Animal Science 2005, **80:** 265-273
1357-7298/05/50020265$20.00

Characteristics of cattle movements in Britain – an analysis of records from the Cattle Tracing System

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Abstract

This paper reviews the main temporal and spatial characteristics of cattle movements in Britain, based on an analysis of records in the British Cattle Movement Service's Cattle Tracing System (CTS) database, focusing on the period 2001 to 2003, during which notification of cattle movements was mandatory. Movements vary weekly and seasonally according to the production cycle, with peaks in late spring (April) and early autumn (October), and an average 1·63 million farm-to-farm movements per month, equivalent to 19·6 million per annum. The geographical distribution of these movements appears to be relatively stable from year to year, with the great majority of animals moving less than 100 km per journey, although many tens of thousands move over far greater distances of up to 1000 km. The procedures developed to extract, match, geo-reference, analyse and display movement records have greatly enhanced the utility of the CTS database, in that it is now feasible to assess, monitor and map the spatial dynamics and geographical distribution of cattle movements, and provide this information in standardized format on a regular basis.

Keywords: *Britain, cattle, livestock, movement.*

Introduction

The movement of infected animals has long been recognized as a critical factor in the spread of disease, as reflected in strict import/export regulations and the extensive movement restrictions imposed during the 2001 foot and mouth disease (FMD) outbreak. The first requirement for cattle to be individually identified in Britain was introduced in 1953, as a support measure in the control of bovine tuberculosis (BTB), and since 1960, farmers have been required to keep records of all movements of animals on and off their premises. Nevertheless, the centralized recording and monitoring of livestock movements in Britain was considered impractical/ unnecessary until recently. The European Union (EU) has been instrumental in setting requirements for livestock identification and tracking in member states, especially since the early 1990s (National Audit Office (NAO), 2003).

In the aftermath of the bovine-spongiform-encephalopathy (BSE) crisis, a cattle passport scheme was introduced in July 1996, requiring farmers to register the date of birth, sex, breed and parentage of each calf born on their farms at their local agricultural office, so that a passport could be issued to ensure that only individually identified animals, under 30 months old, could enter the food chain for human consumption.

After an initial 2-year trial period, the cattle passport scheme was modified slightly in form and reporting procedures, and incorporated in the British Cattle Movement Service (BCMS), which was established in September 1998, as one of a progressive series of measures to restore credibility and consumer confidence in the British meat industry, and to conform with EU regulations. The BCMS is based in Workington, Cumbria, and is now run as part of the Department for the Environment, Food and Rural Affairs (DEFRA) Rural Payments Agency (RPA), responsible for disbursements under the EU's Common Agricultural Policy (CAP).

At the heart of BCMS is the Cattle Tracing System (CTS) database, which in September 2004 was ported from a UniData to an Oracle database environment. DEFRA's other main animal movement database is the Animal Movement Licensing System (AMLS), which records the batch movement of cattle, pigs, sheep, goats and camelids. DEFRA plan to merge the CTS and AMLS into a common database 'The Livestock Register', which may also record details of the movements of other species.

During its first 2 years of operation, the BCMS concentrated on establishing the process of registering all calves born after

September 1998 and progressively transferring the backlog of cattle passport data from two separate databases – one for England and Wales, and the other for Scotland – onto a single, common CTS database for the whole of Britain. Movement data was first captured centrally in 1998 for animals with a cheque-book style passport born after September 1998. In 2000, there was a 'back-capture' of chequebook style passport details (and details of the current location) of all animals still alive and not on the system. Since 29 January 2001, keepers of cattle throughout Britain have been legally obliged to notify the BCMS of all births, movements and deaths of cattle. It is important to note, however, that the initial, primary purpose of the BCMS and the CTS was to ensure the identification and traceability of individual cattle during the recovery period after the BSE crisis and not to serve as a disease control support system for fast moving diseases, such as the FMD epidemic in 2001 (NAO, 2003).

Within the context of the BCMS and CTS, a 'movement' is deemed to have occurred when an animal is moved 'off' or 'on' to a specific holding, or between herds. All such movements must be reported, except for movements between officially approved 'linked-holdings' – discontinuous parcels of land managed as a single unit. 'Off' and 'on' movements are reported separately by the sender and recipient, when, for example, an animal is moved off one farm and on to another, as in a private sale; when an animal is moved off a farm to a market; from a market to a farm; from farm to slaughterhouse; or from a farm to a dealer. Births and deaths are also recorded as 'movements'.

This paper reviews the main temporal and spatial characteristics of cattle movements in Britain, as revealed in an examination of CTS records for an assessment of risk factors associated with the spread of bovine tuberculosis in Britain for DEFRA (Environment Research Group Oxford (ERGO), 2004).

Material and methods

Extracting data from the CTS

For ease of analysis, a sub-set of CTS data was extracted from the Unidata-based system, which is non-compliant with Structured Query Language (SQL) databases and read into a dedicated SQL Server database. Seven CTS data tables were identified to be of potential epidemiological interest, three of which were used in this study, as indicated in Table 1.

DEFRA's Information Technology Directorate at Guildford provided text files for all the historical data in these tables. SQL data transformation service (DTS) code was developed to read the hundreds of text files provided into the SQL database. The total size of the database, after the last download of data used in the analysis on 15 December 2003 (relating to movement data up to and including 19 November 2003), was 148 Gb, relating to some 25·8 million cattle.

Transforming and cleaning data

Two preparatory steps were required prior to analysis : 'geo-referencing' for use in a Geographical Information System (GIS) and 'pairing' of 'on' and 'off' records to link the two locations involved in a cattle movement.

Geo-referencing. Various methods were used to geo-reference locations in a hierarchical sequence, as shown in Table 2. In the first instance, data held on the CTS (e.g. address and Ordnance Survey (OS) reference) were used to establish geographical coordinates. If this failed, location data were cross-referenced against other data sources (e.g. VetNet-DEFRA's veterinary disease database; Census records; and a list of slaughterhouse locations). Ninety-eight percent of the locations associated with cattle movement were geo-referenced.

'Pairing' movement records. For all events, except births and deaths, the BCMS receives two records : one for the location the animal has moved off and the other record for the location the animal has moved on to. For any meaningful analysis of movement patterns, 'off' and 'on' records have to be 'paired'. Figure 1 shows how movement records accumulate over time. A full movement history can be obtained from all 'on' movements and the death record, or, conversely, all 'off' movements and the birth record.

The approach adopted to pairing movement records was to take all the 'on' movements and the death record and order them by date. One problem that soon became apparent was if an animal moved several times in a single day – which is

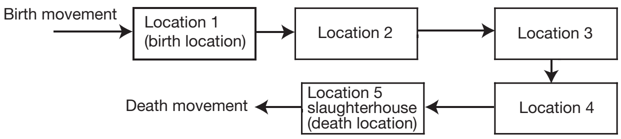
Table 1 *Variables† used in movement analysis, obtained from Cattle Tracing System database tables*

Animal table	Location table	Movement table
Animal ID	Location identifier	Movement ID
Eartag status	Location ID	Eartag
Breed	Location type	Animal ID
Sex	Sublocation type	Location code
Birth date	Premises type	Location movement date
Dam ID	Name and address of owner	Movement direction: on/off
Import date	OS ref	Movement type
Import country	Creation date	Country code
Birth location ID		Record status
Birth location key		
Surrogate dam ID		
Sire eartag		
Death date		
Death move ref		
Birth move ref		

† ID = identity; OS = Ordnance Survey; ref = reference.

Table 2 *Sequence of comparisons used to geo-reference records from Cattle Tracing Scheme database and the incremental proportions of geographical coordinates deduced*

Geo-referencing source	Percentage of records resolved
CapScan: uses address	67·7%
Grid reference: uses OS Reference	+5·5%
VetNet: uses VetNet x,y	+2·0%
Census: uses Census x,y	+1·1%
Slaughterhouse list	+0·1%
Locations geo-referenced	76·4%
Movement locations geo-referenced	98·0%



Animal identity	Movement date	Location	Direction	Type
1	01/01/02	1	On	Birth
1	30/01/02	1	Off	Normal off
1	30/01/02	2	On	Normal on
1	01/05/02	2	Off	Normal off
1	01/05/02	3	On	Normal on
1	01/09/02	3	Off	Normal off
1	01/09/02	4	On	Normal on
1	01/01/03	4	Off	Normal off
1	01/01/03	5	On	Normal on
1	02/01/03	5	Off	Death

Figure 1 Illustration of sequential animal movements from birth to death and 'on' and 'off' movements generated.

not uncommon. Because CTS does not record the time of movement there is no easy way to order these movements. To resolve this problem, premises types were reviewed to determine if a logical order could be applied. For instance, if an animal was on a farm and a slaughterhouse on the same day, the order was most likely to be from farm to slaughterhouse. If an animal had been on a market and a farm on the same day, the sequence of movements was likely to have been from market to farm, because only 'on' movements were being considered.

The overall approach taken was that if any part of an animal's movement history could not be resolved, or was clearly incorrect (e.g. movements after death), then all movement details for that animal were excluded from the paired movements dataset used in subsequent analysis. The reasons for exclusion are summarized in Figure 2 and discussed in further detail in the following section.

Data quality

Data quality issues relate to the history of data handling, data structure and general validation, as commented upon in an NAO (2003) report.

Almost a third (32·4%) of all records were rejected from the paired movement table for lack of logical movement histories. This might appear to be a worryingly large proportion of rejections, but as shown in Figure 3, most rejected records were for 1996, 1997 and 1998, and the number has declined substantially since then, with 12·1% rejection of the 2003 age cohort.

Reason for rejection of animal's movement records	% of animals rejected
Dies on a location it does not appear to have moved onto	20·8
Two or more intra-day movements that can not be rationalized	11·2
Moves onto same location on different dates with no intermediate location	0·2
Birth movement not first movement record	0·2
Death movement not last movement record	0·001
More than three intra-day movements	0·0003

Total number of animals 25·8 million;
number accepted for analysis 17·4 million;

Total % of rejected
32·4

Figure 2 Reasons for excluding animal records from movement analysis.

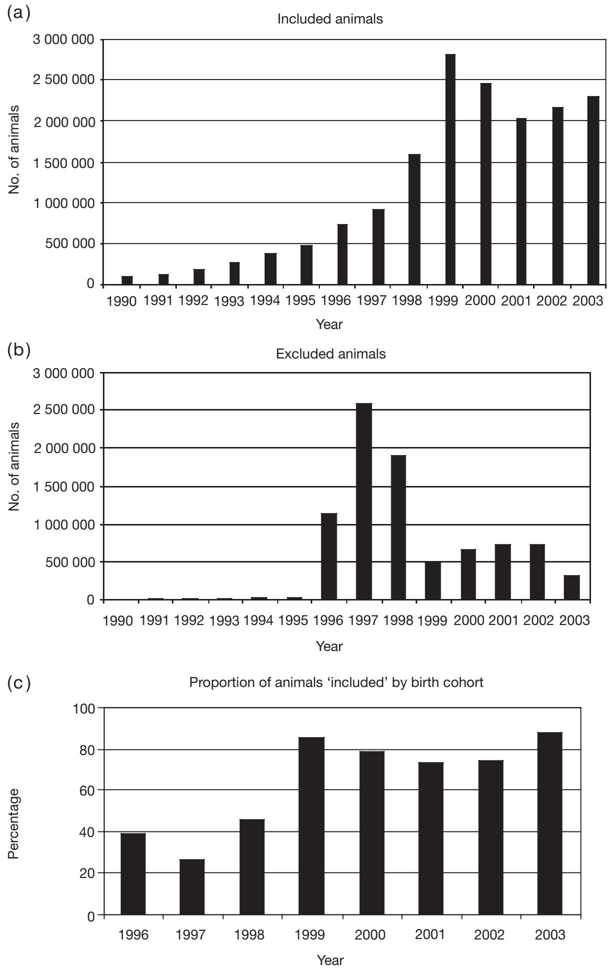


Figure 3 Cattle Tracing Scheme database animal records (a) included and (b) excluded from movement analysis; (c) shows proportion included arranged according to birth cohort.

A fifth (20·8%) of all animal records were rejected because they appeared never to have moved to where they died. In fact, what appear to be errors in the data are a facet of the history of the data handling; most of these animals relate to the early years of the CTS, when only birth and death records were recorded for many animals. In utilizing data from the CTS it is therefore essential to understand the history of data handling and that the system contains records that predate the legal obligation to record all animal movements since January 2001.

The second most common reason for rejecting an animal's movement records (affecting 11·2% of all records) was an inability to resolve within-day movements. If the structure of movement records was such that both 'on' and 'off' locations were included in the same record or the times (as well as the date) of movement were recorded, this problem would not arise.

Other reasons for rejecting an animal's movement history relate to general validation. For instance, movement records exist with the date of movement before the date of birth. Although the percentage occurrence of this type of problem is quite low (0·2%), because there are over 90 million movement records the number of animals affected is not negligible.

In summary, the quality of the CTS data has improved over time, with 87·9% of animals having complete logical movement histories for the latest 2003 birth cohort. This figure could be increased by building the movement history table using both 'on' and 'off' movements in its construction, though the complexity of the extraction algorithm would increase substantially.

Results

Frequency of monthly movements

Cattle movements vary cyclically during the year, with late spring and autumn peaks of around 2 million in April and October, as shown in Figure 4, and a mean value of 1·63 million per month from November 2001 to October 2003, after the lifting of FMD movement restrictions.

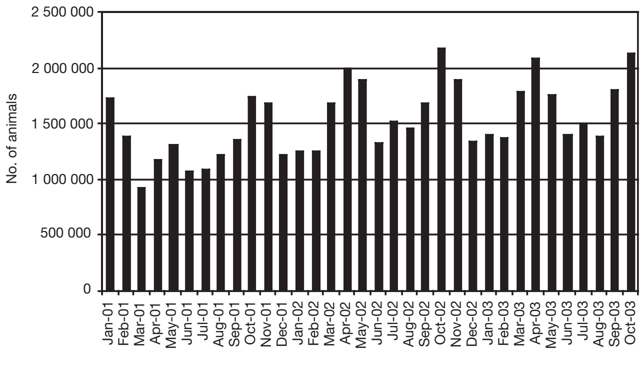


Figure 4 Frequency of cattle movements by month.

Daily variation

As expected, most cattle movements occur on working days, as shown in Figure 5, peaking on Wednesdays with a mean of 72 400 movements per day in 2002, compared with 13 900 per day on Sundays.

Composition of movements

The composition of cattle movement types as recorded by CTS in 2001, 2002 and 2003 are shown in Figure 6. Reassuringly, the total number of 'on' farm movements was similar to that of 'off' farm movements, at just under 7 million in 2002. In that year, death and birth records were also similar at just under 3 million each, indicating a relatively stable overall herd size. In 2001, there were 2 million fewer 'on'/ 'off' farm movements than in 2002, and deaths exceeded births by 534 000, reflecting the impacts of FMD movement restrictions and culling.

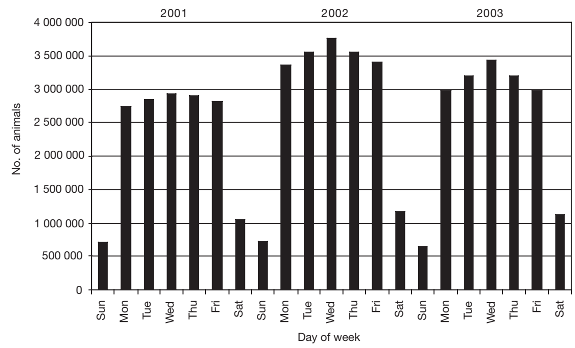


Figure 5 Cumulative total cattle movements by day of week received.

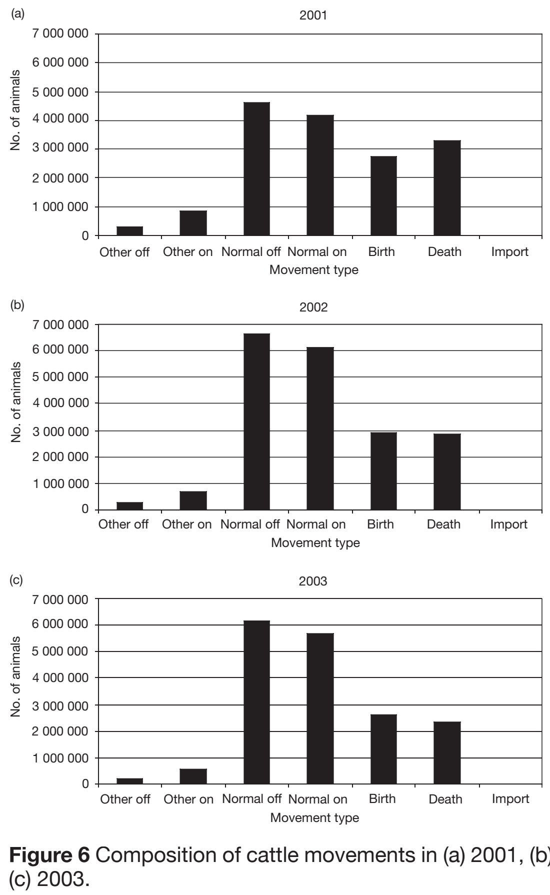


Figure 6 Composition of cattle movements in (a) 2001, (b) 2002 and (c) 2003.

In terms of the potential spread of diseases, it should be noted that imported cattle movements account for a vanishingly small proportion of total cattle movements.

Lifetime movements
The frequency of movements made during an animal's lifetime is shown in Figure 7. Zero movement indicates that the animal never moved, and died on the farm on which it was born. Half a million animals were so recorded in 2001, compared with 200 000 in 2002, reflecting in part at least the impact of FMD culling. One movement means the animal was born on a farm and moved off that farm to slaughter; two movements indicate that the animal moved from where it was born to another location prior to slaughter; etc. Clearly, the great majority of cattle were moved less than three times during their lifetime, although some animals were moved on as many as 24 occasions.

It is not until there are two movements that a genuine farm-to-farm movement (or non-death movement) occurs. It is clear that the great majority of cattle rarely move, either moving only once straight to slaughter, or having one non-death movement in their lifetime.

Births and deaths
The seasonal cycle of calving is reflected clearly in Figure 8, with a primary peak of just under 400 000 calves a month in April and a minor peak of just under 250 000 in September, falling to around 150 000 in December and January.

Normally, between 200 000 and 300 000 cattle are slaughtered or die on farm each month, with a slight increase in October and November (Figure 9). At the height of FMD culling, however, the number of deaths increased to 320 000 and 446 000 in March and April 2001, respectively.

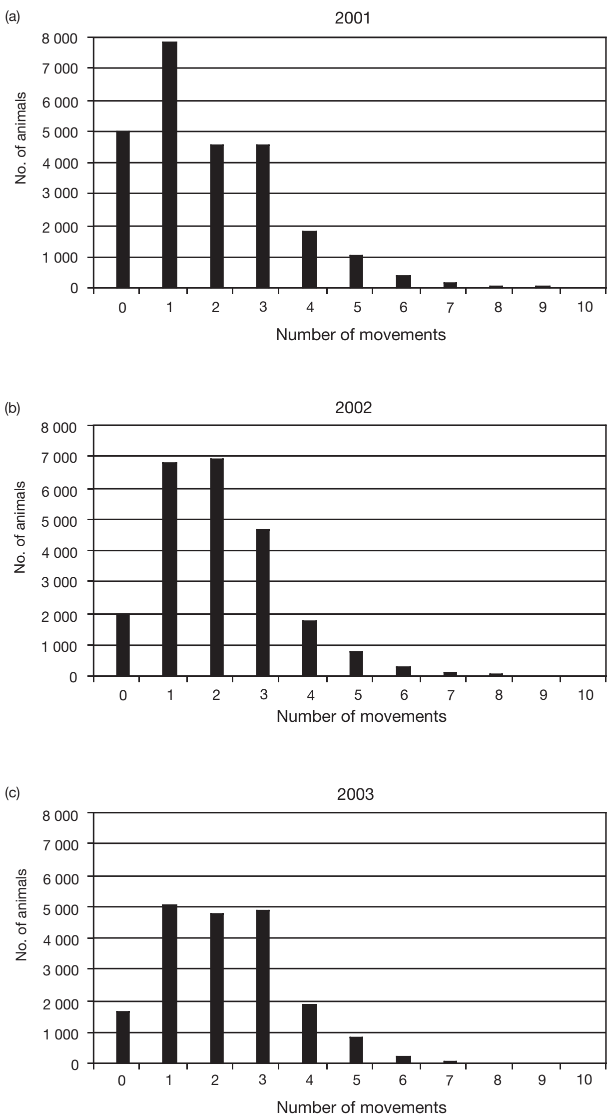


Figure 7 Frequency of movements during an individual's lifetime (i.e. excluding birth and death) in (a) 2001, (b) 2002 and (c) 2003.

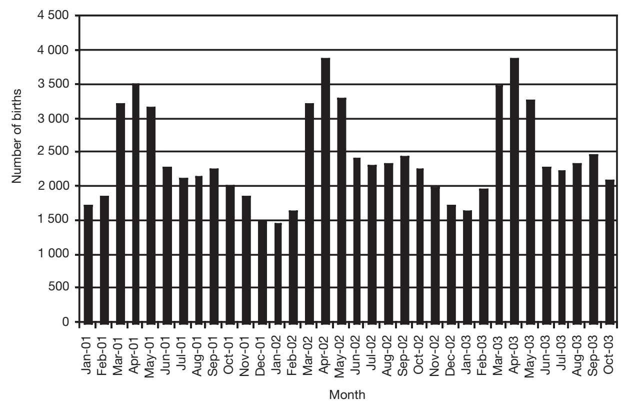


Figure 8 Cattle births by month.

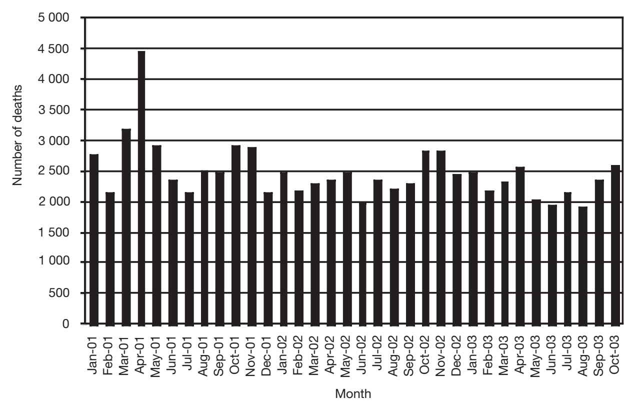


Figure 9 Cattle deaths by month.

The age at death frequency distribution is remarkable consistent from year to year, as shown in Figure 10, with peaks just after birth, reflecting the culling of dairy bull calves and culling at 15 months, 24 months and 30 months, reflecting the general pattern of beef production and the BSE 30-month beef cattle slaughter rule.

Distances moved

The percentage distribution of straight-line distances moved by cattle between farms from January 2001 to November 2003 is shown in Figure 11, in which the *x*-axis has been truncated at 500 km. The mean distance moved was 58 km and 43% of movements were less than 20 km. Nevertheless, a substantial number of long-range movements of up to 1000 km take place each year, and may be important in the spread of diseases such as BTB (Gilbert *et al*., 2005).

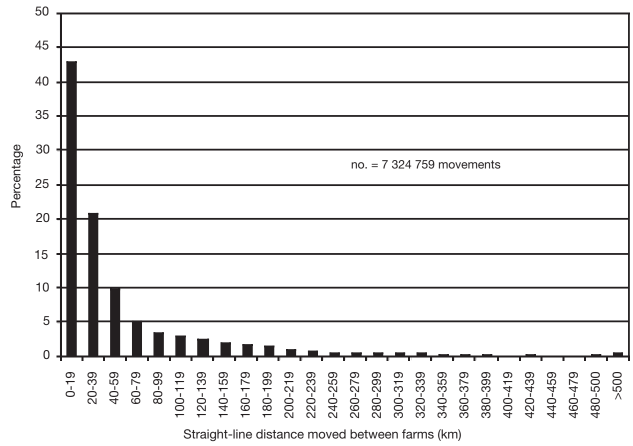


Figure 11 Percentage distribution of straight-line distances moved by cattle in farm-to-farm transfers.

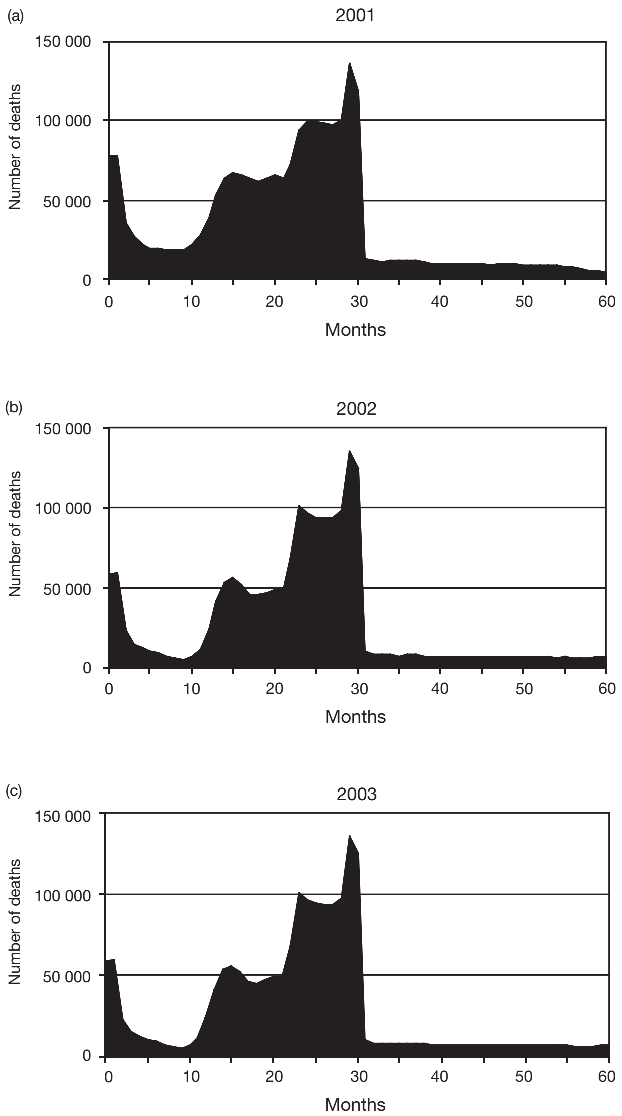


Figure 10 Age at death frequency distributions in (a) 2001, (b) 2002 and (c) 2003.

The percentage distribution of straight-line distances moved to slaughter from January 2001 to November 2003 is shown in Figure 12, in which the *x*-axis has been truncated at 500 km. The mean distance travelled was 75 km and 75% of movements were less than 100 km.

The geographical distributions of cattle 'on' movements across Britain during 2001, 2002 and 2003 are shown in Figure 13. These were produced by assigning each 'on' movement to a 5 km × 5 km Ordinance Survey grid square, using the geo-referenced location and calculating the total number of 'on' movements per grid (using Statistical Packages for the Social Sciences (SPSS), 2001), then importing these data as grid attributes in ESRI ArcView shape files.

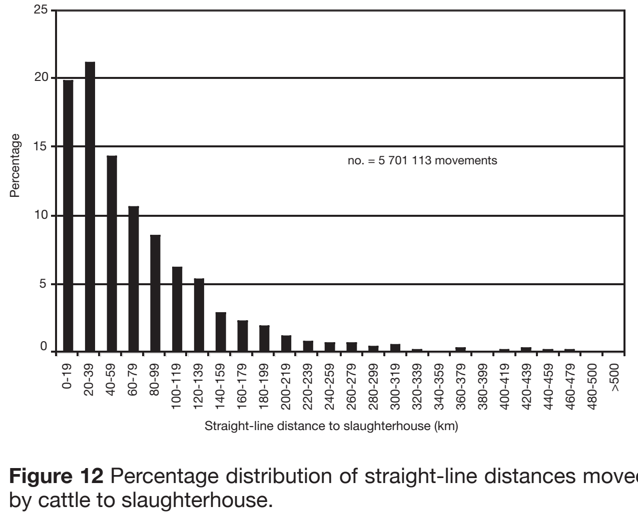


Figure 12 Percentage distribution of straight-line distances moved by cattle to slaughterhouse.

Figure 13 shows these summed annual distributions to be fairly similar in relative terms from year to year, even despite the 2001 FMD epidemic: correlations of pixel values (implemented in IDRISI) for each year produce coefficients of variation (R^2) of 0·80, 0·91 and 0·92 for 2001/3, 2001/2, and 2002/3 respectively. Locations of peak concentrations of inward movements are thus quite consistent, and are in south-west England, the Midlands and south-west Wales – where BTB is established – but also north-central Yorkshire, north Cumbria, southern Dumfries and Galloway, and north-west Grampian, where BTB is sporadic.

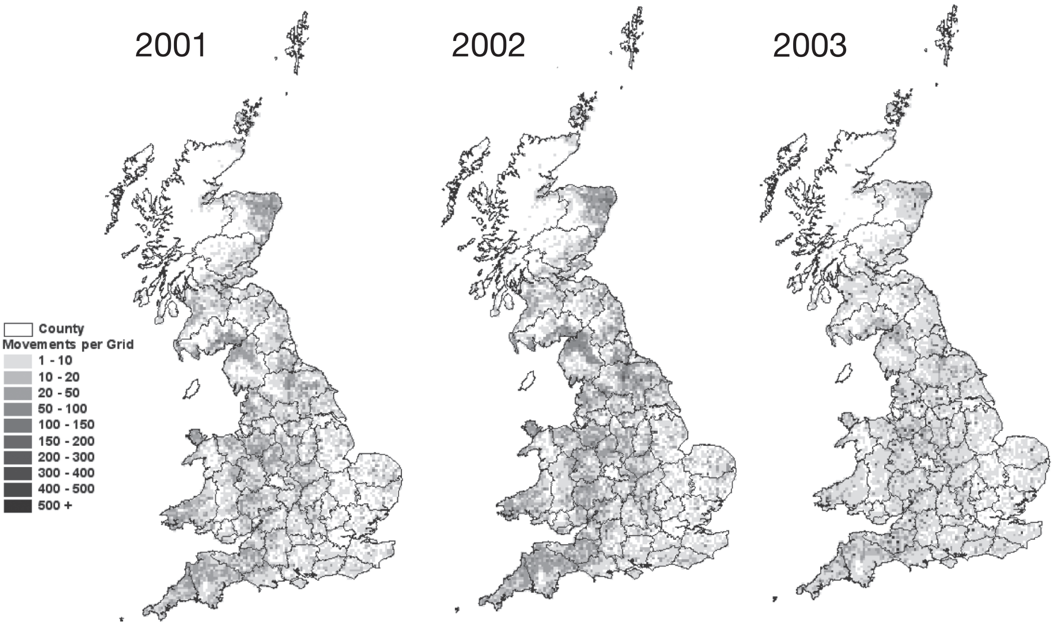


Figure 13 Geographical distribution of cattle 'on' movements in 2001, 2002 and 2003.

Table 3 *Matrix of inter-regional cattle movements, by year, showing that the great majority of cattle movements remain within their region of origin (shaded cells)*

January to December 2001

From \ To	East	North	Scotland	Wales	West	Total from	Total to	To-from
East	220 667	16 075	377	9 780	43 182	**290 081**	**277 340**	**-12 741**
North	27 337	556 702	15 273	29 157	38 350	**666 819**	**607 359**	**-59 460**
Scotland	3 246	13 125	556 439	4 300	6 995	**584 105**	**572 596**	**-11 509**
Wales	2 385	8 787	191	226 207	17 619	**255 189**	**306 972**	**51 783**
West	23 705	12 670	316	37 528	491 016	**565 235**	**597 162**	**31 927**
Total to	**277 340**	**607 359**	**572 596**	**306 972**	**597 162**	**2 361 429**	**2 361 429**	**0**

January to December 2002

From \ To	East	North	Scotland	Wales	West	Total from	Total to	To-from
East	303 476	23 363	1 059	14 361	68 714	**410 973**	**395 603**	**-15 370**
North	49 670	1 058 773	46 463	55 057	81 520	**1 291 483**	**1 164 300**	**-127 183**
Scotland	5 711	39 132	751 913	10 895	17 614	**825 265**	**800 614**	**-24 651**
Wales	1 875	14 088	229	436 753	28 411	**481 356**	**582 049**	**100 693**
West	34 871	28 944	950	64 983	856 420	**986 168**	**1 052 679**	**66 511**
Total to	**395 603**	**1 164 300**	**800 614**	**582 049**	**1 052 679**	**3 995 245**	**3 995 245**	**0**

January to October 2003

From \ To	East	North	Scotland	Wales	West	Total from	Total to	To-from
East	297 162	26 237	736	13 499	66 766	**404 400**	**378 550**	**-25 850**
North	35 089	1,073 902	41 267	44 114	62 083	**1 256 455**	**1 202 227**	**-54 228**
Scotland	10 816	55 659	730 348	11 181	26 689	**834 693**	**773 719**	**-60 974**
Wales	1 867	14 990	564	414 789	29 793	**462 003**	**545 892**	**83 889**
West	33 616	31 439	804	62 309	826 068	**954 236**	**1 011 399**	**57 163**
Total to	**378 550**	**1 202 227**	**773 719**	**545 892**	**1 011 399**	**3 911 787**	**3 911 787**	**0**

Figures exclude birth and death records, and movements for which origin/destination could not be resolved.

Intra- and inter-regional movements
The great majority of cattle movements remain within their region of origin, as shown in Table 3 for 2001, 2002 and 2003. Disregarding 2001, which was atypical because of FMD restrictions, Northern England exports the largest number of cattle, followed by the West of England and Scotland. Regional cattle imports have a similar ranking. Eastern and northern regions of England and Scotland are net exporters of cattle, and Wales and western England are net importers of cattle.

Live cattle imports
Cattle imports increased as foot and mouth restocking took place. Holland, the Republic of Ireland, Northern Ireland and Denmark were the main sources of live cattle imports to Britain from January 2001 to November 2003, as shown in Figure 14. A total of 33 105 cattle from all sources were imported during that period.

Discussion

The temporal and spatial patterns of cattle movements presented in this paper are the first of their kind to illustrate the overall dynamics of the cattle trade in Britain. In summary, cattle movements vary weekly and seasonally according to the production cycle, with peaks in late spring (April) and early autumn (October). From November 2001 to October 2003, after the lifting of FMD movement restrictions, there were an average of 1·63 million farm-to-farm movements per month, equivalent to 19·6 million movements per annum.

In comparison, cattle imports to Britain constitute a very small proportion (0·18%) of total cattle movements and are likely, therefore, to be of relatively minor epidemiological significance as far as the spread of endemic diseases are concerned, although they remain a potential threat with regard to the introduction of new diseases.

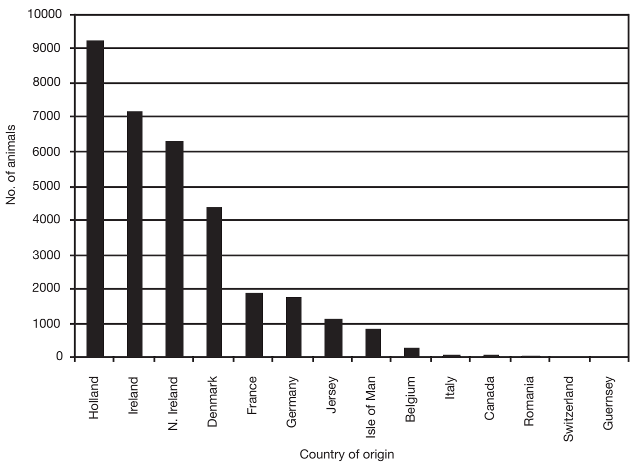


Figure 14 Origins of live cattle imports: January 2001 to November 2003.

The geographical distribution of these movements appears to be relatively stable from year to year, with the great majority being less than 100 km, although many tens of thousands of animals moved over far greater distances of up to 1000 km, with obvious potential implications for bio-security and disease transmission.

The procedures developed to extract, match, geo-reference, analyse and display movement records have greatly enhanced the utility of the CTS database, in that it is now feasible to assess, monitor and map the spatial dynamics and geographical distribution of cattle movements, and provide this information in standardized format on a regular basis. Current procedures utilize 87·9% of the available data from the most recent birth cohort, although this percentage could be improved upon with further development of the 'pairing' algorithm to utilize both 'on' and 'off' movement records. Data query routines are now in place that can extract summary movement information efficiently by date, age, sex, breed, movement type, and destination or origin characteristics. The potential exists for near real-time assessment of movement records, which should be a useful contribution to enhanced veterinary surveillance in Britain (DEFRA, 2003).

The incorporation of a geographic perspective into the CTS data archive has enabled the movement of infected cattle from areas of endemic disease, such as BTB, to be quantified and mapped, and evaluated as a risk factor in the spread of disease (Gilbert *et al*., 2005). In due course, it should also be possible to assess the epidemiological significance of different types of movement, as well as the efficacy of movement restrictions as a disease control measure.

Further methodological refinements that would add value to existing procedures can be envisaged. Assessing the length of stay at the point of arrival would add to the epidemiological value of the data, whilst automating the data extraction and processing routines to produce regular standardized updates for dissemination or incorporation into mapped displays would greatly broaden the potential audience for the information, thereby enhancing its overall relevance and utility.

Acknowledgements

The findings presented here are based on a study undertaken by the Environmental Research Group Oxford Limited and the Veterinary Laboratories Agency, Weybridge, funded by the Department for the Environment, Food and Rural Affairs under research contract number CSA6400 : Exploratory investigation of cattle movement records to enhance animal disease surveillance and control.
We are most grateful to David Evans of the British Cattle Movement Service and Mel Reader of DEFRA's Information Technology Directorate for their helpful comments on an early draft of this paper.
David Bourn and William Wint wish to thank Professor David J. Rogers, Professor Sarah Randolph and Dr. Simon Hay at the Zoology Department of Oxford University for their long-standing support and encouragement.

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(Received 6 January 2005 – Accepted 3 February 2005)