA county map, showing the former HRA sections of five counties with 'split' status between 2013 and 2017

In this chapter, TB incidents are mostly reported with no distinction between status (culture confirmed (OTF-W) or strongly suspected (OTF-S)). This is due to the high positive predictive value of the skin test in the HRA, which indicates that over 90% of all skin test reactors are truly infected (see Explanatory Supplement for further details).

The herd incidence rate in the HRA in 2019 was 16.9 TB incidents per 100 herd years at risk (100HYR). The incidence rate decreased significantly by 8.8% (p value < 0.001) in 2019, compared to 2018 (18.5 incidents per 100HYR) (Table 4.1.1).

Table 4.1.1 Table of headline figures for the High Risk Area for TB in England

Year	Total number of new TB infected herds (TB incidents)[1]	Incidence rate[2]	Median duration of TB incident (days) (interquartile range)[3]	Prevalence (average monthly)[4]
2019	2,501	16.9	205 (166 to 306)	10.5
2018	2,761	18.5	202 (166 to 320)	11.5
Change (%)	-9.4	-8.8	+1.5	-9.0
Statistical significance	(p=0.006)	(p<0.001)	(p=0.331)	(p=0.287)

[1]The change in total number of incidents was compared using a chi-squared test.
[2] New TB infected herds per 100 herd-years at risk (100HYR). The incidence rate ratio was used to compare the difference between 100HYR incidence in 2018 and 2019.
[3]The K-sample equality-of-means test was used to compare the median duration of TB incidents (days).
[4]Average monthly prevalence between 2018 and 2019 was compared using a z-test.

Number of new TB infected herds

The number of new TB infected herds is important in terms of resource planning and number of businesses impacted. Figure 4.1.2 shows the total number of new TB incidents in 2019, split by OTF-W and OTF-S status in each county. The greatest number of incidents were disclosed in Devon, where 25% of HRA TB incidents occurred in 2019. The highest proportion of OTF-W incidents were disclosed in Gloucestershire and Hereford and Worcester (both 75%), followed by Shropshire (74%) (Figure 4.1.2).

With the exception of Avon, the number of new TB incidents decreased in every HRA county in 2019 compared to 2018. For Cornwall, Devon, Dorset and Somerset, the number of new TB incidents has decreased for three or more consecutive years (Figure 4.1.3).

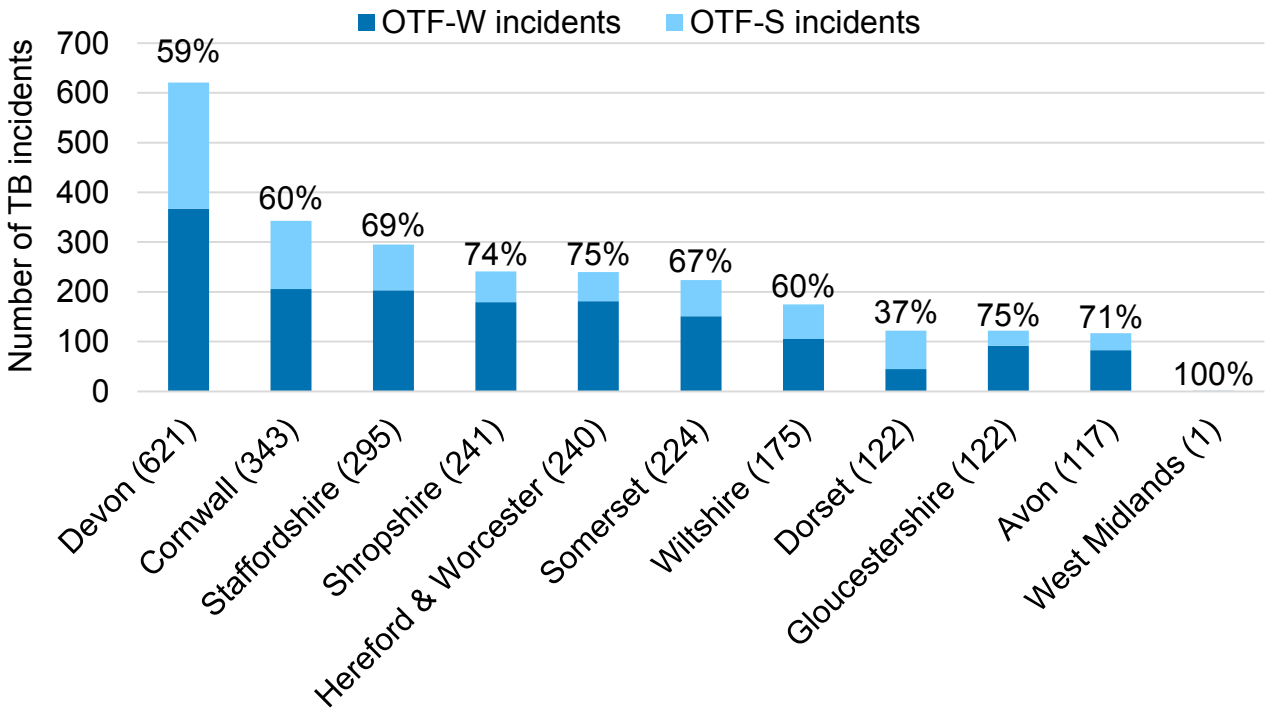


Figure 4.1.2 Number of new TB incidents and confirmed new TB incidents (OTF-W) in HRA counties in 2019. Counties ranked by total TB incidents. Percentage totals above each column represent % OTF-W

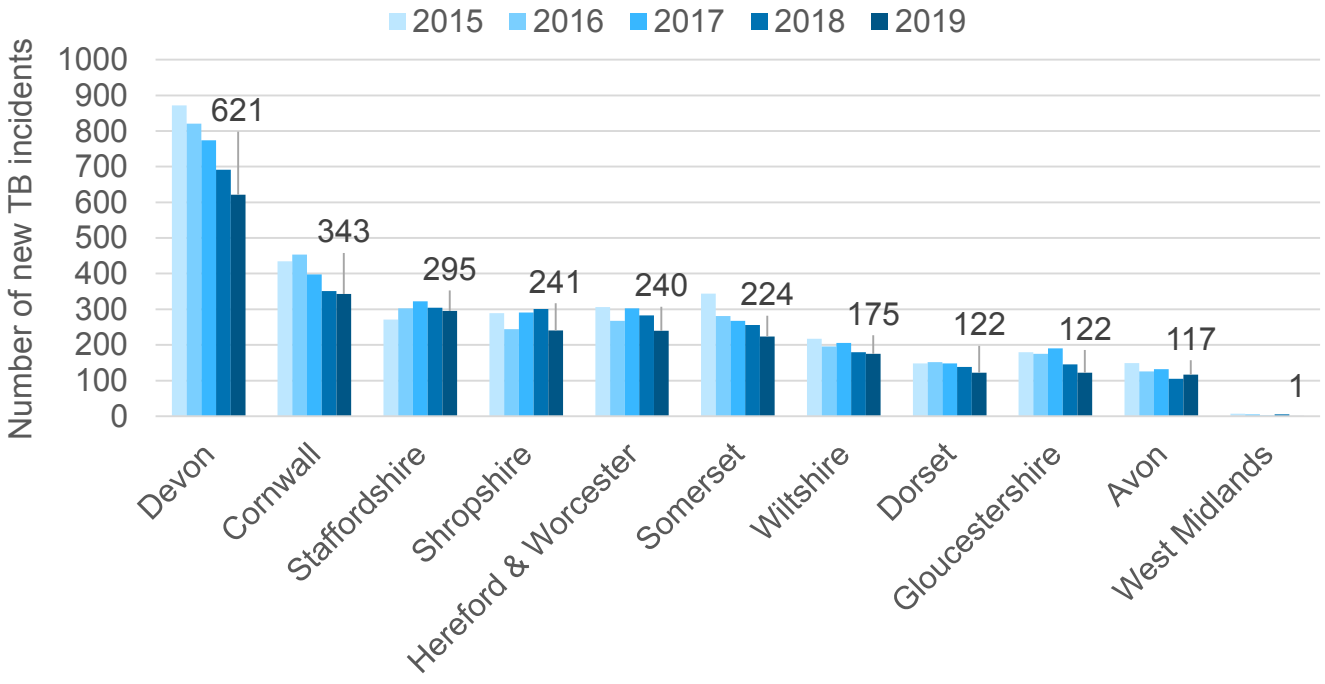


Figure 4.1.3 Annual total number of new TB incidents (OTF-W and OTF-S) by HRA county 2015 to 2019 (2019 incidents labelled on chart)

- With the exception of Avon, the number of new TB incidents fell in all HRA counties in 2019, compared to 2018.

County level TB incidence rate

The preferred measure of disease occurrence is incidence per 100 HYR, which reflects the rate at which new TB incidents are occurring in the population of herds at risk. Figure 4.1.4 ranks counties in the HRA by their incidence rate since 2014.

TB incidence decreased in ten of the eleven HRA counties from 2018 to 2019. The highest incidence was observed in Wiltshire and Avon (22 and 20 TB incidents per 100 HYR respectively). Gloucestershire, Hereford & Worcester and Shropshire all had a 15% reduction in incidence in 2019 compared to 2018, however these changes were not statistically significant ($p>0.05$). A significant inter-year decrease (-10%) was observed in Devon only, from 20.6 to 18.1 incidents per 100 HYR ($p=0.019$).

The only county showing an increase in incidence in 2019 compared to 2018 was Avon. . All other HRA counties had decreased incidence rates in 2019 (Figure 4.1.4).

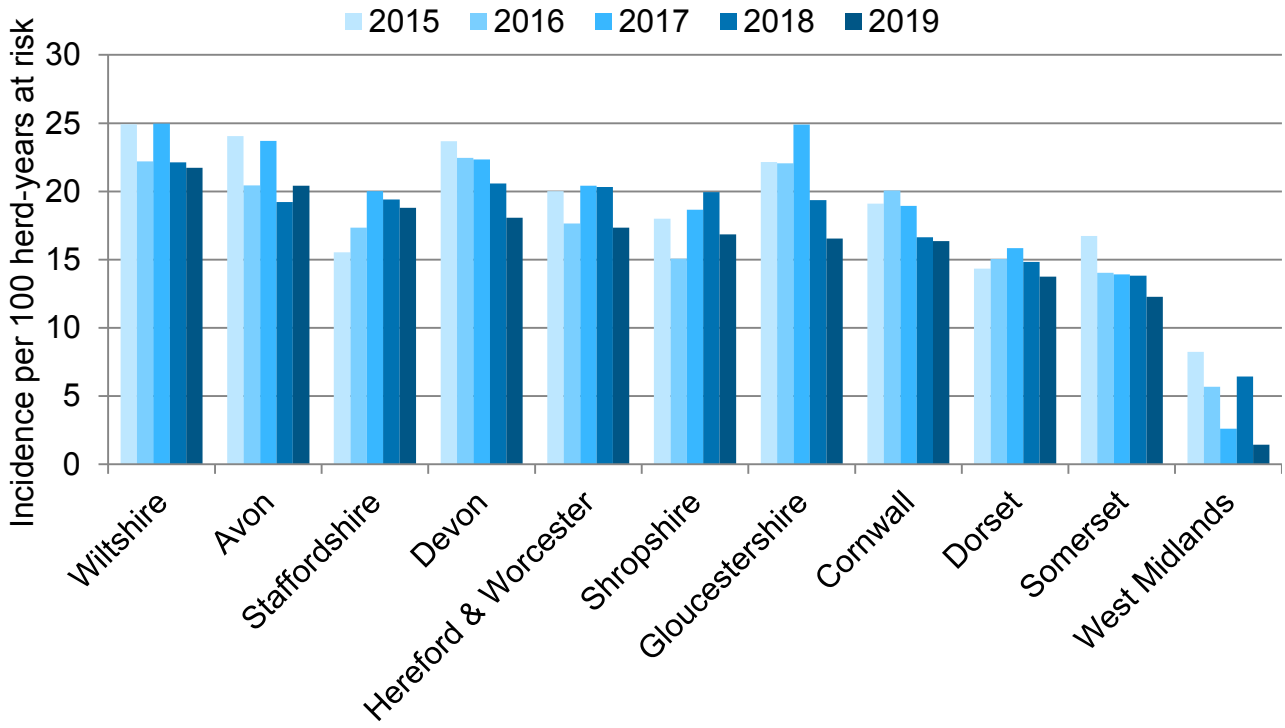


Figure 4.1.4 Incidence rate (per 100 herd-years at risk) from 2014-2019, by HRA county. Counties ranked by incidence in 2019.

- With the exception of Avon, the incidence rate fell in all HRA counties in 2019, compared to 2018.
- Devon, Cornwall, Dorset and Somerset have all experienced a falling TB incidence rate since 2016.

County level end-of-year prevalence

End of year herd prevalence figures for 2019 are provided in Figure 4.1.5. Prevalence reflects the proportion of herds that are infected with TB at a given point in time. Differences in prevalence reflect variation in incidence, the duration of TB incidents, and

the timing of the start of the incident. Further notes on the methodology of incidence and prevalence measures are described in the Explanatory Supplement.

Herd prevalence in 2019 declined in almost all counties of the HRA compared to 2018. As with incidence, Wiltshire and Avon had the highest prevalence in 2019 (both 12%). The lowest prevalence in 2019 was seen in Dorset (7%) and the West Midlands (0%). (Figure 4.1.5).

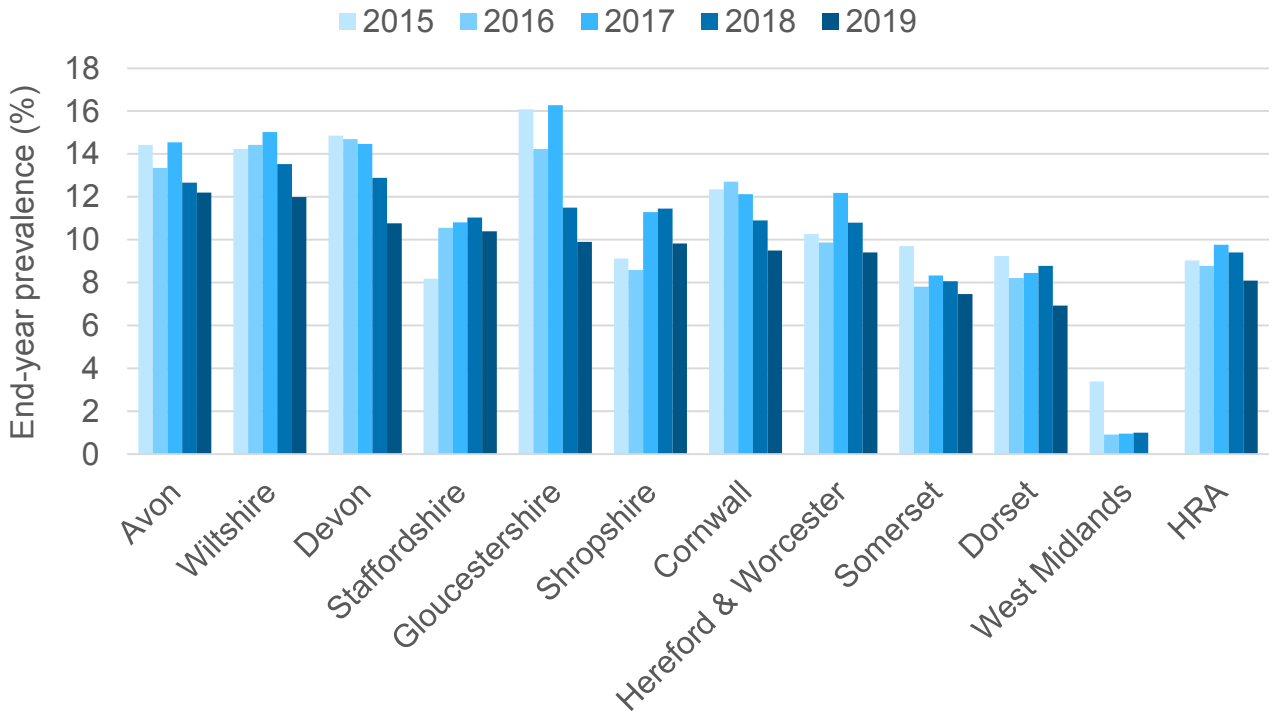


Figure 4.1.5 End of year prevalence from 2015-2019, by HRA county. Counties ranked by decreasing order of prevalence in 2019

- End of year prevalence decreased in every HRA county in 2019 compared to 2018.

Demographics and influence on TB

The risk of TB infection has consistently been shown 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[2]). The total number of cattle is a crude demographic measure, as the cattle distribution and management within herds can influence the risk of disease. Generally, the more cattle within a county, the more TB incidents, but there are exceptions (Figure 4.1.6, also see 3.2.1a and b, Chapter 3.2 Characteristics of herds found infected with TB).

In the HRA, Devon had 25% of all the HRA TB incidents, and also 25% of all HRA cattle (23% of all herds). This was followed by Cornwall, with 14% of TB incidents and 13% of cattle (14% of herds). In contrast to this pattern, despite Somerset having 12% of HRA

[2] Broughan, J. M., et al. (2016). "A review of risk factors for bovine tuberculosis infection in cattle in the UK and Ireland." Epidemiol Infect 144 (14): 2899-2926.

herds and 13% of cattle, only 9% of the TB incidents were disclosed in the county (Figure 4.1.6).

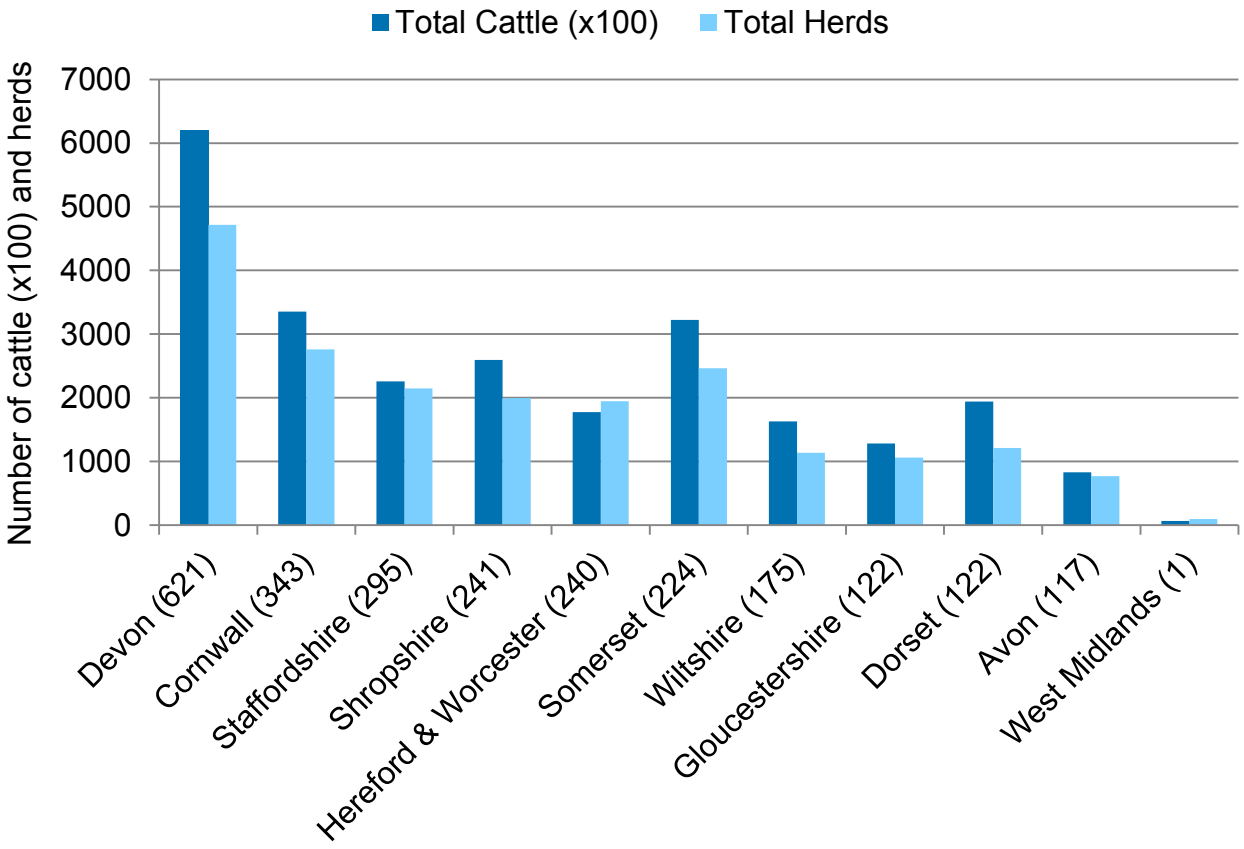


Figure 4.1.6 Total Number of cattle (x100) and herds in HRA counties in 2019. Counties ranked by new TB incident totals (in parenthesis next to county name).

- As expected, counties with larger numbers of cattle and herds, tended to have a greater number of TB incidents.
- Somerset and Dorset appear to have fewer TB incidents than may have been expected, according to the number of cattle and herds in the regions.

Figure 4.1.7 shows the relative numbers of herds, and proportions of large herds in the different counties of the HRA in 2019, ranked by the proportion of large herds (>300 cattle). Although analyses confirm that larger herds are more at risk of disease, the presence of more large herds alone cannot explain the incidence rate in the HRA. Some HRA counties with a high proportion of large herds have a relatively low incidence rate.

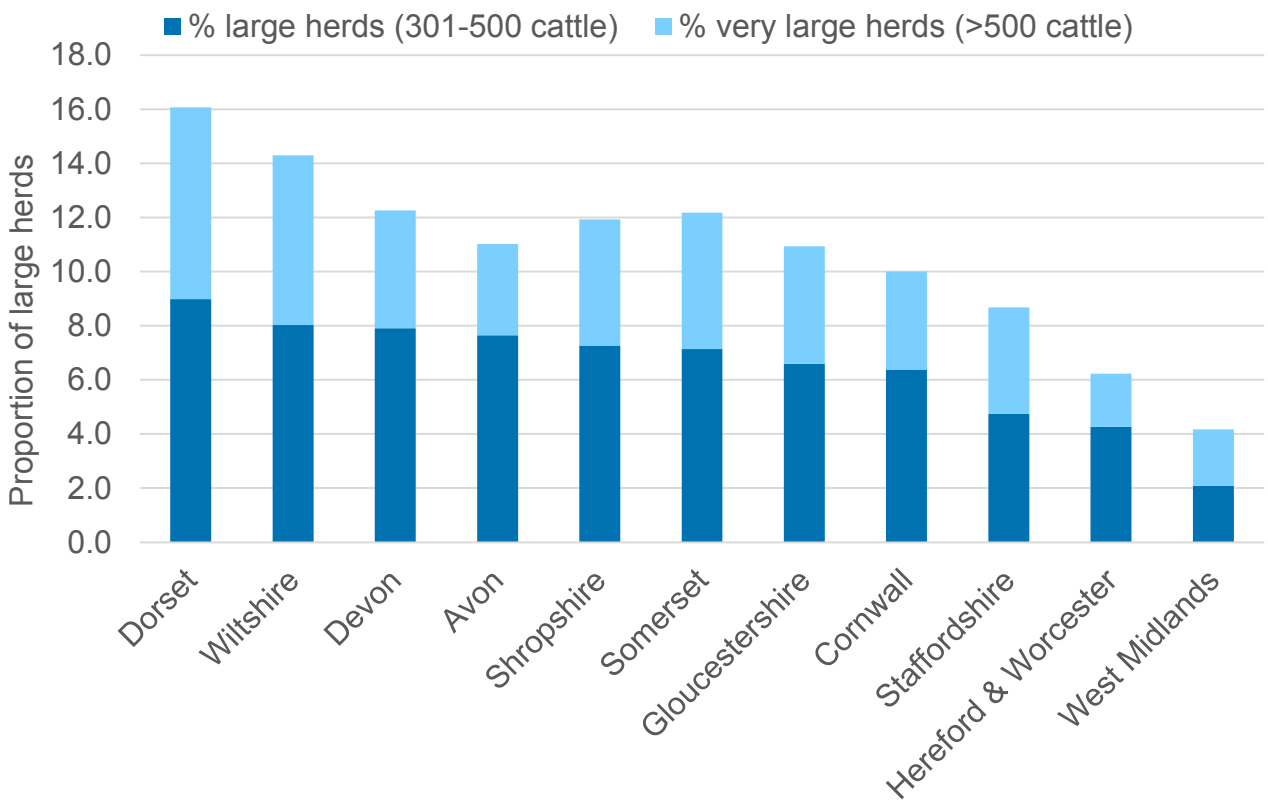


Figure 4.1.7 Proportion of large herds, by HRA county. Counties ranked by herds with 301-500 animals

- Dorset had the highest proportion of herds with greater than 300 cattle (16%) followed by Wiltshire (14%).
- Hereford and Worcester (6%, 121 herds) and West Midlands (4%, 4 herds) had the lowest proportion of herds with over 300 animals.

TB incident duration and persistence

A total of 2,782 TB incidents in the HRA ended in 2019. The longest median duration was observed in the West Midlands (587 days), however this was based on only two herds that closed in 2019. For the rest of the HRA, herds with longer incident durations were located in Wiltshire (median 230 days), Dorset (226.5 days) and Devon (222 days) (Figure 4.1.8).

The median duration of confirmed (OTF-W) incidents was longer compared to the median for all TB incidents in all HRA counties (Figure 4.1.8). This is likely to be a result of compulsory interferon-gamma (IFN-γ) testing for OTF-W herds in some parts of the HRA, which can delay a return to OTF status.

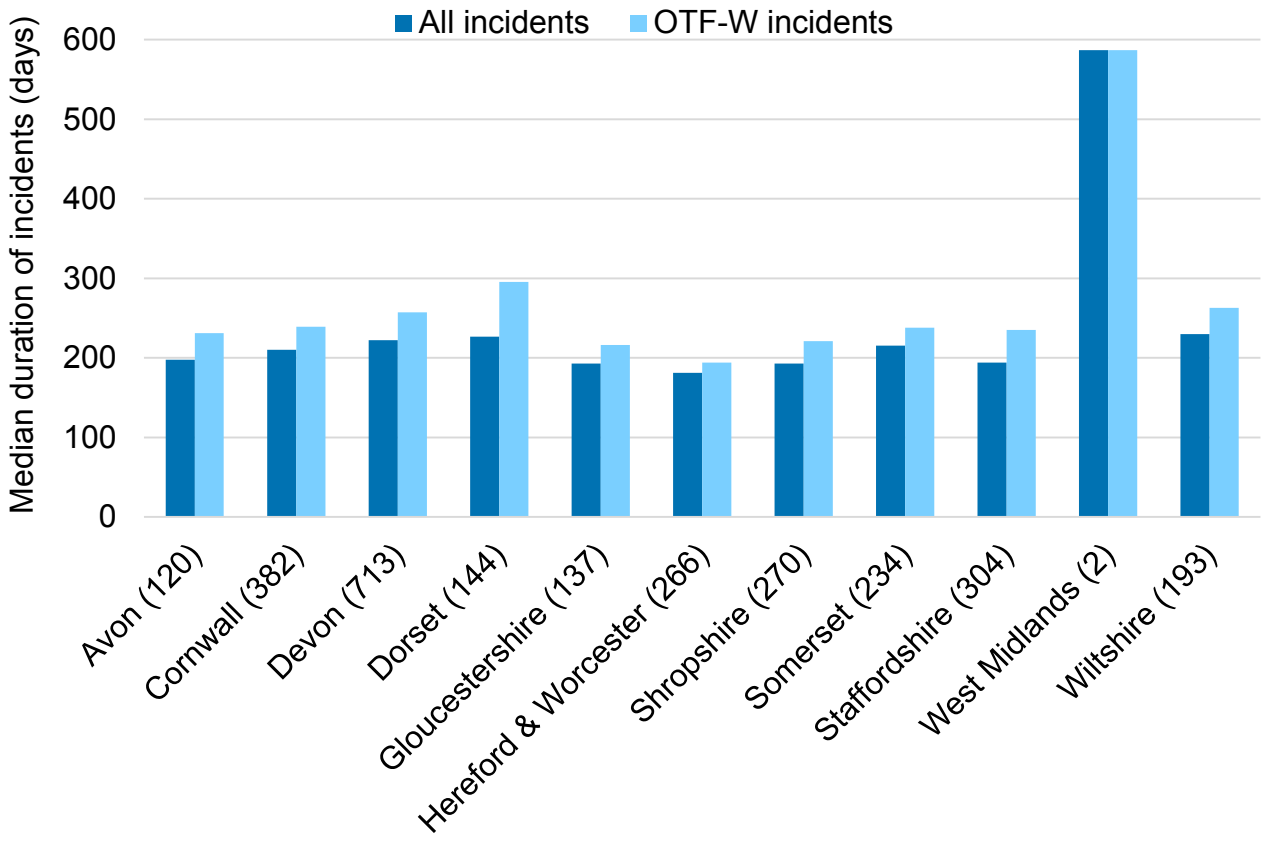


Figure 4.1.8 Median duration (days) of incidents that ended in 2019, by HRA county
Counties ranked alphabetically (number of incidents in parenthesis)

- In all counties duration of herds under movement restrictions was higher in confirmed (OTF-W) incidents compared to total TB incidents.
- Excluding West Midlands, median duration was highest in Wiltshire (230 days for confirmed TB incidents)

In 2019, 56% of TB incidents in the HRA occurred in herds that had experienced at least one TB incident in the previous three years. This recurrence rate was higher than in the other risk areas in England (Edge Area - 46% and LRA - 11%). Within the HRA, recurrence was highest in Wiltshire (65%) and Devon (62%), and lowest in Somerset (51%) and the West Midlands (0%, none of two TB incidents) (Figure 4.1.9).

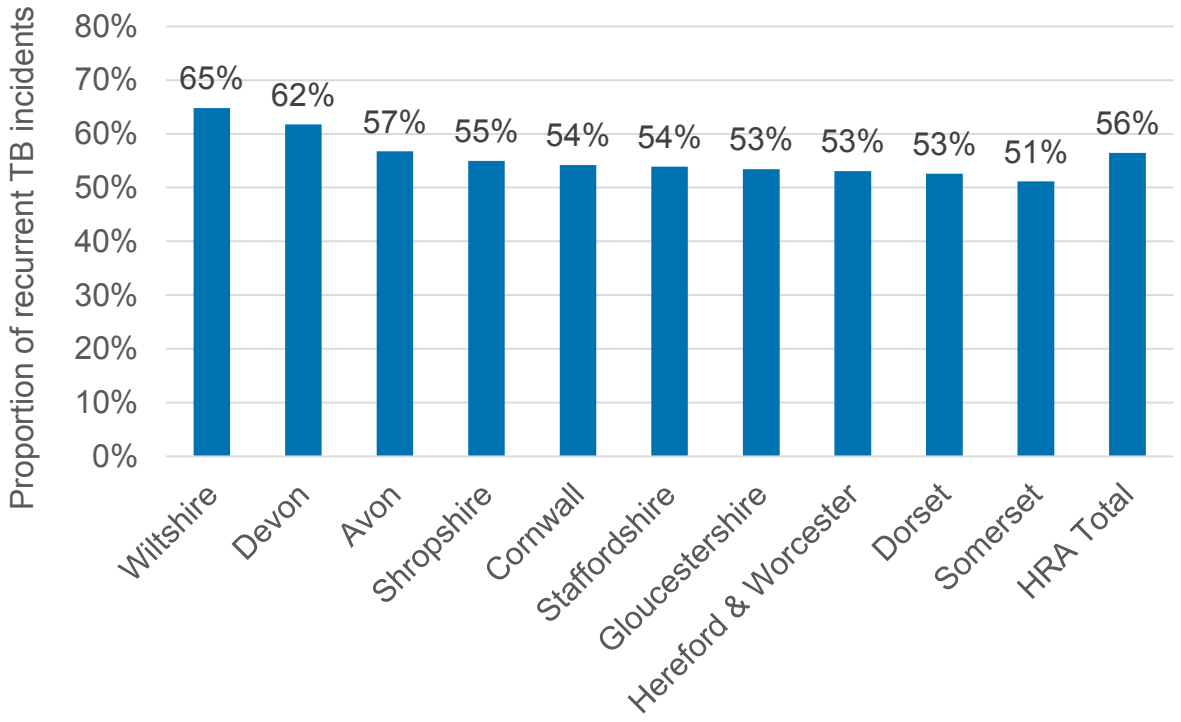


Figure 4.1.9 Proportion of TB incidents in 2019 in herds that had experienced any TB incident in the previous three years, by HRA county

The high positive predictive value of the skin test in the HRA together with the need to intensify the efforts to tackle disease in this area and reduce recurrence, justifies the application of two successive short interval tests (SITs) at severe interpretation at the beginning of any new incident in the HRA irrespective of *post mortem* results. This, along with the increased use of the IFN-γ blood test in the HRA since April 2017, will help reduce recurrence due to recrudescence and may also reduce the severity of incidents. Other measures implemented in the HRA may also contribute to reducing recurrence, for example encouraging good biosecurity and badger control as both target recurrence due to reinfection from wildlife.

Incidents lasting for more than 550 days are deemed to be persistent and affected herds are eligible for enhanced management procedures (Figure 4.1.10). During 2019, 219 persistent incidents were resolved in the HRA, however 192 were still ongoing at the end of the year.

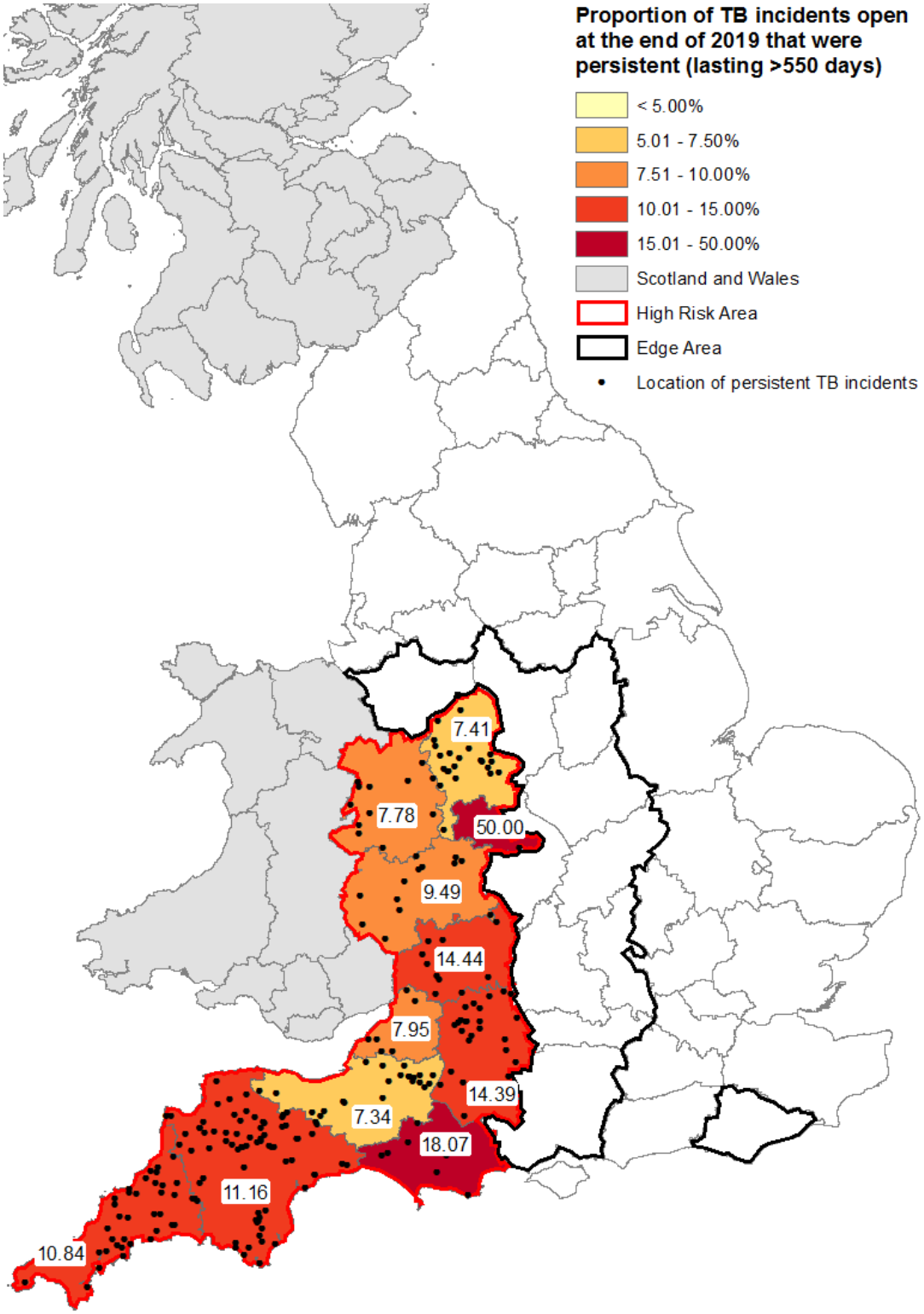


Figure 4.1.10 Distribution of persistent TB incidents (duration over 550 days) that were still ongoing at the end of 2019 in the HRA

- In 2019, a large number of persistent TB incidents were located in Devon and Cornwall. However those counties had more ongoing TB incidents overall.
- The proportion of persistent incidents compared to all TB incidents in a county was highest in Dorset, Gloucestershire, West Midlands and Wiltshire.

TB surveillance and incident detection

For a detailed description of the test types included in each of the four TB surveillance streams explored in this chapter, see Chapter 3.3 Finding Infected herds. Figure 4.1.11 shows the proportion of TB infected herds disclosed by each surveillance stream and county. In the HRA overall, the highest proportion of TB incidents were disclosed by Area & Herd Risk tests (45%). This was the leading surveillance type in all counties, with the exception of Somerset, where an equal number of TB incidents were disclosed by both Area & Herd Risk and Routine testing (86 each).

Routine annual surveillance tests disclosed the next highest proportion of TB incidents in the HRA overall (34%), with the highest proportion of incidents disclosed in West Midlands (1 out of 1 TB incidents, 100%), followed by Dorset (41%). Trade & other surveillance tests led to the fewest detections of TB in the HRA in 2019, with under ten per cent of TB incidents in all HRA counties, with the exception of Avon and Gloucestershire (12% and 13% respectively) detected in this way (Figure 4.1.11).

Overall, backward tracing herd tests were the most efficient tests at detecting incidents within the Area and Herd Risk surveillance stream in the HRA (30 incidents per 100 herd tests). This was second to post-incident tests, carried out at approximately six and 18 months after restoration of OTF herd status, which disclosed 19 TB incidents per 100 herds tested in 2019 (Table 3.3.3.a, Chapter 3.3 Finding Infected herds).

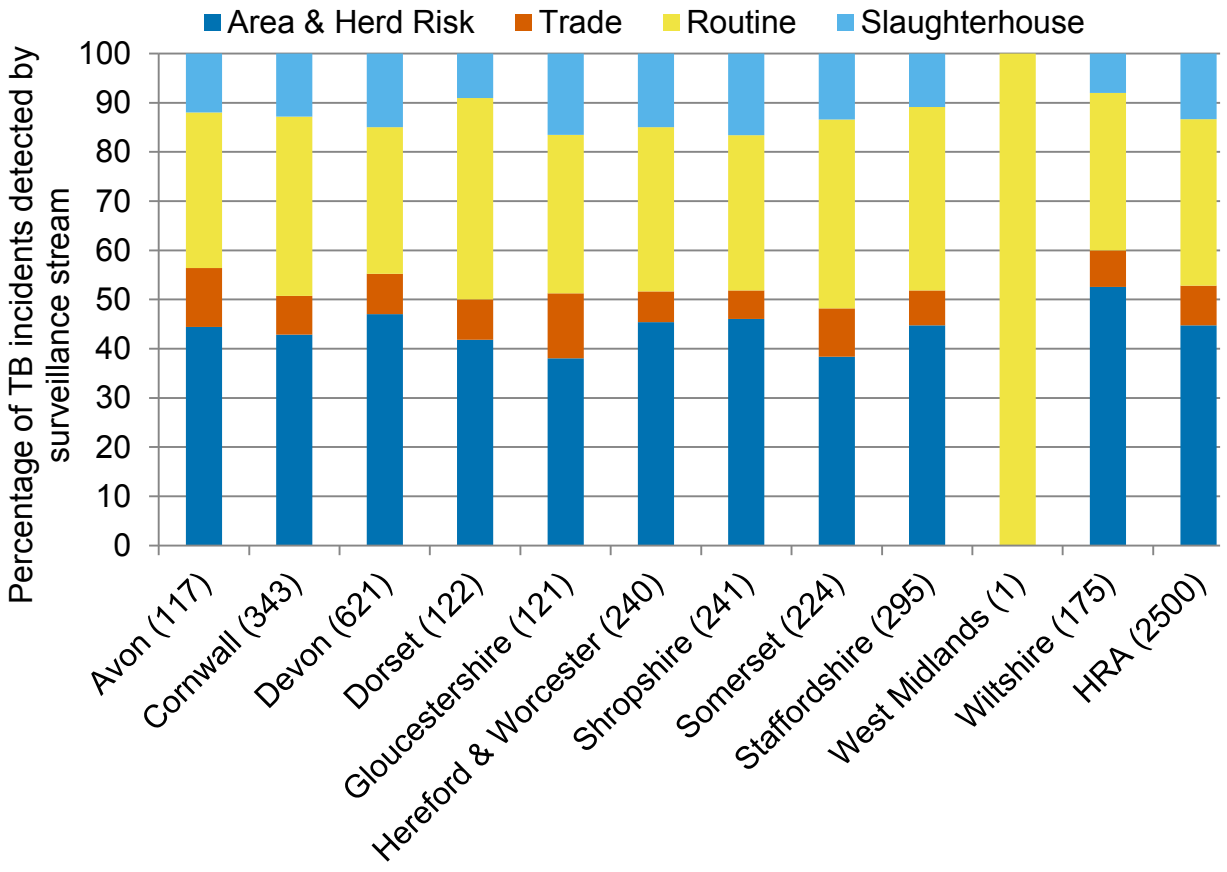


Figure 4.1.11 Proportion of TB infected herds in 2019 in each surveillance stream, by HRA county

In the HRA overall, 14% of all TB incidents and 20% of OTF-W incidents were disclosed through routine *post mortem* meat inspection of cattle in slaughterhouses in 2019. Variation between counties can be seen in Figure 4.1.12. Devon (24%) and Shropshire (22%) detected the highest proportion of OTF-W incidents by SLH surveillance. The lowest rates of OTF-W detection by SLH surveillance were reported in Wiltshire (12%) and Staffordshire (15%).

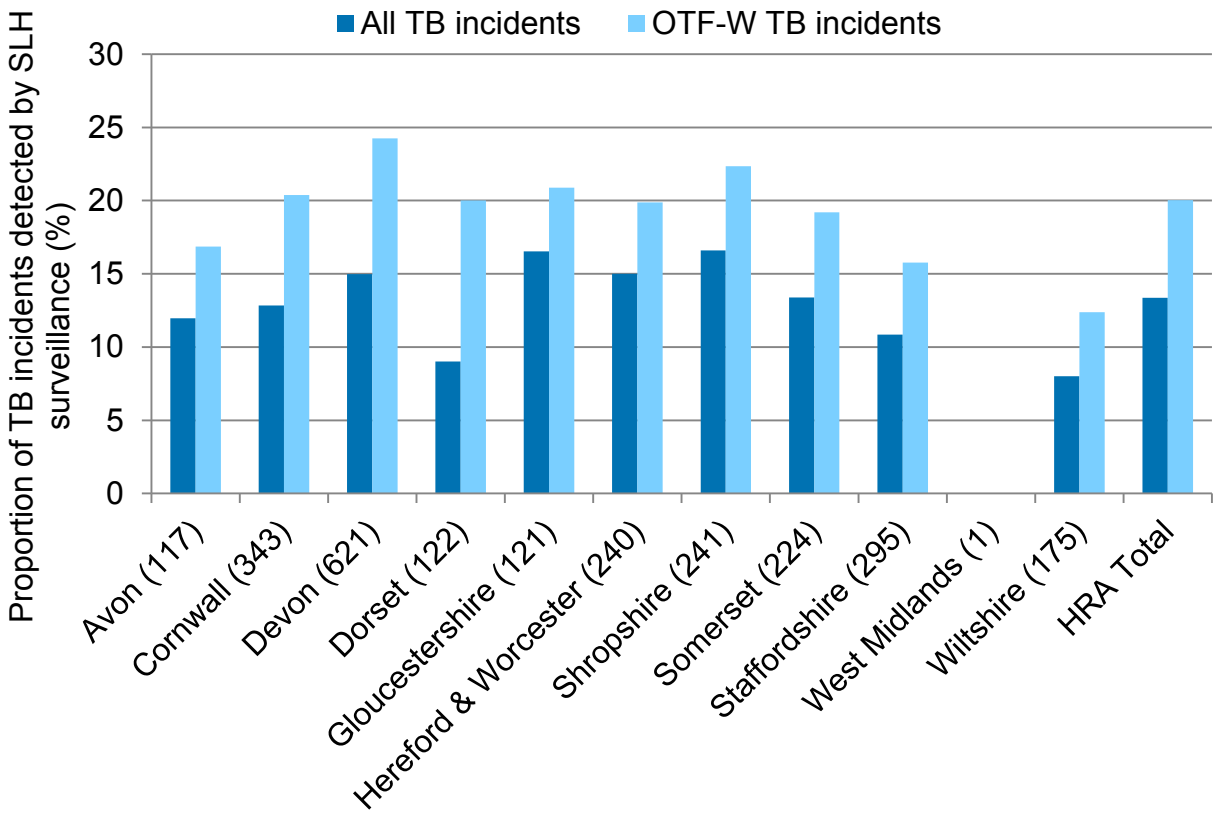


Figure 4.1.12 Percentage of TB incidents disclosed by slaughterhouse surveillance in 2019, for all TB incidents and OTF-W incidents, by HRA county

Number of reactors removed

Overall, 21,876 cattle were slaughtered for TB control purposes in the HRA in 2019. These comprised 16,171 skin test (SICCT) reactors and 5,705 IFN-γ blood test positive animals. The total number of animals removed, and the proportion that were detected by IFN-γ testing, varied by county. Most cattle were removed from herds in Devon (6,121 animals), where 36% of reactors were detected by IFN-γ testing. By far, the county with the highest proportion of reactors detected by IFN-γ testing was Dorset (55%) followed by Wiltshire (38%), Devon (36%) and Gloucestershire (24%) (Figure 4.1.13). No IFN-γ test positives were detected in the West Midlands in 2019.

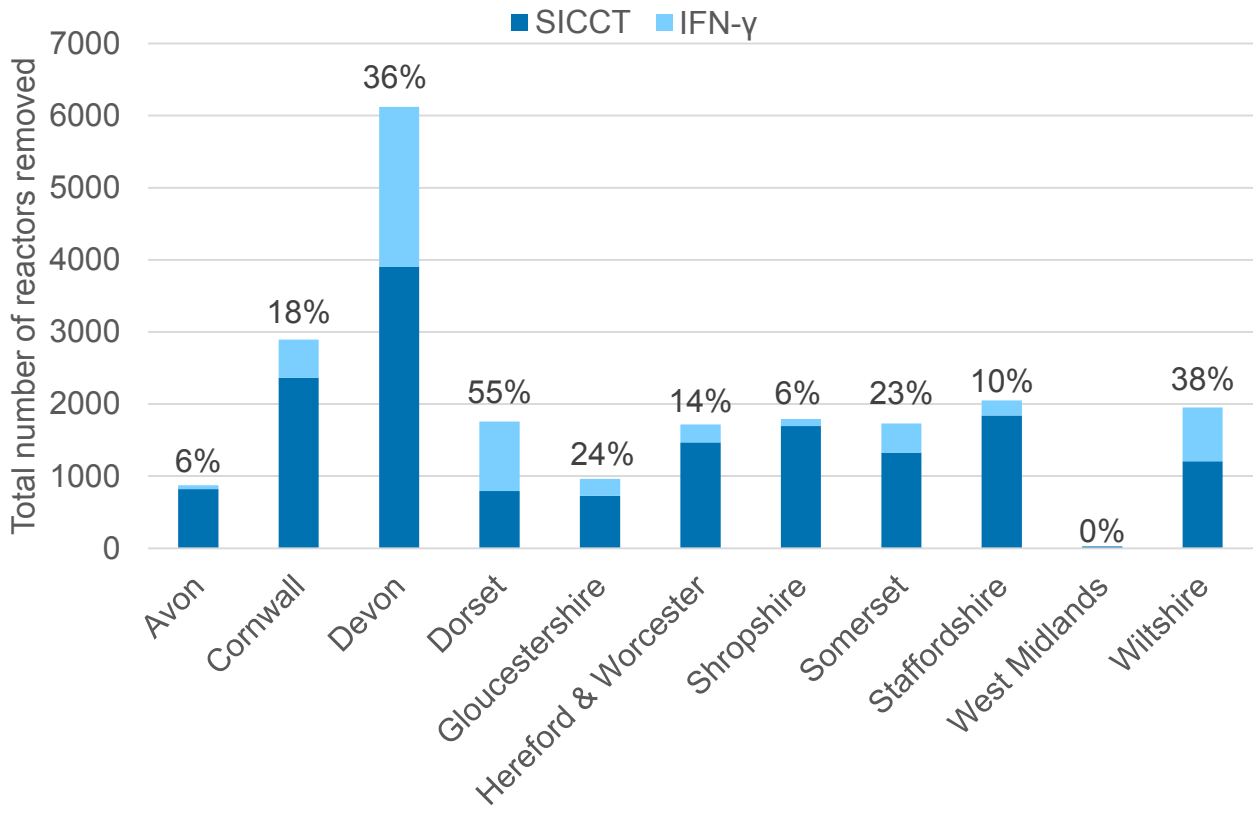


Figure 4.1.13 Number of reactors removed in 2019 due to SICCT and IFN-γ testing, by HRA county. Proportion of reactors removed due to IFN-γ testing above bars.

Use of the IFN-γ test in the HRA

The IFN-γ blood test supplements the SICCT skin test during certain OTF-W TB incidents in the HRA. Supplementary testing is used to maximise the detection of infected cattle and minimise the risk of residual cattle infection when OTF herd status is restored. The total number of IFN-γ tests carried out in the HRA has rapidly increased in recent years. In 2016 just under 6,000 tests were performed. In 2017 this rose to 19,000 IFN-γ tests, increasing four fold to 80,000 in 2018. In 2019, 117,381 animals received an IFN-γ test in the HRA, with 5% identified as positive overall. The proportion of animals testing positive to the IFN-γ test varied by HRA county: from 3% in Avon and Cornwall, to 13% in Staffordshire (Figure 4.1.14).

The application of IFN-γ testing is mandatory for OTF-W TB incidents that occur in BCP areas which have completed two or more culling seasons. In 2019, this applied to parts of Cornwall, Devon, Dorset, Gloucestershire, Herefordshire, Somerset and Wiltshire. Mandatory IFN-γ tests are also used in the enhanced management of persistent incidents where infected herds have been under restriction for more than 18 months. Furthermore, herds with explosive or chronic incidents, which are being considered for whole or partial slaughter, receive mandatory IFN-γ tests. In 2019, additional deployment of the IFN-γ blood test was discretionary in the HRA. This included the application of a flexible extended version of IFN-γ in cases, where co-infection with *Mycobacterium avium*

subspecies *paratuberculosis* (Johne's disease) infection was suspected to interfere with the detection of *M. bovis*-infected animals.

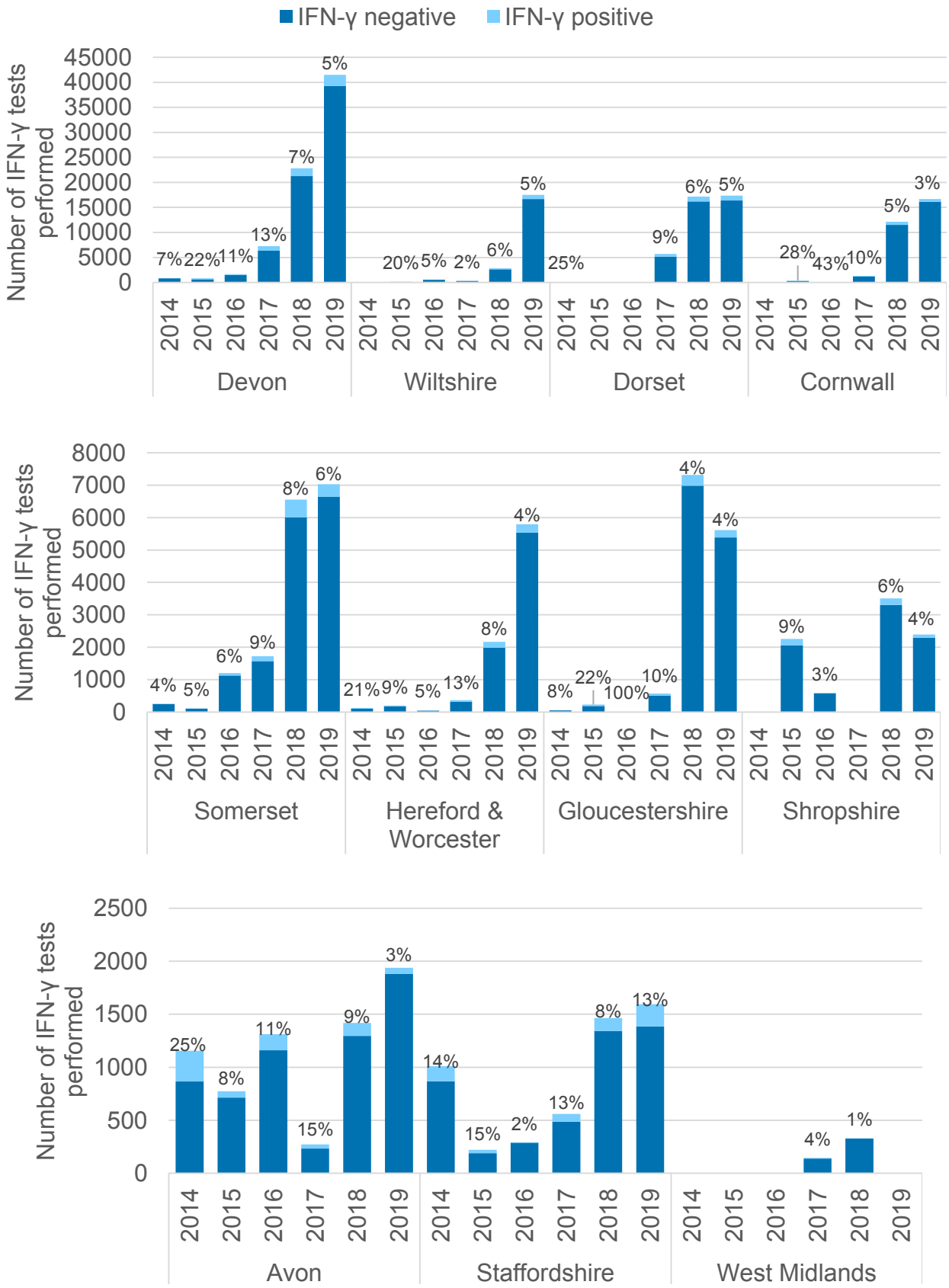


Figure 4.1.14 Number of IFN-γ tests performed and the proportion with a positive result in HRA counties, 2014-2019 (note y axis scale is different between charts)

There is great variability between counties and years. There are several reasons for this. More BCP areas have come into operation in the HRA each year. Furthermore, there is variation in the number of persistent and explosive incidents (where a greater proportion of test positives are usually disclosed) and repeat IFN-γ testing may be carried out in some herds. The number of samples taken in each TB incident depends on the number of cattle over six months old present in the herd and in some cases only specific epidemiological groups are tested, rather than the whole herd over six months of age.

TB control in wildlife

Although the bovine TB bacterium (*Mycobacterium bovis*) can potentially 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 strongest, licensed badger culling has been in progress during the last seven years, in designated badger control programme areas (BCP).

In 2019, ten new badger control areas were authorised in the HRA. In total, 40 licensed badger control areas were in operation in the HRA during 2019. This included Areas 1 to 3 where licensed Supplementary Badger Control was undertaken, after having completed four annual culling seasons.

Badger removal results from 2019 indicate that in the HRA 34 badger control areas undergoing intensive culling (excluding Areas 1 to 3) achieved the minimum number of badger removals required. The remaining three areas finished only marginally below their final minimum number. No area exceeded the maximum number based on badger abundance. Further information can be found in the Summary of badger control monitoring during 2019.

The OTF-W incidence and prevalence of TB in cattle located within the licensed badger control areas can be found in the Bovine TB in cattle: badger control areas monitoring report.

TB in badgers is also controlled through the licensed use of injectable BCG vaccine in the HRA and Edge Area. In 2019, licences to vaccinate badgers were in operation in every HRA county, excluding the West Midlands. These licences covered a total of 82km^2 and 448 badgers were vaccinated. More details can be found in the Summary of badger vaccination in 2019.

4.2 Epidemiology of TB in the Edge Area

- This chapter summarises key findings from the Edge Area Year End Descriptive Epidemiology Reports.
- Six-monthly routine herd surveillance testing was in operation in the endemic portion of the Edge Area in 2019. In the remainder of the Edge Area, compulsory radial testing for herds located within 3km of any OTF-W cattle herd complemented annual routine testing.
- The number of new TB incidents disclosed in the Edge Area in 2019 (n=640) fell compared to 2018 (n=717). This reduction was seen in 10 of the 11 Edge Area counties, with Northamptonshire being the exception. In 2019, the greatest number of new TB incidents were detected in Cheshire (n=168), the least in Nottinghamshire (n=14).
- Overall, there was a slight non-significant increase in TB herd incidence per 100 HYR in the Edge Area in 2019 compared to 2018 (9.9 TB incidents per 100 herd years at risk in 2019, 9.1 in 2018, p=0.025). By contrast, incidence per 100 unrestricted herds tested decreased in 2019 compared to 2018. This apparent anomaly is explained in further detail below figure 4.2.3 and in Chapter 3.1.
- The end-of-year prevalence decreased in 2019 (5.3%) compared to 2018 (6.3%) for the Edge Area overall. This decrease was seen in every county.
- The duration of TB incidents varied between counties. On average, the longest TB incidents (that closed in 2019) were in East Sussex (median 243 days), Berkshire (median 239 days) and Oxfordshire (median 229 days).
- Almost half (46%) of new TB incidents in the Edge Area in 2019 occurred in herds that had experienced at least one TB incident in the previous three years. Recurrence was highest Cheshire (59%), Oxfordshire (57%) and Warwickshire (56%).
- The source of infection for herds with TB incidents was highly variable between counties. Badgers were identified as the primary weighted source of TB infection in eight Edge Area counties, most prominently in Derbyshire (61.4%) and Cheshire (60.7%). Cattle movements were identified as the primary weighted source in Buckinghamshire (47.9%) and Nottinghamshire (27.4%).
- New areas of endemic infection and new clusters are emerging in several counties in the Edge Area. Notably in Hampshire, where there is a potential new area of endemic TB south of the six-monthly testing zone. Additionally in Oxfordshire where a number of persistent clusters are ongoing.
- In Leicestershire, there is a cluster of cases in the north east of the county, and over the border into Lincolnshire (HS23). Despite this, in Leicestershire overall, the number of individual cattle tests increased by 10,000 in 2019, but there was a 15% reduction in new TB incidents. This suggests current measures for TB control have been beneficial.

- In 2019, one new BCP area was licensed in the Edge Area.

Geographical coverage of the Edge Area

The Edge Area forms a buffer separating the HRA of England to the south and west from the LRA of England to the north and east (Figure 4.2.1). In 2018, the Edge Area was expanded westward to fully include five counties that were previously split between the HRA and Edge Area (Cheshire, Derbyshire, East Sussex, Oxfordshire and Warwickshire). Data reported in this chapter is for the 11 full counties that made up the Edge Area from 2018 onwards. TB trends over time compare TB incidents in the fully post-2018 Edge Area counties.

Six-monthly routine herd surveillance testing was in operation in 2019 in the endemic portion of the Edge Area adjoining the HRA (Figure 4.2.1). In the remainder of the Edge Area, compulsory radial testing for herds located within 3km of any OTF-W cattle herd complemented routine annual testing.

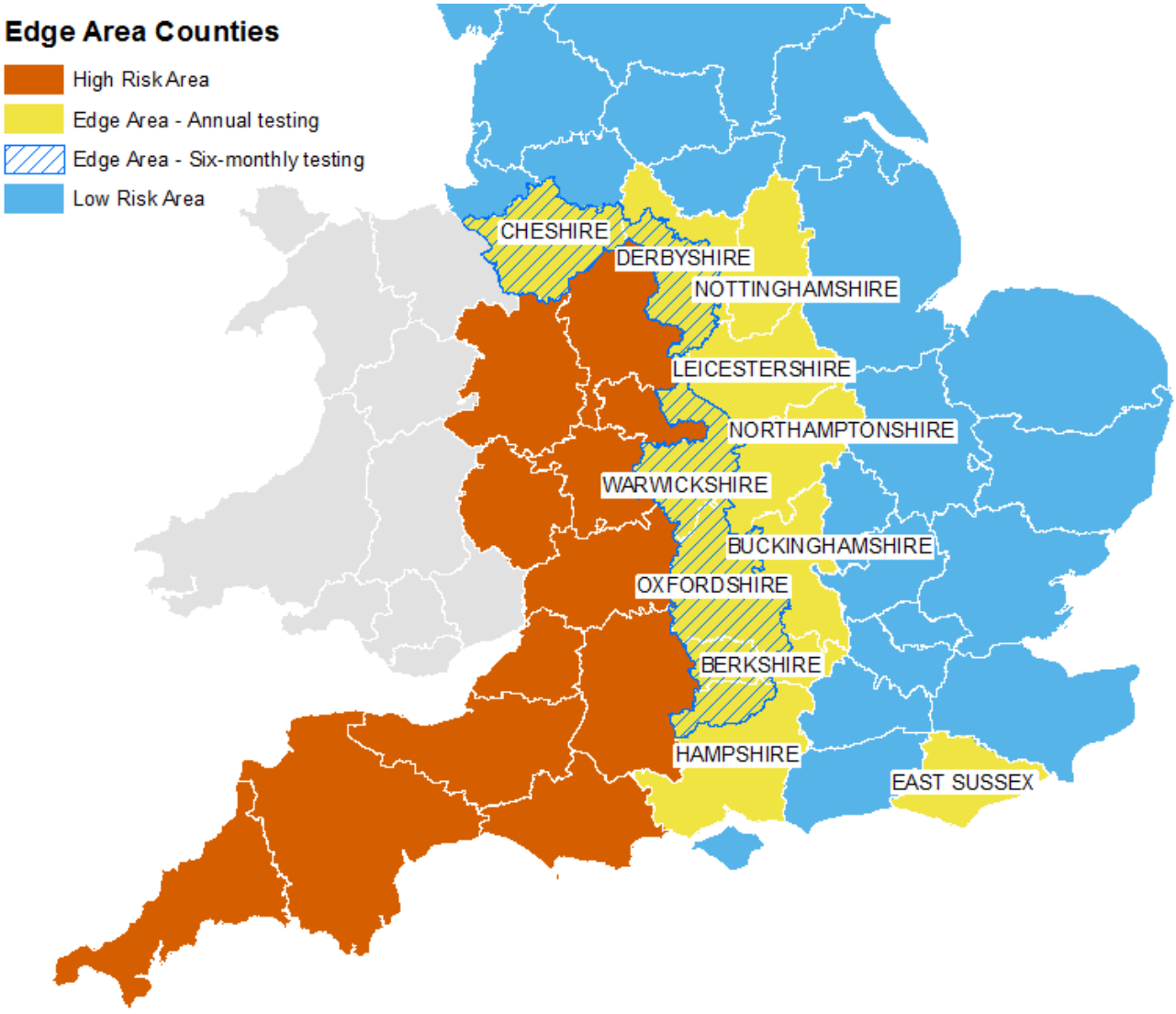


Figure 4.2.1 Edge Area county map, showing the areas under six-monthly routine herd testing

Defra's short term objectives for the Edge Area are to: slow down the geographic spread, maintain crude herd incidence of OTF-W breakdowns <2% overall by 2019, and to begin to reduce the incidence rate.

County level number of new TB incidents

The number of new TB incidents decreased in the Edge Area overall in 2019 (n=640) compared to 2018 (n=717). This was the first decrease in the number of new TB incidents since 2015 (n=526). With the exception of Northamptonshire, the number of new TB incidents decreased in all counties in 2019 compared to 2018 (Figure 4.2.2).

The number of new incidents was highly variable between counties. As in previous years, counties adjacent to the HRA disclosed the highest number of new incidents. These are also the counties where six-monthly routine herd testing is carried out, either in part, or the whole of the counties (Figure 4.2.1). In 2019, the greatest number of incidents were detected in Cheshire (n=168), the least in Nottinghamshire (n=14) (Figure 4.2.2).

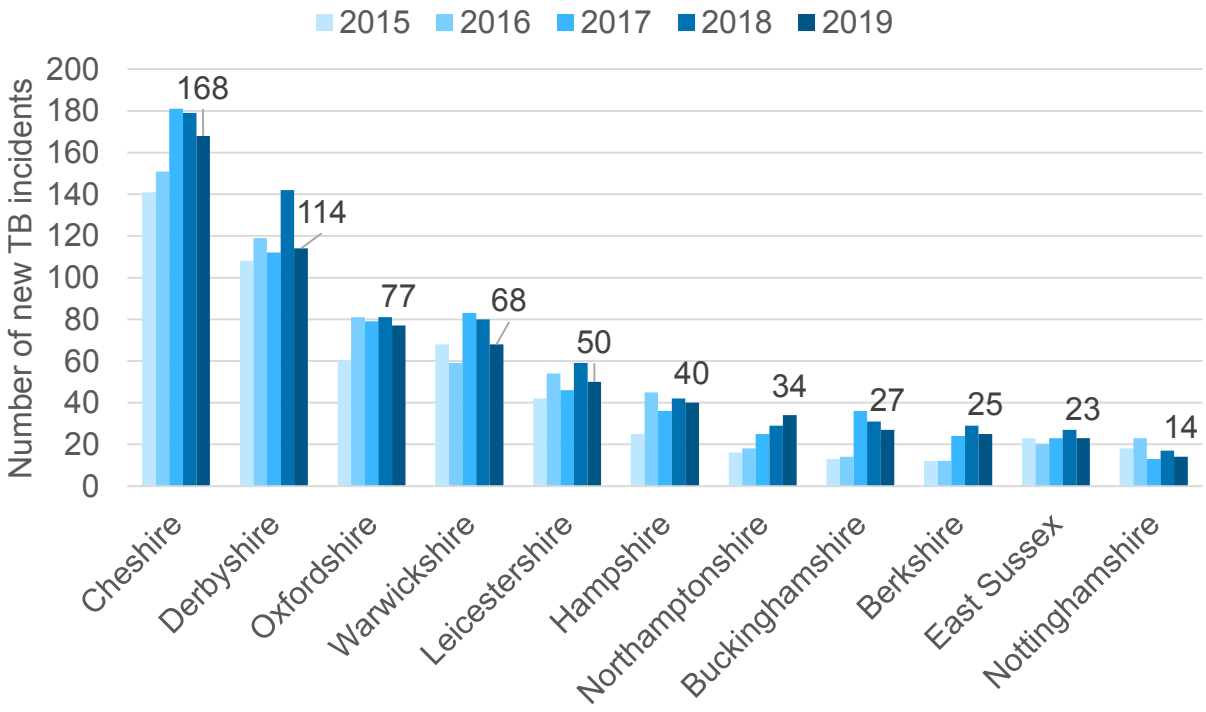


Figure 4.2.2 Annual total number of new TB incidents (OTF-W and OTF-S) by Edge Area county 2015 to 2019 (2019 incidents labelled on chart)

- The number of new TB incidents decreased in all but one (Northamptonshire) Edge Area county in 2019, compared to 2018.

County level TB incidence rate

Despite a decrease in the number of new TB incidents, there was a slight non-significant increase in TB herd incidence in the Edge Area as a whole in 2019 compared to 2018 (9.9 TB incidents per 100 HYR in 2019, up from 9.1 in the same spatial area in 2018, p=0.118).

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At the county level, incidence per 100 HYR increased in seven counties, and decreased in four. Oxfordshire was the only Edge Area county with a significant increase in incidence per 100 HYR between 2018 (16.6) and 2019 (23.8) (p=0.025). As in previous years, there was wide variation in the burden of TB across the Edge Area in 2019. Incidence ranged from 23.8 herds per 100 HYR in Oxfordshire, down to just 3.4 in Nottinghamshire (Figure 4.2.3). Measures of incidence presented here include all incidents (OTF-W and OTF-S). They may differ from those published in the Year End Descriptive Epidemiology reports, which exclude TB incidents in non-grazing Approved Finishing Units.

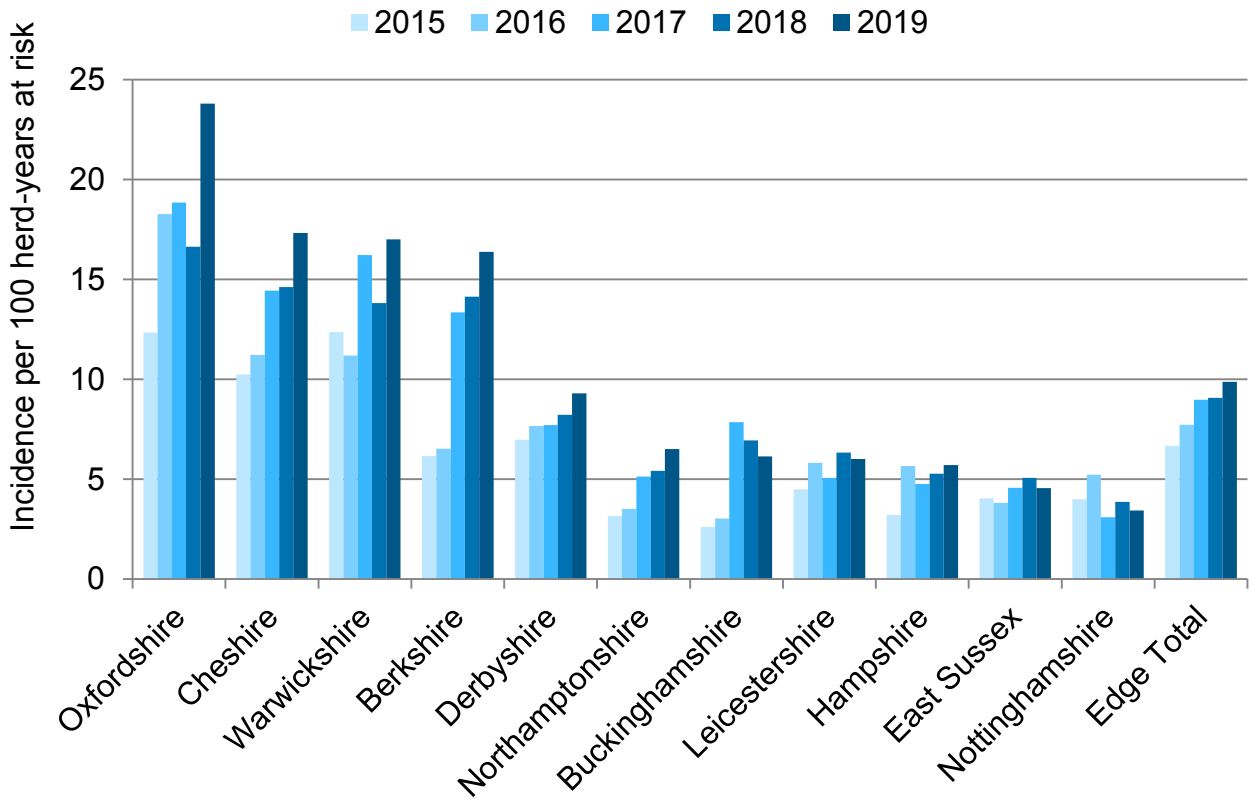


Figure 4.2.3 Incidence rate (per 100 herd-years at risk) from 2014-2019, by Edge Area county. Counties ranked by incidence in 2019.

- The incidence rate increased in 2019 compared to 2018 in the six counties with six-monthly testing, and Northamptonshire.

Oxfordshire, Cheshire, Warwickshire, Berkshire, Derbyshire and Hampshire were all subject to enhanced six-monthly testing in 2019. In these counties the number of herd-years at risk (denominator) decreased at a greater rate than the number of new TB incidents (numerator) in 2019. The likely reasons for this reduction in the number of herd-years at risk are discussed in detail in Chapter 3.1 'Effect of routine TB surveillance changes in the Edge Area in 2018 on the herd incidence rate'. In summary, changing surveillance strategies can impact the periods at which a herd is calculated to be at risk of new infection. These changes are thought to be at least partially responsible for the increased incidence observed in six-monthly testing counties.

A simpler measure of incidence, new cases per 100 unrestricted herds tested, is provided in Figure 4.2.4. Incidence per 100 unrestricted herds tested is less susceptible to changes in surveillance strategies. It is not intended to be a long-term substitute for the incidence per 100 HYR, but is useful to provide clarity when surveillance intervals change.

In the Edge Area overall, the incidence per unrestricted herds tested increased from 6.4 in 2015 to 9.4 in 2018, but fell to 8.7 in 2019. Incidence per 100 unrestricted herds tested decreased or remained the same in all counties in 2019 compared to 2018, with the exception of Northamptonshire (Figure 4.2.4). In Northamptonshire the incidence per 100 unrestricted herds has increased annually for the past five years, consistent with the trend in new TB incidents and incidence per 100 HYR (Figures 4.2.2 and 4.2.3).

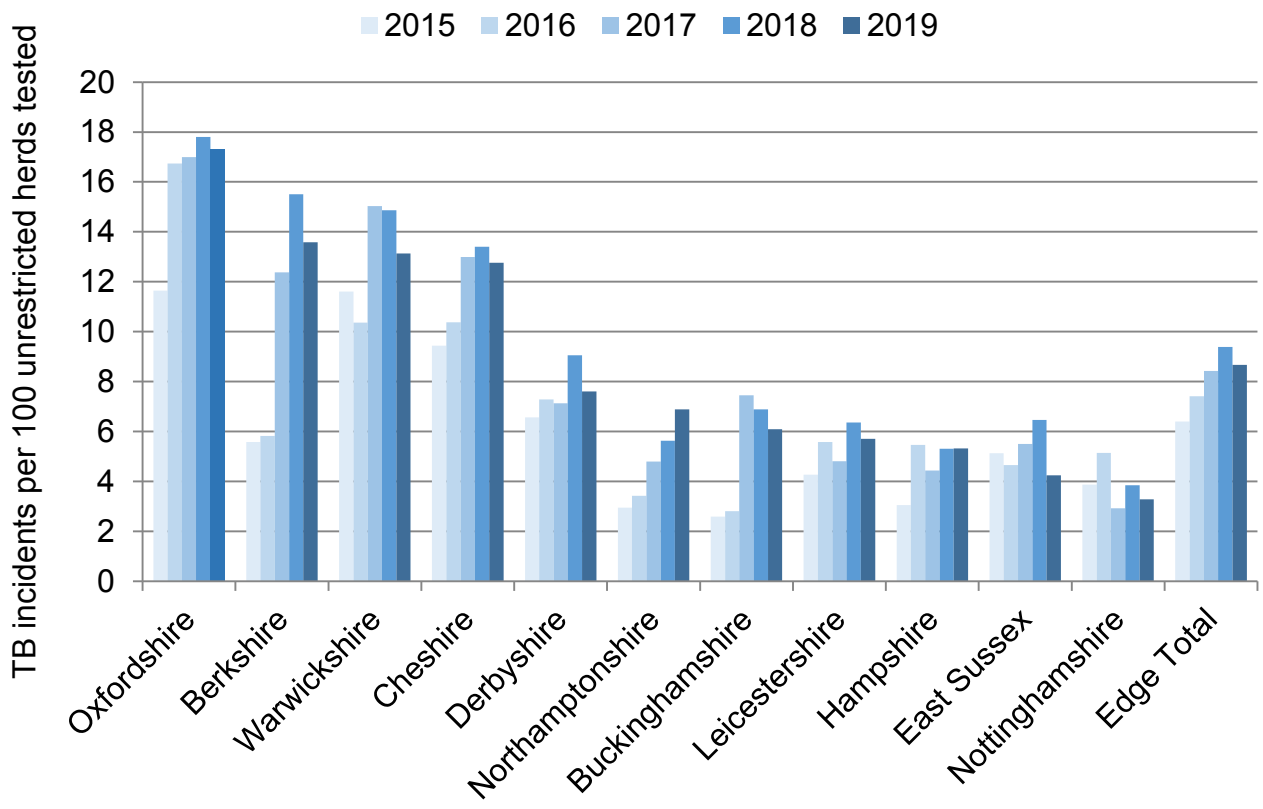


Figure 4.2.4 New TB incidents per 100 unrestricted herds tested from 2015-2019, by Edge Area county. Counties ranked by 2019 incidence value.

- The number of new incidents per 100 unrestricted herds tested has increased every year since 2015 in Northamptonshire.
- The number of new incidents per 100 unrestricted herds tested decreased or remained the same in all other Edge Area counties in 2019 compared to 2018.

County level end-of-year prevalence

The end-of-year prevalence (proportion of herds under movement restrictions on 31st December due to an ongoing TB incident) was lower for every Edge Area county in 2019 compared to 2018. Oxfordshire had the highest prevalence at the end of 2019 (12.1%), and prevalence was lowest in Nottinghamshire (1.4%). Overall, prevalence decreased in

the Edge Area from 6.3% at the end of 2018, to 5.3% at the end of 2019 (Figure 4.2.5). As with incidence, the prevalence figures presented here include all OTF-W and OTF-S incidents irrespective of the herd type. Prevalence figures in the Year End Descriptive Epidemiology reports for Edge Area counties may differ, as they exclude TB incidents in Approved Finishing Units with no grazing.

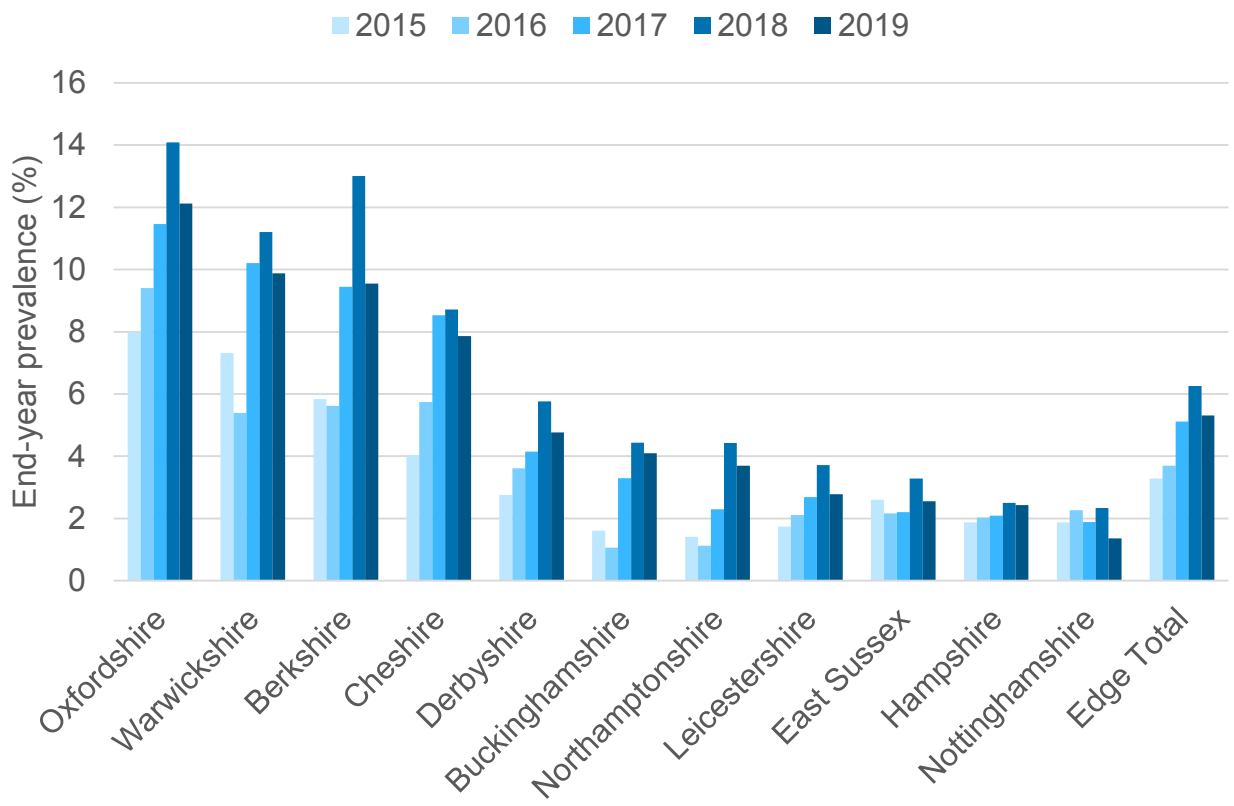


Figure 4.2.5 End of year prevalence from 2015-2019, by Edge Area county ranked by decreasing order of prevalence in 2019

- End-of-year prevalence decreased in every county in 2019 compared to 2018.

TB incident duration and persistence

In the Edge Area a total of 714 TB incidents ended during 2019. The median duration for incidents that closed in the Edge Area in 2019 was 197 days (Interquartile Range (IQR) 168 to 278 days). At the county level, the longest median duration was observed in East Sussex (243 days), followed by Berkshire (239 days) and Oxfordshire (229 days). Counties with the shortest median durations were Northamptonshire (177 days), Nottinghamshire (182 days) and Cheshire (193 days) (Figure 4.2.6).

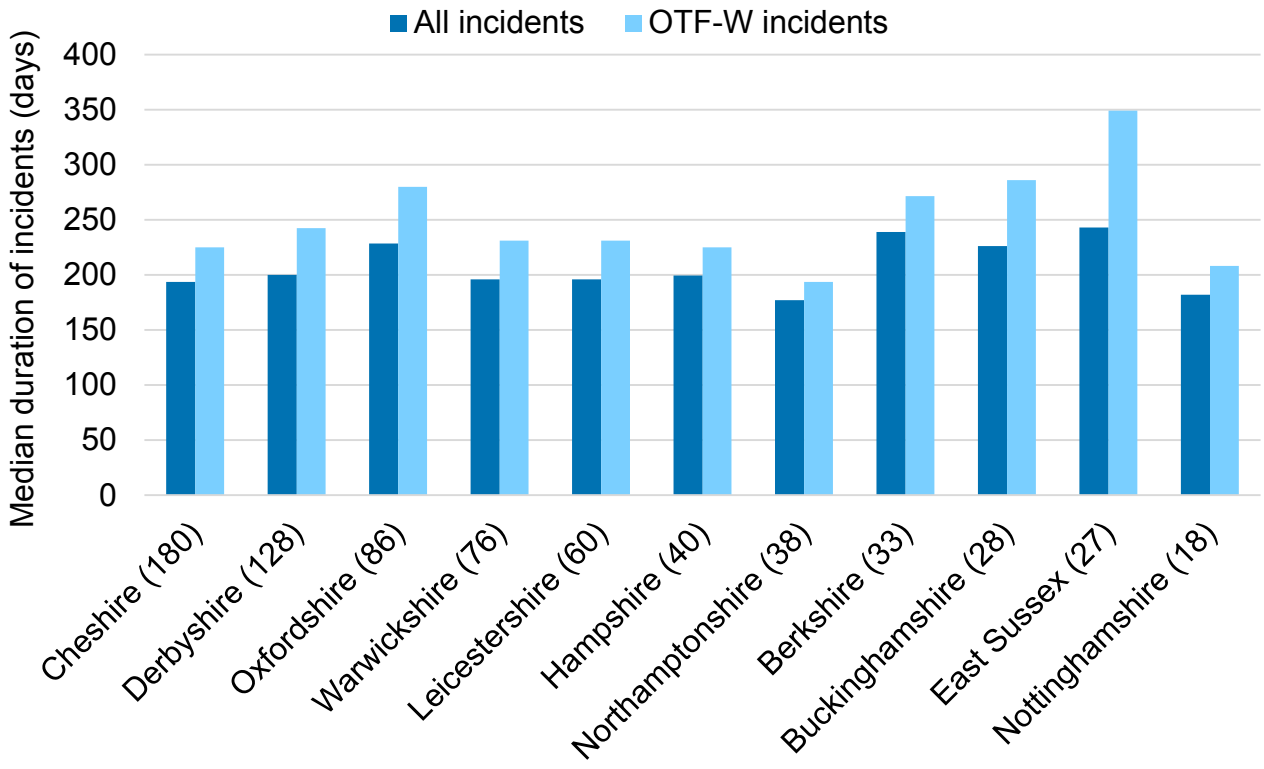


Figure 4.2.6 Median duration (days) of TB herd incidents that ended in 2019, by Edge Area county ranked by number of incidents (in parentheses)

- Median duration was highest in East Sussex for all TB incidents (243 days) and for OTF-W TB incidents (349 days).

Recurrence of TB incidents

In the Edge Area in 2019, 46% of TB incidents occurred in herds that had experienced at least one TB incident in the previous three years. Recurrence was highest in the Edge Area counties of Cheshire (59%), Oxfordshire (57%) and Warwickshire (56%) (Figure 4.2.7). Recurrence in these three counties is higher than the proportion reported in seven of the ten HRA counties (Figure 4.1.8, Chapter 4.1 Epidemiology of TB in the High Risk Area).

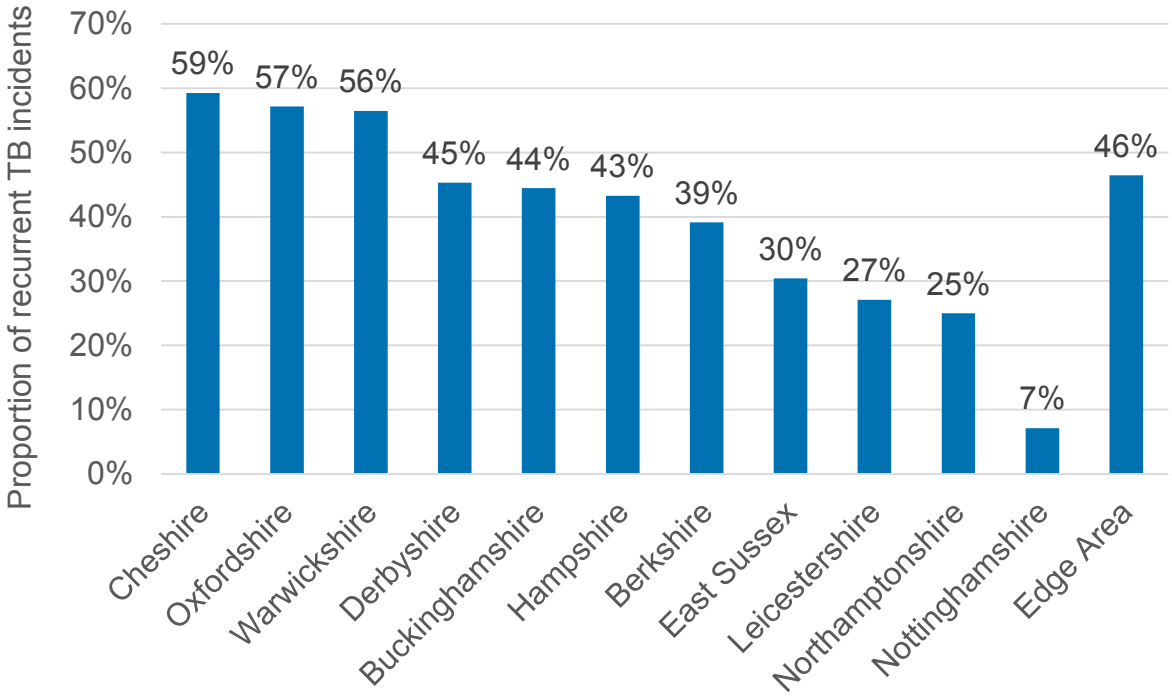


Figure 4.2.7 Proportion of TB incidents in 2019 in herds that had experienced any TB incident in the previous three years, by Edge Area county

- The proportion of recurrent incidents was highest in the counties of Cheshire, Oxfordshire and Warwickshire.

Source of infection

For herds with new TB incidents in the Edge Area, the source of infection was highly variable between counties. Incidents bordering the HRA are more frequently ascribed to badgers, while those closer to the LRA are more commonly linked to cattle movements (Figure 3.2.11, Chapter 3.2 Characteristics of herds found infected with TB). Badgers were identified as the primary weighted source of TB infection in eight Edge Area counties, most prominently in Derbyshire (61.4%), Cheshire (60.7%), Oxfordshire (55.2%), Northamptonshire (51.9%), Leicestershire (45.4%) and East Sussex (45.6%). Cattle movements were identified as the primary weighted source in Buckinghamshire (47.9%) and Nottinghamshire (27.4%) (Table 3.2.1, Chapter 3.2 Characteristics of herds found infected with TB).

New areas of endemic infection and new clusters emerging

In several counties of the Edge Area there were new areas of endemic infection and new clusters emerging in 2019, with anecdotal evidence that the infection was maintained by local wildlife (badger) populations. Areas of significance include:

- Hampshire, where there is a potential new endemic area to the south and west of Winchester due to the detection of three incidents of genotype 10:a and 10:u in closely related dairy herds in 2019.

- Oxfordshire had a number of persistent clusters and a cluster of cases in Buckinghamshire presented some potential evidence that cattle incidents were occurring due to eastward spread of endemic infection from Oxfordshire.
- Leicestershire has a cluster of OTF-W incidents situated near the county's boundaries with both Lincolnshire and Nottinghamshire. The cluster was first recorded in 2015, and has persisted throughout the years. It has a relatively high proportion of OTF-W incidents with genotype 25:a of *M. bovis*, which is attributed to a local wildlife reservoir.

Areas of improvement

In Leicestershire the number of individual cattle tests increased by 10,000 in 2019, while there was a 15% reduction in new TB incidents. This improvement was seen despite the cluster of incidents in the north east of the county, and suggests that TB control measures have been beneficial.

TB control in wildlife

Badger vaccination: a further call for applications under the Badger Edge Vaccination Scheme 2 (BEVS2) was open between 20 June 2019 and 10 August 2019. During 2019, Badger Vaccination was licenced to take place in nine Edge Area counties (in total covering 146km^2). 439 badgers were vaccinated in 2019.

In 2019, one BCP area was authorised in Cheshire. Further information can be found in the Summary of badger control monitoring during 2019.

4.3 Epidemiology of TB in the Low Risk Area

- The following bullet points summarise key findings from the LRA Year End Descriptive Epidemiology Reports.
- Overall, the incidence rate in the LRA remained very low and stable (1.1 incidents per 100 herd years at risk). There were 148 incidents in 2019, an increase from 129 in 2018, but only 36 (24%) of those were lesioned and/or culture-positive (OTF-W) (Figure 4.3.1). Notable increases were seen in South Yorkshire (three new TB incidents in 2018, 10 in 2019) and Essex (one in 2018, six in 2019). A notable decrease was seen in Bedfordshire (six in 2018 to just one in 2019) (Figure 4.3.2).
- There was a higher degree of uncertainty around the source of TB in cases detected in the LRA compared to the HRA and Edge Area. In part this is related to the smaller proportion of OTF-W incidents in the LRA, where *M. bovis* genotyping results can provide key evidence as to the likely source of infection.
- Movement of cattle with undetected infection into the LRA was the most common source of TB for new incidents in 2019, closely followed by an undetermined source, as expected due to the low proportion of OTF-W incidents detected. There were frequent movements of cattle from higher risk areas onto finishing units inside the LRA. Compulsory post-movement testing for such animals goes some way to mitigating the risks associated with sourcing cattle from outside the LRA.
- In the LRA, hotspot procedures are initiated around OTF-W incidents of undetermined origin. Within a potential hotspot area, cattle herds located within 3km of the index herd undergo enhanced testing, and a concurrent survey of found-dead badgers and wild deer is implemented. If *M. bovis* infection is confirmed by the wildlife survey, the potential hotspot becomes a confirmed hotspot (HS).
    - For the first time since 2015, the endemic strain 17:z was not cultured in any cattle herds located in HS21 (East Cumbria).
    - Wildlife surveillance undertaken in HS23 (Lincolnshire/Leicestershire) during 2019 had identified two badger carcases with visible lesions consistent with TB. Further bacteriological culture of the lesions was undertaken with results becoming available in 2020 (see report on TB surveillance in wildlife).
    - Wildlife surveillance began in 2019 in new potential hotspot areas HS24 (West Sussex) and HS25 (Norfolk). One badger carcass submitted in potential HS25 was negative for *M. bovis*.
    - New potential hotspot area (HS26, South Cumbria) had three OTF-W TB incidents due to the 25:a genotype of *M. bovis*, all with identical whole genome sequences. A fourth incident in the vicinity had a very close WGS to these three. This provides evidence of lateral spread of TB within the area, either by contact with infected cattle or wildlife. Wildlife surveillance in HS26

has taken place since August 2019, however *M. bovis* has not been identified in dead badgers or wild deer to date.

- New potential hotspot HS27 (Yorkshire) was established in 2019 along and across the border of North Yorkshire and Lancashire. This area was initiated due to a cluster of two OTF-W and eight OTF-S cases that occurred between 2017 and 2019. A number of these cases involved homebred animals, with no clear source of infection.
- As well as cattle movements, spread of disease from endemic areas of infection in the Edge Area poses a risk to the LRA. Parts of the LRA identified as being at particular risk for this reason included:
- Greater Manchester: incidence in the neighbouring Edge Area county of Cheshire is high and there are concerns there could be disease spillover into the area around Stockport.
- Lincolnshire: a potential hotspot area (HS23) was initiated in 2018 close to the border of Leicestershire where TB appears to be endemic.
- South Yorkshire: a cluster of cases occurred in the south west of the county, close to the Edge Area. This area is under close monitoring for further incidents.

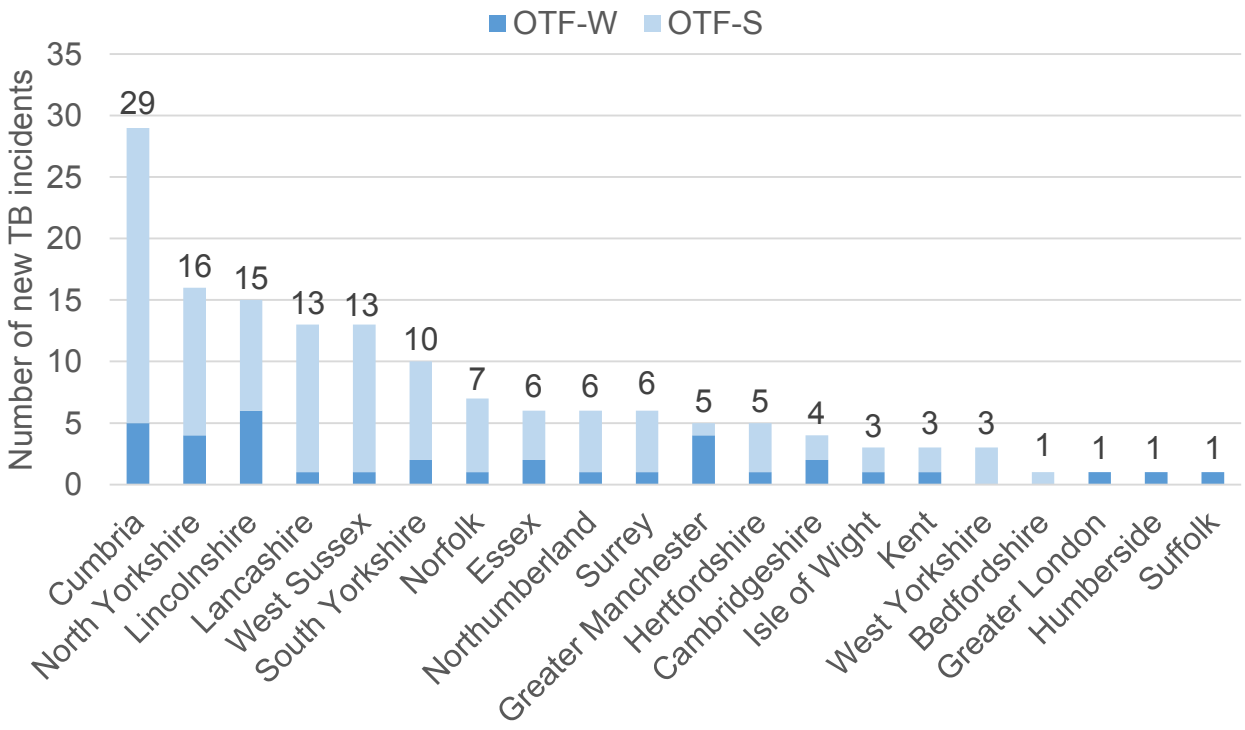
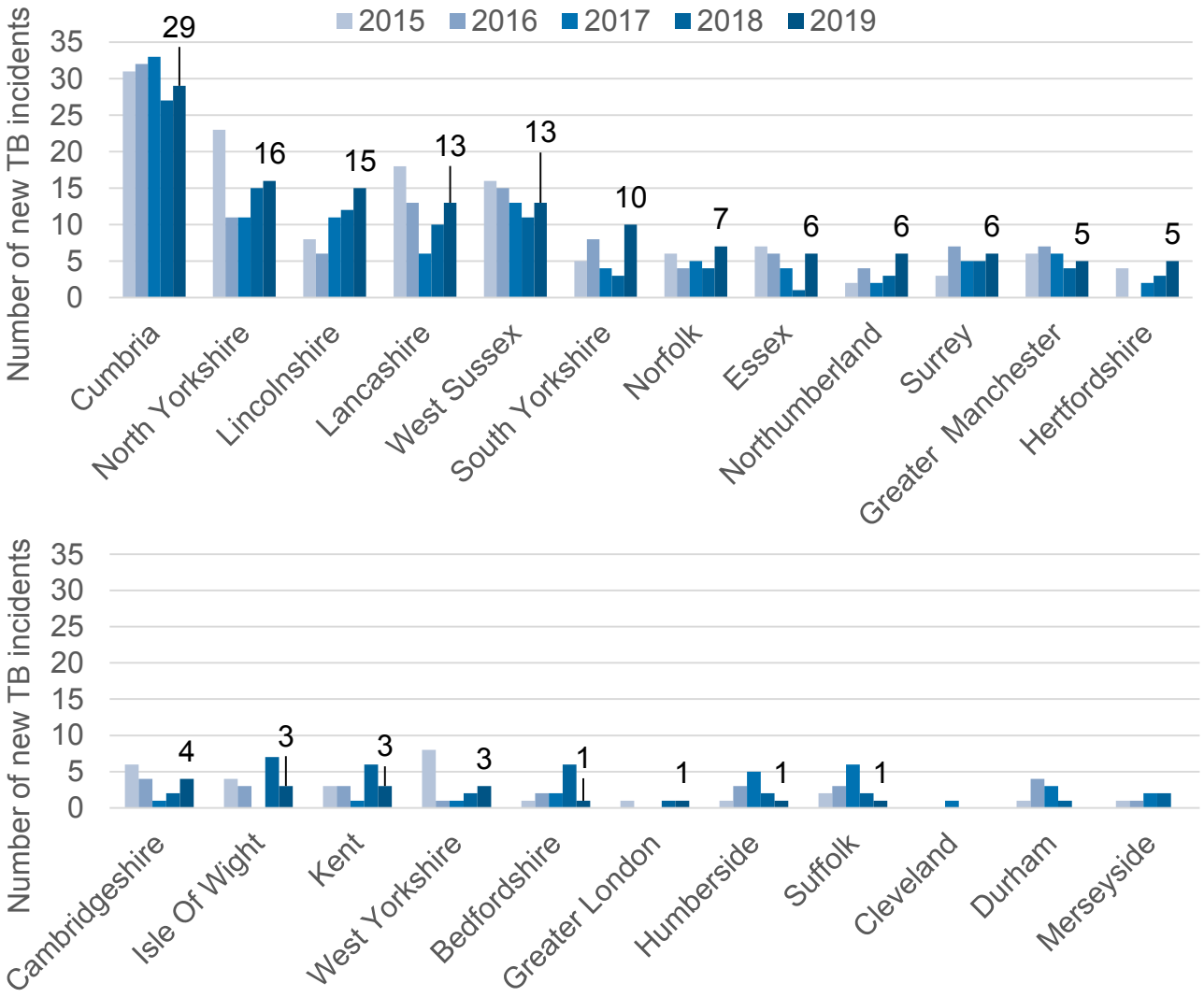


Figure 4.3.1 Total number of new TB incidents (OTF-W and OTF-S) by LRA county in 2019 (Total incidents labelled on chart)



Not shown: Two LRA counties that did not report any new TB incidents between 2015 and 2019 (Isles of Scilly and Tyne & Wear).

Figure 4.3.2 Annual total number of new TB incidents (OTF-W and OTF-S) by LRA county 2015 to 2019 (2019 incidents labelled on chart)