Animal & Plant Health Agency

Risk assessment for bluetongue virus (BTV-3 and BTV-8): Risk assessment of entry into Great Britain

Qualitative Risk Assessment

Date in format: April 2024

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Summary

This document is an update of the risk assessment of the likely incursion of bluetongue virus serotype 8 (BTV-8) into Great Britain (England, Scotland and Wales) produced in 2017. On 5 September 2023, bluetongue virus serotype 3 (BTV-3) was reported in the Netherlands for the first time. It rapidly spread to Belgium and Germany and was later detected in south-east England. In addition, in August 2023, a 'new strain' of BTV-8 was identified in France. It quickly spread across the south of France. The risk question being assessed here is "What is the risk of BTV overwintering or being introduced into Great Britain from northern Europe and infecting livestock at least once in 2024?".

This document looks at the pattern of BTV spread including both the 'new strain' of BTV-8 and BTV-3 from September 2023 to April 2024. It also considers the endemic strain of BTV-8 which re-emerged in France in 2015, although not much is known about the current level of circulation. Finally, it looks at the pathogenicity, the impact and the likely introduction of BTV into Great Britain in 2024 from infected Culicoides or infected animals.

The results are summarised in the table below.

Summary of risks of entry of bluetongue virus in Great Britain such that at least one livestock animal is infected in 2024

Hazard	Route	Probability that at least one livestock animal is infected in Great Britain in 2024	Uncertainty
BTV-3	Overwintering in Culicoides in Great Britain	Very low	High
BTV-3	Entering Great Britain from northern Europe through windborne incursion of infected Culicoides	Very high	High

Hazard	Route	Probability that at least one livestock animal is infected in Great Britain in 2024	Uncertainty
BTV-8	Entering Great Britain from northern France through windborne incursion of infected Culicoides	Medium	High
BTV-3 and BTV-8	Imported live animals	Very low	Low
BTV-3	Overwintering in livestock within Great Britain	Very low	Low

BTV-3 was reported for the first time in northern Europe in 2023 on 5 September 2023 following this, it was confirmed through clinical signs on 4 sheep farms in the Netherlands and samples were taken for sequencing. Analysis confirmed it to be BTV-3 (House of Representatives of the Netherlands 2023). Following this, BTV-3 rapidly spread across the entire of the Netherlands. On 10 October 2023 BTV-3 was reported in Belgium and on 13 October, it was also reported in Germany. On 10 November 2023 BTV-3 was also identified in Great Britain for the first time. As of 15 April 2024, there have been 6001 reported detections in the Netherlands (NVWA 2024), 7 in Belgium (Sciesano 2024) and 56 in Germany (TSIS 2024). These cases are primarily in sheep and cattle (mainly subclinical in cattle) but there have also been a number of detections in alpacas and other ruminant species (PAFF Netherlands 2023). BTV-3 vaccines are in development and being tested in northern Europe, but at this time there is no commercially available vaccine. Updates on this will be provided in later reports.

BTV-8 re-emerged in 2015 in central France, despite being undetected in mainland Europe for at least 5 years prior to this. Since then, BTV-8 has become endemic in France and is still circulating. As of June 2021, BTV-8 was confirmed to be present in the north of France but since then there have not been any updates (WAHIS). In August 2023, severe clinical cases, uncharacteristic of the previously reported strain of BTV-8, were identified in cattle and sheep in Aveyron. This prompted sequencing of the viral genome, which confirmed it to be an exotic strain of BTV-8, different from the strain of BTV-8 endemic in France since 2015 (ESA September 2023). The origin of this 'new strain' is not currently known. By December 2023, France had reported 1,300 detections of the 'new strain', across 23 departments in mainland France. The French authorities have confirmed that the vaccine for BTV-8 is still effective against the new strain (ESA December 2023). This is to be expected, as the naming of serotypes is based on the gene responsible for the immune response. As the ribonucleic acid (RNA) segments in BTV can reassort during coinfection, the rest of the genome may give the virus different virulence characteristics, but vaccine efficacy should not be affected if the serotype is unchanged. Since December, there has been no further update and it is not known how far the 'new strain' of BTV-8 has spread. However, the French authorities have communicated that an update may be made in the event of a significant change in the epidemiological situation (ESA April 2024). Bluetongue is a category C+D+E disease under EU Regulation (EU) 2018/1882 meaning that in Europe, eradication is optional, but surveillance is required as well as additional trade requirements to prevent spread to disease free member states. France is required to provide update reports every 6 months to the World Organization for Animal Health (WOAH).

As of 15 April 2024, the total number of reported cases of BTV-3 in Great Britain stands at 126 (7 sheep and 119 cattle) across 73 locations in 4 counties in south-east England (Kent, Norfolk, Suffolk and Surrey). The last case was confirmed on 8 March 2024. All cases reported this year (2024) are historical from 2023 with the seasonal vector low period (SVLP) starting on 8 January 2024. This raises the question of whether BTV-3 could have successfully overwintered in Great Britain such that it is already here in 2024. There are several suggested mechanisms by which overwintering may occur. These are, within the ruminant host through prolonged infection or transplacental transmission, the use of infected germplasm, or in the vector through an infected adult Culicoides surviving the winter.

The aggregated probability that BTV-3 has overwintered in Great Britain, such that at least one livestock animal is infected in 2024 is estimated to be very low with high uncertainty reflecting lack of data on the ability of adult midges to survive the winter and the unknown incidence of transplacental transmission. This risk estimate takes into account the small number of BTV-3 cases (119 cases) reported in south-east England in 2023. However, given the relatively mild winter in 2023 to 2024 together with the very large number of livestock cases in 2023 in the Netherlands, it is considered that the aggregated probability of BTV-3 overwintering in northern Europe such that at least one livestock is infected in northern Europe is very high. The probability of newly emerged adult Culicoides subsequently being infected and then blown over into Great Britain at some point during 2024, based on risk predictions and events from 2023, is also very high.

Overall, it was concluded that there is a very high probability of introduction of BTV-3 into livestock at least once in 2024 through windborne incursion of Culicoides from northern Europe. This contrasts with the 2017 risk assessment when the risk for BTV-8 was considered medium (DEFRA 2017), The 2017 risk assessment was based on confirmation of a small number of cases of BTV-8 in northern France and the effective use of a vaccine for trade purposes.

There is high uncertainty in the estimated very high risk of introduction of BTV-3 from the Continent in 2024 in part because it assumes a substantial resurgence of BTV-3 in livestock in northern Europe in the summer of 2024, so that there is potential for large numbers of infected Culicoides to be transported by wind into Great Britain. The actual levels of disease on the Continent in the summer 2024 are difficult to predict due to variable daily temperatures, rain fall and humidity and unknown livestock movements. There is unlikely to be much immunity in livestock on the Continent in 2024.The 'on-farm' prevalence in the Netherlands was reported to be only 5-30%, with only a proportion of all susceptible livestock premises affected, so the majority of the livestock population will still be immunologically naïve, in addition to replacement animals over the winter.

The risk of importing infected livestock with BTV-3 or BTV-8 is very low. All imports of susceptible livestock from BTV affected counties are required to comply with the health certificate requirements including the appropriate vaccination. Countries affected with BTV-3 (Belgium, Germany and the Netherlands) are unable to comply with the Great Britain health certificate. Although there is a vaccine available for BTV-8, France also has epizootic haemorrhagic disease virus (EHDV) present, preventing it from meeting the requirements for exporting livestock to Great Britain. There is a small possibility of BTV-3 being brought into Great Britain through the importation of infected cattle, if BTV-3 spreads to new countries undetected. At this time, in northern Europe the only country trading live susceptible animals with Great Britain is Denmark. Although importation is allowed from other countries if livestock do not transit through a BTV-3 affected region. Germinal products are not included in this assessment as they are considered lower risk, due to the strict requirements for importing, highlighted in the health certificates (Great Britain HC003E and Great Britain HC009E).

It should be noted that the risk assessment here predicts the probability of at least one livestock animal being infected in Great Britain in 2024. It does not give any information on the number or frequency of livestock animals infected. A single livestock animal being infected in Great Britain may result in onward spread to other livestock through Culicoides during the vector active season.

Introduction

Bluetongue (BT) is a notifiable disease of ruminants, most commonly associated with clinical disease in sheep but can also affect cattle. It is caused by infection with the bluetongue virus (BTV), an orbivirus of the Reoviridae family (1). There are 29 known serotypes (2-4, 52) and these viruses are usually transmitted via the bites of infected Culicoides midges.

The virus is found in southern Europe, with BTV serotypes 1, 2, 3, 4, 9 and 16 have all been identified in the Mediterranean basin (5). Until recently only BTV serotypes 1, 4 and 8 and three vaccine strains of BTV-6, BTV-11 and BTV-14 had previously been identified in northern Europe; BTV-8, BTV-1 and BTV-14 are known to have circulated efficiently in Culicoides in Europe (6, 7). The BTV-8 virus reached Great Britain during 2007, the second year of the epizootic in northwest Europe when infection rates were very high in Continental Europe and BTV-1 reached northern France (8-10).

The identification of BTV-3 in the Netherlands in September 2023 has led to concerns that an epizootic across north Europe may develop again this year with the potential for significant losses of livestock. BTV-3 rapidly spread from the Netherlands to Belgium and Germany and was later detected in Great Britain. At the time of writing (April 2024), there is no commercially approved vaccine available for BTV-3. This means that there is a substantial naïve livestock population present in northern Europe with very limited immunity. It should also be noted that BTV vaccines do not provide cross protection for other serotypes. Controls are limited for BTV-3 and are focused mainly on the movement of livestock in and from affected areas. This document considers the risk of an incursion of BTV-3 in Great Britain in 2024, primarily through windborne spread of infected Culicoides from northern Europe.

In addition to this, there was an emergence of a ‘new strain’ of BTV-8 in France in August 2023, but little data is published about how far it has spread. It was identified due to uncharacteristically causing severe clinical cases in unvaccinated sheep and cattle. Genetic analyses of the virus have shown that it is different to the previous northern European strain of BTV-8, but vaccines were identified to still be effective. As a vector borne disease, vaccination is the best control option which is highlighted in the Great Britain control strategy for Bluetongue.

Risk question

Within this QRA, we review the risk of BTV-3 or BTV-8 entry to Great Britain during 2024, via overwintering and also via infected imported animals. As such, the specific risk question is:

"What is the risk of BTV overwintering or being introduced into Great Britain from northern Europe and at least once affecting livestock in 2024?".

It should be noted that the risk assessment here predicts the likelihood of at least one livestock animal being infected in Great Britain in 2024. It does not give any information on the number or frequency of livestock animals infected. The risk and extent of onward spread within Great Britain would depend upon the time of year of an incursion, vector activity, temperature and animal movements.

Hazard identification

The hazard is bluetongue virus. There are 2 serotypes considered, namely serotype 8 (BTV-8) and serotype 3 (BTV-3).

BTV-3

On 5 September 2023, BTV was confirmed on 4 sheep farms in the Netherlands following reports of clinical suspicion by private veterinarians. Sequencing was conducted by Wageningen Bioveterinary Research and it was confirmed as BTV-3 by the EU Reference Laboratory in Madrid (House of Representatives of the Netherlands 2023). Since then, there have been 6001 reports across the entire of the Netherlands, at this time it is not clear what the effects are on mortality or morbidity but the prevalence within herds is currently being analysed to provide more insight (NVWA 2024).

In December 2023, the Netherlands Food and Consumer Product Safety Authority (NVWA) highlighted that a variety of ruminants were found to be infected with BTV-3 which included sheep, goats, cows, alpacas, lamas, mouflon, water buffalo, wisent and yak (PAFF Netherlands 2023). On 10 October 2023, BTV-3 was reported in Belgium (Sciesano 2024) and on the 13 October 2023, it was also reported in Germany (TSIS 2024). As of 15 April 2024, there have been 7 outbreaks of BTV-3 in Belgium and 53 outbreaks in Germany. Boender et al (68) have concluded that in addition to short-distance dispersal of infected Culicoides, other transmission routes such as livestock transport probably played an important role in disease spread in the Netherlands in 2024.

On 10 November 2023, it was confirmed that 1 cow on a farm in Kent, England tested positive for BTV-3 after samples were taken as part of annual bluetongue surveillance, no clinical signs were observed. As of 15 April 2024, the total number of reported cases of BTV-3 in England is 126 (7 sheep and 119 cattle) across 73 locations in 4 counties (Kent, Norfolk, Suffolk and Surrey) ([GOV 2024](GOV 2024)). The locations are shown in Figure 1.

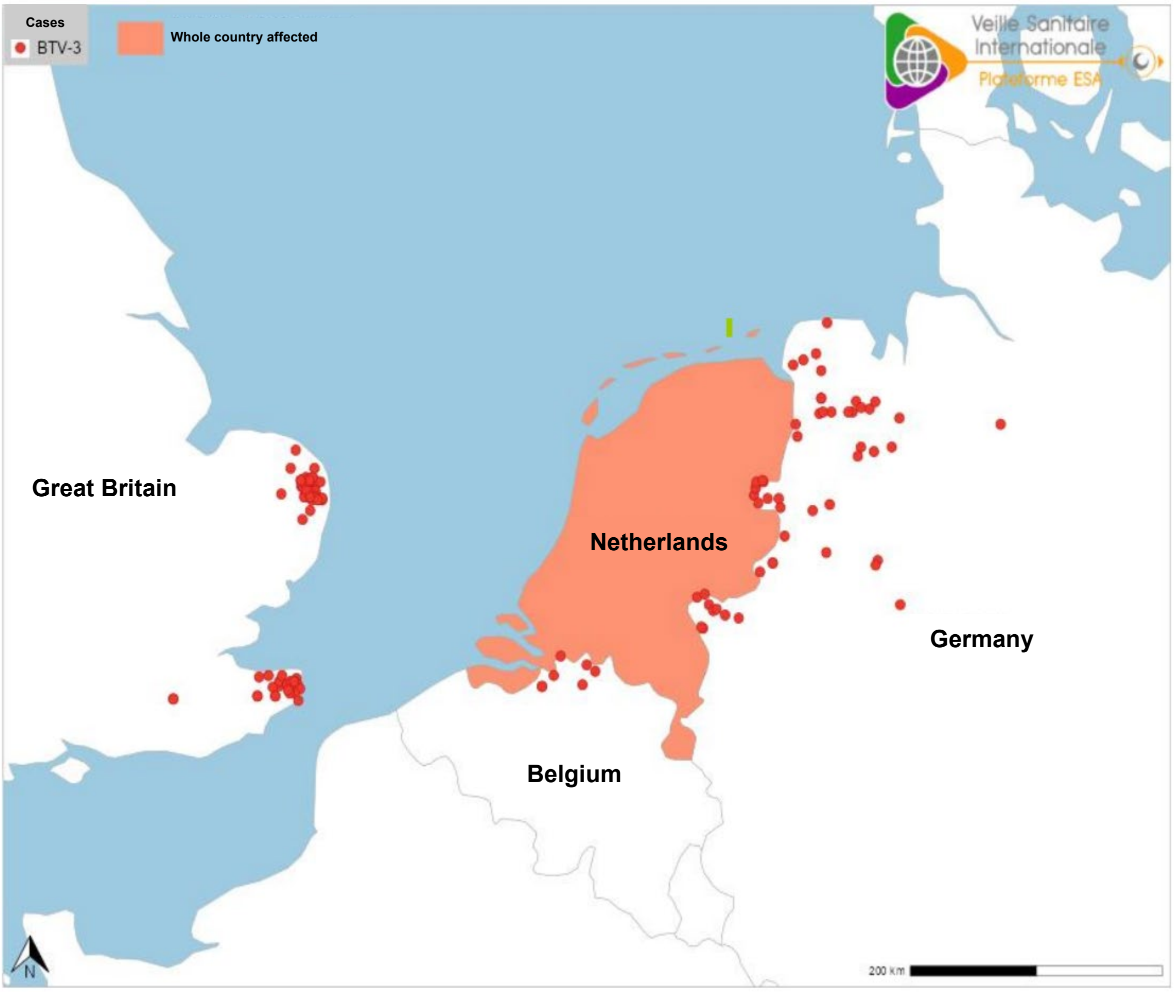


Figure 1: The locations of BTV-3 cases (red dots) in Great Britain, Belgium, Germany and the Netherlands where the whole country is affected (Source: Plateforme ESA, accessed on 15 April 2024).

Figure 1 shows all reported cases of BTV-3 in northern Europe since it was first discovered in the Netherlands in September 2023. The map shows that the entire of the Netherlands has been affected. In Germany cases are sporadic but confined to the states of Lower Saxony and North Rhine-Westphalia. In Belgium there are a limited number of cases in the province of Antwerp. In Great Britain all cases are located in England, primarily in Kent and Norfolk, with one located in Surrey.

BTV-8

In 2015 a ram located in central France was clinically diagnosed with BTV, but none of the other animals in the herd showed any clinical signs. Genetic sequencing identified the virus to be closely related to the BTV-8 strain that circulated in 2006 – 2008. Although the origin of the outbreak is unclear, it is thought that BTV-8 was likely circulating at very low levels from the time it first emerged in 2006 (52).

Since then, this strain of BTV-8 has become endemic in France. However, a 'new strain' of BTV-8 was first reported in the country in August 2023. The cases were unusual given the severity of clinical signs not seen with the endemic BTV 8 strain; namely, pyrexia, mouth ulcers and coughing, leading to authorities to sequence the viral genome. This confirmed it to be an exotic strain of BTV-8, different from the strain of BTV-8 which has been endemic in France since 2015, but existing vaccines against serotype 8 remain effective against this 'new strain' (ESA September 2023). By November 2023, the newly identified strain had been implicated in 1,300 reports (1000 in cattle and 300 in sheep), spread across 25 departments in France (ESA December 2023) (Figure 2). However, since November 2023 there have been no further updates reported. The French authorities have communicated that due to a lack of consolidated data the extent of the spread of the 'new strain' of BTV-8 will not be regularly updated, but an update may be made if a significant change in the epidemiological situation occurs (ESA April 2024).

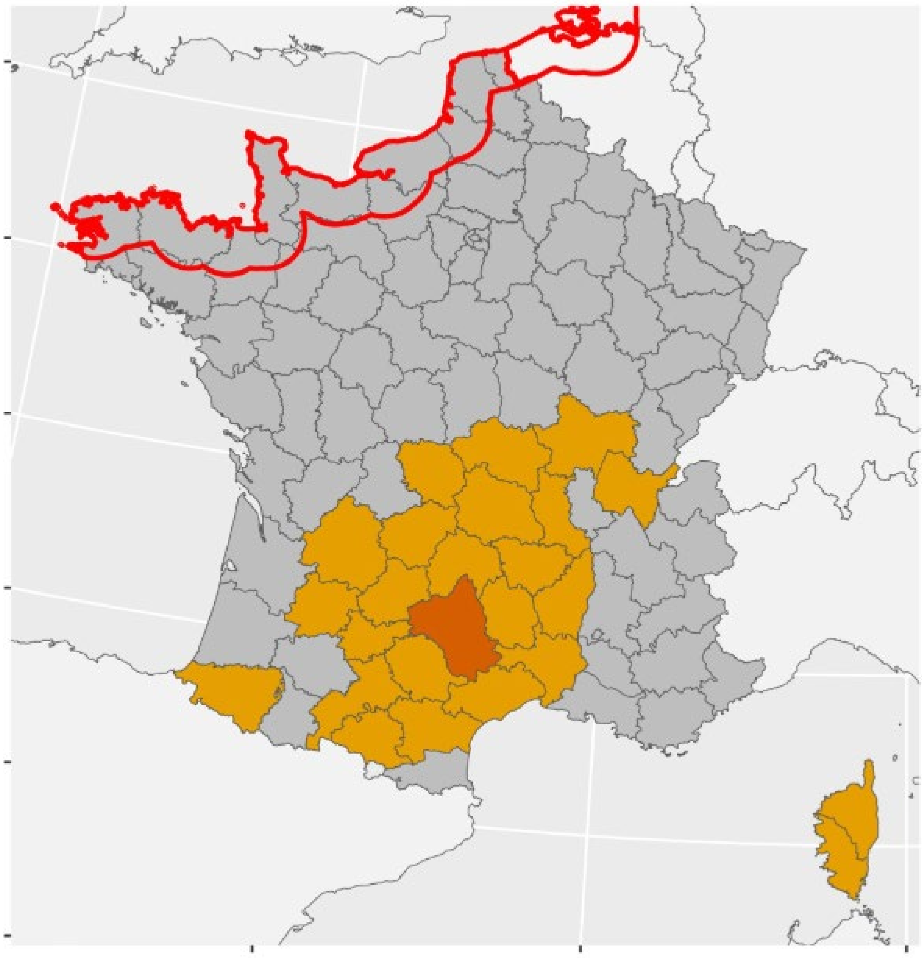


Figure 2: The initial report of the ‘new strain’ of BTV-8 in the department of Aveyron (represented as dark orange). Subsequent detections in other departments (represented as light orange) and the 50km coastal area where windborne incursion to Great Britain would be possible (represented as red lines) (This map was created from data published by Platform ESA 28 November 2023 accessed 10 April 2024).

Figure 2 highlights that the initial reports of a ‘new strain’ of BTV-8 were found in the department of Aveyron in August 2023. By November 2023, there were reports of the ‘new strain’ of BTV-8 in 24 other departments primarily in the south of France and on the Island of Corsica. The departments affected are as follows, Pyrenees-Atlantiques, Haute-Garonne, Ariege, Aude, Herault, Tarn, Tarn-et-Garonne, Lot-ete-Garonne, Lot, Dordogne, Correze, Creuse, Cantal, Lozere, Gard, Ardeche, Loire, Haute-Loire, Puy-de-Dome, Creuse, Allier, Saone-et-Loire, Ain, Haute-Corse (Corsica), Corse du-Sud (Corsica). No update has been provided since November 2023. The Map also shows the 50km northern coastal area of France where windborne incursion to Great Britain is most likely.

Source of infection in Europe

The source of infection is still not fully understood. Possible factors include:

1. A new introduction through imported animals, germinal products or infected midges from the Continent.

2.Other countries outside of northern Europe. During 2006 the first outbreak of bluetongue ever recorded in northern Europe started in Belgium and the Netherlands, spreading to Luxemburg, Germany and north-east France. The virus overwintered (2006 to 2007) re-appearing during May to June 2007 with greatly increased severity in affected areas. It then spread further into Germany and France, reaching Denmark, Switzerland, the Czech Republic and Great Britain. The origin was never discovered but sequencing revealed that the virus was related to strains from sub-Saharan Africa. It is uncertain how it originally arrived in northern Europe. Therefore, it is not possible to rule out that a similar incursion event that occurred in central France in 2023 or may happen again.

At this time, the origin of this strain of BTV-3 in the Netherlands is unknown. It is noteworthy that the sites in the Netherlands first found to be infected were approximately 20km from Schiphol airport which is a major international hub.

Clinical impact of BTV

Given BTV is a seasonal disease in northern Europe with a history of re-emerging, it would not be surprising if we saw incidents of BTV-3 and BTV-8 being reported in northern Europe this year.

Endemic BTV-8 in France

In the previous epizootics of BTV-8 in 2006 to 2007, there were distinct patterns which could be drawn from the epidemiology of disease (50). Five phases can be seen: firstly, in a naïve population, the disease may not be detected as there are so few infected animals. In phase 2 the prevalence rises rapidly until phase 3 when prevalence plateaus. In phase 4, which can last several years, endemicity is reached or disease prevalence may drop again and phase 5 is where there is disease freedom, but still a history of disease can be found (Figure 3). But it is dependent on a number of factors including, the surveillance system sensitivity, vaccine effectiveness (where applicable) and environmental conditions. The duration of the phases depends on the circulation of the virus and therefore in winter, phase 4 may start but as there are still naïve animals present, phase 5 is not reached, and the increase continues in the following year. While BTV-8 was widely reported in 2006 to

2007 to have had a devastating effect on sheep and cattle populations, its impact was very variable as the outbreak progressed and clearly depended on host factors.

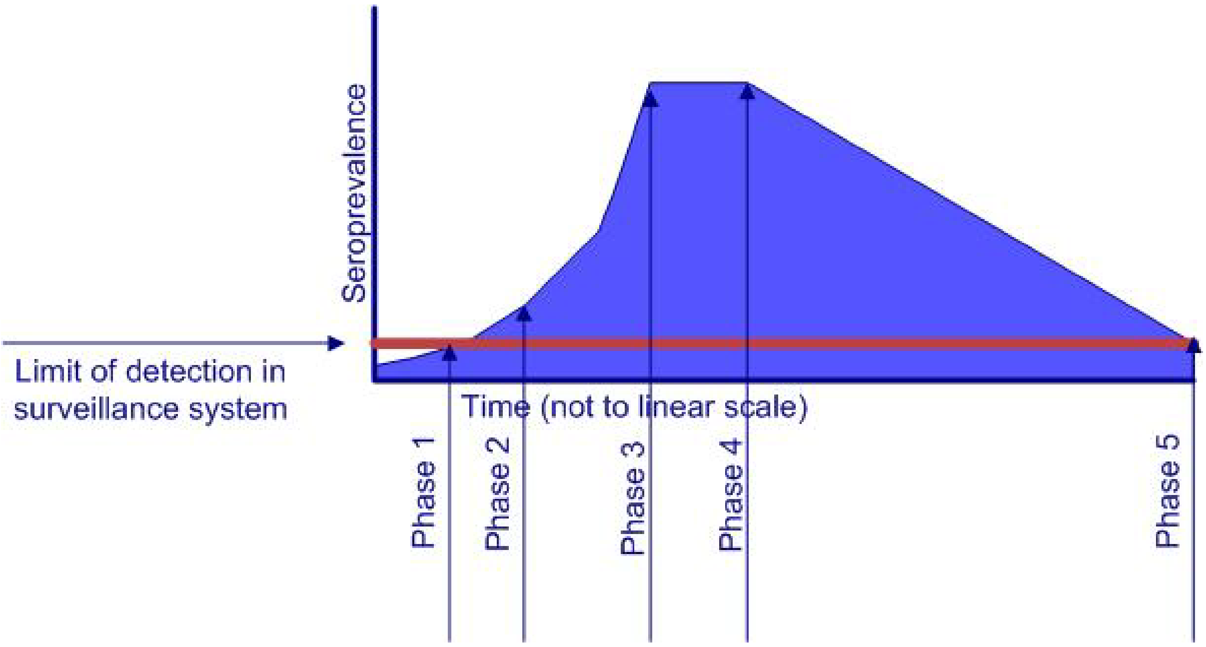


Figure 3: Different phases of seroprevalence in animal populations based on the epizootics of BTV-8 in 2006 to 2007 (Source DEFRA 2017).

After France regained BTV free status in 2012, vaccination of livestock was no longer enforced, and a surveillance programme was implemented. Several years later in 2015 BTV-8 re-emerged (60). It was speculated that it likely circulated in low levels throughout this period but was undetected due to a significant number of the livestock population having immunity from either the vaccine or from natural immunity from the previous outbreak that started in 2006 (60). As the proportion of susceptible young unvaccinated animals increased there was likely a greater opportunity for BTV-8 transmission (60). Another possibility was the use of stored infected germinal products, as there was so little strain variation from the 2007 virus (60).

BTV-3

As with other serotypes of BTV, sheep have shown the most severe clinical signs. There have been similar numbers of sheep and cattle infected with BTV-3 in the Netherlands, however cattle were less likely to show clinical signs, but, almost every cow experienced reduced milk production (NFU 2024). Moreover, there have been reports of cases in goats, alpacas, llamas, mouflon, water buffalo, wisent and yak. There has also been a case of transplacental transmission of BTV-3 in Great Britain and another case was reported in the Netherlands in cattle. Since the emergence of BTV-3 in northern Europe in 2023, it is estimated that 0.2% of the Dutch cattle population have died as well as 3.9% of the sheep population (no data on the specific mortality rate of those infected) (NFU 2024). As BTV-3 is new to northern Europe, there is potential for it to have a significant effect on livestock population as almost all will be naïve and there is no commercially available vaccine at the time of writing. Natural immunity provides protection against BTV-8 for life (60). This is thought to be similar for BTV-3, so previously BTV-3 infected livestock will likely have resistance, but the proportion of the total livestock population with immunity will be minimal in northern Europe and can be discounted for the purpose of risk assessment.

‘New strain’ of BTV-8 in France

In unvaccinated or naïve cattle and sheep, the ‘new strain’ of BTV-8 appears to cause severe clinical signs including pyrexia, locomotion difficulties, mouth ulcers and cough, this is uncharacteristic of the strain of BTV-8 which is endemic in France. However, the full clinical impact of this ‘new strain’ is difficult to assess as it is still emerging and there is a lack of consolidated data.

Risk assessment terminology

In this qualitative risk assessment, the likelihood of entry and exposure, levels of uncertainty and outcome of the consequence assessment are described using the established terminology defined in Tables 1 and Table 2.

It should be noted that these European Food Safety Authority (EFSA) definitions merely give an indication of relative risk with respect to each other for the reader and the use of terms such as ‘regularly’ and ‘very often’ for medium and high respectively reflect a generic time frame. It should be stressed in this risk assessment that, although the risk question specifies ‘per year’, the predicted qualitative risks give no indication of the number of times in 2024 that BTV infection may occur in Great Britain livestock. The qualitative risks merely indicate the relative magnitude of the probability of at least one infection in Great Britain livestock per year as specified in the risk question.

Table 1:Terminology and definitions used to describe likelihood of entry and exposure (EFSA, 2006)

Probability	EFSA definition
Negligible	Event is so rare that it does not merit consideration
Very low	Event is very rare but cannot be excluded
Low	Event is rare but does occur
Medium	Event occurs regularly
High	Event occurs very often
Very high	Event occurs almost certainly

Table 2: Terminology used to describe the level of uncertainty in the entry, exposure and consequence assessment (EFSA, 2006, Spiegelhalter and Riesch, 2011)

Uncertainty category and definition	Type of information – evidence to support uncertainty category
Low Further research is very unlikely to change our confidence in the assessed risk	Solid and complete data available (For example long-term monitoring results) Peer-reviewed published studies where design and analysis reduce bias (For example systematic reviews, randomised control trials, outbreak reports using analytical epidemiology) Complementary evidence provided in multiple references Expert group risk assessments, specialised expert knowledge, consensus opinion of experts Established surveillance systems by recognised authoritative institutions Authors report similar conclusions

Uncertainty category and definition	Type of information – evidence to support uncertainty category
Medium Further research is likely to have an important impact on our confidence in the risk estimate	Some but no complete data available Non peer-reviewed published studies - reports Observational studies - surveillance reports - outbreak reports Individual (expert) opinion Evidence provided in a small number of references Authors report conclusions that vary from one another
High Further research is very likely to have an important impact on our confidence in the risk estimate	Scarce or no data available No published scientific studies available Evidence is provided in grey literature (unpublished reports, observations, personal communication) Individual (non-expert) opinion Authors report conclusions that vary considerably between them

Entry assessment

The presence of BTV in livestock in Great Britain may result from:

- overwintering of BTV-3 through survival of infected Culicoides over winter 2023 to 2024 in south-east England
- overwintering of BTV-3 in the ruminant population over winter 2023 to 2024 in south-east England
- an infected or infectious vector reaching Great Britain and then infecting a susceptible host
- entry via import of infected livestock
- use of infected germinal products

Onward spread is dependent on the number and location of susceptible hosts and climatic conditions suitable for virus replication and vector activity. Not every

Culicoides arriving from northern Europe will be infectious, not every infected vector will lead to an infected susceptible host, and it is possible more than one susceptible host is infected when many Culicoides arrive in a single period.

The risk pathway for the entry of BTV into Great Britain is shown in Figure 8. The pathways highlight the 2 key routes of entry, namely, the windborne spread of infected Culicoides or, the importation of infected animals. Other mechanisms include overwintering in livestock (prolonged viraemia and transplacental transmission) and germinal products, which are not included in the pathway as they are considered lower risk, due to strict requirements for importing highlighted in the health certificates (Great Britain HC003E and Great Britain HC009E).

It is also important to note that we define disease entry as the presence of a BTV positive livestock animal in the Great Britain, as opposed to the presence of an infected vector. This is based on the assumption that a cloud of vectors arriving from an affected area on the Continent to Great Britain has potential to include infected individuals, but not all will be infectious or lead to transmission. An outbreak would be declared if there is onward transmission to susceptible livestock within Great Britain. The likelihood of transmission via Culicoides to susceptible hosts depends on a number of factors, including, the immune status of the livestock host, and suitable meteorological conditions.

Transmission of bluetongue virus in northern Europe

The cycle of BTV transmission has been well documented, with transmission occurring during peak vector activity periods with appropriate temperatures, ceasing during the winter before re-emerging at the start of the next vector period (16). In northern Europe, transmission is therefore temperature dependent.

Virus replication within the midge occurs when mean daily temperatures are at or above 12°C (66, 67). The rate of replication increases at higher temperatures, however the longevity of Culicoides may increase from 3 weeks to up to 90 days in colder conditions (17). A mild winter, however, could increase the duration of suitable conditions for vector activity, longevity, and virus replication. The time of year at which the disease may reappear varies. This was estimated to be between April and May during the 2007 to 2008 outbreak of BTV-8, when the first new infections were detected in ruminants, but this will depend upon temperatures and vector feeding behaviour (18). The seasonal vector low period (SVLP) is informed by findings of Culicoides traps placed across England. As a blood meal is needed for egg production, only female Culicoides feed on animals. Following egg production, pigmentation can be observed in the female’s abdomen, with pigmented individuals therefore serving as a proxy for previous biting activity. The start of the SVLP is declared when fewer than 5 pigmented Culicoides vectors are found in a single night's trap catch at all sites in the surveillance networks over 2 consecutive weeks (communication from The Pirbright Institute, 2024), and ends when more than 5 are identified in any single trap. In England the SVLP usually ends during April.

Figure 4 shows the basic reproduction number (R0) for bluetongue as a function of temperature. R0 represents the number of secondary infections arising from an infected susceptible during the infectious period. The plot was generated using the uncertainty analysis presented in Burgin et al. (2012) but using updated distributions for the underlying epidemiological parameters. From Figure 4, R0 exceeds one between 15°C and 33°C, with a peak R0=3.3 at 22°C.

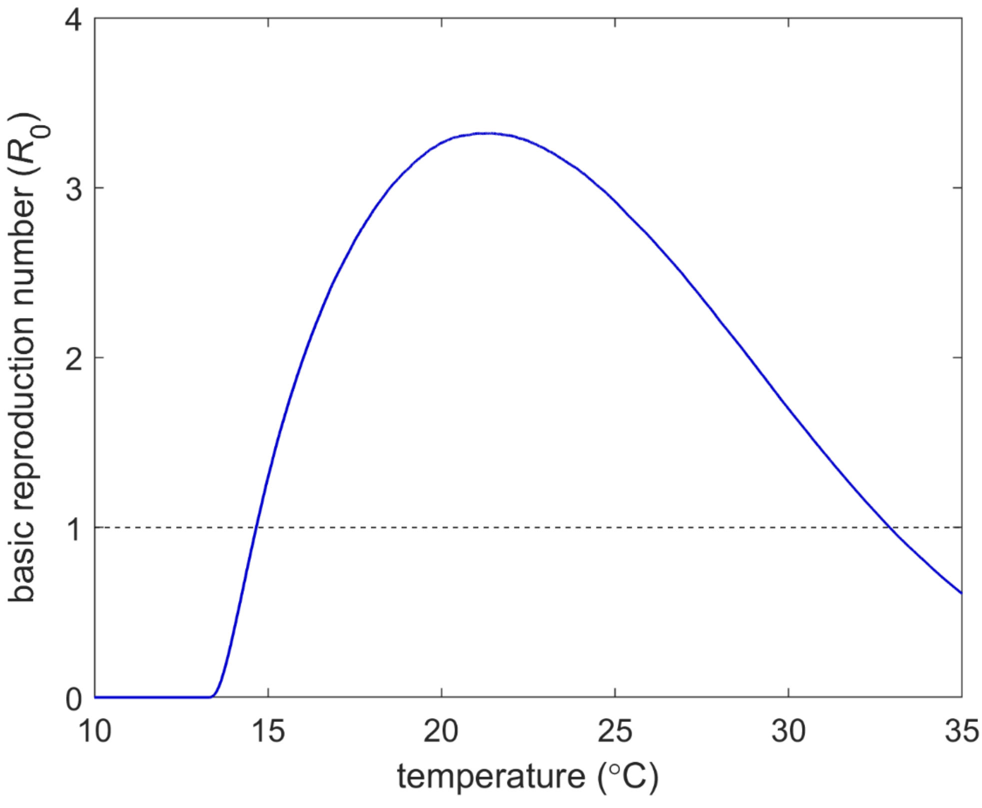


Figure 4: Basic reproduction number (R0) for BTV as a function of daily average temperature. The blue line shows the mean for the uncertainty analysis used to calculate R0 (allowing for uncertainty in the underlying epidemiological parameters), while the black dotted line indicates the threshold at R0 = 1 (from Simon Gubbins, The Pirbright Institute April 2024).

Overwintering of BTV-3 in 2023 to 2024 in south-east England

Wilson and Mellor (18) write "In many temperate regions classical BTV transmission is almost completely interrupted for several months of the year by cold weather, but outbreaks often resume after interruptions far longer than the typical lifespan (3 weeks) of an adult vector or the normal period of host infectiousness, a phenomenon termed 'overwintering'". There are three suggested mechanisms of overwintering as set out in Figure 5. Transovarial transmission of bluetongue from adult midge to the eggs does not occur in Culicoides midges.

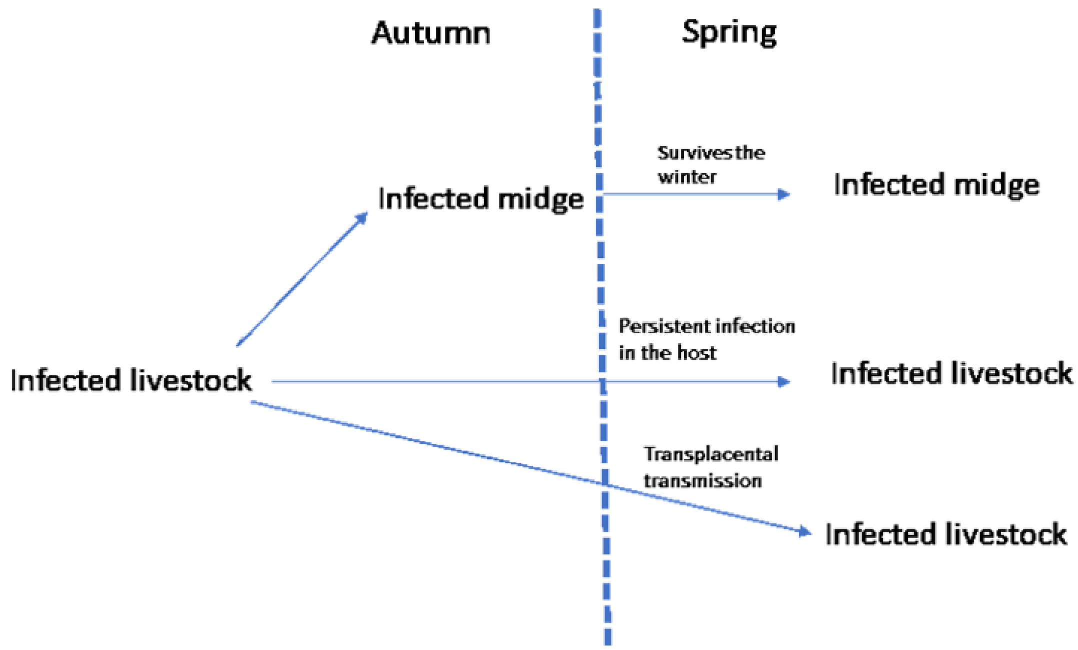


Figure 5: Suggested overwintering mechanisms for bluetongue virus in northern Europe and Great Britain, including Culicoides midges biting infected livestock in autumn then surviving winter, infected livestock having a persistent BTV infection which lasts through to spring and infected livestock spreading BTV to offspring through transplacental transmission. These mechanisms all provide an opportunity for an uninfected midge in the vector active season to bite an infected host and become infected.

Overwintering of BTV could potentially occur due to virus persistence in either long-lived vectors or vertical transmission amongst animal hosts (16), but the frequency of overwintering remains largely unknown. BTV-8 is known to cause transplacental transmission in pregnant heifers (40, 41), and a case of transplacental transmission of BTV-3 has been recently recorded in Great Britain (APHA 2024). Overwintering of vectors in livestock accommodation is a possible mechanism for maintaining disease transmission from year to year (13). An EFSA opinion has described these mechanisms for BTV-8 in more detail, but the conclusion was that the infection clearly overwinters successfully, and that disease eradication using vaccination would require several years of repeated vaccination of suspect animals, but the current surveillance levels required in EU legislation are not sensitive enough to detect low levels of circulation in Europe (51).

In this risk assessment we are looking at a scenario where we assess whether BTV has successfully overwintered in England and in northern Europe. Here only overwintering in adult Culicoides (rather than egg, larval or pupal stages) are considered. Since BTV is not transmitted transovarially in Culicoides, the mechanism is survival of the infected adult Culicoides over the winter period, and eggs or larval stages do not need to be considered (unlike some mosquito-borne viruses). Two other overwintering routes are considered by Wilson and Mellor (18), these are extended viraemia in the ruminant host and transplacental transmission in the ruminant and are now discussed.

Duration of viraemia in the ruminant population

The duration of BTV viraemia in cattle has been suggested as a potential overwintering mechanism (16). Infectious BTV can be isolated from the blood of cattle for longer than sheep and goats and a small fraction of individuals may exhibit viraemia beyond 60 days post infection. It has been estimated that in 99% of cattle viraemia ceases by 9 weeks (63 days), with the possibility that just 1% are still viraemic after 9 weeks (73). Detection of BTV genome in cattle by reverse transcription polymerase chain reaction (RT PCR) may be possible for a much longer period but may not be indicative of infectious viraemia (74,75).

Since Culicoides numbers and Culicoides activity are both decreased in the winter, the number of bites each cow receives is much lower than in summer. Furthermore, while a single Culicoides bite is sufficient to infect a cow, the probability of transmission from cow to Culicoides is less efficient such that a large number of bites are required to infect at least one Culicoides. In Great Britain, 119 cattle and 7 sheep were infected (out of over 48,000 samples PCR tested) and many of these infected cattle were culled, making them unable to contribute to overwintering through prolonged viraemia. However, the larger infection pressure observed in the Netherlands means there is a possibility of overwintering through prolonged viremia. The likelihood of BTV-3 overwintering via prolonged viremia in the ruminant population in Great Britain is considered to be very low to negligible.

Overwintering by transplacental transmission

The gestational period of a cow is 9 months. The high-risk period for infection in 2023 was from August to November. Any cows infected in the first trimester would have likely aborted. Cows infected in the second trimester would have given birth between February and April and would have been tested at birth if present in the temporary control zone (TCZ) or on a traced premises. Cows infected in the third trimester have already calved and would have been tested in the TCZ. The gestational period for sheep is 5 months, therefore pregnant sheep infected during the high-risk period have already given birth.

Overwintering in adult Culicoides

Wilson et al. (16) noted that the winter of 2006 to 2007 was the mildest on record in Europe and small numbers of adult Culicoides were caught throughout the winter period. Wilson et al (16) adds that in mild winters such as 2006 to 2007 it is possible that a small fraction of the infected adult Culicoides population might survive long enough to bridge the gap between transmission seasons. Adult Culicoides may also be sheltered from the worst conditions of winter to some degree by their choice of resting place. Studies in Europe have suggested small numbers of some vectors may move indoors when outdoor temperatures begin to drop (77, 78). It should be noted that cattle are often housed through the winter months in northern Europe and microclimates within the housing may afford protection from very low temperatures.

The overwintering of BTV-3 either in Culicoides in south-east England (Figure 5) or more likely in northern Europe (Figure 8) is considered here.

Though the mechanism through which BTV-8 successfully overwintered in Europe in 2006 to 2007 is undetermined, the very mild winter in terms of recorded temperatures could have helped BTV overwinter in the Culicoides population in Europe. BTV-8 was not present in Great Britain in the winter of 2006 to 2007, although it entered Great Britain from Europe in 2007.

Monthly temperatures for the winters of 2006 to 2007 and 2023 to 2024 in England were compared in Table 4 using Met Office data (62, 63, 64). Although these are average temperatures across England rather than the south-east of England, they give an indication of relative temperatures during each month. It should be noted that the mean temperature of 7.5°C in February 2024 is the highest mean temperature for February recorded since 1884 according to Met Office data (64). The mean temperature for the winter of 2024 is the second highest on record at 6.2°C (the highest being winter 2016 of 6.5°C) while the mean winter temperature for 2007 was the third highest temperature at 6.2°C according to Met Office data (63). Mean temperatures in December 2023, February 2024 and March 2024 were higher than those in the corresponding 2006 to 2007 period (Table 3). It is concluded that the higher temperatures in England in 2023 to 2024 compared to 2006 to 2007 would not allow us to rule out overwintering of BTV-3 in south-east England.

Typically, the SVLP starts in November and ends in April. The SVLP for 2023 to 2024 was short (January to March) due to the warm temperatures. This may have made it more likely for adult Culicoides to survive for a longer period, but it is not clear how this would increase the likelihood of BTV overwintering, given the daily temperatures required for the virus replication within the insect vector to occur.

Table 3: Comparison of mean temperatures (°C) and temperature ranges (monthly average minimum to monthly average maximum) in England for the winter of 2006 to 2007 and the winter of 2023 to 2024. Data from the Met Office (62, 63, 64).

Month	2006 to 2007 temperature (°C)	2023 to 2024 temperature (°C)	Difference in mean temperature (°C)
November	7.9 (4.3 to 10.6)	7.3 (4.3 to 10.3)	–0.6
December	6.1 (3.5 to 7.8)	6.8 (4.3 to 9.4)	+0.7
January	6.6 (3.8 to 9.5)	4.4 (1.6 to 7.3)	–2.2
February	5.8 (2.7 to 8.9)	7.5 (4.5 to 10.5)	+1.7
March	6.9 (2.9 to 11.0)	7.8 (4.4 to 11.1)	+0.9

Table 3 shows a comparison of the temperatures in England over the 2023 to 2024 winter months and those in Maastricht over the same months in 2006 to 2007, where BTV-8 overwintered. While December and February mean temperatures are higher for England 2023 to 2024 the temperature of January 2024 is 2.2°C lower than that in Maastricht for 2007. Thus, the relatively cold January in England in 2024 may offer some protective effect against overwintering this season.

Table 4: Comparison of mean temperatures (°C) and temperature ranges (monthly average minimum to monthly average maximum) in Maastricht (south-east Netherlands) and England for the winter of 2006 to 2007 (65).

Month	Maastricht 2006 to 2007 temperature (°C)	England 2023 to 2024 temperature (°C)	Difference in mean temperature (°C)
November	9.1 (3.4 to 15.7)	7.3 (4.3 to 10.3)	-1.7
December	6.0 (0.0 to 13.3)	6.8 (4.3 to 9.4)	+0.8
January	6.6 (-2.9 to 12.7)	4.4 (1.6 to 7.3)	-2.2
February	6.4 (-0.7 to 9.9)	7.5 (4.5 to 10.5)	+1.1
March	7.8 (2.7 to 11.4)	7.8 (4.4 to 11.1)	0.0

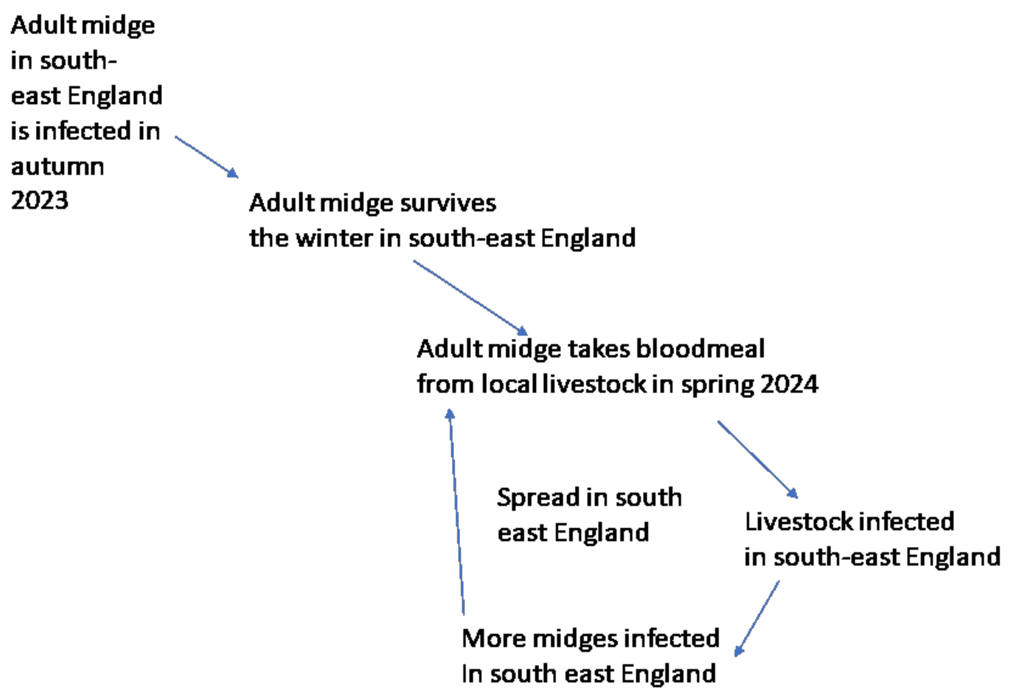


Figure 6: Overwintering of BTV-3 in adult Culicoides in Great Britain, in a scenario where an infected adult female Culicoides is able to survive the winter, then later bite a susceptible host causing infection in the livestock, providing an opportunity for other previously uninfected Culicoides to feed and become infected, continuing the cycle.

The lifetime of the Culicoides may be extended by mild winter conditions with individual Culicoides sonorensis surviving up to 3 months at 10°C. Thus, according to Lysyk and Danyk (59) the maximum longevity of Alberta females (Culicoides sonorensis) increased from 28 days at 30°C to 84 days at 10°C, and females of C. sonorensis survived from 25 to 91 days at the same temperatures. Median longevity was 12 days to 19 days at 10°C, so 50% survived for almost 3 weeks at 10°C.

The probability that an infected Culicoides in autumn (referred to now as an 'autumn Culicoides) in south-east England infects a livestock animal the following spring in south-east England is calculated (see below) as negligible per autumn Culicoides. The uncertainty in this negligible estimate is medium reflecting the uncertainty that a Culicoides in south-east England is infected in the autumn together with the uncertainty that the Culicoides survives the winter.

Estimation of the probability that an infected Culicoides in the autumn 2023 infects a livestock animal in the following spring 2024 in south-east England

Note the units are 'per autumn Culicoides midge'.

1. The probability that an adult Culicoides is infected in autumn in south-east England is very low. This probability takes into account the relatively small number of infected livestock in south-east England in autumn 2023. There is a medium level of uncertainty for this based on the unknown infection status of Culicoides in the affected areas and the limited geographical spread of cases. Were there to be more infected livestock, as in northern Europe (see below), then this probability would be higher at low.

2. The probability that an adult Culicoides survives the winter in south-east England is very low. Since it is unclear if any Culicoides would be capable of surviving the unfavourable winter conditions, there is a medium level of uncertainty for this.

3. The probability that an adult Culicoides takes a bloodmeal from local livestock in spring in south-east England is medium based on the assumption that host seeking behaviour will resume when temperatures are suitable and based on the possibility that Culicoides may bite wild mammals rather than livestock. There is a high level of uncertainty as post-overwintering behaviour of a surviving Culicoides is unknown and host selection in some vector species has been shown to be highly opportunistic (76).

4. The probability that a livestock animal is infected after a bite from an infected Culicoides is high as just one bite from a BTV-infected Culicoides adult female is sufficient to initiate infection. There is a low level of uncertainty for this. Due to the small number of livestock cases in autumn 2023 is south-east England herd immunity is low and virtually all livestock will be immunologically naive.

5. The overall probability that at least one livestock animal is infected in the spring 2024 in south-east England per 'autumn Culicoides' was calculated to be negligible. This is a combination of probabilities 1 to 4 above and is calculated on the basis that the product of 'very low' and 'very low' probabilities is 'negligible' per Culicoides midge. There is a high level of uncertainty for this based on the uncertainties for the key steps, namely the probability that the Culicoides is infected and the probability that the Culicoides survives the winter.

To calculate the aggregated probability that at least one livestock animal is infected in spring 2024 in south-east England requires a quantitative estimate of the number of infected Culicoides in south-east England present prior to winter to use in Figure 7. Although the risk per autumn midge is negligible, the huge number of autumn midges present would increase the aggregated risk to a non-negligible level. It is important to note that the negligible risk estimated per autumn midge is not zero risk, albeit a very small risk per autumn midge. Based on the huge abundance of Culicoides, the aggregated probability that at least one livestock animal is infected in spring in the south-east is assessed as at least very low on the basis of Figure 7. The uncertainty in this estimate is high based on lack of information on the actual number of Culicoides in south-east England in the autumn together with the probability they were infected in the autumn and the ability of Culicoides to survive through the winter.

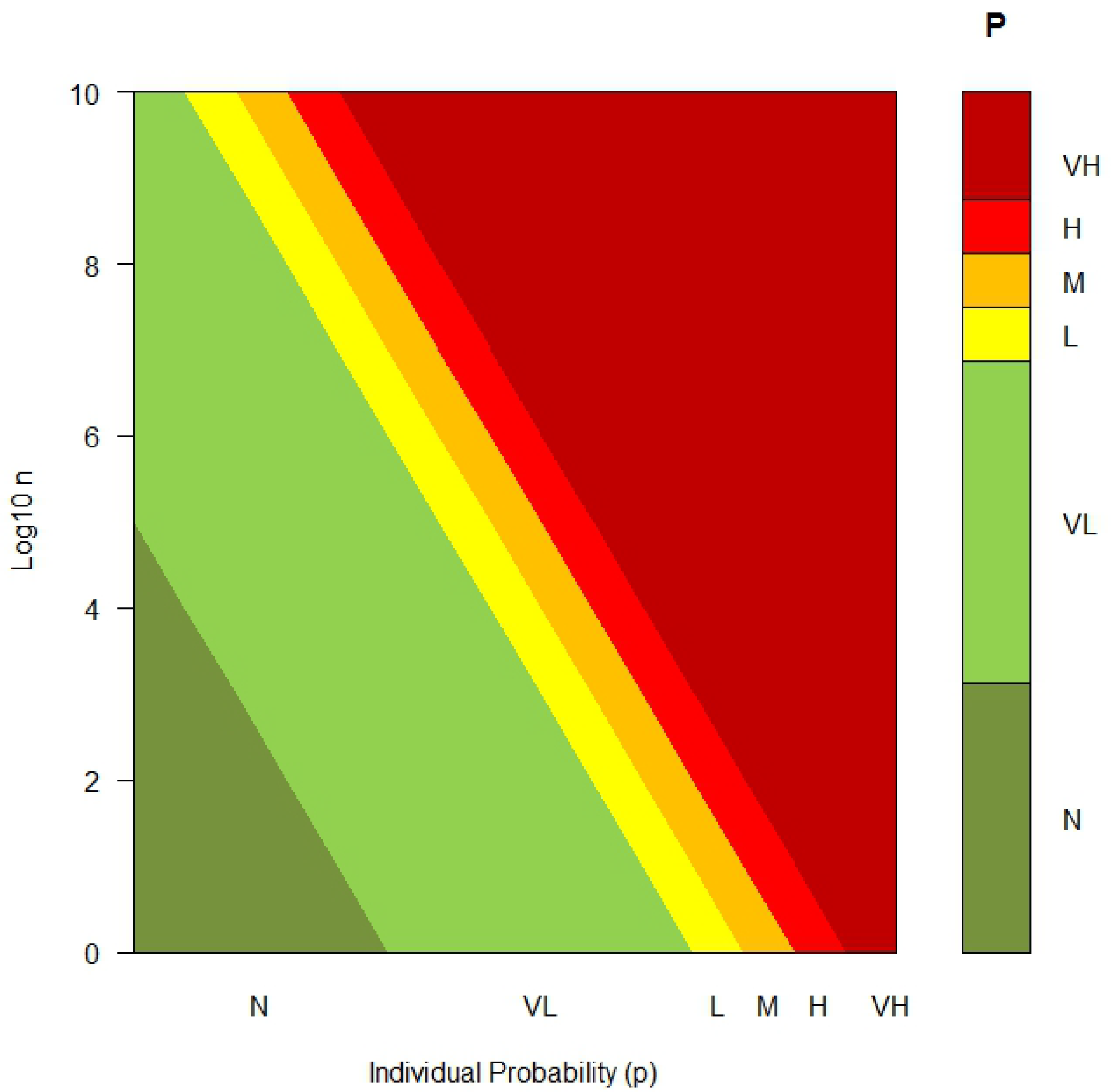


Figure 7: Contour plot, showing on the x axis individual probability (p) including negligible (N, dark green), very low (VL, light green), low (L, yellow), Medium (M, orange), high (H, light red) and very high (VH, dark red). On the y axis is the Log10 value which increases based on the number of samples. The x and y are multiplied to get aggregated probability scores (Adapted from Kelly et al. 2018).

Infectious vector reaching Great Britain and infecting an animal

Survival of BTV-infected Culicoides in northern Europe and subsequent entry into south-east England

The main route of BTV transmission is via infected Culicoides (2), notably the C. obsoletus (5) and C. pulicaris groups for Great Britain and northern Europe. In order for infected Culicoides to reach Great Britain, a number of events must occur, such as successful overwintering of the virus in northern Europe and initial travel of infected Culicoides from the affected areas, over the English Channel. Such long-distance travel is assisted by the wind, although active movement from the midge is required to stay airborne (22).

Specifically, we were interested in the suitability of weather conditions in France, Belgium, the Netherlands, Germany and Denmark, as these influence the likelihood of infected Culicoides entering Great Britain. We are also interested in the suitability in southern England, the wind direction and humidity. The estimates for temperature suitability for Great Britain, France, Belgium, Netherlands, Germany and Denmark during the 2023 vector period are set out in Table 5. In this risk assessment we are assuming that for previous years there was a similar pattern for temperature suitability each month. For the months measured (August 2023 to January 2024), estimates were very high every fortnight from August through to October, suggesting that temperatures during this would have been optimal for BTV transmission. It is also possible that in the months leading up to August 2023 (May to July), meteorological conditions would have been suitable for infected Culicoides to enter Great Britain, but no data was recorded for the months prior to August. Temperatures in northern Europe are likely to become suitable for midge activity from April onwards, and virus replication will be possible sometime after that.

Table 5: Qualitative risk estimates for temperature suitability for each country in Europe and Great Britain during the 2023.

Date	Suitability of temperature in France	Suitability of temperature in Belgium	Suitability of temperature in Netherlands	Suitability of temperature in Germany	Suitability of temperature in Denmark	Suitability of temperature in Great Britain
02 August 2023	Very high	Very high	Very high	Very high	Very high	High
16 August 2023	Very high	Very high	Very high	Very high	Very high	High
30 August 2023	Very high	Very high	Very high	Very high	Very high	High
08 September 2023	Very high	Very high	Very high	Very high	Very high	High
13 September 2023	Very high	Very high	Very high	Very high	Very high	Very high
27 September 2023	Very high	Very high	Very high	Very high	Very high	Medium
11 October 2023	Very high	Very high	Very high	Very high	Very high	Medium
25 October 2023	Medium	Medium	Medium	Medium	Low	Low
08 November 2023	Low	Low	Low	Low	Very low	Low

Date	Suitability of temperature in France	Suitability of temperature in Belgium	Suitability of temperature in Netherlands	Suitability of temperature in Germany	Suitability of temperature in Denmark	Suitability of temperature in Great Britain
22 November 2023	Low	Low	Low	Low	Very low	Very low
06 December 2023	Very low	Very low	Very low	Very low	Negligible	Very low
20 December 2023	Low	Low	Low	Very low	Negligible	Low
03 January 2024	Low	Low	Low	Very low	Negligible	Low
17 January 2024	Very low	Very low	Very low	Negligible	Negligible	Very low
Overall, calculated as highest or sum	Very high	Very high	Very high	Very high	Very high	Very high

The risk of a windborne Culicoides incursion will increase during the vector activity season as the season progresses due to the increased likelihood of viraemic hosts in coastal areas of continental Europe. During an outbreak, the number of infected (and therefore viraemic) hosts increases and, as a consequence, the number of infected Culicoides also increases and similarly the likelihood that one will be carried by the wind as they will be close enough to the coast. It will also depend on there being present a high density of susceptible (naïve) animals in areas where infected Culicoides arrive.

The pathway for entry of infected Culicoides into Great Britain from northern Europe is set out in Figure 8 and requires the infected adult Culicoides to blow over after BTV overwintered in northern Europe.

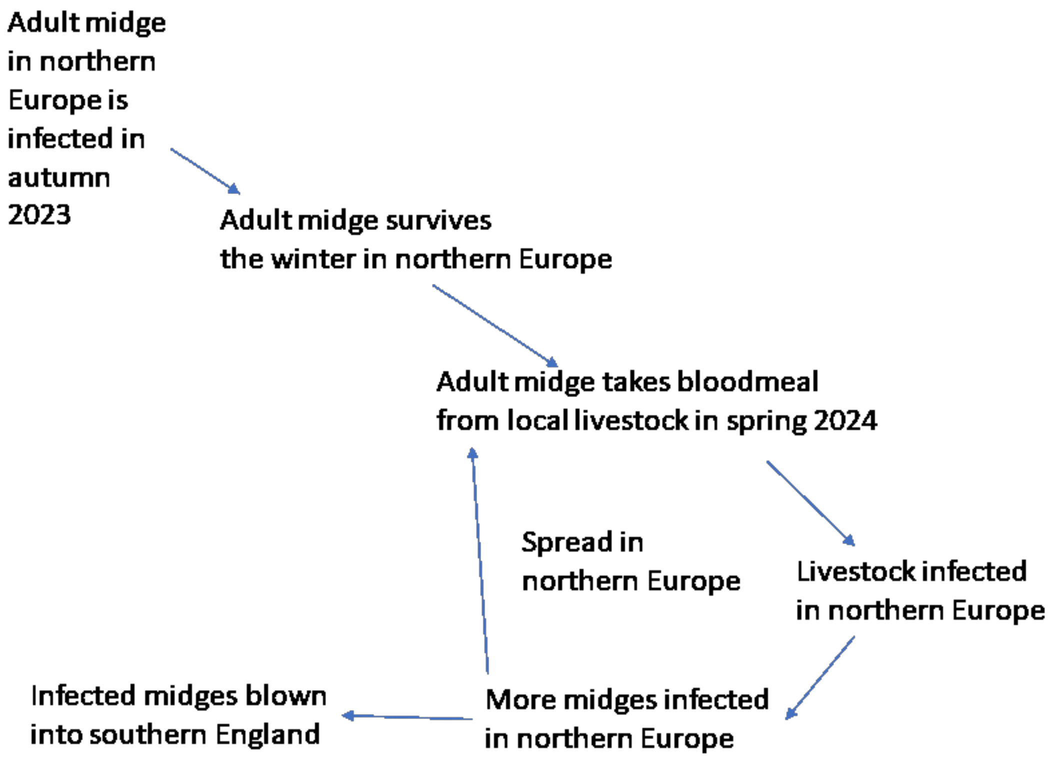


Figure 8: Entry of BTV-3 into Great Britain from northern Europe in 2024, in a scenario where an infected adult female Culicoides is able to survive the winter, then later bite a susceptible host causing infection in the livestock, providing an opportunity for other previously uninfected Culicoides to feed and become infected, continuing the cycle, then some infected Culicoides are carried over to England by the wind.

BTV-3 from northern Europe

During 2023, there were large numbers of incidents of BTV-3 in livestock in the Netherlands (6,001 incidents), as well as some reports in Belgium and Germany. If BTV-3 is able to successfully overwinter in these countries such that disease spreads within the livestock population in northern Europe in 2024, then there is a very high likelihood that BTV-3 infected Culicoides will reach Great Britain at some stage. BTV-8 reached northern Europe for the first time in 2006 affecting 2,000 holdings before reports ceased in January 2007. The outbreak then re-emerged months later and spread to a further 45,000 holdings by the end of 2007 (Wilson et al 2008). Thus, BTV-8 overwintered in the Netherlands in 2006 to 2007. Table 6 compares the mean temperatures in Maastricht in south-east Netherlands in the winter 2006 to 2007 with those of 2023 to 2024. While mean temperatures in

Maastricht were higher in December, February and March in 2023 to 2024 compared to 2006 to 2007 the mean temperature for January 2024 was 3.5°C lower than that for January 2007.

Table 6: Comparison of mean temperatures (°C) and ranges (monthly average minimum to monthly average maximum) in Maastricht (south-east Netherlands) for the winter of 2006 to 2007 and the winter of 2023 to 2024 (65).

Month	Maastricht 2006 to 2007 temperature (°C)	Maastricht 2023 to 2024 temperature (°C)	Difference in mean temperature (°C)
November	9.1 (3.4 to 15.7)	7.5 (0.8 to 12.1)	–1.6
December	6.0 (0.0 to 13.3)	6.5 (–1.5 to 10.8)	+0.5
January	6.6 (–2.9 to 12.7)	3.1 (–5.6 to 10.7)	–3.5
February	6.4 (–0.7 to 9.9)	8.0 (3.7 to 13.3)	+1.6
March	7.8 (2.7 to 11.4)	9.2 (5.7 to 12.8)	+1.4

Estimation of the probability that an infected Culicoides in the autumn 2023 manages to infect a livestock animal in the following spring 2024 in northern Europe.

Note the units are ‘per autumn Culicoides midge’.

1. The probability that an adult Culicoides is infected in autumn in northern Europe is low. This takes into account the large number of infected livestock in northern Europe (mainly the Netherlands) in autumn 2023. Were there to be fewer infected animals as in Great Britain (see above) then this probability would be very low. There is a medium level of uncertainty for this, but the probability is likely to be higher than that of Great Britain due to the number of reported cases seen on the continent in 2023.

2. The probability that an adult Culicoides survives the winter in northern Europe is assumed to be very low. Only a small proportion will be capable of surviving the unfavourable winter conditions. Comparing mean monthly temperatures in England for winter 2023 to 2024 in Table 3 with those for Maastricht in Table 6 suggests that the December and January mean temperatures were slightly lower in northern Europe. Overall, it is assumed that the probability of survival of Culicoides in northern Europe is similar to that in Great Britain and that

probability for Culicoides surviving over winter is very low. There is a medium level of uncertainty for this based on the limited amount of data available.

3. The probability that an adult Culicoides takes a bloodmeal from local livestock in spring in northern Europe is medium based on the assumption that host seeking behaviour will resume when temperatures are suitable, and based on the possibility that Culicoides may bite wild mammals rather than livestock. There is a high level of uncertainty as post overwintering behaviour of a surviving Culicoides is unknown and host selection in some vector species has been shown to be highly opportunistic (76).

4. The probability that livestock is infected after a bite from an infected Culicoides is high as one bite from a BTV-infected Culicoides adult female is sufficient to initiate infection in a naive livestock animal and the livestock animal is likely to be naïve even in Europe. Due to the significant number of livestock cases in Europe, there may be some herd immunity on the Continent. However, the 'on-farm' prevalence in Netherlands was reported to be only 5% to 30% so the majority of the livestock population will still be immunologically naïve not taking into account replacement animals over the winter. There is a proposed study (69) in the Netherlands to determine the percentage of sheep and cattle in 2024 with antibodies to BTV-3. There is a medium level of uncertainty for this high probability depending on the immune status of the livestock in northern Europe.

5. The overall probability that at least one livestock animal is infected in the spring 2024 in northern Europe per Autumn Culicoides midge is calculated as very low. This is a combination of the probabilities above such that the product of 'low and very low' (in steps 1 and 2) is 'very low', albeit at the negligible end of 'very low'. The uncertainty is limited by medium uncertainties in the lowest risk steps in the pathway, namely probabilities 1 and 2 above. There is therefore a medium level of uncertainty for this.

The probability that an autumn Culicoides in northern Europe infects a livestock animal with BTV-3 the following spring in northern Europe is calculated as very low per Culicoides (see above). This is validated against the modelling predictions of Napp et al. (61). Modelling by Napp et al. (61) for Germany indicated that overwintering was only possible for vectors infected during the period of low vector activity (PLVA) that infected the host after this period finished, and only by vectors that emerged after January with mean probabilities (per Culicoides) increasing from 0 per Culicoides in December and January to 5.9×10^{-8} per Culicoides in February, 9.2×10^{-8} per Culicoides in March and 1.1×10^{-7} per Culicoides in April. While these transmission probabilities are qualitatively more in the negligible range per Culicoides (lower than the very low probability per Culicoides predicted above), it should be noted that levels of BTV-3 across northern Europe may have been higher in 2023 than in 2006 to 2007. Also, Napp et al. (61) do not appear to take into account that Culicoides may survive up to 3 months at 10°C according to Lysyk and Danyk (59).

As set out above, the probability that that at least one livestock animal is infected with BTV-3 in 2024 per autumn midge in northern Europe is very low. To calculate the aggregated probability that at least one livestock animal is infected with BTV-3 in spring 2024 in northern Europe requires a quantitative estimate of the number of autumn Culicoides in northern Europe. While this number is unknown, it is undoubtedly huge, such that the aggregated probability that at least one livestock animal is infected with BTV-3 in spring in northern Europe is very high according to Figure 7. The uncertainty is high reflecting lack of information on the number of overwintering Culicoides in northern Europe.

Estimations for the probability that BTV-3 infected Culicoides enter Great Britain in 2024 from northern Europe

1. The probability that at least one livestock animal is infected with BTV-3 in the spring 2024 in northern Europe is very high (see above). The individual probability is very low, but when aggregated, due to the huge numbers of Culicoides this becomes very high (Figure 7). The uncertainty for this is high, as there is no way to confirm accurate numbers of Culicoides.

2. The probability that more Culicoides become infected in northern Europe is very high with high uncertainty. This assumes that there will be spread within livestock in northern Europe and there is no immunity in livestock in Europe to BTV-3.

3. The probability that Culicoides transported by wind from northern Europe into southern England taking into account temperature conditions for BTV transmission in northern Europe is very high when combining the risk for France, Belgium, the Netherlands, Germany and Denmark. The level of uncertainty is low based on observations from 2023.

4. The overall probability that BTV-3 infected Culicoides enter Great Britain from northern Europe in 2024 is very high, calculated based on the combined risks

of the steps above. The uncertainty for this is high, based on uncertainty that BTV-3 overwinters in northern Europe.

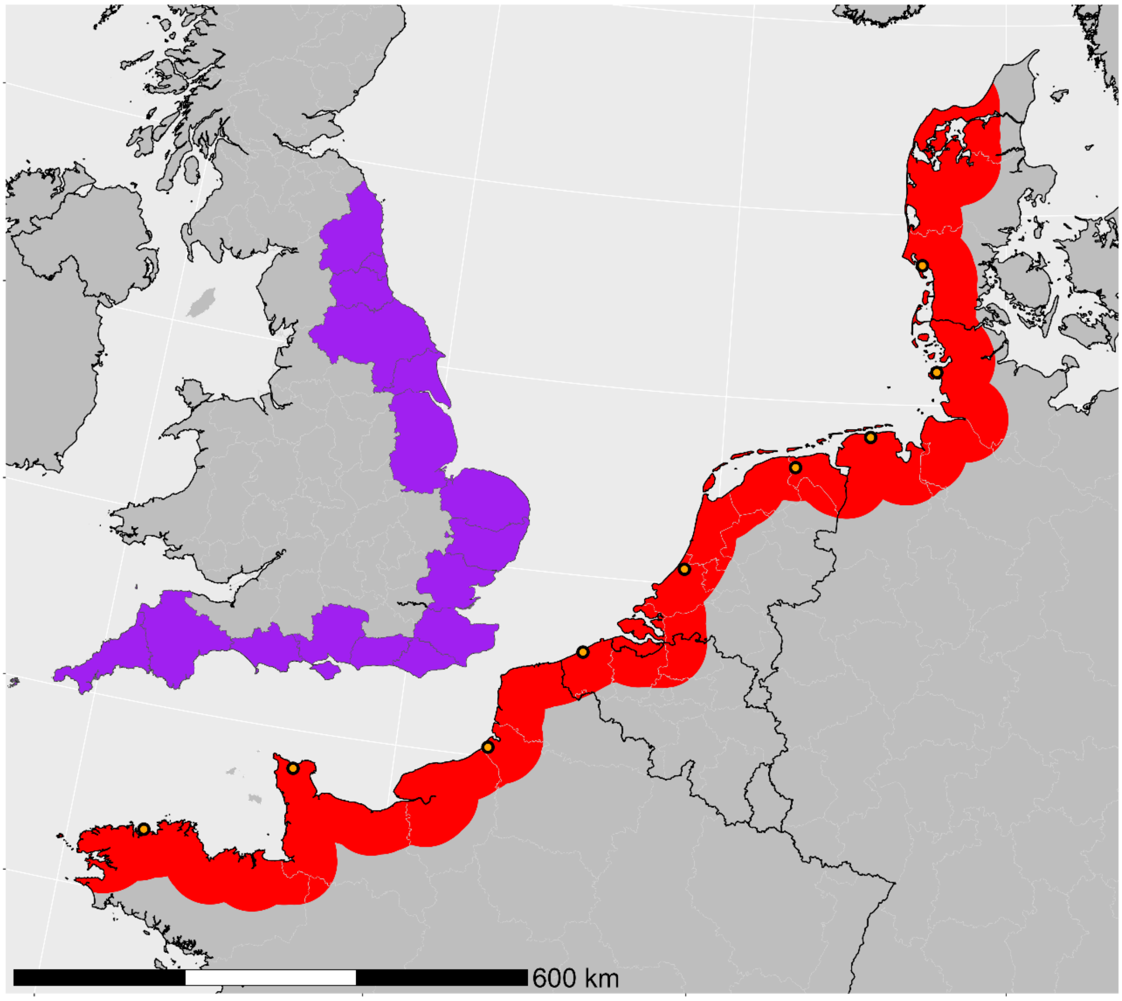
BTV-8 from France

For BTV-8 the annual likelihood of BTV entry into Great Britain via windborne incursion is considered to be medium**.** The uncertainty is high primarily due to the lack of consolidated data in France and the uncertainty around the monthly surveillance being carried out in France in sentinel herds. There is a potential time lag in reporting new cases of either BTV-8 or the 'new strain' of BTV-8 further north. Additionally, the extent of the spread of the 'new strain' of BTV-8 is unknown. Viraemic animals from the affected areas in central France could move quite legally to other premises in the north. It should be noted that although BTV-8 has been in France since 2015, Great Britain has remained BTV free, suggesting that there have been no windborne incursions of infected Culicoides resulting in infected livestock. However, the 'new strain' of BTV-8 has spread rapidly through the south of France and presents a possibility of increased infection pressure. This may lead to new foci of BTV, which would increase the likelihood of infected Culicoides arriving along the south coast of England.

Initial location of an infectious vector

When France first reported BTV-8 in 2015, the Met Office carried out modelling of the likely wind-borne distribution of Culicoides from the area of the outbreak in the days leading up to reporting. During the vector-active season, Met Office Numerical Atmospheric-dispersion Modelling Environment (NAME) model is used to conduct regular risk assessments of the potential for windborne incursion of BTV-infected Culicoides into Great Britain from continental Europe (in the 2023 to 2024 season, these were generally held fortnightly except for a period of weekly assessments following the emergence of BTV-3 in the Netherlands they are currently still being held weekly) (Nelson et al., 2022). The NAME model relies on a combination of current meteorological data and known relationships between Culicoides population data and meteorological conditions to predict the windborne movement of Culicoides from coastal areas of continental Europe across the English Channel and North Sea. Although the NAME model does not consider overland movement of vectors, it is considered plausible that infected livestock within 50km of the northern coast of France, Belgium, the Netherlands, or Germany, or the western coast of Denmark, could give rise to infected vectors able to be blown into Great Britain (30,56) (Figure 9).

In the event of disease overwintering successfully, the risk of incursion from windborne vector movement will continue to be retrospectively estimated on a regular basis using such modelling. At present, we cannot predict the risk of incursion in advance as the average daily temperature and wind direction cannot be determined so far in advance.



1Figure 9: The counties in the south, south-east and north-east of England at risk of windborne incursion determined by NAME model outputs (shown in purple) and a 50km wide area of northern coast of France, Belgium, the Netherlands, Germany and the west coast of Denmark considered to be most likely to lead to windborne incursion of Culicoides in Great Britain (shown in red).

It is important to note that while BTV-8 was able to reach Great Britain during the 2007 to 2008 outbreak, and the point of entry was Suffolk to Essex (although it is likely that there were at least 2 separate incursions) (31) a similar event occurred in 2023 with BTV-3, where BTV-3 was first discovered in Kent then shortly after in

Norfolk and Suffolk. Data for 2023 highlighted that Kent, East Sussex, Essex and Suffolk had the greatest number of meteorological events suitable for windborne incursion of Culicoides (Figure 10) It is difficult to extrapolate if there will be similar meteorological conditions in 2024, but if this is the case then we would expect both the south coast and east coast to be at risk.

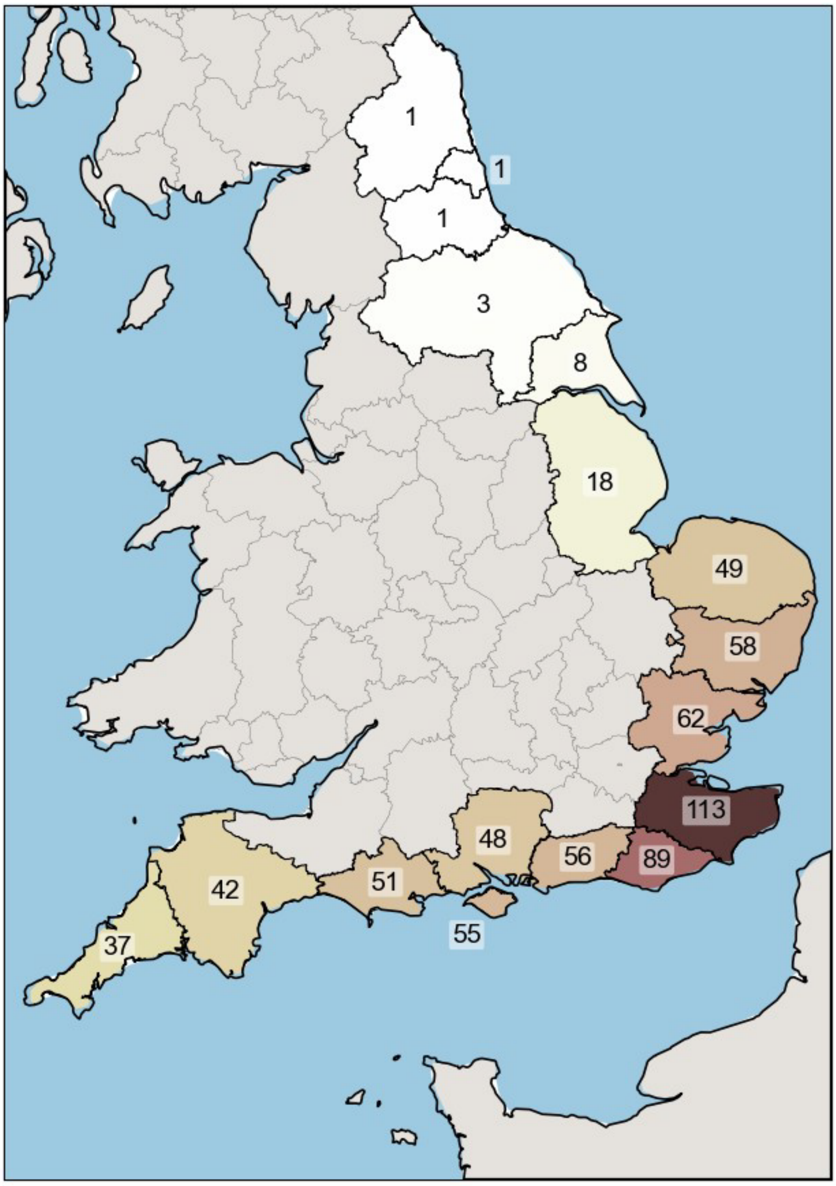


Figure 10: The counties in the south, south-east and north-east of England at risk of windborne incursion determined by NAME model outputs, and the number of meteorological events that occurred, which were capable of transporting Culicoides to Great Britain, between April and October in 2023.

Figure 10 shows that the most meteorological events suitable for transporting Culicoides between April and October 2023 occurred in south-east England. Specifically in Kent, this county had 113 events. East Sussex and Essex also had a large number of events at 89 and 62 respectively. North-east England had much lower numbers of meteorological events in 2023, with Tyne and Wear, Durham and Northumberland all having just 1 suitable event.

Culicoides can be blown long distances over sea by the wind (EFSA AHAW Panel, 2009). The maximum possible distance postulated for Culicoides dispersal is 700km over sea, or 150km over land (Mellor, Boorman and Baylis, 2000, Hendrick et al., 2008, Mintiens et al., 2008, Nelson et al., 2022). At this time, it is not known which parts of France are affected by the new strain of BTV-8 or the endemic strain of BTV-8, but the north coast of France is within this postulated dispersal distance. There is a lot of uncertainty regarding the location of BTV-8 in France and uncertainty surrounding the level of surveillance being carried out.

Regarding BTV-3, in the 2023 vector season, there were numerous cases that were previously in the 50km high likelihood areas in Belgium, the Netherlands and Germany. If BTV-3 successfully overwinters in these areas, there will be a very high risk of windborne incursions happening in 2024. The presence of cases of BTV-3 in England in the previous season highlights the large geographic jumps that can be made by the virus. If BTV infected Culicoides are able to reach Great Britain and infect livestock, the south-east of England will be most suitable for BTV infection as this is the warmest region of Great Britain (Figure 11). Additionally, livestock density will be a factor, south-west England has warm temperatures and large livestock populations, making this area also suitable for BTV infection.

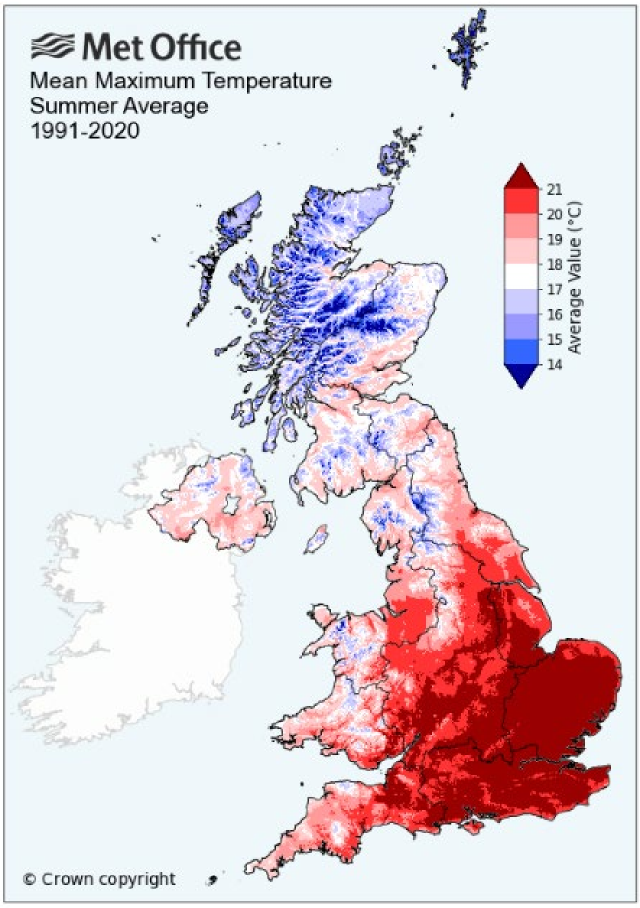


Figure 11: Weather data for the United Kingdom between 1991 to 2020, highlighting that south has warmer mean maximum temperatures than the north, with south-east England being the warmest at 21°C (dark red), and Scotland being the least warm with a maximum mean of 14°C (dark blue) (Met Office, no date).

Time period of risk

Meteorological events with conditions suitable for Culicoides movements to Great Britain in 2023 are highlighted below (Table 7). This data looks at the areas in which incursions were predicted for 2023. It is difficult to determine from 2023 data if there will be a similar pattern in 2024 and it should also be noted that the vector populations peak around the end of May to June, and September. When vector populations are high there is a greater risk of incursions, assuming that meteorological events are suitable. Therefore, there is a strong correlation between the vector population and the greatest number of suitable meteorological events for 2023 occurring between June to September (Table 8). Additionally, Culicoides will not fly in strong wind or heavy rain (28). Previous studies, looking at various sources, showed the south and south-east coast of Great Britain to be more exposed to wind patterns that would be sufficient for vector movement (29).

Table 7: Number of events with meteorological conditions suitable for potential incursions into Great Britain coastal counties each month during 2023 vector season. Note that there can be a maximum of 2 incursion events per day, one for sunrise Culicoides activity and one for sunset activity.

County	April	May	June	July	August	September	October
Cornwall	1	4	5	2	4	12	9
Devon	2	3	5	8	4	17	3
Dorset	4	4	11	9	5	15	3
Hampshire	3	4	9	10	5	11	6
Isle of Wight	5	3	10	8	7	13	9
West Sussex	4	4	14	9	6	14	5
East Sussex	8	11	20	12	12	21	5
Kent	9	14	26	12	15	27	10
Essex	6	6	19	3	5	16	7
Suffolk	4	4	21	5	4	16	4
Norfolk	2	3	18	4	4	15	3
Lincolnshire	0	2	10	2	0	1	3
East Riding of Yorkshire	0	0	7	1	0	0	0
North Yorkshire	0	0	2	1	0	0	0

The time of year at which virus transmission re-occurs in northern Europe and then the time of year at which it spreads are both likely to play crucial roles in the likelihood of BTV entry to the Great Britain. Assuming that the virus is present, transmission would be expected to resume in northern Europe from around April to May onwards, depending on the average daily temperature.

The mean temperatures over the past 140 years across the whole of the UK are plotted below (Figure 12). Assuming a minimum mean temperature for virus replication of 12ºC to 15ºC (Carpenter et al., 2011), in an average year, temperatures would be high enough for BTV to replicate within a vector between May and September.

2

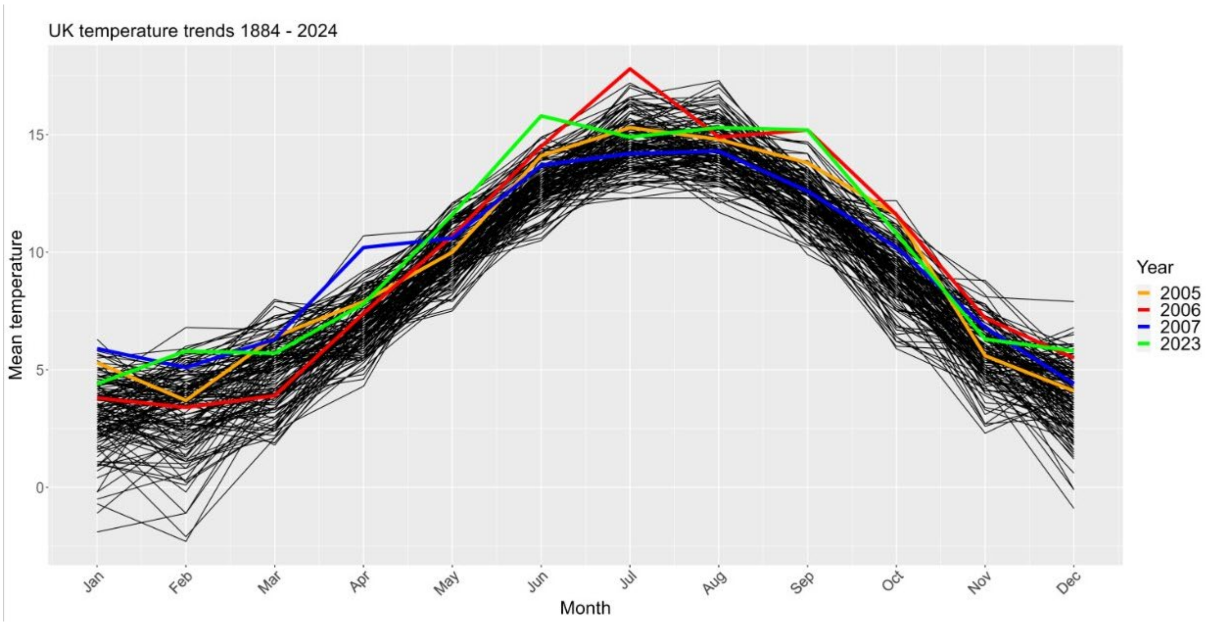


Figure 12: Daily mean temperatures within the UK for each year from 1884 to 2024, showing that the mean temperatures are greatest between May and October, and highlighting 2005 which had a cold February. 2006 which had the highest peak temperature (red), 2007 which had a much warmer April (blue) and 2023 temperatures which is most recent (green).

Incursion through imported live animals

Under the conditions of the health certificate requirements, live ruminants imported from EU countries must have been resident within holdings since birth or within 40 days prior to export, in an area where there have been no BTV cases within a 150km radius within the previous 60 days (WOAH, 2021). Animals imported from EU countries which have not been free from BTV in the past 24 months and are not seasonally disease free must also have been isolated before export and they must have received the appropriate vaccine.

If the animal originates from a country affected by BTV, the animals are banned from entering Great Britain, unless the animal is vaccinated against the correct serotype or is naturally immune. Currently, as there is no commercially available vaccine for BTV-3, countries affected with BTV-3 are unable to comply with the health certificate requirements. This means that at this time, Belgium, Germany and the Netherlands are unable to send livestock to Great Britain. Additionally, France is currently also affected by epizootic haemorrhagic disease virus serotype 8 (EHDV-8) a similar disease to BTV for which there is no vaccine. Therefore, livestock from France cannot meet the health certificate requirements at this time. Further details on how bluetongue in Europe is affecting imports is published on GOV.UK: Imports, exports and EU trade of animals and animal products: topical issues. Due to testing requirements of livestock entering Great Britain and surveillance it is highly unlikely that moves would be permitted. The uncertainty is low.

The overall risk of importing livestock infected with BTV into Great Britain from Europe is very low with low uncertainty. It should be noted that it is possible that undetected spread to neighbouring countries could occur. For example, there is a small risk of BTV-3 reaching Denmark without being detected and in this scenario, it is plausible that an infected animal may be sent to Great Britain (Figure 13). To mitigate this risk, Great Britain conducts post import testing on livestock from Demark. Complete vector control is difficult to achieve (Carpenter, Mellor and Torr, 2008), therefore, animals may still become infected with BTV during pre or post movement isolation. Partly for this reason, the animals need to have tested negative on 2 separate occasions. The first test must have been conducted at the point of isolation and the second test at least 28 days later, but within 10 days of export.

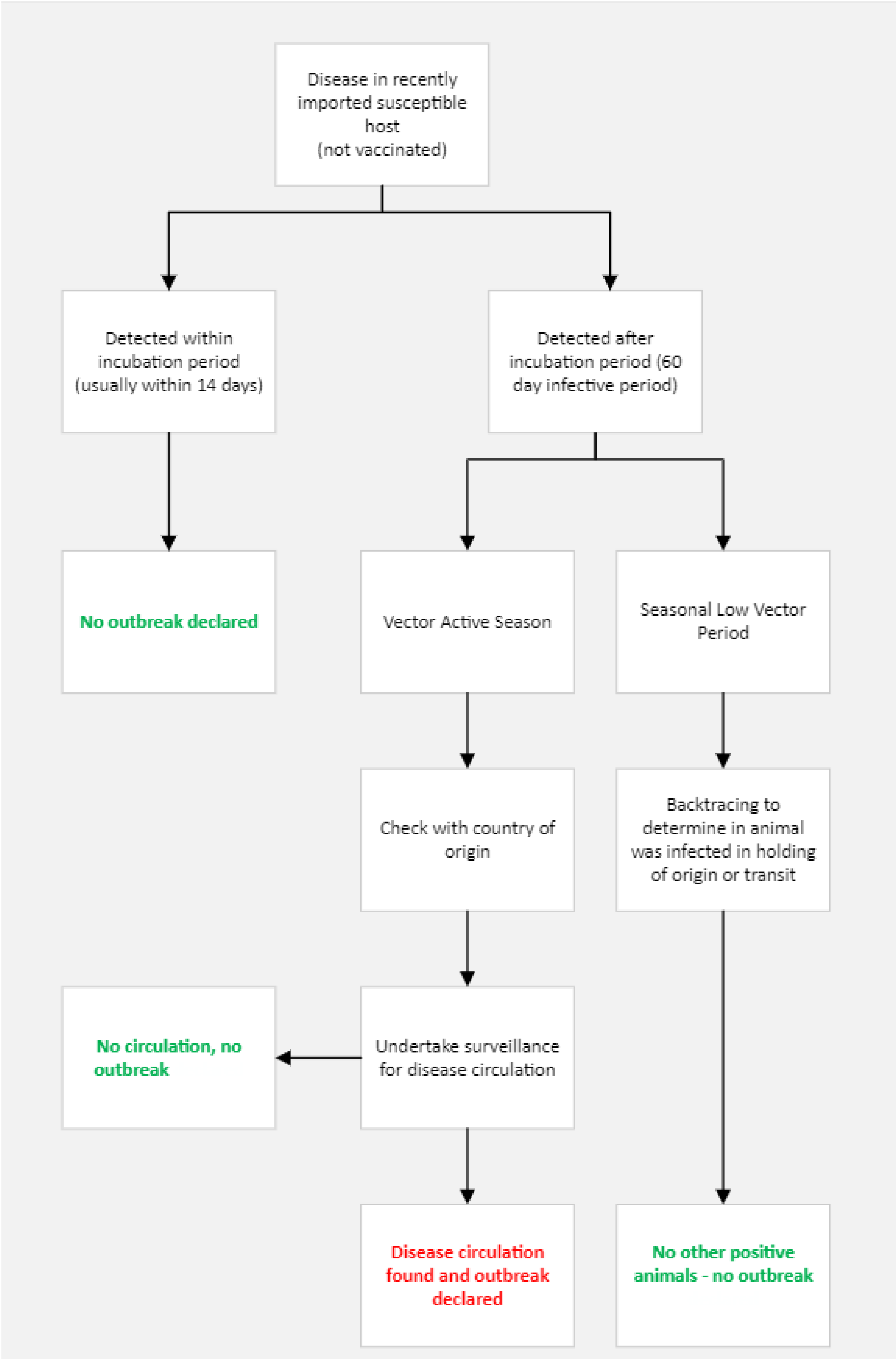


Figure 13: Risk pathways for importing infected live susceptible animals in a scenario where there has been undetected spread to a country with no known presences of BTV and the animal is not vaccinated.

Figure 13 highlights 4 scenarios when importing an unvaccinated infected animal. If detected during the incubation period, no outbreak would be declared. If detection occurs during the infectious period and Great Britain is in the seasonal vector low period (SVLP), back tracking is conducted to determine if the animal if infected at the origin or during transit. As circulation cannot occur during the SVLP, no outbreak occurs. If this same scenario occurs in the vector active season, surveillance must be conducted to determine if circulation has occurred, if this is found to be the case an outbreak would be declared.

The annual average number of BTV-8 infected livestock which would not be detected by serological testing or clinical checks before leaving isolation in Great Britain was estimated to be 0.04 (rounded to 1 significant figure) (72). This is a conservative estimate, based on the assumption that 100 animals per month are imported from an affected country (when there has been undetected spread). However, the actual number of live animals imported is likely lower, therefore, the annual likelihood of BTV entry into Great Britain, is likely to be lower. This likelihood is also based on a worst-case assumption that infected animals would remain infectious for up to 60 days.

Under the conditions of the health certificates, live ruminants may not pass within 10km of an BTV case reported within the past 30 days while being transported. However, Culicoides have the potential to disperse up to 150km over land by the wind (Nelson et al., 2022). Therefore, 10km is not necessarily far enough away from reported cases to prevent the animals from being exposed to BTV infected Culicoides during transit, particularly if transport vehicles stop off along the way (Nelson et al., 2022).

While infection during transit cannot be ruled out, there are no known reports of live ruminants becoming infected with BTV in this way. It is also unlikely that an infected Culicoides would bite an animal in a rapidly moving ventilated vehicle (Marion England, The Pirbright Institute, personal communication, 2023).

Exposure assessment

Although the NAME modelling work described above only considers movement of infected vectors over water bodies, simulation models are also available which can simulate the spread of virus between farms, both through the movement of infected Culicoides vectors and the movement of infected livestock animals. These include The Pirbright Institute's (TPI's) Bluetongue Virus Transmission Model, a model run by Scotland Government's Centre of Expertise on Animal Disease Outbreaks (EPIC), and a model run by Liverpool University. These 3 models were all used following the re-emergence of BTV in France in 2015 to explore potential BTV-8 spread within Great Britain if infected vectors entered the south of England, and the TPI model has since been used to identify potential reasonable worst-case scenarios for BTV-3 spread within Great Britain following the incursion of infected Culicoides as well as due to the importation of infected livestock. These models explicitly include the impact of temperature on virus transmission (which can influence the biting rate, mortality rate, and rate of development of infectiousness in Culicoides) and were fitted to data from the 2007 BTV-8 outbreak in Great Britain, which remains the only large-scale outbreak the country has experienced to date. This parameterisation is considered appropriate for both the post 2015 and 2024 outbreak scenarios (S. Gubbins, The Pirbright Institute, personal communication, 2024).

The TPI modelling work from 2015 onwards explored the impact of different vector incursion locations and timings, different movement restrictions, different temperature profiles, as well as the impact of pre-existing immunity and vaccination. Some scenarios of particular interest are:

- incursion via infected Culicoides happening in spring (May), summer (July) or autumn (September), to account for seasonality in spread
- incursion via infected Culicoides happening at 3 locations in southern England (Hampshire, Kent and Suffolk), to account for differences in livestock demographics and risk of airborne vector incursions from continental Europe
- different historical temperature profiles, to account for the impact of temperature on vector behaviour and virus spread
- different movement restrictions (including zones with complete movement cessation as well as zones in which movements to areas of lower risk were not permitted)

The TPI modelling work commissioned in early 2024 was used to estimate a Reasonable Worst-Case Scenario (RWCS) for BTV-3 spread, which was then used to inform resource planning. As for previous work, the impact of virus incursion timing and location was considered, along with a range of different livestock movement restrictions. As well as vector-borne incursions, a number of scenarios relating to virus incursion through the importation of infected animals (cattle or sheep). As the focus was on a RWCS, it was assumed that daily temperatures were as for 2006 (which has consistently given the greatest amount of BTV spread in Europe for all years assessed over the last 20 years).

A total of 42 different scenarios were considered, representing:

- 2 different incursion dates (May and July)
- 7 different incursion locations
- 3 different movement restrictions approaches

Of the incursion locations, 2 are associated with the windblown movement of infected vectors into 5 randomly selected farms (informed by historical predicted vector incursions):

- east coast (Norfolk, Suffolk, Essex, Kent, East Sussex), to represent potential vector incursions from the Netherlands or Belgium
- south coast (Cornwall, Devon, Somerset, Dorset, Hampshire, Isle of Wight, West Sussex, East Sussex), to represent potential vector incursions from France

There are also 5 incursion locations associated with the importation of infected cattle or sheep into high livestock density areas of Great Britain:

- south coast (Cornwall, Devon, Somerset, Dorset, Hampshire, Isle of Wight, West Sussex, East Sussex), to represent potential vector incursions from France
- sheep into North Powys or South Powys
- sheep into Cumbria
- cattle into Cheshire, Staffordshire or Derbyshire
- cattle into Devon or Somerset
- cattle into Dumfriesshire or Ayrshire

The 3 movement restrictions approaches are:

- no movement restrictions
- 100km protection zones (PZs) and 150km surveillance zones (SZs) around detected premises
- PZs and SZs with 20km control zones (CZs) with complete movement restrictions maintained for the duration of the simulation

The following maps (Figure 14) are livestock demographic maps for sheep and cattle livestock density in both 2014 and 2022, which are used as inputs in the modelling work). These are still considered suitable representations of our livestock populations. The Pirbright model does not replay historical movements but generates similar movement patterns based on historical movement data (grouped by month and county). The post 2015 work used 2006 movement data and the 2024 work used 2019 data (selected to avoid any changes in movement patterns immediately following the COVID-19 pandemic).

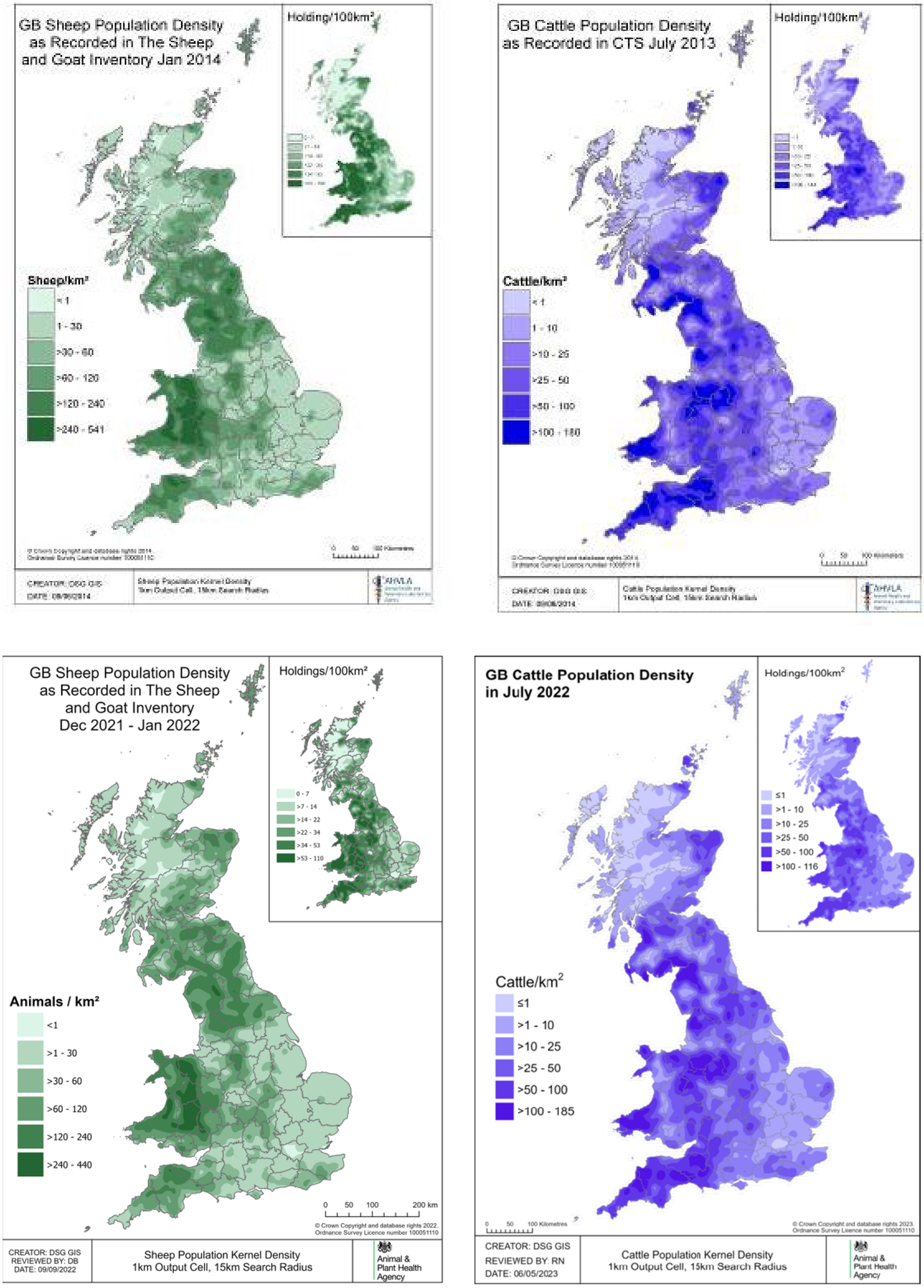


Figure 14: Data from the Sheep and Goat Inventory, January 2014 and January 2022 and the Cattle Tracing System, July 2013 and July 2022, highlighting the density of sheep and cattle in Great Britain. Wales, south-west and north England have the greatest populations of sheep and goat (Dark green) and cattle (dark blue).

Temperature

Temperature has a large impact on virus spread and is included in the TPI model as the daily temperature within a 5km gridded landscape across Great Britain (grid squares of 25km^2 in area) from a historical year. The impact of temperature was explored in the post-2015 work, which demonstrated that temperatures from 2007 (which had a relatively cool summer and autumn) resulted in lower amounts of spread than under temperatures from 2005, which themselves resulted in lower spread than temperatures from 2006 (which had the warmest summer and autumn (56). Temperature data from 2006 were therefore used for the RWCS modelling work in 2024.

As well as variation year on year, seasonal temperature fluctuations mean that virus spread varies over the course of a single year, with most spread occurring in the summer and autumn months. This can impact upon the probability of virus spread following initial entry. In the post 2015 modelling work, a baseline scenario with no controls showed that there was a high probability that an incursion of vectors in May, July or September would lead to an outbreak developing as a result, but that not all incursions will develop into cases and not all cases will lead to secondary spread. Similar results were obtained for the 2024 vector incursion scenarios work when the number of incursion locations was reduced from 5 to a single location. For the scenarios considering the import of (single) infected livestock, secondary virus spread only occurred in a minority of scenarios. Approximately 1 in 6 (single infected) imports in May and between 1 in 4 and 1 in 2 in July resulted in any onwards virus spread.

In cases where secondary spread occurs, the total number of farms which experience infection over the course of the year is greatest following incursions in May and lowest following incursions in September. This is of course related to the duration of the remaining vector period, the time needed for disease spread and the temperature under which BTV can replicate in the vector. The 2024 modelling (using 2006 temperature data) has also shown that even with May virus incursions, the vast majority (over 95%) of infections and detections occur between July and October (inclusive), with most in September or October. A peak of detection routinely occurs around late September.

The initial location of infection also impacts upon the number of farms which experience infection. In the post 2015 work, infected vector incursions into Hampshire led to more infected farms than those in Kent and in turn more than those in Suffolk. Similarly, in the 2024 work, incursions into the southern coastal counties generally resulted in larger numbers of infected farms than those in the eastern coastal counties. These patterns are related to livestock density. When considering virus entry through livestock import, the total outbreak size also varies depending on the initial infection location, with the largest outbreaks (amongst simulations in which secondary spread occurred) following from initial infection in Cheshire, Staffordshire, and Derbyshire, or in Devon and Somerset. The scale of these outbreaks was comparable to those following vector incursions.

Movement controls

Measures to prevent and control incursions of bluetongue are outlined in the Great Britain Bluetongue Virus Disease Control Strategy. The main controls once disease is confirmed to be circulating in the Culicoides population rely on movement controls and vaccination. In the absence of an authorised vaccine for bluetongue serotype 3 (BTV-3) the main controls rely on slowing the spread of the virus through movement controls. Such controls would be given effect by establishing disease control zones that restrict movements of susceptible animals out of those zones, except under licences approved by APHA, to prevent transporting virus elsewhere. The size of such zones will depend on a number of factors, including the extent of geographical spread, and may change over time to reflect evolving circumstances.

Modelling work has shown that movement restrictions would be effective at reducing the total numbers of infected farms and the total spread of virus by the end of the season, but are not able to prevent spread. This is because they would not be expected to have any substantial impact on vector dispersal (which is considered to be responsible for the majority of virus movement). However, as livestock movements are able to move the virus over much longer distances than vectors are capable of, removing or reducing the range of these moves through restrictions is able to reduce the risk of distant seeding of new foci of infection. The 2024 modelling work showed that the relative impact of these measures are greater for May than July virus incursions. For May entries of infected vectors into either the east or the south of the country:

- PZs and SZs reduce the number of infected farms by about half (eastern entries) or one-quarter (southern entries)
- PZs, SZs and CZs reduce the number of infected farms by about five-sixths (eastern entries) or two-thirds (southern entries) for May incursions; with less of an effect for later incursions

Despite these findings, it is worthy of note that there are considerable challenges when attempting to model vector movement. The current TPI model assumes that vector movements occur as a random, diffusive, process, with the vast majority of between-farm moves occurring within a distance of around 25km (56). However, modelling vector movement in different ways could impact upon vector spread and therefore the predicted efficacy of movement restrictions.

Pre-existing immunity

There would be very limited immunity in animals in Great Britain for BTV-3 from the recovered animals in 2023 (7 sheep and 119 cattle were infected out of over 48,000 PCR tested samples, and all positive animals were serologically tested).

There would be very little immunity in animals in Great Britain for BTV-8, there may be some imported animals which would have received the BTV-8 vaccine as a requirement of the health certificate if they originated from a country affected with BTV-8.

Animals which are naturally infected are immune for life and will test positive for antibodies. Although vaccination is recommended to protect an animal for a single year, there are still likely to be residual antibodies as demonstrated by several authors and as confirmed by the OIE (now WOAH) and EU Reference Laboratory at the time (The Pirbright Institute) who demonstrated antibodies could be detected up to 4 years after vaccination (57, 58).

Our own testing of animals destined for third country exports has also highlighted those vaccinated animals still express antibodies several years later.

Summary of key uncertainties

There are several key uncertainties in this assessment that impact on the estimate of the likelihood of disease entry and exposure.

These uncertainties include:

- the extent of spread of different BTV serotypes, including the ‘new strain’ of BTV-8 in France and BTV-3 in Northern Europe over the coming months
- the level of vaccination used on the Continent against BTV-8, or any future vaccination against BTV-3 (amongst sheep and cattle) and the efficacy of these vaccines
- the suitability of climatic conditions (especially temperature) on the Continent for virus spread during 2024, higher temperatures (particularly over the summer and autumn months) would be expected to result in greater virus spread and wind patterns could potentially result in longer vector movement distances than are currently included in the model
- the frequency, timing, and locations of any potential windborne incursions of vectors into Great Britain from Northern Europe. Previous work conducted by the Met Office has demonstrated that this is highly variable year on year
- the probability of BTV-3 overwintering (through long-lived infected vectors, vertical transmission in ruminants and, or duration of viraemia)

- the suitability of climatic conditions in Great Britain for virus establishment and spread during 2024
- the impact of seasonality in livestock numbers and demographics (around lambing) on the risk of virus infection and spread
- the impact of livestock movement restrictions on livestock movement patterns within Great Britain, the introduction of movement restrictions may result in changes to movement patterns rather than a complete cessation of non-permitted moves (as is assumed in the model) in south-east England

Summary of key assumptions

This report assumes that:

- BTV-3 has similar transmission rates and overwintering mechanisms to BTV-8 with a lack of published data
- BTV-8 is circulating in northern France
- a large number of cases of BTV will occur in Belgium, Netherlands, Germany and northern France in 2024 if BTV-3 overwinters in Europe
- 2024 will have similar meteorological conditions in Europe to 2023
- over the course of the year, plumes of infectious vectors are likely to reach Great Britain
- BTV requires a minimum mean daily temperature of 12-15°C for virus replication
- Infected animals could remain infectious for up to 60 days
- there is very little, if any, herd immunity to BTV-3 or BTV-8 in Great Britain

Conclusions

The risk question is “What is the risk of BTV overwintering or being introduced into Great Britain (Great Britain) from northern Europe and infecting livestock at least once in 2024?”

The results of the risk assessment are summarised in. These represent the probability that at least one livestock animal in infected in Great Britain in 2024.

Table 9: Summary of risks of entry of bluetongue virus in Great Britain such that at least one livestock animal is infected in 2024.

Hazard	Route	Probability that at least one livestock animal is infected in Great Britain in 2024	Uncertainty
BTV-3	Overwintering in Culicoides in Great Britain	Very low	High
BTV-3	Entering Great Britain from northern Europe through windborne incursion	Very high	High
BTV-8	Entering Great Britain from northern France through windborne incursion	Medium	High
BTV-3 and BTV-8	Imported live animals	Very low	Low
BTV-3	Overwintering in livestock	Very low	Low

Given the current data, the number of cases of the ‘new strain’ of BTV-8 in France is unknown and was last reported to have spread across most of the south of France. The whole of France is being treated as a restriction zone, and so it is not known how far the disease has spread. Although BTV-8 itself does not prevent importation of susceptible livestock into Great Britain (these animals can be imported from countries affected by BTV-8 given that the animal is vaccinated and conforms with the Great Britain health certificate requirements), susceptible livestock cannot be imported from France due to the presence of EHDV-8, for which there is currently no vaccine. Similarly, the lack of an approved vaccine for BTV-3 means that it is not possible to import susceptible livestock from any countries affected with BTV-3 into Great Britain. For this reason, the risk of import of BTV in live animals is considered as very low. At present the risk of BTV-8 being introduced into Great Britain through windborne Culicoides is medium. The lack of consolidated data in France and the uncertainty around the monthly surveillance being carried out in France in sentinel herds contribute to the high uncertainty.

There was a brief cold snap in northern Europe in winter of 2023 to 2024 with temperatures in January 2024 in Maastricht in south-east Netherlands and in England on average lower by 3.5°C and 2.2°C respectively than that in January 2007 in Maastricht (Table 4) when BTV-8 overwintered in northern Europe. However, overall the winter of 2023 to 2024 has been very mild with the warmest February on record in England (63) and the winter monthly temperatures in England 2024 (Table 1) and in Maastricht 2023 to 2024 (Table 4) have generally been higher than those in Maastricht in 2006 to 2007. This may have made it easier for adult Culicoides to survive, but it is not clear how this would increase the likelihood of BTV overwintering.

Based on the numbers of infected livestock in 2023, with much higher numbers in northern Europe compared to south-east England, the probability that an autumn Culicoides was infected is assumed to be very low in south-east England but low in northern Europe. However, only a fraction of the Culicoides may survive the winter, and hence the probability of each individual Culicoides surviving the winter is assumed to be very low both in south-east England and northern Europe. By combining these scores, the probability that at least one livestock animal is infected in the spring of 2024 by an autumn midge is negligible for Great Britain and very low for Europe. The aggregated probability that BTV-3 reemerges in cattle or sheep is estimated to be very high in northern Europe in 2024 but only very low in south-east England. Thus, even if BTV-3 does not re-emerge in south-east England this year, there is the much higher probability that it will in northern Europe simply because of the higher infection prevalence last season.

There is also a possibility of BTV overwintering through other mechanisms, including transplacental transmission and viraemic animals in livestock. The risk of BTV-3 overwintering in livestock is thought to be very low with low uncertainty for Great Britain. But for Northern Europe, this risk is likely greater. Additionally, there is high uncertainty in overwintering in northern Europe because of lack of information on overwintering mechanisms, potential of infected Culicoides, rates of transplacental transmission in ruminants and duration of infectious viraemia.

Predicting the likely incursion and spread is therefore difficult particularly given the uncertainty around whether BTV-3 will overwinter in northern Europe and spread further, and regarding the new strain of BTV-8 in France. This new season will need to be monitored closely. Certain future events will trigger close monitoring such as the first clinical cases reported in northern Europe as confirmation of overwintering, and onward circulation of BTV-3 in previously affected countries or new territories adjacent to Great Britain such as Denmark or France. Any suspicion of disease in Great Britain must be reported promptly, and any changes will be carefully considered with regards to risk management.

References

1. World Organisation for Animal Health (WOAH)., Listed diseases 2024., Available at: https://www.woah.org/en/what-we-do/animal-health-and-welfare/animal-diseases/ (Accessed 15 April 2024).

2. Mintiens, K., et al., Possible routes of introduction of bluetongue virus serotype 8 into the epicentre of the 2006 epidemic in Northwestern Europe. Preventive veterinary medicine, 2008. 87(1): p. 131-144.

3. Schwartz-Cornil, I., et al., Bluetongue virus: virology, pathogenesis and immunity. Veterinary research, 2008. 39(5): p.1.

4. Chaignat, V., et al., Toggenburg Orbivirus, a new bluetongue virus: initial detection, first observations in field and experimental infection of goats and sheep. Veterinary microbiology, 2009. 138(1): p. 11-19.

5. Gould, E.A., et al., Potential arbovirus emergence and implications for the United Kingdom. Emerging infectious diseases, 2006. 12(4): p. 549.

6. Saegerman, C., D. Berkvens, and P.S. Mellor, Bluetongue epidemiology in the European Union. Emerging infectious diseases, 2008. 14(4): p. 539.

7. European Commission. Bluetongue: Bluetongue serotypes 6 and 11 vaccine-like strains circulation. 2017 Available at: Scientific opinion on bluetongue | EFSA (europa.eu) (Accessed 15 April 2024).

8. Gubbins, S., et al., Assessing the risk of bluetongue to UK livestock: uncertainty and sensitivity analyses of a temperature-dependent model for the basic reproduction number. Journal of the Royal Society Interface, 2008. 5(20): p. 363-371.

9. Turner, J., R.G. Bowers, and M. Baylis, Modelling bluetongue virus transmission between farms using animal and vector movements. Scientific reports, 2012. 2.

10. Turner, J., R.G. Bowers, and M. Baylis, Two-Host, Two-Vector Basic Reproduction Ratio (R0) for Bluetongue. PloS one, 2013. 8(1): p. e53128.

11. Defra, Updated Outbreak Assessment: Bluetongue virus (BTV-4) in Southern Europe. 2014.

12. Kelso, J.K. and G.J. Milne, A Spatial Simulation Model for the Dispersal of the Bluetongue Vector Culicoides brevitarsis in Australia. PLoS ONE, 2014. 9(8): p.e104646.

13. Mayo, C.E., et al., Seasonal and Interseasonal Dynamics of Bluetongue Virus Infection of Dairy Cattle and Culicoides sonorensis Culicoides in Northern California – Implications for Virus Overwintering in Temperate Zones. PLoS ONE, 2014. 9(9): p.e106975.

14. OIE, Handbook on import risk analysis for animals and animal products. 2004:Paris, France: OIE.

15. EFSA, Opinion on "Migratory birds and their possible role in the spread of highly pathogenic avian influenza". The EFSA Journal, 2006. 357: p. 1 - 46.

16. Wilson, A., K. Darpel, and P.S. Mellor, Where does bluetongue virus sleep in the winter? PLoS biology, 2008. 6(8): p. e210.

17. Wilson, A., et al., Re-emergence of bluetongue in northern Europe in 2007.Veterinary Record, 2007. 161(14): p. 487.

18. Wilson, A.J. and P.S. Mellor, Bluetongue in Europe: past, present and future. Philosophical Transactions of the Royal Society B: Biological Sciences, 2009. 364(1530): p. 2669-2681.

19. Githeko, A.K., et al., Climate change and vector-borne diseases: a regional analysis. Bulletin of the World Health Organization, 2000. 78(9): p. 1136-1147.

20. Gloster, J., et al., Will bluetongue come on the wind to the United Kingdom in 2007? The Veterinary Record, 2007. 160(13): p. 422-426.

21. DEFRA, International disease monitoring: Monthly report, February 2015. 2015.

22. Burgin, L.E., Gloster, J., Sanders, C., Mellor, P.S., Gubbins, S. and Carpenter, S. Investigating Incursions of Bluetongue Virus Using a Model of Long-Distance Culicoides Biting Culicoides Dispersal. Transboundary and emerging diseases, 2013. 60(3): p. 263-272.

23. Rogers, D. and S. Randolph, Climate change and vector-borne diseases. Advances in parasitology, 2006. 62: p. 345-381.

24. Carpenter, S., A. Wilson, and P.S. Mellor, Culicoides and the emergence of bluetongue virus in northern Europe. Trends in microbiology, 2009. 17(4): p. 172-178.

25. Hendrickx, G., et al., A wind density model to quantify the airborne spread of Culicoides species during north-western Europe bluetongue epidemic, 2006. Preventive veterinary medicine, 2008. 87(1): p. 162-181.

26. De Koeijer, A.A., et al., Quantitative analysis of transmission parameters for bluetongue virus serotype 8 in Western Europe in 2006. Vet Res, 2011. 42: p. 53.

27. Burgin, L. and M. Hort, An assessment of windborne incursion of FMDV into England and Wales from mainland Europe. 2013.

28. Sumner, T., et al., Comparison of pre-emptive and reactive strategies to control an incursion of bluetongue virus serotype 1 to Great Britain by vaccination. Epidemiology and infection, 2013. 141(01): p. 102-114.

29. Burgin, L. and G. Marris, An initial assessment of windborne incursion of Asian hornets into Great Britain. 2013.

30. Sedda, L., et al., A new algorithm quantifies the roles of wind and Culicoides flight activity in the bluetongue epizootic in northwest Europe. Proceedings of the Royal Society B: Biological Sciences, 2012. 279(1737): p. 2354-2362.

31. EFSA, Epidemiological analysis of the 2006 bluetongue virus serotype 8 epidemic in north-western Europe. 2007.

32. Defra, The Cattle Book 2008. 2008.

33. EBLEX, UK Yearbook 2014: Cattle. 2014.

34. Defra, Great Britain Bluetongue Virus Disease Control Strategy: August 2014. 2014.

35. Batten, C., et al., Bluetongue virus: European Community inter-laboratory comparison tests to evaluate ELISA and RT-PCR detection methods. Veterinary microbiology, 2008. 129(1): p. 80-88.

36. Defra. International trade: Importer information notes (IIN) - conditions for the movement of Bluetongue susceptible ruminant into Great Britain due to bluetongue control measures in the EU (IIN - BTEU - 1). 2014 Available via email- Imports@apha.gsi.gov.uk (Accessed 16 March 2015).

37. Gale, P., et al., Assessing the impact of climate change on vector-borne viruses in the EU through the elicitation of expert opinion. Epidemiology and infection, 2010. 138(02): p. 214-225.

38. Jones, A., D. Thomson, M. Hort, and B. Devenish (2007), Great Britain Met Office's next generation atmospheric dispersion model, NAME III, in Air Pollution Modelling and its Application, edited by C. Borrego and A.-L. Norman, pp. 580–589, Springer, New York.

39. Gubbins, S., Hartemink, N.A., Wilson, A.J., Moulin, V., Vonk Noordegraaf, C.A., vander Sluijs, M.T.W., de Smit, A.J., Sumner, T. & Klinkenberg, D. (2012) Scaling

from challenge experiments to the field: quantifying the impact of vaccination on the transmission of bluetongue virus serotype 8. Preventive Veterinary Medicine 105, 297-308.

40. Darpel, K.A. Batten, C.A., Veronesi, E., Williamson, S., Anderson, P., Dennison, M., Clifford, S., Smith, C., Philips, L., Bidewell, C., Bachanek-Bankowska, K., Sanders, A., Bin-Tarif, A., Wilson, A.J., Gubbins, S., Mertens, P.P.C., Oura, C.A & Mellor, P.S. (2009) Transplacental transmission of Bluetongue virus 8 in cattle, UK. Emerging Infectious Diseases 15: 2025-2028.

41. Menzies, F.D., McCullough, S.J., McKeown, I.M., Forster, J.L., Jess, S., Batten, C., Murchie, A.K., Gloster, J., Fallows, J.G., Pelgrim, W., Mellor, P.S. & Oura, C.A.L. (2008) Evidence of transplacental and contact transmission of bluetongue virus in cattle. Veterinary Record 163: 203-209.

42. Roberts, H.C., Elbers, A.R.W., Conraths, F.J., Holsteg, M., Hoereth-Boetngen, D., Gethmann, J. & van Schaik, G. (2014) Response to an emerging vector borne disease: Surveillance and preparedness for Schmallenberg virus. Preventive Veterinary Medicine 116: 341-349.

43. Elbers, A.R.W., Backx, A., Mintiens, K., Gerbier, G., Staubach, C., Hedrickx, G. & van der Spek (2008) Field observations during the Bluetongue seroype 8 epidemic in 2006 II. Morbidity and mortality rate, case fatality and clinical recovery in sheep and cattle in the Netherlands. Prev Vet Med 87: 31-40.

44. Defra (2015) QRA on incursion of BTV-4 from Europe.

45. Niedbalski, W. (2015) Bluetongue in Europe and the role of wildlife in the epidemiology of disease. 18: 455-461.

46. SCoFCAH (2012) Information demonstrating the absence of bluetongue virus circulation in continental France. Available at: [Bluetongue | EFSA (europa.eu)] (Accessed 16 March 2015).

47. SCoFCAH (2009) Fievre Catarrhale Ovine: Situation epidemiologique 2009. Available at: [Bluetongue | EFSA (europa.eu)] (Accessed 16 March 2015).

48. Conraths, F.J., Gethmann, J.M., Staubach, C., Mettenleiter, T.C., Beer, M. & Hoffmann, B. (2009) Epidemiology of Bluetongue virus serotype 8, Germany. Emerging Infectious Disease 15: 433 – 435.

49. Gosling, J. P., Hart, A., Mouat, D. C., Sabirovic, M., Scanlan, S. and Simmons, A. (2012), Quantifying Experts' Uncertainty About the Future Cost of Exotic Diseases. Risk Analysis, 32: 881–893. doi: 10.1111 - j.1539-6924.2011.01704.

50. EFSA (2011) Sceintific Opinion on bluetongue monitoring nad surveillance. EFSA Journal 9(6):2192.

51. EFSA (2017) Bluetongue: control, surveillance and safe movement of animals. EFSA Journal doi: 10.2903 - j.efsa.2017.4698

52. Sailleau C, Bréard E, Viarouge C, Vitour D, Romey A, Garnier A, Fablet A, Lowenski S, Gorna K, Caignard G, Pagneux C, Zientara S. (2017) Re-Emergence of Bluetongue Virus Serotype 8 in France, 2015. Transbound Emerg Dis. 64(3):998-1000. Brand SP & Keeling MJ. (2017) The impact of temperature changes on vectorborne disease transmission: Culicoides Midges and bluetongue virus. J R Soc Interface. 2017 Mar;14(128). pii: 20159481. doi: 10.1098 - rsif.2016.0481.

53. Drolet BS, Reister-Hendricks LM, Podell BK, Breitenbach JE, McVey DS, van Rijn PA, Bowen RA. (2016) European Bluetongue Serotype 8: Disease Threat Assessment for U.S. Sheep. Vector Borne Zoonotic Dis. 16(6):400-7.

54. Nusinovici S, Madouasse A, Fourichon C. (2016) Quantification of the increase in the frequency of early calving associated with late exposure to bluetongue virus serotype 8 in dairy cows: implications for syndromic surveillance. Vet Res.13;47:18.

55. Mayo C, Mullens B, Gibbs EP, MacLachlan NJ. (2016) Overwintering of Bluetongue virus in temperate zones. Vet Ital. 52(3-4):243-246.

56. Sumner T, Orton RJ, Green DM, Kao RR, Gubbins S. (2017) Quantifying the roles of host movement and vector dispersal in the transmission of vector-borne diseases of livestock. PLoS Comput Biol. 13(4):e1005470.

57. Batten, C.A., L. Edwards, and C.A.L. Oura, Evaluation of the humoral immune responses in adult cattle and sheep, 4 and 2.5 years post-vaccination with a bluetongue serotype 8 inactivated vaccine. Vaccine, 2013. 31(37): p. 3783-5.

58. Oura, C.A.L., L. Edwards, and C.A. Batten, Evaluation of the humoral immune response in adult dairy cattle three years after vaccination with a bluetongue serotype 8 inactivated vaccine. Vaccine, 2012. 30(2): p. 112-115.

59. Lysyk, T.J., and Danyk, T. (2007) Effect of temperature on life history parameters of adult Culicoides sonorensis (Diptera: Ceratopogonidae) in relation to geographic origin and vectoral capacity for bluetongue virus. J. Med. Entomol., 44(5), 741-751.

60. Courtejoie, N., Durand, B., Bréard, E., Sailleau, C., Vitour, D., Zientara, S., Gorlier, A.,Baurier, F., Gourmelen, C., Benoit, F. and Achour, H., 2018. Serological status for BTV-8 in French cattle prior to the 2015 re-emergence. Transboundary and emerging diseases, 65(1), pp.e173-e182.

61. Napp, S., Gubbins, S., Calistri, P., Allepuz, A., Alba, A., Garcia-Bocanaegra, I.Giovannini, A., and Casal, J. (2011). Quantitative assessment of the probability of bluetongue virus overwintering by horizontal transmission: application to Germany. Vet Res, 42:4.

62. Met Office (2024c) England Minimum Temperature (Degrees C) Available at: metoffice.gov.uk/pub/data/weather/uk/climate/datasets/Tmin/ranked/England.txt (Accessed 15 April 2024).

63. Met Office (2024b) England Mean Temperature (Degrees C) Available at: metoffice.gov.uk/pub/data/weather/uk/climate/datasets/Tmean/ranked/England.txt (Accessed 15 April 2024).

64. Met Office (2024a) England Maximum Temperature (Degrees C) metoffice.gov.uk/pub/data/weather/uk/climate/datasets/Tmax/ranked/England.txt (Accessed 15 April 2024).

65. Weather Underground. Beek, Limberg, Netherlands Weather History (2024) (Beek, Netherlands Weather History | Weather Underground. Available at: Local Weather Forecast, News and Conditions | Weather Underground (wunderground.com) (Accessed 15 April 2024).

66. Tugwell, L.A., England, M.E., Gubbins, S., Sanders, C.J., Stokes, J.E., Stoner, J., Graham, S.P., Blackwell, A., Darpel, K.E. and Carpenter, S., 2021. Thermal limits for flight activity of field-collected Culicoides in the United Kingdom defined under laboratory conditions. Parasites & Vectors, 14, pp.1-13.

67. Carpenter, S., Wilson, A., Barber, J., Veronesi, E., Mellor, P., Venter, G. and Gubbins, S., 2011. Temperature dependence of the extrinsic incubation period of orbiviruses in Culicoides biting Culicoides. PloS one, 6(11), p.e27987.

68. Boender, G.-J.; Hagenaars, T.J.; Holwerda, M.; Spierenburg, M.A.H.; van Rijn, P.A.; van der Spek, A.N.; Elbers, A.R.W. Spatial Transmission Characteristics of the Bluetongue Virus Serotype 3 Epidemic in The Netherlands, 2023. Viruses 2024, 16, 625. https://doi.org/10.3390/v16040625

69. Royal GD Netherlands., Research into antibodies and possible protective measures against bluetongue virus in sheep and cattle in the Netherlands., Available at: Research into antibodies and possible protective measures against bluetongue virus in sheep and cattle in the Netherlands (gddiergezondheid.nl) (Accessed 15 April 2023).

70. Gu, X., Davis, R.J., Walsh, S.J., Melville, L.F. and Kirkland, P.D., 2014. Longitudinal study of the detection of Bluetongue virus in bull semen and comparison of real-

time polymerase chain reaction assays. Journal of Veterinary Diagnostic Investigation, 26(1), pp.18-26.

71. Givens, M.D., 2018. Review: Risks of disease transmission through semen in cattle. Animal 12: s165–s171.

72. Gale, P., Kelly, L., Simons. R., Gauntlett, F. and Roberts, H. (2019) Risk assessment for infection of UK livestock by Bluetongue virus (BTV) through importation of live animals from northern Europe in 2019.

73. Singer, R.S., MacLachlan, N.J. and Carpenter, T.E., 2001. Maximal predicted duration of viremia in bluetongue virus infected cattle. Journal of veterinary diagnostic investigation, 13(1), pp.43-49.

74. Bonneau, K. R., C. D. DeMaula, B. A. Mullens, and N. J. MacLachlan. "Duration of viraemia infectious to Culicoides sonorensis in bluetongue virus-infected cattle and sheep." Veterinary microbiology 88, no. 2 (2002): 115-125.

75. Di Gialleonardo, L., Migliaccio, P., Teodori, L. and Savini, G., 2011. The length of BTV-8 viraemia in cattle according to infection doses and diagnostic techniques. Research in veterinary science, 91(2), pp.316-320.

76. England, M.E., Pearce-Kelly, P., Brugman, V.A., King, S., Gubbins, S., Sach, F., Sanders, C.J., Masters, N.J., Denison, E. and Carpenter, S., 2020. Culicoides s pecies composition and molecular identification of host blood meals at two zoos in the UK. Parasites & vectors, 13, pp.1-13.

77. Magliano, A., Scaramozzino, P., Ravagnan, S., Montarsi, F., Da Rold, G., Cincinelli, G., Moni, A., Silvestri, P., Carvelli, A. and De Liberato, C., 2018. Indoor and outdoor winter activity of Culicoides biting midges, vectors of b luetongue virus, in I taly. Medical and veterinary entomology, 32(1), pp.70-77.

78. Sarvašová, A., Kočišová, A., Liptáková, E., Hiavatá, H. and Mathieu, B., 2016. First insights into indoor and outdoor Culicoides activity related to the risk period for Bluetongue virus transmission in Eastern Slovakia. Acta Parasitologica, 61(4), pp.743-755.