MALFORMED fetuses attributable to Schmallenberg virus (SBV) were found in 49 cattle herds and 30 sheep flocks exclusively in the southern and eastern parts of Ireland (Barrett, D., More, S. J., O’Neill, R., Bradshaw, B., Casey, M., Keane, M., McGrath, G. & Sammin, D. Submitted) Prevalence and distribution of exposure to Schmallenberg virus in Irish cattle during November 2012 to November 2013. National bovine serological studies late in 2012 and 2013 confirmed exposure to SBV was effectively confined to the south-east (Barrett and others, submitted). It was unclear whether the distribution of seroconversion in cattle reflected the situation in sheep. Several studies have shown that Culicoides species preferentially feed on cattle rather than sheep (Ninio and others 2011, Ayllon and others 2014), leading to lower levels of seroconversion in sheep flocks than in neighbouring cattle herds (Gache and others 2013). It was anticipated that SBV would continue to spread across the country over the second (2013) vector season, similar to the experience in mainland Europe (Garigliany and others 2012, Veldhuis and others 2013, Balmer and others 2014). The objectives of this study were to determine the geographical distribution of SBV exposure in Irish sheep before and during the 2013 vector season, and to determine if SBV was active in 2013 in flocks where SBV infection was previously confirmed.

Two studies were conducted, each in different sets of sheep flocks. In the first study, serum samples were collected in 32 sentinel flocks sampled on two or three occasions at six-week intervals between May 2013 and September 2013. The flocks were distributed across the country (15, 9 and 8 flocks from the south-east, midlands and north-west, respectively), and had been volunteered through Sheep Ireland (www.sheep.ie) (n=24) and veterinary practitioners (n=8). For welfare and legislative reasons, individual adult sheep were blood sampled only once. In the second study, serological samples were collected in 14 sheep flocks where SBV infection had been confirmed in malformed fetal lambs the previous spring. In these flocks, samples were collected from 15 lambs aged between 8 months and 10 months on a single occasion, in November 2013. For both studies, it was estimated that a minimum number of 15 samples would be required per round of sampling, to ascertain freedom from infection assuming a flock prevalence of 40%, a test sensitivity of 80% and a test specificity of 99%. In practice, 15 animals were sought at each round of sampling.

For both studies, sera were tested using commercially available test kits, an indirect ELISA (Idexx Laboratories) and a competition ELISA (ID. vet), each according to the manufacturer’s instructions. In the second study, sera were additionally tested by serum neutralisation test (SNT), with a threshold titre of 1:16 used to determine SBV seroconversion (Loeffen and others 2012, Bouwstra and others 2013).

In the first study, there were 17 (53%) seropositive flocks, including all 15 in the east and south-east (Fig 1), with no subsequent change in SBV status. A single seropositive animal was found in two flocks: in counties Sligo and Meath, in the north-west and north-east, respectively. These two seropositive animals had been purchased from flocks in the south-east region in 2012 and it was assumed these animals had seroconverted before movement.

In the second study, two (14.3%) flocks had multiple seropositive lambs. Each flock had used vaccination and the lambs were seropositive by both ELISA methods but not by SNT. Two other flocks each had a single seropositive lamb; in both cases, the lamb was seropositive to SNT and one or both ELISA methods (Table 1).

In Irish sheep flocks, seroconversion to SBV virus was confined to the south and south-east of the country with no further circulation in 2013, similar to earlier results from Irish cattle (Barrett and others, submitted). In considering the probability of transmission of SBV from the south and east coast to locations further inland, it is noteworthy that the prevailing wind direction in Ireland is from the south-west and as such this would not have facilitated long-distance windborne spread of biting midges in a north-westerly direction. Further spread would be largely reliant on local transmission dynamics. Regional differences in availability of suitable vectors is also unlikely to explain the limited geographical spread of SBV as a previous study demonstrated several potentially bluetongue-competent Culicoides species were abundant and widely available throughout Ireland, especially in the northern half of the country (McCarthy and others 2010). However the timing of the initial incursion of SBV, which is considered to have occurred during the latter half of the vector active season (O’Neill and others 2014), may provide an explanation. Scottish modelling has shown that SBV introduction late in the vector season under climatic conditions similar to Ireland markedly reduced the spread of infection compared with an introduction earlier in the vector season (Bessell and others 2015). That study also showed that mean Scottish summer temperatures facilitate only limited spread, as vector life cycles are very temperature dependent. Temperatures in the south-east of Ireland in the summer and autumn of 2012 were approximately 1°C less than the 50-year average (Anon 2015). Therefore the incidence of SBV relatively late in the vector season in a year with below average temperatures was likely to have curtailed the spread of Irish SBV in 2012.

In flocks with confirmed SBV infection in the first (2012) vector season, there was no evidence of detectable exposure...
FIG 1: Location of the 32 study flocks in the first study, by Schmallenberg virus (SBV) serological status. County-level evidence of SBV exposure (% holdings positive) was based on serological surveys conducted in cattle during 2012–13 (Barrett, and others, submitted). Counties included in the second study (of 2013-born lambs) are highlighted (Carlow [CW], Cork [CK], Kilkenny [KK] and Wexford [WX]).

TABLE 1: Serological survey of 2013-born lambs in flocks where Schmallenberg virus (SBV) had been confirmed by PCR in Spring 2013 (study 2)

| Flock | County    | No tested | Indirect ELISA (prevalence) | Competition ELISA (prevalence) | SNT (prevalence) | Vaccinated |
|-------|-----------|-----------|------------------------------|-------------------------------|-----------------|------------|
| A     | Carlow (CW) | 15        | 0                            | 0                             | 0               | No         |
| B     | Cork (CK)  | 15        | 0                            | 0                             | 0               | No         |
| C     | Cork (CK)  | 15        | 0                            | 0                             | 0               | No         |
| D*    | Cork (CK)  | 7         | 0                            | 0                             | 0               | No         |
| E     | Kilkenny (KK) | 15   | 0                            | 0                             | 0               | No         |
| F     | Kilkenny (KK) | 15   | 0                            | 0                             | 0               | No         |
| G     | Kilkenny (KK) | 15   | 0                            | 0                             | 0               | No         |
| H     | Kilkenny (KK) | 15   | 0                            | 0                             | 0               | No         |
| I     | Kilkenny (KK) | 15   | 0                            | 0                             | 0               | No         |
| J     | Kilkenny (KK) | 15   | 1 (7%)                       | 0                             | 1 (7%)          | No         |
| K     | Wexford (WX) | 15   | 4 (26%)                      | 4 (26%)                       | 4 (26%)         | Yes        |
| L     | Wexford (WX) | 15   | 1 (7%)                       | 1 (7%)                        | 1 (7%)          | No         |
| M     | Wexford (WX) | 15   | 6 (40%)                      | 6 (40%)                       | 6 (40%)         | Yes        |
| N     | Wexford (WX) | 15   | 0                            | 0                             | 0               | No         |

*Number of lambs sampled less than the 13 required to substantiate freedom
SNT, serum neutralisation test
Ireland is immunologically naive to SBV should re-emergence or a sizeable proportion of the current sheep population in south-east Ireland among 2013-born lambs in those exposed to SBV during 2012 and the lack of SBV seroconversion of cattle over sheep (Ayllon and others 2014, Elbers 2008). Samples are more readily available and midges have a known preference for cattle over sheep, as bovine SBV, and other vector borne viral pathogens of ruminants, might be used to predict the exposure in sheep, as bovine SBV emerged in domestic cattle in Belgium. This suggests that future serological studies in cattle for classical SBV in sheep and the distribution of exposure SBV among lambs more than six months of age have been attributed to persistent maternal antibodies (L. van Wuyckhuise, personal communication) or false positives (Veldhuis and others 2015). There is a possibility this seroconversion occurred as a result of maternal antibodies being presumed to have waned (Elbers and others 2014). While there was evidence of seroconversion in two lambs among lambs more than six months of age have been attributed to persistent maternal antibodies (L. van Wuyckhuise, personal communication) or false positives (Veldhuis and others 2015).

The spatial distribution of seroconversion in sheep closely mirrored both the spatial distribution of confirmed cases of clinical SBV in sheep and the distribution of exposure SBV among cattle. This suggests that future serological studies in cattle for SBV, and other vector borne viral pathogens of ruminants, might reasonably be used to predict the exposure in sheep, as bovine SBV incursion into Ireland. The incomplete seroconversion in flocks exposed to SBV during 2012 and the lack of SBV seroconversion among 2013-born lambs in those flocks would suggest that a sizeable proportion of the current sheep population in south-east Ireland is immunologically naive to SBV should re-emergence or reintroduction occur.

Open Access This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

References

ANON. (2015) Met Eireann, summary weather reports. Accessed July 31, 2015 http://www.met.ie/climate/monthly-data.asp

AYLION, T. NIIJHOE, A. M., WEBER, W., ALLENE, X. & CLAUSEN, P. H. (2014) Feeding behaviour of Culicoides spp. (Diptera: Ceratopogonidae) on cattle and sheep in northeast Germany. Parasites and Vectors 18, 34

BALMER, S., VOGLIN, A., THUR, B., BUCHHUCI, M., ABRIL, C., HOUMARD, M., DANIUSER, J. & SCHWERMER, H. (2014) Serosurveillance of Schmallenberg Virus in Switzerland Using Bulk Tank Milk Samples. Preventive Veterinary Medicine 116, 370–379

BESSELL, P. R., SEARLE, K. R., AUTY, H. K., HANDEL, I. G., PURSE, B. V. & DEC BRONSVOORT, B. M. (2014) An epidemic of an emerging vector borne disease in a marginal environment: Schmallenberg in Scotland. Scientific Reports, vol. 18, 5746

BOUWSTRA, R. J., KOOI, E. A., DE KLUIJVER, E. P., VERSTRATEN, E. R. A. M., BOUGZERS, J. H., VAN MAANEN, C., WELLENBERG, G. J., VAN DER SPEK, A. N. & VAN DER POEL, W. H. M. (2013) Schmallenberg virus outbreaks in the Netherlands: Routine diagnostics and test results. Veterinary Microbiology 165, 102–108

CLAIREF, COUPEAU, D., WIGGERS, L., MUYLKEN, B. & KIRCHVINK, N. (2013) Schmallenberg virus among female lambs, Belgium, 2012. Emerging Infectious Disease 19, 1115–1117

ELBERS, A. R. W. & MEISWINKEL, R. (2014) Culicoides (Diptera: Ceratopogonidae) host preferences and biting rates in the Netherlands: comparing cattle, sheep and the black-light suction trap. Veterinary Record 205, 336–337

ELBERS, A. R. W., STOCKHOFE-ZURWIEDEN, N. & VAN DER POEL, W. H. (2014) Schmallenberg virus antibody persistence in adult cattle after natural infection and decay of maternal antibodies in calves. BMC Veterinary Research 10, 103

GACHE, K., DOMINGUEZ, M., PELLETIER, C., FETIT, E., CALAWS, D., HENDRICKX, P. & TOURATHEUR, A. (2013) Schmallenberg virus: a seroprevalence survey in cattle and sheep, France, winter 2011–2012. Veterinary Record 173, 141

GARCIGLIANY, M. M., BAYROU, C., KLEIJNEN, D., CASSART, I. & DESMECHT, D. (2012) Schmallenberg virus in domestic cattle, Belgium 2012. Emerging Infectious Diseases 18, 1512–1514

GUBBINS, S., CARPENTER, S., BAYLIS, M., WOOD, J. L. N. & MELLOR, P. S. (2005) 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 5, 363–371

LOEFFEN, W., WIJG, S., DE BOER-LUJTZE, E., HULST, M., VAN DER POEL, W., BOUWSTRA, R. & MAAS, R. (2012) Development of a virus neutralisation test to detect antibodies against Schmallenberg virus and serological results in suspect and infected herds. Acta Veterinaria Scandinavica 54, 44

MCCARTHY T. K., BATEMAN A., NOWAK D. & LAWLESS A. (2010) National BTV Vector Surveillance Programme 2007–2009. http://www.malusfarms.gov.uk/media/migration/animalhealthwelfare/diseasescontrols/bluetonguedisease/BTVVectorSurveillance0910FinalReport.pdf

NINIO, C., AUGOT, D., DELECOLLE, J. C., DUFOUR, B. & DEPAQUIT, J. (2011) Contribution to the knowledge of Culicoides (Diptera: Ceratopogonidae) host preferences in France. Parasitology Research 108, 657–663

O’NEILL R. G., BOLAND, C. & ROSS, P. (2014) Retrospective profiling of the 2012 Schmallenberg virus incursion into Ireland. Proceedings of the BSAS and AVTRW annual conference, 28–30 April 2014, Nottingham. Advances in Animal Biosciences 5, Abstract 001

TARLINTON, R., DAILY J., DUNHAM, S. & KYDD, J. (2012) The challenge of Schmallenberg virus emergence in Europe. The Veterinary Journal 194, 10–18

VELDHUIS, A. M., MARS, M. H., ROOS, C. A., VAN WUYCKHUISE, L. & VAN SCHAIK, G. (2013) Two years after the Schmallenberg virus epidemic in Europe: does the virus still circulate? Transboundary and Emerging Diseases Published Online First: 23 Apr 2015. doi:10.1111/tbed.12349

VELDHUIS, A. M. B., VAN SCHAIK, G., VELLAMA, P., ELBERS, A. R. W., BOUWSTRA, R., VAN DER HEIDEN, H. M. J. F. & MARS, M. H. (2013) Schmallenberg virus epidemic in the Netherlands: spatiotemporal introduction in 2011 and seroprevalence in ruminants. Preventive Veterinary Medicine 112, 55–47

WERNERIE, K., CONRATHEIS, F., ZANIELLA, G., GRANZOW, H., GACHE, K., SCHIRMER, H., VALAS, S., STAUBACH, C., MARIANNEAU, P., KRAATZ, E., MORETH-BONTGEN, D., REIMANN, I., ZIENTARA, S. & BEER, M. (2014) Schmallenberg virus - two years of experiences. Preventive Veterinary Medicine 116, 423–54