Animal & Plant Health Agency

Asiantaeth Iechyd Anifeiliaid a Phlanhigion

Epidemiology of bovine tuberculosis in Wales

Annual surveillance report

For the period

January to December 2016

Commissioned by the Welsh Government under Project SB4500

Report to: TB team
Office of the Chief Veterinary Officer,
Welsh Government,
Cathays Park,
Cardiff,
CF10 3NQ

Project Leader: Mr P A Upton[1]
Data Systems Workgroup,
Animal and Plant Health Agency (APHA, Weybridge),
New Haw, Addlestone,
Surrey KT15 3NB
Telephone 01932 341 111, ext. 3440

Compilers: Miss H M O'Connor[2], Mr J Dale[3] and Mr P A Upton[1]
APHA (Weybridge)

Others involved in this compilation: Mr A Brouwer[2], Mrs J Gibbens[2]
APHA (Weybridge)

Acknowledgements: Mr Ryan Pike (Statistician)
Welsh Government

Dr Paul Schroeder, Mr Terry Galloway
APHA (Cardiff)

[1] Data Systems Group
[2] Department of Epidemiological Sciences
[3] Bacteriology Department

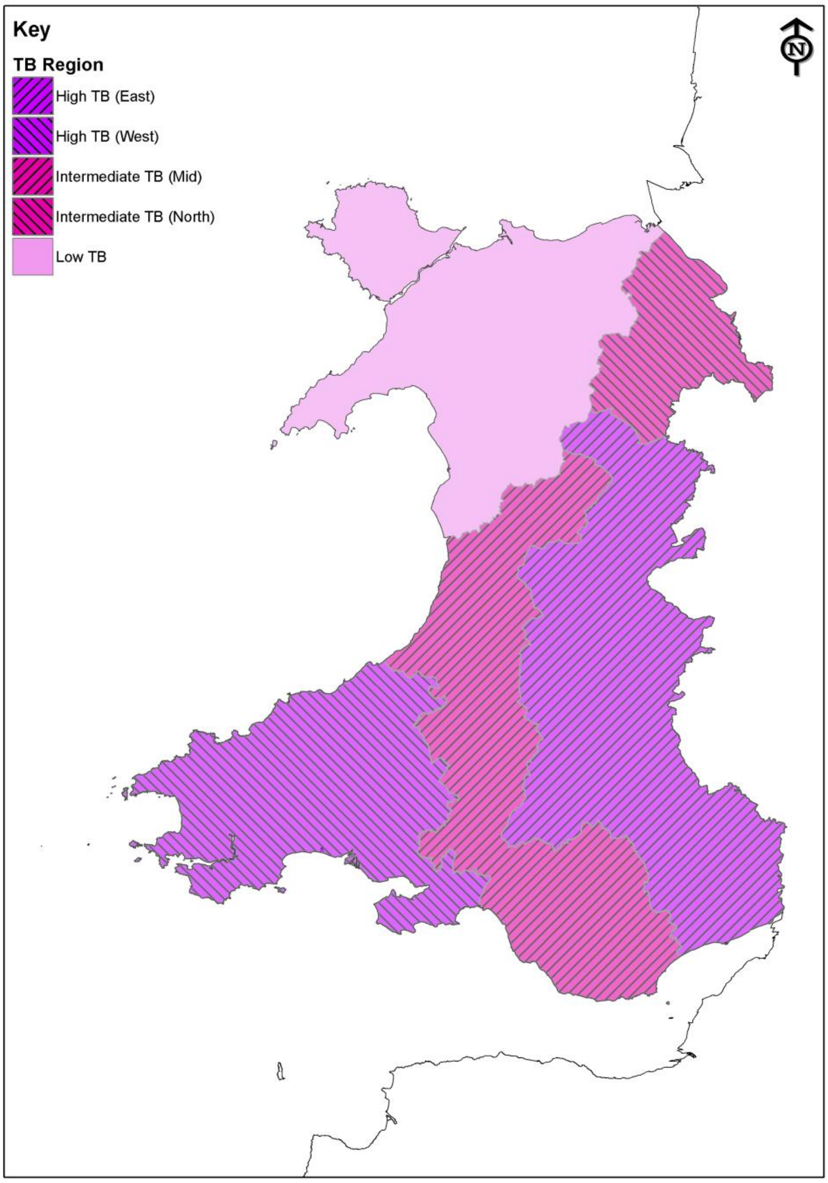
Table of Contents

Summary 6
Introduction.. 12
1.0 Welsh cattle population characteristics and TB tests 13
1.1 Welsh cattle population characteristics 13
1.2 Bovine tuberculosis testing applied to the Welsh cattle population 16
2.0 Bovine tuberculosis incidence and prevalence in Wales............... 17
2.1 Bovine tuberculosis incidence and prevalence in 2016...17
2.2 Temporal trends in TB incidence and prevalence in Wales.......................................18
2.3 Incidence and prevalence of TB across Wales 21
2.4 New TB incidents identified by different test types 27
2.5 Animal level frequency of TB..29
2.6 Variation in TB incidence by herd type, herd size and geographical area 29
2.7 Summary of new, closed and ongoing incidents in Wales..31
3.0 Routine slaughterhouse surveillance 33
3.1 Submission of samples from animals with lesions suspicious of TB 34
3.2 Incidents disclosed at slaughterhouse inspection...35
3.3 Reactors in herd tests following detection of slaughterhouse cases 39
4.0 Post mortem examination and culture of suspected TB cases........ 42
4.2 Lesion status of suspected TB cases that were slaughtered....................................46
4.3 Culture results of animals with detected lesions or no detected lesions..................48
5.0 Duration of bovine TB incidents in Wales... 50
5.1 Bovine TB incident duration in 2016 and the annual trend in median duration trends 50
5.2 Variation in TB duration by TB-free status, herd type, herd size and geographical area...53
6.0 Recurrent incidents 58
7.0 Inconclusive reactor herds that subsequently suffered an incident 64
7.1 Understanding the fate of IRs..73
8.1 Overview of the isolates in the spoligotype database (Wales only). 75
8.2 Cattle isolates from Wales for bTB incidents commencing in 2016. 76
8.3 Genotype frequency in cattle bTB incidents 76
8.4. Non-bovine isolates from Wales, 2016..78
Annexe – Wales TB Area Statistics 79
Appendix 1 - Materials and Methods 89
Appendix 2 – Definitions and abbreviations... 94
Appendix 3 – Test type frequency...101
Appendix 4 - Extract from European Union (1998), Council Directive 98/46/EC 103
Appendix 5 – The geographical areas used in this report 104
Appendix 6 – The number of herds, incidents, herds under restriction and cattle slaughtered for different reasons relating to TB control between 1990 and 2016 106

List of Tables and Figures (in order of appearance in the report)

Figure S1: Reactors per 1,000 animal tests, 2016 (includes SICCT and gIFN tests) 8
Figure S2: New, closed and ongoing TB incidents in Wales, 2012 – 2016 9
Figure S3: Homeranges for genotypes 9:b, 9:c, 17:a and 22:a using 2012-16 data 12
Figure 1.1: Density of cattle herds in Wales and English border counties, 2016 14
Table 1.1a: Herds in Wales (active on SAM) by herd type and geographical area, end-2016 15
Table 1.1b: Herds in Wales (active on SAM) by size category, geographic location and herd type, end-2016 16
Table 1.1c: Percentage of herds (active on SAM) by size category, geographic location and herd type, end-2016 16
Table 1.2: Herds (active on SAM), cattle and animal-level tests, 2012-2016 17
Table 2.1: Incidence and prevalence of TB in Wales, 2016 19
Figure 2.1: Quarterly number of total and OTF-W incidents per 100 unrestricted herds between January 1990 - December 2016 20
Figure 2.2: Proportion of herds that were under movement restrictions, January 1990 – December 2016 21
Figure 2.3 a to c: ten year trends in a) new incidents per 100 herds, b) new incidents per 100 herd years at risk, and c) point prevalence of herds under movement restrictions, December of each year 22
Figure 2.4: Geographical distribution of new OTF-W and OTF-S incidents occurring in Wales and bordering English counties in 2012 - 2016 24
Figure 2.6: New incidents per 100 herd years at risk, 2007 – 2016, by county. The grey dotted line represents the trends in Wales overall 26
27
Table 2.2: Tests taken from animals in herds not under restriction (surveillance tests), resulting incidents and incidents per 100 herd surveillance tests, 2016 28
Figure 2.8: New TB incidents detected by different surveillance testing methods 29
Table 2.3: Animal level frequency of reactors and inconclusive reactors, 2016 30
Table 2.4: Analysis of incidence rates by herd size, type and location and results of Poisson Regression analyses of the associations between these factors and the incidence rate of all new bTB incidents that started in 2016 .31
Table 2.5: The number of new, closed and ongoing TB incidents in Wales in 2016 32
Figure 2.9: Incidents (new, closed and ongoing) occurring in Wales and bordering English counties, 2016 33
Table 3.1: Culture results from cattle with TB-like lesions detected during slaughterhouse surveillance 35
Table 3.2: Culture results from cattle with TB-like lesions detected during slaughterhouse surveillance, by geographical area 35
Figure 3.1: Proportion of OTF-W incidents disclosed in the slaughterhouse 36
Figure 3.2: New incidents disclosed in the slaughterhouse, 2012 – 2016 37
Table 3.3: Results of Logistic regression analyses of the associations between herd type, herd size and geographical area and the odds of an OTF-W incident being disclosed in the slaughterhouse (SLH) in 2016 39
Table 3.4: Reactors identified at the first whole herd test following an incident 40
Table 3.5: Total number of reactors identified in incidents that closed in 2016 40
Figure 3.3: Reactors identified at the first whole herd test following disclosure of the incident, 1990 – 2016 42
Figure 3.4: Reactors identified per incident that closed, 1990 – 2016 42
Figure 4.1: Testing pathways of animals slaughtered for TB control in Wales, 2016 45
Figure 4.2a: Reactors inconclusive reactors and direct contacts slaughtered for suspected TB, 1990 – 2016 47
Figure 4.2b: Inconclusive reactors and direct contacts slaughtered, 2012 – 2016 47
Table 4.1: Lesion status of animals for animals slaughtered in 2016 48
Figure 4.3: Proportion of slaughtered cattle with detected lesions[1],2012 – 2016 49
Figure 4.4: Monthly proportion of reactor culture samples from which M. bovis was obtained, 1990 – 2016 50
Table 5.1: Restriction durations of incidents closed in 2016 52
Figure 5.1: Median duration of OTF-W incidents ending between 1990 and 2016 (a), with interquartile ranges for OTF-W (b) and OTF-S (c) incidents presented separately 53
Table 5.2: Analysis of factors associated with incident duration (log-transformed), 2016 54
Figure 5.2: OTF-W incidents by duration, closing 2012 – 2016 56
Figure 5.3: OTF-S incidents by duration, closing 2012 – 2016 57
Figure 5.4: Incidents of longer than 550 days duration, closing in 2016 58
Figure 5.5: Open incidents at the end of the year which started prior to 2016 58
Table 6.1: Incident and non-incident herds by TB history, 2016 60
Figure 6.1: Proportion of herds with a history of TB, by OTF status, 2012 – 2016 61
Table 6.2: Herds with and without an incident in 2016, by TB history 62

Table 6.3: Time elapsed between the end of movement restrictions in the most recent TB incident in the history period and the start date of the first incident in the current period 63
Figure 6.2: Herds with new bovine TB incidents in 2012 - 2016 that had had between one and four OTF-W incidents in the previous 36 months (recurrent incident herds)...64
Figure 7.1: Proportion of IR-only herds with a new TB incident at the IR-retest 66
Figure 7.2: Proportion of herds that had a new TB incident following a clear IR-retest...67
Table 7.1: TB incidents in the fifteen months subsequent to tests in which only inconclusive reactors (IRs) were found, and TB incidents in the fifteen months following a clear whole herd test, 2016...................................68
69
Figure 7.3a: IR herds with no subsequent TB incident within 15 months. The grey dotted line represents the trends in Wales overall..69
Figure 7.3b: IR herds with a new TB incident at the IR retest. The grey dotted line represents the trends in Wales overall 70
Figure 7.4: IR herds with no subsequent incident; a new TB incident at the IR retest or a new TB incident at the test subsequent to a clear IR retest within fifteen months, 2016 72
Figure 7.5: Density of herds with at least one inconclusive reactor, 2012 – 2016...73
Figure 7.6: Flow diagram illustrating the fate of animals which had an inconclusive reaction to the SICCT test in 2016 75



..80
Figure 1.0: The new TB Areas in Wales 80
Table 1.1a: Herds in Wales (active on SAM) by herd type and TB area, end-2016..81

Table 1.1b: Herds in Wales (active on SAM) by size category, TB area and herd type, end-2016 81
Table 1.1c: Percentage of herds (active on SAM) by size category, TB area and herd type, end-2016........................81
Table 2.1: Incidence and prevalence of TB by TB area, 2016 82
b) 83
Figure 2.3 a to c: ten year trends by TB area in a) new incidents per 100 herds, b) new incidents per 100 herd years at risk, and c) point prevalence of herds under movement restrictions, December of each year......................84
Table 2.3: Animal level frequency of reactors and inconclusive reactors by TB area, 2016 85
Table 5.1: Restriction durations of incidents closed in 2016 85
Table 6.1: Incident and non-incident herds by TB history and TB area, 2016 87
Appendix table 1: Definitions of terms used throughout the report 95
Appendix table 2: Definitions of surveillance test codes used in Section 2 and Appendix Table 3 100
Appendix table 3: Number of surveillance tests (herds not under restriction), reactors and resulting incidents and the number of disease control tests taken in herds under restriction...102
Appendix Table 4: The number of herds, incidents, herds under restriction and cattle slaughtered for different reasons relating to TB control between 1990 and 2016..107

Summary

This report is presented in eight sections in which the cattle population and testing regime are summarised, and various measures of disease are used to describe the epidemiology of bovine TB in Wales in 2016.

The following summary highlights the main findings described in each section. The data suggest that positive progress continues to be made in Wales to tackle bovine TB through the comprehensive TB eradication programme introduced in 2008.

Welsh cattle population characteristics and TB tests applied to this population

Over the last five years, the number of herds in Wales has decreased by 9% to approximately 11,700 herds (Table 1.2). Much of the apparent change in the number of herds between 2011 and 2015 was concentrated between 2013 and 2015. However, this is likely to be an artefact, attributable to a cleansing exercise that was undertaken on the British Cattle Movement Service (BCMS) data during 2014, which has resulted in the closing of inactive herds, and the true change is likely to be less.

Since 2012, the total number of tests (including inspections of carcases) conducted on cattle in Wales has risen by around 3% from 2.2 million to 2.3 million in 2016 (Table 1.2). All herds in Wales have been tested annually since October 2008, but since 2010 around 300 herds in the Intensive Action Area of Pembrokeshire have been tested twice annually.

Bovine tuberculosis incidence and prevalence in Wales

There were 706 new TB incidents in 2016, of which 624 (88%) were classified as OTF-W incidents and 82 (12%) were classified as OTF-S incidents; there were no unclassified incidents (see Appendix 2 for definitions).

The level of TB in Wales has declined overall since 2008. Overall, 6% of Welsh herds incurred a new TB incident (OTF-W or OTF-S) in 2016 and 5% of herds were under movement restrictions in mid-December 2016 due to any TB incident starting at any time before this date (excluding herds restricted due to overdue tests) (Table 2.1). There were 7 new TB incidents per 100 herd years at risk in 2016, compared to 8.2 in 2015. This is equivalent to detecting 70 new incidents for every 1,000 herds that had been unrestricted for one year (Table 2.1).

Between 2001 and 2009 there was a nearly 5-fold increase in the number of new incidents per 100 unrestricted herds. Subsequently, there have been periods of sharp decline, punctuated by short-term increases, giving a long-term downward trend since the peak in the last quarter of 2008 (40% reduction) (Figure 2.1).

The largest clusters of new incidents were found in the south west (Pembrokeshire, Ceredigion, and Carmarthenshire) and along the Welsh/English border. Areas such as Anglesey, Gwynedd, and Clwyd continued to have notably fewer new incidents per 100 herd years at risk than in the south west and border areas (Figure 2.8). The animal-level frequency of reactors and inconclusive reactors in 2016 followed similar geographical patterns to herd incidence with frequency being highest in Carmarthenshire, Pembrokeshire, and Gwent reflecting the geographical distribution of incidents in Wales (Table 2.3). The number of reactors per 1,000 animal tests was lowest in North Wales and highest in the south west of Wales and along the border with England (Figure S1).

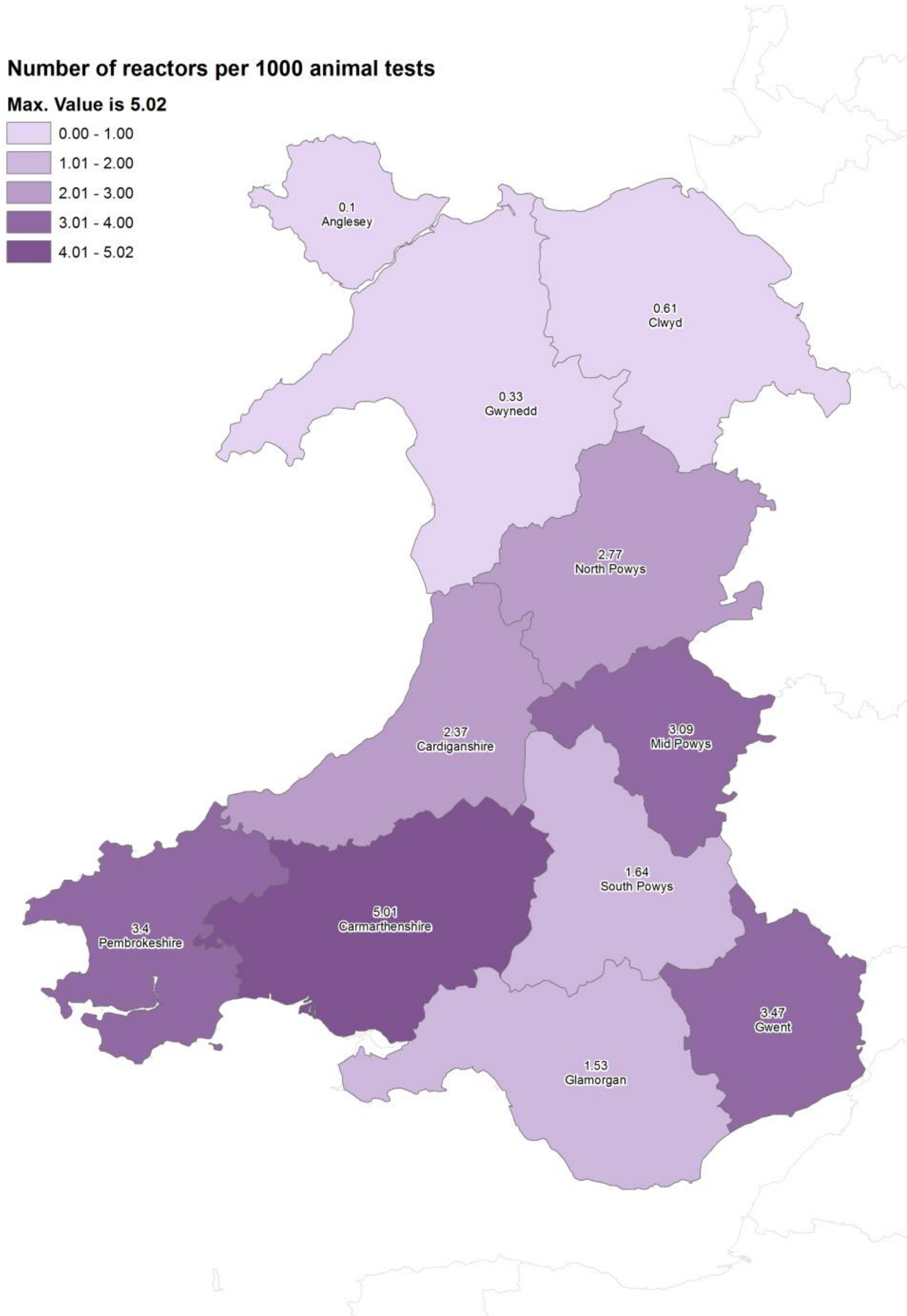


Figure S1: Reactors per 1,000 animal tests, 2016 (includes SICCT and gIFN tests)

The incidence of TB increased with herd size, with lower incidence rates observed in herds with fewer than 300 cattle relative to those with more than 300. This effect remains after adjusting for the effects of herd type and location. Similarly, the incidence rate remained significantly higher for dairy herds even after adjustment for herd size and location (Table 2.4).

Trends in the number of new, closed and ongoing incidents in Wales are presented in Figure S2. The numbers of new incidents and closed incidents have decreased overall in the last five years, although there was a peak in the number of closed incidents corresponding with a drop in new incidents in 2013. The number of ongoing incidents in Wales has been fairly stable over the last five years.

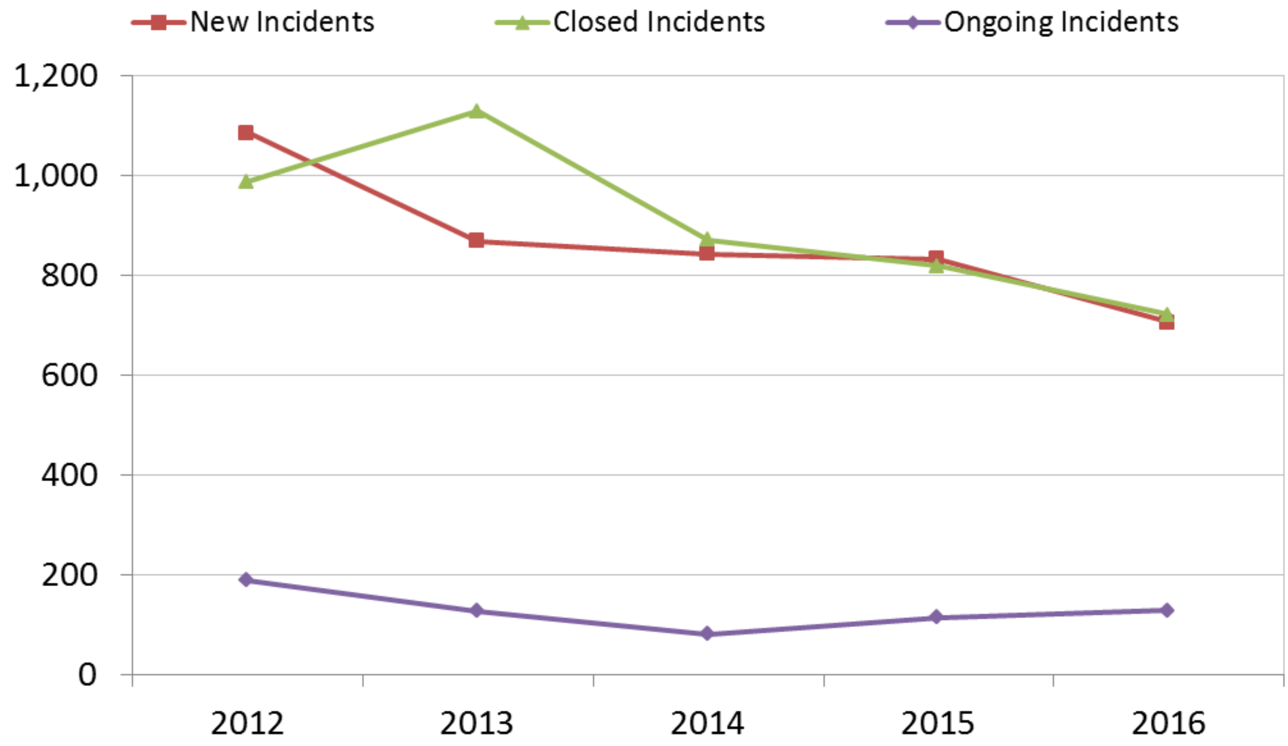


Figure S2: New, closed and ongoing TB incidents in Wales, 2012 – 2016

Routine slaughterhouse surveillance

Of the 706 new TB incidents that started in 2015, 40 (6%) were disclosed in the slaughterhouse. All of these were OTF-W incidents, which equates to 6% of the 624 OTF-W incidents in 2016. Fifty-two per cent of the samples submitted from slaughterhouses were *M. bovis* positive, similar to previous years in Wales and compared to 73% in GB

When incidents were first disclosed through slaughterhouse inspection fewer median reactors were found *at the first whole herd test* compared to when incidents were disclosed through *risk-related* skin testing and through *routine* skin testing. A similar pattern was seen for the *total number of reactors taken in incidents that closed* in 2016 (Tables 3.4 and 3.5). The mean number of reactors identified at the first whole herd test peaked around the time of the Foot and Mouth Disease outbreak in 2001 which caused considerable disruption to TB surveillance. Since 2009, the mean number of reactors per incident for both methods of disclosure has remained between two and four (Figure 3.3). Since 2004 the mean total number of reactors identified per skin-test-disclosed incident has fluctuated between 5 and 8, although in 2013 it increased to almost 10 and again similarly in 2016. For slaughterhouse-disclosed incidents the mean is a volatile series, jumping between 3 and 12 since 1996. This is primarily due to the small number of slaughterhouse cases and the occasional high reactor number incident (Figure 3.4).

Post mortem examination and culture of suspected TB cases

In addition to the 70 slaughterhouse cases where retrospective evidence of TB was identified, a further 10,151 cattle were slaughtered in Wales in 2016 following detection of a new TB incident in their herd of origin. Of these, 80% were skin test or interferon-gamma reactors, 9% were inconclusive reactors (IR) and 11% were direct contacts (DC) (Figure 4.1).

An increase in the number of animals that were slaughtered was observed since 1990 across all reasons for slaughter for TB control, reaching a peak of around 10,000 in 2008. Since 2008, the overall number of reactors and DCs slaughtered for TB control reasons has been variable with no obvious trends The number of reactors slaughtered decreased between 2012 and 2013 by 37% but has increased again between 2014 and 2016 (Figure 4.2a). The number of IRs slaughtered increased approximately 4-fold between 2008 and 2009, and following a drop in 2010, has remained relatively stable over the subsequent 6 years (Figure 4.2b).

Overall, 14% of slaughtered reactors, IRs and DCs had detected lesions (DL) (where lesion status was recorded). Lesions were more likely to be detected in reactors, particularly at standard interpretation, than in either DCs or IRs (Table 4.1). Of the 590 DL samples with culture results in 2016, 94% were *M. bovis* positive. A similar proportion of DL samples with culture results were *M. bovis* positive in England in 2016 (95%, Bovine tuberculosis in Great Britain. Surveillance data for 2016 and historical trends). This proportion has varied in Wales from 89% to 97% since 2003 (mean = 93%; SD = 2%) (Figure 4.4).

Of the 2,451 samples from animals with no detectable lesions (NDL) and for which culture results were available in 2016, only 2% were *M. bovis* positive (Table 4.1), though this does not mean that the remaining 97% were not infected since infected animals often do not have detectable lesions or yield positive culture results. Indeed, the earlier reactors are identified the less likely they are to have such lesions or to provide positive culture samples. Since 2002 the proportion of NDL samples with culture results that were *M. bovis* positive has remained relatively constant, although this does fluctuate year-on-year (Figure 4.4).

Duration of bovine TB incidents in Wales

The mean and median durations of incidents that closed in 2016 were 287 and 202 days respectively. The duration of movement restrictions for OTF-S incidents was significantly shorter than for OTF-W incidents, with 70% of OTF-S incidents closing within 150 days, compared with 10% of OFTW incidents (Table 5.1).

Since 2001, the median duration of OTF-W and OTF-S incidents remained consistently around 250 days and 130 days respectively and despite more fluctuation in recent years, a slight decreasing trend has been observed (Figure 5.1).

Relative to the durations of incidents in Pembrokeshire, incident durations were shorter in almost all counties in Wales. However, incidents were most notably shorter in Anglesey, Gwynedd, Clwyd, South Powys and Glamorgan after adjusting for the effects of herd type and herd size which are factors associated with incident duration (Table 5.2).

Recurrent incidents

Of the 11,300 herds included in analyses, 84% had no incidents in either 2016 or the previous 36-months (Table 6.1). Herds with OTF-W incident(s) in the previous 36-months were more likely to have an OTF-W incident than only an OTF-S incident in 2016. Herds with a history of TB were five times more likely to have a new incident in 2016 than herds with no history (Table 6.2). The proportion of OTF-W herds that had a history of TB has not changed substantially in the last five years although there is a decreasing trend in OTF-S herds due to most recurrent OTF-S herds being reclassified as OTF-W (Figure 6.1).

The odds of a new TB incident were higher in herds with a history of TB compared to herds with no history of TB after adjusting for herd size, herd type and geographical area (Table 6.2).

Of the 318 recurrent incidents included in the analyses, the time elapsed between incidents was a median of 16.1 months and mean of 16.6 months. The mean duration between incidents tended to be longer where the 2016 incident was OTF-S compared with when the 2016 incident was OTF-W (Table 6.3).

Inconclusive reactor herds that subsequently suffered an incident

Twenty-one per cent of IR-only herds in Wales in 2016 were shown to be infected with TB at the first IR retest. Following a clear IR test, 19% of IR only herds were disclosed as infected in the following 15 months, and this was more common in dairy herds compared with beef herds.

There were 970 IR-only herds that had IR-retests, of which 15% had an OTF-W incident at the IR-retest, 6% had an OTF-S incident and the remaining 79% had no new TB incident (Table 7.1). Significantly more IR-only herds that were clear at the retest went on to have an incident compared with herds that tested clear at a routine whole herd test ($p<0.001$ Fishers Exact test).

There was an increase in the proportion of IR-only herds that had a subsequent OTF-S incident at the IR retest up to 2009 (8 % in 2006 to around 25 % in 2009). However, since 2009 the figure has decreased considerably, particularly after the change to the way incidents are classified in 2011. The proportion of IR-only herds that had a subsequent OTF-W incident at the IR retest remained constant, at between 7% and 9% prior to 2011. As would be expected, this has increased as more herds were classified as OTF-W from 2011 (Figure 7.1).

The characteristics of herds that are associated with high incidence of TB infection are also associated with increased likelihood of subsequent incidents following an IR-only test (Table 7.1). This suggests that where an IR-only test occurs in a herd that is at high risk of infection, it is more likely that this herd was truly infected and will suffer a subsequent incident.

Of the 3,393 animals which had an inconclusive reaction to the skin test, 76% tested clear at the first re-test, 5% became reactors at the first re-test using either standard or severe interpretation of the skin test, and 15% of animals had a second inconclusive reaction and became 2xIRs. Of the 524 2xIR animals, 67% went on to be tested using gamma interferon (gIFN), and 69% had a negative test result and were subjected to a third skin test. Of these, 21% had a third inconclusive reaction to the skin test and became 3xIRs. Of the animals which tested clear at the first retest, 5% became a reactor or an IR within the original incident, and a further 5% became a reactor or an IR at a test subsequent to the initial incident (Figure 7.6).

Genotypes identified in bovine and non-bovine species in Wales

There were 365 isolates with full genotypes originating from 330 separate bovine TB incidents in cattle in Wales commencing in 2016. The most common *M. bovis* genotypes (9:b, 17:a, 9:c and 22:a) make up over 85% of all Welsh incidents and have homeranges in Wales (Table 8.2, Figure S3).

Twenty two non-bovine isolates were genotyped in 2016. They included 12 isolates from badgers, eight from pigs, one alpaca and one cat.

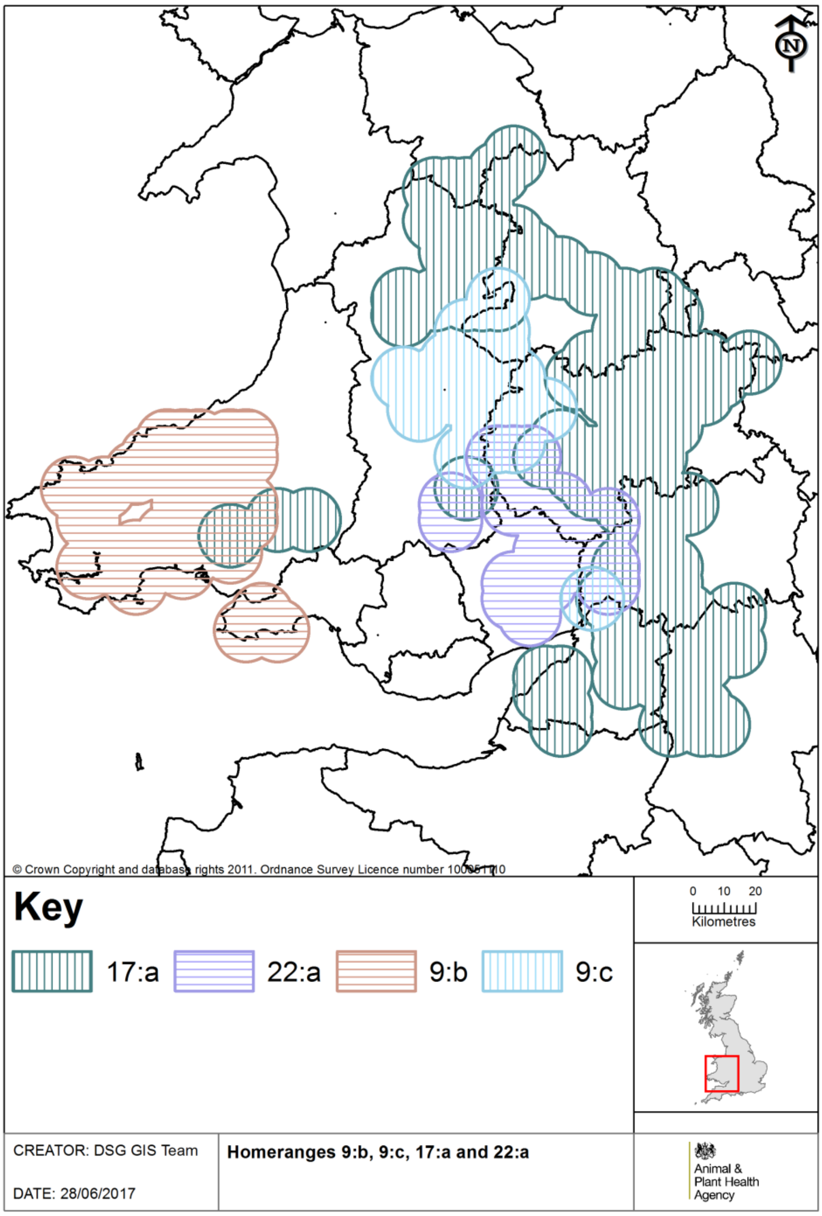


Figure S3: Homeranges for genotypes 9:b, 9:c, 17:a and 22:a using 2012-16 data

Introduction

This report is the seventh iteration of a series of annual reports that commenced with the report for the period January to December 2010. The primary purpose of these reports is to provide important information about the bovine tuberculosis epidemic in Wales. This report focuses on the period January to December 2016 but, where it is useful to do so, the report includes historical data.

Like those before it, this report is designed to be a principal resource to those people directly involved in making policy decisions about the bovine tuberculosis eradication programme in Wales. The epidemiology of bovine tuberculosis is complex and in order to be fit for its primary purpose the report contains complex technical information that some may find inaccessible. Notwithstanding this it is published in the hope that others will find its content informative and useful. A summary is provided and much of the information contained here will form the basis for other publications aimed at different audiences.

It is inevitable and entirely appropriate that the format and content of the reports in this series will evolve over time. The challenge will be to do so while remaining true to the primary purpose and maintaining a consistent narrative of the bovine tuberculosis epidemic in Wales.

The considerable effort that colleagues in the APHA have put into producing this valuable and informative report is greatly appreciated.

Office of the Chief Veterinary Officer
Welsh Government
July 2017

1.0 Welsh cattle population characteristics and TB tests

Key Points:

- Herd density highest in the South-West, North-East and Anglesey
- Dairy herds make up higher proportion of large (>300 animals) herds, although beef herds more common
- Numbers of tests per animal stable following increase between 2014 and 2015

This section describes demographics of the cattle population in Wales. This includes factors which can affect the risk of infection with TB such as herd type and herd size. A summary of the number of TB tests performed is provided. Skin testing is a key component of TB surveillance and includes both routine testing at predetermined intervals, and enhanced testing in response to specific risks such as in herds that are contiguous to infected herds. The intensity of surveillance is related to the estimated risk of infection. It can be expressed as the number of tests in relation to the number of herds, animals or other subsets (e.g. herd types).

1.1 Welsh cattle population characteristics

The density of live cattle herds registered as active on SAM at the end of 2016 in Wales and the bordering English counties is shown in Figure 1.1 (see Appendix 5 for description of areas).

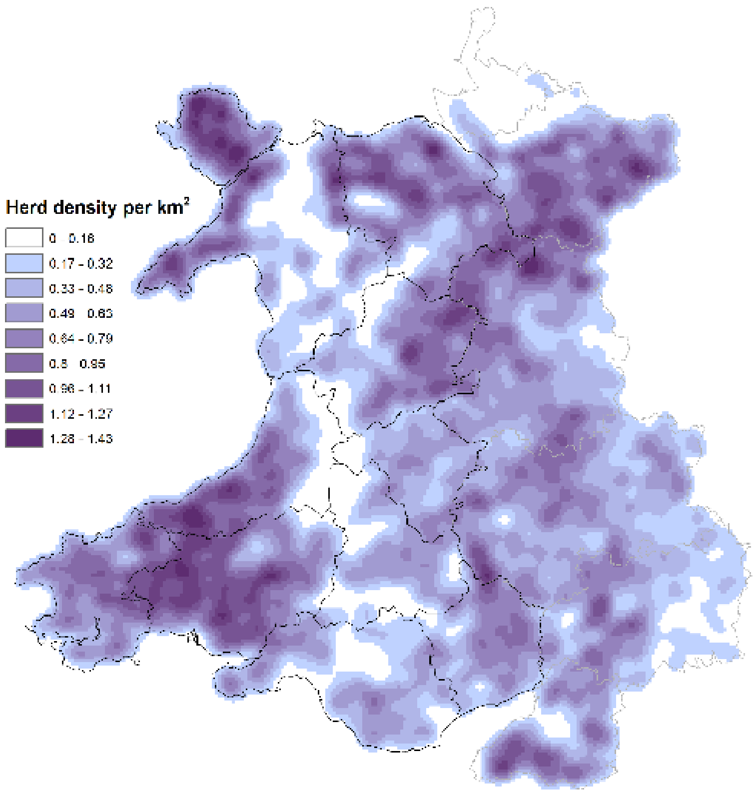


Figure 1.1: Density of cattle herds in Wales and English border counties, 2016

Tables 1.1a and 1.1b show the number of herds in the counties and TB areas of Wales, and by herd type and size. There were 11,651 live cattle herds in Wales on 31st December 2016. Compared with previous years, the geographical distribution of herds in Wales remains stable. Carmarthenshire continued to have the largest number of herds (1,921; 16% of total), followed by Clwyd (1,624; 14%) and Gwynedd (1,324; 11%). Large areas of low herd density (<0.24 herds per km^2) exist across the central/western mountainous section of Wales; from mainland Gwynedd in the North to the Glamorgans in the south. Herd density was high across Carmarthenshire, Clwyd and much of Ceredigion. Anglesey had few herds (706, 6% of total) relative to some other areas, but herd density is relatively high across the island.

Beef herds form the majority (78%) of cattle herds in Wales; dairy herds account for 20% and 2% are classified as Mixed/Other. There is considerable regional variation in these proportions, and this is consistent with previous years. Dairy herds are more common in Pembrokeshire and Carmarthenshire than in other geographical areas, with very few in Mid or South Powys (Table 1.1a).

Table 1.1a: Herds in Wales (active on SAM) by herd type and geographical area, end-2016

	Herds	Percentage of Wales total	Herd type [no. herds (%)]		
			Beef	**Dairy**	**Mixed / Other**
County:					
Anglesey	706	6.1	607 (86)	75 (11)	24 (3)
Gwynedd	1,324	11.4	1,154 (87)	138 (10)	32 (2)
Clwyd	1,624	13.9	1,173 (72)	410 (25)	41 (3)
Pembrokeshire	1,142	9.8	707 (62)	407 (36)	28 (2)
Ceredigion	1,122	9.6	814 (73)	290 (26)	18 (2)
Carmarthenshire	1,921	16.5	1,258 (65)	609 (32)	54 (3)
North Powys	1,138	9.8	976 (86)	147 (13)	15 (1)
Mid Powys	518	4.4	503 (97)	7 (1)	8 (2)
South Powys	543	4.7	509 (94)	20 (4)	14 (3)
Glamorgans	860	7.4	749 (87)	91 (11)	20 (2)
Gwent	753	6.5	574 (76)	168 (22)	11 (1)
Total	**11,651**		**9,024 (77)**	**2,362 (20)**	**265 (2)**

The size of cattle herds in Wales in 2016 ranged from 1 to 4,008, with 66% of herds having fewer than 100 cattle. However, herds in Pembrokeshire tended to be larger with 18.4% having a herd size greater than 300 cattle (median herd size = 82). This is related to the high proportion of dairy herds in Pembrokeshire (Tables 1.1b and 1.1c). Despite making up a larger proportion of the total, beef herds typically contain fewer animals than dairy herds (Table 1.1b); around 76% had 100 animals or fewer compared with only 29% of dairy herds.

Table 1.1b: Herds in Wales (active on SAM) by size category, geographic location and herd type, end-2016

	Herd size							
	Undeter-mined	1-10	11-50	51-100	101-200	201-300	>300	Total
County:								
Anglesey	10	138	224	118	120	46	50	706
Gwynedd	18	188	501	275	196	78	68	1,324
Clwyd	32	232	431	309	319	138	163	1,624
Pembrokeshire	24	134	283	187	199	105	210	1,142
Ceredigion	16	167	337	226	215	79	82	1,122
Carmarthenshire	39	328	587	344	322	122	179	1,921
North Powys	8	138	351	262	229	78	72	1,138
Mid Powys	5	47	173	160	100	17	16	518
South Powys	10	75	174	139	98	30	17	543
Glamorgans	10	175	314	167	130	37	27	860
Gwent	15	133	245	145	114	41	60	753
Herd type:								
Beef	130	1,553	3,294	1,981	1,419	388	259	9,024
Dairy	14	97	251	336	605	380	679	2,362
Other	43	105	75	15	18	3	6	265
Total	**187**	**1,755**	**3,620**	**2,332**	**2,042**	**771**	**944**	**11,651**

Table 1.1c: Percentage of herds (active on SAM) by size category, geographic location and herd type, end-2016

	Herd size [%]							
	Undeter-mined	1-10	11-50	51-100	101-200	201-300	>300	Median herd size
County:								
Anglesey	1	20	32	17	17	7	7	47
Gwynedd	1	14	38	21	15	6	5	46
Clwyd	2	14	27	19	20	8	10	64
Pembrokeshire	2	12	25	16	17	9	18	82
Ceredigion	1	15	30	20	19	7	7	59
Carmarthenshire	2	17	31	18	17	6	9	51
North Powys	1	12	31	23	20	7	6	62
Mid Powys	1	9	33	31	19	3	3	59
South Powys	2	14	32	26	18	6	3	53
Glamorgans	1	20	37	19	15	4	3	38
Gwent	2	18	33	19	15	5	8	47
Herd type:								
Beef	1	17	37	22	16	4	3	42
Dairy	1	4	11	14	26	16	29	195
Other	16	40	28	6	7	1	2	10
Total %	**2**	**15**	**31**	**20**	**18**	**7**	**8**	

Table 1.2 shows the numbers of herds, cattle and individual animal-level tests between 2012 and 2016. The number of herds in Wales has decreased over the last five years by 8.5%, while the estimated number of animals has increased by 1.9%. Much of the apparent change in herd numbers between 2012 and 2016 was concentrated in 2014 and 2015. This is likely to be attributable to a cleansing exercise that was undertaken on the British Cattle Movement Service (BCMS) data during 2014, which resulted in the closing of inactive herds.

Changes in herd size were very similar to the changes observed across Great Britain as a whole, exhibiting only a slight decrease in herds (0.2% and 0.1%) A 1.4% increase in cattle numbers was observed in 2016, higher than for Great Britain as a whole which was only 0.7%.

Table 1.2: Herds (active on SAM), cattle and animal-level tests, 2012-2016

Year	Total herds	% change in herds[1]	Total cattle[2]	% change in cattle[1]	Total tests (animal level)[3]	% change in tests[1]
2012	12,729	↓ 0.7	1,113,141	↓ 0.9	2,191,960	↑ 2.5
2013	12,676	↓ 0.4	1,094,644	↓ 1.7	2,179,763	↓ 0.6
2014	12,067	↓ 4.8	1,102,768	↑ 0.7	2,146,122	↓ 1.5
2015	11,675	↓ 3.2	1,118,979	↑ 1.5	2,243,768	↑ 4.6
2016	11,651	↓ 0.2	1,134,341	↑ 1.4	2,266,799	↑ 1.0

1 Arrows indicate the direction of the percentage change: ↓ = reduction in number, ↑ = increase in number
2 Sourced from official DEFRA statistics
3 Tests for both surveillance and for disease control purposes are included here. Numbers of routinely slaughtered cattle (derived from CTS) are included, because every carcase undergoes inspection for macroscopic lesions that could indicate TB.

1.2 Bovine tuberculosis testing applied to the Welsh cattle population

The total number of tests conducted on cattle in Wales remained relatively stable between 2015 and 2016, at nearly 2.27 million (Table 1.2). The total number of tests conducted on cattle in Wales includes around 232,000 cattle per year which are slaughtered by the meat industry and undergo a routine inspection for the presence of lesions indicative of infection with *M. bovis*. The ratio of animal-level tests to the number of cattle has remained fairly static, 2:1 in 2012 and in 2016 (Table 1.2). All herds in Wales have been on an annual testing regime since October 2008 when the Health Check Wales initiative was introduced, and some 300 herds in the Intensive Action Area of Pembrokeshire have been tested twice yearly since May 2010 (265 herds in 2016).

See Appendix 3 for a full list of surveillance test types performed.

2.0 Bovine tuberculosis incidence and prevalence in Wales

Key points

- There was a drop in measures of incidence in 2016, while prevalence remained relatively stable
- TB rates are highest in South-West and Eastern Wales
- TB incidence increases with herd size

In this section, the scale of TB infection in Welsh herds in 2016 is compared with previous years. The variation in TB incidence and prevalence between different geographical areas, herd sizes and herd types is described to facilitate the development of targeted surveillance strategies.

Three methods are used in this section to determine the incidence or prevalence of TB in Welsh cattle herds. These are described in detail in the Materials and Methods section, and summarised here:

- **Incidence of TB** – this is expressed as the number of newly detected infected herds during 2016, per 100 active herds tested by whole herd test when not under movement restrictions and therefore at risk of having a new incident.
- **Incidence rate** – this is calculated by dividing the number of new incidents by the total amount of time the herds tested during the period in question were unrestricted and at risk of infection since the end of their last TB incident or negative herd test. This is an established methodology for disease incidence estimation. Its chief advantage is that it provides a more reliable time series because changes and differences in testing frequency regionally and over time are taken into account.
- **Prevalence of TB** – this is calculated as the proportion of herds that are under movement restriction at a single point in time (mid-December), per 100 live herds.

2.1 Bovine tuberculosis incidence and prevalence in 2016

Table 2.1 presents the prevalence and incidence rates of TB in Wales in 2016. Six per cent of Welsh herds incurred a new TB incident in 2015 and 5% of herds were under movement restrictions in mid-December 2016 (excludes herds under restriction due to an overdue test). There were 7.0 new TB incidents per 100 herd years at risk. This is equivalent to detecting 70 new incidents for every 1,000 herds that had been unrestricted for one year. This is a fall of 14.6% compared with the 2015 figure of 8.2 per 100 herd years at risk.

Table 2.1: Incidence and prevalence of TB in Wales, 2016

	Total incidents	OTFW	OTFS	Denominator
New incidents	706	624	82	NA
New incidents per 100 live herds	6.1	5.4	0.7	11,651
New incidents per 100 unrestricted herds tested	6.6	5.8	0.8	10,742
New incidents per 100 herd years at risk	7.0	6.2	0.8	3,690,925 days (10,105 years) at risk
Herds under restriction (mid-December 2016)	566	532	34	NA
Herds under restriction per 100 live herds	4.9	4.6	0.3	11,652[1]

[1] This is the number of 'live' herds in *mid-December* 2016 so differs from the herd number given in Section 1.

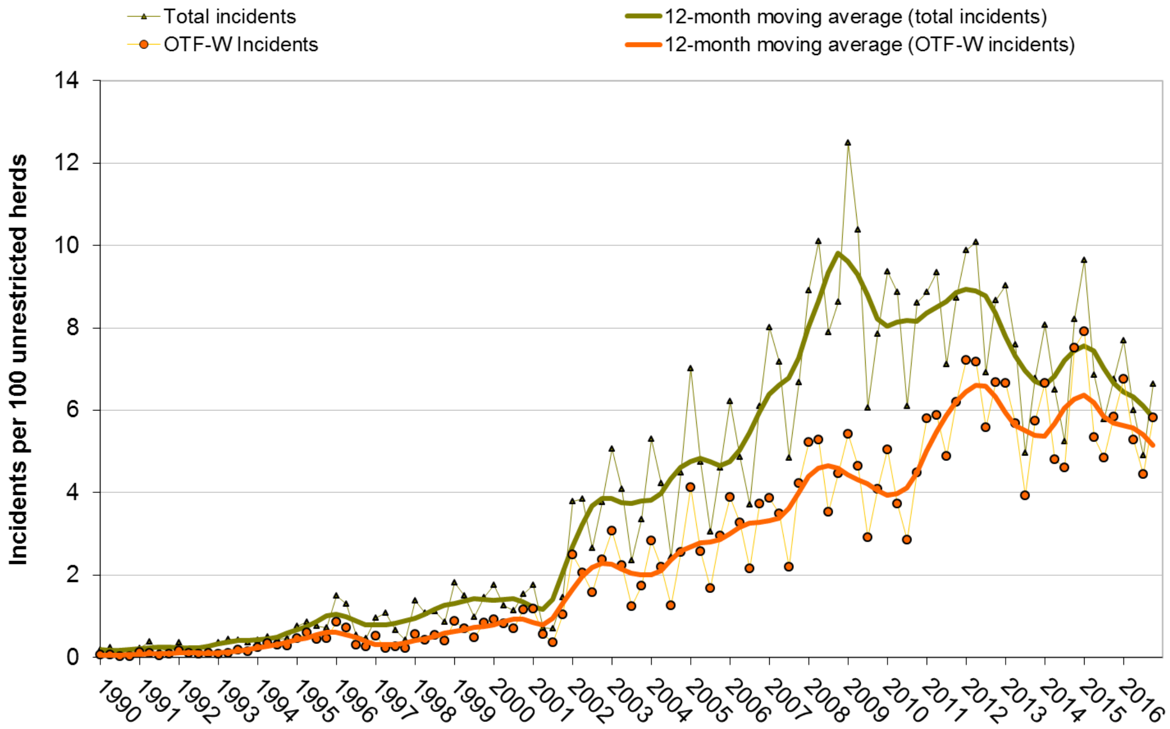
2.2 Temporal trends in TB incidence and prevalence in Wales

Figures 2.1 and 2.2 illustrate trends in the incidence and prevalence of TB in Wales since 1990. In Figure 2.1 the quarterly incidence is also presented as a 12-month moving average to facilitate comparison with the overall annual incidence.

An overall decrease in the total number of new incidents per 100 unrestricted herds has been observed since the end of 2008, despite increases in 2011 and 2014. There was an 11% increase in the trend (i.e. the 12-month moving average) between 2013 and 2014. Subsequently, there was an 11% decrease in 2015 followed by a further decrease in 2016, of 13%. The difference in incidence between OTF-W and total incidents has continually narrowed since 2011 due to the change in classification of OTF-W[1] incidents and the subsequent increase in the proportion of all incidents classified as OTF-W.

[1] Throughout this report the OTF-W cohort contains incidents without post mortem evidence of infection that have been determined to have sufficient epidemiological evidence to withdraw OTF status (OTF-W-2; see Materials and Methods section for more information).

Figure 2.1: Quarterly number of total and OTF-W incidents per 100 unrestricted herds between January 1990 - December 2016



A similar shaped trend was observed for prevalence (proportion of herds under restriction, Figure 2.2). However, there is a 4-5 month time-lag compared with incidence measures because prevalence is affected by the length of time herds are under restriction. In recent years the proportion of herds under restriction has peaked on a roughly three-yearly basis, at 8% of herds in the middle of May 2009, at 7% in the middle of July in 2012 and at around 6% in the middle of May 2015.

The explanation for this oscillation in incidence risk is currently unclear but could be a trend introduced due to the high risk of recurrence of infection in herds and the sequence by which herds were tested in relation to bTB risk before annual testing was introduced. If this is the explanation, one might expect the oscillation to reduce with a reduction in disease transmission due to a reduction in recurrence.

Following a peak in July 2012, the proportion of herds under restriction declined to around 5%, where it has remained relatively stable.

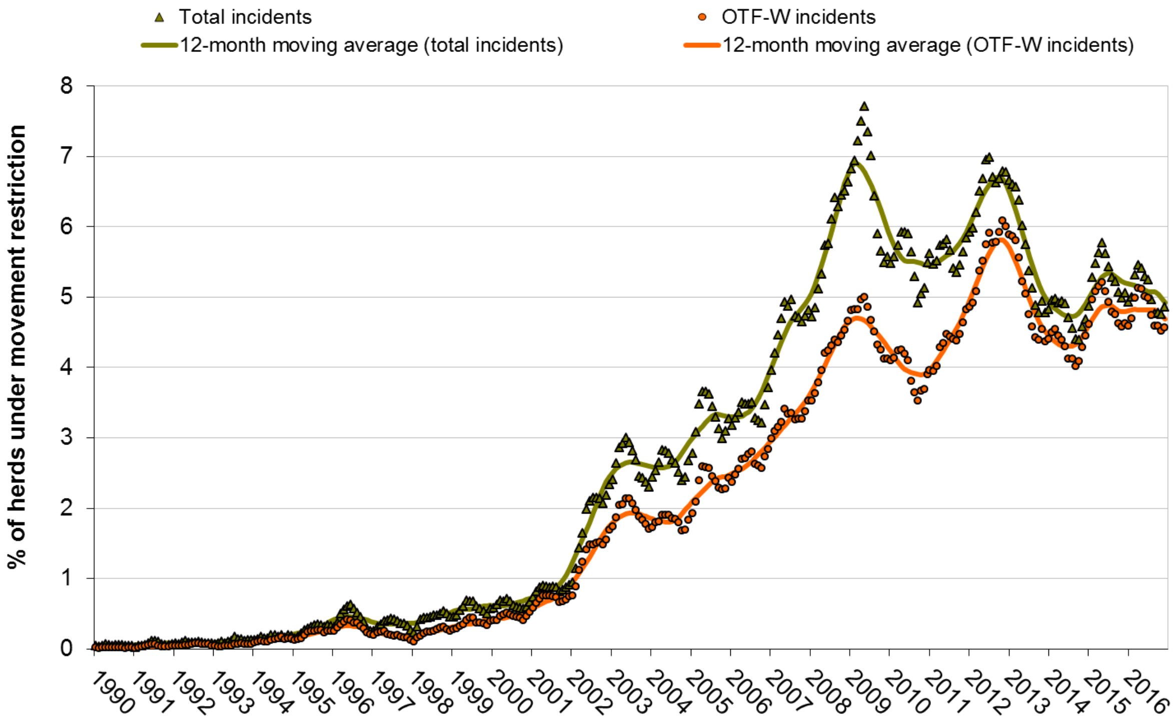


Figure 2.2: Proportion of herds that were under movement restrictions, January 1990 – December 2016

The temporal changes in the three measures used to assess the scale of the TB epidemic in Wales are compared in Figure 2.3. In general, similar shaped trends are observed. The change in the classification of OTF-W herds since 2011 is particularly noticeable, with all measures illustrating comparable patterns for OTF-W and OTF-S incidents prior to this change. There is one notable difference between the three charts – new incidents per 100 herds increased slightly in 2009, while the other measures both decreased. This is likely to be due to the move of all herds in Wales to annual testing regimens, since more frequent testing is likely to identify infected herds earlier, as well as marginally increasing the probability of detecting false positive results. The denominator in the incidence rate (herd years at risk) would also have been inflated in 2009 compared with more recent years because of the large contribution of months from herds previously on 2 or 4 yearly testing. New incidents per 100 live herds and per 100 herd years at risk show gradual declining trends since 2012. Prevalence (herds restricted per 100 live herds) has been stable for 3 years, following a fall in 2013.

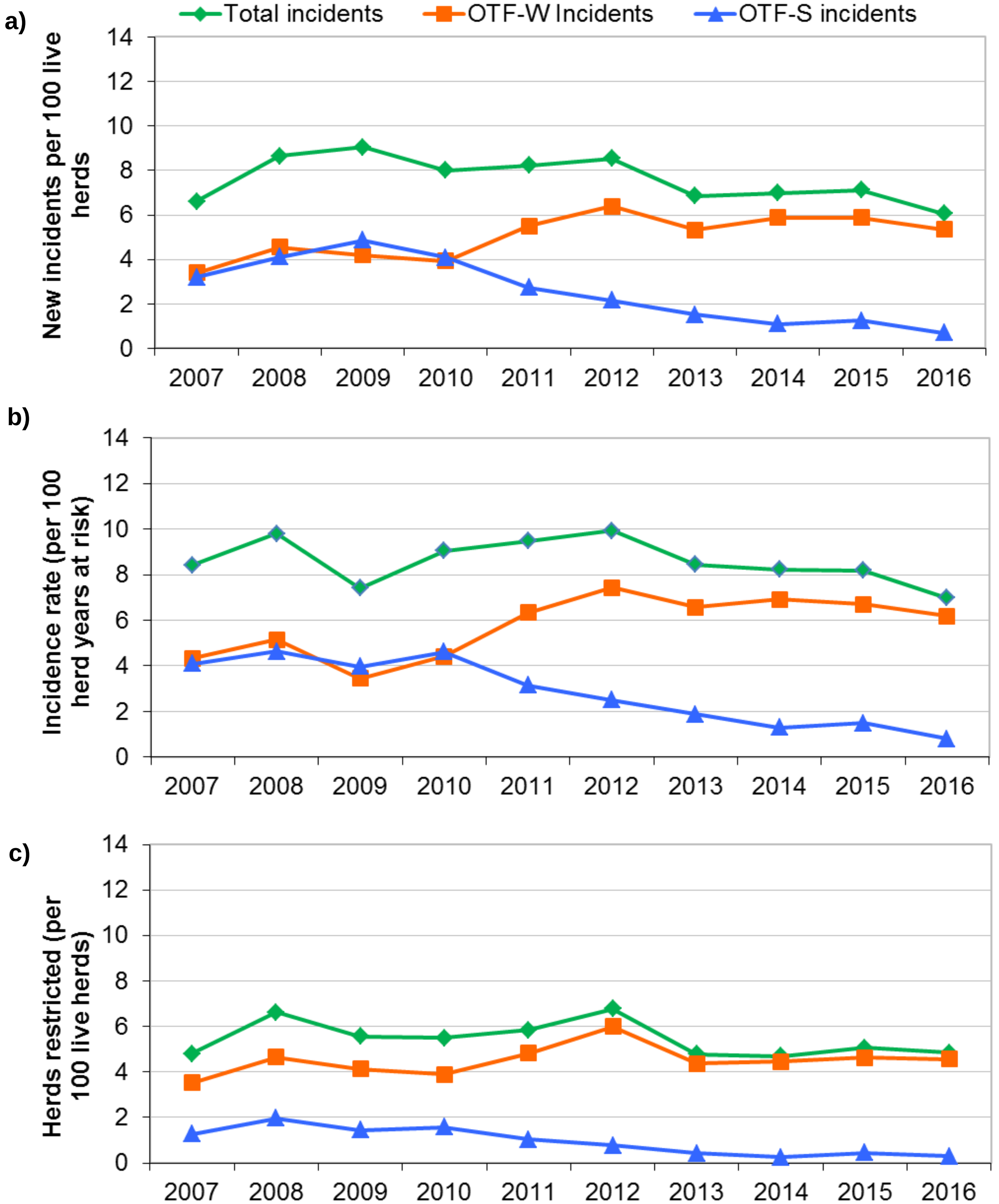


Figure 2.3 a to c: ten year trends in a) new incidents per 100 herds, b) new incidents per 100 herd years at risk, and c) point prevalence of herds under movement restrictions, December of each year

2.3 Incidence and prevalence of TB across Wales

Figure 2.4 shows the geographical distribution of OTF-W and OTF-S incidents starting between 2012 and 2016. There has been little change in the geographical distribution of new TB incidents over this period.

New TB incidents were detected in every county in Wales in 2016, but, as has been observed historically, the majority of incidents were found in the south west (Pembrokeshire, Ceredigion and Carmarthenshire) and along the Welsh/English border. Larger numbers of new incidents are typically detected in areas where there are more cattle herds (Figure 1.1). However, the distribution of the cattle population does not entirely account for variation in the number of new incidents detected in each geographical area. This becomes evident when the number of herds is adjusted for, as areas such as Anglesey, Gwynedd and Clwyd continued to have fewer new incidents per 100 unrestricted herds in 2016 than areas in the south west and Welsh/English border areas (Figure 2.5). Of these new incidents, 88% were OTF-W. However this varied somewhat by geographical area. No OTF-W incidents were observed in Anglesey, while Gwynedd saw over 50% OTF-S incidents (11/20) (Figure 2.4).

The temporal trends in the number of new incidents per 100 unrestricted herds (Figure 2.5) and the incidence rates of TB per 100 herd years at risk (Figure 2.6) vary across Wales. Unsurprisingly these two figures show similar trends, with almost all areas observing a decrease in 2016. An overall decrease in incidence of around 15% between 2015 and 2016 was observed. At the county level, the largest decrease between 2015 and 2016 was observed in Glamorgans (↓32.3%), closely followed by Carmarthenshire (↓31.8%), Mid Powys (↓19.7%), and Clwyd (↓19.6%).

Prevalence (proportion of herds under restriction) typically was generally stable or downwards across Wales in 2016 (Figure 2.7). Consistent with previous years, prevalence was higher in Pembrokeshire than in any other county.

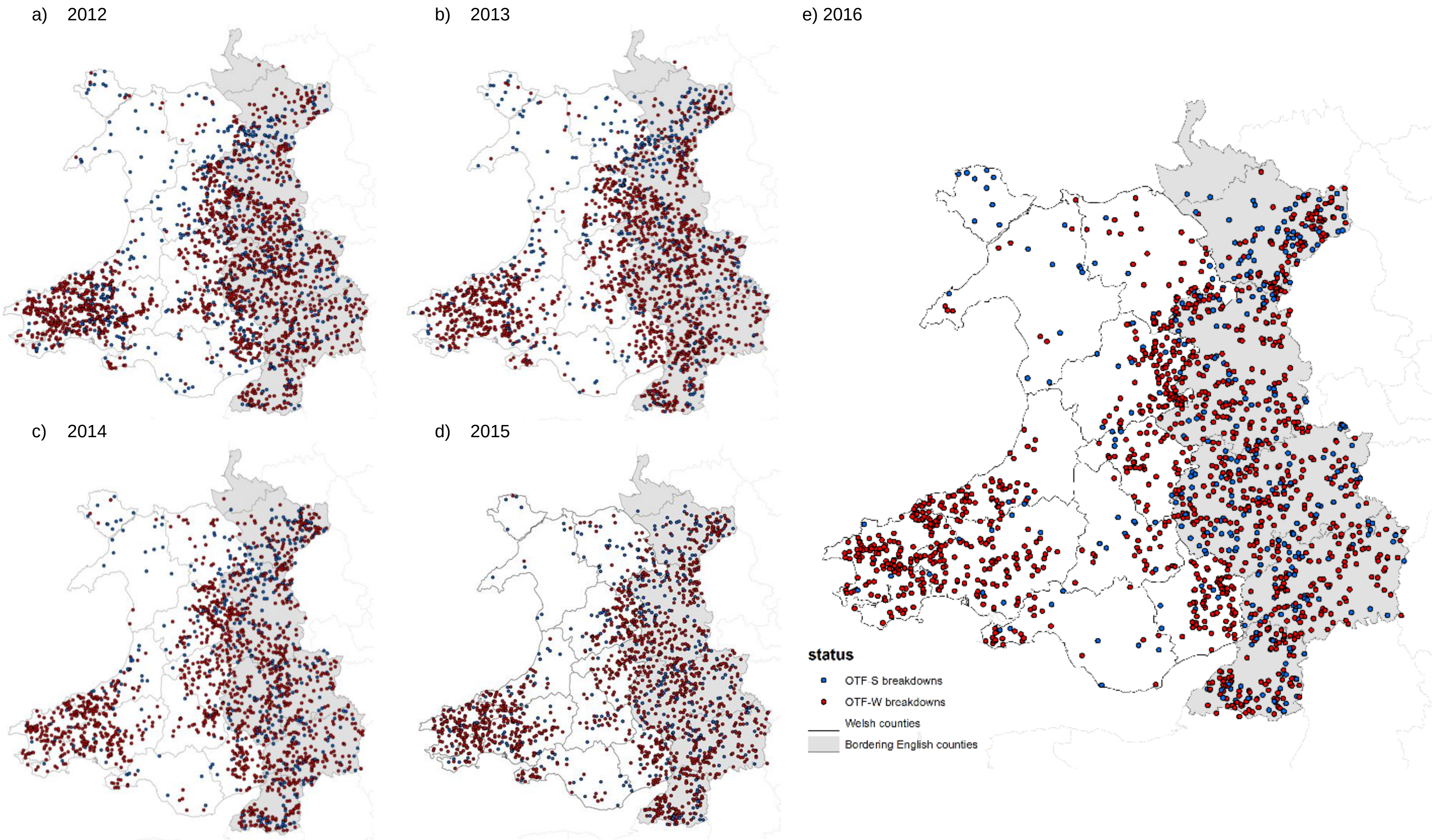


Figure 2.4: Geographical distribution of new OTF-W and OTF-S incidents occurring in Wales and bordering English counties in 2012 - 2016

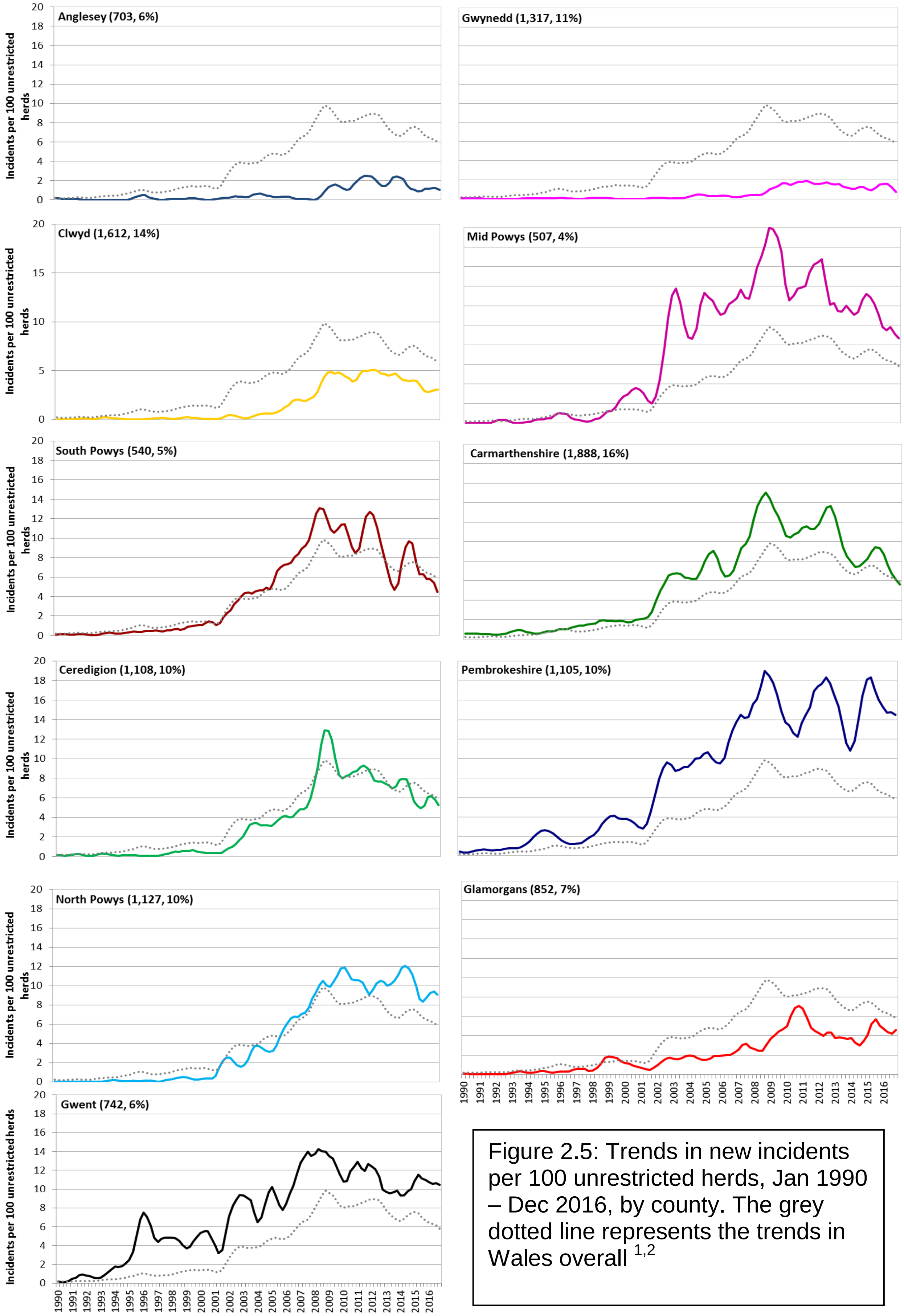


Figure 2.5: Trends in new incidents per 100 unrestricted herds, Jan 1990 – Dec 2016, by county. The grey dotted line represents the trends in Wales overall [1,2]

[1] Quarterly (annualised), smoothed 12-month moving average[1]The raw number of herds and the percentage this makes up for Wales overall is given for each count

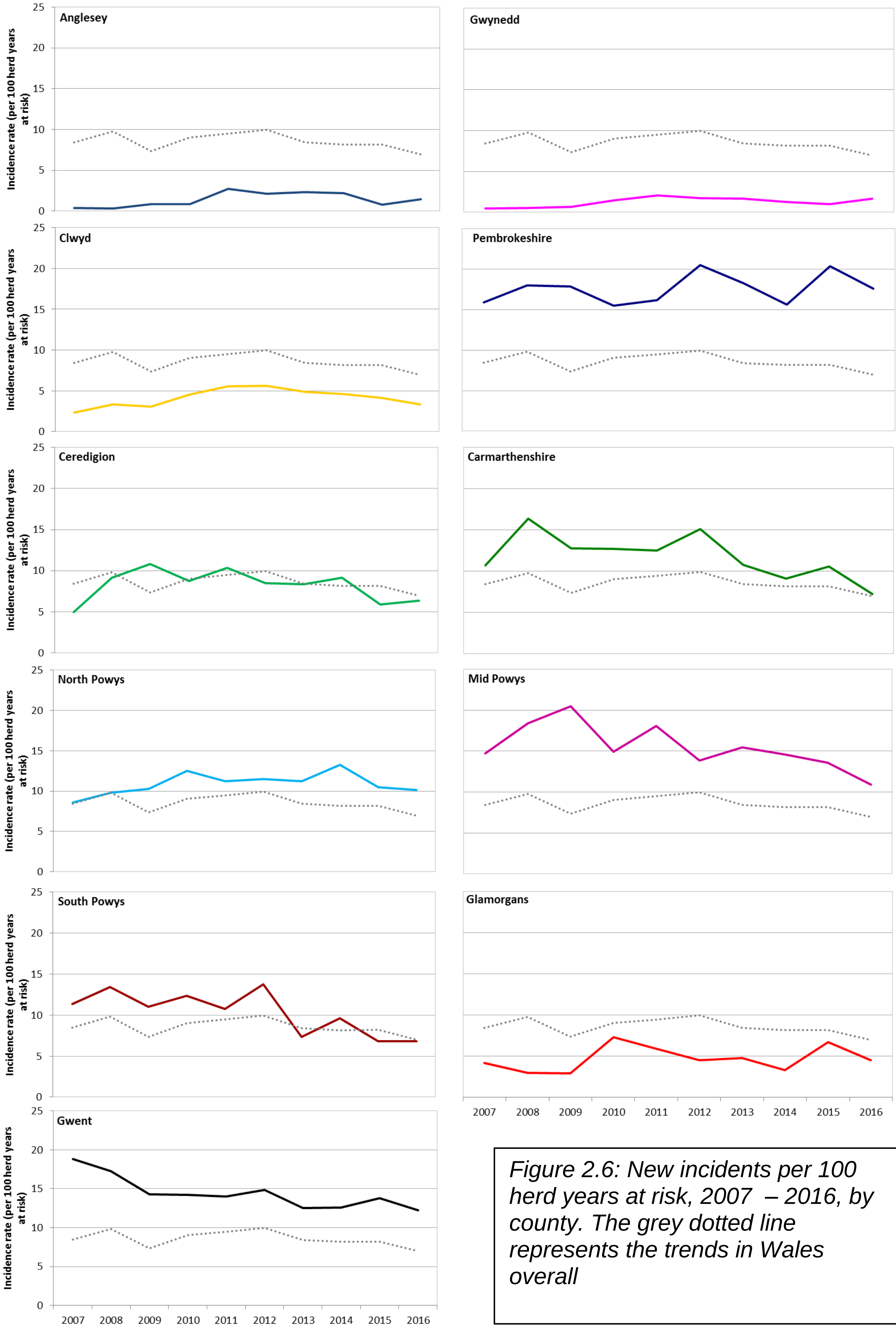


Figure 2.6: New incidents per 100 herd years at risk, 2007 – 2016, by county. The grey dotted line represents the trends in Wales overall

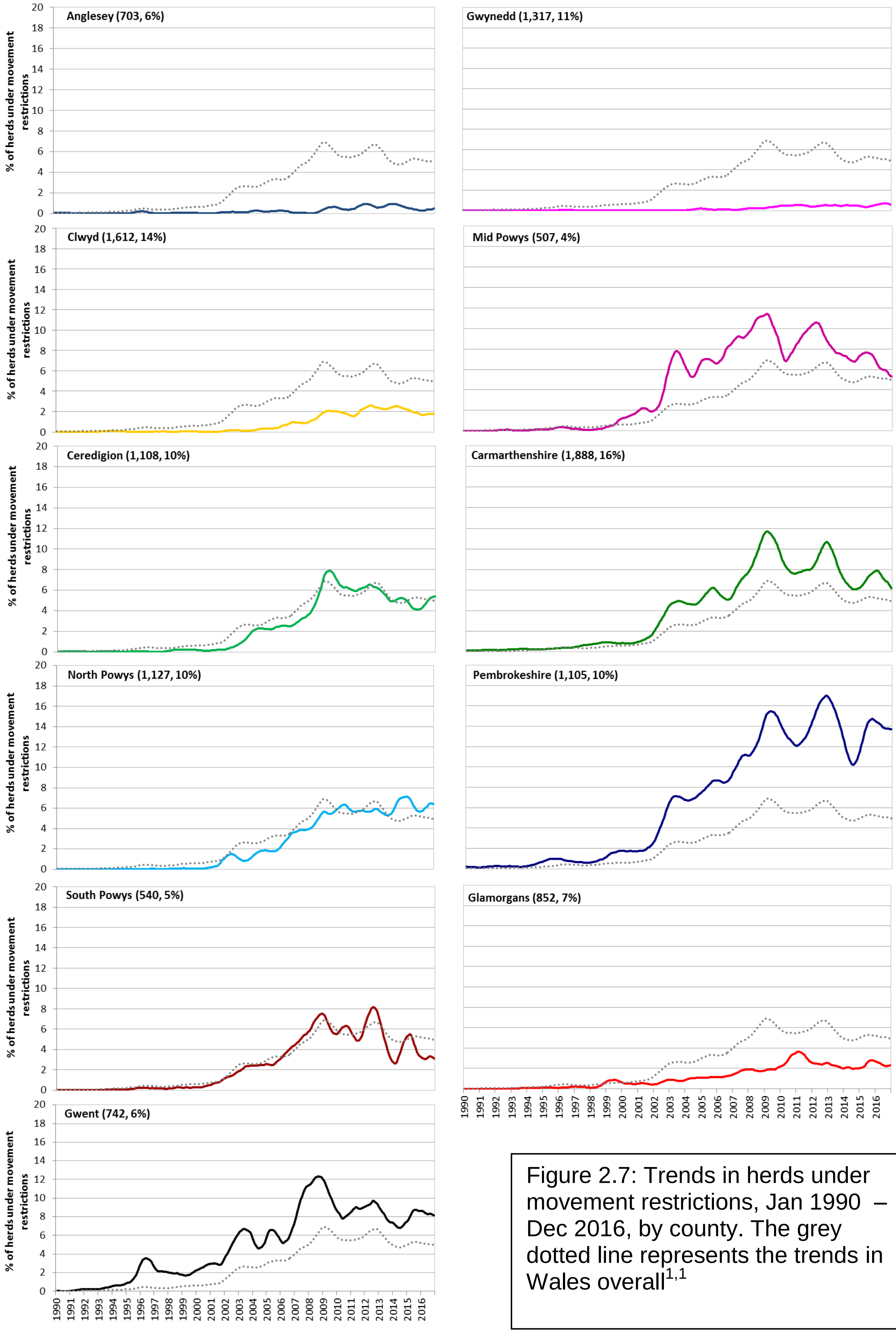


Figure 2.7: Trends in herds under movement restrictions, Jan 1990 – Dec 2016, by county. The grey dotted line represents the trends in Wales overall[1,1]

2.4 New TB incidents identified by different test types

In 2016, there were 706 new TB incidents, of which 624 (88%) were classified as OTF-W incidents and 82 (12%) were classified as OTF-S incidents (see Appendix 2 for definitions).

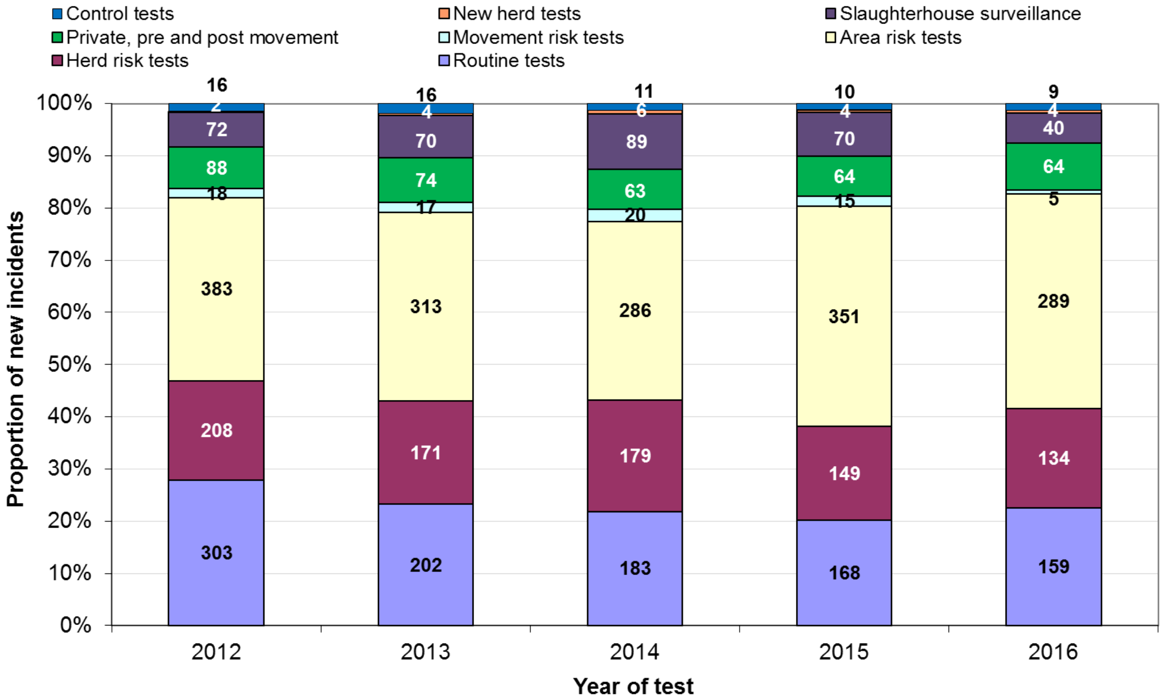
Table 2.2 shows the number of tests on animals in herds not under restriction (surveillance tests), resulting incidents and incidents per 100 surveillance tests. Similar numbers of OTF-W incidents were detected by 'Routine' and 'Herd Risk' test types, whilst a higher number were detected by 'Area Risk' tests (see Appendix 3 for the test types included in each category). However, when considered as a proportion of all tests, nearly seven times as many incidents were detected per 100 'Herd Risk' tests and five times as many incidents per 100 'Area Risk' tests than through 'Routine' herd tests. This is expected given that these tests are conducted in locations, herds, and animals perceived to be at increased risk of infection.

Table 2.2: Tests taken from animals in herds not under restriction (surveillance tests), resulting incidents and incidents per 100 herd surveillance tests, 2016

Surveillance test type [1]	**Herd Tests**	**Incidents**		**Incidents per 100 herd tests**		**Restricted following inconclusive reactor test[2]**	
		Total	**OTFW**	**Total**	**OTFW**	**Total**	**OTFW**
Routine	7,046	159	115	2.26	1.63	52	32
Area Risk	3,675	289	272	7.86	7.40	69	62
Herd Risk	1,194	134	129	11.22	10.80	46	44
Movement Risk	14,652	64	52	0.44	0.35	14	9
Private, pre and post movement	2,522	5	5	0.20	0.20	0	0
Slaughterhouse[3]	191,127	40	40	0.02	0.02	0	0
Control	183	9	8	4.92	4.37	2	2
New Herds	391	4	1	1.02	0.26	0	0
Total	**220,790**	**704**[4]	**622**	**0.32**	**0.28**	**183**	**149**

[1] The tests types included within each test type category are given in Appendix 3
[2] Incidents in which movement restrictions did not commence (in 2016) until an inconclusive reactor test was performed
[3] Number of animals slaughtered from herds that were not under restriction; this is at the animal-level and not the herd-level and therefore not directly comparable with other surveillance test types within this table.
[4] 2 breakdowns of atypical disclosure not included

Figure 2.8 shows the proportions of new incidents detected by different test type categories between 2012 and 2016. In 2012, nearly 30% of new incidents were detected by ‘Routine’ tests; however, this fell to around 20% in subsequent years. This reduction has largely been due to a gradual increase in the proportion of incidents detected through area risk tests from around 35% to over 40% in the same period.



* Incidents were detected in “other” test type category in 2012 (n=2), 2014 (n=1) and 2016 (n=2) – these are not shown.

Figure 2.8: New TB incidents detected by different surveillance testing methods

2.5 Animal level frequency of TB

Table 2.3 shows animal level frequency of reactors and inconclusive reactors (IRs) by counties and TB areas. An additional denominator, total number of skin tests performed on animals, is also presented. In high incidence areas such as Pembrokeshire and Carmarthenshire the number of tests performed is around twice the number of animals tested. The application of short interval tests during incidents means that animals were tested more frequently in high incidence areas. In addition, parts of Pembrokeshire were subject to six monthly testing as part of the Intensive Action Area strategy.

Reactor frequency and IR frequency had similar geographical patterns with frequency being highest in Carmarthenshire, Pembrokeshire, and Gwent reflecting the geographical distribution of incidents in Wales.

Table 2.3: Animal level frequency of reactors and inconclusive reactors, 2016

	Animals tested	Skin Tests Performed on Animals	Animals slaughtered as reactors	Reactor frequency	Animals slaughtered as IRs[1]	IR frequency
				%		%
Geographical area:						
Anglesey	59,394	73,547	7	0.01	2	<0.01
Gwynedd	104,575	135,280	44	0.04	3	<0.01
Clwyd	187,053	245,350	149	0.08	11	0.01
North Powys	117,571	188,229	521	0.44	33	0.03
Mid Powys	43,557	66,258	205	0.47	6	0.01
South Powys	42,046	59,671	98	0.23	8	0.02
Ceredigion	118,619	192,794	456	0.38	70	0.06
Pembrokeshire	206,955	429,682	1,460	0.71	205	0.10
Carmarthenshire	218,332	406,586	2,039	0.93	210	0.10
Glamorgans	62,523	83,425	128	0.20	10	0.02
Gwent	71,125	128,311	445	0.63	68	0.10

Note: the numbers of reactors and IRs in this table are determined using the date of test, not slaughter, and therefore differ to the numbers presented in section 4.

[1] Includes 2 and 3 x IRs

2.6 Variation in TB incidence by herd type, herd size and geographical area

Table 2.4 shows TB incidence rates by county, herd type and herd size. The rate ratios in the table indicate the size of the difference between the different categories of herd size, type and geographical area, relative to a reference category (see Materials and Methods for explanation of the choice of reference category). For example, if a category had an incidence rate ratio of 2.0, this means that the incidence rate in herds within that category was twice as high as that of the reference category. A ratio of less than 1 represents categories where the incidence rate is lower than that of the reference category.

The results from the analysis of incidence rates are consistent with previous years. The results demonstrate that bTB incidence increases with herd size. This effect remains after adjusting for the influence of herd type and location, and has been observed consistently for the past five years. Dairy herds had a substantially higher incidence rate (15 per 100 years at risk) than beef herds (4.7). However, some of this effect is attributable to differences in herd size and location. Nevertheless, even after adjusting for these factors, there remains a statistically significant difference between beef and dairy herds; this is consistent with recent years, with the exception 2014 where the difference between dairy and beef herds was not significant. The lowest incidence rates were seen in Anglesey, Gwynedd, and Clwyd, and the highest in Pembrokeshire, Gwent, and Mid Powys. After adjusting for herd size and type, Anglesey, Gwynnedd and Clwyd still had significantly lower incidence rates than the reference category Carmarthenshire, whilst Mid Powys, Gwent, Pembrokeshire, and North Powys had significantly higher incidence rates.

Table 2.4: Analysis of incidence rates by herd size, type and location and results of Poisson Regression analyses of the associations between these factors and the incidence rate of all new bTB incidents that started in 2016

	Time at risk (years)	**Number new bTB incidents**	**bTB incidence rate (per 100 herd years)**	**Unadjusted[1] incidence rate ratio[3]**	**Adjusted[2] incidence rate ratio[3]**
Herd size					
1 – 10	1,431	14	0.98	0.04***	0.05***
11 – 50	3,439	86	2.50	0.09***	0.12***
50 – 100	2,180	147	6.74	0.25***	0.31***
100 – 200	1,791	182	10.16	0.38***	0.46***
200 – 300	621	101	16.26	0.61***	0.71**
>300	661	176	26.64	*Ref*	*Ref*
Herd type					
Beef	8,636	403	4.67	*Ref*	*Ref*
Dairy	2,016	302	14.98	3.21***	1.41***
Other/mixed	183	1	0.55	0.12*	0.18[ns]
Geographical area					
Anglesey	689	9	1.31	0.19***	0.22***
Gwynedd	1,307	20	1.53	0.22***	0.27***
Clwyd	1,561	48	3.07	0.45***	0.39***
North Powys	1,064	103	9.68	1.42*	1.51**
Mid Powys	485	50	10.30	1.51*	1.97***
South Powys	513	33	6.44	0.94[ns]	1.22[ns]
Ceredigion	1,073	65	6.06	0.89[ns]	0.87[ns]
Pembrokeshire	932	151	16.20	2.37***	1.80***
Carmarthenshire	1,695	116	6.84	*Ref*	*Ref*
Glamorgans	836	35	4.19	0.61*	0.82[ns]
Gwent	679	76	11.19	1.63**	1.95***

*, **, *** and [ns] denote probability values of p≤0.05, p≤0.01, p≤0.001 and p>0.05 respectively with p>0.05 interpreted as not statistically significant.

[1] Results of univariable Poisson regression analysis of the associations between herd size, herd type or geographical area and the incidence rate of new bTB incidents.

[2] Results from Poisson regression analysis where the associations between herd size, herd type or geographical area and the bTB incidence rate were simultaneously adjusted for.

[3] The rate ratio is the incidence rate in each category / incidence rate in the reference category ['*Ref*'])

2.7 Summary of new, closed and ongoing incidents in Wales

There were 706 new incidents in 2016: Overall, the numbers of new incidents have decreased in the last five years (-35%).

There were 448 TB incidents which closed during 2016, having begun prior to 2016. Of these, 90% were OTF-W incidents (Table 2.5). This is similar to the 450 (94% OTF-W) incidents which closed in 2015 having begun before 2015, and similar numbers of new incidents and all incidents closed during the year have been observed in the past three years (Figure S2 in Summary).

Finally, there were 129 ongoing (started prior to 2016) TB incidents, 126 (98%) of which were OTF-W incidents. This number has remained fairly stable over the last five years (Figure S2 in Summary) and reflects the longer restriction duration of these incidents relative to OTF-S incidents.

Table 2.5: The number of new, closed and ongoing TB incidents in Wales in 2016

	Total incidents	**OTF-W**	**OTF-S**
New incidents in 2016	706	624	82
Closed[1] incidents in 2016	448	404	44
Ongoing[2] incidents in 2016	129	126	3

[1] Closed incidents begun prior to 2016 but ended during 2016
[2] Ongoing incidents began prior to 2016 and were still ongoing at the end of 2016

The geographical location of all new, closed and ongoing incidents stratified by OTF-W and OTF-S status can be seen in Figure 2.9. Most of the OTF-W incidents (encompassing new, closed and ongoing) appear to be clustered in the south west of Wales and along the eastern border with England, while OTF-S incidents seem to be more evenly spread across Wales.

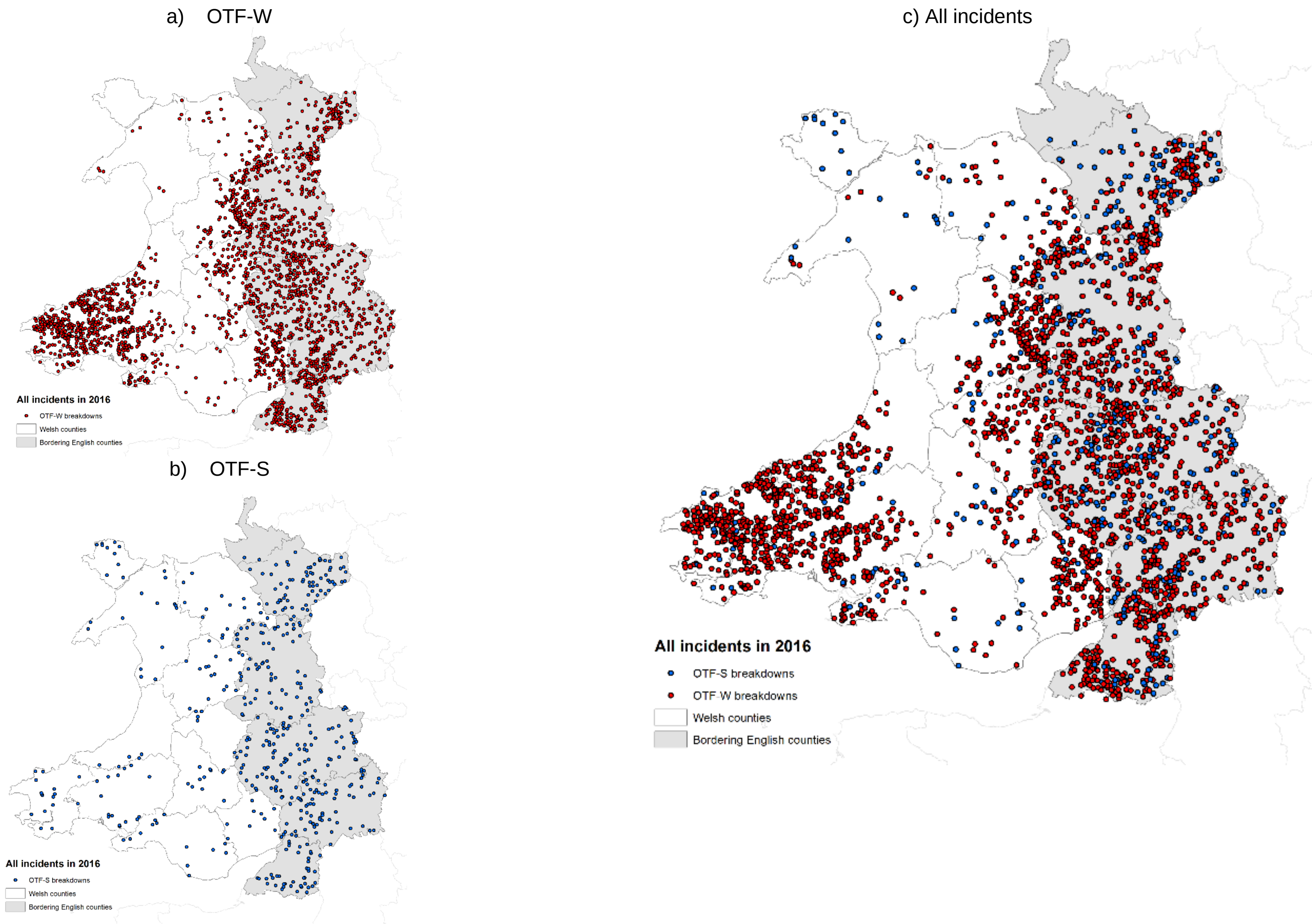


Figure 2.9: Incidents (new, closed and ongoing) occurring in Wales and bordering English counties, 2016

3.0 Routine slaughterhouse surveillance

Key Points:

- 52% of the samples submitted from slaughterhouses were *M. bovis* positive, lower than the proportion for Great Britain as a whole (73%) (Table 3.1)
- There was a 43% decrease in the proportion of OTF-W incidents disclosed at slaughter between 2015 and 2016 (Figure 3.1)
- The median number of reactors identified per slaughterhouse-disclosed OTF-W incident was significantly lower than the median number of reactors per OTF-W incidents disclosed through routine skin testing (Table 3.5)

The routine inspection of all animals at slaughter which are destined to enter the food chain, functions as an additional surveillance stream for detecting TB infection. It provides an opportunity to identify infected animals that have not responded to a recent skin test (e.g. because of anergy[1] due to advanced infection or poor immune responses, or perhaps because of a testing error or infection since last test). As part of this inspection, the lungs and the major lymph nodes of the head and thorax in all cattle are inspected for the presence of TB-like lesions. Slaughterhouse surveillance helps us review the efficacy of the live animal testing component of the surveillance system. By monitoring trends in the proportion of TB incidents disclosed at the slaughterhouse, we can identify changes which may warrant further investigation. The proportion of TB incidents disclosed as a result of slaughterhouse surveillance in Wales has fluctuated over time; in GB this proportion has varied, but due to the introduction of risk areas in England a direct comparison is not available. This could be due to a number of factors such as improvements to the sensitivity of slaughterhouse surveillance, changes to live animal testing protocols, reduced efficacy of the skin test, or a reduction in the severity of infections.

Routine slaughterhouse surveillance identifies animals with TB-like lesions from a population that are not being sent to slaughter as reactors on the basis of a positive field test result in the animal (i.e. Single Intradermal Comparative Cervical Test (SICCT; skin test) or interferon-gamma (gIFN) test. As such, to increase the specificity of routine slaughterhouse surveillance, *M. bovis* must be isolated from suspect lesions by laboratory culture before TB infection can be confirmed. The following section compares detection of TB by slaughterhouse inspection with detection by skin testing. Observable changes in trends may be due to real changes in the epidemiology of the disease, or to changes in testing. Through comparing live animal testing with slaughterhouse surveillance we can monitor our testing efforts. The number of cattle culled as a result of suspicion of TB infection, for example skin test reactors and 'direct contacts' will be discussed in Section 4.

[1] Anergy is the lack of normal immune response to an allergen or in the case of tuberculin testing, antigen, i.e., infected cattle would have a negative response to the skin test result due to reduced responsiveness.

3.1 Submission of samples from animals with lesions suspicious of TB

The number of slaughterhouse samples submitted between 2012 and 2016 from cattle originating from Welsh herds and their culture results are presented in Table 3.1. There was a sharp decline in the number of submissions made in 2016. This reduction follows a 4-year period of little variation in the number of submissions made and has been accompanied by a decrease in the proportion of samples submitted from slaughterhouses which were positive for *M. bovis* (52%). Despite the proportion of submissions from slaughterhouse which had *M. bovis* isolated appearing consistent with previous years, this is lower than the proportion for Great Britain as a whole (73%; Bovine tuberculosis in Great Britain. Surveillance data for 2016 and historical trends).

Table 3.1: Culture results from cattle with TB-like lesions detected during slaughterhouse surveillance

Year	Number of samples submitted	Authorised culture result						Proportion *M. bovis* (%)
		M. bovis	*M. avium*	*Actinobacillus spp.*	Unclassified mycobacterium	Contaminated	Negative	
2012	154	96	0	14	0	0	44	62
2013	135	70	0	15	0	0	50	52
2014	143	98	0	11	0	0	34	69
2015	138	94	0	4	0	0	40	68
2016	95	49	0	11	0	0	35	52

The culture results of samples processed in 2016, split by geographical area of animal origin, are shown in Table 3.2. The largest percentages of *M. bovis* positive submissions came from animals originating from herds in North Powys, followed by Mid Powys, Clwyd and Carmarthenshire. This is similar to previous years.

Table 3.2: Culture results from cattle with TB-like lesions detected during slaughterhouse surveillance, by geographical area

Region	No. samples submitted	*M. bovis* positive	*M. bovis* negative	Contaminated	Proportion *M. bovis* (%)
Anglesey	0	0	0	0	0
Gwynedd	3	0	3	0	0
Clwyd	8	5	3	0	63
North Powys	12	10	2	0	83
Mid Powys	8	5	3	0	63
South Powys	1	0	1	0	0
Ceredigion	8	1	7	0	13
Pembrokeshire	24	13	11	0	54
Carmarthenshire	21	13	8	0	62
Glamorgans	5	1	4	0	20
Gwent	5	1	4	0	20
Total	**95**	**49**	**46**	**0**	**52**

3.2 Incidents disclosed at slaughterhouse inspection

Of the 706 total new TB incidents that started in 2016, 40 (5.6%) were disclosed in the slaughterhouse. All of these were OTF-W incidents, which equates to 6.4% of the 624 OTF-W incidents in 2016[1]. The number of OTF-W incidents disclosed in the slaughterhouse in 2015 was 70 (10% of all incidents), which means there was a 43% decrease in the number of slaughterhouse cases between 2015 and 2016. This follows a 22% decreased between 2014 and 2015.

The number of incidents is partly linked to the surveillance effort at the slaughterhouse. This surveillance underwent major changes in the period following a training exercise in 2010 which resulted in more submissions being made. Figure 3.1 illustrates that the proportion of OTF-W incidents that are detected in the slaughterhouse in Wales continues to fluctuate. The low proportions in 2002 and 2009 may be due to the resumption of testing following the 2001 FMD outbreak, and the increase in testing for Health Check Wales in 2008 respectively, both of which resulted in increases in the number of incidents disclosed through live animal testing.

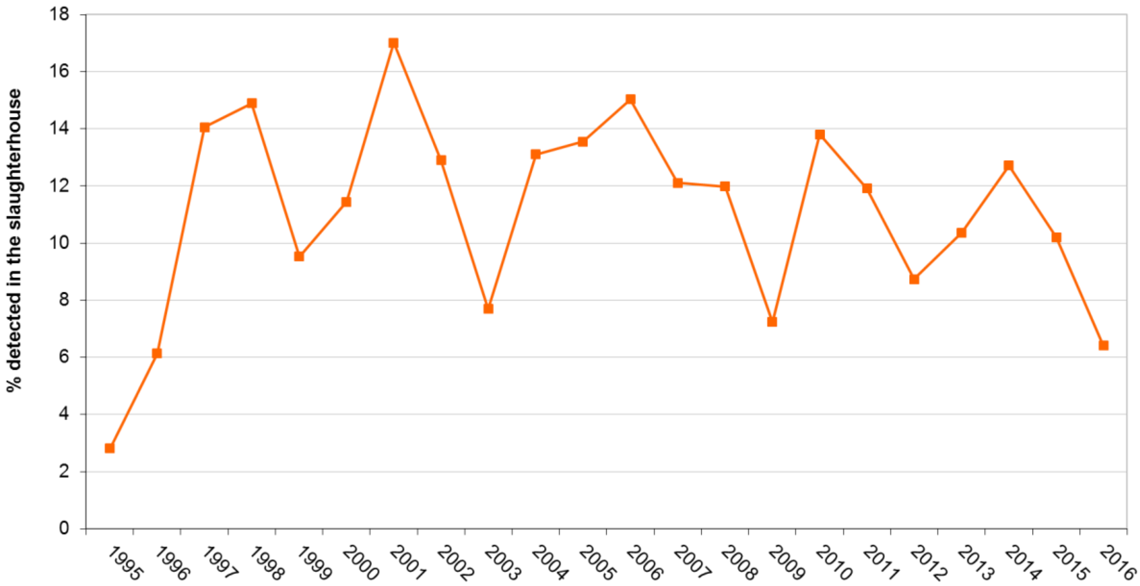


Figure 3.1: Proportion of OTF-W incidents disclosed in the slaughterhouse

The geographical distribution of new incidents detected in the slaughterhouse between 2012 and 2016 is shown in Figures 3.2a to 3.2e. The distribution of slaughterhouse-detected incidents reflects the distribution of total incidents (i.e. those detected by live animal testing OR slaughterhouse inspection) (Section 2, Figure 2.5). Clusters of slaughterhouse-detected incidents occur consistently in Pembrokeshire, Carmarthenshire and along the Welsh/English border. Sporadic incidents also occur in the rest of Wales. However, the reduction in slaughterhouse-detected incidents observed in 2016 is encouraging and indicates the success of live animal testing policies but the cyclical trend observed in figure 3.1 suggests this should still be treated with caution at this stage.

[1] An OTF-S incident can be triggered indirectly by a slaughterhouse case when *M. bovis* is not isolated from the submitted tissue, but tuberculin skin testing (Check Testing) of the herd of origin discloses one or more reactors.

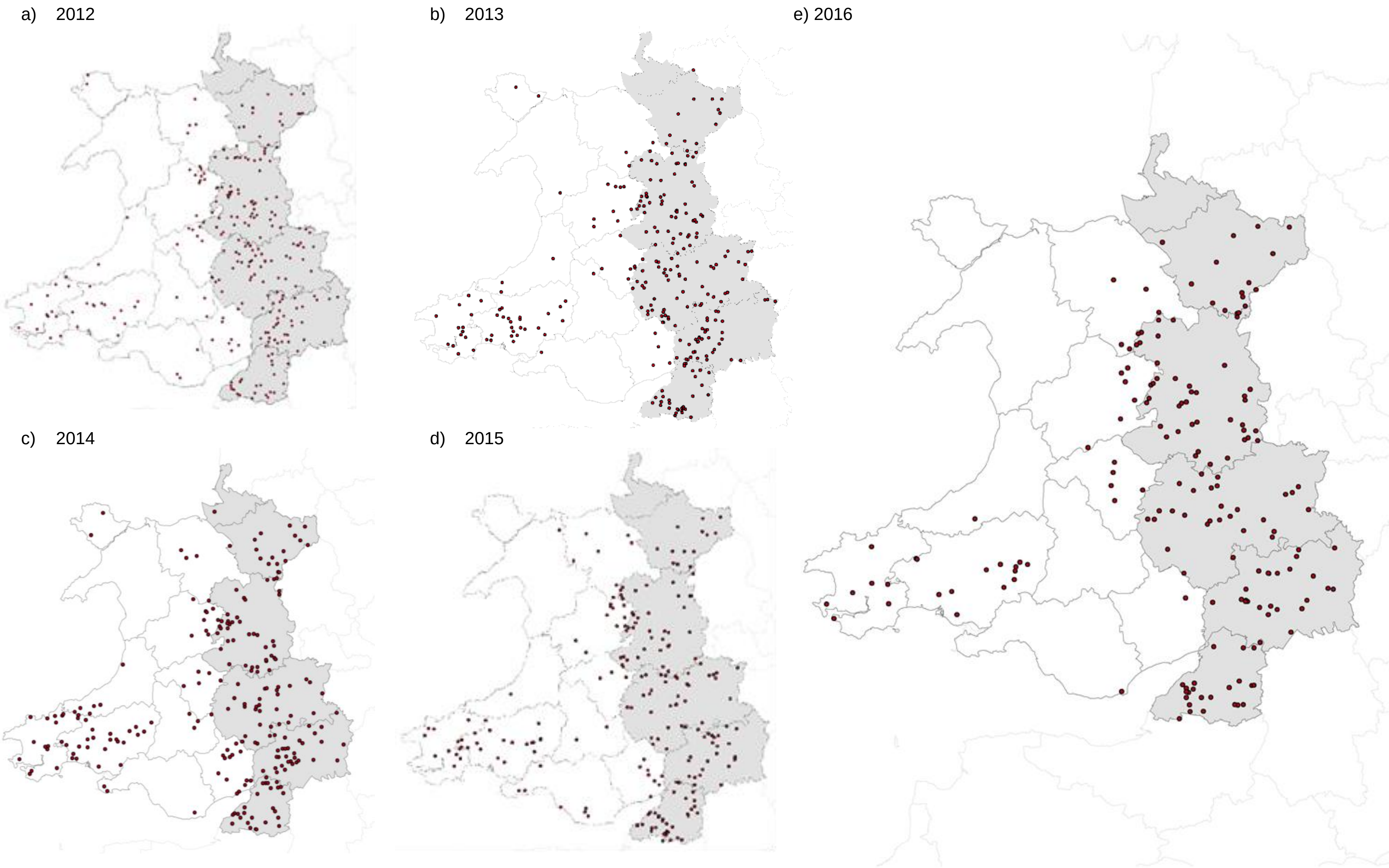


Figure 3.2: New incidents disclosed in the slaughterhouse, 2012 – 2016

The sensitivity of slaughterhouse surveillance, i.e. the ability of the surveillance to identify truly infected animals, can be affected by multiple factors. These factors may be intrinsic to the disease itself, to the management of the herd, such as its size, type, or location, or intrinsic to the process at the slaughterhouse. The odds of an incident being detected at slaughterhouse rather than through live animal testing will be affected by these factors. Therefore they should be taken into account when assessing the odds of an incident being detected to control for any effects they might be having on the direction or magnitude of the outcome.

The results of a logistic regression analysis of the associations between herd type, herd size and geographical area on the odds of an incident being disclosed in the slaughterhouse in 2016 are presented in Table 3.3. The odds ratios[1] indicate the size of the difference in the odds of an incident being detected in the slaughterhouse between the different categories of each variable, relative to a reference category (see Materials and Methods for explanation of the choice of reference category).

When controlling for the effects of herd size and location, dairy herds had reduced odds of an incident being disclosed in the slaughterhouse relative to beef herds. This is likely explained by the fact that dairy herds do not send animals to slaughter as frequently as beef herds, some of which may be exempt from live animal testing, e.g. finishing units. Similarly, after controlling for the effects of herd type and location, the odds of an incident being disclosed in the slaughterhouse rather than through live animal testing was reduced in herds of between 51 and 200 animals relative to herds of more than 300 animals. There was no significant difference in the odds of an incident being disclosed at slaughterhouse between regions at any stage of analysis. This indicates that slaughterhouse surveillance sensitivity does not vary meaningfully across Wales, as would be expected given that all areas are subject to a similar intensity of live animal testing, despite differences in disease incidence.

[1] The ‘odds ratio’ in this case is the odds (probability) of an incident being detected in the slaughterhouse divided by the odds of an incident being detected via skin testing.

Table 3.3: Results of Logistic regression analyses of the associations between herd type, herd size and geographical area and the odds of an OTF-W incident being disclosed in the slaughterhouse (SLH) in 2016

	Total OTF-W incidents	No. SLH cases (%)	No. non-SLH cases (%)	Unadjusted[1]			Adjusted[2]		
				odds ratio[3]	95% confidence interval		odds ratio[3]	95% confidence interval	
Herd size									
1 - 10	9	2 (22.22)	7 (77.78)	3.00^{ns}	0.57	15.85	1.41^{ns}	0.23	8.63
11 - 50	76	4 (5.26)	72 (94.74)	0.58^{ns}	0.19	1.84	0.28^{ns}	0.07	1.11
51 - 100	121	6 (4.96)	115 (95.04)	0.55^{ns}	0.20	1.47	0.27*	0.08	0.86
101 - 200	165	9 (5.45)	156 (94.55)	0.61^{ns}	0.25	1.44	0.32*	0.11	0.90
201 - 300	91	5 (5.49)	86 (94.51)	0.61^{ns}	0.21	1.75	0.50^{ns}	0.17	1.51
>300	161	14 (8.7)	147 (91.3)	*Ref*			*Ref*		
Undetermined	1	0 (0)	1 (100)	-			-		
Herd type									
Beef	336	25 (7.44)	311 (92.56)	*Ref*			*Ref*		
Dairy	287	15 (5.23)	272 (94.77)	0.69^{ns}	0.35	1.33	0.32*	0.13	0.81
Other/mixed	1	0 (0)	1 (100)	-	-	-	-	-	-
Region									
Anglesey	0	0 (0)	0 (0)	-	-	-	-	-	-
Gwynedd	9	0 (0)	9 (100)	-	-	-	-	-	-
Clwyd	40	5 (12.5)	35 (87.5)	2.16^{ns}	0.68	6.85	2.48^{ns}	0.76	8.09
North Powys	92	7 (7.61)	85 (92.39)	1.24^{ns}	0.45	3.47	1.21^{ns}	0.42	3.49
Mid Powys	44	5 (11.36)	39 (88.64)	1.94^{ns}	0.61	6.12	1.68^{ns}	0.49	5.70
South Powys	26	0 (0)	26 (100)	-	-	-	-	-	-
Ceredigion	62	1 (1.61)	61 (98.39)	0.25^{ns}	0.03	2.00	0.32^{ns}	0.04	2.66
Pembrokeshire	145	9 (6.21)	136 (93.79)	*Ref*			*Ref*		
Carmarthenshire	109	11 (10.09)	98 (89.91)	1.70^{ns}	0.68	4.25	2.29^{ns}	0.87	5.98
Glamorgans	27	1 (3.7)	26 (96.3)	0.58^{ns}	0.07	4.78	0.69^{ns}	0.08	6.04
Gwent	70	1 (1.43)	69 (98.57)	0.22^{ns}	0.03	1.76	0.22^{ns}	0.03	1.79
Total	**624**	**40 (10.15)**	**611 (89.85)**	**-**			**-**		

*, **, *** and ns denote levels of statistical significance of p≤0.05, p≤0.01, p≤0.001,p>0.05 and not significant respectively.

[1] Results of univariable logistic regression analyses of the associations between herd size, herd type or geographical area and the odds of an incident being detected in the slaughterhouse.

[2] Results of multivariable logistic regression analyses where the associations between herd size, herd type or geographical area and the odds of an incident being detected in the slaughterhouse were adjusted for the effects of each other.

[3] The odds ratio is the odds of disease in the exposed categories relative to the odds of disease in the unexposed (reference ['*Ref*']) category.

3.3 Reactors in herd tests following detection of slaughterhouse cases

Following the detection of new incidents via slaughterhouse testing, whole herd tests are administered. Table 3.4 shows the average number of reactors identified at the first whole herd test for incidents identified at slaughterhouse and via skin testing in 2016. The merit in considering the first whole herd test, rather than the entire incident, is that some incidents detected in 2016 may still have been open at the end of the year. This can give an indication of the severity of the incidents which began in 2016. The fact that means are higher than the medians reflects the positively skewed distribution of reactors. Most incidents result in only 1 or 2 reactors, so the median (the mid-point) is low, but there are a minority of incidents with much larger numbers of reactors, pulling the mean upwards. Increases in the median number of reactors from a slaughterhouse incident could be an indicator of built-up infection.

The number of reactors identified in incidents disclosed at the slaughterhouse appears to have been increasing since 2013, although levels remain consistent with previous years (Figure 3.3).

*Table 3.4: Reactors identified at the **first whole herd test** following an incident*

Disclosing test	**New incidents**		**Reactors identified at first herd test, per incident**				**Reactors identified at first herd test, per OTFW incident**			
	Total	OTFW	Mean	Median	IQR[1] 25%	IQR[1] 75%	Mean	Median	IQR[1] 25%	IQR[1] 75%
Slaughterhouse inspection	40	40	4.2	0	0	2	4.2	0	0	2
Skin testing – Risk tests	507	469	3.9	2	1	5	4.1	2	1	5
Skin testing – Routine tests	159	115	3.1	1	1	3	4.1	2	1	4
Total	**706**	**624**	**3.7**	**2**	**1**	**4**	**4.1**	**2**	**1**	**5**

[1]Inter-quartile range

Table 3.5 shows the **total number of reactors** identified in incidents that **closed** in 2016, comparing those that were first detected at slaughterhouse inspection with those detected by skin testing. This includes incidents which began prior to 2016.

*Table 3.5: **Total number of reactors** identified in incidents that closed in 2016*

Disclosing test	**Number of closed incidents**		**Total number of reactors identified in any incident**				**Total number of reactors identified per OTFW incident**			
	Total	OTFW	Mean	Median	IQR[1] 250%	IQR[1] 75%	Mean	Median	IQR[1] 25%	IQR[1] 75%
Slaughterhouse inspection	63	63	13.1	1	0	8	13.1	1	0	8
Skin testing – Risk	505	454	10.0	3	1	10	11.0	4	2	11
Skin testing – Routine	153	106	4.8	2	1	5	6.5	2	1	7
Total	**721**	**623**	**9.2**	**3**	**1**	**9**	**10.4**	**3**	**1**	**10**

[1]Inter-quartile range

Temporal trends in the mean and median number of reactors identified at the ***first whole herd test*** by method of disclosure are presented in Figure 3.3. The mean number of reactors identified at the first whole herd test peaked around the time of the Foot and Mouth Disease outbreak in 2001 which caused considerable disruption to TB surveillance. Since 2009, the mean number of reactors per incident for both methods of disclosure has remained between two and four.

The peak observed in 1996 reflects two slaughterhouse disclosed incidents in west Wales which together produced 89 reactors. Aside from this anomaly, the temporal trends indicate that there has been little difference in the mean number of reactors found in incidents disclosed through slaughterhouse cases and the mean number found in incidents detected through skin testing.

Generally the trends in the median number of reactors mirror the trends in the mean, albeit at a lower level. The median is less affected by extreme values and more appropriate for skewed data, such as this, where the frequency of observations is generally low but there may be a handful of extreme values. In 2016, the median number of reactors identified per incident at the first herd test after slaughterhouse inspection was zero, consistent with the low levels of previous years.

The temporal trends in the mean and median ***total*** number of reactors identified per incident by method of disclosure are presented in Figure 3.4. The mean *total* number of reactors identified per skin-test-disclosed incident has increased over time from around two reactors per incident in 1990-1994 to a peak of nearly ten per incident in 2013. This number was equivalent to that observed in 2016 (8.8), despite a decline in the previous two years. A similar trend can be seen for slaughterhouse disclosed incidents, although the series is much more volatile due in part to the relatively small number of slaughterhouse cases.

The median total number of reactors identified per skin-test-disclosed incident remained relatively constant between 2005 and 2015, typically at 2, although this increased to 3 in 2016. The median number disclosed in the slaughterhouse has fluctuated between one and two reactors over the same time period.

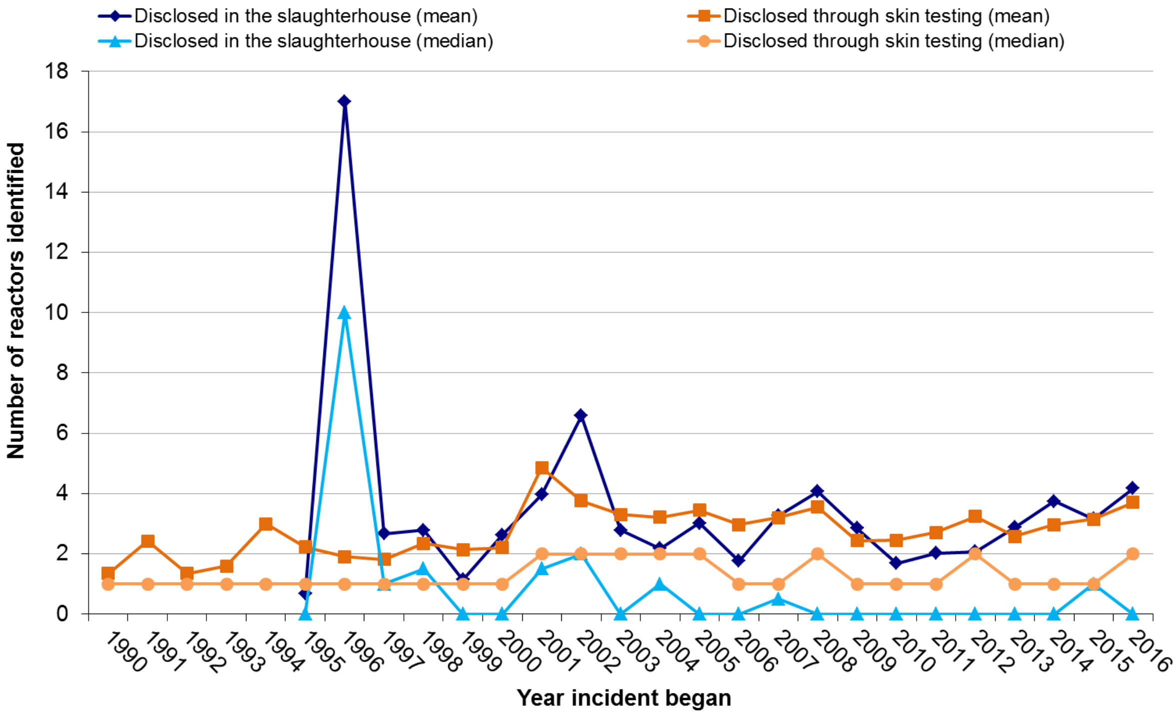


Figure 3.3: Reactors identified at the first whole herd test following disclosure of the incident, 1990 – 2016[1]

[1]Slaughterhouse data not available prior to 1995

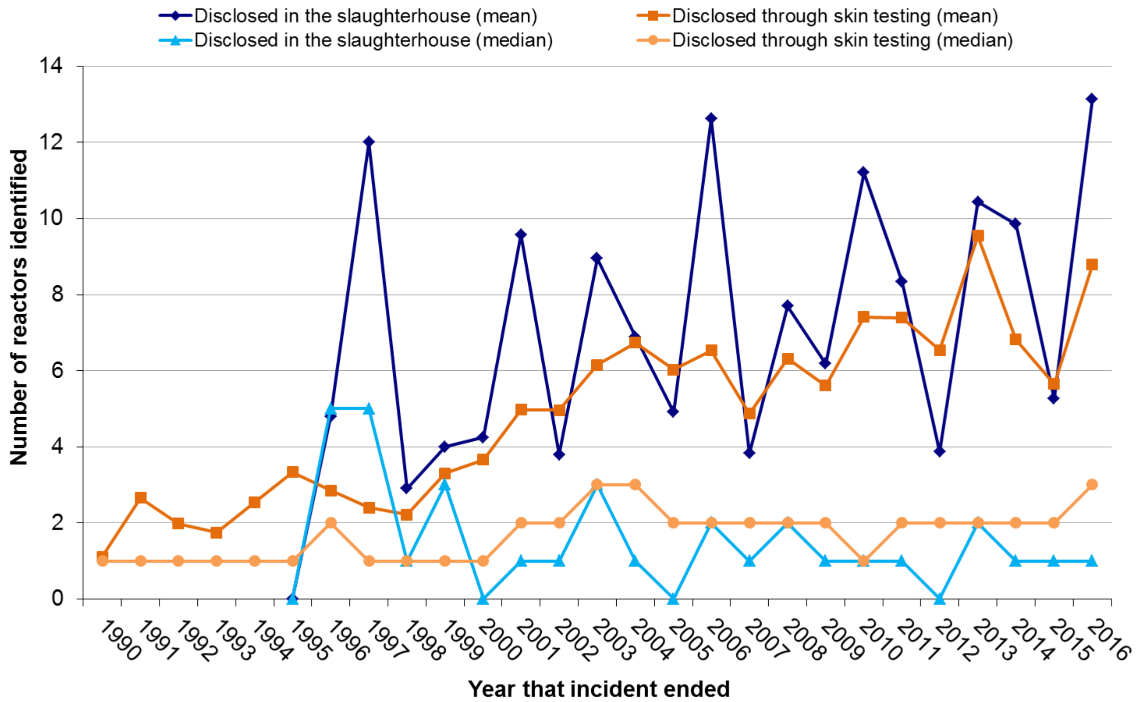


Figure 3.4: Reactors identified per incident that closed, 1990 – 2016[1]

[1]Slaughterhouse data not available prior to 1995

4.0 Post mortem examination and culture of suspected TB cases

Key Points:

- Reactors with detected lesions were significantly more likely to be *M. bovis* positive than direct contacts and inconclusive reactors with detected lesions (Table 4.1)
- There were increases in the number of animals slaughtered as reactors (17%) and IFN-g positive reactors (52%).
- Of the 590 detected lesion samples with culture results in 2016, 94% were *M. bovis* positive (Figure 4.4)
- Of the 2,451 samples from animals with no detectable lesions and for which culture results were available in 2016, only 2% were *M. bovis* positive (Figure 4.4)

The tuberculin skin test is more sensitive than slaughterhouse inspection for detecting cattle at an early stage of infection with *M. bovis* before detectable lesions have developed. Lesion and culture results for animals slaughtered according to various TB risks (reactors, inconclusive reactors (IR) or direct contacts (DC)) are illustrated in the following section. The section reports on the total number of TB suspect cattle slaughtered per year, regardless of when the incident started. Further information about inconclusive reactors is provided in Section 7.

Overall, lesions were detected or *M. bovis* isolated in 22.7%[1] of reactors to the tuberculin skin test (Figure 4.1), and the proportion was higher than this when considering only reactors identified through standard interpretation of the skin test (31.3%). Severe interpretation of the skin test is a more sensitive reading of the test which leads to additional animals with a smaller response to the test being classified and slaughtered as reactors. This decreases the likelihood of truly infected animals testing negative to the skin test and therefore increases the likelihood of detecting all infected animals within the herd. A smaller proportion of these animals yield carcases with detectable lesions from which *M. bovis* can be isolated and cultured compared with animals classed as reactors via the standard interpretation. However, the use of the severe interpretation of the skin test may result in earlier detection of infected animals which could explain this difference (see Appendix 2 for definitions of standard and severe interpretation.

[1] The majority of reactors, IRs, and DCs are not sent for culture, irrespective of whether they have detected lesions or not (Figure 4.1). Consequently, this data should not be used to estimate the true proportion of animals slaughtered for TB that would have been confirmed as TB positive via culture. However, since so few animals without detected lesions are found to be positive via culture test, we would not expect the true proportion to differ by much.

4.1 Number of suspected TB cases that were slaughtered[1]

A summary of cattle slaughtered as suspected TB cases in Wales in 2016, along with the outcome of carcase inspection, is presented in Figure 4.1.

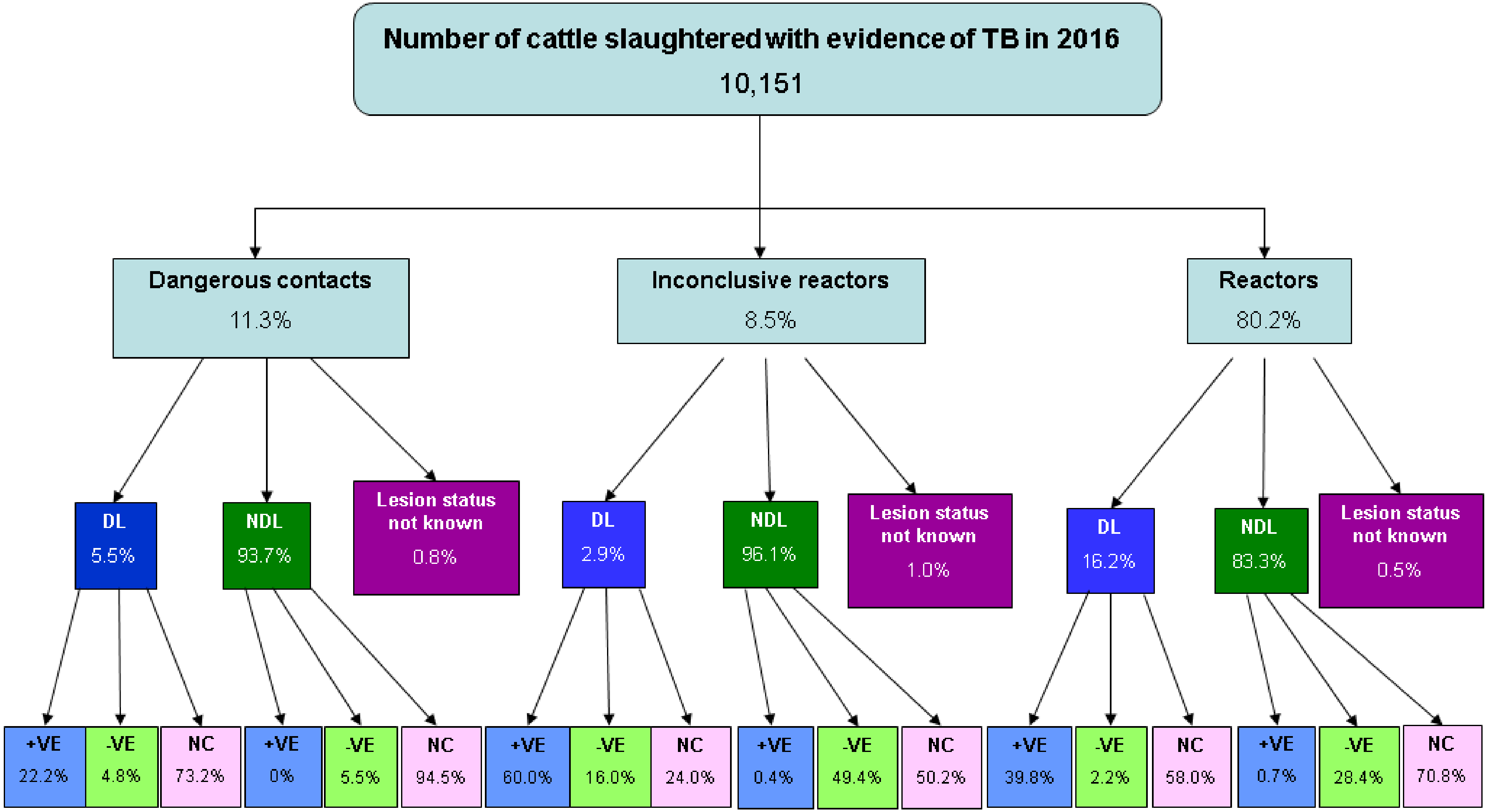
In addition to the 70 slaughterhouse cases where retrospective evidence of TB was identified (see Section 3), a further 10,151 cattle were slaughtered in 2016 for TB control. Of these, 80% were skin test or interferon-gamma (gIFN) reactors, 9% were inconclusive reactors and 11% were direct contacts. This distribution differs slightly from that of England where 93% of compulsorily slaughtered animals were reactors; 5% were IRs and 2% were DCs (Bovine tuberculosis in Great Britain. Surveillance data for 2016 and historical trends).

There was a 23% increase in the number of cattle slaughtered for TB control in 2016 compared with 2015. This follows a 27% increase between 2014 and 2015, and a 5% increase between 2013 and 2014. There were increases in the number of animals slaughtered as reactors (17%), although the level of increase varied greatly between standard reactors (10%), severe reactors (1%), standard and severe reactors together (6%) and IFN-g positive reactors (52%). There was a significant increase in the number of direct contacts slaughtered in 2016 compared to 2015 (+137%), although the number of IRs slaughtered remained relatively constant.

Overall, lesions were detected in 14% of slaughtered animals, although this proportion varied depending on whether the method of disclosure was as reactors (16%), inconclusive reactors (3%) or direct contacts (6%) (Figure 4.3). There was further variation amongst reactors, as to whether testing was at standard (30%), severe interpretation (8%), or if reactors were identified via IFN-g testing (4%). The lower proportion of animals which were gIFN-positive with DL is expected due to the greater sensitivity of the gIFN test which allows the detection of disease at any earlier stage of infection before lesions are likely to be detectable, and the lower specificity which means that the test is more likely to generate false positive results.

Generally the proportion of animals with *M. bovis* isolated has remained consistent with 2015, by method of disclosure. Although there appears to have been an increase in the proportion of direct contacts with detected lesions from which *M. bovis* were isolated, this is potentially due to the low number of direct contacts with detected lesions year-on-year (17 in 2016),

[1] Defra statistics report true reactors, IRx2 and IRx3 as "reactors" (which are compulsorily slaughtered), whereas in this report reactors includes only true reactors (including severe) as "reactors", and not IRx2 or IRx3. Defra statistics report only IRx1 as IRs whereas this report includes IRx1, IRx2 and IRx3 as IRs.



KEY: DL = detected lesions; NDL = no detected lesions; +VE = *M. bovis* positive; -VE = *M. bovis* negative; NC = not cultured

Figure 4.1: Testing pathways of animals slaughtered for TB control in Wales, 2016

Trends in the number of cattle slaughtered for different TB control reasons are shown in Figure 4.2a and Appendix 6. The 5-year trend in the number of one-, two- and three-times IR animals and direct contacts slaughtered is shown in Figure 4.2b.

An increase in the number of animals that were slaughtered was observed since 1990 across all reasons for slaughter for TB control, reaching a peak of around 10,000 in 2008. The number of IRs slaughtered increased 4-fold between 2008 and 2009 and, following a drop in 2010, has remained relatively stable over the subsequent 6 years. The increase between 2008 and 2009 can be explained by a change in policy, implemented in 2009, which reduced the number of times that an animal testing inconclusive could be re-tested from two to one. An IR that fails to give a negative result at this re-test is considered to be positive.

Since 2008, the overall number of reactors and DCs that were slaughtered for TB control reasons has been variable with no obvious trends. The number of reactors slaughtered decreased between 2012 and 2013 by 37% but has increased again between 2014 and 2016. The recent increase in reactors is primarily attributable to increases in gamma-testing, which is more sensitive than the skin test. Gamma-testing is used to help clear infection in recurrent and persistent breakdowns and to prevent disease from becoming established in low incidence areas. There was a sharp apparent increase in direct contacts in 2016 (up 135%). However, this primarily reflects an issue with how some Inconclusive Reactors (IRs) were recorded in Sam. During 2016 official veterinarians were directed to apply more sensitive testing procedures in certain circumstances, and this included removing IRs. Until April 2017 it was not possible to record these cases as IRs on Sam in such a way as to enable the intended removal and compensation processes to take place. Consequently, these animals were recorded as DCs.

It is not possible to retrospectively identify these cases to enable us to quantify the impact that they have had on the apparent overall increase in DCs reported here.

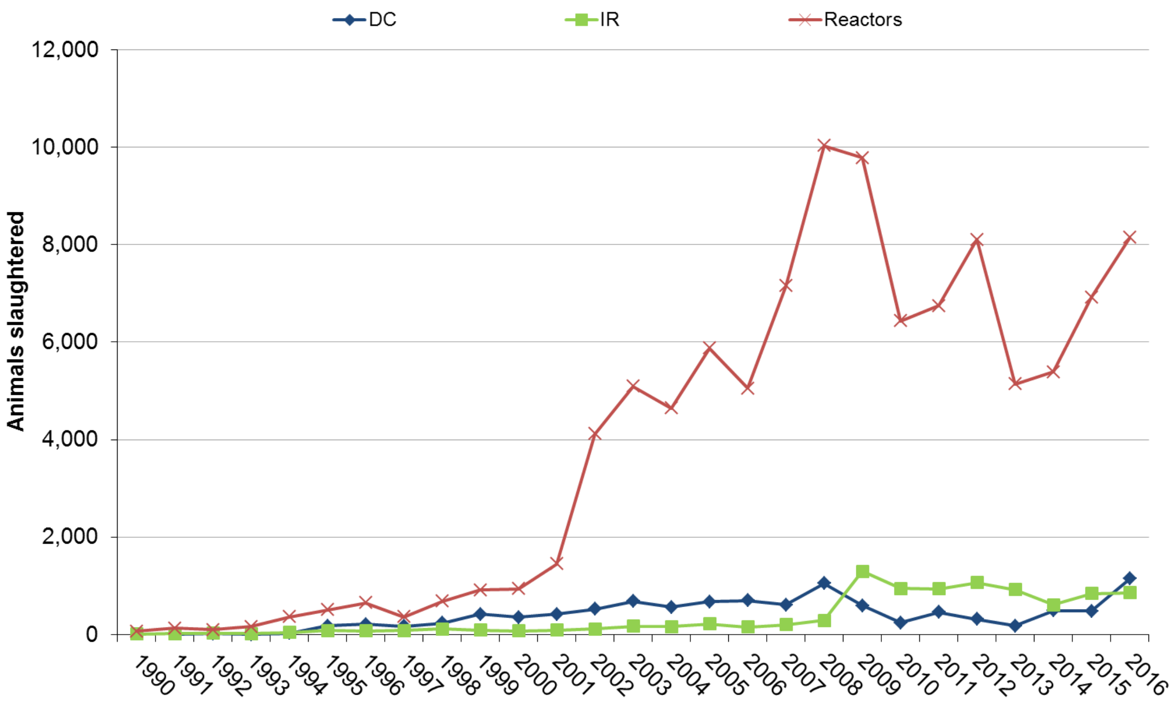


Figure 4.2a: Reactors inconclusive reactors and direct contacts slaughtered for suspected TB, 1990 – 2016

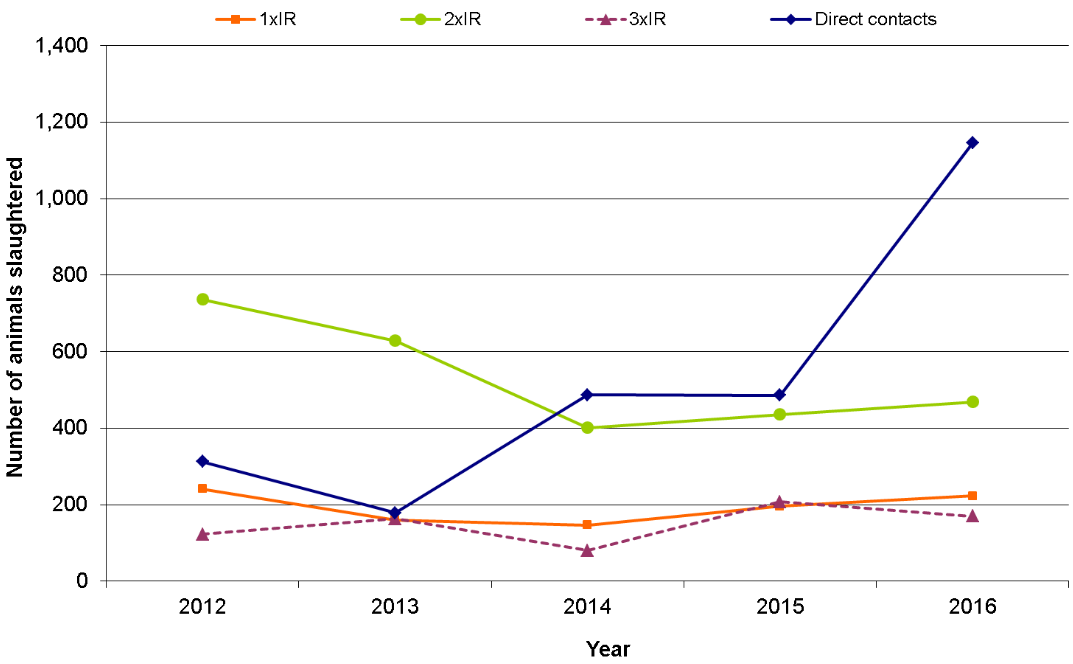


Figure 4.2b: Inconclusive reactors and direct contacts slaughtered, 2012 – 2016

4.2 Lesion status of suspected TB cases that were slaughtered

The lesion status at post mortem examination (PME) of all suspected TB cases that were slaughtered for different TB control reasons in 2016 is shown in Table 4.1 as well as Figure 4.1.

The proportion of reactors (at standard interpretation) in Wales with TB infection confirmed by either DL or culture of *M. bovis* (31%) was lower than the proportions observed in the High Risk area of England (44%) and the Edge area of England (39%). This lower proportion in Wales compared to the High Risk and Edge areas in England could be due, in part at least, to the progress Wales has made due to the introduction of annual testing some time ago, which means particularly in the lower incidence areas, disease is found earlier, so there are less lesions to find and culture. The M.bovis recovery rate from detected lesions is similar in both England and Wales

Fifty three percent of the samples submitted from slaughterhouses were *M. bovis* positive, compared to 75% for Great Britain as a whole so unless detection of infection in slaughterhouses in Wales is very different to that in England; this would also support infection being detected earlier in Wales compared to England. In addition to this, samples are submitted for culture from animals which have tested positive to gIFN testing following two inconclusive skin tests at severe interpretation.

In Wales in 2016 significantly more reactors with DL were *M. bovis* positive compared with both DCs ($p<0.001$, applying z-test) and IRs ($p<0.001$, applying z-test). A larger proportion of samples from animals without DL had no culture results (pending or not cultured) compared with those from animals that did have lesions (72% vs. 58%). Over half (58%) of samples from DL animals in 2016 were not cultured (or were pending); although this was higher still in DCs (73%), gIFN reactors (74%) and reactors at severe interpretation (64%).

Table 4.1: Lesion status of animals for animals slaughtered in 2016

	Total	Lesion status not recorded	Detected lesions			No detected lesions		
			Proportion[1] of Total	Proportion *M. bovis* +ve[2]	Pending or not cultured	Proportion[1] of Total	Proportion *M. bovis* +ve[3]	Pending or not cultured
			%	%		%	%	
1. Direct contacts (DC)	**1,144**	**9**	**5.6**	**82.4**	**46**	**94.4**	**0**	**1,013**
2. Inconclusive reactors (IR)	**862**	**9**	**2.9**	**78.9**	**6**	**97.1**	**0.7**	**416**
After 1 test as IR	223	8	2.3	75.0	1	97.7	0	108
After 2 tests as IR	469	0	4.1	80.0	4	95.9	1.1	187
After 3 tests as IR	170	1	0.6	0	1	99.4	0	121
3. Reactors (R)	**8,145**	**38**	**16.3**	**94.8**	**766**	**83.7**	**2.5**	**4,807**
IFN-gamma positive	2,535	6	3.5	95.7	66	96.5	1.7	1,968
At standard interpretation	3,537	20	30.5	95.8	598	69.5	4.2	1,627
At severe interpretation[4]	2,073	12	7.7	86.0	102	92.3	1.2	1,212
TOTAL	**10,151**	**56**	**13.9**	**93.9**	**818**	**86.1**	**2.2**	**6,236**

[1] The denominator for the proportion is the sum of the number of animals with detected lesions (DL) and those without (NDL). Animals whose "lesion status was not recorded" have been disregarded.
[2] The denominator for the proportion is the number with DLs that were cultured.
[3] The denominator for the proportion is the number without DLs, where recorded, that were cultured.
[4] These include *all* animals recorded as reactors irrespective of skin test measurements, but do not have measurements of a standard reactor i.e. it will include animals classified as a reactor during a TB incident because of oedema at the site of injection of bovine tuberculin as well as bovines classified as a reactor on the basis of severe interpretation.

The five-year trend in the proportion of slaughtered suspect TB cases with DL is shown in Figure 4.3. By monitoring trends over time we can identify changes which might warrant further investigation to see if they represent real changes in the underlying disease, changes in the testing regime, or changes in tuberculin sensitivity. Compared with 2015, there were decreases in the proportion of animals with DL for reactors and all levels of IRs. The proportion of DCs with DL has remained at a similar level for the last five years. The proportions of IRs with DL have typically been below 10% across the five-year period with a general decreasing trend since 2014.

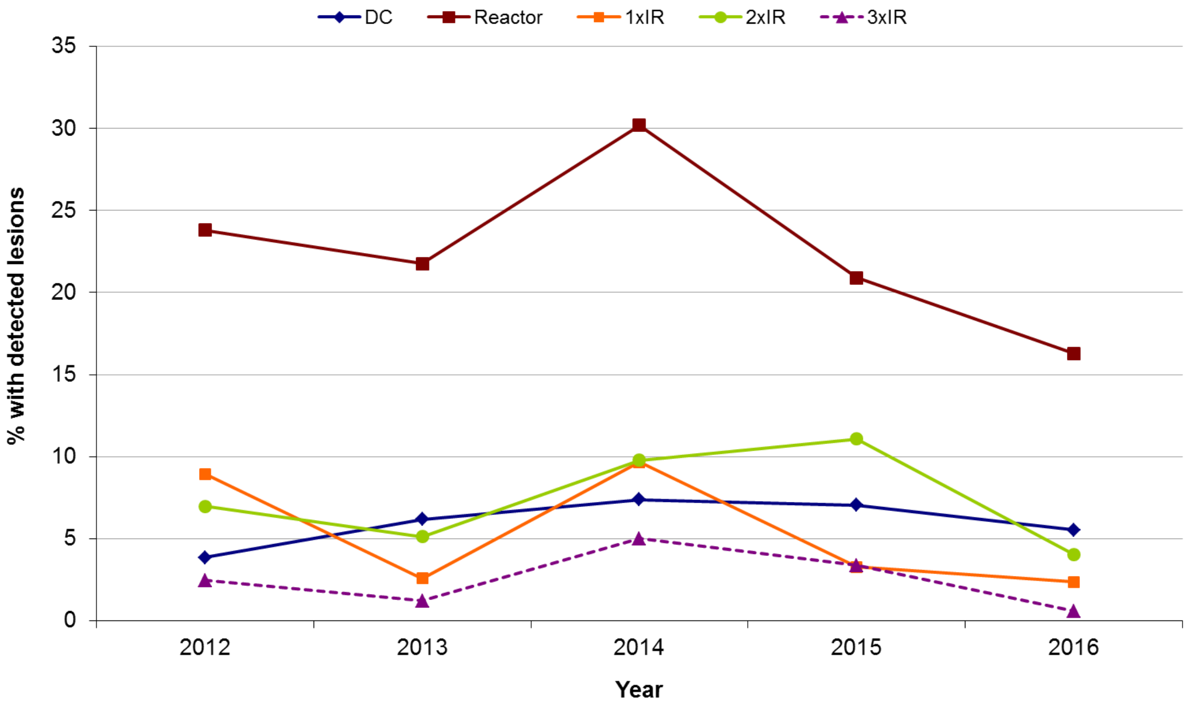


Figure 4.3: Proportion of slaughtered cattle with detected lesions[1],2012 – 2016

[1]Where lesion status was known; lesion status was not recorded in around 0.4% of slaughtered suspect TB cases

4.3 Culture results of animals with detected lesions or no detected lesions

In multiple-reactor incidents only a sample of reactors are cultured and generally no more than three animals with DL are cultured per incident. Only one culture positive sample is collected from each incident for genotyping by spoligotyping and VNTR methods (see Section 8). In addition, if the OTF status of the herd is withdrawn and a genotype is available no further sampling is undertaken from additional DL reactors and DCs.

Of the 554 DL samples from reactors with culture results in 2016, 95% were *M. bovis* positive. A similar proportion of DL samples with culture results were *M. bovis* positive in England in 2015 (96%; Bovine tuberculosis in Great Britain. Surveillance data for 2016 and historical trends). This proportion has ranged in Wales from 89% to 97% since 2003 (mean = 93%; SD = 2%; Figure 4.4).

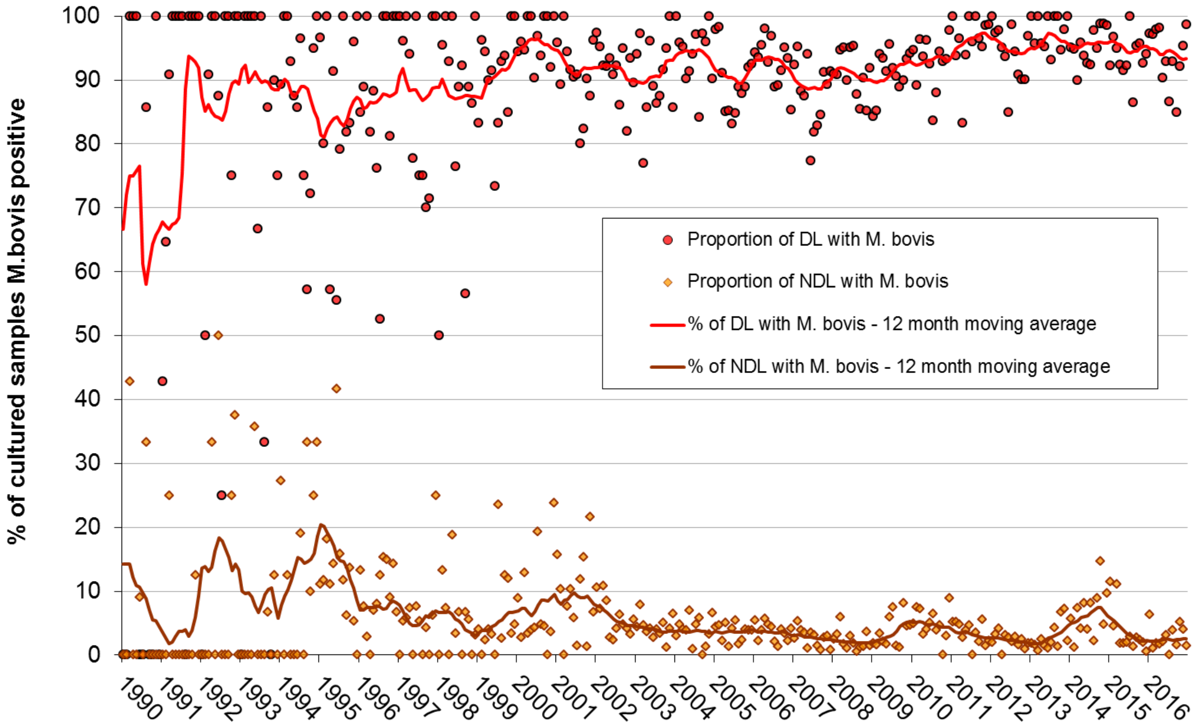


Figure 4.4: Monthly proportion of reactor culture samples from which M. bovis was obtained, 1990 – 2016

Of the 2,451 NDL samples with culture results in 2016, 53 (2%) were confirmed to be *M. bovis* positive. Importantly however, this does not mean that the remaining 98% were not infected since infected animals do not always have detectable lesions or yield positive culture results. Indeed, the earlier reactors are identified the less likely they are to have such lesions or provide positive culture results. Since 2002 there has been a gradual decline in the proportion that were *M. bovis* positive, although a slight increase was observed in 2014 (Figure 4.4). Prior to 2002 there had been substantial variation in the proportion of NDL samples that were *M. bovis* positive, with the 12-month moving average ranging from around 2% to 20% (mean = 9%; SD = 4%). This is, at least in part, a consequence of the small number of samples that were processed at this time, and is evident when looking at the monthly proportions which give us an indication of the variation around the moving average.

Of the 3,041 animals where both the lesion status and culture result was known (i.e. all DL and NDL animals with a positive or a negative result and therefore excluding all animals where lesions status was not known or where no cultures were carried out; excluding slaughterhouse cases), 643 (21%) had evidence of TB: either having detected lesions *OR* being culture positive (i.e. all DL, and NDL animals with positive results only; Figure 4.1). In England the proportion was significantly higher (Bovine tuberculosis in Great Britain. Surveillance data for 2016 and historical trends: 49%; Z-test = 25.9, p<0.001). There was also a significantly higher proportion of culture positive NDLs in England compared with Wales in 2016 (5.3% vs. 2.2%; Z-test = 4.5, p < 0.001). This difference could be due to contrasting criteria for culture submissions between England and Wales. Other possible explanations could be that the application of annual testing in all counties in Wales has led to reactors being detected at an early stage of infection when many lesions are not sufficiently developed to be detected. Alternatively differences in cattle demography and management could affect the risk of exposure to *M. bovis* and susceptibility.

5.0 Duration of bovine TB incidents in Wales

Key points:

- 52% of OTF-W incidents closed within 240 days, compared with nearly 90% of OTF-S incidents (Table 5.1)
- Incident duration was significantly longer in herds with more than 300 animals and in dairy herds (Table 5.2)
- OTF-W incidents of very long duration were more common in the south west of Wales (Figure 5.2)

The management of cattle herds is affected by the extent and duration of movement restrictions imposed as a consequence of a TB incident. Lengthening the time herds are under restrictions increases the burden on the farmer and the financial burden on the government of managing the incident. However increasing movement restrictions duration can also be part of a control strategy as it increases the likelihood that infection has truly been removed from the herd through the identification and removal of any remaining infected animals in a herd. This reduces the risk of recurrence. Restrictions are maintained until there is sufficient weight of evidence from negative tests to suggest infection has been removed from the herd. There are many factors which may increase the duration of time that herds are under restrictions. These include poor responsiveness of some animals to the skin test, intense cattle-to-cattle transmission (as can occur, for example in large herds), and continuing reinfection (for example, from wildlife or neighbouring herds). In this section we look at trends in the duration of TB incidents and the effects of various factors on those trends.

5.1 Bovine TB incident duration in 2016 and the annual trend in median duration trends

The mean and median (i.e. the mid-point) durations of incidents closing in 2016 were 287 and 202 days respectively (Table 5.1). The difference between the mean and the median reflects the fact that there are a relatively small number of outliers in the distribution – i.e. incidents which last for many years. Such cases pull the mean away from what may be considered 'typical'. The longest duration of restrictions for incidents closing in 2016 was 14 years. Restriction duration varied with OTF status: the duration of movement restrictions of OTF-S incidents was significantly shorter than those of OTF-W incidents, with 70% of OTF-S incidents closing within 150 days, compared with 10% of OTF-W incidents ($p=<0.001$; $z=-11.43$, using the Wilcoxon rank sum test). This reflects the different management protocols for OTF-W and OTF-S incidents in Wales: OTF-S incidents require one clear whole herd test, while OTF-W incidents require two, with a minimum of 60 days between each.

Table 5.1: Restriction durations of incidents closed in 2016

	Total (% of total)	OTF-W (% of total)	OTF-S (% of total)
Incidents closed in 2016	721	623	98
Incident duration (days):			
Up to 100	50 (6.9)	3 (0.5)	47 (48.0)
101 to 150	76 (10.5)	54 (8.7)	22 (22.4)
151 to 240	283 (39.3)	264 (42.4)	19 (19.4)
241 to 550	254 (35.2)	244 (39.2)	10 (10.2)
551+	58 (8.0)	58 (9.3)	0
Mean duration (days)	287	310	141
Median duration (days)	202	231	104
Duration range (days)	21 - 5123	21 - 5123	63 - 543

Figure 5.1 shows trends in the median duration of incidents ending between 1990 and 2016. The median duration of OTF-W incidents slowly increased between 1990 and 2000 before rising to around 250 days in 2001, coinciding with the Foot and Mouth Disease outbreak in that year. Subsequently, it has remained relatively stable, although there has been an overall decrease in duration of nearly 10%. It is important to note that some or all of the decrease in median incident durations since 2010 may be attributable to a change in the definition of OTF-W and OTF-S incidents. From January 2011 some incidents that would have traditionally been classified as OTF-S were instead classified as OTF-W for epidemiological reasons. This meant that some of the longer-lasting OTF-S incidents were lost from the OTF-S cohort (bringing the average down). On average, these incidents were still shorter than the existing OTF-W cases, so they also served to pull the OTF-W average down.

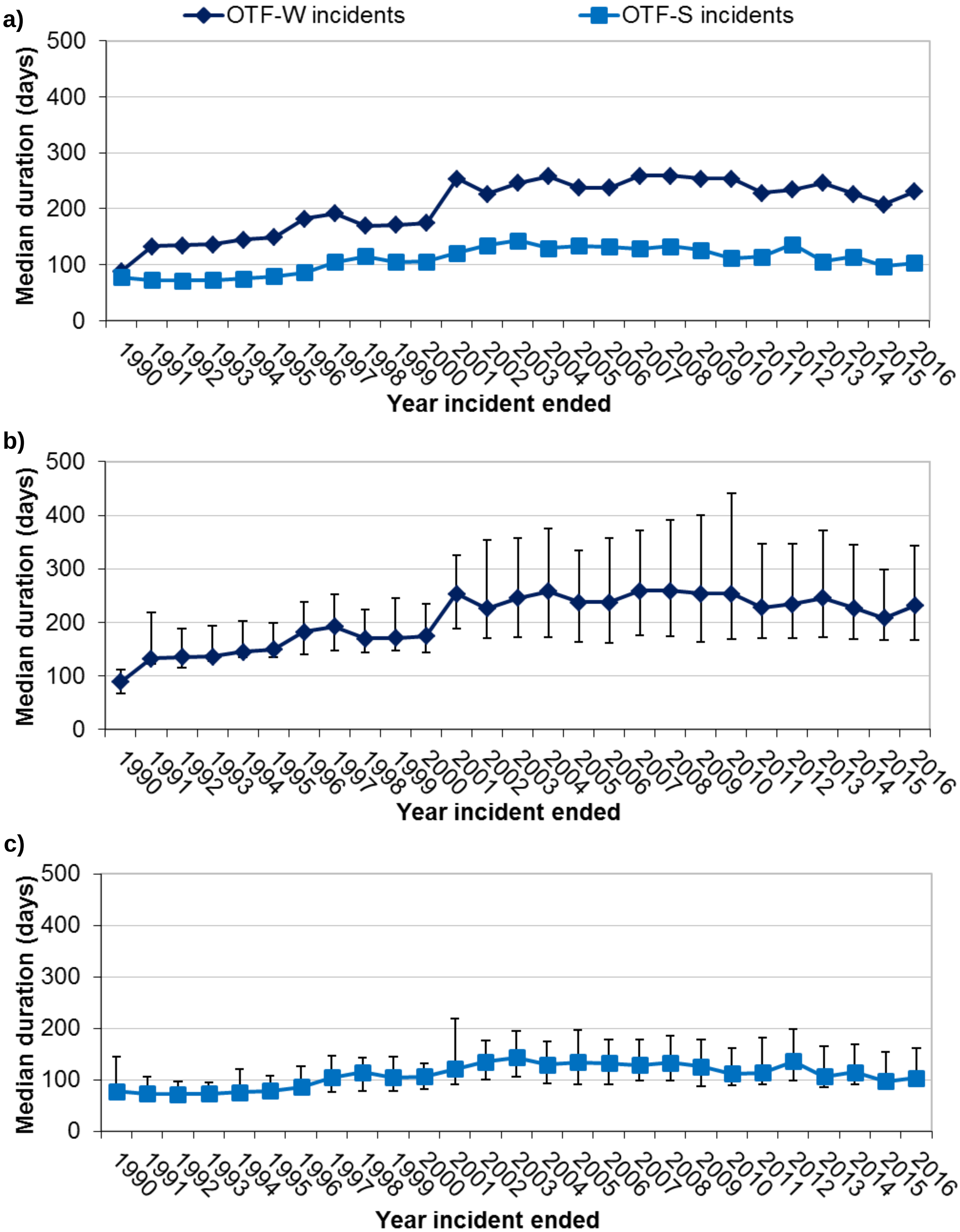


Figure 5.1: Median duration of OTF-W incidents ending between 1990 and 2016 (a), with interquartile ranges for OTF-W (b) and OTF-S (c) incidents presented separately

5.2 Variation in TB duration by TB-free status, herd type, herd size and geographical area

Table 5.2: Analysis of factors associated with incident duration (log-transformed), 2016

	Number of incidents	Mean duration (days)	Median duration (days)	Linear regression analysis: Unadjusted[1]			Linear regression analysis: Adjusted[2]		
				Coefficient[3]	95% CI		Coefficient[3]	95% CI	
TB-free status type									
OTF-W	623	310	231	*Ref*			*Ref*		
OTF-S	98	141	104	-0.73***	-0.84	-0.61	-0.50***	-0.62	-0.39
Herd size									
0 – 10	14	202	171	-0.71***	-1.01	-0.42	-0.42**	-0.70	-0.14
10 – 50	90	194	165	-0.63***	-0.76	-0.49	-0.40***	-0.54	-0.25
50 – 100	123	194	168	-0.61***	-0.74	-0.48	-0.39***	-0.52	-0.26
100 – 200	204	256	193	-0.39***	-0.50	-0.28	-0.26***	-0.36	-0.15
200 – 300	116	329	251	-0.21**	-0.34	-0.08	-0.14*	-0.26	-0.03
> 300	174	417	325	*Ref*			*Ref*		
undetermined	0	-	-	-	-	-	-	-	-
Herd type									
Beef	398	225	179	*Ref*			*Ref*		
Dairy	321	362	272	0.39***	0.30	0.47	0.11*	0.02	0.20
Other/mixed	2	509	509	0.72[ns]	-0.06	1.50	0.59[ns]	-0.10	1.27
Geographical area									
Anglesey	7	111	96	-1.03***	-1.45	-0.61	-0.44*	-0.82	-0.05
Gwynedd	17	134	106	-0.87***	-1.15	-0.60	-0.42**	-0.68	-0.16
Clwyd	39	204	187	-0.47***	-0.66	-0.28	-0.34***	-0.51	-0.16
North Powys	93	224	181	-0.38***	-0.52	-0.24	-0.27***	-0.39	-0.14
Mid Powys	51	221	181	-0.40***	-0.57	-0.23	-0.20*	-0.36	-0.04
South Powys	28	172	154	-0.60***	-0.82	-0.38	-0.32**	-0.52	-0.12
Ceredigion	52	293	225	-0.14[ns]	-0.31	0.03	-0.14[ns]	-0.30	0.01
Pembrokeshire	163	367	256	*Ref*			*Ref*		
Carmarthenshire	156	324	265	-0.04[ns]	-0.16	0.08	-0.03[ns]	-0.14	0.08
Glamorgan	38	198	165.5	-0.46***	-0.65	-0.26	-0.21*	-0.39	-0.03
Gwent	77	336	243	-0.07[ns]	-0.22	0.08	0.01[ns]	-0.13	0.14

*, **, *** and ns denote levels of statistical significance of p≤0.05, p≤0.01, p≤0.001 and not significant respectively.
[1] Results of univariable linear regression analyses of the logarithm of duration of TB incidents that ended in 2016 on each of the independent variables (OTF status, herd size, herd type or geographical area).
[2] Results of multivariable linear regression analyses of the logarithm of duration of TB incidents that ended in 2016 on the OTF status, herd size, herd type or geographical area, adjusted for the effects of other independent variables.
[3] The outcome 'duration' was log transformed for analysis due to non-normal distribution and unequal variance; the coefficient was derived following this log transformation.

Table 5.2 shows the duration of movement restrictions of incidents ending in 2016 by TB-free status, herd size, herd type and location. Also presented are regression coefficients, which indicate the size and direction of the associations between incident duration (outcome) and herd size, type and geographical area (predictors). The coefficients of the categories within the predictor variables are calculated *relative* to a reference category ("*Ref*") (see Materials and Methods for explanation of the choice of reference category). Coefficients greater than 0, i.e., positive coefficients, indicate that the incident duration is longer in that category than in the reference category, whereas negative coefficients indicate the duration is shorter compared with the reference category.

As herd size increases, so does the median duration of restrictions. Incident duration was significantly shorter in herds with fewer than 300 animals compared with the largest herds. This effect remained for all herd sizes after adjusting for herd type and location and is consistent with previous years. This is not surprising since increasing herd size is likely to increase density-dependent transmission of infection. Although the multivariable regression analysis attempts to adjust for herd size this is likely to be incomplete because the effective herd size is imperfectly measured, i.e. it does not take account the number and size of any epidemiological groups within a herd. However, the effect of herd size on incident duration observed in Wales was consistent with that observed in England, whereas the effect of herd type was not (Bovine tuberculosis in Great Britain, Surveillance data for 2016 and historical trends).

After adjusting for herd size and location, incidents in dairy herds were significantly longer than incidents in beef herds. This is consistent with the effect observed over the previous 4 years.

Consistent with analysis for previous years, incident duration varied significantly between the Welsh counties. Relative to Pembrokeshire, incidents were shorter in almost all counties in Wales. However, incidents were most notably shorter in Anglesey, Gwynedd, Clwyd, and South Powys after adjusting for herd size, type and OTF status.

Figure 5.2 shows the geographical distribution of OTF-W incidents of various durations. Incidents of very long duration (>18 months) tended to be clustered in the south west of Wales and in counties along the border with England. This is clearly reflected in Figure 5.4, which shows the geographical location of incidents which lasted for longer than 550 days. In areas where there were fewer incidents, such as Gwynedd, Anglesey, and the Glamorgans, these tended to be of shorter duration. However, some isolated incidents of long duration did occur in areas where TB incidence was low. A clustering pattern was not clearly reflected with OTF-S incidents due to the very small number of such incidents (Figure 5.3).

At least part of the reason that OTF-W incidents last longer than OTF-S incidents, on average, is the requirement for two consecutive clear tests as opposed to only one for OTF-S incidents, and the use of the higher-sensitivity severe interpretation of the skin test. Also, to some extent additional post-mortem evidence of infection in OTF-W incidents indicates the presence of more advanced stages of *M. bovis* infection, and these incidents are likely to take longer to clear.

Figure 5.5 shows incidents that were open for the whole of 2016 but started prior to 2016. There were 129 such incidents, 98% of which were OTF-W, and they were clustered in high-incidence areas.

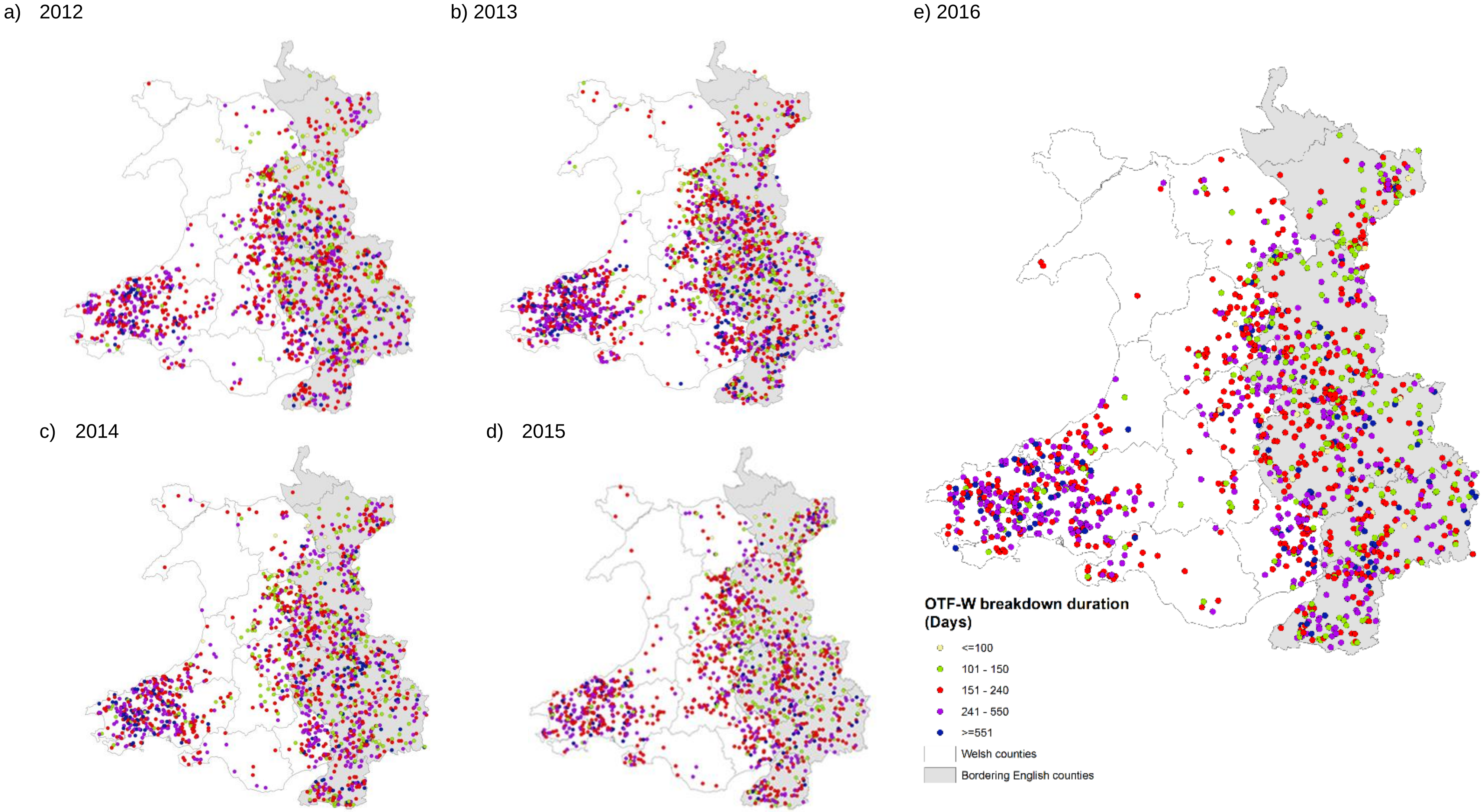


*Figure 5.2: **OTF-W** incidents by duration, closing 2012 – 2016*

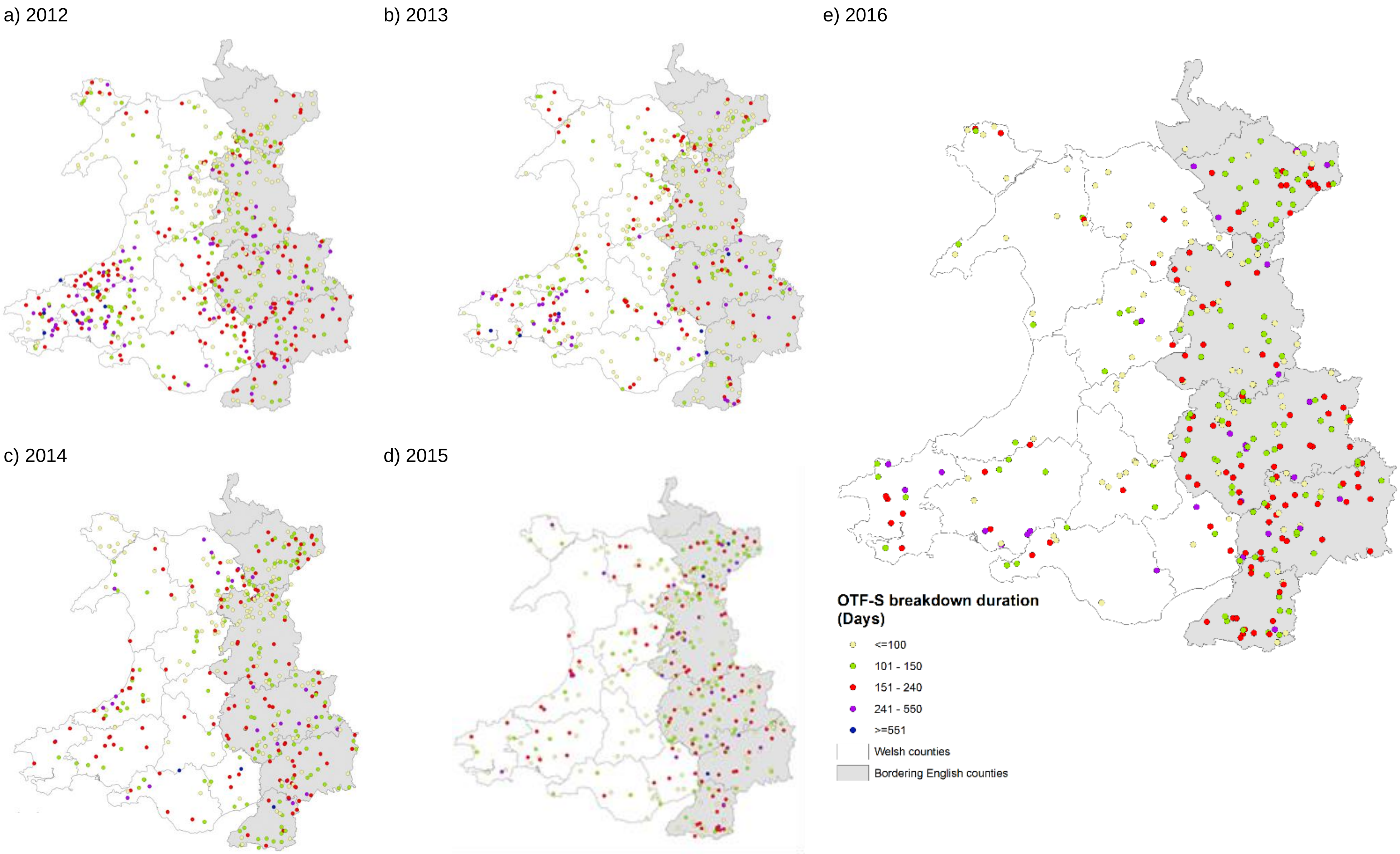


*Figure 5.3: **OTF-S** incidents by duration, closing 2012 – 2016*

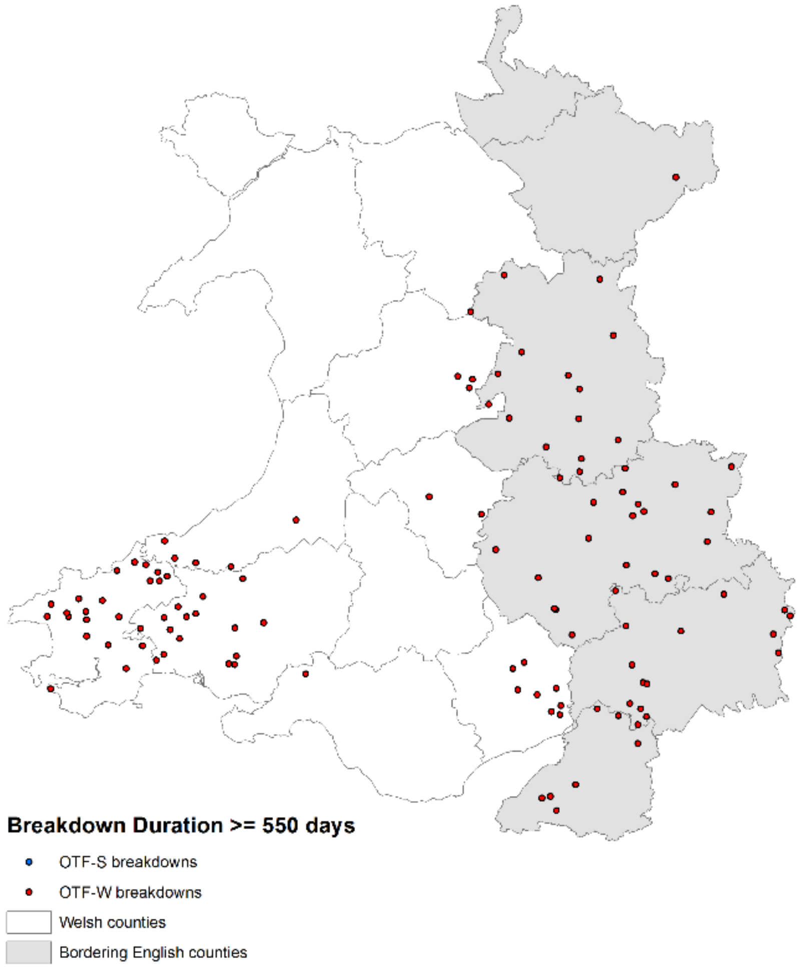


Figure 5.4: Incidents of longer than 550 days duration, closing in 2016

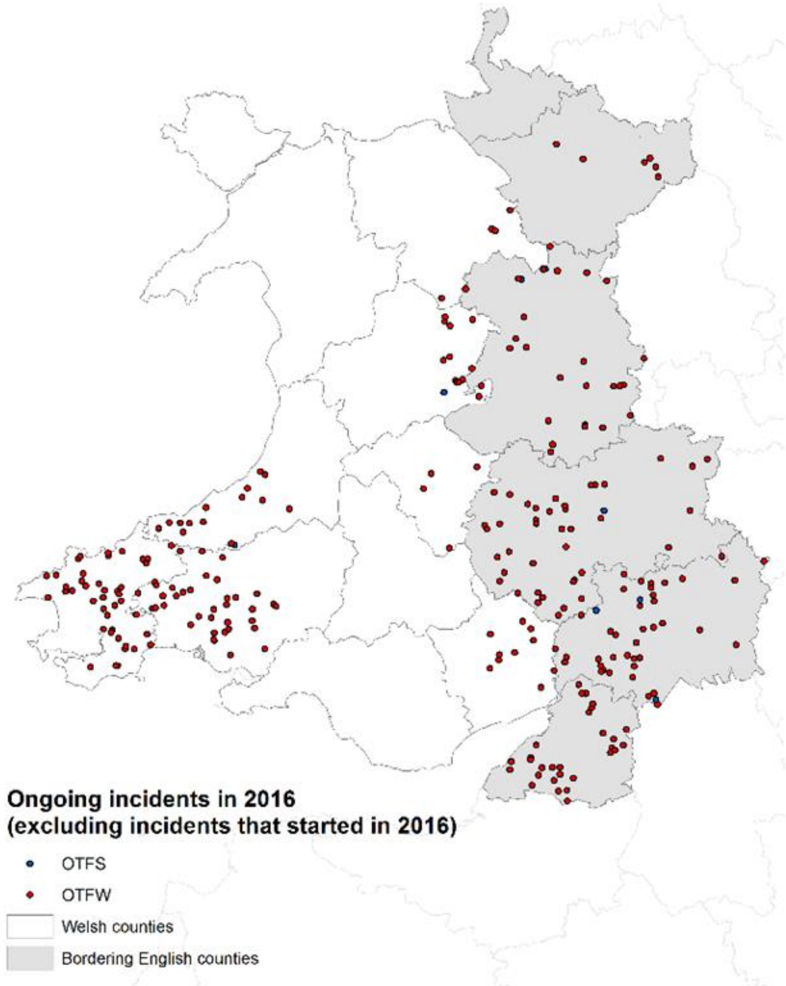


Figure 5.5: Open incidents at the end of the year which started prior to 2016

6.0 Recurrent incidents

Key points:

- Herds with a history of TB were four times more likely to have a new incident than herds with no history (Table 6.2)
- Intervals between incidents were longer for OTF-S incidents in 2016 compared to OTF-W (Table 6.3)

Recurrence of TB in a herd may be due to persistence of infection from a previous TB incident, or the result of a newly introduced infection. In this section we look at the proportion of herds with recurrent TB incidents, to identify how recurrence changes over time and to describe factors associated with recurrence.

A recurrent incident is defined in this report as the first TB incident disclosed during the Current Period (2016) where the herd was previously under restriction for TB at any time during a History Period. The History Period is defined as the 36 months preceding the start date of the recurrent incident or, where no recurrent incident has occurred in a herd, is the 36 months prior to the mid-point of the Current Period[1]. Further details are provided in Appendix 1.

Table 6.1 shows the number of herds with and without new TB incidents in 2016, according to their TB history. Of all herds that had a history of TB, 17% (318/1,859) had a new incident in 2016, similar to the proportions observed from 2013 onwards. Of the 11,300 herds included in the analysis, 80% had no incidents of TB in either the current or history period; a similar proportion as that seen in previous years.

Herds that had a new TB incident in 2016 were significantly more likely to have been restricted due to a TB incident during the history period compared with herds that remained OTF in the current period (p<0.001 by Fisher's Exact test). Additionally, herds that had a new OTF-W TB incident in 2016 were significantly more likely to have been restricted due to an OTF-W TB incident during the history period compared with herds that had a new OTF-S incident in the current period (p<0.001 by Fisher's Exact test).

[1] The recurrence analyses included all herds active at the end of the Current Period (2016). Herds that were under restriction for four or more months in the Current Period due to an incident that started prior to the Current Period were excluded from the analyses. It was considered that such herds had limited opportunity to become cases since there may have been no further testing in the Current Period following the close of the incident. Setting a threshold of four months allows for the detection of possible recurrence at the 'six months' (6M) test scheduled after lifting of restrictions in herds within the first four months of the current year; Some latitude was allowed for practical issues relating to scheduling of tests towards year end of the Current Period.

Table 6.1: Incident and non-incident herds by TB history, 2016

	TB incidents in the history period[1] (36 months)						
	No previous incidents (a)	Previous incidents					
		Any incident		≥ 1 OTFW incidents		OTFS incidents only	
		Number (b)	% (b/(a+b))	Number (c)	% (c/(a+b))	Number (d)	% (d/(a+b))
TB status in current period							
OTF herds [1,2]	9,071	1,541	15	1,216	11	325	3
Any new TB incident	370	318	46	291	42	27	4
OTF-W herds	297	311	51	287	47	24	4
OTF-S herds	73	7	9	4	5	3	4
Total herds	9,441	1,859	16	1,507	13	352	3

[1] Whether a herd was active in the History Period was not checked

[2] A herd was classified as OTF in 2016 if it suffered no new incident in 2016 or was under movement restrictions due to a previous incident for less than four months of 2016, and thus had the potential to have a recurrent incident later in the current period. Herds under restriction for four or more months of 2016 due to an incident that started before 2016, were excluded from analyses (n=351)

In 2016 there was a decrease in the proportions of breakdown herds that also had a history of TB, although there has generally been little change over the last five years (Figure 6.1). The only exception to this is for OTF-S incidents in the current period, where continuing declines are observed. This trend is due to changes in the classification of OTF-W incidents brought in in January 2011 (see Appendix 1), which has resulted in a decline in the proportion of OTF-S incidents in Wales. This is because an incident within the history period may support epidemiological reasoning to confirm a breakdown within the current period, reducing the likelihood of an incident being categorised as OTF-S. This has resulted in a continuing decline in the OTF-S cohort.

The trend for declining recurrent incidents closely reflects the patterns of overall TB incidence, irrespective of incident classification. This is expected as declines in incidence in one year will result in fewer herds with a history of TB later on.

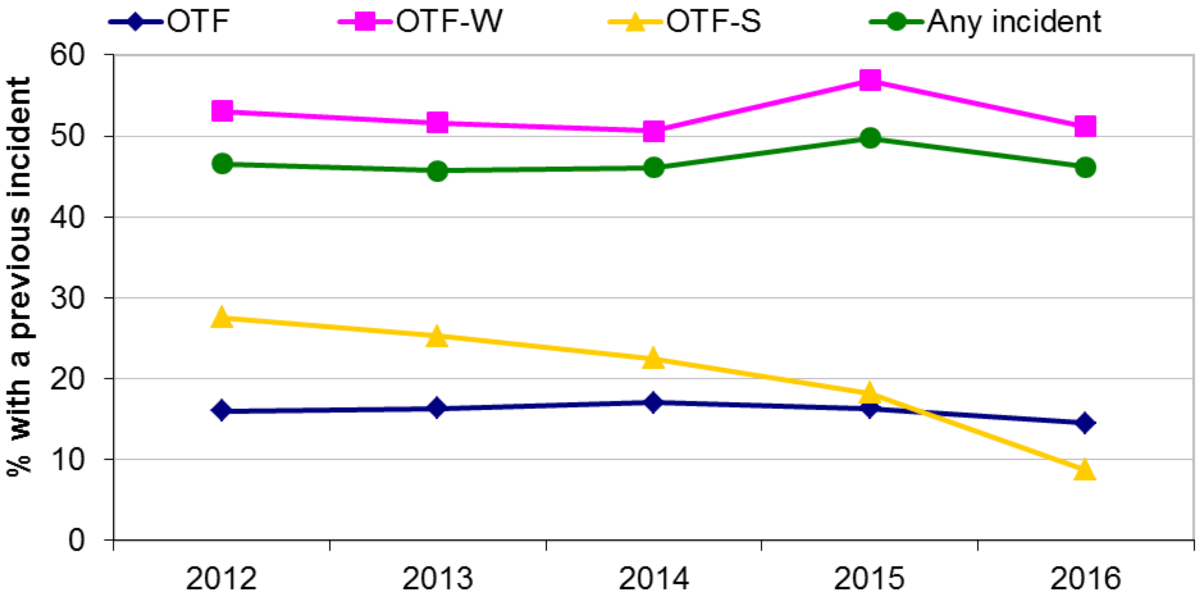


Figure 6.1: Proportion of herds with a history of TB, by OTF status, 2012 – 2016

In recent years, recurrence was described in terms of the relative risk that herds under movement restrictions in the 36-month history period had a new TB incident in the reporting year when compared with herds with no history of restrictions and this was stratified by herd size, herd type and county. The relative risk was calculated by dividing the proportion of herds with a recent history of TB that had an incident in the reporting year, by the proportion of herds without a recent history of TB that had an incident in the reporting year. Using this method invites comparisons between the relative risks but given that for each level of each factor the risk to the denominator population is quite different, these comparisons are not strictly valid. This is particularly true for the differences across counties, but is also likely to be the case with respect to herd size categories and herd types, as well as the potential that each of these factors are confounded with one another.

To account for the differences in the underlying risk in the population, a logistic regression analysis has been performed where the outcome is the odds ratio after adjustment for herd size, herd type and county. The odds ratio represents the odds of a herd having a TB incident in the current year following an incident in the previous 36 months, compared with the odds of a TB incident occurring where there is no history of an incident.

Table 6.2: Herds with and without an incident in 2016, by TB history

	TB incident in the History Period[1]		No TB incident in the History Period[1]		Odds ratio (adjusted)[2]	95% CI for odds ratio	
	Herds	Incident in 2016 (%)	Herds	Incident in 2016 (%)			
Herd size							
0 - 10	65	2 (3.1)	1,873	12 (0.6)	3.6[ns]	0.8	16.6
11 - 50	315	22 (7.0)	3,290	71 (2.2)	2.4	1.4	3.9
51 - 100	371	46 (12.4)	1,933	99 (5.1)	1.9	1.3	2.8
100 - 200	527	79 (15.0)	1,433	101 (7.0)	1.6	1.2	2.2
200 - 300	225	52 (23.1)	474	38 (8.0)	2.2	1.4	3.5
>300	356	117 (32.9)	438	49 (11.2)	2.4	1.6	3.5
Undetermined	0	-	-	-	-	-	-
Herd type							
Beef	1,163	150 (12.9)	7,737	246 (3.2)	2.1	1.7	2.6
Dairy	689	168 (24.4)	1,447	123 (8.5)	2.0	1.5	2.5
Other/mixed	7	0 (0)	257	1 (0.4)	1.0	-	-
Wales region							
Anglesey	33	0 (0)	673	9 (1.3)	1.0	-	-
Gwynedd	37	1 (2.7)	1,287	19 (1.5)	1.2[ns]	0.2	9.3
Clwyd	158	12 (7.6)	1,452	34 (2.3)	2.0	1.0	4.0
Ceredigion	177	25 (14.1)	913	40 (4.4)	1.9	1.1	3.3
Pembrokeshire	324	86 (26.5)	712	57 (8.0)	2.2	1.5	3.3
Carmarthenshire	346	61 (17.6)	1,474	51 (3.5)	2.7	1.8	4.0
North Powys	253	53 (20.9)	851	48 (5.6)	2.4	1.6	3.7
Mid Powys	157	17 (10.8)	344	32 (9.3)	0.8[ns]	0.4	1.5
South Powys	99	14 (14.1)	439	19 (4.3)	2.1	1.0	4.5
Glamorgans	95	12 (12.6)	759	23 (3.0)	2.6	1.2	5.5
Gwent	180	37 (20.6)	537	38 (7.1)	1.6[ns]	0.9	2.6
Total	1,859	318 (17.1)	9,441	370 (3.9)			

[1] Herds under restriction any time in the history period, unless the restriction lasted for more than four months into 2016; in which case the herd was excluded from analyses; the History Period is defined as the 36 months preceding the start date of the recurrent incident or, where no recurrent incident has occurred in a herd, is the 36 months prior to the mid-point of the Current Period

[2] The odds that herds under movement restrictions in the 36-month history period had a new TB incident in 2016 when compared with herds that had no history of movement restrictions.

[ns] Not statistically significant

The odds of a new incident in herds with TB history compared with no history were highest among herds with fewer than 50 animals and more than 300 (Table 6.2). For beef and dairy herds the odds of a new incident in herds with TB history compared with no history were virtually the same. Regionally the odds varied from 0.8 (North Powys) to 2.7 (Carmarthenshire). The confidence intervals for the odds ratios across counties overlap, meaning that it is not possible to distinguish true differences between counties.

Table 6.3 shows descriptive statistics for the time elapsed between the end of movement restrictions in the most recent TB incident in the history period and the start date of the first incident in the current period.

*Table 6.3: Time elapsed between the end of movement restrictions in the **most recent** TB incident in the history period and the start date of the first incident in the current period*

Previous incident type[1]	2016 incident type[2]	Time elapsed (days)[3]				
		Mean	Median	SD	Min	Max
Any	Any	498	486	282	11	1,092
OTF-W	Any	499	483	279	11	1,074
OTF-S	Any	492	510	315	56	1,092
Any	OTF-W	494	481	282	11	1,092
OTF-W	OTF-W	495	478	278	11	1,074
OTF-S	OTF-W	474	498	324	56	1,092
Any[4]	OTF-S	697	609	205	499	1,047
OTF-W	OTF-S	735	697	239	499	1,047
OTF-S	OTF-S	647	546	185	535	861

[1] Any: The most recent incident in the history period regardless of whether OTF-S or OTF-W incident; OTF-W: the last incident where the last incident was OTF-W; OTF-S: the last incident where the last incident was OTF-S

[2] Any: OTF-S or OTF-W incident(s) in 2016; OTF-W: OTF-W incident(s) occurred at any time in 2016 (not necessarily the first); OTF-S: only OTF-S incident(s) occurred in 2016

[3] For herds that had an OTF-S incident in the current period followed later in the year by an OTF-W incident, the date of the OTF-W incident was used but the OTF status was classified as OTF-W. Includes only recurrent incidents where the preceding incident ended between 1st January 2013 and the end of April 2016; Time elapsed was calculated as the number of days between the end of the last incident and the start of the first new incident in 2016. If the first incident in 2016 was OTF-S but the herd subsequently had an OTF-W incident, the 2016 incident type is shown as OTF-W but the date of the first incident (OTF-S) is used to calculate the time elapsed.

[4] There were only 7 herds which had an OTF-S incident in 2016; 3 of these had an OTF-S incident in the history period and the remaining 4 had an OTF-W incident in the history period

Of the 318 recurrent incidents included in the analyses, the time elapsed between incidents ranged from 11 days to 36 months (median = 16 months). The median duration between incidents tended to be longer where the 2016 incident type was OTF-S compared with where the 2016 incident type was OTF-W; this is converse to what was observed in 2015. This increasing length of time between OTF-S incidents can be attributed to the decreasing number of such incidents owing to the use of epidemiological evidence to re-classify breakdowns as OTF-W, especially as breakdowns in the previous three years should be a trigger for reclassification.

Figure 6.2 illustrates the distribution of recurrent incidents in Wales and bordering English counties between 2012 and 2016. There was very little difference in the distribution of recurrent incidents in 2016 compared with 2015. The majority of recurrent herds in 2016 had experienced just one previous OTF-W incident in the history period, and no herds had experienced more than three incidents in the past three years.

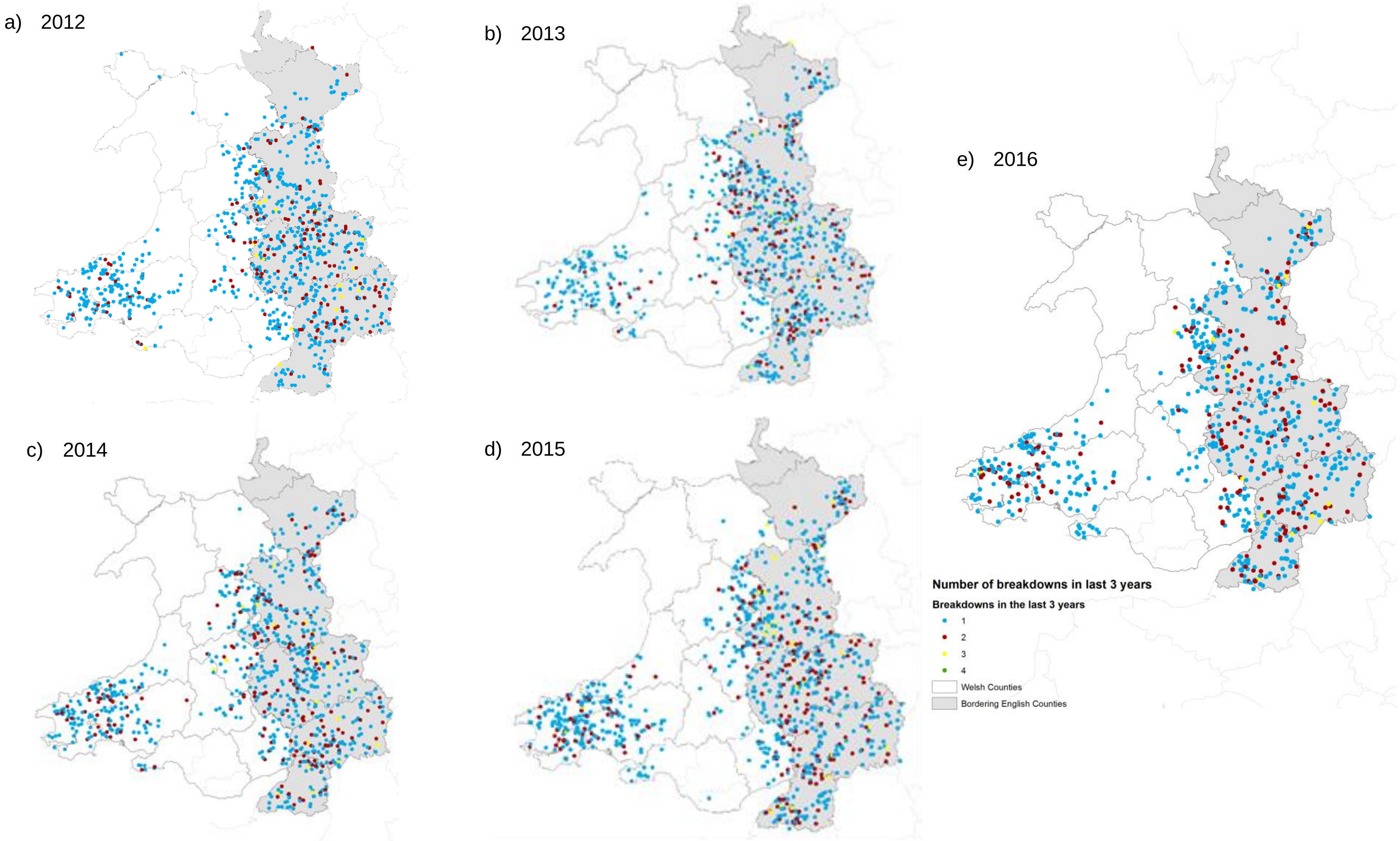


Figure 6.2: Herds with new bovine TB incidents in 2012 - 2016 that had had between one and four OTF-W incidents in the previous 36 months (recurrent incident herds)

7.0 Inconclusive reactor herds that subsequently suffered an incident

Key points:

- 19% (140/762) of IR only herds that were clear at retest went on to have an incident in the subsequent 15 months compared with only 5% (463/9,276) of non-IR herds that tested clear at a routine whole herd test
- More dairy herds which were clear at the IR retest went on to have a TB incident at a test subsequent to this compared with beef herds (23% vs 14%) (Table 7.1)
- 49% of IR-only animals tested clear at the first retest and remained clear for the follow-up period (Figure 7.6)

This section analyses the fate of herds in the fifteen months following an *initial* herd test at which:

- the herd was not already under restriction
- there were no unresolved inconclusive reactors (IR) in the herd at the time of the initial herd test
- one or more IRs were found
- an incident was not disclosed by the initial herd test
- the test took place in the 12 months preceding the reporting year to allow for a 15 month follow-up period

In this section, this type of initial herd test is described as an *IR-only test.* The current minimum interval between retests of IRs is 60 days. It is important to quantify IR-only herds that suffer subsequent incidents as animals in these herds may in fact be infected at the IR-only test. However, some of these herds might not be subject to movement restrictions due to the interpretation of the skin test as inconclusive whereas others will until the retest owing to a recent history of TB. This has important implications for the efforts to control disease spread in Wales.

There were 970 IR-only herds in Wales in 2016, of which 146 (15%) had an OTF-W incident at the IR-retest and 62 (6%) had an OTF-S incident. The remaining 762 (79%) had no new TB incident at IR-retest. Thus, a new TB incident was detected at the IR retest in 208 (21%) herds with IR-only tests in 2016.

Of the 762 herds that tested clear at an IR retest, 748 subsequently had a whole herd test within the 15-month follow up period. Of these herds, 19% (n=140) went on to have an incident at the next whole herd test, compared to 5% (463/9,276) of non-IR herds that had a whole herd test in 2015; significantly more IR-only herds that were clear at a retest went on to have an incident compared with non-IR herds that tested clear at a routine whole herd test in the same period (19% vs. 5%, $p<0.001$ Fishers Exact test). The proportions observed in 2016 were similar to those observed in recent years.

Figures 7.1 and 7.2 show the change in the proportion of IR-only herds with a new TB incident at the IR retest or subsequent whole herd test since 2007. There was an increase in the proportion of IR-only herds that had a subsequent OTF-S incident at the IR retest up to 2009 (8% in 2006 to around 25% in 2009; Figure 7.1). This increase was most likely due to the application of interferon-gamma tests for second retests, introduced in 2006, which tended to detect many animals with borderline immunological responses to the skin test which had an increased likelihood of being NDL or culture negative. However, since 2009 the figure has decreased considerably, standing at around 7% for the last three years. This is related to the change to the way incidents were classified from 2011. The proportion of IR-only herds that had a subsequent OTF-W incident at the IR retest remained constant, at between 7% and 9% before 2011. As would be expected, this proportion increased following this point as more herds were classified as OTF-W from 2011 onwards. However, despite this increase the proportion itself has remained relatively stable since 2013, between 15% and 17%.

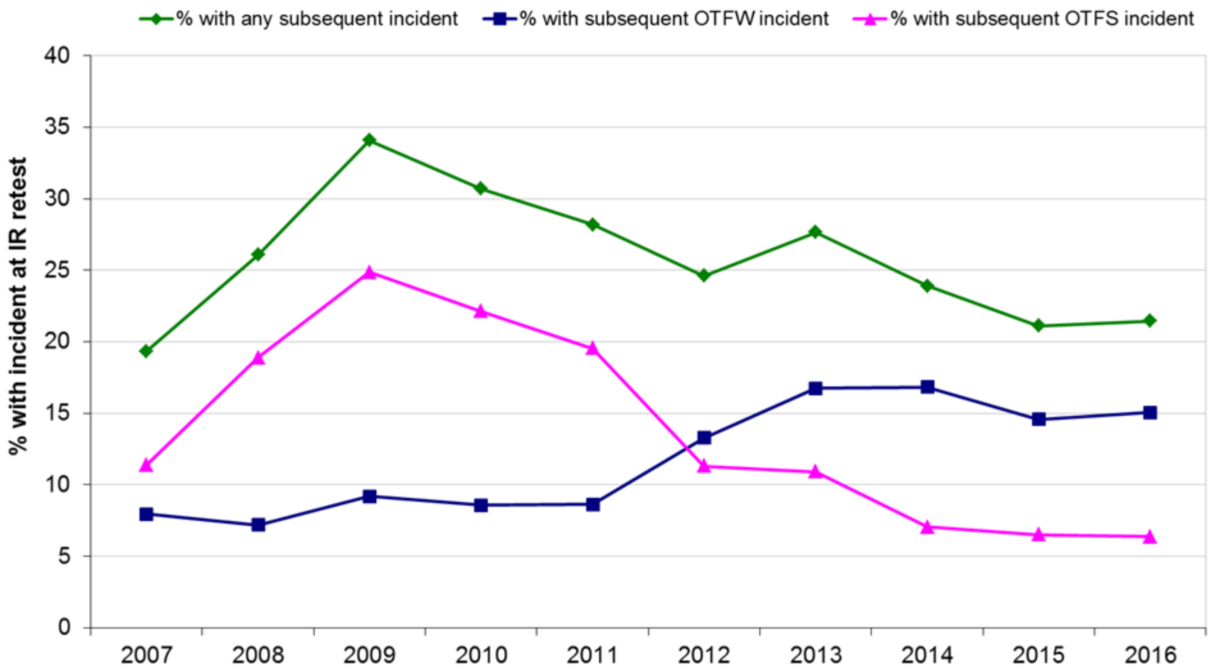


Figure 7.1: Proportion of IR-only herds with a new TB incident at the IR-retest

The proportion of herds that had any incident at the test subsequent to a clear IR retest decreased from 27% in 2008 to 17% in 2011 (Figure 7.2); although this proportion has remained between 15% and 18% since. Following the change to the way incidents were classified from 2011, the trend for herds with OTF-W incidents following clear IR retests tracked the trend for all incidents. This is as expected since OTF-W incidents now make up a large majority of all incidents. Conversely, the proportion of herds that had an OTF-S incident at test subsequent to a clear IR retest has followed a reducing pattern since 2010, dropping to 1% in 2016.

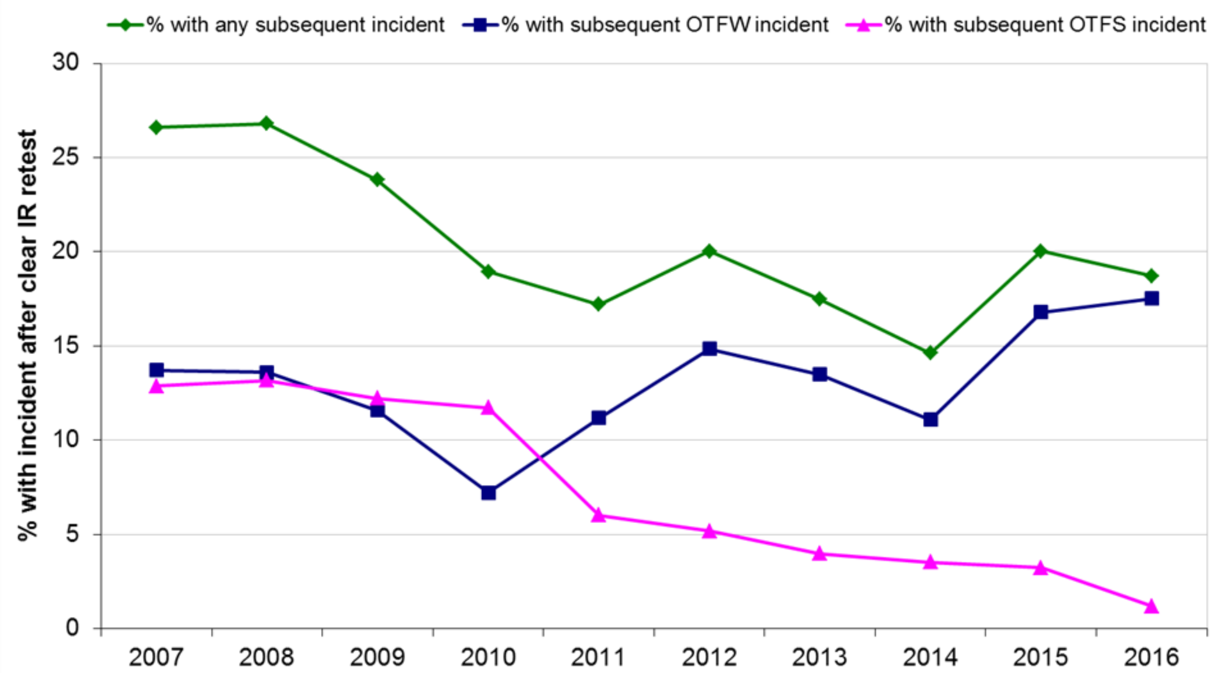


Figure 7.2: Proportion of herds that had a new TB incident following a clear IR-retest[1]

[1]Herds that did not have a whole herd test within the 15 month follow up period were excluded from the denominator

The proportion of IR-only herds that had a new incident at the IR retest or at subsequent tests in the 15 month period appears to vary by herd size, herd type, and geographical area (Table 7.1). For example, 22% of IR only beef herds had an incident at the IR retest which was similar to the proportion for dairy herds (21%). Of the herds that were clear at the IR retest, 12% of beef herds had an incident at the subsequent whole herd test, compared with 23% for dairy herds. In general, the relationships between herd demographics and rates of TB identified in Section 2 are also seen in the proportions of IR-only herds going on to have subsequent incidents, i.e. factors which are associated with higher rates of TB are also associated with higher levels of IR-only herds going on to have a subsequent incident.

Similarly to the IR-only herds, the proportion of clear herds that had a new incident at a subsequent whole herd test in the 15 month period appeared to vary by herd size, herd type, and geographical area and reflected the incidence of TB. This suggests that herds that are at high risk of infection are more likely to suffer an incident at a subsequent whole herd test after testing clear at the initial test.

The trends in the proportion of IR herds with subsequent incidents vary across Wales (Figures 7.3 a-c).

Figure 7.4 shows the geographical distribution of IR-only herds that had no subsequent incident, a new TB incident at the IR retest or a new TB incident at the test subsequent to a clear IR retest in 2016. The density of herds with at least one IR over the last five years also shows a general decrease (Figure 7.5); this pattern is reflective of herd density (Section 1; Figure 1.1).

Table 7.1: TB incidents in the fifteen months subsequent to tests in which only inconclusive reactors (IRs) were found, and TB incidents in the fifteen months following a clear whole herd test, 2016

	IR-only herds with retest[1]	**IR only herds with incident at retest (%)**		**Herds clear at retest with subsequent WH test**	**IR only herds with incident at subsequent WH test (%)**		**Clear herds with a subsequent test**[1]	**Incident at subsequent test (%)**	
		Total	OTF-W		Total	OTF-W		Total	OTF-W
Herd size									
1-10	26	4 (15.4)	1 (3.8)	13	1 (7.7)	0 (0)	1,450	15 (1.0)	11 (0.8)
11-50	121	24 (19.8)	12 (9.9)	95	4 (4.2)	3 (3.2)	3,327	97 (2.9)	75 (2.3)
51-100	182	33 (18.1)	19 (10.4)	148	25 (16.9)	22 (14.9)	2,021	104 (5.1)	84 (4.2)
101-200	286	63 (22)	45 (15.7)	223	27 (12.1)	26 (11.7)	1,521	119 (7.8)	100 (6.6)
201-300	132	30 (22.7)	26 (19.7)	102	26 (25.5)	25 (24.5)	505	67 (13.3)	63 (12.5)
>300	223	54 (24.2)	43 (19.3)	167	57 (34.1)	55 (32.9)	452	61 (13.5)	55 (12.2)
Type									
Beef	481	107 (22.2)	65 (13.5)	362	51 (14.1)	44 (12.2)	7,547	313 (4.1)	250 (3.3)
Dairy	482	99 (20.5)	80 (16.6)	381	89 (23.4)	87 (22.8)	1,603	149 (9.3)	137 (8.5)
Other/mixed	7	2 (28.6)	1 (14.3)	5	0 (0)	0 (0)	126	1 (0.8)	1 (0.8)
Geographical Area									
Anglesey	17	7 (41.2)	1 (5.9)	10	0 (0)	0 (0)	619	7 (1.1)	0 (0)
Gwynedd	28	8 (28.6)	3 (10.7)	20	3 (15)	2 (10)	1,173	13 (1.1)	4 (0.3)
Clwyd	79	13 (16.5)	2 (2.5)	63	8 (12.7)	7 (11.1)	1,379	38 (2.8)	29 (2.1)
Pembrokeshire	193	51 (26.4)	45 (23.3)	140	42 (30)	42 (30)	755	81 (10.7)	74 (9.8)
Ceredigion	129	12 (9.3)	10 (7.8)	115	17 (14.8)	16 (13.9)	903	42 (4.7)	38 (4.2)
Carmarthenshire	219	41 (18.7)	31 (14.2)	177	30 (16.9)	29 (16.4)	1,426	71 (5.0)	65 (4.6)
North Powys	80	30 (37.5)	21 (26.3)	49	9 (18.4)	8 (16.3)	934	78 (8.4)	67 (7.2)
Mid Powys	50	11 (22)	9 (18)	38	7 (18.4)	5 (13.2)	412	34 (8.3)	30 (7.3)
South Powys	46	10 (21.7)	7 (15.2)	35	4 (11.4)	4 (11.4)	444	20 (4.5)	16 (3.6)
Glamorgans	51	6 (11.8)	4 (7.8)	43	4 (9.3)	3 (7)	684	30 (4.4)	20 (2.9)
Gwent	78	19 (24.4)	13 (16.7)	58	16 (27.6)	15 (25.9)	547	49 (9.0)	45 (8.2)
Total	**970**	**208 (21.4)**	**146 (15.1)**	**748**	**140 (18.7)**	**131 (17.5)**	**9,276**	**463 (5.0)**	**388 (4.2)**

[1] Only herds that had a whole herd test are included here as those with clear animal level tests cannot be guaranteed free of TB infection

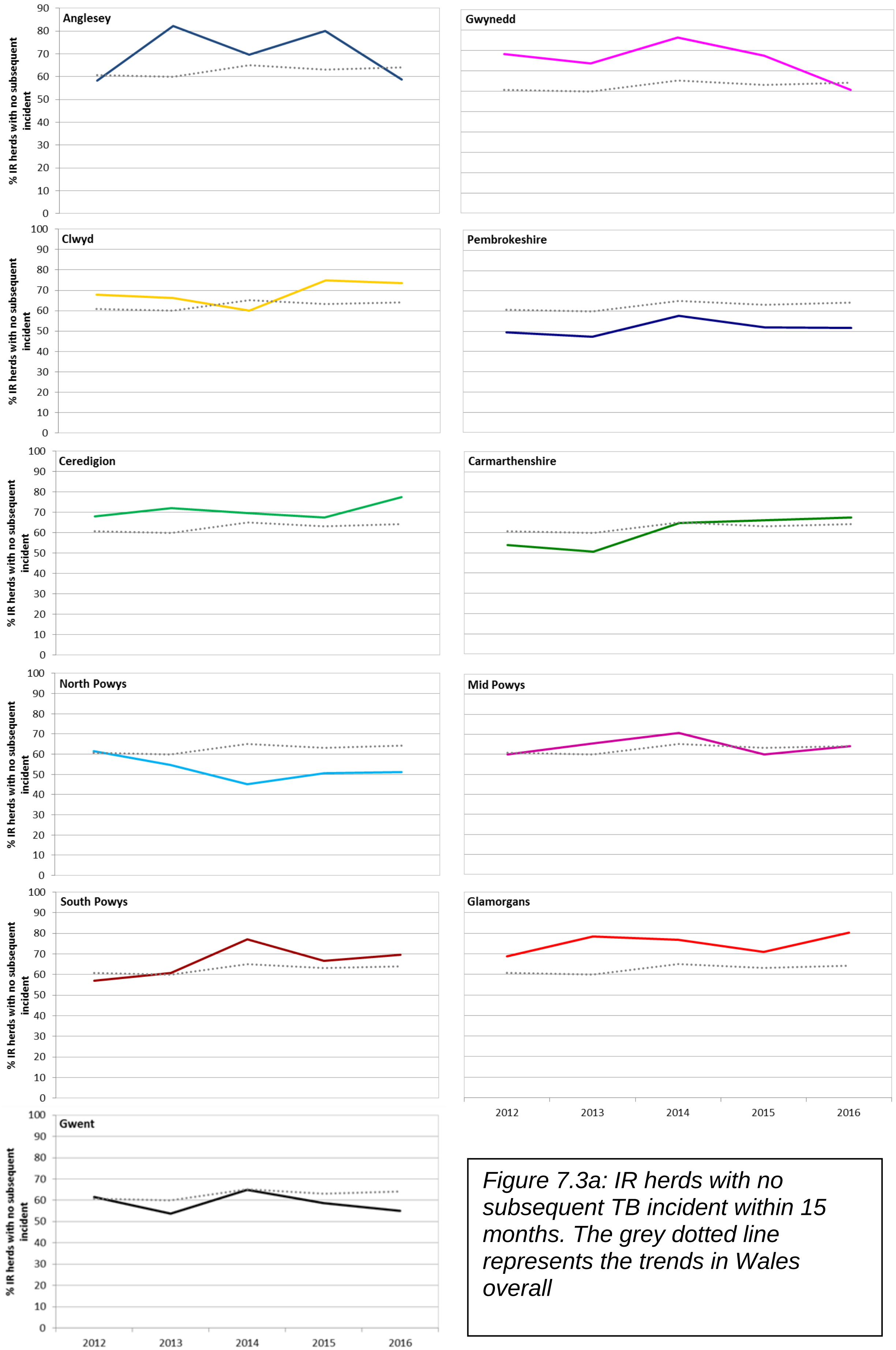
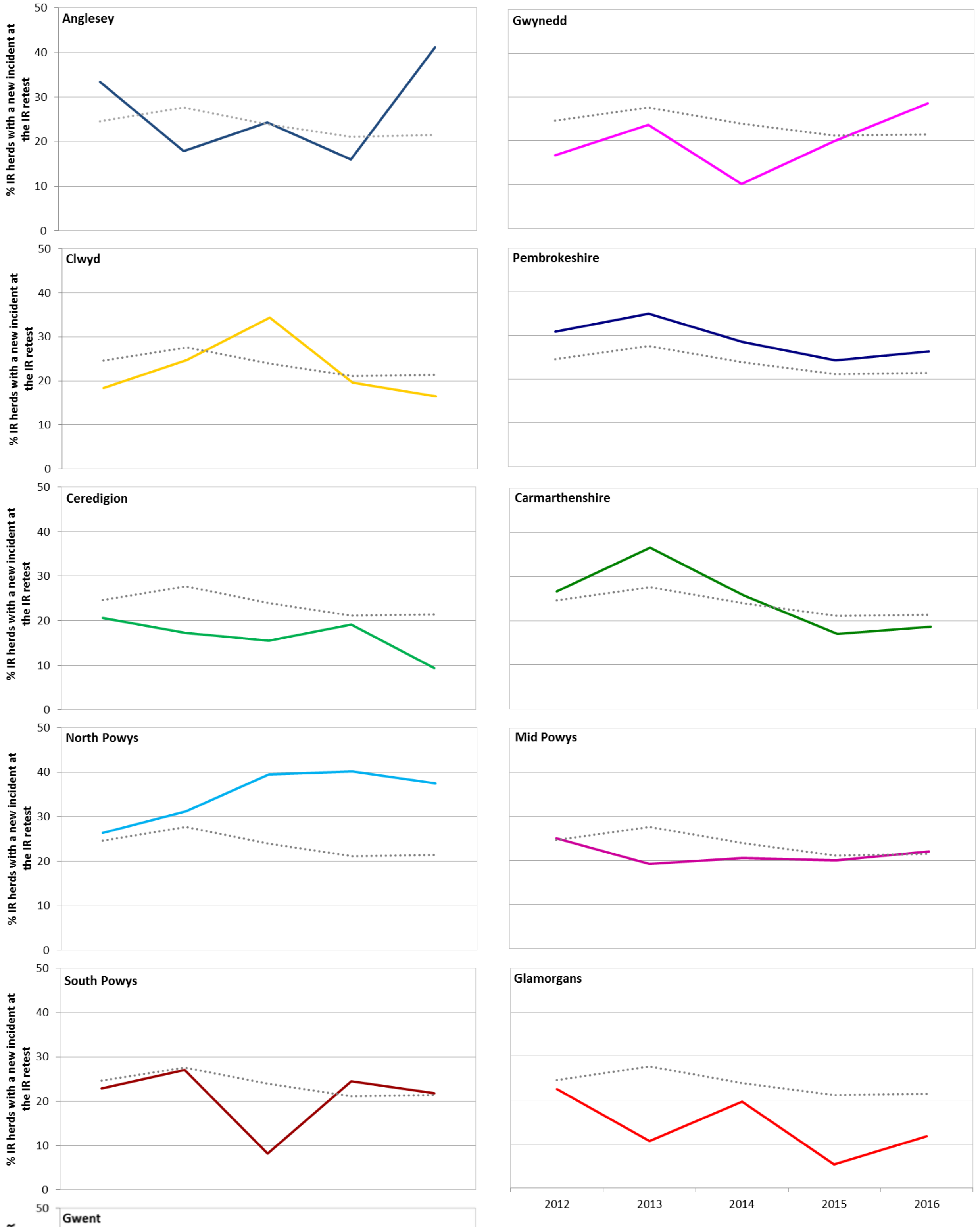


Figure 7.3a: IR herds with no subsequent TB incident within 15 months. The grey dotted line represents the trends in Wales overall



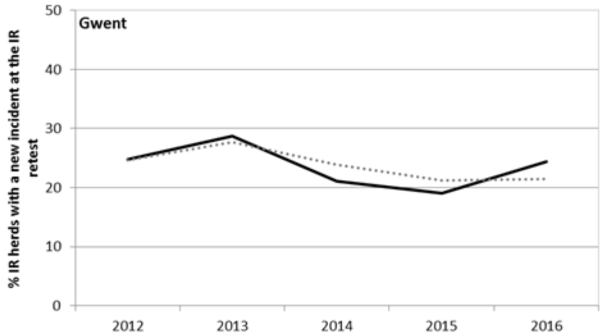


Figure 7.3b: IR herds with a new TB incident at the IR retest. The grey dotted line represents the trends in Wales overall

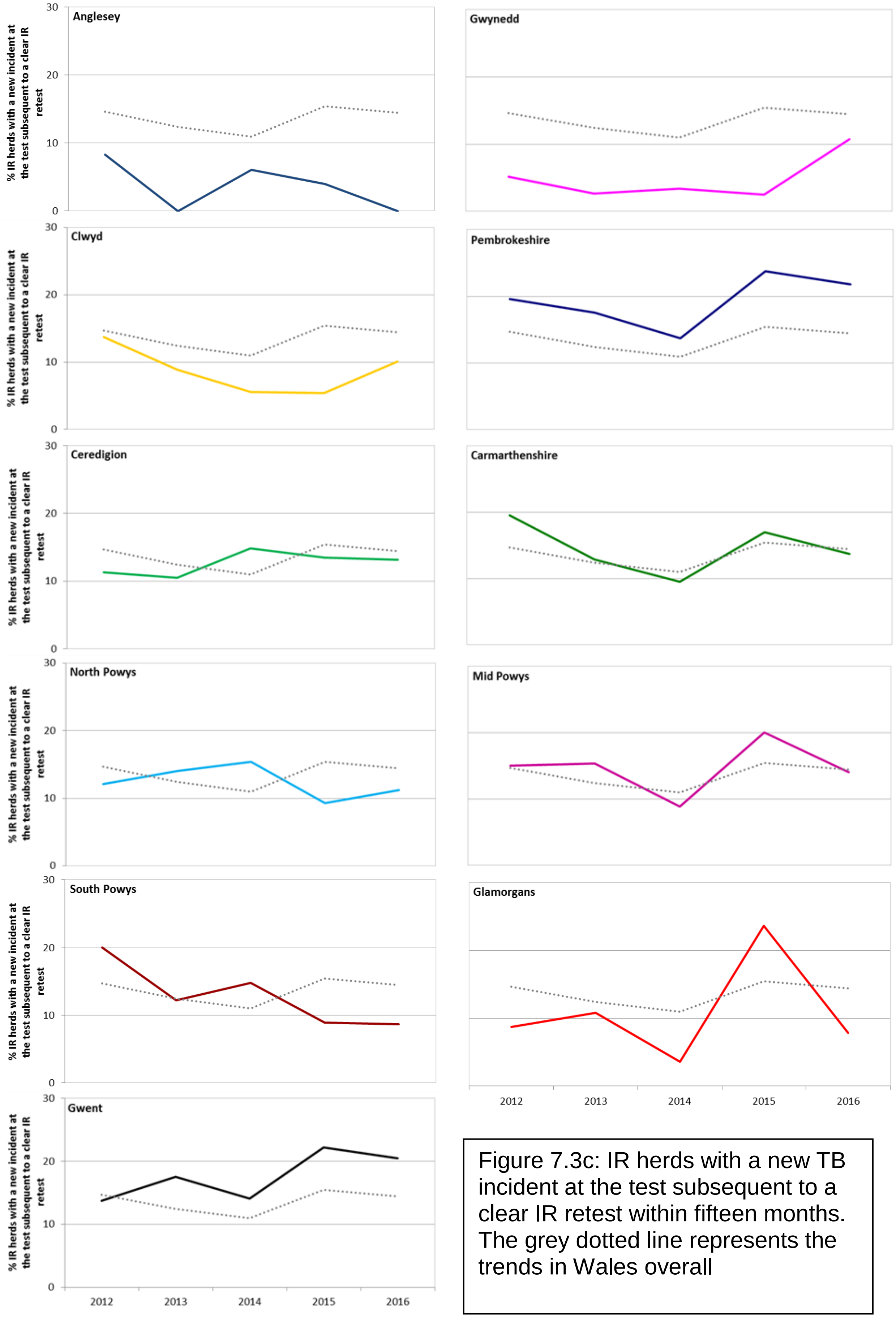


Figure 7.3c: IR herds with a new TB incident at the test subsequent to a clear IR retest within fifteen months. The grey dotted line represents the trends in Wales overall

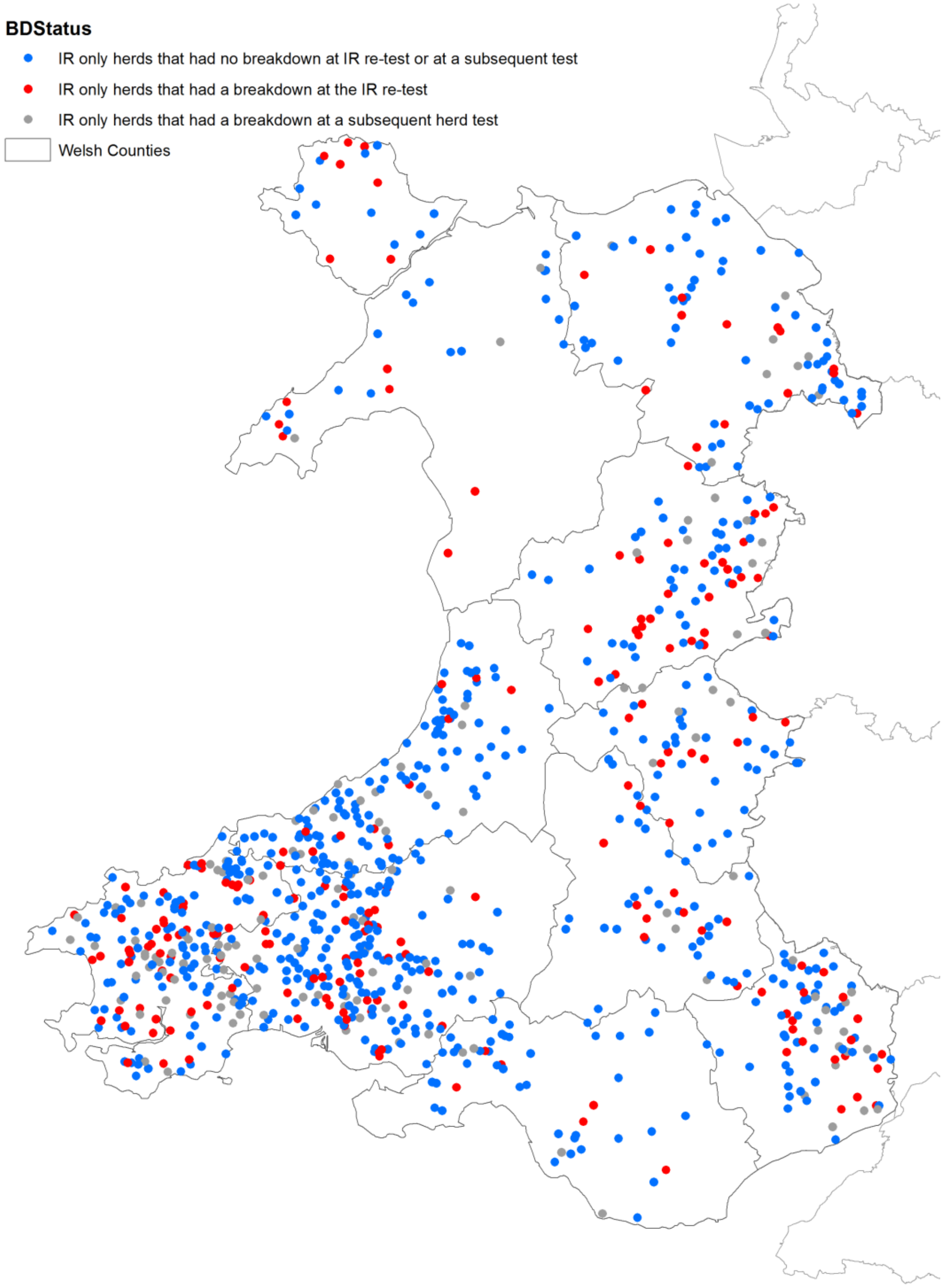


Figure 7.4: IR herds with no subsequent incident; a new TB incident at the IR retest or a new TB incident at the test subsequent to a clear IR retest within fifteen months, 2016

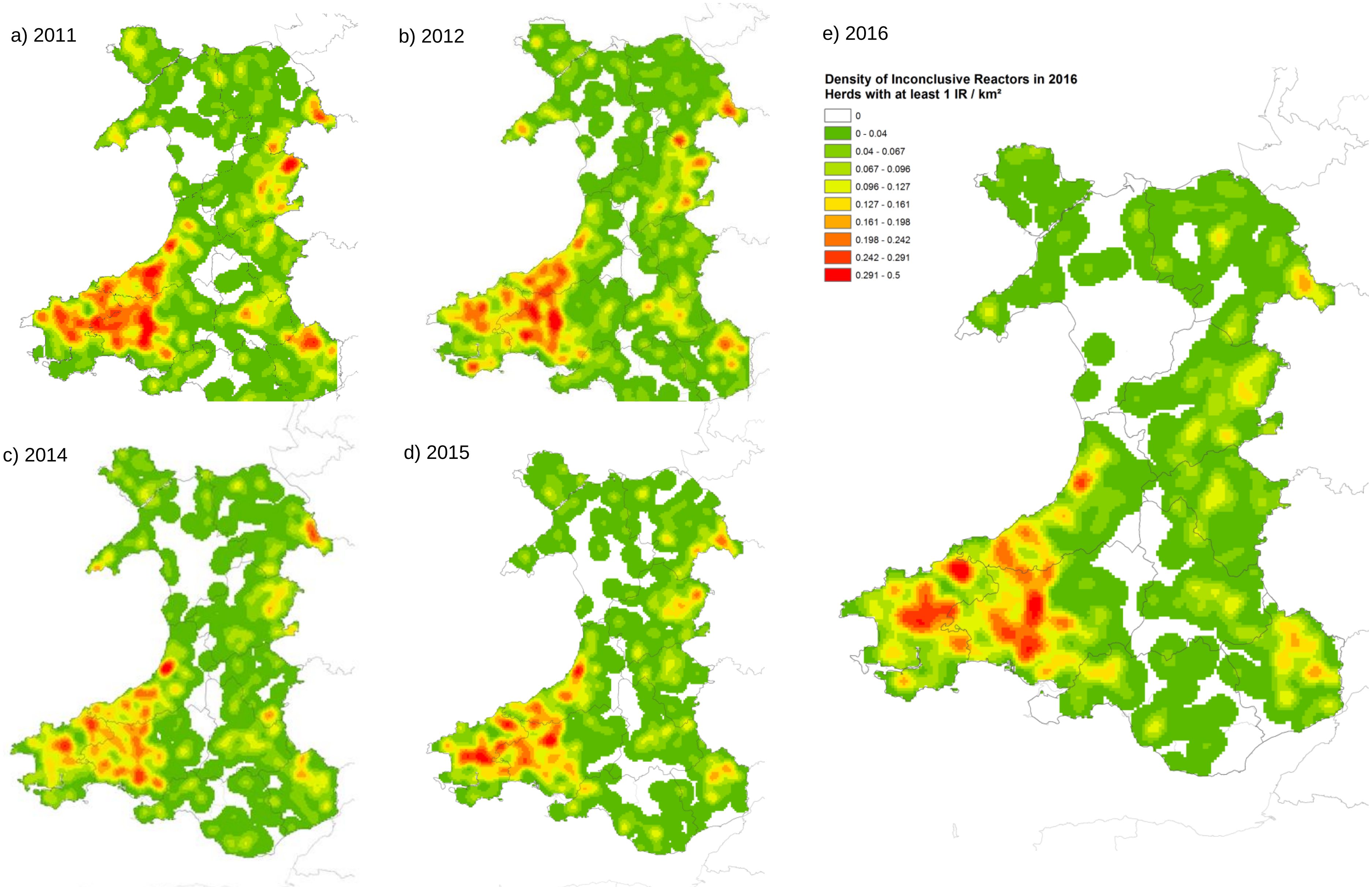


Figure 7.5: Density of herds with at least one inconclusive reactor, 2012 – 2016

7.1 Understanding the fate of IRs

Determining what happens to IRs at the animal level is crucial for reviewing the policy applied to these animals. A flow-diagram identifying the fate of IRs taking into account testing history and slaughterhouse surveillance has been developed (Figure 7.6).

The cohort of animals that were followed was those which had an inconclusive reaction at the initial test outside of an incident in 2015, and these animals were followed for 15 months after the initial test. Figure 7.6 is split in to the initial IR sequence (above the grey line) which follows animals through to testing clear or becoming a 2xIR, 3xIR, reactor or being removed, and the subsequent IR sequence (below the grey line) which describes what happens to animals which test clear at IR retesting. An IR can test clear at first or third retest, and this is represented by the two streams in the subsequent IR sequence. If an animal becomes a 2xIR using the standard interpretation of the test it is removed for slaughter. If it becomes a 2xIR using the severe interpretation of the test, it has a second retest using the gamma interferon (gIFN) test. Passing that triggers another skin test and if the animal becomes a 3xIR, it is removed for slaughter as a reactor.

Of the 3,393 IR-only animals which had an inconclusive reaction to the skin test in 2015, 2,564 (76%) tested clear at the first retest, and 1,255 of these (49%) remained clear during the follow up period with a further 525 being routinely slaughtered and screening negative in the slaughterhouse. Of those 1,255 animals, 47 (4%) went on to experience an incident within 3 months of that clear test and another 97 (8%) within 12 months (data not shown). In this same period there were 186,502 non-IR animals (i.e. clear testing animals) of which 149,419 (80%) remained clear.

Of the 2,564 IR-only animals which tested clear at the first retest, 135 (5%) became a reactor or an IR within the original incident, and a further 135 (5%) became a reactor or an IR at a test subsequent to the initial incident. Seven animals from this cohort went on to be slaughterhouse cases within the 15 months following their initial 1xIR result.

Eleven animals, which were neither subjected to a gIFN test nor slaughtered, despite a 2xIR result, tested clear at their second retest; 182 animals cleared by gIFN 2xIR also tested clear at their third retest. Two of these animals went on to become reactors (both at severe interpretation) during the 15 month follow-up period and seven became an IR again, all during the original incident. Thirty-seven animals which tested clear at the third retest tested clear again; seven of these experienced an incident within 12 months.

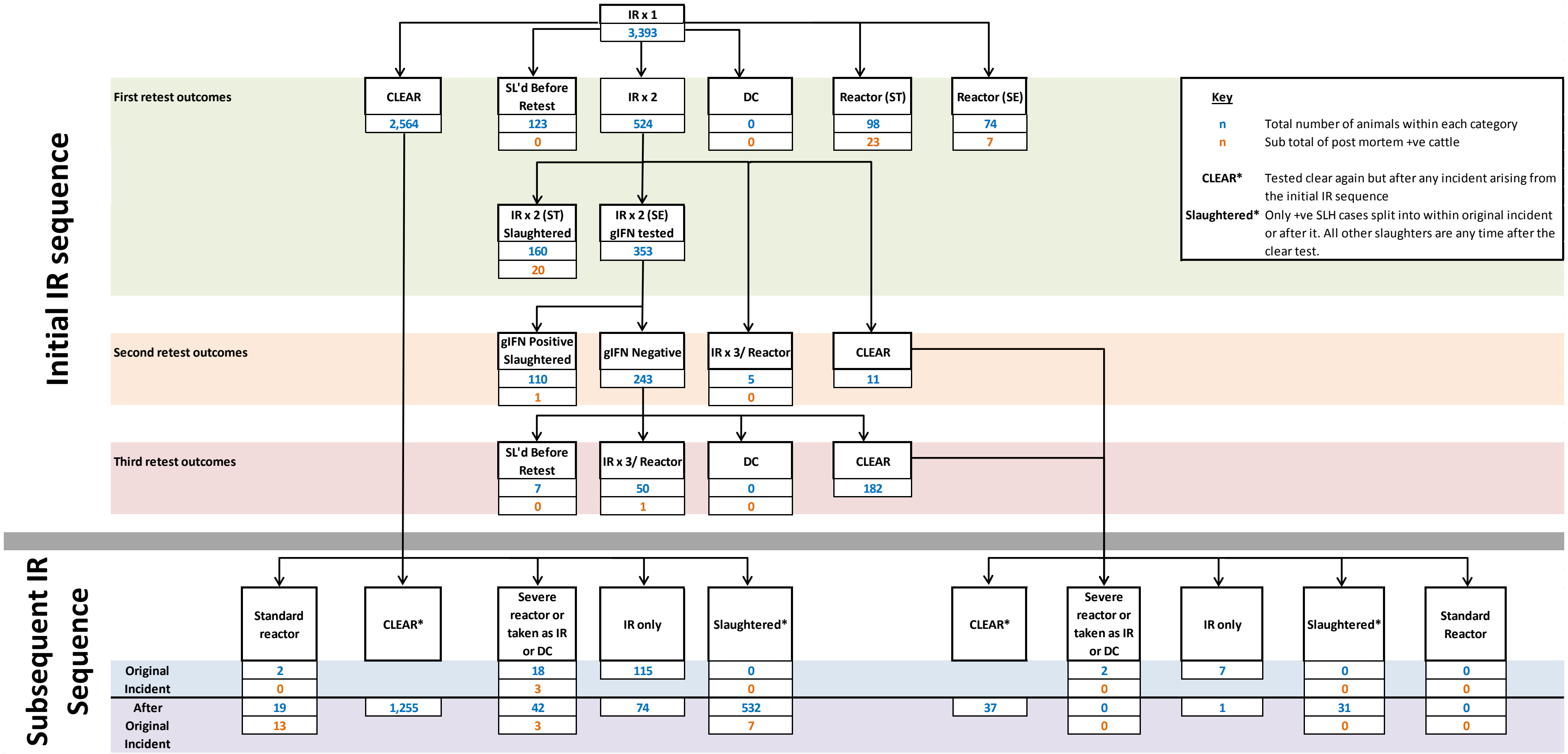


Figure 7.6: Flow diagram illustrating the fate of animals which had an inconclusive reaction to the SICCT test in 2016

8.0 Genotypes identified in bovine and non-bovine species in Wales

Key points:

- There were 365 isolates from cattle for incidents in Wales that started in 2016 and all were spoligotyped.
- The most common spoligotype in Wales (spoligotype 9) had two main clusters: one in the south-west corner of Wales and the other mainly located in Mid Powys (fig 8.1).
- Twenty two non-bovine isolates were genotyped in 2016.

The APHA has a database of genotypes for over 12,000 isolates of bTB from Wales (1988 to end 2016). These genotyped isolates of *M. bovis* show clear geographical clustering. Since 2002 the combination of spoligotype and the variable number of tandem repeat (VNTR) profile is known for the majority of OTF-W incidents. In combination with homerange maps the genotype of *M. bovis* can help to decide on the origin of infection, in particular if the farmer has purchased animals from an area where the prevalent genotype differs from the local one. The current distribution of genotypes is shown in Fig. 8.1

8.1 Overview of the isolates in the spoligotype database (Wales only).

There are over 12,000 isolates in the spoligotype database that originated from Wales between 1988 to the end of 2016. Each of these isolates were spoligotyped and VNTR data (using standard 6 genomic loci characterization) is available for 87 % of these isolates. The distribution of bovine and non-bovine isolates by year is shown in Table 8.1.

Table 8.1: The frequency of bovine and non-bovine isolates genotyped by year 1988 to 2016.

Year	Bovines**	Non-bovines
1988	1	2
1989	8	0
1990	9	0
1991	48	0
1992	58	0
1993	51	4
1994	128	5
1995	122	2
1996	180	11
1997	143	21
1998	202	10
1999	276	6
2000	291	1
2001	381	0
2002	258	2
2003	1010	2
2004	675	1
2005	814	3
2006	809	59
2007	867	12
2008	1095	32
2009	964	5
2010	722	13
2011	555	17
2012	606	11
2013	445	14
2014	543	17
2015	468	37
2016	365	22
unknown year*		7
Total:	**12,094**	**316**

** Year is the year the bovine incident commenced
*Seven M. microti isolates from cats originating from the Glamorgans do not have a year assigned.

8.2 Cattle isolates from Wales for bTB incidents commencing in 2016.

There were 365 isolates from cattle for incidents in Wales that started in 2016 and all were spoligotyped (2015 = 468). Full genotype (spoligotype plus 6 locus VNTR) was obtained for 96 % of these isolates (2015 = 95%). The 351 cattle isolates with full genotype represent 330 separate breakdowns in cattle herds in Wales (2015 = 423). An average of 1.06 isolates were spoligotyped per breakdown (2015 = 1.05).

8.3 Genotype frequency in cattle bTB incidents

The frequency and percentage of each genotype found in the 330 cattle breakdowns (351 individual cattle) from 2016 are shown in Table 8.2. Genotypes 17:a, 9:b, 9:c and 22:a, which made up over 85% of Welsh isolates in 2016, have homeranges in Wales.

Table 8.2: Frequency and percentage of genotypes in OTF-W incidents in cattle, 2015 and 2016.

Genotype	2016		2015
	Frequency	Percentage	Percentage
9:b	106	30.2	36.6
17:a	112	31.9	27.2
9:c	47	13.4	13.0
22:a	31	8.8	8.7
25:a	14	4.0	2.8
9:e	8	2.3	0.5
9:d	4	1.1	0.7
11:a	4	1.1	1.2
10:a	3	0.8	1.2
9:an	3	0.8	0.2
9:7-5-2-4*-3-4.1	3	0.8	0
17:c	2	0.6	0.7
9:s	2	0.6	0.5
9:8-5-5-5*-3-2.1	2	0.6	0
9:f	2	0.6	0
21:a	1	0.3	0.9
22:b	1	0.3	0.7
104:a	1	0.3	0.2
10:h	1	0.3	0
17:h	1	0.3	0
25:f	1	0.3	0
9:m	1	0.3	0
9:5-5-2-4*-3-3.1	1	0.3	0
Total:	351		

The geographical distribution of the major spoligotypes identified in OTF-W incidents in 2016 is presented in Figure 8.1. The most common spoligotype in Wales (spoligotype 9) had two main clusters: one in the south west corner of Wales and the other mainly located in Mid Powys. Spoligotype 9 is much less common over the border in England, where spoligotype 17 predominates. Spoligotype 17 is the second most common type in Wales, with a large cluster seen in North Powys.

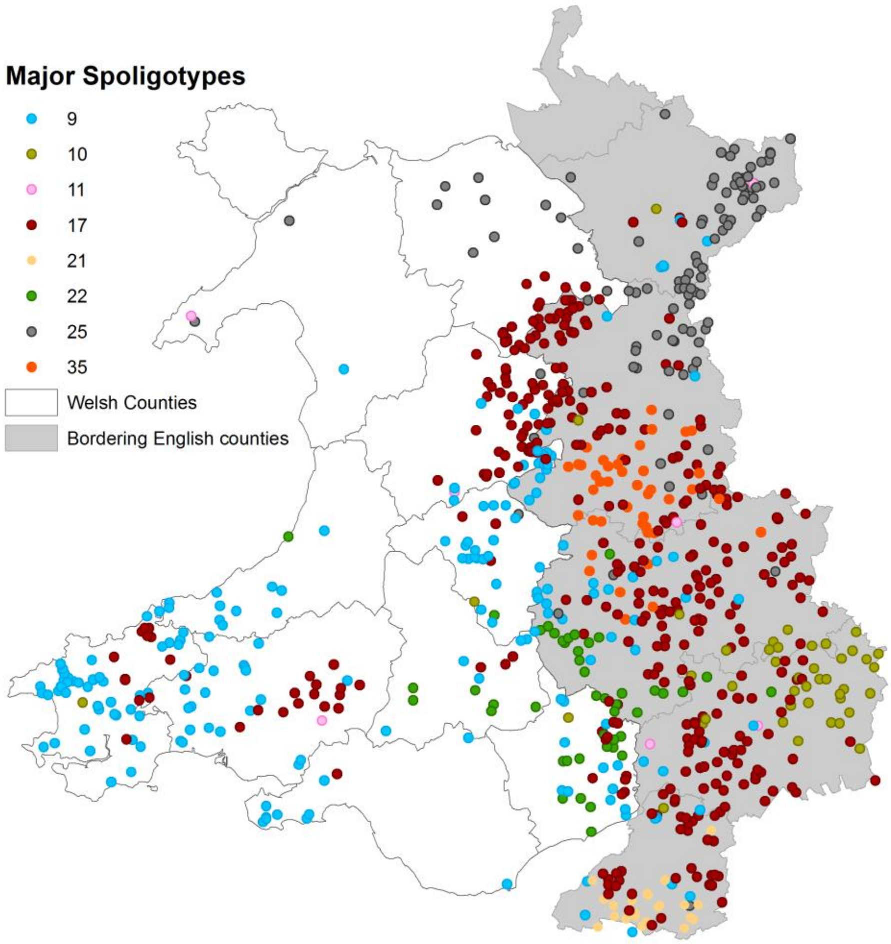


Figure 8.1: Geographical distribution of the major spoligotypes in Wales and English bordering counties in 2016

8.4. Non-bovine isolates from Wales, 2016.

Twenty two non-bovine isolates were genotyped in 2016 (2015 = 37). This total included 12 badger samples (2015 = 26), eight pigs (consisting of two incidents), one cat and one *M.microtii* alpaca sample.

Full genotype was available for eleven badger isolates. Two of the badger-derived isolates did not have a homerange (VNTR mutations of the common homerange genotype at their location). Two of the remaining nine isolates were out-of-homerange.

Full genotype was available for all eight of the pig isolates. One was within homerange with the remaining seven not having a homerange (VNTR mutations of the common homerange genotype at their location).

Annexe – Wales TB Area Statistics

This annexe provides select outputs from the main report aggregated by the new Welsh TB areas that were formally announced in June 2017. Although these are new areas the historical disease situation within them can be determined and are presented here. In addition, the High–West area has in the tables presenting 2016 data been subdivided into the Intensive Action Area of Pembrokeshire (IAA). It has only been possible to compile the herds that have been identified as being present in the IAA for 2016, as there has been insufficient time to accurately determine which were active for previous years in order to include them in the time series given in the charts. It is hoped this can be addressed for future reports but for this report the charts do not show the IAA and all herds will be part of the High–West TB area. There is no commentary for the 2016 report.

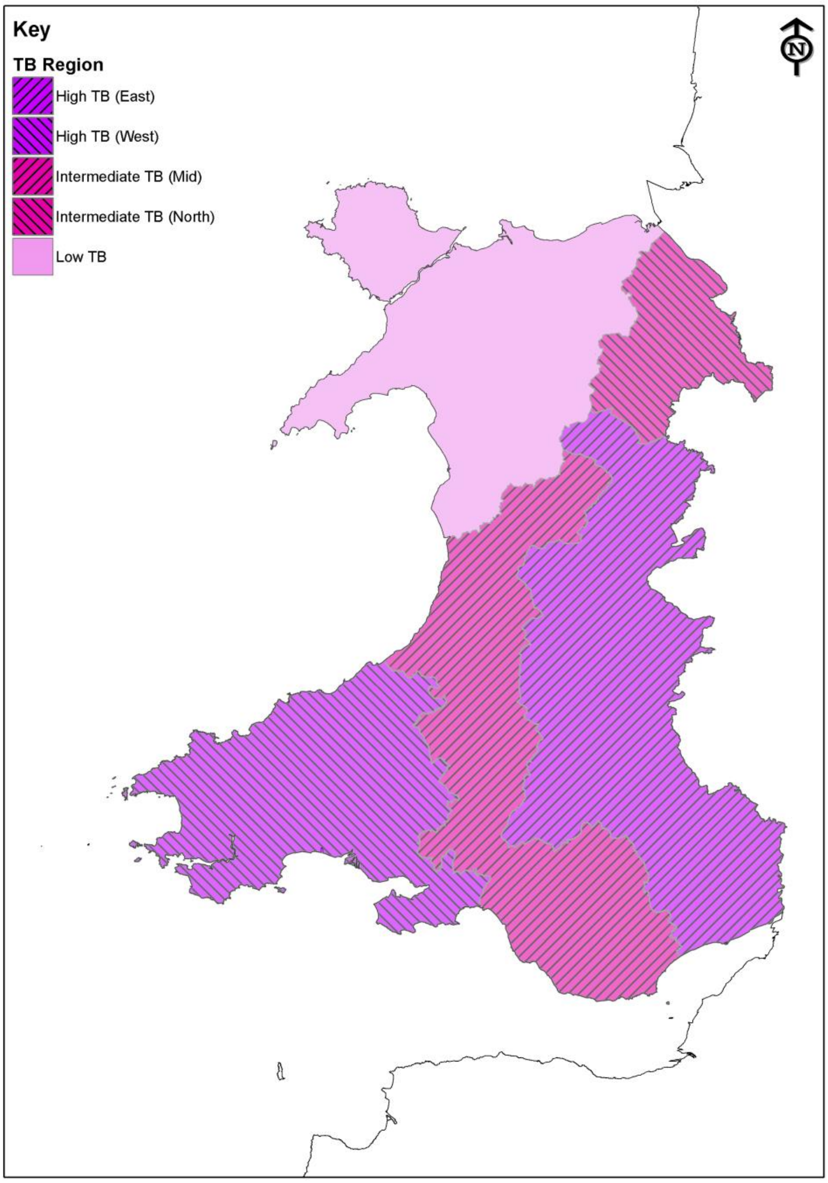


Figure 1.0: The new TB Areas in Wales

Table 1.1a: Herds in Wales (active on SAM) by herd type and TB area, end-2016

	Herds	Proportion of total herds in Wales	Herd type [no. herds (%)]		
			Beef	Dairy	Mixed / Other
IAA	261	2	149 (57)	109 (42)	3 (1)
High (East)	2,685	23	2,295 (85)	341 (13)	49 (2)
High (West)	2,955	25	1,900 (64)	977 (33)	78 (3)
Int (North)	1,130	10	797 (71)	305 (27)	28 (2)
Int (Mid)	2,025	17	1,678 (83)	308 (15)	39 (2)
Low	2,595	22	2,205 (85)	322 (12)	68 (3)
Total	**11,651**		**9,024 (77)**	**2,362 (20)**	**265 (2)**

Table 1.1b: Herds in Wales (active on SAM) by size category, TB area and herd type, end-2016

	Herd size [no. herds]							
	Undeter-mined	1-10	11-50	51 - 100	101 - 200	201 - 300	>300	Total
IAA	0	30	62	44	55	20	49	261
High (East)	37	359	850	640	489	154	156	2,685
High (West)	66	454	815	506	510	225	379	2,955
Int (North)	21	169	298	205	230	94	113	1,130
Int (Mid)	24	337	717	423	342	107	75	2,025
Low	38	406	878	514	416	171	172	2,595
Total	**186**	**1,755**	**3,620**	**2,332**	**2,042**	**771**	**944**	**11,651**

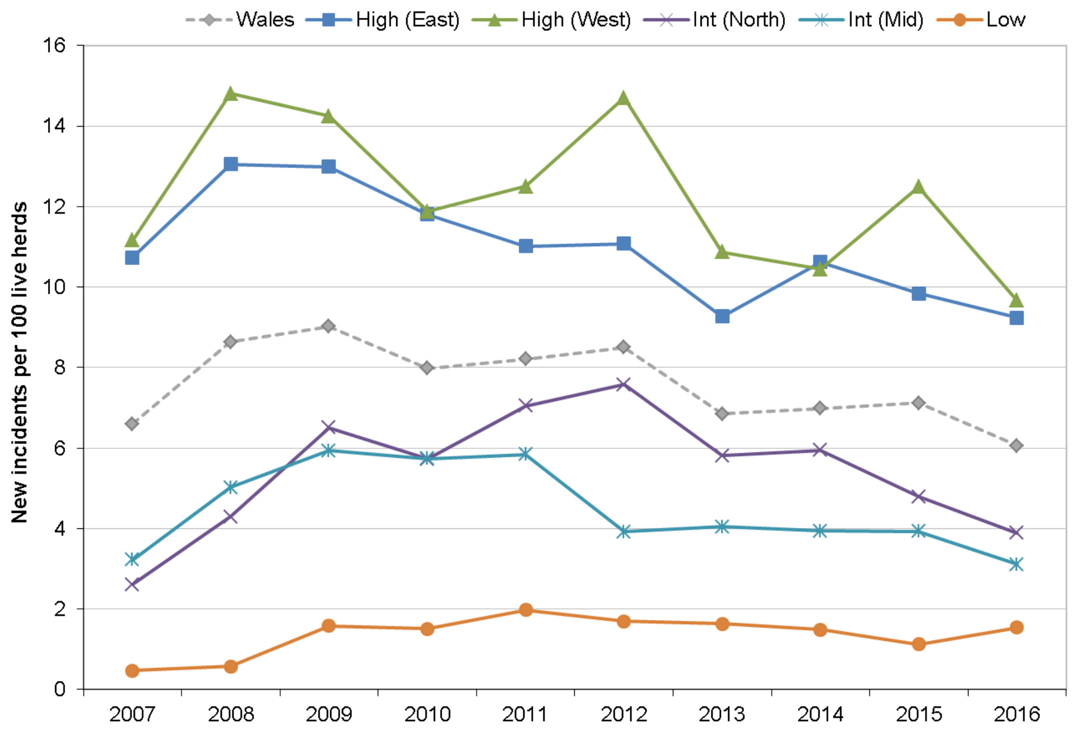
Table 1.1c: Percentage of herds (active on SAM) by size category, TB area and herd type, end-2016

	Herd size [%]							
	Undeter-mined	1-10	11-50	51 - 100	101 - 200	201 - 300	>300	Median herd size
IAA	0	11	24	17	21	8	19	87
High (East)	1	13	32	24	18	6	6	57
High (West)	2	15	28	17	17	8	13	61
Int (North)	2	15	26	18	20	8	10	64
Int (Mid)	1	17	35	21	17	5	4	46
Low	1	16	34	20	16	7	7	50
Total	**2**	**15**	**31**	**20**	**18**	**7**	**8**	

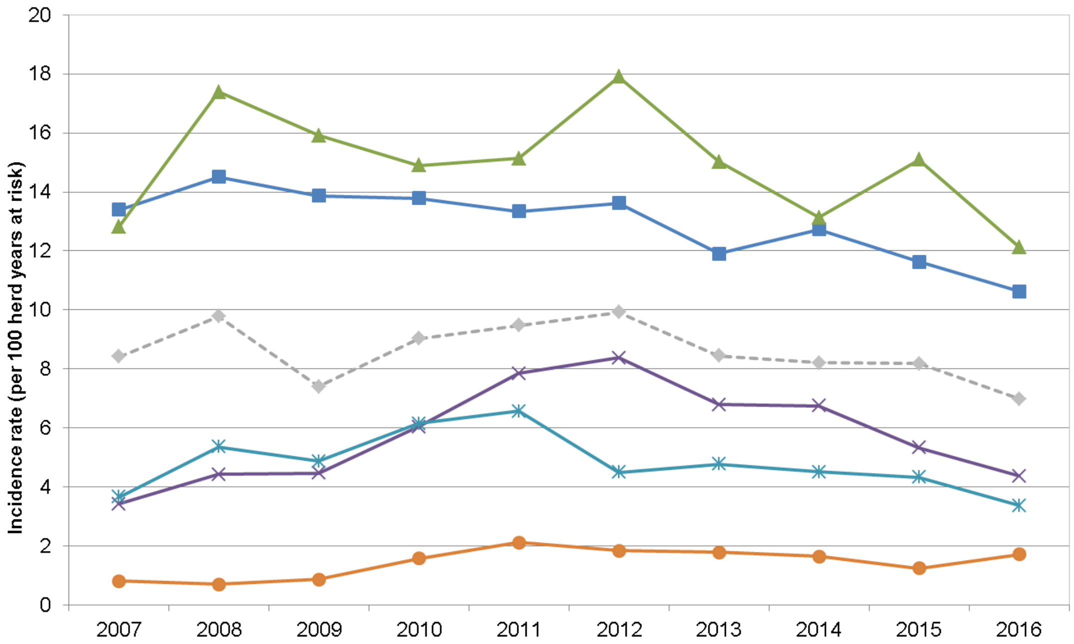
Table 2.1: Incidence and prevalence of TB by TB area, 2016

	Total incidents	OTFW	OTFS	Denominator
New incidents				
IAA	45	45	0	NA
High (East)	248	220	28	NA
High (West)	266	250	16	NA
Int (North)	44	37	7	NA
Int (Mid)	63	54	9	NA
Low	40	18	22	NA
New incidents per 100 live herds				
IAA	17.2	17.2	0.0	261
High (East)	9.2	8.2	1.0	2,685
High (West)	9.0	8.5	0.5	2,955
Int (North)	3.9	3.3	0.6	1,130
Int (Mid)	3.1	2.7	0.4	2,025
Low	1.5	0.7	0.8	2,595
New incidents per 100 unrestricted herds tested				
IAA	19.1	19.1	0.0	236
High (East)	9.9	8.8	1.1	2,497
High (West)	10.1	9.5	0.6	2,645
Int (North)	4.2	3.5	0.7	1,044
Int (Mid)	3.3	2.8	0.5	1,908
Low	1.7	0.7	0.9	2,412
New incidents per 100 herd years at risk				
IAA	21.6	21.6	0.0	75,998 days (208 years at risk)
High (East)	10.6	9.4	1.2	852,126 days (2,333 years) at risk
High (West)	11.3	10.6	0.7	859,909 days (2,354 years) at risk
Int (North)	4.4	3.7	0.7	367,917 days (1,007 years) at risk
Int (Mid)	3.4	2.9	0.5	682,290 days (1,868 years) at risk
Low	1.7	0.8	0.9	852,685 days (2,335 years) at risk
Herds under restriction (mid-December)				
IAA	45	45	0	NA
High (East)	170	161	9	NA
High (West)	257	250	7	NA
Int (North)	32	28	4	NA
Int (Mid)	45	40	5	NA
Low	17	8	9	NA
Herds under restriction per 100 live herds				
IAA	17.2	17.2	0.0	261
High (East)	6.3	6.0	0.3	2,686
High (West)	8.7	8.5	0.2	2,956
Int (North)	2.8	2.5	0.4	1,128
Int (Mid)	2.2	2.0	0.2	2,026
Low	0.7	0.3	0.3	2,595

a)


Wales
High (East)
High (West)
Int (North)
Int (Mid)
Low
New incidents per 100 live herds
0
2
4
6
8
10
12
14
16
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

b)


Incidence rate (per 100 herd years at risk)
0
2
4
6
8
10
12
14
16
18
20
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

c)

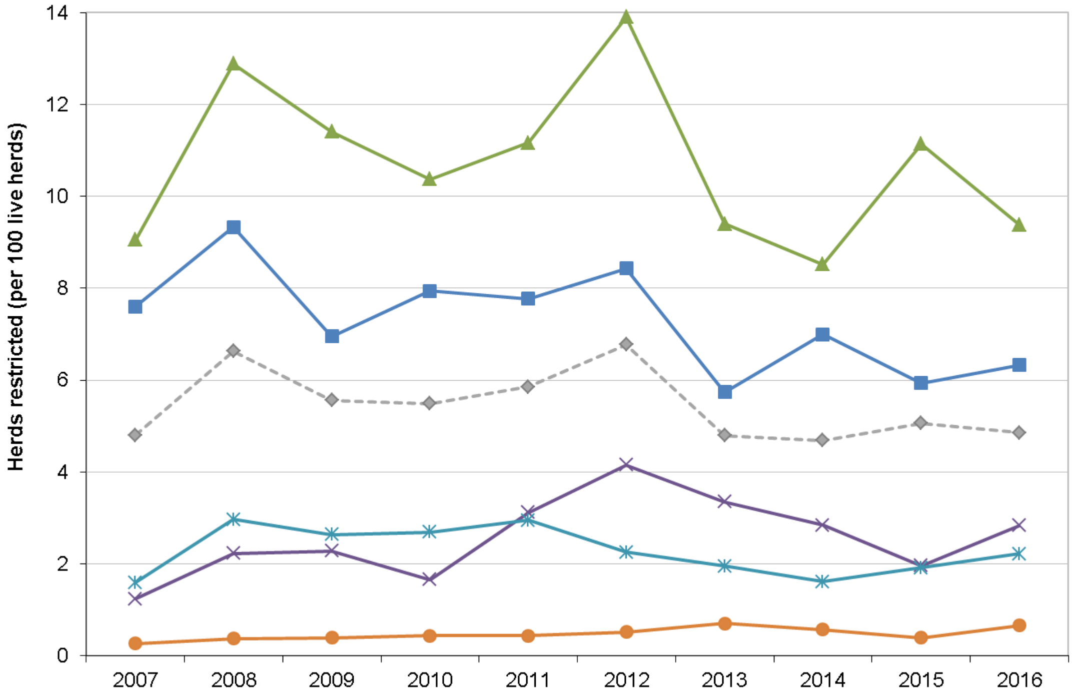


Figure 2.3 a to c: ten year trends by TB area in a) new incidents per 100 herds, b) new incidents per 100 herd years at risk, and c) point prevalence of herds under movement restrictions, December of each year

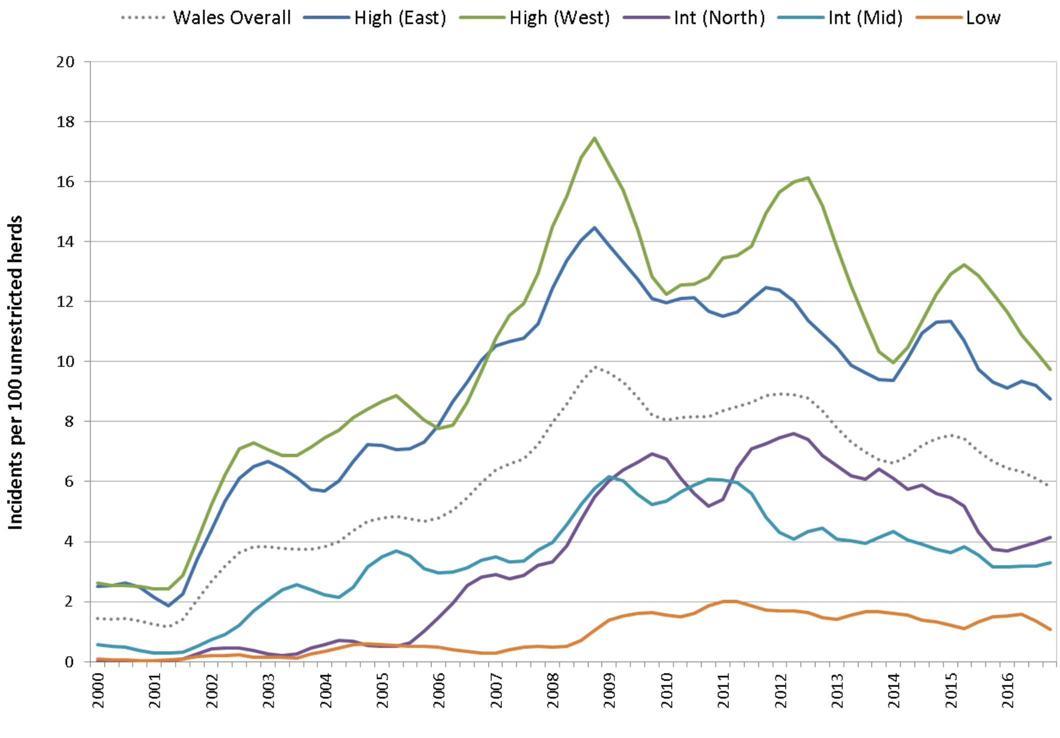


Figure 2.5: Trends in new incidents per 100 unrestricted herds, Jan 2000 – Dec 2016, by TB area

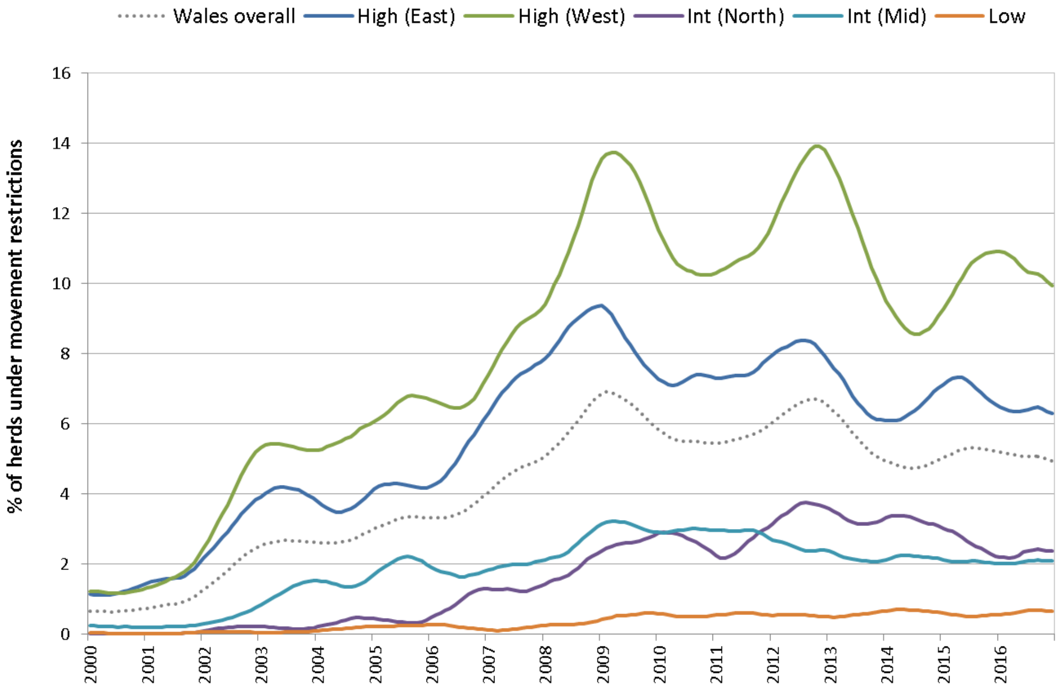


Figure 2.7: Trends in herds under movement restrictions, Jan 1990 – Dec 2016, by TB area

Table 2.3: Animal level frequency of reactors and inconclusive reactors by TB area, 2016

	Animals tested	Skin Tests performed on animals	Animals slaughtered as reactors	Reactor frequency %	Animals slaughtered as IRs	IR frequency %
TB area:						
High (East)	253,400	413,759	1,237	0.49	109	0.04
High (West)	461,108	915,046	3,791	0.82	480	0.10
Intermediate North	131,317	175,661	149	0.11	11	0.01
Intermediate Mid	160,962	217,692	304	0.19	16	0.01
Low TB area	224,964	286,975	71	0.03	10	<0.00

Table 5.1: Restriction durations of incidents closed in 2016

TB Area			**Total (% of total)**	**OTF-W (% of total)**	**OTF-S (% of total)**
IAA	Number incidents closed in 2016		37	36	1
	Incident duration (days):	Up to 100	0	0	0
		101 - 150	2 (5.4)	2 (5.6)	0
		151 - 240	11 (29.7)	11 (30.6)	0
		241 - 550	17 (45.9)	16 (44.4)	1 (100.0)
		551 plus	7 (18.9)	7 (19.4)	0
	Mean incident duration (days)		435.2	440.0	263.0
	Median incident duration (days)		328	329	263
	Duration range (days)		133 - 2723	133 - 2723	263 - 263

High (East)	Number incidents closed in 2016		238	207	31
	Incident duration (days):	Up to 100	22 (9.2)	3 (1.4)	19 (61.3)
		101 - 150	26 (10.9)	20 (9.7)	6 (19.4)
		151 - 240	106 (44.5)	103 (49.8)	3 (9.7)
		241 - 550	70 (29.4)	67 (32.4)	3 (9.7)
		551 plus	14 (5.9)	14 (6.8)	0
	Mean incident duration (days)		256.0	273.9	136.5
	Median incident duration (days)		186	195	95
	Duration range (days)		21 - 2248	21 - 2248	78 - 543
High (West)	Number incidents closed in 2016		320	292	28
	Incident duration (days):	Up to 100	3 (0.9)	0	3 (10.7)
		101 - 150	30 (9.4)	21 (7.2)	9 (32.1)
		151 - 240	113 (35.3)	103 (35.3)	10 (35.7)
		241 - 550	140 (43.8)	134 (45.9)	6 (21.4)
		551 plus	34 (10.6)	34 (11.6)	0
	Mean incident duration (days)		327.4	340.5	190.2
	Median incident duration (days)		254.5	262	156.5
	Duration range (days)		96 - 5123	110 - 5123	96 - 453
Intermediate (North)	Number incidents closed in 2016		34	25	9
	Incident duration (days):	Up to 100	7 (20.6)	0	7 (77.8)
		101 - 150	3 (8.8)	3 (12.0)	0
		151 - 240	15 (44.1)	13 (52.0)	2 (22.2)
		241 - 550	8 (23.5)	8 (32.0)	0
		551 plus	1 (2.9)	1 (4.0)	0
	Mean incident duration (days)		201.9	236.5	105.6
	Median incident duration (days)		180.5	197	95
	Duration range (days)		74 - 762	144 - 762	74 - 181
Intermediate (Mid)	Number incidents closed in 2016		58	50	8
	Incident duration (days):	Up to 100	4 (6.9)	0	4 (50.0)
		101 - 150	8 (13.8)	5 (10.0)	3 (37.5)
		151 - 240	28 (48.3)	27 (54.0)	1 (12.5)
		241 - 550	16 (27.6)	16 (32.0)	0
		551 plus	2 (3.4)	2 (4.0)	0
	Mean incident duration (days)		232.2	251.3	112.9
	Median incident duration (days)		179.5	195	103.5
	Duration range (days)		89 - 1057	146 - 1057	89 - 185
Low	Number incidents closed in 2016		34	13	21
	Incident duration (days):	Up to 100	14 (41.2)	0	14 (66.7)
		101 - 150	7 (20.6)	3 (23.1)	4 (19.0)
		151 - 240	10 (29.4)	7 (53.8)	3 (14.3)
		241 - 550	3 (8.8)	3 (23.1)	0
		551 plus	0	0	0
	Mean incident duration (days)		142.9	211.0	100.7
	Median incident duration (days)		113	192	94
	Duration range (days)		63 - 341	104 - 341	63 - 189

Table 6.1: Incident and non-incident herds by TB history and TB area, 2016

IAA		TB incidents in the history period (36 months)					
		Any incident		≥ 1 OTFW incidents		OTFS incidents only	
	No previous incidents (a)	Number (b)	% (b/(a+b))	Number (c)	% (c/(a+b))	Number (d)	% (d/(a+b))
TB status in current period							
OTF herds[1]	126	67	35	65	34	2	1
Any new bTB incident	11	34	76	33	73	1	2
OTFW herds	11	34	76	33	73	1	2
OTFS herds	0	0	0	0	0	0	0
Total herds	137	101	42	98	41	3	1

High (East)		TB incidents in the history period (36 months)					
		Any incident		≥ 1 OTFW incidents		OTFS incidents only	
	No previous incidents (a)	Number (b)	% (b/(a+b))	Number (c)	% (c/(a+b))	Number (d)	% (d/(a+b))
TB status in current period							
OTF herds[1]	1,827	527	22	448	19	79	3
Any new bTB incident	127	117	48	106	43	11	5
OTFW herds	102	115	53	106	49	9	4
OTFS herds	25	2	7	0	0	2	7
Total herds	1,954	644	25	554	21	90	3

High (West)		TB incidents in the history period (36 months)					
		Any incident		≥ 1 OTFW incidents		OTFS incidents only	
	No previous incidents (a)	Number (b)	% (b/(a+b))	Number (c)	% (c/(a+b))	Number (d)	% (d/(a+b))
TB status in current period							
OTF herds[1]	1,953	543	22	479	19	64	3
Any new bTB incident	118	138	54	129	50	9	4
OTFW herds	105	135	56	126	53	9	4
OTFS herds	13	3	19	3	19	0	0
Total herds	2,071	681	25	608	22	73	3

Intermediate (North)		TB incidents in the history period (36 months)					
		Any incident		≥ 1 OTFW incidents		OTFS incidents only	
	No previous incidents (a)	Number (b)	% (b/(a+b))	Number (c)	% (c/(a+b))	Number (d)	% (d/(a+b))
TB status in current period							
OTF herds[1]	940	134	12	74	7	60	6
Any new bTB incident	29	13	31	12	29	1	2
OTFW herds	23	12	34	11	31	1	3
OTFS herds	6	1	14	1	14	0	0
Total herds	969	147	13	86	8	61	5

Intermediate (Mid)	TB incidents in the history period (36 months)						
		Any incident		≥ 1 OTFW incidents		OTFS incidents only	
	No previous incidents (a)	Number (b)	% (b/(a+b))	Number (c)	% (c/(a+b))	Number (d)	% (d/(a+b))
TB status in current period							
OTF herds[1]	1,764	176	9	116	6	60	3
Any new bTB incident	47	15	24	12	19	3	5
OTFW herds	39	15	28	12	22	3	6
OTFS herds	8	0	0	0	0	0	0
Total herds	1,811	191	10	128	6	63	3

Low	TB incidents in the history period (36 months)						
		Any incident		≥ 1 OTFW incidents		OTFS incidents only	
	No previous incidents (a)	Number (b)	% (b/(a+b))	Number (c)	% (c/(a+b))	Number (d)	% (d/(a+b))
TB status in current period							
OTF herds[1]	2,461	93	4	33	1	60	2
Any new bTB incident	38	2	5	0	0	2	5
OTFW herds	17	1	6	0	0	1	6
OTFS herds	21	1	5	0	0	1	5
Total herds	2,499	95	4	33	1	62	2

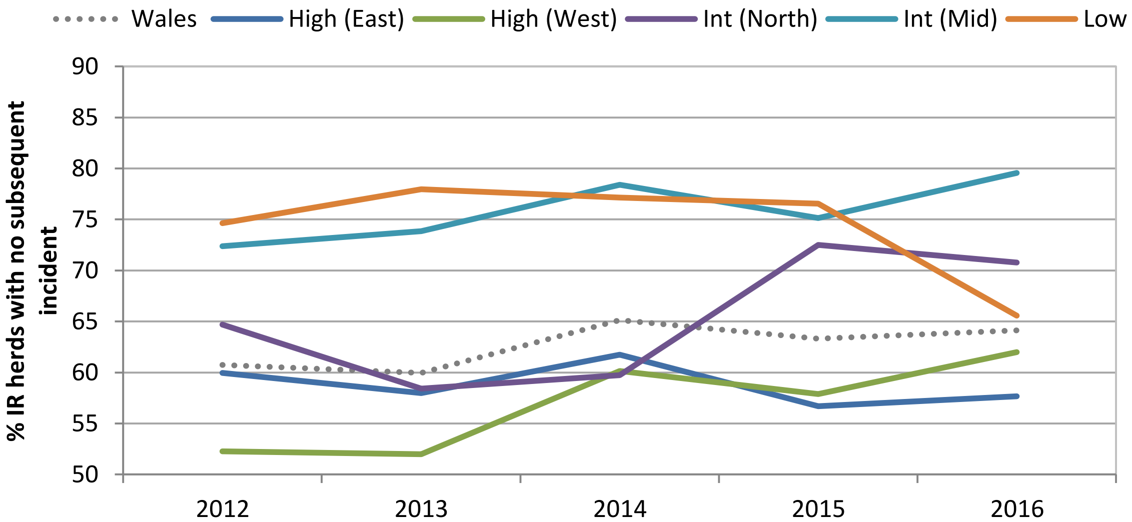


Figure 7.3a: IR herds with no subsequent TB incident within 15 months, by TB area

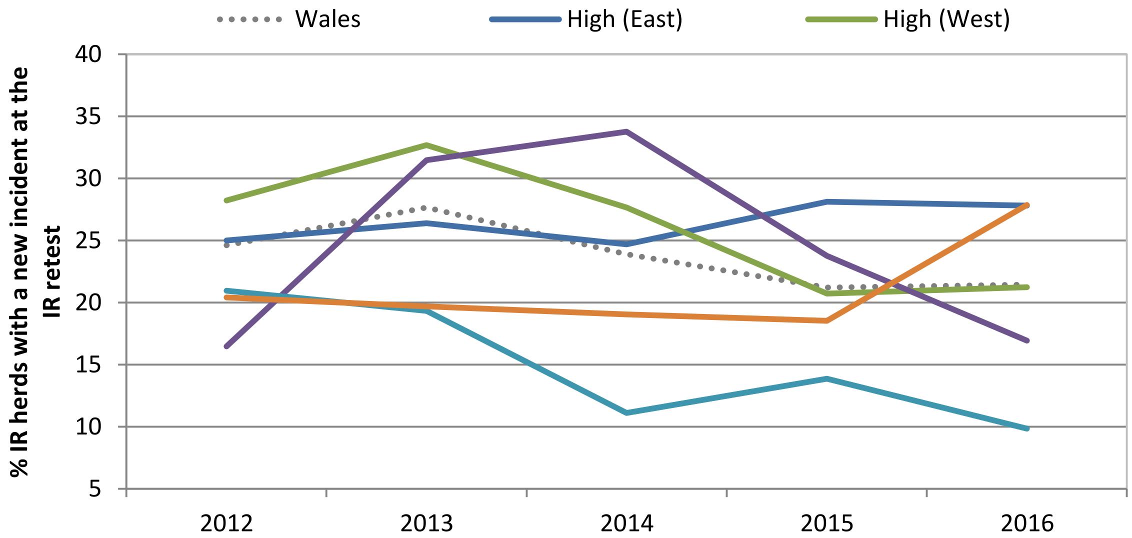


Figure 7.3b: IR herds with a new TB incident at the IR retest, by TB area

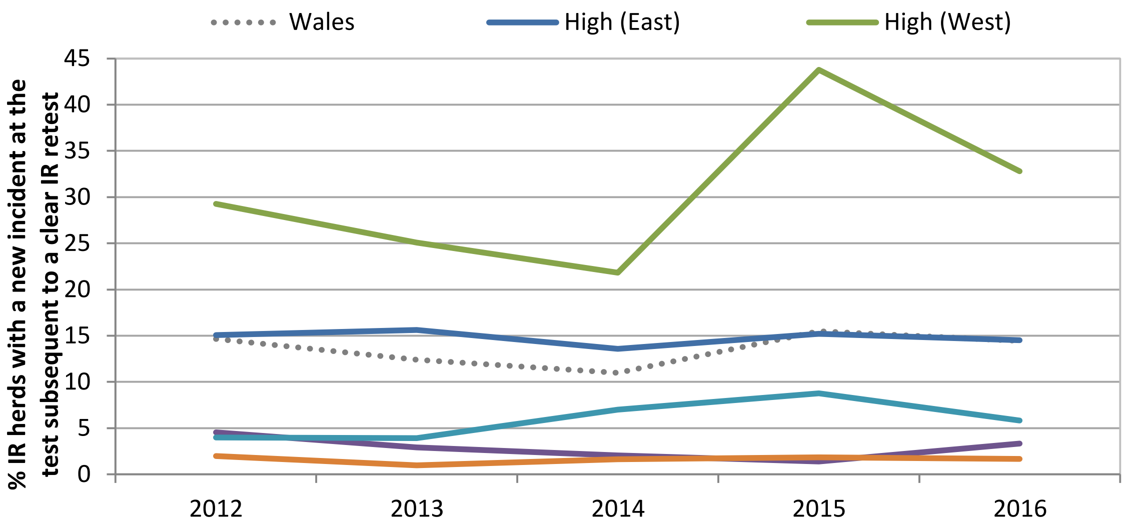


Figure 7.3c: IR herds with a new TB incident at the test subsequent to a clear IR retest within fifteen months

Appendix 1 - Materials and Methods

Data extraction and manipulation

The data on herds, animals, bovine tuberculosis (TB) incidents and tests applied to the British cattle population were downloaded from the Animal and Plant Health Agency's (APHA) SAM RADAR TB reception database on 13th April 2017, and includes skin tests entered on to SAM and completed on or before 8th April 2017. Data prior to late September 2011 derives from the APHA VetNet system, which was migrated into SAM when that system went live at the end of September 2011. Information relating to culture results of all TB suspect samples exists on SAM but is derived from the APHA's LIMS system and prior to that from the APHA TB Culture System (TBCS), plus a short cross-over period when both were in use. Apparent missing results data on SAM have been retrieved directly from LIMS where possible, in particular for samples from around the time of SAM TB going live.

Data is downloaded three months after the reporting year in order to capture confirmation by culture of incidents commencing in the reporting year. This date is, however, too early to capture all events during most of these incidents, for example the dates of removal of movement restrictions, from which the duration of incidents is calculated. Therefore, incidents that *ended* during the reporting year are used to calculate the duration of incidents and the total number of reactors in an incident.

The geographical areas used in this report are based on the old Welsh county structure recognised by SAM, with certain modifications. Gwynedd is divided into Anglesey and mainland Gwynedd; Powys is divided into North, Mid and South Powys; Dyfed is divided into Ceredigion, Pembrokeshire and Carmarthenshire. As the Glamorgans (West, Mid and South Glamorgan) have relatively few cattle, they are treated as a single entity. See Appendix 5 for more information about the geographical areas used in this report.

Unlike in England, where testing intervals may be one or four years, all herds in Wales are subject to an annual testing regimen. Consequently, the effect of testing interval is not reported here.

Since 2012 denominator herd numbers have been those active at the end of the reporting period rather than those in existence for 6 months of it, to match methodologies of the National Statistics which may account for minor differences observed with reports prior to 2012.

Data Issues

Incidents have been screened at Weybridge to determine duplicate, concurrent, and missing incidents in order to include all herd incidents and only one at any one time for each herd. Greater than one incident on the same CPHH at the same time does exist in SAM, which we have attempted to eliminate. Incidents clearly missing from SAM, with reactors or lesions at tests but no incident apparently in existence on SAM, have been included, although these are now very few. The status of incidents will also have been upgraded if post mortem results exist on LIMS or the TBCS that have not been put onto SAM although this is now much less common than at the outset of SAM.

Inaccurate or missing TB10 information, which mark the end of restrictions, has also been a serious issue within SAM and one addressed since the 2012 report. Revisions in SAM, policy changes and user training have reduced many errors in this respect and the situation is now greatly improved, although there are still a small number of incidents with obviously incorrect or missing TB10 dates which have been corrected. It should be noted that management of the closure of incidents involves the receipt of a BT5 form which provides evidence of cleansing and disinfection on the incident premises. This is required before a TB10 can be issued to formally close the incident. Delays to the BT5 receipt, or non-receipt at all will artificially prolong the duration of incidents, which in effect should last until the final clearing skin test. Policy introduced late in 2015 has attempted to penalise non-returners of the BT5 and the situation appears to be much improved, although slow returns will artificially lengthen the incident duration

Considerable effort has been made to correct as much of the data inconsistencies as possible, and we are fairly confident we have used a dataset that is broadly correct. It is possible that on-going scrutiny of the data may uncover further necessary corrections that could affect trend lines in future reports, but it is not envisaged that trends observed within this report will be significantly affected.

Officially TB-free status terminology

A full glossary of terms and abbreviations used in this report is given in Appendix 2. However, terms relating to the officially TB-free status of herds are frequently used throughout most sections of this report and therefore a clear understanding of their definitions is necessary.

Bovine TB incidents with evidence of *Mycobacterium bovis* infection detected in at least one animal from the herd at post mortem examination (PME) or sample culture (including those triggered by slaughterhouse surveillance), as well as incidents where there is no evidence of infection at PME but there is epidemiological evidence that the herd is at high risk of being infected, are in this report referred to as ‘officially TB free status withdrawn (OTF-W)’. New TB incidents with no evidence of *M. bovis* infection detected at PME or in sample culture, and with no epidemiological risk of infection, are referred to as ‘officially TB free status suspended (OTF-S)’. Animals that are slaughterhouse cases must always have provided samples from which *M. bovis* is recovered.

The number of OTF-W and OTF-S TB incidents in this report may differ from other official TB statistics due to slight differences in data interpretation and the aforementioned data cleansing. Bovine TB incidents commence when one or more animal has skin test or interferon-gamma results indicative of TB (a "reactor") or when any infected animal is detected at slaughter. This report treats any slaughterhouse case first detected by lesion(s) disclosed at slaughterhouse surveillance from which *M. bovis* is isolated by culture as being able to trigger an OTF-W incident if the herd of origin is not under restriction at the time the lesions were found, whether or not there are reactors found subsequently in the herd. The report uses cleaned incident data to ensure all genuine incidents are included and concurrent incidents are counted only once; and ignores herds placed under restriction because their test is overdue.

Unclassified incidents are those without results to determine the status of the incident. Some tables within the report reject these incidents; others combine them with the OTF-S incidents. These may be genuine incidents that are missing results, or begun as a result of tracing or connection with another incident herd and not a normal incident. Attempts have been made to exclude those that do not appear to be genuine incidents.

Calculations of incidence and prevalence

Several methods are used in this report to describe the level of TB in Wales. The first is the number of new incidents that started in a given year divided by the number of herds in Wales that were 'live' in that year (see Appendix 2 for definition of 'live herds'). This is reported as the number of new incidents per 100 live herds and is thus a measure of the proportion of Welsh herds that sustained a new incident. This is the standard method of reporting TB incidence in GB. However, this method does not take into account the dates on which tests occur and can cause difficulties when making comparisons of incidence rates between populations having differing testing intervals in the immediate past.

Consequently, the second method used to estimate the incidence of TB in Wales in this report calculates the number of new incidents relative to the 'herd time spent at risk'. The time at risk is calculated for each herd at each test or incident as the time spent not under restriction since the previous herd-level test. As all herds are tested annually In Wales, the maximum time at risk expected would be around 12 months. If this time exceeds 18 months due to previous herd inactivity, then the time at risk for that herd is capped at 18 months. If a herd is not tested in a given year, it does not contribute towards the incidence rate calculations for that year because detection of TB in the majority of animals in the herd was not possible aside from slaughterhouse surveillance. But if a herd has more than one test and/or incident in a year the respective times at risk are added together. It should be noted that all information regarding time at risk is based only on herd-level tests because the sensitivity of individual animal-level tests for determining the TB status of the herd is low. Thus when a new incident is disclosed following an animal-level test, the accumulated time at risk is attributed to the incident, rather than being deferred until the planned but forestalled herd level test.

The third method used to estimate the level of TB infection in cattle herds in Wales is concerned with the effect of the disease on the management of the herd at a single point in time, regardless of when infection entered the herd. That is, the total number of herds that are under movement restrictions due to a TB incident on a given date divided by the total number of active herds at that point in time. This is termed the *prevalence* of TB. As stated above, herds restricted due to an overdue test rather than a TB incident are not classified as 'restricted' in this report and therefore estimates of the proportion of herds under restriction will be lower in this report than in some of the official TB statistics.

Method for classification of recurrent-incident herds

Recurrent TB is defined as a TB incident disclosed during the *Current Period* occurring in a herd that was under restriction for TB at any time during the *History Period*. A key date or *Reference Date* is first calculated for each herd. It falls as near as possible to the *middle Date* in the Current Period (2nd July 2016[1]), unless a TB incident starts in the Current Period.

- If there is one or more OTF-W in the Current Period, the Reference Date is day 1 of the disclosing test of the OTF-W nearest to the Middle Date of the Current Period;
- If there are no OTF-W incidents but one or more OTF-S in the Current Period, the Reference Date is day 1 of the disclosing test nearest to the Middle Date;
- If no TB incident is disclosed in the Current Period, the Reference Date is the Middle Date of the Current Period (2nd July).

[1] 2nd July is actually day 183 of a 365-day year or day 184 of a 366-day year.

Where the herd is under movement restriction for four or more months at the start of the Current Period, recurrence cannot be defined and the herd is excluded from the analyses.

The *History Period* is the 36 months ending on the day before the Reference Date. In this report, restrictions in the History Period end on the day of issue of a TB10 form. The three types of History Period are:

- (A), if the herd is under restriction on one or more days in the History Period for an OTF-W incident;
- (B), if at any time during the History Period, the herd is not under restriction for an OTF-W incident but *is* under restriction for an OTF-S incident;
- (C), if the herd is not under restriction for TB at any time during the History Period.

There are also three types of *Current Period*: (1) if any OTFW incidents start in the period; (2) if no OTFW incidents start, but one or more OTF-S incident starts, and (2) if the herd remains OTF through the entire Current Period.

Statistical analysis

Statistical tests were performed where appropriate. For data in 2 x 2 tables, Fisher's Exact test was used. Comparisons between the means of continuous variables where the variable was not normally distributed were performed using the Wilcoxon Rank Sum test. The Z-test was used to compare differences in proportions.

Univariate Linear (continuous outcomes), Logistic (binary outcomes) and Poisson (count data) regressions were used to assess the associations between predictor variables such as herd size, herd type and geographical area and outcomes such as incidence and recurrence rates. The confounding effects of these predictor variables upon one another were adjusted by including all predictors in a multivariable model. However, the number of factors available for use in multivariable analysis was limited by the source data.

Predictor variables were generally categorical; continuous variables were categorised. Categories were chosen based either on quantiles of the distribution of the population or (more often) biologically relevant categories. For example, for the predictor ‘herd size’, categories could ideally be based on either equal numbers of herds or equal numbers of animals; as a result, the numbers of herds in the categories for large herd sizes tended to be smaller than for smaller herd sizes.

The reference category chosen for categorical predictors in regression analyses varied. Ideally the reference category was both biologically relevant and had a sufficient number of observations or cases to be statistically sound. However, if the most biologically relevant category had insufficient observations/cases or there was no clear biological advantage in selecting a reference category, then the category with the most observations/cases was chosen.

All data analyses were performed using Stata v12.0.

OTF-W-2 herds

The term officially tuberculosis free status withdrawn (OTF-W) is applied to a herd with a TB incident in which additional evidence of *Mycobacterium bovis* infection has been identified in at least one slaughtered animal (see Appendix 2 for more detail). This case definition has been used in previous iterations of the report and in the related reports for England and Great Britain.

In January 2011 changes were implemented in Wales that were designed to ensure that the officially tuberculosis free (OTF) status of cattle herds was withdrawn rather than merely suspended in cases of incidents that met defined epidemiological criteria. These criteria included herds with a pre-existing history of infection with bovine tuberculosis (TB), consideration of the local disease situation and where an additional epidemiological risk is identified by the Animal and Plant Health Agency. This cohort has become known as OTF-W-2 herds. In common with other herds where OTF status is withdrawn (OTF-W), two consecutive clear herd tests are required to restore their OTF status rather than the single clear test required by herds with only a suspended OTF status (OTF-S).

In reports prior to 2014, OTF-W-2 herds were difficult to identify within the data available for analysis, and so were included in the OTF-S cohort. These difficulties with the data have now been resolved and, as such, OTF-W-2 herds are now identified and included in the OTF-W cohort. This change has been applied retrospectively to the data for all incidents since the policy was introduced in 2011, so there will be some differences in the data presented in this report compared to the reports for 2011, 2012 and 2013.

Appendix 2 – Definitions and abbreviations

Appendix table 1: Definitions of terms used throughout the report

Abbreviation	Detail	Definition or description
APHA	Animal and Plant Health Agency	The Animal and Plant Health Agency (APHA) was launched on the 1st October 2014. It merged the former Animal Health and Veterinary Laboratories Agency with the Plant and Bee Health and GM Inspectorates and the Plant Varieties and Seeds Office (previously based in Fera), creating a single agency responsible for animal, plant and bee health.
	Annualised	Conversion of a variable into a yearly sum (e.g. by multiplying a quarterly incidence by 4).
TB	Bovine tuberculosis	Disease of cattle and other mammals caused by infection with Mycobacterium bovis
	Contiguous herd	Strictly speaking, a herd that has a common boundary with the herd of interest, but includes herds separated only by a short distance e.g. across a road or river, or where an epidemiological assessment indicates they are likely to be at risk of exposure to infection.
DC	Direct contact	Animals in an OTF-W herd whilst not reactors are considered to be at such high risk of being infected that slaughter is justified, usually for the reason of contact with infected cattle.
DL	Detected lesions	Lesions typical of bovine TB detected in the carcass of a SICCT or IFN-γ test reactor at *post mortem* examination or during routine slaughterhouse inspection of cattle.
	Disclosing test	The test that triggers the start of a new TB incident (OTF-S or OTF-W) which in turn marks the start of movement restrictions. For the purposes of analysis it includes the detection of a slaughterhouse case.
	Eradication programme[1]	Programme to result in biological extinction of an animal disease or zoonosis and-or to obtain the free or officially free-status of the territory according to EU legislation, where such possibility exists.
	Genotype	The genotype currently used for the molecular epidemiology of TB in GB (and therefore Wales) is a combination of Spoligotype and VNTR type.
HCW	Health Check Wales	A surveillance initiative operating between 1st October 2008 and 31st December 2009 during which all herds in Wales were tested. Annual testing of herds has continued thereafter.
	Herd	A bovine herd defined in the County/Parish/Holding/Herd notation. A Live herd is one flagged active on SAM (formerly VetNet) at the end of the study year. Unless stated, all such herds are included in the denominator for the analysis of incidence, whether or not they had been tuberculin tested or under restriction in the year. It is acknowledged that this definition of a herd does not give the same values as the Agricultural Census or the Cattle Tracing System (CTS). On the other hand, unlike census or CTS data, SAM gives separate data for each herd within a holding, is maintained continuously for all herds (not just by sample surveys), and represents all herds no matter how small. Delays in reflecting the true activity periods of herds in SAM, and changes in herd sizes since it was recorded on Sam at the previous TB test, can affect the accuracy of SAM-derived estimates of numbers of herds or of cattle.

Abbreviation	Detail	Definition or description
	Herd size	For a TB incident, herd size is the largest number entered in SAM at any time during the incident. For officially TB free herds, herd size is generally that recorded at the most recent whole herd test. However, veterinarians performing tests do not always record numbers of animals not tested (e.g. in herds where only breeding bulls, cows that had calved and animals purchased since the previous test were tested) and therefore herd size may be underestimated in some lower-risk herds and areas. Where no size is retrievable from a testing history, the typical number of animals indicated on SAM has been used.
	Herd test	A surveillance or control test triggered by a herd level event, rather than a test triggered for an individual animal. For example, a routine herd test is a herd test applied because a regular surveillance test is due, whereas a pre-movement test is not a herd test.
	Herd years at risk	The sum of the time (days, months or years) herds in the population are unrestricted and are therefore at risk of a new incident. The time at risk is calculated for each herd at each SICCT test or start of a TB incident as the total time the herd was not under restriction since the last test before or at the beginning of the time period for which the rate is being calculated and then summed across all herds.
	Herd types	*'Beef' includes* Beef, Finishing, Suckler, Beef Heifer Rearer, Beef Bull Hirer and Stores herds *'Dairy*' includes Dairy, Dairy Dealer, Dairy Bull Hirer, Dairy Producer, Dairy Heifer Rearer and Domestic herds; *'Other'* includes Calf Rearers, unspecified Dealer Herds, AI, and herds described on SAM as 'Other herds'.
	Homerange	The geographical area in which a genotype is most frequently recovered. A simple algorithm to define homerange area for the common genotypes of M. bovis was developed as part of Defra Project SE3257. A 5 km square is considered as part of the homerange if there have been three different incidents of that genotype, on at least 2 holdings, within a 5 year window. A 10km buffer is then applied in order to create coherent homerange area for each genotype.
	Incidence	For the purposes of this report, incidence is the ratio between the number of a TB incidents detected ("disclosed") and a denominator for the population, which is either (a) the number of "live or active" herds regardless of whether they have been tuberculin tested, or (b) the total time that herds have been at risk of being detected with TB (i.e. accounts for testing history).
IR	Inconclusive reactor	An animal showing a particular pattern of reactions to a comparative intradermal tuberculin test that uses bovine and avian reagents, where the difference in size of reactions to bovine and avian tuberculin is not large enough to cause it to be described as a reactor. In Wales, both standard and severe interpretation inconclusive reactors are recognised. Animals having two successive tests giving Inconclusive reactor measurements are generally considered to be skin test reactors, but may be described as "IRs After 2 [or more] tests as IR" to distinguish them from other reactors in some parts of this report. IRs may be re-classified as reactors when interpreted severely.
IAA	Intensive Action Area	An area with high TB prevalence in North Pembrokeshire, adjacent to Ceredigion, in which additional cattle control measures (including twice-yearly routine testing and enhanced testing for OTF-S incidents) have been applied since May 2010.

Abbreviation	Detail	Definition or description
IFN-γ or gIFN	Interferon-gamma test	Laboratory-based blood test used in parallel with the tuberculin skin test to improve the sensitivity of the testing regimen. The in vitro gamma-interferon (IFN-γ) assay is only approved as an **ancillary** diagnostic tool and measures the release of IFN-γ in whole blood cultures stimulated with tuberculin. Most frequently used to enhance the sensitivity of testing in OTF-withdrawn herds. http://intranet/v1p3r/workareas/Tuberculosis/Bovines/Gamma_Test/Eligibility_in_Wales.html
IQR	Inter-quartile range	A measure of statistical dispersion (equal to the difference between the upper and lower quartiles): referring to the 25th and 75th percentile of the median value described.
	Linear regression	A statistical approach for modelling the relationship between a continuous outcome variable (e.g. restriction duration, which can take any value) and one or more 'predictor' variables (e.g. herd size, herd type or county).
CPHH	Live herd or Active herd	Bovine herd defined in the County/Parish/Holding/Herd notation which was flagged as active on SAM on 31st December, 2016. This does rely on a degree of accuracy of the activity dates given on SAM for herds. This gives different values from the Agricultural Census, as SAM gives separate data for each herd within a holding, is maintained continuously for all herds (not just by sample surveys), and represents all herds no matter how small.
	Logistic regression	A statistical approach for modelling the relationship between a binary outcome variable (e.g. positive or negative result) and one or more 'predictor' variables (e.g. herd size, herd type or county).
M. avium	*Mycobacterium avium*	The causative organism of avian tuberculosis, which occasionally infects cattle
M. bovis	*Mycobacterium bovis*	The causative organism of bovine tuberculosis
	Monitoring (programme)[1]	Programme to investigate an animal population or subpopulation, and/or its environment (including wild reservoir and vectors), to detect changes in the occurrence and infection patterns of an animal disease or zoonosis.
	Movement restrictions / restrictions	Prohibitions on the free movement of animals into and out of a herd. Movement restrictions may be imposed on a herd because of the presence, or the suspicion of the presence, of *M. bovis* infection or because statutory tests are overdue. Herd restrictions due to overdue tests are excluded from analyses in this report to avoid overestimates of disease.
	New TB incident	A herd previously OTF in which at least one test reactor, IR taken as a reactor, or a culture-positive slaughterhouse case has been found. The *restriction*, and thus the incident, begins on the disclosing test date and ends on the date that *Form TB10* is issued. To qualify as being "new", the incident must have been *disclosed* in the period specified. Note, this report uses the TT1 date as the incident commencement date, originally to be consistent with VetNet.
NDL	No detected lesions	No lesions typical of bovine TB detected in the carcass of a SICCT or IFN-γ test reactor at *post mortem* examination or during routine slaughterhouse inspection of cattle.
OTF	Officially bovine tuberculosis free	See Appendix 3 for Extract from European Union (1998), Council Directive 98/46/EC for full definition of the officially TB free status
OTF-W	Officially bovine tuberculosis free status withdrawn	This term refers to a herd with a TB incident in which additional evidence of *M. bovis* infection has been identified in at least one slaughtered bovine animal, i.e. *M. bovis identified* in a cultured tissue sample and/or lesions detected in the carcass of a SICCT or IFN-γ test reactor. It also includes other incidents upgraded to OTF-W for epidemiological reasons.
OTF-S	Officially bovine tuberculosis free status suspended	This is the status of a herd with a TB incident where there is a suspicion of infection being present.

Abbreviation	Detail	Definition or description
	Poisson regression	A type of statistical modelling based on a particular type of numerical distribution that is used to compare rates of rare occurrences between different population groups, different areas, or different times.
PME	*Post mortem* examination	Examination (to various extents) of the carcass and organs of slaughtered cattle for suspected lesions of bovine TB. Such post mortem examinations included those undertaken at an APHA Regional Laboratory, those undertaken at the slaughterhouse following *in vivo* suspicion of infection (e.g. reactors, IRs and DCs), and those undertaken as part of routine meat inspection.
	Prevalence	For the purposes of this report, prevalence is the proportion of active herds under movement restrictions on a given date due to a TB incident, and excludes herds restricted due to an overdue test.
R	Reactor	An animal showing a particular pattern of reactions to a single intradermal tuberculin comparative test (SICCT test) or to a gamma interferon (IFN-γ) assay that uses bovine and avian reagents, and not including an animal first suspected to have TB at the slaughterhouse. An inconclusive reactor (IR) will be treated as a reactor if a retest yields a second inconclusive result, but will not count towards statistics for reactors throughout this report.
	Recurrent herd	A herd that had a TB incident disclosed in the reporting year (i.e. 2014) that had also been under movement restrictions for a different TB incident in the previous 36 months.
Ref	Reference category	In regression analyses the reference group acts as a baseline against which we compare other groups of interest.
	Risk Area	On 1 January 2013, a new TB surveillance testing regime was introduced for bovine herds in England. TB testing intervals for bovines are now either on an annual or four yearly basis at county rather than parish level. In the England surveillance report, data is presented by risk area: high risk (HRA – annual testing), edge area (annual testing) and low risk area (LRA – 4-yearly testing)
SAM	SAM database	APHA's TB control and surveillance system, which records details of herds, TB tests, TB incidents and the details of any slaughtered (reactors, slaughterhouse cases and direct contacts) and inconclusive reactor cattle
Se	Sensitivity (of a test)	The proportion of truly infected individuals in the screened population who are identified as infected by the test
	Severe interpretation	Using this interpretation of the comparative intradermal tuberculin test, animals showing either i) a positive bovine reaction and negative avian reaction or ii) a positive bovine reaction more than 2mm greater than a positive avian reaction are deemed reactors
SICCT, tuberculin skin test, skin test	Single Intradermal Comparative Cervical Test	Also commonly referred to as the 'skin test' or 'tuberculin skin test'. The testing procedure involves the simultaneous injection of a small amount of *M. bovis* and *M. avium* tuberculins (purified protein derivative (PPD); a crude extract of bacterial cell wall antigens), into two sites of the skin of the animal's neck, followed by a comparative measurement of any swelling (delayed-type hypersensitivity reaction) which develops at the two injection sites after 72 hours.
SLH	Slaughter-house case	This refers to an incident (rather than an animal) that is triggered by the disclosure of an animal from an OTF herd that had lesions consistent with TB during routine post-mortem meat inspection. In order that the case becomes an OTF-W incident, *M. bovis* must be isolated on culture from samples of the lesions. Until *M. bovis* is isolated at culture, a slaughterhouse case remains suspect and does not contribute to incident figures within this report, unless any subsequent skin check test performed in the herd of origin identifies reactors.

Abbreviation	Detail	Definition or description
	'Smoothed' and/or '12-month moving average'	A 12-month moving average is the average of the values for the current month and the previous 11 months. Moving averages can be any length. But, in general, shorter lengths will be best at identifying turning points and longer lengths best at identifying trends.
Sp	Specificity (of a test)	The proportion of truly uninfected individuals in the screened population who are identified as uninfected by the test.
	Spoligotype	The result of one form of genomic typing of organisms of the *Mycobacterium tuberculosis* group described as Spacer Oligonucleotide typing.
SD	Standard deviation	The standard deviation measures the spread of the data around the mean value. It is useful in comparing sets of data which may have the same mean but a different range of raw values.
	Standard interpretation	Using this interpretation of the comparative intradermal tuberculin test, animals showing a positive bovine reaction more than 4mm greater than a negative or positive avian reaction are deemed reactors.
	Surveillance	Surveillance refers to activities to collect and record data on specific diseases in defined populations over a period of time, in order to assess the epidemiological evolution of the diseases and the ability to take targeted measures for control and eradication.
	TB10 form	The form issued at the end of a TB incident to lift the restrictions imposed on cattle movements onto and off the holding.
	Testing interval	Testing interval for herds denotes the Area Testing Interval (ATI or Area Monitoring Regime) to which herds have been allocated; the ATI is recorded for the third quarter of the year in question, whether or not the herd was tested in that year. Any shorter interval assigned specifically to an individual herd within a parish has not been used.
	Time at risk	Time spent not under restriction since the most recent herd-level test or end of incident
VetNet	VetNet database	VetNet is the predecessor of SAM, APHA's TB control and surveillance system, which records details of herds, TB tests, TB incidents and the details of any slaughtered (reactors, slaughterhouse cases and direct contacts) and inconclusive reactor cattle. VetNet data was migrated into SAM.
VNTR	VNTR type	The result of a form of genomic typing based on repeated sequences of genomic DNA described as Variable Number Tandem Repeat typing.

[1] EU Commission Staff Working Document technical details on the outcome of the EU co-financed programmes for the eradication, control and monitoring of animal diseases and zoonosis over the period of 2005-2011. Brussels, 5.3.2014. SWD(2014) 55 final.

Appendix table 2: Definitions of surveillance test codes used in Section 2 and Appendix Table 3

Surveillance test type	Definition
VE-IFN_ANOM	Gamma interferon anomalous reactions procedure
VE-IFN_LOW_IN	Gamma interferon testing in an OTFW herd in a low TB incidence area
VE-IFN_PERSI	Gamma interferon testing in an OTFW herd with persistent infection
VE-IFN_SLHERD	Gamma interferon testing in whole or partial slaughter of reactor herds
VE-IFN_2x_IR	Gamma interferon testing of 2x IR cattle
VE-IFN_NSR	IFN Non-Specific Reactor Herd - Investigation and Intervention
VE-IFN_OTH_SP	IFN test performed due to disease in other species
VE-TBU	Test of a herd every 90 days in an Approved Finishing Unit (AFU – a holding that takes cattle from herds under TB restrictions) (this is the former VE-90D)
VE-SI (& VE-IASI)	Whole herd short interval test, used only during TB incidents (& those 2nd SI tests performed on OTFS herds done in the 'intensive action area')
VE-CT	Check test of herd following slaughterhouse cases, clinical cases, evidence of TB in other non-reactors or in deer, or for any other reason at the RVL's discretion
VE-CT(EM)	Check test carried out outside normal testing frequency to determine the herd's disease status when there is a suspicion of infection (e.g. following back-tracing from an infected herd)
VE-CT(I-I)	As for CT(EM) except it will be for the voluntary slaughter of an IR identified in an IR-only herd, identification of a clinical case of TB, disclosure of lesions suggestive of TB at slaughter or post-mortem or for any other reason at the RVL's discretion
VE-CT-HS1, 2	First and second tests of a herd in a recognised hotspot
VE-CT-RTA	Check test following the discovery of an infected road-killed badger
VE-CT-NH1, 2, 3	First, second and third check tests of newly-established herds
VE-CT-RH1, 2, 3	First, second and third check tests of re-formed herds
VE-6M (& VE-IA6)	Test six months after the end of an incident (& those done in the 'intensive action area')
VE-12M (& VE-IA12)	Test twelve months after the six-month (VE-6M) test (& those done in the 'intensive action area')
VE-CON	Test carried out on herds contiguous to OFTW herds outside their regular test frequency (first test)
VE-CON6	Test of a contiguous herd (after 6 months)
VE-CON12	Test of a contiguous herd (12 months after VE-CON, or 12 months after VE-CON6, if done)
VE-RAD 6, 12	Radial herd test. Eligibility will be as for contiguous herd tests. RAD6 and RAD12 conducted at 6 and 12 months post initial radial test.
VE-WHT	Whole herd test in a parish with a testing interval of one year
VE-WHT2	Whole herd test applied to a herd in a parish with a testing interval of 2 years
VE-RHT	Routine herd test (only in parishes tested at intervals of 2 or more years)
VE-CTW1	(Whole herd) Check test for herds previously tested at longer intervals in Health Check Wales
VE-CTW2	Check test for Health Check Wales, done at the scheduled time but upgraded to a whole herd test
VE-IR	Inconclusive reactor re-test
VE-TR	Forward tracing test of bovines moved from OFTW herds prior to service of restrictions
VE-SLH	A pseudo-test code applied to an incident disclosed by confirmed infection in

Surveillance test type	Definition
	a routinely slaughtered animal (*slaughterhouse case*)
VE-QSLH	A pseudo-test code for a potentially disclosing slaughterhouse case suspected to be infected, pending culture results. The code is changed to VE-SLH or removed from VetNet according to the culture result.
VE-EX	Test on cattle to be exported from Great Britain
VE-PII	Post-import test performed on cattle imported from Northern Ireland and the Republic of Ireland
VE-PIO	Post-import test performed on other imported cattle
VE-AI	Test performed on cattle prior to admission to an artificial insemination centre
VE-PRI	Private TB test (a test approved by the AHDO, paid for by the owner and carried out by an official veterinarian)
VE-PRMT	Pre-movement test
VE-POSTMT	Post-movement test to be carried out where cattle have been moved to a holding without a required pre-movement test
VE-PRMTS	Pre-movement test (Scotland)
VE-POSTMTS	Post-movement test (Scotland) at 60-120 days of any animal coming from a 1 or 2-yearly tested parish (and therefore from outside Scotland)
VE-REST	A pseudo-test code to indicate that a herd has been put under restrictions, for example because a scheduled test is overdue. *This code is removed from VetNet when testing is performed.*
VE-ASG	Testing of restricted isolated groups of cattle within an incident or a non-incident herd at the RVL's discretion

Appendix 3 – Test type frequency

Appendix table 3: Number of surveillance tests (herds not under restriction), reactors and resulting incidents and the number of disease control tests taken in herds under restriction

Test type[1]	Surveillance tests[2]			Disease control tests[3]
	No. tests	Reactors	Incidents	No. tests
Routine	**472,077**	**429**	**159**	**76**
VE-CTW1	0	0	0	0
VE-CTW2	0	0	0	0
VE-WHT	446,710	387	145	76
VE-WHT2	81	0	0	0
VE-IA6	16,237	35	10	0
VE-IA12	9,049	7	4	0
Herd Risk	**185,820**	**396**	**134**	**288**
VE-12M	51,213	136	39	288
VE-6M	134,607	260	95	0
Area Risk	**437,604**	**911**	**289**	**1,313**
VE-CON	304,464	649	208	613
VE-CON12	132,587	262	81	700
VE-CON6	553	0	0	0
VE-CT-HS1	0	0	0	0
Movement Risk	**8,554**	**6**	**5**	**211**
VE-TR	7,565	6	5	208
VE-EX	7	0	0	0
VE-AI	67	0	0	0
VE-PII	915	0	0	3
VE-PIO	0	0	0	0
Private, pre and post movement	**186,399**	**110**	**64**	**1,311**
VE-POSTMT	48	0	0	0
VE-PRI	1,402	0	0	45
VE-PRMT	184,949	110	64	1,266
Inconclusive reactors	**1,765**	**1**	**1**	**1,638**
VE-IR	1,765	1	1	122
VE_IFN_2X_IR	0	0	0	1,516
Slaughterhouse	**191,127**[4]	**0**	**40**	**40,439**
VE-SLH	191,127	0	40	40,439
New Herds	**8,292**	**4**	**4**	**0**
VE-CT-NH1	7,335	4	4	0
VE-CT-NH2	957	0	0	0
VE-CT-NH3	0	0	0	0

Test type[1]	Surveillance tests[2]			Disease control tests[3]
	No. tests	Reactors	Incidents	No. tests
Control	**19,410**	**36**	**9**	**710,425**
VE-CT	0	0	0	0
VE-IASI	0	0	0	0
VE-SI	6,163	10	2	619,248
VE-CT(I-I)	8,537	13	5	63,637
VE-CT(EM)	2,879	10	2	624
VE_IFN_ANOM	0	0	0	217
VE-IFN_LOW_IN	30	0	0	11,711
VE-IFN_NSR	0	0	0	99
VE-IFN_OTH_SP	0	0	0	0
VE-IFN_PERSI	0	0	0	11,028
VE-IFN_SLHERD	42	3	0	1,457
VE-TBU	1,729	0	0	2,404
Other	**80**	**0**	**0**	**0**
VE-ASG	80	0	0	0
Not initiated at a specific test	0	0	1	0

[1] Refer to Appendix table 2 for an explanation of these codes
[2] Animal-level tests done in herds not under movement restrictions
[3] Animals-level tests done in herds under movement restrictions
[4] Figure derived from the number of animals slaughtered from herds that were not under restriction.

Appendix 4 - Extract from European Union (1998), Council Directive 98/46/EC

A bovine herd will retain officially tuberculosis-free status if:

- the conditions detailed in 1(a) and (c) [i.e. no clinical cases, no reactors at two tests 6 months apart, some controls on imports] continue to apply;
- – all animals entering the holding come from herds of officially tuberculosis-free status;
- – all animals on the holding, with the exception of calves under six weeks old which were born in the holding, are subjected to routine tuberculin testing in accordance with Annex B at yearly intervals.
- However, the competent authority of a Member State may, for the Member State or part of the Member State where all the bovine herds are subject to an official programme to combat tuberculosis, alter the frequency of the routine tests as follows:
- – if the average – determined at 31 December of each year – of the annual percentages of bovine herds confirmed as infected with tuberculosis is not more than 1 % of all herds within the defined area during the two most recent annual supervisory periods, the interval between routine herd tests may be increased to two years and male animals for fattening within an isolated epidemiological unit may be exempted from tuberculin testing provided that they come from officially tuberculosis-free herds and that the competent authority guarantees that the males for fattening will not be used for breeding and will go direct for slaughter,
- – if the average – determined at 31 December of each year – of the annual percentages of bovine herds confirmed as infected with tuberculosis is not more than 0,2 % of all herds within the defined area during the two most recent biennial supervisory periods, the interval between routine tests may be increased to three years and/or the age at which animals have to undergo these tests may be increased to 24 months,
- – if the average – determined at 31 December of each year – of the annual percentages of bovine herds confirmed as infected with tuberculosis is not more than 0,1 % of all herds within the defined area during the two most recent supervisory triennial periods, the interval between routine tests may be increased to four years, or, providing the following conditions are met, the competent authority may dispense with tuberculin testing of the herds:
    - before the introduction into the herd all the bovine animals are subjected to an intradermal tuberculin test with negative results;
    - all bovine animals slaughtered are examined for lesions of tuberculosis and any such lesions are submitted to a histopathological and bacteriological examination for evidence of tuberculosis.
- The competent authority may also, in respect of the Member State or a part thereof, increase the frequency of tuberculin testing if the level of the disease has increased.

Appendix 5 – The geographical areas used in this report

There is a need to describe the bovine TB epidemic in Wales at some geographical level above that of the ‘parish’ but below that of ‘Wales’. This need is not unique to this report and there is much ongoing discussion about what geographical unit best meets this need.

The reality is that no one option is perfect. Current options such as ‘unitary authority’ or ‘post code’ are subject to continuing change. While no longer subject to change, historical ‘areas’ all had their own problems. For example, in the county structure in place until 1974 Flintshire was divided by Denbighshire. The successive iterations of the county structure in Wales have involved changes of the inter-county boundaries themselves, amalgamations or dissociations of counties and changes in the names of counties, collectively too numerous to catalogue here. None are ideal.

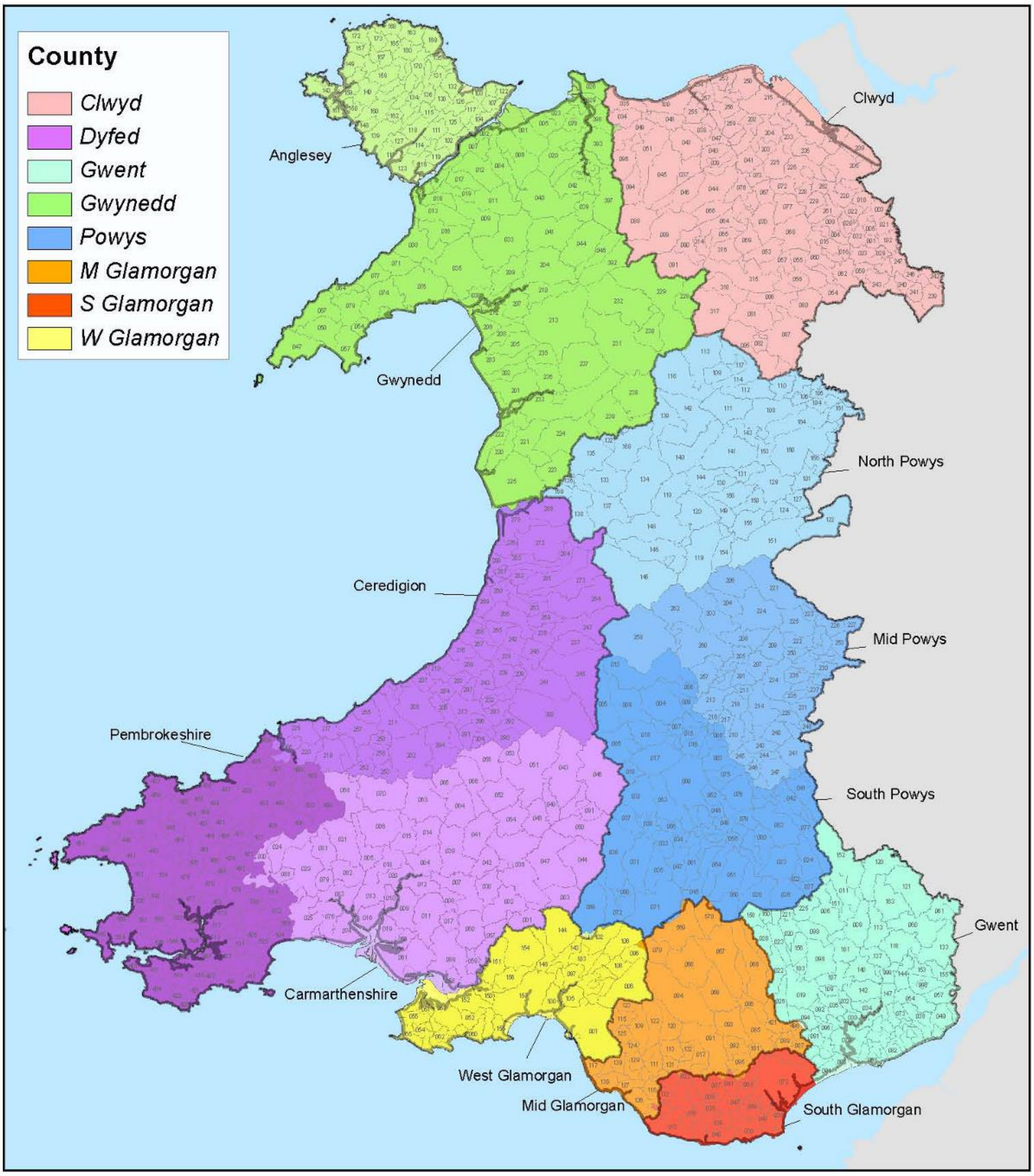
The core ‘identifier’ used for cattle herd data, including data in the APHA VetNet database, is that of the numerical County Parish Holding Herd (CPHH) system. In this context the focus is on the ‘CP’ part of the identifier. The merits of this system are outside the scope of this paper, the key point being that this will remain the case for the foreseeable future. This being the case, it makes sense to work with the system rather than against it.

A study of the data reveals that CP codes in Wales naturally subdivide into the structure shown in Appendix Figure 1. Thus while the county code of ‘55’ (Dyfed) covers all the parishes comprising Pembrokeshire, Carmarthenshire and Ceredigion, the parish element of the code cleanly subdivides the data into the three constituent ‘counties’. Similarly the parish codes provide for Anglesey to be separated from the rest of Gwynedd and Powys to be subdivided into North, Mid and South (analogous to the ‘old counties’ of Montgomeryshire, Brecknockshire and Radnorshire respectively). This structure reflects the way that the CP codings were originally allocated rather than any fundamental biological or epidemiological property. Nevertheless it does represent an innate structure to the data that, in the absence of an over-riding reason to do otherwise, it was decided to follow.

Office of the Chief Veterinary Officer,
Welsh Government,
July 2011

Technical Services Division Geographical Information Unit | Date: 28/09/2009

County Parish Groupings Across Wales



Llywodraeth Cynulliad Cymru
Welsh Assembly Government

Policy GIU Technical Services Division

For Internal Use Only

Please note the information displayed above has been derived from a range of data each carrying its own set of caveats.
GIU has prepared the information above with consideration of the appropriate use of source data.
Please consult GIU if any additional interpretation of this information is required.

This map is based upon the Ordnance Survey Boundary Line data for The Welsh Assembly Government with the permission of Ordnance Survey on behalf of The Controller of Her Majesty's Stationery Office,© Crown Copyright.

Cartography by TSD GI Unit, DRA, Aberystwyth.

Data Correct to: **GIU REF:**

Description:

Appendix 6 – The number of herds, incidents, herds under restriction and cattle slaughtered for different reasons relating to TB control between 1990 and 2016

Appendix Table 4: The number of herds, incidents, herds under restriction and cattle slaughtered for different reasons relating to TB control between 1990 and 2016

Year	Number of herds	Total new incidents	OTFW incidents	Herds under restriction[1]	Inconclusive reactors slaughtered[2]	Reactors slaughtered[2]	Direct contacts slaughtered[2]
1990	21,507	35	11	8	8	64	
1991	21,507	53	21	14	20	132	10
1992	21,507	51	26	16	29	100	18
1993	21,507	87	29	26	23	162	1
1994	21,507	99	63	40	43	361	27
1995	21,339	168	107	68	82	505	178
1996	20,450	202	114	53	78	649	208
1997	19,201	157	61	51	80	361	169
1998	18,657	209	91	84	119	729	236
1999	18,580	269	136	106	88	882	416
2000	18,134	261	165	120	72	956	358
2001	17,981	207	141	163	88	1,555	421
2002	17,360	619	374	412	111	4,393	520
2003	16,546	624	348	386	165	4,910	679
2004	15,881	653	351	425	163	4,798	557
2005	15,075	732	427	493	211	5,847	669
2006	14,897	766	478	554	152	5,253	700
2007	14,122	934	479	681	200	7,095	606
2008	13,766	1,192	626	914	293	10,462	1,033
2009	13,172	1,192	553	734	1,310	8,946	590
2010	12,932	1,036	507	710	940	6,519	241
2011	12,821	1,055	705	751	938	6,651	460
2012	12,729	1,086	813	864	1,064	8,235	315
2013	12,676	869	675	608	964	5,141	180
2014	12,067	843	709	568	630	5,387	491
2015	11,675	831	680	591	840	6,926	486
2016	11,651	706	624	566	862	8,145	1,144

[1] The number of herds under movement restrictions in the middle of December of each year. Excludes herds restricted due to an overdue test.

[2] The number of cattle slaughtered for different reasons within a year regardless of when the incident began. Data for previous years has been updated using the latest available source data, and so may differ from that presented in previous reports.