Bluetongue in the United Kingdom and northern Europe in 2007 and key issues for 2008

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As predicted, bluetongue arrived in the UK in 2007. Here, John Gloster and colleagues investigate the meteorological parameters that allowed this incursion into the UK and discuss key issues related to the disease's possible re-establishment in 2008.

FOR the UK's farming community the confirmation of bluetongue disease on September 15, 2007, at a rare breeds farm in Suffolk, was most unwelcome, but not entirely unexpected, news. This followed an extremely difficult summer, which had included the wettest May to July period in the last 250 years (Pitt 2007) and outbreaks of foot-and-mouth disease in August and September (DEFRA 2007). While the introduction of bluetongue may not have been unexpected, the full weight of the subsequent movement and trading restrictions has had a serious impact on trade across a wide section of the agriculture industry and has caused considerable distress and concern to many involved with farming. With restrictions likely to extend well into 2008 and the possibility of further outbreaks of bluetongue the future is uncertain.

Bluetongue virus (BTV) is an insect-transmitted pathogen that can infect all species of ruminants. Cattle are reservoirs and usually show little evidence of disease, but in sheep the virus causes a disease of major importance. During 2007, in Belgium alone around 12·5 per cent of the national sheep flock died (Wilson and Mellor 2008) and costs to the cattle and sheep industries have been estimated to exceed £100 million (K. Hoogendam, personal communication). A full description of bluetongue and how the virus is transmitted between animals, plus a comprehensive reference list, can be found in Mellor and Wittmann (2002) and descriptions of the clinical signs of the disease, advice to farmers and the public, movement guidance, and so on, can be found at www.defra.gov.uk or www.nfuonline.com

Bluetongue was first described in South Africa after Merino sheep from Europe were introduced in the late 18th century (Verwoerd and Erasmus 1994). The disease in Africa was initially restricted to the sub-Saharan region, but with time it spread to the southern Mediterranean Basin with occasional incursions into the Iberian Peninsula from 1956 to 1960. More recently, in the late 1990s and early 2000s a more prolonged series of incursions has taken place to islands in the Mediterranean and subsequently to large areas of southern mainland Europe. These have involved the transport of BTV-infected midges over long sea passages ranging from 100 to 300 km (reviewed by Gloster and others 2007a). In general, the northern movement of the virus has been attributed to climate change, in particular the general warming of winter temperatures (Purse and others 2005).

In 2006, BTV serotype 8 (BTV-8) jumped without warning from far beyond the European continent to invade areas substantially further north than the previous southern incursions. Initially, the Belgian/Dutch/German border areas around Maastricht were involved and then during the late summer and autumn BTV-8 spread more generally throughout the area, with outbreaks also being recorded on the borders of northern France, Luxembourg and as far west as the coastal regions of Belgium and the Netherlands. By the end of the year just over 2000 cases had been confirmed (A. R. W. Elbers, personal communication). The first case in 2007 was reported on June 16 on a holding in North Rhine/Westphalia, Germany. This was followed shortly by outbreaks being recorded in many of the areas where disease had been confirmed during 2006. This demonstrated that the virus had successfully overwintered on the continent. Whether this was as a result of the mild winter (the second warmest in northern Europe on record) or as a result of another overwintering mechanism is not clear. Disease subsequently spread rapidly throughout northern Europe and by November 2007 around 45,000 outbreaks had been confirmed and it is possible that many others have gone undetected. Disease was reported in all of the northern countries that experienced disease in 2006 and additionally in the UK, Denmark, Switzerland and the Czech Republic. Samples from these newly infected areas, together with those where BTV had been isolated in 2006, were typed by the accepted molecular genetic methods and confirmed as BTV-8 (P. Mertens, personal communication).

With the identification of BTV infection in continental Europe during 2006 and again in 2007 DEFRA introduced a ban on imports of susceptible animals from restricted zones in other countries. Movement of livestock from disease-free areas on the near continent was permitted, subject to the animals being tested for BTV on arrival in the UK. Laboratory tests on all such animals tested before November 2007 were negative. During the vector-free period for the UK, declared on December 20, 2007, movement of livestock between control zones has been authorised by the EC, subject to premovement testing; a number of these animals have tested positive by PCR for BTV-8.

On September 15, 2007, clinical signs of BTV infection were first detected in a Highland cow at a rare breeds farm near Ipswich, Suffolk, UK. Within a few days of the first case, BTV was confirmed in a second animal on the same farm and in cattle near Lowestoft and in Essex. By early December 66 cases of the disease had been confirmed in eastern England (Suffolk, Norfolk, Essex, Cambridgeshire, Kent and Surrey). A more detailed description of the epidemiology of the outbreak, together with the latest disease situation and current control zones, can be found on the DEFRA website (www.defra.gov.uk).

The almost simultaneous occurrence of disease at several different locations separated from north to south by approximately 100 km (Lowestoft to Chelmsford) combined with the lack of any links between the farms involved indicates the possibility of a single common external source. The restriction of animal movements from infected areas on the near continent combined with rigorous laboratory testing of livestock from disease-free areas suggests that the source was not a result of the introduction of infected livestock. Consequently, the introduction of BTV-infected midges in the air is worthy of careful investigation.

In this paper the meteorological aspects of the northern European outbreaks, particularly in the UK but also in mainland Europe, are considered and a number of key issues for 2008 discussed. This article builds on three previous papers in *The Veterinary Record* that assessed the risk of the windborne spread of bluetongue in the 2006 outbreaks in northern Europe (Gloster and others 2007b), asked the question

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TABLE 1: Summary of all risk categories for the period April 1 to November 30, 2007

Month	Black	Green	Yellow	Red
April	23	7	0	0
May	27	4	0	0
June	23	7	0	0
July	28	3	0	0
August	28	0	3	0
September	25	3	2	0
October	15	13	3	0
November	27	3	0	0
Total (%)	196 (80)	40 (17)	8 (3)	0

whether BTV could come to the UK on the wind (Gloster and others 2007a) and discussed the re-emergence of bluetongue in northern Europe in 2007 (Wilson and others 2007). Only the initial introduction of BTV is considered in this paper; the possible meteorological links between the first few farms within the UK and others will be documented in due course.

Factors affecting the potential windborne spread of BTV to the UK

Gloster and others (2007a) identified a number of criteria that needed to be met simultaneously for the windborne introduction of BTV-infected midges from the near continent to the UK:

- An active source of infected midges close to the western coast of the near continent. The risk of the successful transport to the UK of infected midges is assessed as decreasing with increasing distance of the source from the coast. This is as a result of a combination of circumstances including the relative availability of infected livestock for the midges to feed on, the airflow being much more turbulent over land resulting in more rapid mixing of any airborne midges into the atmosphere, or simply the increased midge journey/survival times.
- Warm temperatures. Experimental work has shown that temperatures in the range 27 to 30°C are optimal for BTV transmission in the laboratory, whereas temperatures below 9 to 15°C are predicted to inhibit virus replication within the midge, depending on the strain of BTV concerned (Mellor 2000, Wittmann and others 2002, Purse and others 2005).
- Light wind speeds around dusk and night when the midges are most active. Wind speeds of greater than 3 m/sec have been shown to reduce midge activity (Hendry 1996).
- Minimal/no precipitation. While it has not been fully quantified it has been observed that midge activity is substantially reduced when it is raining.
- A steady wind from the source area to the UK, reducing the length of time for the transit. A typical transit from the near continent to the UK may take from two to 10 hours. The longer the transit the greater the chance of midge mortality.
- Mid-range relative humidity of between 75 to 85 per cent (Wittmann and others 2002). At low relative humidity there is a danger that the midge can become desiccated, at high levels it may become saturated.
- Susceptible livestock at the end of the transit. Given the distribution of livestock in the UK this criteria is readily met.

Meteorological risk assessment

Anticipating the possibility of spread of BTV to the UK during 2007 DEFRA requested the provision of an early warning advisory scheme, based on the above factors. This service, designed primarily for research purposes, was run daily at the Met Office headquarters at Exeter for the period April 1 to November 30, and the information was delivered to DEFRA via a dedicated website every weekday. Meteorological information was supplemented by disease intelligence and more general disease-related information from the Institute for Animal Health (IAH) and was summarised in a fortnightly risk assessment for DEFRA.

The prime component for the advisory service was the Met Office's atmospheric dispersion model, NAME (Ryall and Maryon 1998, Jones and others 2006); the model is used to provide advice to a range of customers concerning atmospheric pollutants, ranging from nuclear and chemical accidents, volcanic releases and airborne spread of foot-and-mouth disease virus. The model had been used by Gloster and others (2007b) to assess the likely spread of BTV at the start of the 2006 BTV outbreak.

Before the reappearance of disease on the near continent in June 2007 it was assumed that a standard source of infected midges existed in the Ostend area of Belgium from 18.00 to 21.00 each day. When disease became more widespread on the near continent, the modelling was extended from one release site up to seven along the western coast.

The track of the NAME model particles, representing the passive dispersal of midges, was plotted daily for the overnight period to identify the area at risk. A simple traffic light scheme, using a flow chart similar to that given by Gloster and others (2007b), was then used to estimate the overall likelihood of infection. This estimate was based on meteorological data from the Met Office's unified model, including temperature, wind speed and direction, the presence/absence of precipitation and a close inspection of the synoptic weather conditions that existed at the start of the trajectory

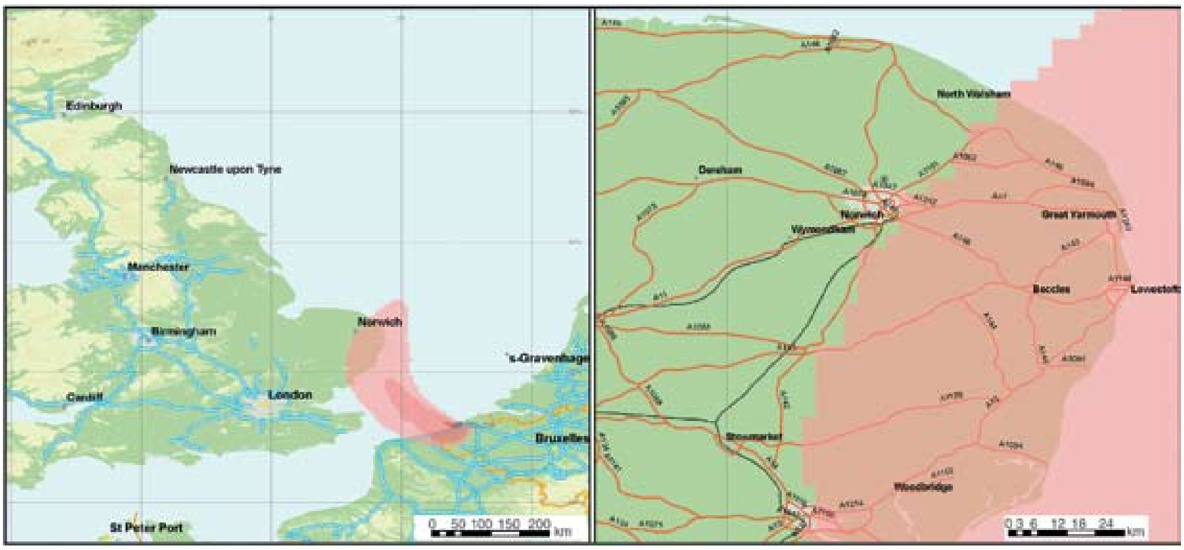

FIG 1: Risk of airborne introduction of bluetongue virus-infected midges to the UK, issued to DEFRA on August 7, 2007. Release start August 4, 2007, 18.00, release stop August 4, 2007, 21.00. Red shows area at risk

and along the route. The traffic light categories were black (no risk to the UK), green (minimal risk), yellow (some risk) and red (heightened risk). Black risk levels signified the wind was blowing away from the UK, green when the wind would have blown towards the UK but there was a low likelihood of infected midges being airborne as conditions were too cold or wet. Yellow categories were used when conditions were assessed as much more likely to cause concern and red when conditions were assessed as being ideal for carriage of infected midges to the UK. Overall, the traffic light scheme was empirical and had never been used in an operational setting; as a result the boundaries between categories were fairly arbitrary, but sought to identify occasions that might pose the greatest risk to livestock in the UK.

Risk assessment results

Table 1 summarises the output from the risk assessment scheme for the period April 1 to November 30, involving more than 1000 NAME runs. Of the total of 244 days there were 196 occasions when livestock in the UK were assessed as not being at risk, 40 when UK livestock were at minimal risk, eight at some risk and 0 at heightened risk. Given that the prevailing winds in the UK are from the west it is not surprising that for the majority of days (80 per cent) livestock in the UK were assessed as not being at risk. For 17 per cent of occasions, the wind was conducive to carriage from a mainland European source to the UK, but either the air temperature was too cold, it was raining or simply there were uncertainties about the number of BTV-infected midges within 20 to 30 km of the coast. These instances are particularly noticeable at the start of the assessment period and again towards the end. However, it is believed significant that on eight occasions (3 per cent) the assessment identified livestock on the eastern coast of the UK to be at some risk. Table 2 provides details of these yellow risk assessments.

No heightened risk assessment days were identified. On reflection it is believed that the temperature/time threshold used in the flow chart, selected before the commencement of the modelling period, was set too high; a temperature at dusk of 25°C was required before the heightened risk category could be achieved. Temperatures around this value were recorded on a number of occasions during the very hot summer of 2006, but rarely during the cooler summer of 2007.

Meteorological modelling of the start of the 2007 outbreak of bluetongue in UK

Both serological and reverse transcriptase-PCR tests on samples from the initial case at Baylham Rare Breeds Farm were positive, with the results indicating that the first clinically affected cow had been infected 10 to 20 days previously (C. Oura, personal communication). Similar results were found for livestock from the two farms in the Lowestoft and Chelmsford areas. If more than one cycle of BTV infection was involved before detection of the first case, as has been suggested on the basis of a serological survey in the area (C. Oura, personal communication), the initial introduction of BTV to the rare breeds farm possibly could have occurred any time from late July.

Assuming that the virus could have been introduced to the UK at any time from the end of July through to early September, the meteorological conditions and particularly the risk assessments were investigated to determine if there were any suitable occasions when infected midges could have been carried in the wind from Europe. For much of August and early September the wind would have carried any midges that became airborne on the near continent away from the UK, thus making it impossible for introduction of the virus to the UK by this route. However, overnight on August 4 to 5 any insects that became airborne in the Ostend area, where BTV was well established, were predicted to be carried towards Norfolk and Suffolk (Fig 1). On the other two occasions when yellow assessments were issued in the period of interest, livestock in Kent could have been at risk on August 20 to 21 and in Kent and Sussex on August 26 to 27. The last two dates can be discounted for the introduction of infected midges to Norfolk and Suffolk, but may not be discounted as possible dates for the introduction of infected midges to Kent and Sussex.

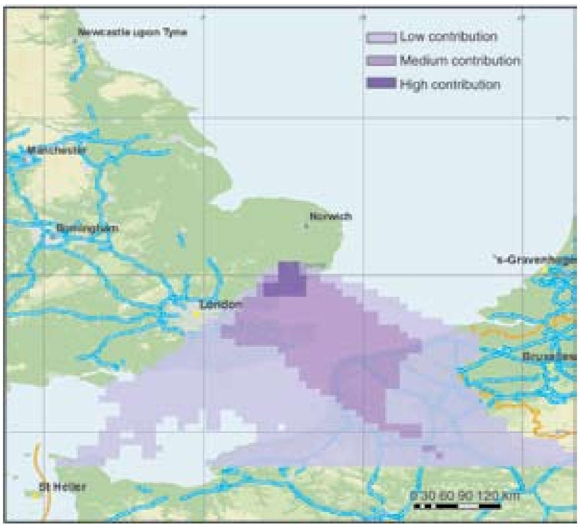

FIG 2: Air history map for air arriving at Baylham Rare Breeds Farm on August 5, 2007

An in-depth examination of the meteorological records for the whole period was then made to determine if there were any other possible occasions when infected midges could have been blown towards eastern England, but which had been missed by the risk assessment scheme. This study confirmed that August 4 to 5 was the most likely time for the introduction of BTV-infected midges to the UK.

In an attempt to recreate the events overnight on August 4 to 5, NAME was run in several different configurations.

First, air history maps were produced for air arriving at the first two reported cases. Fig 2 shows an analysis for Baylham, Ipswich for the 24-hour period starting at 00.00 UTC (Coordinated Universal Time) on August 5. It shows that a significant percentage of air arriving at Baylham would have come from an area just south of Ostend. A very similar pattern also emerged for Lowestoft (data not shown).

Secondly, the location of 100 individual model particles/midges was followed as a function of time and location. The objective was to establish the most likely time for take off and arrival time in Suffolk. The model was run starting at 18.00, 19.00, 20.00 and 21.00 UTC. All start times suggest an arrival time between 03.00 and 06.00 UTC on August 5, indicating a transit time of between nine and 12 hours (laboratory work at the IAH has established that midges can remain active and airborne for these periods of time [C. Sanders, personal communication]). The trajectories for the first two start times pass over both of the two initial disease centres near Ipswich and Lowestoft while the last two are more centred on Lowestoft. Fig 3 shows the data for the 18.00 trajectory runs.

TABLE 2: Summary of yellow risk assessments

Date of concern	Assumed virus source	Area at risk	Risk issued to DEFRA
August 4/5	Ostend, Belgium	Norfolk, Suffolk	August 7
August 20/21	Haag/Harlem, Netherlands	Kent	August 21
August 26/27	Calais, France	Kent, Sussex	August 27
September 12/13	Calais, France and Ostend, Belgium	Hampshire, Sussex, Kent	September 13
September 13/14	Calais, France	Kent, Essex	September 14
October 12/13	Abbeville, France	Sussex, Kent, Essex, Suffolk	October 15
October 13/14	Abbeville and Calais, France	Sussex, Kent, Essex, Suffolk	October 15
October 14/15	Abbeville, France	Sussex, Kent, Essex, Suffolk	October 15

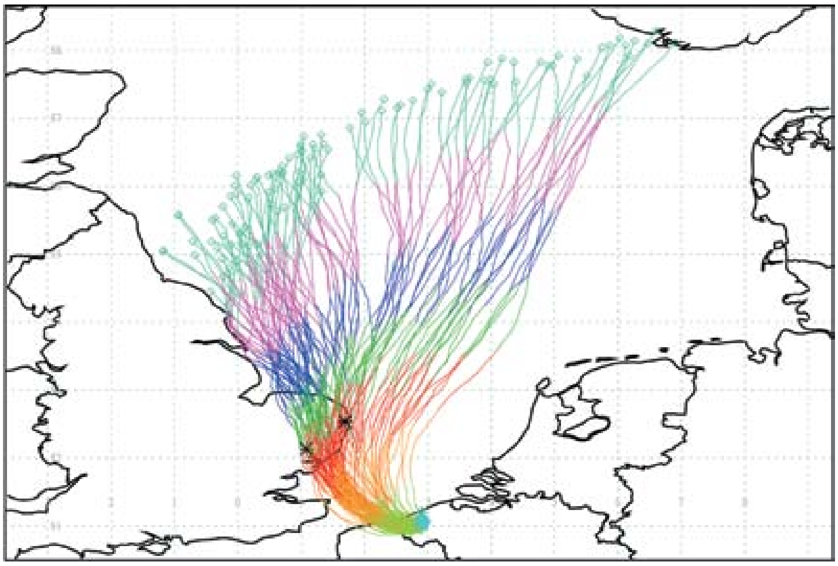

FIG 3: Trajectories of 100 particles released from Ostend, Belgium at 18.00 UTC (Coordinated Universal Time) on August 4, 2007. Red shows arrival time 03.00 to 06.00 UTC

TABLE 3: Possible sequence of events for August 4 to 5

Time	Meteorological conditions/activity
Middle of the day	Hot dry summer's day with clear skies Maximum air temperature 28·6°C and light winds
Early evening (approximately 18.00)	Midge commences flight looking for a blood meal Light wind initially from the north and then from the south-east carries the midge over the sea towards UK Midge travelling around 50 m from the ground in the boundary layer
Evening/night	Temperature of air above 16°C Maximum flight height 200 m Wind speed few to 10 ms^{-1} Relative humidity of the air ranging from 50 to 82 per cent, caused by dry descending air associated with the synoptic anticyclonic weather system
Early morning (03.00 to 06.00)	Temperatures near the surface around 15°C Relative humidity around 90 per cent Dry with wind speeds <3 ms^{-1} Midge journey time 9 to 12 hours

The likely meteorological conditions experienced on the transit to the UK were studied by following one NAME particle trajectory, investigating upper air data and examining the temperature and relative humidity fields produced by NAME at a height of 50 m above the surface. A possible sequence of events for the transit of an infected midge to the UK is given in Table 3. In summary, near ideal conditions for transport of infected midges to the UK were recorded overnight of August 4 to 5.

DISCUSSION

The meteorological analysis described in this paper combined with the lack of a credible alternative scenario strongly supports the theory that windborne BTV-infected midges were responsible for the introduction of virus to the UK on August 4 to 5.

With the establishment of BTV in the eastern part of the UK the thoughts of those involved in the farming community have naturally turned to what the future has in store. Among the many questions that have been raised, three have a direct meteorological link and these are discussed below.

Can the virus overwinter in the UK?

The mechanism(s) by which BTV overwintered in northern Europe from 2006 to 2007 is at yet uncertain, but could have occurred by low level cycling between the ruminant hosts and small numbers of surviving adult midges as suggested by Wilson and others (2007), by vertical transmission through the vectors or by extended survival of the virus in some ruminants infected in 2006. Transovarial transmission of BTV through its midge vectors has never been confirmed, and extended survival of BTV in ruminant hosts has not been reported in the field. Low level virus circulation and midge survival are influenced by the weather conditions, particularly temperature, to which the midges are exposed. For example, during a typical winter period there are likely to be days in the UK in which the temperatures are warm enough to encourage midge activity and even possibly virogenesis; this is particularly the case if the wind is from either the west or south. Winter temperatures around the mid-teens are not uncommon. If this is combined with the availability of a BTV viraemic animal the virus has the potential for being passed on. Only a few of these cycles are required to cover the full winter period. If the winter is particularly warm, as was 2006 (the second warmest in Europe on record), the chances of virus overwintering are greatly enhanced. In a similar way, the colder the temperature the greater the mortality. Overall, based on our current limited understanding of the overwintering mechanism, a very cold, prolonged winter is believed likely to reduce the risk of virus overwintering. It is important that the overwintering mechanisms are identified as soon as possible and that, if possible, preventive action is taken by those involved with animal husbandry.

Will BTV-8 vaccine be a viable control measure for 2008?

Inactivated BTV-8 vaccines have not been commercially available for use on the near continent or the UK and as such their effectiveness in a disease control programme has not been assessed. However, the situation is likely to change in 2008. On December 19, 2007, DEFRA announced that it had placed a firm order with a pharmaceutical company (Intervet) to supply 22·5 million doses of bluetongue vaccine. It is hoped that the vaccine will be available as early as summer 2008 (*VR*, January 5, 2008, vol 162, p 2). The timing of delivery from the manufacturers and the associated vaccination programme is believed by the authors to be of critical importance. With midge activity typically commencing towards the end of April and full activity by June it is imperative to raise the BTV-8 immunity level of the animals around this period; this is particularly the case if the spring is warmer than normal with associated midge activity increasing earlier than normal. If disease were to take hold before the livestock are vaccinated then it may not be as effective at controlling disease spread across the UK. While the level of vaccine cover required to halt BTV spread has not been accurately calculated it is likely that coverage of more than 80 per cent in and around infected areas will be required to be effective.

Will there be any further introductions of virus from the near continent?

Gloster and others (2007a) analysed the hourly wind directions from the near continent over a 10-year period and established that the wind blows from the near continent to the UK for about 100 hours per month. While in the winter months the air will be cool, during the summer and autumn months the air is likely to be warm. Overall, the winds during 2007 were consistent with this climatological assessment suggesting that the meteorological conditions experienced during 2007 were typical of what might be expected again. If there is a source of BTV on the near continent and it occurs simultaneously with the appropriate meteorological conditions, the events of August 2007 could easily be repeated during 2008. Much will depend on whether disease establishes itself on the near continent in 2008; this is not inevitable if all of the remaining livestock has developed BTV-8 immunity. What may be of more concern is if BTV establishes itself in currently uninfected areas, perhaps further to the west, for example, the Cherbourg Peninsula. If this were to be the case then livestock on the south coast of the UK and in the Channel Islands would be at increased risk of becoming a new disease centre.

In conclusion, it is worth considering just how severe the disease could be in 2008. In 2006, slightly more than 2000 holdings were affected by BTV on the near continent, in 2007 this number increased dramatically to over 45,000 and animals were more severely affected by disease. In 2007, the UK recorded only 65 infected farms with little clinical disease, but should the virus succeed in overwintering in the UK into 2008, the lesson from the near continent suggests that the virus could extend massively through the UK's ruminant livestock causing major losses. Clearly this situation could be mitigated by the successful implementation of a BTV-8 vaccine programme. Is this warning of a substantial increase in the presence of bluetongue a doomsday scenario or a realistic assessment of what the coming summer and autumn hold for the livestock industry? The authors believe that overwintering of the virus in either the UK or near continent is not inevitable and that even if it does, the introduction of an effective vaccine programme may well significantly reduce any future disease spread.

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Papers in this week's Veterinary Record

Surgical colic in Andalusian horses and other breeds

THERE have been a number of studies of survival and complication rates in horses undergoing exploratory laparotomy, but these have largely involved thoroughbreds. On p 303, Dr Encarnacion Muñoz and colleagues review cases of surgical colic in 192 Andalusian horses and 276 horses of other breeds in Spain. Andalusian horses had higher rates of small intestinal ischaemic disease, and Andalusian stallions had a 30 times greater risk of inguinal hernia than horses of other breeds. The overall surgical survival rate was 82·7 per cent; survival rates were highest for horses that had undergone surgery for an obstruction of the large intestine, and lowest in those with large intestinal strangulation. Nearly half of the horses that recovered from surgery suffered complications, most commonly related to infections or abdominal pain. Surgeries, and cases of inguinal hernia, were both most common in the summer months.

Porcine epidemic diarrhoea in Italian herds

PORCINE epidemic diarrhoea (PED) causes outbreaks of acute diarrhoea that can affect pigs of all ages. The disease was first noted in Europe in the 1970s. On p 307, Professor Paolo Martelli and colleagues describe an epidemic of diarrhoea due to PED in pigs in Italy occurring between May 2005 and June 2006. Outbreaks of acute watery diarrhoea with high morbidity were observed in pigs of all ages, mainly in areas with dense pig populations. Mortality was 34 per cent in newborns but was low to absent in growers and fatteners, which recovered after approximately five days. Samples of faeces examined by electron microscopy and immunoelectron microscopy using antibodies to PED virus (PEDV) contained coronavirus particles typical of PEDV. Reverse transcriptase-PCR on samples of faeces or intestinal contents, and immunoperoxidase monolayer assays on serum from pigs on eight farms, also confirmed the presence of PEDV. In total, 63 herds were affected.

Field detection of FMD virus by real-time RT-PCR

RAPID diagnosis is essential in outbreaks of foot-and-mouth disease (FMD), but laboratory diagnosis can be delayed by the time needed to transport samples. On p 315, Dr Donald King and colleagues test a portable real-time PCR instrument to assess its potential for use in the field diagnosis of FMD. In the study, a real-time reverse transcriptase-PCR assay was adapted for use in the instrument and tested with RNA prepared from a reference FMD virus (FMDV) strain. The limit of detection of the real-time assay was comparable with that of a laboratory-based diagnostic assay, and the variability between the six modules on the instrument, and between runs, was low. The authors conclude that the instrument has the potential to provide a sensitive assay for FMDV that gives a result within one hour, although further work is required to develop simple-to-use nucleic acid extraction protocols for field use.