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Papers

Postal survey of contacts between cattle farms on the Isle of Lewis

M. C. Vernon, C. R. Webb, M. F. Heath

The British Cattle Movement Service (BCMS) database contains an unprecedented quantity of data on the movement of cattle within the UK. These data may be used to construct models of the contact structure of the UK cattle herd, for epidemiological purposes. There are two significant potential sources of inaccuracy within such models: movements that are not reported or are reported inaccurately to the BCMS, and contacts between farms that might transmit infection, but are not animal movements. This field study addressed these issues. Cattle farmers on the Isle of Lewis were recruited with the assistance of the local veterinary surgeon, and asked to record a range of potential risk behaviours for a one-month period. They were also asked questions about husbandry practices on their farm. Comparison of the BCMS contact data with that reported by Lewis' farmers highlighted use of common grazing land as a significant source of contact, and potential disease transmission, between cattle that currently goes unreported; around half of responding holdings on Lewis use common grazing land at some point during the year, and these movements are not reported to the BCMS.

SINCE January 2001, it has been a legal requirement in the UK to report all movements of bovine animals to the British Cattle Movement Service (BCMS). These movement data have been made available to researchers as part of the Rapid Analysis and Detection of Animal-related Risks project (RADAR); as well as containing the movement data supplied by BCMS, RADAR also generates descriptive summaries of the UK cattle population by premises (Lysons and others 2007).

RADAR's animal movement data may be an inaccurate measure of the contact structure of the UK cattle herd if some movements are not reported to BCMS (whether due to fraud or lack of understanding of the finer points of movement regulations), or if there are significant levels of contact between holdings that might transmit infection but are not cattle movements, for example, the sharing of transport vehicles or cattle contacting each other in neighbouring fields.

A National Audit Office report raised the following concerns about the data held in BCMS: information about 8 per cent of animals was incomplete, the location of 2 per cent of animals could not be determined, 20 per cent of movements were reported late (so the BCMS database was out of date) and 3 per cent of movements were anomalous. It also expressed concern about the effect of linked holdings upon the ability of BCMS to locate cattle accurately (National

Audit Office 2003). The data quality of BCMS has improved over time, although attempts to construct movement histories for animals have highlighted inconsistencies in the recorded movements (Mitchell and others 2005). Statistical analyses of BCMS movement data have highlighted biases in the reporting of birth dates (Robinson and Christley 2006) and the fact that certain classes of movements (specifically those of older animals, longer-distance movements and movements to slaughterhouses) are under reported (Green and Kao 2007).

The contact structure of cattle may be abstracted into a network, with cattle holdings being represented as nodes, and contacts between holdings being represented as edges. The resulting network may then be studied using existing techniques from social network analysis (Wasserman and Faust 1994). Such an approach has been used before to consider the structure of the UK sheep population (Webb 2005), as well as to analyse BCMS cattle movement data (Heath and others 2008, Vernon and Keeling 2009). Furthermore, the structure of cattle movement networks has been shown to be significant in the dynamics of infectious diseases of cattle (Christley and others 2005, Woolhouse and others 2005, Bigras-Poulin and others 2006, Robinson and others 2007).

The aims of this study were to characterise as completely as possible the contact structure of a geographically limited region, and to assess the extent to which movements not reported to BCMS and contacts other than cattle movements between holdings affected that structure.

The Isle of Lewis, which is one of the Western Isles of Scotland, was selected for this study because of an existing professional connection with the veterinary surgeon on the island, whose support was thought to be key to ensuring a good participation rate from the farmers. Additionally, as an island, it has a clear boundary, and contains sufficient farms to provide a useful but manageably small data set. There is an abattoir on the island in Stornoway (the largest settlement), and shows are held at Barvas (in July) and Carloway (in August). Some of the communities on Lewis own common grazing land; this is land that can be used for grazing cattle by residents, but is not common land as the term is used in English law (for instance, it is not land over which people may exercise rights of common such as grazing or cutting bracken).

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This paper describes a postal survey of the cattle farmers of Lewis to collect data on the movements of cattle in August 2005 and other potential routes of disease transmission between holdings, and the comparison of these data with movement data for the same period collected by RADAR.

Materials and methods

The addresses of cattle holdings on the Isle of Lewis were obtained from the Scottish Executive Environment and Rural Affairs Department (SEERAD) based on data from the 2004 agricultural census. Movement data from RADAR were based on an extract provided by Defra in May 2006. A letter inviting cattle farmers to participate in the study was posted in June 2005, along with a questionnaire upon which they were requested to record any movement of cattle between August 1 and August 31, 2005, inclusive. Additionally, farmers were requested to record occasions when they shared agricultural equipment with other farmers as this was a potential route of disease transmission (Wilesmith and others 2003). They were also asked to record if and when they used shared grazing, or attended agricultural shows or sales (all of which are opportunities for livestock to transmit infectious diseases to one another) within the same period.

A second letter was posted to those farmers who had not opted out of the study on August 29, 2005. It included a questionnaire about the number and breed(s) of cattle held on the farm, the county/parish/holding (CPH) number of the farm, the ownership of the land the farm was on, the artificial insemination (AI) company used (if any), when (if at all) the cattle were housed or put on shared grazing land, and a prompt for any further comments about BCMS. This holding details questionnaire was sent separately to the movement questionnaire to reduce the burden of paperwork arriving with farmers at one time, as well as to remind them about the request to record movements during August.

Non-responders were sent further letters encouraging them to participate (by returning the questionnaires about their holding and any movements in August 2005) on September 27 and on November 30, 2005.

Movement data were abstracted to form a contact network by representing holdings as nodes, and placing an edge between two nodes if a movement of livestock between the two nodes occurred during August 2005. The in-degree of a node is the number of edges that end at that node, and the out-degree of a node is the number of edges that begin at that node. The density of a network is the proportion of possible edges that are extant. A component of a network is a group of nodes that may all be reached from one another; here only weakly-connected components were considered, in which case, the direction of edges was ignored.

A contact network was derived from the movement data supplied by the farmers, and information was collected from RADAR on movements during the study period from or to those holdings that had returned movement questionnaires. Where movements reported by farmers were not recoverable from RADAR the following steps were taken in order to try and locate a suitable movement record in RADAR: 1 Interrogate RADAR about any movement between the two holdings in July or September 2005; 2 Interrogate RADAR about any movement between the two holdings in 2005; 3 Consider other movements in August 2005 in RADAR where one end-point corresponds to the movement record supplied by the farmer, and see if the 'incorrect' end-point of the movement is likely to have been incorrectly entered by the farmer or by BCMS staff; 4 Extend the previous search to include July and September 2005; 5 Extend the previous search to include all of 2005; 6 Extend the previous search to have no date restriction; 7 Locate the animal(s) involved in the movement in RADAR by ear tag, and search for movements involving that animal during July, August and September 2005; and 8 Where the ear tag supplied by the farmer could not be matched, search through the ear tags of livestock that have stayed on the holding in question for a similar ear tag, and then repeat the above search.

Three further contact networks were constructed by interrogating RADAR for movements in August 2005 between all the cattle farms of Lewis; one taking SEERAD's list as definitive (referred to

later as 'SEERAD Holdings'), one using all holdings listed in RADAR with the string 'ISLE OF LEWIS' in their address (referred to later as 'ISLE OF LEWIS Holdings'), and one using RADAR's location data based on the postcode address file (PAF) to collect holdings with HS1 or HS2 postcodes, that is, those postcodes corresponding to Lewis (referred to later as 'PAF Holdings').

Data entry and analysis were performed largely using small Python scripts. Network analyses were performed using the Contagion software package (Vernon 2007).

Results

Response level and holding details

Letters were sent to 154 distinct addresses. Four were returned by the Post Office as 'address inaccessible' or 'addressee has gone away'. Of the remaining 150 addresses, 54 returned at least one of the two questionnaires (38 of these returned both), and 17 explicitly refused to participate in the study. Nine of these refusing holdings reported that they no longer had any cattle (and thus were useful responses). The only replies to the letter of November 30 were refusals to participate in the study, so sending out further reminder letters was considered unlikely to be productive. A summary of the responses to the holding details questionnaire is shown in Table 1.

Four holdings reported having a small number of dairy cattle, the maximum number of cattle held being five. Forty-nine holdings reported having beef cattle; the median number of beef cattle on these holdings was six and the range was one to 50.

Fifty holdings supplied information regarding land ownership, of which five (10 per cent) owned their land, and 45 (90 per cent) rented it. Of the 50 holdings answering the AI question, 14 (28 per cent) used AI, 11 (79 per cent) of which used the same local operator, and three (21 per cent) used a national company; 36 (72 per cent) holdings specified that they never used AI. No holdings said they shared a bull.

Twenty-eight of 52 (54 per cent) holdings specified that they made some use of shared pasture, 18 (64 per cent) of which used shared grazing during the summer (May to October), and four (14 per cent) specified that they use it all year; the remaining six holdings made use of shared grazing outside the summer months.

Reportable contacts

Responders reported 36 movements of livestock. These included movements to or from 11 holdings on the island to which questionnaires had not been sent, and other connections (ie, not animal movements) to four other such holdings. These 15 holdings included the showground and abattoir on the island, eight holdings in the BCMS database but not in the list of holdings provided by SEERAD, three properties with no entry in either the BCMS database or the SEERAD list, and two patches of common grazing land.

Three holdings reported movements between two other holdings (movements that neither began nor ended on the responding holding); this accounts for the fact that there are 15 nodes in the network described by questionnaire returns, even though only 14 holdings reported movements. The 36 reported movements of animals resulted in only 10 edges in a movement network; this is due to two factors. First, multiple animals moved in a single batch only contribute one edge to a movement network, and secondly movements between two holdings on separate days only contribute one edge to a static movement network. Forty-seven responding holdings reported no movements.

TABLE 1: Summary of responses to the holding details questionnaire

Variable	Number
Land ownership	
Own	5
Rent	45
Other	2
No response	1
AI use	
Yes	7
Sometimes	7
Never	36
No response	3
Cattle housed	
Yes	24
No	28
No response	1
Shared grazing used	
Yes	28
No	24
No response	1
Type of cattle kept	
Beef	49
Dairy	4

TABLE 2: Summary network properties of the five different representations of the Isle of Lewis in August 2005. Only holdings with at least one movement on or off during the study period are included

Network	Questionnaire data	RADAR questionnaire holdings	RADAR 'ISLE OF LEWIS' holdings	RADAR SEERAD holdings	RADAR PAF holdings
Nodes	15	8	54	51	43
Edges	10	5	74	66	53
Density	0.05	0.09	0.03	0.03	0.03
Largest component	4	4	36	34	29

PAF Postcode address file, RADAR Rapid Analysis and Detection of Animal-related Risks, SEERAD Scottish Executive Environment and Rural Affairs Department

holdings on Lewis with 'common grazing' in their addresses have had any movements to or from them recorded in RADAR. Including the available data on shared grazing from the questionnaires adds one component of size 2 to the contact network.

There were eight instances of holdings sharing agricultural equipment related to cattle, such as cattle trailers; one respondent mentioned that they cleaned the equipment between uses, although the circulated questionnaires did not ask about this.

Three holdings of the 47 that supplied one filled in an incorrect CPH number on their form. Two holdings' addresses are supplied by SEERAD were not found in RADAR, although a similar address was found in both cases.

A free comment box was available on the questionnaire. The following points were raised: 'birth registration forms seem too large for the information required'; 'passports are dated when cattle are delivered to the local mart, but the mainland mart date will be forwarded to BCMS, so producing a discrepancy when SEERAD does checks'; 'stock not registered soon enough after birth should be able to leave the birth holding as long as they do not enter the food chain'; 'paperwork should be reduced (and made easier to fill in); and '[BCMS does] a good job in difficult circumstances'.

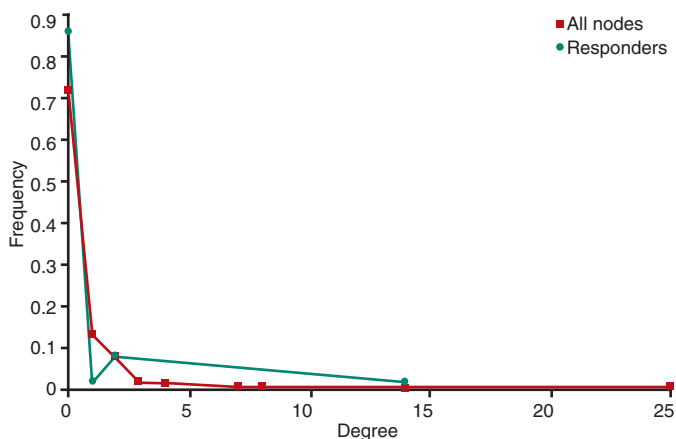


FIG 1: Line plot showing the degree distribution (summed in- and out-degree) of responding holdings and all holdings on Lewis, according to the data from the Scottish Executive Environment and Rural Affairs Department

A summary of the size and density of the reported network of movements, as well as the networks derived from RADAR, is in Table 2; only holdings with at least one movement reported to or from them are included in the node counts. It is apparent that the contact structures of the different sets of holdings (ie, the RADAR networks corresponding to the holdings supplied by SEERAD, the holdings with Lewis postcodes in the PAF, and the holdings with 'ISLE OF LEWIS' in their address field) are similar; while the set of PAF-matched holdings is somewhat smaller due to problems with address quality in the underlying BCMS data, it is of similar density. It is difficult to meaningfully compare these three networks with the two networks based on the questionnaire holdings, due to the substantial difference in their sizes (for example, a larger network will have lower density than a smaller network with similar mean degree). The degree distribution (summed in- and out-degree) according to RADAR for those holdings that responded compared with all the holdings on Lewis (according to the SEERAD data) is shown in Fig 1.

During the study period, there were two agricultural shows locally – the Carloway Show on August 3, and the North Harris Show on August 13; one holding reported attending these, but did not report them as movements on the questionnaire, and RADAR records movements of animals from that holding to and from the relevant showgrounds. RADAR records the movement of animals to and from one other respondent to these shows, but that respondent did not report having attended either show. One holding reported a movement of an animal that RADAR reports as having never moved from the holding it was born on, in mainland Scotland.

Non-reportable contacts

While 54 per cent of holdings reported making some use of shared grazing land during the year, three holdings reported movements during the study period to common grazing lands (none of these movements was in RADAR); one of these supplied a CPH number for the common grazing land but the relevant location in RADAR has no movements to or from it reported ever. No holdings in RADAR are specified as being common grazing land, and none of the three

Discussion

A substantial proportion of cattle holdings on Lewis use shared grazing, and their movements to and from these shared grazing lands are not reported to BCMS. This is a significant source of contact between animals and potential disease transmission that is not represented in BCMS cattle movement data.

Not all movements of cattle are required to be reported to BCMS; specifically, movements between linked holdings, within crofter townships, or to and from temporary grass lets or common grazing land are exempted, although they must still be recorded in the herd register. Across the UK, there are only 28 holdings in RADAR with 'common grazing' in their address (and none classified as common grazing land), of which only 17 have ever had livestock staying on them. If this search is widened to just requiring 'grazing' in the address field, 90 holdings are found, only 31 of which have ever had livestock stays reported in RADAR; some of these may well be rented grazing lands, rather than common grazing land. In some areas of the UK (including the Isle of Lewis), this means that a substantial quantity of cattle movements are not being reported to BCMS. While movements to common grazing land are not relevant to BCMS since the animals stay under the same ownership, they are clearly significant from the point of view of epidemiology. It is difficult to assess the contribution of these unreported movements to contact network structure nationally, but this issue highlights one of the problems of BCMS as an epidemiological tool – it was not designed to be one. Sensitivity analysis of network-based models is therefore important, so that they are not invalidated by omissions in BCMS.

Some respondents who declined to participate said that they thought their holdings were 'too boring' to participate in the study, suggesting there may be bias against holdings with no cattle movements in August among the respondents. Comparing the summed in- and out-degree distribution of those nodes that responded (the study group) with all the holdings on Lewis (the study population) suggests that this was not a significant factor, although the small sample size prevents any meaningful statistical analysis.

As is typical for the Western Isles, most of the study group were small rented crofts. Small holdings are only selected for the annual census every three years, so it is unsurprising that some respondents said that they had not had any cattle for a number of years.

There were a number of basic errors in the data supplied by farmers, regarding the ear tag of their cattle or the CPH number of their holding. These particular errors are more difficult to make when reporting movements to BCMS, since passports are preprinted with

the correct ear tag, and keepers have adhesive labels with their CPH number on them to use on the passports; nonetheless, the system does largely rely on keepers accurately reporting movements, and there is a potential source of error here. A review of livestock movement controls has noted that the current regulations are overly complex, and prone to fraud (Madders 2006).

The differences between the three sets of Lewis holdings extractable from RADAR are interesting; RADAR lists some holdings on Lewis that were not in the list of holdings SEERAD provided, but the quality of address details of some of the holdings on Lewis stored in RADAR is sufficiently poor that it is not possible to look these addresses up in the PAF. Only 74 per cent of holdings in RADAR have an associated PAF entry, so the problem of address quality in RADAR is clearly somewhat widespread. Performing the agricultural census on individual premises more frequently has significant cost implications. Since 2007, cattle populations have been reported based on data from RADAR, not the Agricultural Survey.

This survey detected only a very low level of non-cattle-movement contacts between farms that had the potential for disease transmission, whether reported to BCMS or otherwise. This reinforces the use of cattle movement data for contact network analysis for epidemiological purposes in the UK. A larger-scale study would be needed to establish more fully the level at which such contacts occur throughout the year.

A potential criticism of the present study is that the Isle of Lewis does not represent a typical population of UK cattle farms. Given the heterogeneity of the UK's cattle farms, it would be difficult to define a typical cattle farm (or set of cattle farms). The conclusions drawn from this study, furthermore, do not depend for their validity upon the typicalness of the population of farms studied. The similarly populous but smaller mainland of Shetland had a similar movement network (based on number of nodes and edges, and giant weak component size) in August 2005, while the similar sized Isle of Skye, which has about half the human population, had many more animal movements (data not shown, BCMS/RADAR data). Accordingly, the results from Lewis should be naively extrapolated to other Scottish islands. It would have been preferable to use a longer study period than one month, but this would have increased the burden on farmers, and might well have resulted in a lower response rate.

Further work in this area would usefully include the measuring of prevalence and/or spread of infectious disease among a small cattle population alongside the collection of movement data. This would allow the utility of contact network-based methods to be compared with simpler modelling techniques. Additionally, larger-scale studies to establish the level of non-reportable movements (and infectious contacts that are not animal movements) across the UK throughout

the year would be beneficial for the formation of more accurate models of the contact structure of the UK cattle herd.

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