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The prevalence and distribution of sheep scab in Wales: A farmer questionnaire survey

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Abstract

The prevalence of outbreaks of ovine psoroptic mange in the UK has increased 100-fold since its deregulation in 1992, with the highest prevalence in Wales, a region of high sheep density. A cross-sectional retrospective questionnaire survey of 7,500 members of the association of Welsh Lamb and Beef Producers was used to investigate the prevalence and distribution of sheep scab in this region in 2015. The survey was completed by 14% ($n=972$) of potential respondents. Scab outbreaks were reported on 16% ($n=154$) of farms in 2015, however 29% ($n=282$) of farms reported at least one scab outbreak in the last 10 years; 2.4% ($n=23$) of farms had experienced between 6-10 outbreaks in the last 10 years. Most outbreaks occurred between September-January (83%, $n=150$), and were clustered around Brecon (mid Wales) and Bangor (North Wales). Farmers who used common grazing were significantly more likely to have had scab outbreaks in the last 10 years than farmers who did not. No quarantine procedures for bought-in sheep were used by 29% ($n=262$) of farmers. Future research should be directed towards localised management programmes, with a particular focus on areas of common grazing.

Key Words: *Psoroptes*; Disease; Management; Mange; Prevalence; Survey; Treatment

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Introduction

Sheep scab (psoroptic mange) is a major animal welfare issue, caused by infestation by the astigmatid mite, *Psoroptes ovis*, leading to pruritus, excoriation and self-trauma (Berriatua *et al.*, 1999). Effective management of psoroptic mange in sheep over the last 40 years has proved to be an intractable problem in the UK. After initial eradication, compulsory plunge dipping was imposed when scab was inadvertently reintroduced in 1972, however this was ineffective and cases continued to be reported in low numbers (French *et al.*, 1999). Given its low incidence and the cost of enforcement, scab was deregulated in 1992. This was followed by an almost exponential rise in disease incidence, increasing from fewer than 100 outbreaks per year to more than 7,000 outbreaks per year in 2003/04 (Bisdorff *et al.*, 2006).

In a retrospective questionnaire survey of 1067 farmers in the UK in 2003/2004, 9% (± 1.72) of respondents reported at least one outbreak of scab between March 2003 and February 2004, but there was strong regional variation in this prevalence; the percentage of farms with at least one outbreak of scab was highest in Wales (17%), followed by Scotland (14%) and Northern England (11%). The percentage of farms affected in England was substantially lower and similar in all four regions, at between 3-6% (Bisdorff *et al.*, 2006). Further questionnaire surveys have supported this strongly regional pattern with a particularly high incidence of scab in Wales; a cumulative annual incidence of 8.6% was reported by Rose *et al.*, (2009) for Great Britain, with a prevalence in Wales of 24.2%. A study by Cross *et al.* (2010), which used a face-to-face interview methodology reported that 36.5% of sheep farmers in Wales had at least one outbreak of scab over a 5-year period.

Scab can be highly localised, so persistent reports of outbreaks may be seen on individual farms over prolonged periods of time; 85% of farms reporting a scab outbreak in 2007/08 also reported having one or more outbreaks in the previous ten years (Rose *et al.*, 2009). In contrast, the same study showed that 76% of the farms that were free from scab in 2007/08 had not had scab in the previous ten years (Rose *et al.*, 2009). This suggests that there are likely to be specific management or environmental risk factors which distinguish the farms on which persistent scab is reported. Poor fencing and bought in sheep were identified as important risk factors for scab in Ireland by O'Brien (1992), who suggested that upland and mountain sheep should remain the primary focus of infection management. This was confirmed by Rose & Wall (2012), who showed that farms using common grazing were at significantly higher risk of infestation than farms not using common grazing, as were farms that had direct contact with neighbours' sheep that may have scab.

Scab was estimated to cost the UK sheep industry £8-14 million per year in 2005, with the costs of insecticide applications far exceeding the economic losses associated with mortality and reduced weight gain (Nieuwhof & Bishop, 2005). Scab control is now largely dependent on

macrocyclic lactones (MLs), the overuse of which is likely to contribute to the development of ML resistance in a wide range of sheep parasites (Bisdorff & Wall., 2008). This increases the risk of selecting for resistance both within the *Psoroptes* populations and, as a side effect, other ovine parasites. Despite numerous education campaigns, little apparent progress has been made towards identifying the best approach to scab management or implementation. Nevertheless, the appropriate management of scab is essential on both welfare and economic grounds. Identifying the most appropriate manner in which future efforts should be focussed, however, is difficult.

The aim of the current study was to focus on Wales, the region of the UK with the highest scab prevalence, in an attempt to identify any changes in prevalence since the previous surveys some 10 years ago. As a relatively geographically isolated region, Wales would be an ideal location for the evaluation of a regional scab management programme, prior to which the precise scab prevalence, spatial distribution, risk factors and any recent changes, need to be quantified.

Methods

A retrospective questionnaire was prepared in English and Welsh (Appendix A), and hard copies were circulated at the end of February 2016 to approximately 7500 members of the Welsh Lamb and Beef Producers association (WLBP). Respondents were asked if they experienced a scab outbreak in 2015 and if they had experienced a scab outbreak in the previous 10 years. They were also asked about quarantine treatment of bought-in sheep, scab prophylaxis and treatment methods and the type(s) of grazing system used (upland, lowland, or a combination). Farm postcodes were used to generate British National Grid coordinates (Northing and Easting) for each farm, with a precision of 100m (Grid Reference Finder, 2011). The distribution of scab outbreaks was mapped in Q-GIS (Version 2.16, Nødebo).

Data from returned surveys were entered into an Excel spreadsheet (Microsoft Corporation), and Chi-square analysis was used to compare subsets of respondents. Sequential Bonferroni corrections were made to the acceptance thresholds (P-value) to mitigate the effect of multiple comparisons (University of Sheffield, 2012). Denominators were not the same for each question as some were not completed by all respondents.

The spatial distribution of respondents and reported scab outbreaks was analysed to identify focal regions with high incidence. The *density* function from the *stats* package in R (R Core Team, 2015) was used to apply a kernel density method a quartic kernel and adaptive bandwidth to estimate the spatial density of all respondents, respondents reporting sheep scab in 2015 (2015 cases), respondents reporting no outbreak in 2015 (2015 controls), respondents

reporting scab in 2015 and/or the preceding 10 years (i.e. all farms reporting scab in the previous 10 years; 2005-2015 cases) and respondents who reported no cases in the previous 10 years (2005-2015 controls). As farms, and therefore survey respondents, are rarely randomly or homogeneously distributed across the landscape, foci cannot be identified based on the density of respondents reporting scab alone and further analysis is required to take into consideration the underlying distribution of the study population. The *Gest* and *envelope* functions from the *spatstat* package (Baddeley and Turner, 2005) in R was used to estimate the G-function and significance envelope (by Monte Carlo simulation of the expected proportion of nearest neighbours within a range of cut-off distances) to confirm departure of the geographic distribution of respondents from complete spatial randomness (Baddeley et al., 2015). The probability distribution of reporting a scab outbreak in 2015 was estimated using the ratio of the density estimate for the 2015 cases and controls (i.e. the odds ratio; OR) using the formula $probability = OR/1+OR$. The probability distribution of reporting at least one scab outbreak between 2005 and 2015 was estimated using the density estimates of the 2005-2015 cases and controls in the same way. Finally, the analysis was repeated, weighting each point (respondent's farm) based on the number of outbreaks reported between 2005 and 2015 to further identify foci for persistent sheep scab. SatScan™ v8.0 (Kulldorff and Information Management Services, Inc., 2009) and Bernoulli models (Kulldorff and Nagarwalla, 1995; Kulldorff, 1997) were used to confirm the presence and locations of clusters statistically.

Results

A total of 982 questionnaires were received by the deadline (01/04/2016). There were 972 sufficiently completed surveys remaining, once incomplete/blank surveys were removed, resulting in a response rate of 14% (correcting for around 600 WLBP members who were dairy-only).

Scab prevalence since January 2015

At least one scab outbreak in 2015 was reported by 15.8 % (95% confidence interval ± 2.29 %, $n=154$) of respondents; 26 farms (2.7%) reported multiple scab outbreaks (Fig. 1a). The highest incidence of scab outbreaks was in November and January (Fig. 2), with the majority of cases occurring between September and January (83%, $n=150$). The average reported duration of a scab outbreak was 2 months. Diagnostic confirmation of psoroptic mange by a veterinarian was reported by 27% ($n=41$) of farms that had scab in 2015, while 4% ($n=6$) had it confirmed by an alternative health professional. A confirmative scab diagnosis was not obtained by 69% ($n=106$) of farmers who had an outbreak in 2015. There was no answer

provided regarding diagnostic confirmation by one of the respondents claiming to have had a scab outbreak in 2015.

More than 95% of farmers relied on either doramectin, moxidectin or various formulations of ivermectin (all MLs) to treat established scab; only 15.3% ($n=21$) organophosphate (OP) dipped for scab treatment (Table 1). On average, 1.63 (SD± 1.36) doses of treatment were used to treat scab outbreaks. Multiple treatments were used by 15% ($n=20$) of farms with scab infestations, and two individuals reported using 6 and 10 doses to treat an outbreak. The use of products with no label claim for scab were reported by 9.3% ($n=14$) of farmers.

At least one type of scab preventative (prophylactic) treatment was used by 47% ($n=453$) of farms. Surprisingly, OP dipping was the most popular method of prevention (43.7%, $n=189$), followed by doramectin (21.7%, $n=94$) (Table 1). On average, farms that used preventative measures treated their flock once a year (mean = 1.34, SD±0.61).

Information on flock sizes was provided by $n=955$ of respondents. Average total flock size (including ewes, rams, lambs, and 'other') was 1090 (SD±1065.9) with an average of 475 (SD±440.7) ewes. Larger flocks had significantly more reported scab outbreaks in 2015 than smaller flocks ($\chi^2=41.91$, $n=942$, $P<0.01$). In flocks that had scab outbreaks in 2015 the average total flock size was 1615 (SD±1065.4), while the average total size of unaffected flocks was 969 (SD±931.8). Only 8% ($n=26$) of flocks of 1-500 sheep in total experienced a scab outbreak in 2015.

Scab in the last 10 years

At least one outbreak in the last 10 years was reported by 29% (95% confidence interval ±2.85 %, $n=282$) of farmers, with affected farms suffering on average two outbreaks in the last decade (Fig. 1b 3). Notably, 2.4% ($n=23$) of farmers experienced between 6-10 outbreaks. Of the 154 farms that reported scab in 2015, 70% ($n=108$) also had an outbreak within the previous 10 years (Fig. 3). Farms with scab in 2015 were significantly more likely to have had an outbreak in the previous 10 years than farms that did not have scab in 2015 ($\chi^2 = 106.6$, $n = 972$, $P<0.025$). For the farms that did not have scab in 2015 ($n= 818$), 79% ($n=644$) reported having had no outbreaks in the last 10 years.

Flocks that had scab in the last 10 years were significantly larger than flocks that reported no scab ($\chi^2=52.5$, $n=942$, $P<0.01$). Furthermore, farms that had scab every year for the last 10 years were significantly more likely to be larger than smaller flocks ($\chi^2=71.5$, $n=942$, $P<0.01$).

Spatial analysis

The distribution of respondents was not homogenous, with respondent density highest in the central Powys region bordering England (Fig. 4a). Further analysis using the G statistic confirmed significant clustering of respondents and departure from complete spatial randomness at distances less than 30km ($P=0.02$). Based on the probability distribution of 2015 cases and controls, clusters centred near Bangor (Gwynedd, North Wales) and Brecon (Powys, South Wales) were apparent (Fig. 4b). The clusters were identified and confirmed as significant by the SatScan Bernoulli model, which identifies regions where the number of reported outbreaks is higher than expected when using the respondents' reports of scab outbreaks between 2005 and 2015, weighted for the frequency of outbreaks within this period, which integrates both the spatial distribution and frequency of sheep scab outbreaks (Table 2, Fig 4b).

Scab risk factors

Of the 906 farmers (93.2%) who said that they bought in sheep, 29% ($n=262$) said that they did not quarantine the introduced animals. Furthermore, 58% ($n=526$) did not use any preventative treatments on the bought in sheep. Information on the type(s) of treatment used on bought in sheep was provided by 347 respondents; the most widely used active ingredient was doramectin (32.1%, $n= 118$), followed by moxidectin (21.7%, $n=80$).

Land type(s) were provided by 907 of the respondents. Hill/upland farms were most common (66.3%; $n= 601$), followed by lowland farms (28.5%; $n= 259$). Some farms occupied both types of grazing (5.2%; $n= 47$). Post codes were provided by 79.3% ($n=771$) of respondents. Common grazing was used by 17.5% ($n=170$) of respondent farms. Farms that used common grazing were significantly more likely to have had scab in 2015 ($\chi^2=10.01$, $n = 972$, $P=0.017$); 27% ($n=42$) of the farms that used common grazing had scab in 2015, whereas just 14% ($n=114$) of farms without common grazing have had scab. Farmers who used common grazing were also more likely to have had scab in the past 10 years than farmers who did not use common grazing ($\chi^2 =35.3$, $n = 972$, $P=0.05$). Scab outbreaks were experienced 1-5 times in the last 10 years by 64.7% ($n=110$) of farmers who used common grazing, whereas 7.1% ($n=12$) of farmers who used common grazing had 6-10 outbreaks in the last 10 years.

Discussion

The 2015 scab outbreak prevalence of 16% reported here is similar to previous retrospective questionnaire studies in Wales (Bisdorff *et al.*, 2006; Rose *et al.*, 2009) but all are considerably lower than the 36% reported by Cross *et al.* (2010). The data suggest that although the prevalence of scab in Wales (16% in this study) is higher than the UK national average (9%; Bisdorff *et al.*, 2006; 8.6% Rose *et al.*, 2009), it does not appear to have continued to increase

over the previous 10 years since the last similar survey. Furthermore, the proportion of farmers reporting a scab outbreak in 2015 (15.8%) and in the previous 10 years (29%) was similar in this study. It is possible that scab prevalence has now reached a stable level, although recent reports of resistance to macrocyclic cyclic lactones in *Psoroptes* mites on Welsh farms is likely to destabilize this pattern in the future (Doherty *et al.*, 2017).

One of the problems with using questionnaire-based approaches is that they rely entirely on the co-operation and reliability of the respondents, the sample size and the representative nature of the sample population. It is a valuable way to obtain large amounts of data, but questionnaires need to be carefully worded, appropriately routed, avoid forcing answers, and achieve as unbiased a set of responses as possible. In the current studies, 10 questionnaires were removed because respondents failed to complete the survey satisfactorily, but 972 were completed correctly, indicating that the questionnaire design was generally well understood by the sample population. However, the majority of the farmers surveyed here are members of the Welsh Lamb and Beef Producers Association and most are members of various, farm assurance schemes, so are likely to manage their flock to a higher standard than non-member farmers and this cohort of farmers may also have been more likely than the general population to be interested and participate in the study. This may have resulted in the prevalence estimates presented here being a slight underestimate of the true prevalence.

The cost of scab in terms of losses and treatment have been estimated to be approximately £12.30 per infested ewe and her lambs (ADAS, 2014). There are approximately 9.8 million sheep in Wales, including at least 4,418,000 ewes (Welsh Government, 2016). Therefore, these data suggest that the cost of scab in Wales is likely to be in excess of £8 million per year.

Some respondents ($n = 201$; 20.7%) did not provide their post codes. There is not sufficient data from this study to conclude why so many farmers were not prepared to share their addresses; but it is likely to be because there is perceived to be some stigma associated with scab infection in a flock. Based on the geo-references derived from postcodes provided by respondents, outbreaks of scab, both in 2015 and over the previous 10 years, appeared to be widely dispersed. However, as would be expected due to the heterogeneous distribution of farms in the landscape, respondents were not randomly distributed throughout the country, complicating the identification of disease foci. Many of the farms affected by scab were in upland areas and farmers who used common grazing were significantly more likely to experience scab. A similar result was reported by Rose and Wall (2012), who showed that common grazing was a critical risk factor, with farms that used common grazing almost twice as likely to report scab than farms that did not. Similarly, this study has confirmed that there is a cohort of farmers who experience repeat outbreaks year after year, clustered near Brecon

(Powys) and Bangor, whereas the majority of sheep farmers (71%) had not had scab in the last 10 years (Rose & Wall, 2012). This highlights the fact that control and management efforts can be focussed on a relatively small group of farms and farming systems to maximise its cost-effectiveness.

As expected, most outbreaks occurred during winter, between September-January (French *et al.*, 1999). Various reasons have been suggested to explain the high winter prevalence of scab, including poorer body condition and immunocompetence associated with more limited feed and gestation, higher stocking rates of overwintering sheep 'away-grazed' or 'on-tack' on dairy holdings, effects of favourable microclimate in the longer winter fleeces on the growth of mite populations, and transmission at autumn sheep sales (French *et al.*, 1999; van den Broek & Huntley, 2003). Misdiagnosis of some cases of scab cannot be ignored, because the majority of farmers (69%) did not have their scab outbreaks confirmed, thereby raising the potential for confusion of scab for lice infestation.

Treatment to prevent scab was reported by 44% of farmers in a 2003/04 survey of UK sheep farmers (Bisdorff & Wall, 2008). The current study found a similar percentage using preventative treatment (47%) in Wales in 2015. However, notably, 58% of farmers said that they did not use a preventative treatment on their introduced sheep. Therefore, bought in sheep may represent a significant source of new infections. SCOPS' (Sustainable Control of Parasites in Sheep) 2012 guidelines advise the isolation of bought in sheep for at least 14 days. Here, 29% of the farmers who bought in sheep said that they did not quarantine their introduced animals. However, no specific definition of the quarantine period was provided in the questionnaire, so the answers provided do not give any information about whether farmers followed the SCOPS (2012) guidelines.

Farmers administered a mean of 1.63 (SD± 1.36) treatments to treat established scab outbreaks. However, this figure is not considered to indicate widespread treatment failure and the administration of multiple ineffective treatments, as some treatments such as Ivermectin require multiple doses, and 91% of farmers found the treatment of established outbreak to be effective. Nevertheless, a key finding from this study is the apparent confusion among a relatively large group of farmers about which products are suitable for the prevention or treatment of scab, and 9% of treatments were reported to be ineffective. This highlights the need for clearer education and training, particularly since the participants, who were members of the Welsh Lamb and Beef Producers Association, might be expected to be a group who were particularly well informed and committed to good husbandry.

Previous questionnaire studies have achieved response rates of 30.2-56.4% (Bisdorff *et al.*, 2006; Bisdorff & Wall, 2008; Rose *et al.*, 2009). The current survey was completed by 14%

(n=972) of potential participants. The relatively low response rate in the present study could relate to its timing, as the survey was distributed during the spring lambing season.

The present study has confirmed the importance of common grazing as a risk factor for scab and it has highlighted that fact that most farmers do not quarantine bought in sheep or use routine prophylaxis. It has further highlighted fact that scab is highly unevenly distributed between farms, with a small cohort experiencing repeat outbreaks year on year and the majority of farms being scab-free most of the time. These farms were clustered in several foci throughout Wales which could be targeted for scab management efforts to help control what would appear to be a reservoir of scab infected sheep.

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Conflicts of interest

The authors certify that there are no conflicts of interest to disclose.

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Figure legends

Fig. 1: The distribution of farms that reported that they (A) had an outbreak of scab in 2015, or (B) that they had an outbreak of scab in the previous 10 years.

Fig. 2: Reported scab outbreaks in 2015 by month (n=181). If farms reported more than one month where scab was first detected, both months are included.

Fig. 3: Number of farmers reporting outbreaks over the last 10 years.

Fig. 4: (A): The density of respondents to the 2015 sheep scab survey determined using kernel density estimation. Warmer colours (yellow) indicates a higher density and cooler colours (blue) indicates a lower density. (B): The probability distribution of reporting a scab outbreak between 2005 and 2015, weighted for the reported frequency of outbreaks, estimated from the odds ratio of kernel density estimates for reported cases and controls in the 2015 sheep scab survey. Warmer colours (yellow) indicate a higher probability, cooler colours (blue) indicate a lower probability. Black circles indicate clusters identified using SatScan software, where the number of reported cases was significantly higher than expected.

Table 1. The percentage and number of farms in Wales responding to a retrospective questionnaire survey reporting the use of various active ingredients to treat an active scab outbreak in 2015 ($n= 137$) and all scab outbreaks within the last 10 years ($n=432$). Some farms ($n=31$) who used treatments for scab within the last 10 years used multiple treatments.

Active ingredient	% of farms (n) which used active ingredient in 2015 scab outbreak	% of farms (n) which used active ingredient in any scab outbreaks within the last 10 years
Diazinon (OP)	15.3% (21)	0
Doramectin	38% (52)	21.7% (94)
Moxidectin	35.8% (49)	18.5% (80)
Ivermectin ¹	22.6% (31)	28.7% (124)
Cypermethrin	0.7% (1)	0.2% (1)
Synthetic pyrethroid	0	4.9% (21)
Deltamethrin	0	0.7% (3)
Dicyclanil	0	0.7% (3)
Cyromazine	0	0.2% (1)
Vaccine	0	0.2% (1)
Ivermectin, Closantel ²	0	0.5% (2)
Other (spot-on/herbal) ²	0.21% (3)	0
Unknown	0	3.7% (16)

Note: ¹ Some of the ivermectin products reported to have been used by farmers have no label claim for scab (2015 outbreaks: $n=19$; 13.9%; outbreaks within the last 10 years: 7.2%; $n=31$) (Summary of Product Characteristics, Veterinary Medicines Directorate Product Information Database). For products containing ivermectin, doramectin and moxidectin, it was assumed that the farmer used the injectable formulation at the recommended dose rate and interval. ² Closamectin can be used for the treatment of scab if followed by a second dose of ivermectin 7 days later. According to the data, all farmers that used closamectin also used ivermectin, however, it cannot be determined whether this was given 7 days later.

Table 2. Significant clusters identified by SatScan™ analysis, based on 2005-2015 cases and controls, weighted by the number of years when outbreaks were experienced within the 10-year period.

Cluster	No. of respondents within the cluster	No. scab outbreaks within the cluster	Scab prevalence (%)	Relative risk	Log likelihood ratio	P-value
Powys and Northern Dyfed	575	380	66.1	1.49	27.7	<0.001
Northern Gwynedd/ Western Clwyd	40	38	95	1.77	16.7	<0.001

Figure 1

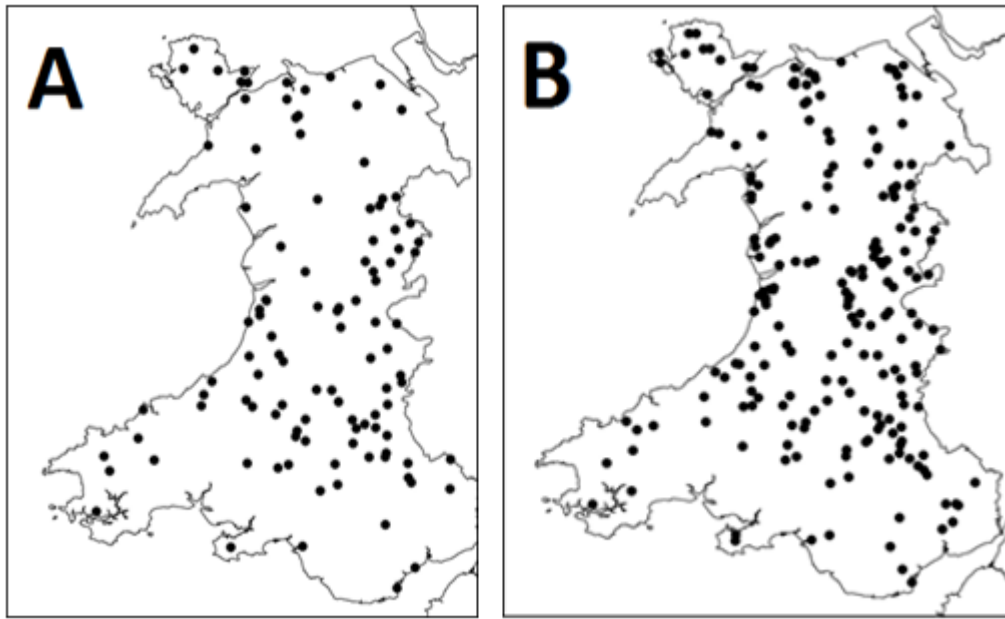


Fig 2

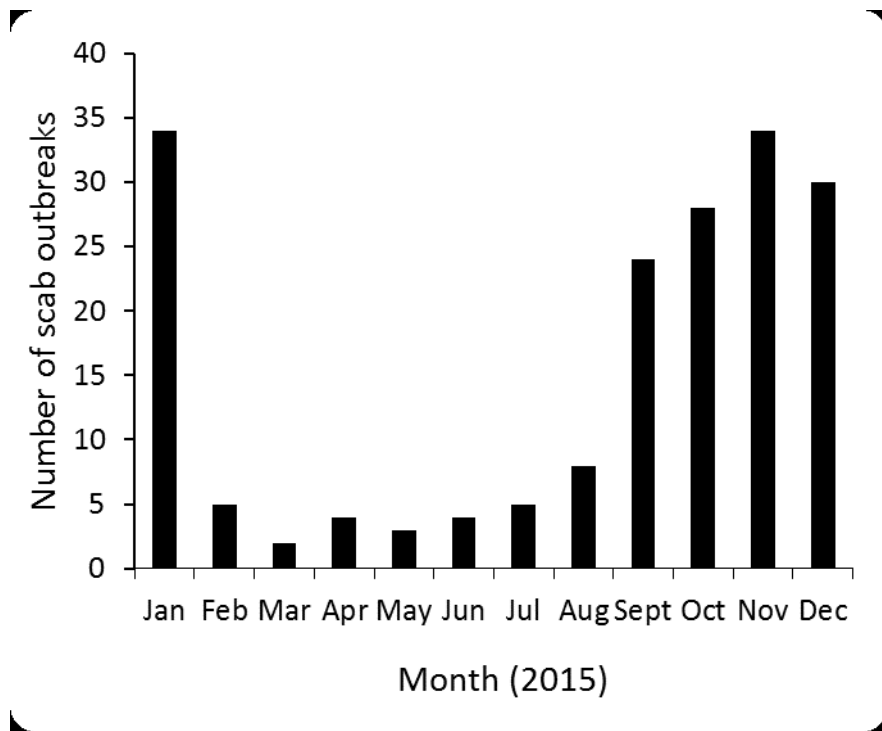


Fig 3

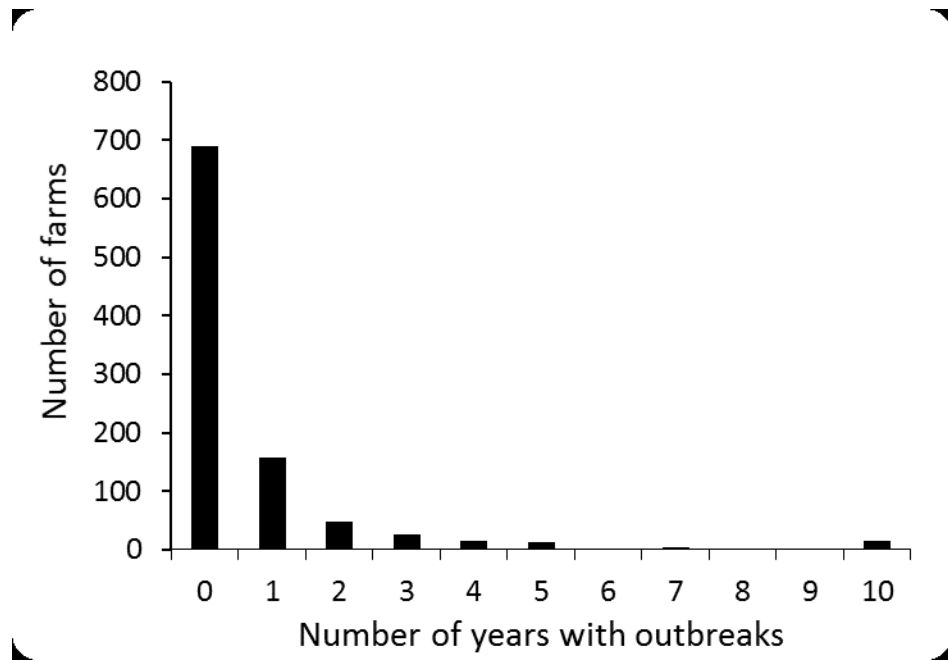


Fig 4

