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Evidence Project Final Report

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Project identification

1. Defra Project code: AW0943
2. Project title: Study to Identify Risk Factors Associated with Welfare Outcomes for Sheep During and After Journeys of Short Duration
3. Contractor organisation(s):
   University of Bristol
   Senate House
   Tyndall Road
   Bristol BS8 1TH
4. Total Defra project costs (agreed fixed price): £ 529,272
5. Project: start date 01/07/2010
   end date 31/01/2013

6. It is Defra's intention to publish this form.
   Please confirm your agreement to do so...YES ☒ NO ☐

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   Defra recognises that in a small minority of cases there may be information, such as intellectual property or commercially confidential data, used in or generated by the research project, which should not be disclosed. In these cases, such information should be detailed in a separate annex (not to be published) so that the Evidence Project Final Report can be placed in the public domain. Where it is impossible to complete the Final Report without including references to any sensitive or confidential data, the information should be included and section (b) completed. NB: only in exceptional circumstances will Defra expect contractors to give a "No" answer.
   In all cases, reasons for withholding information must be fully in line with exemptions under the Environmental Information Regulations or the Freedom of Information Act 2000.

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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

The UK has the largest population of sheep in the EU (33 million) with a complex supply chain requiring many sheep movements. This project was designed to give Defra an appraisal of different types of short (under 8 h) journey in terms of the welfare of the sheep involved and of the economic and environmental impacts of the different marketing systems and the journeys that these involve, in order to inform policy. Within Council Regulation (EC) No 1/2005 a journey is defined as 'the entire transport operation from the place of departure to the place of destination, including any unloading, accommodation and loading occurring at intermediate points in the journey'. A short journey is defined in EU welfare legislation, as a journey taking less than 8 hours. However, time in auction markets is currently interpreted by Defra to be 'neutral' time. In terms of the application of 'neutral' time, Defra was particularly interested in the degree to which such time could be regarded as a period of rest and how conditions experienced by sheep during their time at markets compared with sheep being transported directly to slaughter.

We briefly summarise the methods and main findings for each of the five project objectives below:-

Objective 1 - *To identify risk factors within journeys of short duration (less than 8 hours) that are associated with welfare outcomes for sheep. To include an analysis of the effect of live auction markets as part of the journey.*
We concentrated on movements to slaughter to collect information on a wide range of journey types and distances travelled and to easily obtain blood samples. In total 1,509 sheep were sampled from five slaughter plants, each visited three times. On each visit the aim was to sub-sample 10 sheep from 10 distinct transport groups of animals arriving for slaughter. The groups of animals were selected to represent lambs and cull ewes, shorter and longer journeys within the 8 hour limitation, livestock markets/collection points and direct from farm transports involving a range of journey times. Details of each journey were obtained and each group of sheep was observed for resting, eating and drinking behaviour in lairage. Immediately after slaughter blood samples were obtained and later analysed.
The majority of older lambs went direct to slaughter, in transit for less than 8 h. For younger lambs and ewes the initial journey to market or collection centre was generally short, with almost all taking less than 1.5 h. Most sheep resumed their journey from a market/collection centre within 8 h and overall journey time, which included time spent in market, was generally under 12 h, but with a very small number (two groups) taking between one and two days.
Multilevel modelling revealed consistent differences between the types of sheep in the levels of the blood variables found following transport. Sheep arriving at their final destination from auction markets had increased levels of plasma sodium and higher plasma osmolality, both indicative of a greater degree of dehydration. The sheep also had higher levels of plasma free fatty acids (FFA) and β-hydroxybutyrate (BHB); both indicative of the animals drawing more heavily on energy reserves within the body. These variables increase linearly over time once feed is removed. However, the lower levels of plasma CK activity found for sheep passing via markets were indicative of a greater degree of recovery having taken

place from the initial muscular exertions associated with gathering, loading and transport. Whilst passing via auction markets made extra demands on the animals in terms of potential thirst and hunger, it did not appear to be unduly physiologically demanding compared with other circumstances sheep endure. Sheep have evolved to cope with arid climates and can tolerate longer periods without feed and water than, for example, the pig, a monogastric animal.

Objective 2 - *To survey the holding facilities for sheep at livestock auction markets with regard to their ability to provide 'rest' or 'neutral' time during a journey, including the opportunity to drink and to eat.*
Of the 31 markets which provided sheep for Objective 1, 23 were visited once and at least 12 holding pens in representative areas of the market were observed for 10 minutes each. Overall, 40.4% of these pens were estimated to have sufficient space for all animals to lie, while 10.1% did not allow enough space for any animals to lie. About half (50.2%) of the pens experienced minor disturbance from passers-by (including sheep being moved), while 5.8% experienced handling either from inside or outside the pen. The majority of pens (85%) contained animals which appeared to the experienced observers to be relatively calm, with some lying or ruminating. One or more sheep within each pen were observed lying, ruminating, panting, sleeping and sucking/nibbling pen fittings in 35%, 67%, 5%, 4%, and 6% of scans, respectively (out of a total of 1,638 scans). Multilevel modelling revealed the following significant results: both the likelihood of observing lying and of observing rumination (both indicative of rest) increased as stocking density and disturbance from outside the pen decreased ($p<0.05$). Where animals were observed lying or ruminating both the proportion of animals lying and the proportion of animals ruminating increased as stocking density decreased ($p<0.01$). If 'neutral' time as currently applied in markets were to be considered as a period of genuine rest, it is suggested that there should be a requirement for sheep to have sufficient space for lying and that, in order for sheep to rest during their stay at market, they should experience a reasonable period of time during which their resting behaviour (e.g. lying) is not disturbed by activity in the market around them. A structured interview of market operators indicated that the majority considered that sufficient rest periods were allowed in the course of current market processes. Expense, maintenance issues, fouling and fighting for access were given as major concerns regarding provision of water within holding pens.

Objective 3 - *To place the results from Objective 1 into context by describing the extent to which the different journey types (with accompanying risk factors) actually take place within the GB.*
Data for 2009-2011 were extracted from the Animal Movement Licensing System (AMLS), through the Rapid Analysis and Detection of Animal-related Risks (RADAR) system, by the Centre for Epidemiology and Risk Analysis (CERA), Animal Health and Veterinary Laboratories Agency (AHVLA). Additionally transport data from Scotland (Scottish Animal Movements, SAMS) and Wales (Welsh Animal Movement Licensing, WALMS) were extracted via RADAR, although these did not come via the AMLS data set. Data used for this project comprises over 1.9 million movements of sheep, over three years, or 118.9 million sheep moved, and 43.6 animals per movement, within Great Britain, with significant variation between month and year. During 2010 and 2011 21.3% of movements to slaughter went via a market (25.5% of animals) and 0.3% via collection premises (1.4% of animals), while the remainder arrived at slaughter plants from farms and other premises. Those movements going via collection centres had the longest journeys (estimated at 89 miles) and arrived in larger groups (mean 248). Journeys via markets were of intermediate length (estimated at 76 miles and a mean group size of 66 animals), while journeys from other premises to slaughter were shortest (estimated at 40 miles, with a mean group size of 52).It is notable that these journey lengths are likely to be underestimates, since they are calculated 'as the crow flies'.

Objective 4 - *To integrate the approach and results from Objectives 1 & 3 to evaluate the environmental and economic impact of the different types of journey and to provide a holistic evaluation of the benefits and costs, with recommendations for the most sustainable options.*
A subset of data from Objective 3 were analysed using Markov Chain analysis to determine the probabilities of movement from farm to farm, abattoir, market or collection centre for one period in a sheep's life and thus to model the economics and environmental impacts.
The straight economic comparison between liveweight (mainly via markets) and deadweight (direct to abattoir) trading is not simple, because of different killing out percentages and carcass dressing specifications. A variety of levies and commission charges also apply. Within Objective 1 carcass quality data were collected for a small sample from across the different marketing routes. For new season lambs there is some evidence to suggest more over-fat lambs (graded 3H or higher) go through markets (37% compared with direct deadweight sales to abattoir at 19% or deadweight sales going via collecting points at 34%). Markets would like to be able to give farmers better feedback, but carcase data can seldom be traced back to the farm of origin as heads are disposed with the EID at the start of slaughter, before grading. Nationally, 46% of lambs are 3H or above. If just 1% of lambs were reared to 2H/3L instead of 3H or above it would be worth £230,000 a year.
It is self-evident that introducing the extra stage of a market imposes additional environmental burdens (e.g. energy and water use and green house gas emissions) in the overall cycle of sheep production. These appear, however, to be relatively small compared with primary production and operations in the

abattoir. There was no significant difference in energy use or green house gas emissions between the routes to slaughter.

Objective 5 – Some key points to emerge from a *Stakeholders Meeting* held to discuss project results were: The transport of unfit animals was obviously considered a major concern by stakeholders and it was felt that drivers may be put under pressure to take animals which are not fit to travel. Stocking densities were discussed at length and considerable concerns were raised regarding changes in regulations which will require maximum stocking densities to be listed on pens. A number of the issues at auction markets could be eased by all farmers booking their animals in advance.

Overall Conclusions

- Large numbers of sheep *do* travel through markets, and are subject to longer journeys on average, carrying more animals. This may also exacerbate physiological effects, however, of the commonly transported livestock, sheep are the most robust.

- Avoiding overcrowding in pens at market, in collection centres and in lairage at abattoir would allow sheep the space to use behavioural adaptations to reduce physical, physiological and social stress. This would to some extent ameliorate the overall effects of any extended marketing time. If 'neutral' time as currently applied in markets were to be considered as a period of genuine rest, it is suggested that there should be a requirement for sheep to have sufficient space for lying and that they should be left undisturbed for a reasonable period of time (a minimum of 1 hour).

- There is some evidence (see outcome of Objective 1) that sheep subject to short journeys to markets have the ability to recover from the physical demands of the initial stages of transport, in contrast to sheep being directly transported to their place of destination.

- The extra environmental and economic consequences of marketing via collection centres and markets are small compared with overall sheep production costs.

Future studies

Future studies should investigate when, whether and how sheep should be given feed and water at markets and determine optimum feed withdrawal times before slaughter. Practical methods of preventing the transport of unfit sheep should be determined. Ways of reducing environmental inefficiencies need more research, especially in fuel and water use.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:
   - the objectives as set out in the contract;
   - the extent to which the objectives set out in the contract have been met;
   - details of methods used and the results obtained, including statistical analysis (if appropriate);
   - a discussion of the results and their reliability;
   - the main implications of the findings;
   - possible future work; and
   - any action resulting from the research (e.g. IP, Knowledge Exchange).

Introduction

The UK not only has the largest population of sheep (33 million or 24% of EU-27), but is unique in the EU in terms of the stratification of production. While the production of sheep is resource efficient (with respect to pasture availability), there is a complex supply chain requiring large numbers of sheep movements. In 2008 there were some 846,261 sheep movements (or 34,730,499 animals moved) (Upton 2009). Thus, any welfare issues associated with sheep transport affect a large number of animals. Further, the potential environmental impacts of such movements are substantial in terms of atmospheric emissions and waste disposal.

The journeys serve a number of purposes; lambs move from hill and upland areas to the lowlands for finishing, and older ewes are moved from higher to lower pastureland to continue their productive life. Lambs and sheep of all ages are transported to slaughter. Journeys may be direct or incorporate stages, for example, at auction markets or collection centres, which have developed to assist this pattern of sheep movement. Special annual sales of hill or upland animals are widespread in relevant areas. Markets are also traditionally used for the sale of lambs and sheep ready for slaughter. Larger buyers often use collection points where animals are accumulated before final transport to a slaughter house. More recently, larger buyers of slaughter animals have moved to buying directly from contracted farmers and in some parts of the country electronic auctions have emerged. Defra asked for an appraisal of these different journey types in terms of the welfare of the sheep involved and of the economic and environmental impacts of the different marketing systems and the journeys that these involve. Specifically:-

Research was needed to inform policy on the relative welfare impact of different types of journey for sheep, for example those in which animals are transported directly to slaughter from farm, those where animals are transported via a market or those that incorporate multiple pick-ups during the pre-market journey. The focus of the study should be on short journeys (those less than 8 hours).

- Research was required to identify the risk factors associated with welfare outcomes, including long term outcomes where applicable, in order to assess the validity of the definition of a ‘short journey’ in legislation.
- The study must consider the cost benefits of transport to markets, farms and abattoirs and the welfare implications within a market of the time spent there being classified as ‘neutral’.
- The results of this study are aimed, amongst other policy issues, to inform the debate on the need for provision of food and more consistent provision of water at markets.
- The environmental impact of different journey types should be quantified as well as welfare and economic impacts, to provide a holistic evaluation of the benefits and costs and recommendations for most sustainable options.

General Approach

The approach taken in this study towards helping to answer the above questions is given in outline by the five Objectives of the study, below (note the renumbering of the Objectives from those in the original proposal for the benefit of ease of presentation of the results of the study) :-

> **Objective 1 -** To identify risk factors within journeys of short duration (less than 8 hours) that are associated with welfare outcomes for sheep. This is to include an analysis of the effect of live auction markets as part of the journey.
>
> **Objective 2 -** To survey the holding facilities for sheep at livestock auction markets with regard to their ability to provide ‘rest’ as part of the ‘neutral’ time during a journey, including the opportunity to drink and to eat.
>
> **Objective 3 -** To place the results from Objective 1 into context by describing the extent to which the different journey types (with accompanying risk factors) actually take place within GB
>
> **Objective 4 -** To integrate the approach and results from Objectives 1 & 3to evaluate the environmental and economic impact of the different types of journey and to provide a holistic evaluation of the benefits and costs, with recommendations for the most sustainable options.
>
> **Objective 5 -** To hold a Stakeholders meeting towards the end of the project.

Given the space constraints of this reporting form, a summary of the main results within each of the Objectives is given here and the main findings are drawn together. A separate document has been prepared which more comprehensively describes the work and results within each of the Objectives.

Objective 1 (University of Bristol)

To identify risk factors within journeys of short duration (less than 8 hours) that are associated with welfare outcomes for sheep. This is to include an analysis of the effect of live auction markets as part of the journey.

Introduction

The University of Bristol has taken the primary role in accomplishing Objective 1. This included identifying the welfare risk factors associated with different types of journey and marketing system and evaluating the welfare of sheep subjected to the different types of ‘short’ journey. Within Council Regulation (EC) No 1/2005 a journey is defined as ‘the entire transport operation from the place of departure to the place of destination, including any unloading, accommodation and loading occurring at intermediate points in the journey’. A short journey is defined as a journey taking less than 8 hours. However, because of the difficulties involved in observing and enforcing journey time rules for animals being traded at markets, Defra currently interprets the period of time spent by livestock at markets as 'neutral' time. The approach taken was to survey sheep arriving at a range of types of sheep slaughterhouse. By taking measurements from a large number of sheep across a wide range and combination of journey types, their relationship with different aspects of a journey can be teased out using statistical modelling techniques. Further, it is possible to gain a much more accurate picture of what commercial transport means to these animals than could be obtained from controlled studies, which have repeatedly been found to fail to properly replicate real world, commercial conditions. The modelling of results from slaughter animals can, in addition, provide considerable information concerning journeys other than to slaughter. They will indicate the relative effects of variables such as passing via live auction markets, journey duration, age, sex, etc. on welfare outcomes.

Materials and Methods

Sampling: In total 1,509 sheep were sampled from five slaughter plants in England and Wales, each visited three times throughout a year, to account for season. The three visits to each of the five abattoirs took place between 10th November 2010 and 20th September 2011 across a range of days of the working week, excluding Friday. It was not possible to sample on a Friday as blood samples required next day analysis. The five plants were chosen based on movement data provided by the Animal Health and Veterinary Laboratories Agency (AHVLA), identifying slaughter plants with the highest number of movements onto the premises; they accounted for 25% of the approximate total of 13 million head of sheep kill for England and Wales during the survey period (EBLEX, pers. comm.). On each visit the aim was to sub-sample 10 sheep from 10 distinct transport groups of animals arriving for slaughter. The groups of animals were selected from the kill sheet for the day to represent lambs and cull ewes, short and long journeys, livestock markets/collection points and direct from farm transports involving a range of journey times. For each group selected, the following details were recorded from the transport records: timings of the journey (time loaded, departed, arrived and unloaded) and details of the sheep within the group (lambs or ewes, number transported and whether they were a mixed group e.g. from market). Groups which came through livestock markets or collection centres often consisted of sheep from multiple source farms. Wherever possible, one transport group was selected from within the market group using their ear tags to match them to the paperwork and enable tracing back to the original farm. Individuals from the group being sampled were given a unique spray mark to aid sampling. This was consistent for all sheep sampled and in the main was carried out in conjunction with the pre-mortem veterinary inspection, to minimise additional disturbance.

The sheep were observed in the lairage and the levels of food, water and space were recorded as was the flooring type by scientists experienced in behavioural observation who positioned themselves so as not to disturb the sheep, and allowed a short acclimatisation period for the sheep before beginning their observations. The behaviour of the sheep was scan sampled every two minutes during a twenty minute period and the number of sheep lying, standing, feeding and drinking was recorded. If the sheep were disturbed during a sampling period e.g. by staff walking through or near the pen, this was noted.

At the point of exsanguination the time of slaughter and ear tag id were recorded, a blood sample was collected, blood temperature was recorded using a high performance infra-red thermometer (Raytek) and the animal was marked. Blood was collected directly into 4 vacutainers (1 x serum, 1 x Oxalate Fluoride, 2 x EDTA). Plasma was extracted within 30 minutes of sampling from the Oxalate Fluoride and one of the EDTA tubes and stored in 2ml microcentrifuge tubes, which were placed in liquid nitrogen. The remaining blood tubes were stored on ice for transportation back to the laboratory for analysis the following day.

The sampled sheep were individually tracked along the slaughter line and a 10g slice of the liver and a sample of urine from the bladder were also collected. Samples were frozen in liquid nitrogen and then stored at -80°C. Carcass quality data (weight, grade, animal type, sex and rejections) were recorded from the FSA (Food Standards Agency) online recording system for each sampled sheep.

Journey details; The majority of the details for journeys from farm to slaughter plant or from market to slaughter plant were available on the day of the visit. The details of any initial journeys to a market or collection centre were sometimes available from the markets, or otherwise were later calculated using the agricultural holding registration information associated with the ear tag. On occasion this was not feasible and then the details were estimated using an average of the journeys for the lots that were bought from that market on that day. Records were kept of how the journey details were obtained.

Statistical analysis: The statistics package IBM SPSS (v20) was used to produce summary statistics. For the main analysis, the statistics package MLwiN (v2.24) (Rasbash, 2009) was used to produce a multilevel model, to accommodate the repeated measures and clustering within the design, of the overall effect of source of sheep (direct supply, auction market or collection centre) and type of sheep (new season lamb (NSL), old season lamb (OSL), ewe and ram) as main effects on the individual outcome measures - interaction terms were not fitted. The amount of time spent in lairage at the abattoir was included in these analyses as a covariate to eliminate as far as possible the effect of abattoir on the outcome variables. Further subsidiary analyses are described within the Results section. There were few missing values in the primary analyses, and where they occurred they were assumed to be missing at random. The residuals from the models were checked for normality and homogeneity.

Results

Abattoirs categorise sheep as ‘ewe’, ‘new season lamb’ (NSL), ‘old season lamb’ (OSL) and ‘ram’. Table 1 gives a breakdown of the numbers of each of these types of animal sampled within the five plants, further broken down by the type of marketing process which brought them to the plant; where ‘Direct’ was purchase and delivery from the farmer direct to the plant, ‘Auction Market’ was purchase and delivery from a licensed livestock auction market and ‘collection centre’ was from a centralised collection centre where animals are generally taken in the morning by the farmer/producer for delivery to the plant later the same day. Across the study, sheep were sampled from eight different collection centres and from 29 different auction market sources. Six collection centres supplied one batch of 10 sheep, one was a source of 20 sheep and one of 30. The majority of markets supplied only one batch of 10 sheep to the study, only three supplied more than 30 animals (50, 60 and 88) and these were spread across multiple abattoirs for each of the markets. The annual throughput of the market sources accounted for approximately 20% of that for GB.

Histograms showing the distributions of the amount of time spent in the abattoir lairage before slaughter are given in Figure 1, broken down by abattoir and also by type of sheep. It can be seen that the time spent in lairage could be prolonged. Sheep with lairage times of greater than 2000 minutes were excluded from the statistical modelling as any residual effect of transport would have been diminished following this amount of time. Figure 1 shows that the distributions of the lairage times were similar both across abattoirs and across the type of sheep.

Table 1. *The number of animals sampled within the study broken down by abattoir, the three categories of journey type and the four categories of type of sheep.*

		Category of sheep			
Abattoir	**Journey Type**	EWE	NSL	OSL	RAM
		Count	Count	Count	Count
A	Direct	0	10	0	0
	Auction Market	0	290	0	0
	Collection Centre	0	0	0	0
B	Direct	24	20	0	6
	Auction Market	124	110	0	4
	Collection Centre	10	0	0	0
C	Direct	52	139	90	0
	Auction Market	0	20	0	0
	Collection Centre	0	0	0	0
D	Direct	0	130	90	0
	Auction Market	0	0	0	0
	Collection Centre	0	80	10	0
E	Direct	50	110	80	0
	Auction Market	0	40	10	0
	Collection Centre	0	0	10	0
TOTAL		260	949	290	10

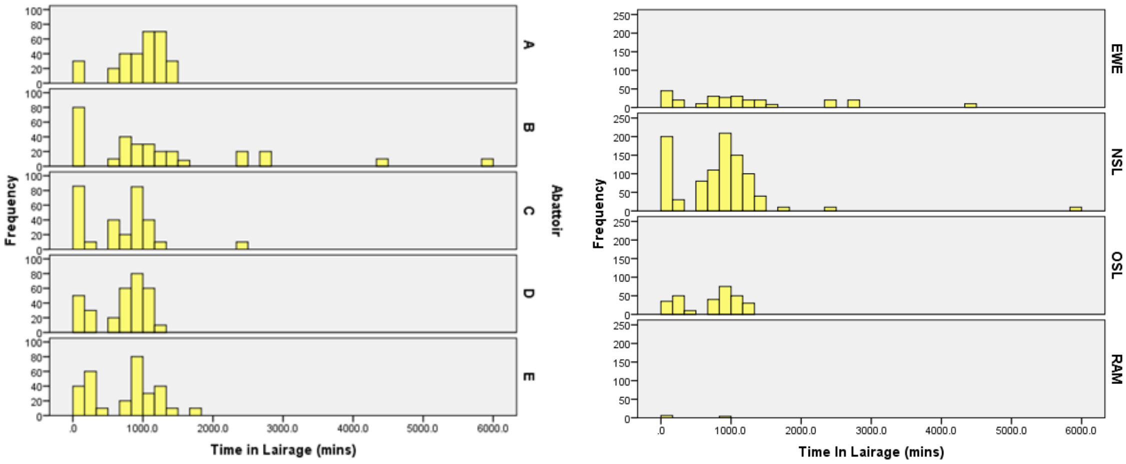

Figure 1. *The distributions of times spent in the abattoir lairage before slaughter broken down by abattoir (left) and by type of sheep (right).*

Figure 2 shows a histogram of the additive distribution of the durations of the components of the marketing system (journey to market/collection centre, holding at market/collection centre, journey to abattoir) as the total time in transit across all three components broken down by type of marketing system. There were two batches of ten ewes which spent a prolonged time at auction market (approximately 5500 and 7500 minutes or 3.8 and 5.2 days) and these have been excluded from these Figures and analyses.

The majority of OSL were sold straight from farm and for NSL and ewes the initial journey to market or collection centre was generally short, with almost all taking less than an hour and a half. Once at the stop point (market or collection centre), most of the NSL and ewes resumed their journey within 8 hours (480 mins), however, a number of sheep underwent a prolonged stay. The distributions of the durations of final journey to the abattoir were similar for all classes of sheep. The majority of OSL were in transit for less than 8 hours (480 mins) whilst for NSL and ewes, of which a much greater proportion went through market or collection centre, this figure was 12 hours (720 mins), with a small number undergoing total transit times of several days. The data for mature rams have been included for completeness and interest, but with only 10 animals recorded in the study (6 direct marketed and 4 from auction market) the amount of information regarding this class of sheep is limited.

Journey lengths to market and collection centres were similarly short, the majority taking less than an hour. However the length of stay at a collection centre was likely to be considerably less (maximum recorded was 2 hours) than at an auction market, although most animals passed through the markets within 8 hours (480 mins). This is then reflected in the total time in transit for each of the marketing systems (Figure 2). Journeys direct from farm having a mode of only a few hours whilst with auction market the mode was 8 hours with approximately 50 per cent of animals in transit for greater than this and a small group in transit for just over 24 hours (1440 mins). The distribution of times for collection centres were similar to those for direct from farm, but simply shifted by the addition of one to four hours taken up by an initial short journey and a short time in holding at the collection centre.

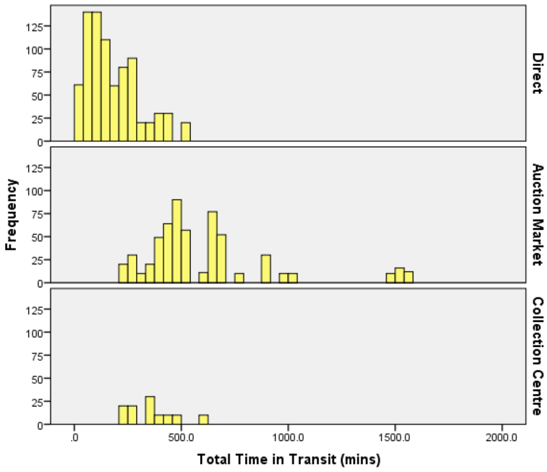

Figure 2. *Histogram showing the distribution of total time in transit within each of the the marketing systems. Two batches of ewes that spent approximately 5500 and 7500 minutes at (different) market are excluded.*

A multilevel model was fitted to the individual outcome variables using MLwiN (v2.24) to test for a difference between the three marketing systems (direct, auction and collection centre) and for a difference in the response between the type of sheep (NSL, OSL, ewe and ram). The amount of time spent in the abattoir lairage was included in all models to eliminate the effect of abattoir. A squared term for the time in lairage (to test for a curvilinear relationship) was tested in all of the models but was found not to be required. Given the large number of outcome variables measured, only the models for the blood variables are presented within this report as these are of primary interest. The output from this analysis and a guide to its interpretation is given in the accompanying full report.

There was a consistent effect of passing through an auction market, over and above that of sheep transported direct or through a collection centre and there were consistent differences between the types of sheep in the levels of the blood variables found following transport. Overall, for sheep that had passed through auction markets the activity at slaughter of plasma CK was lower, whilst levels of plasma free fatty acids (FFA), β-hydroxybutyrate (BHB), sodium (Na) and osmolality were raised compared with direct marketing from farm. The levels of the blood variables found in animals which were marketed through collection centres were essentially similar to those in animals directly marketed from farm; levels of Na were recorded as slightly raised in collection centre animals but this difference only just reached statistical significance ($P < 0.05$).

The levels of the blood variables recorded in the ewes differed from those recorded in NSL, with higher levels of protein, Na and lactate, less CK activity and lower levels of albumin, FFA and BHB. The levels of the blood variables found in the mature rams differed from those in the NSL in exactly the same pattern as that of the ewes, indicative of an overall effect probably related to age and maturity. There were fewer significant differences in the levels of the blood variables between lambs; in OSL levels of plasma urea, albumin, BHB and Na were decreased, whilst levels of plasma protein and lactate were increased relative to NSL. These differences were generally of a similar pattern but of lesser magnitude to those seen in ewes and rams, again indicative of a consistent effect of maturity.

These results need to be interpreted with caution, and viewed in conjunction with Table 1 as the data are sparse for some effects. Specifically, although the levels of many blood variables are significantly different in rams from the other types of sheep it is not reasonable to draw a conclusion about the effect of marketing system explicitly on rams as there are only ten within the data set. Similarly, few OSL underwent either transport through a collection centre or auction market and so the analysis carries little information about the effect of marketing system on OSL. There was, however, a reasonable balance of information across marketing systems within NSL and ewes. As a check on the results presented here the data for only ewes and then for only NSL were analysed separately. The parameter estimates from these analyses were in broad agreement with the models and interpretation presented here that are based on all types of sheep.

There was a significant effect of the period of time in lairage at the abattoir: as time in lairage increased, there was an increase in the levels of plasma protein, FFA and BHB, but a decrease in urea levels occurred. Blood temperature, liver glycogen, plasma cortisol and ghrelin were also measured but no significant differences were found between marketing system or with lairage time. Mean level of plasma cortisol in NSL and OSL was 130 (se 9.0) nmol/l, while that of ewes was significantly different and 36 (se 11.5) nmol/l higher. The mean value for the rams was similar to that of the ewes but given the small number of rams this was not significantly different from the mean levels of cortisol in NSL and OSL. Mean plasma ghrelin activity was 2523 (se 191.3) pg/ml in NSL, ewes and rams but was 926 (se 287.2) pg/ml lower in the OSL. Urine osmolality and urine specific gravity were both measured and were highly correlated (R = 0.962). Both were correlated with plasma osmolality (R = 0.135 and 0.114, respectively); only the results for plasma osmolality are presented, as there were fewer missing values for this variable, of the three variables associated with state of hydration.

The behaviour of all the sheep in each lairage pen containing the ten sheep subsequently sampled was recorded as per cent lying, standing, eating and drinking and these were analysed as response variables as above, but no significant effects of type of sheep or marketing system were apparent. Across all of the observations carried out in lairage, at any one time 88.2 per cent of sheep were standing (11.8 per cent lying), 0.26 per cent were seen feeding and 0.21 per cent seen drinking. Note that food and water were not always available within a pen and if present not necessarily available to all sheep because of a high stocking density which prevented sheep from exploring and moving around within the pen. All pens had drinkers, but these were not always functional.

A further analysis was carried out to test for effects associated with a simple, short journey between two points. To accomplish this the data set was reduced to only those 801 sheep transported direct to the abattoir (409 NSL, 260 OSL, 126 ewes and 6 rams) and the predictor variables 'type of sheep', time in lairage and journey duration fitted to the model. Squared terms for both time in lairage and journey duration were also tested in all models to test for a curvilinear relationship. The same set of outcome variables as above was tested in the models. A similar pattern of significant differences in the outcome variables between the 'type of sheep' was found, but no significant effects of journey time were detected except for an effect on levels of plasma cortisol and on ghrelin. In sheep transported directly from farm to abattoir, for which there was a maximum journey time of 8.5 hours, there was an increase in mean levels of cortisol of 6.76 nmol/l for every hour in transit and an increase in ghrelin of 277.81 pg/ml per hour transported. Overall, levels of cortisol were 39.5 nmol/l higher in the ewes in this group than NSL and levels of ghrelin 1043 pg/ml lower in OSL than in NSL.

Discussion

The actual durations of the 'on road' components of marketing, those journeys to an intermediate stop point and the final journeys to the abattoir were almost all accomplished within 8 hours (480 mins), the current definition of a 'short' journey. The reader should note that the sheep sampled within Objective 1 are not a random sample, as at each abattoir an attempt was made to sample an even balance of type of sheep (NSL, OSL, ewe and ram). However, within 'type of sheep', the data on transport times should be reasonably representative and indeed the overall data appear to be in general agreement with the transport data reported in Objective 3.

The data in Table 1 showing the sampling distribution, within the study, of types of sheep across marketing system across abattoir reflects the extent to which the abattoirs themselves have tended to specialise in a type of animal from a particular source. The study was successful in sampling a reasonable balance of NSL and ewes across the three different types of marketing system. The majority of OSL in this study were marketed directly from farm to slaughterhouse and it is likely that there is a preference for marketing this type of sheep direct to abattoir. The study also successfully obtained a sample from across a large number of GB livestock auction markets and several collection centres.

The data from the study show that the type of marketing system used to transport sheep to the abattoir resulted in differences in overall marketing time and that these extended times in transit led to subsequent differences in blood variables. A detailed account of the interpretation of physiological variables as indicators of 'stress' during transport can be found in the chapter 'Stress Physiology of Animals During Transport' by Knowles and Warriss in Grandin (2014). Marketing through a livestock auction market on average took the greatest amount of time with most of the additional time being spent actually at the market. Sheep arriving at their final destination from auction markets had increased levels of plasma sodium and higher plasma osmolality, both indicative of a greater degree of dehydration. The sheep also had higher levels of plasma free fatty acids (FFA) and β-hydroxybutyrate (BHB); both indicative of the animals drawing more heavily on energy reserves within the body. These variables increase linearly over time once feed is removed. However, the lower levels of plasma creatine kinase (CK) activity found for sheep passing via markets were indicative of a greater degree of recovery having taken place from the initial muscular exertions associated with gathering, loading and transport. The study was sensitive enough to measure these differences between marketing systems; however, the extent of the differences measured needs to be put in the context of their relevance to the animals.

Although the differences were measurable, they are not extreme differences. Based on results from other studies, they were at an expected level, given the extra time spent at market, if the sheep were without food or water (Knowles 1998). The range of levels of all these variables, found in sheep passing through auction markets, could also be found in sheep arriving at the abattoir direct from farm or from collections centre. The significant differences arose because the higher levels were slightly more consistently seen with sheep from auction markets.

There is a question as to what extent the time at a livestock auction market affords the animals the opportunity to rest and recover from transport? Sheep which had passed through a market tended to have elevated plasma Na and osmolality indicative of some degree of dehydration and elevated levels of BHB and FFA, indicative of a greater draw on energy reserves. However, previous studies indicate that under reasonable conditions sheep appear to cope well with transport (Knowles 1998). Fisher and colleagues found that "healthy adult sheep, transported under good conditions, can tolerate transport durations of up to 48 h without undue compromise to their welfare" (Fisher, Niemeyer et al. 2010).

The current study is in agreement with this view in that the extra time at an auction market generally did not appear to make extreme physiological demands on the animals. Further, the lower levels of plasma CK seen in sheep from auction indicated that the animals had had greater time to recover from the initial exertions of transport and gathering. Thus, whilst passing through auction markets made extra demands on the animals in terms of potential thirst and hunger, it did not appear to be unduly physically demanding. However, of the commonly transported farm species sheep are the most robust to this having evolved within an arid environment. Prolonged feed and water deprivation (over several days) might be considered a welfare issue but in the short term sheep have some reservoir within their rumen.

At the stakeholders' meeting (Objective 5) it was suggested that an analysis could be carried out to test for a difference in the effect of markets between those that use a ring for sales and those that only use pens. The data were reduced to data from just auction markets and a multilevel statistical model fitted to predict the level of each of the blood variables. The models tested for a difference between auctions which used a ring and those which used a pen sale system, and the data were adjusted for the effects of total time in transit, time in lairage at the abattoir and the type of sheep. A statistically significant difference was found in the level of plasma lactate between the two systems with 2.33 (0.271) mmol/l the mean for rings and that for pens 0.57 (0.247) mmol/l lower ($P = 0.011$). The higher levels found in sheep from ring sales systems suggest that overall, these systems may be more physically demanding than pen sales.

There have been several controlled experimental studies that have monitored sheep during transport by road. These are summarised in Knowles (1998) and some more recent papers in de la Fuente et al (2012). From loading and at the beginning of transport there is an increase in variables associated with psychological stress and exertion such as plasma cortisol, heart rate and CK. The variables associated with psychological stress peak within the first few hours of transport and then return to more usual levels within 9 hours of continuous transport, whilst in the short term CK activity may continue to increase. Levels of FFA, BHB and osmolality, variables indicative of mobilisation of energy reserves and dehydration tend to show a linear increase with journey time and continued depravation of feed and water. However, Knowles et al (1995) reported that sheep simply transported by road for 24 hours within the UK and without feed and water showed little sign of dehydration. When sheep are unloaded and given access to feed and water following depravation they are generally primarily interested in feeding and only secondarily go to water (Knowles et al. 1996). Recovery from transport, once sheep are unloaded, given space to move and feed and water is described in Knowles et al (1993) as taking place within three stages. Within 24 hours of the end of transport, variables associated with short term stress and with dehydration return to near normal levels; by 96 hours levels of metabolites such as FFA and BHB had returned to near normal levels and after 144 hours CK activity and plasma protein levels had returned close to resting levels.

The analysis of the sheep subject only to 'direct from farm' marketing gives some insight into the effect of a simple farm to farm transport and the results from this study are in general agreement with the historical findings reported in the literature above, in that 8 hours is sufficient time for a rise in cortisol to still be apparent, but not sufficient time for a consistent increase in FFA, BHB or osmolality to be registered. This analysis of a short, direct journey was the only analysis in which a change in ghrelin was detected. Ghrelin is a hormone which increases with food deprivation and drops to low levels immediately following feeding. It has not been widely measured before in sheep. The results here suggest that it may be a useful marker of shorter term feed deprivation in sheep.

The times in lairage at the abattoir recorded in the study show a bimodal pattern that was common across all abattoirs and all types of sheep, and was due to sheep commonly being delivered and held overnight. Figure 1 shows that sheep are routinely held in lairage up to 24 hours and the results show that during this time the animals continue to draw on body energy reserves. Abattoirs are generally not keen to process animals with a full gut because of the extra waste produced and an increased danger of carcass contamination.

There were a small number of sheep that had extreme total marketing times of over 33 hours as a consequence of either being held at an auction market for one or several days or in lairage for one or several days. The values of the blood variables in this group were examined separately, and whilst levels of FFA, BHB and osmolality were significantly above mean values for the study as a whole, they were not extreme, indicating that these animals had probably had some access to food and water during their protracted period of marketing.

Objective 2 (University of Bristol)

To survey the holding facilities for sheep at livestock auction markets with regard to their ability to provide 'rest' or 'neutral' time during a journey, including the opportunity to drink and to eat.

Current legislation requires that sheep are not subjected to transports of longer than fourteen hours without a minimum rest period of 1 hour. Time spent in markets is currently regarded by Defra as 'neutral time' or, potentially, a rest period (Defra, 2011). Results from Objective 1 show there are significant, albeit small, differences in welfare indicators between sheep that were moved directly to slaughter, and those that arrived via a market or collection centre (see Objective 1). Thus this objective was designed to obtain both background data on market facilities and practices, and to examine whether the time in a market can truly be regarded as providing a rest period.

Time at markets may involve a number of potential stressors, including unfamiliar surroundings, loading and unloading, handling, contact with unfamiliar sheep, restriction of feed and water, and disturbances from noise and activity in the market. Baldock and Sibly (1990) found that isolation of sheep, and mixing of unfamiliar sheep, were associated with increases in heart rate. Head alert reactions, movements, and decreased lying were associated with human activity in passageways at slaughterhouse lairage (Kim et al., 1993). An association between lying behaviour and stocking density was also observed, with more than 1m^2 required per sheep before the majority of animals in a pen would lie down. In cattle, observations of slaughterhouse lairages found that cattle required at least 2h before lying behaviour started, and 3-10h before the majority of cattle within a group would lie down. Furthermore, amongst other things, resting behaviour was affected by group size and the level of human and animal activity nearby (Cockram, 1990, 1991).

Therefore, in order to provide an insight into the capacity of markets to provide a rest period for sheep, markets were surveyed: details of facilities and procedures at markets were recorded, as well as calmness in pens, and the level of disturbance to sheep, and sheep behaviour.

Methods

Sheep sampled by the University of Bristol for Objective 1 came from groups which had passed through one of 31 different markets in Great Britain. We aimed to survey a pre-defined sample of 23 of these chosen to represent a range of throughput and geographical locations. Each of these 23 markets was contacted by one of four experienced staff, and agreement to visit the market was obtained. Markets which agreed to be involved in the survey were visited once, by the same member of staff. All staff were standardised against one principal person in initial joint visits. Visits took place primarily on days of prime stock sales, with the intention that observations of sheep destined for slaughter would provide better context for Objective 1. The visiting member of staff arrived at the market to commence behavioural observations at least 2h prior to auction, and continuing at least 1h post-sale (or for as long as sheep remained in the market, if the market emptied less than 1h after the sale). Data on design of, and environment inside, the market were also collected. After the sale data on facilities and procedures at the market were collected via an interview with the market operator.

<u>Behavioural observations:</u> Observations of at least 12 holding pens of sheep were carried out. Each observation lasted for 10 minutes, during which period 6 scan samples at 2 minute intervals were carried out. During scan samples observers recorded number of animals lying, ruminating, panting (>90 breaths/minute) 'sleeping' (eyes closed) or sucking/nibbling fittings. Reduced rumination has been associated with increased stress (e.g. Cockram et al., 2004). Panting indicates thermal stress, while sucking/nibbling at pen fitting may indicate hunger or thirst. Also during the observation period all instances of disturbance to the sheep (from other sheep in the same pen, from handling by humans, or from general activity outside the pen) were recorded, as were any instances of trampling, feeding, drinking or vocalising. Pens were also scored, using a four-point scoring system (see Appendix) for floor cleanliness, sheep calmness, space allowance, level of disturbance throughout the observation period. Additionally pens were scored either 'yes' or 'no' for access to water. The numbers of sheep in the observed pens were recorded, as well as the time since arrival in market, where this information was available.

The pens observed were chosen to comprise a representative sample in all areas of the market (i.e. busier and quieter areas, pens with high and low stocking densities, both inside and outside, and time present in market). Where markets were visited during sales of prime sheep observations were concentrated on fat lambs (new season lambs [NSL] and cull ewes).

After the auction, data were requested on the origin of the animals in each of the observed pens, the weights of the animals observed, and the type of vehicle used to transport them to the market.

Physical measurements: On arrival a Tinytag or Hobo ultra temperature/humidity logger was placed close to sheep in a representative part of the market, to record temperature and humidity at 2 minute intervals. This was removed at the end of the visit. Air temperature readings inside and outside were recorded with a thermistor probe 3/4 times during each visit. A plan of the market was obtained or drawn, and measurements were made of pen dimensions and raceways. Pen dimensions were recorded for pens where behavioural observations were carried out. Records were made of the construction, design and layout of the market, and the location and type of drinkers available. Light levels were assessed by the ability to see to the far side of the market building and to clearly read text; they were scored as poor, adequate or good. Light levels are important to be able to properly assess sheep within pens and for efficient handling and movement. All markets were considered to have adequate or good lighting, and so this is not reported further. Four-point scores (based on those described by FAWC, 2003, see Appendix) were used to evaluate race floor cleanliness and slipperiness, sheep stress levels from handling, and provision of feed, bedding and water.

Market operator interviews: An interview with the market operator was conducted to obtain data on: the capacity of the market; numbers of sheep of different classes handled by the market, with seasonal variation; planned stocking rates and variation, including for overnight lairage; policy for providing feed and water; contingency plans for extra-large seasonal sales; operating procedures (indicating how many separate handling, movement and mixing procedures the sheep undergo). In addition, where possible, estimates were obtained of the cost and feasibility of providing 1 hour of quality resting time, water for all animals and feed for those sheep staying for longer than 8 h in the market. Market operators were also asked to provide an opinion on the main issues for sheep welfare at markets.

Analysis: Data were analysed using multilevel modelling techniques in Stata 12.0. Multilevel modelling was used to reflect the hierarchical nature of the dataset (scans within pens within markets). Where results of behavioural scans were analysed (number of sheep lying, ruminating, panting, sleeping, sucking/nibbling pen fittings) three level models were used (scan within pen, within market). Behavioural outcome variables were calculated as proportion of sheep in the pen occupied with each of these behaviours during the scan. Observations of these behaviours were examined and where appropriate associations with management and environmental factors at the market were investigated. In addition, incidence of trampling, feeding, drinking and vocalising were calculated per sheep per hour for each observation period, while incidence of disturbance was calculated as number of disturbances per hour (since this was independent of the number of sheep in the pen). Associations between these factors and the behaviours recorded during the behavioural scans were also investigated.
Stocking density was calculated both as the number of sheep per m^2 for each pen and, where the data was available, the number of kilogrammes per m^2; cull ewes were rarely weighed before sale, thus weights for these groups were not available. Data from behavioural scans were investigated for associations with stocking density. Stocking density was also examined for associations with pen characteristics, such as floor cleanliness.

Results

Of the 23 markets visited seven were in Wales, two in Scotland and the remainder in western England and the midlands, reflecting principal areas of production. Capacity of the markets visited ranged from 1,500 – 20,000 animals. Visits took place from June to November 2012.

Market conditions and facilities: During the visits average temperatures ranged from 8-20^{o}C indoors, and 7-20^{o}C outside. Of the 23 markets visited 19 used natural lighting, some supplementing with electric lighting. All markets were considered to have adequate or good lighting. All markets used metal rails for pen walls and gates, although some pens also had one or more brick wall. The condition of the gates, pens and races was considered good in 13/23 markets, average in 8/23 markets, while it was considered poor in the remaining two, due to rusting rails and/or hurdles not being fixed firmly in place (thus either falling down, or moving with the animals inside the pens). In total, five markets employed measures, such as flaps, to prevent legs becoming trapped. All markets had grooved concrete floors for pens and races, with the exception of one fully outdoor market, which was held on grass and gravel.

Markets were scored according to the condition of pens, facilities available, and handling procedure at markets. These scores are summarized in Table 2. The majority of markets had acceptable scores (scores of ≤2; FAWC, 2003) for handling and floor cleanliness and slipperiness. Feed or edible bedding (or pasture) was provided to all animals staying longer than eight hours in market. During normal market hours one market provided feed/bedding to all animals; two markets provided feed/bedding to animals staying after the sale (even if for less than eight hours); in one market feed/bedding was provided only if farmers brought it; and in two markets feed was made available where necessary e.g. for lambs, or for ewes in milk. Water was available in all markets for animals staying overnight, or for an extended period after the sale. In addition three markets provided water in loading/unloading bays, and two markets provided water via fixed drinkers in some pens, available to sheep which happened to be placed in those pens. All markets had the facilities to provide water if they considered it was required e.g. portable troughs, buckets, etc.

In total 279 pens were observed, and 1,638 behavioural scans were carried out. Mean stocking density was 2.8 sheep/m^2 (range 0.42-7.8, n=276) and 118.8 kg/m^2 (range 32.9-366.6, n=173).

Conditions of the pens observed were summarised. During the 10 minute observation periods, No pre-sale holding pens were observed in which the animals had access to water. Overall, 40.4% of pens were estimated to have sufficient space for all animals to lie, while 10.1% did not allow enough space for any animals to lie. About half (50.2%) of the pens experienced minor disturbance from passers-by (including sheep being moved), while 5.8% experienced handling either from inside or outside the pen. The majority of pens (85%) contained animals which appeared to the experienced observers to be relatively calm, with some lying or ruminating. Within holding pens, clean, dirty and intermediate floor conditions were seen in similar proportions across the study; analyses showed that higher stocking densities (sheep/m^2) were associated with dirtier floors (χ^2=10.5, df 3, p=0.015).

Table 2. *General facilities at markets. The percentage of markets with each score for each measure (Underlying scoring 1=good/available to all, 2=acceptable/available to most, 3=poor/available to few, 4=very poor/available to none – see Appendix for details). The number (n) of markets for which each measure was recorded in full is given in brackets.*

Measure	**Score**			
	1	**2**	**3**	**4**
Handling procedures (n=22)	22.7	72.7	4.5	0
Provision of edible bedding or feed (n=21)	9.5	23.8	23.8	42.9
Provision of water (n=20)	5.0	0	5.0	90.0
Floor cleanliness in races (n=23)	39.1	52.2	8.7	0
Floor slipperiness in races (n=23)	39.1	52.2	8.7	0

Behavioural observations and scans: During behavioural observations no sheep were observed to drink, as water was not available to animals in any of the pens observed. Very few instances were observed of sheep being trampled, feeding, or having their rest disturbed by other sheep in the same pen (0.01, 0.04, and 0.09 occurrences/sheep/hour, respectively). Vocalising was recorded at a rate of 0.19 (Confidence Interval (CI): 0.1, 0.3) vocalisations/sheep/hdisturbance from human handling at 0.93 (CI: 0.5, 1.4) times/h, and disturbance from activity outside the pen at 8.81 (CI: 7.5, 10.1) times/h.

During behavioural scans all behaviours were observed infrequently. Some sheep within each pen were observed lying, ruminating, panting, sleeping and sucking/nibbling pen fittings in 35%, 67%, 5%, 4%, and 6% of scans, respectively (of a total of 1,638 scans). The low incidence of the latter three precluded robust analysis of these behaviours.

Lying: The proportion of sheep lying was transformed into a binary variable (0 for no animals lying during a scan, 1 for any animals lying during a scan) and subjected to multilevel logistic regression. The likelihood of any sheep lying during a behavioural scan decreased as disturbances outside their pen increased (Odds ratio [OR] = 0.90, χ^2=4.03, df 1, p=0.045, n=1638). There was also a complex relationship with stocking density (calculated as kg per m^2); there was a quadratic relationship which indicated that likelihood of any sheep lying during a behavioural scan decreased with increasing stocking density (χ^2=5.19, p=0.023, n=1010). It is notable that the sample size for the association between likelihood of lying and stocking density (kg per m^2) is much lower, since there were a large number of missing datapoints for stocking density by weight, as explained above. Insufficient lying behaviour was seen to be able to develop a full model.

Factors associated with the proportion of sheep lying were also analysed using multilevel linear modelling, with zero values for lying removed. There was a quadratic relationship between proportion of sheep lying and stocking density, which meant that when any lying behaviour was observed during a behavioural scan, a higher proportion of sheep within the pen were observed to lie at lower stocking densities (χ^2=42.7, df 1, p<0.001, n=491).

The relationship with stocking density in both logistic and linear regression models remained when outliers of stocking density were removed (stocking densities greater than 300 kg/m^2).

Ruminating: The proportion of sheep ruminating was transformed into a binary variable (0 for no animals ruminating during a scan, 1 for any animals ruminating during a scan) and subjected to multilevel logistic regression. The final model was based on 1,612 datapoints, and accounted for time of year (using sine and cosine transformed date variables). Sheep were more likely (χ^2=11.6, df 3, p=0.009) to be observed ruminating when the level of disturbance to the pen was low): sheep were observed to ruminate in 76% of behaviour scans in pens which had no disturbance (score 1) and in 60%, 43% and 59% of behaviour scans which had low disturbance from passersby, disturbance due to handling from outside the pen, and disturbance from handling inside the pen (scores 2, 3 and 4, respectively). The likelihood of observing rumination during a behavioural scan also increased as stocking density increased (OR: 1.76, χ^2=8.9, df 1, p=0.003).

Multilevel linear modelling was further used to identify variables associated with proportion of animals ruminating. Proportion of animals ruminating was log transformed and all zero values were excluded. The final model was based on 1,089 datapoints, and accounted for time of year (using sine and cosine transformed date variables). This confirmed that higher proportions of sheep ruminating were associated with lower stocking densities (sheep/m^2; χ^2=47.8, df 1, p<0.001) and fewer disturbances per hour from outside the pen (χ^2=10.1, df 1, p=0.002). Proportion of animals ruminating was also associated with location of electronic identification (EID) tag reading and class of sheep (χ^2=12.4, df 3, p=0.006; χ^2=23.7, df 4, p<0.001). The proportion of sheep ruminating was less where sheep ID was checked in the pen or in the ring compared with in a raceway. The proportion of sheep ruminating was less in: breeding ewes compared with all other categories; cull ewes compared with new and old season lambs; and new season lambs compared with old season lambs.

Market operator views: Market operators were asked to estimate the feasibility of providing water, feed and a rest period of at least 1h, on a scale of 0-10 (zero being easy, and ten, impossible). With regard to provision of water within holding pens, although several operators thought all suggested changes were reasonably feasible, or were already doing it, 9/20 market operators that answered the question gave scores of eight or more, citing expense, maintenance issues, and fighting for access between sheep, as major concerns. With regard to provision of feed 7/19 market operators that answered the question gave scores of eight or more, with the majority commenting that slaughterhouses would object. Finally, with regard to provision of a rest period 15/23 market operators stated that all sheep already had access to a rest period meeting these requirements. A further five market operators stated that some sheep would have such a rest period depending on when they arrived in the market, and where they were penned. Ten market operators commented that rest periods would have to be (or currently are) before sale, while six considered that rest periods would have to be (or currently are) after sales. Nine market operators, of the 15 that made comments, stated that separating resting sheep from non-resting sheep would not be possible. Thus the majority of market operators considered that sufficient rest periods were allowed in the course of current market processes.

Responses to the final question to market operators, which asked for an opinion as to how sheep welfare could be improved at markets, were varied. The most common response was that the market had been designed with welfare in mind and could not be improved or that inspectors would indicate if any improvement was necessary (6/23).Three felt overhead cover was desirable for slaughter sheep or those staying a long time. Measures to reduce noise levels and echo were thought necessary. Minority opinions included designing races with rounded corners, fans for hot weather, limiting the size of markets (to reduce handler fatigue) and having specific lairage areas for sheep staying over 8h.

Discussion

We visited a wide range of markets, and generally found pens and races were in good repair, with adequate or good lighting. Floor conditions varied in pens, although slipperiness in the races/aisles was not generally considered to be a problem.

In order to rest fully, sheep need sufficient space to be able to lie if they wish e.g. 1m^2 per sheep (Kim et al., 1993). We found that likelihood of observing animals lying down decreased as stocking density increased, furthermore, where lying or rumination were observed, the proportion of animals performing these behaviours decreased as stocking density increased. Mean stocking density in this study was 2.8 sheep/m^2, or 0.42 m^2 per sheep, thus it may be that stocking densities are generally too high to afford all animals the opportunity to lie down, although this was not a concern raised by market operators. For sheep under 55kg (as were the sheep observed in this study) the required space allowance during transport is 0.2-0.3m2 per animal (Defra, 2012). Thus mean space allowance in markets exceeded that required during transport, however, our observations suggest that the higher allowance was required for sheep to readily lie in pens at market.

We also found evidence that the likelihood of observing animals lying or ruminating during a behavioural scan, and proportion of animals ruminating, decreased as the level of disturbance outside pens increased. The likelihood of observing rumination was reduced, even where disturbances were merely people and animals briefly passing their pen. These observations suggest that sheep are not necessarily allowed to rest fully during their time at market, since their behaviour was altered by even minor disturbances. We suggest that in order for sheep to rest during their stay at market they should experience a period of time during which their resting behaviour (e.g. lying) in not disturbed by activity in the market around them.

Objective 3 (AHVLA)

To place the results from Objective 1 into context by describing the extent to which the different journey types (with accompanying risk factors) actually take place within GB

The purpose of Objective 3 was to put the results of Objective 1 into context by describing sheep transportation within Great Britain as a whole. To achieve this we quantified the different types of transport, to a variety of destinations in Great Britain, including the distances travelled and the numbers of animals concerned. Our analyses then concentrated on journeys which were identified by the University of Bristol as having potential welfare implications, such as those through markets and collection premises.

Methods

To perform these analyses, data were extracted from the Animal Movement Licensing System (AMLS) data set, through the Rapid Analysis and Detection of Animal-related Risks (RADAR) system, by the Centre for Epidemiology and Risk Analysis (CERA), Animal Health and Veterinary Laboratories Agency (AHVLA).

Additionally transport data from Scotland (Scottish Animal Movements, SAMS) and Wales (Welsh Animal Movement Licensing) were extracted via RADAR, although these do not come via the AMLS data set. Data were imported into an SQL database for analysis.

Data quality was examined, and data cleaning was necessary: The type (purpose) of the departure and destination points was cross-checked with RADAR records external to AMLS. Duplicate movements were removed. Particular attention was paid to movements from Scotland or Wales into England, since Scottish and Welsh movements were extracted from databases other than AMLS.

Data were summarized in terms of the numbers of journeys, the numbers of animals transported, and the distances travelled. They were broken down by departure and destination points, and the number of journeys which went to slaughter via a market or collection premises was investigated. Journey times are not stored by AMLS; consequently it was necessary to estimate them. In the first instance Euclidean distances were calculated (the length of a straight line from the start to end point). This study is concerned with short journeys, of less than 8hours. However, full journey times could not be estimated, since information on loading/unloading times was not available, thus we present estimated transit times from here on (time taken to travel from start to end point of journey). It was assumed that a vehicle travelling at approximately 60mph could cover a distance of 472 miles in 8h, while a vehicle travelling at approximately 40mph would cover a distance of 311 miles.

In addition, a GIS network was also created to estimate transit times, using ArcGIS 10 Network Analyst. The Ordnance Survey (OS) Open data Meridian 2 roads dataset (a mid-scale vector product that contains road centre lines for Motorways, ‘A’ roads, ‘B’ roads and minor roads across Great Britain) was used as the basis for the network dataset. OS data were encoded with a rural/urban classification, based on the 2001 Census Rural/Urban land use classification. These data were then supplemented with average speeds data for HGVs and cars towing trailers from the 2009 Department for Transport (DfT) statistics. Thus each road link in the OS dataset was encoded with its distance, the estimated time that it would take a 3-axle HGV to cover that distance and the estimated time that it would take a car towing a trailer to cover that distance. Origin-Destination data (O-D pairs) for animal movements, categorised according to whether the movement was made by car/trailer or HGV were input into the network model. Journey times for these O-D pairs were calculated based on the routes that generated the fastest journey time (rather than shortest distance) while prioritising as great a percentage of the journey on major roads as possible (i.e. a hierarchical solution).

However, this analysis could only be carried out where vehicle details were available. Further movement data for GB, containing vehicle details, were extracted from a separate AMLS source for 2009 and 2010; 199,941 records included date of movements and vehicle registration information. However, registration marks were sometimes incomplete or recorded as ‘unknown’. Once a list of unique registration marks had been identified (43,022 unique records), these data were sent to the Department of Transport who attempted to match the registration marks with vehicle and emission details held on their database. This matched 14,409 unique vehicles which were responsible for 75,601 movements across 2009 and 2010. Thus this subset of data was compared to the wider dataset in terms of estimated distance travelled (Euclidean), journey type (origin and destination type), and county of destination. The subset was not found to be biased in any of these areas. This subset of data was used to estimate distances using the GIS network analysis.

It is important to note that the transit times we estimate, either Euclidean, or using GIS network analysis, do not take into account either rest stops for drivers, loading and unloading times, or the additional time associated with multiple pickups in one journey. Thus time spent on a lorry in a given journey may be considerably longer than our journey time estimates suggest.

Results

There were 890,004; 934,436 and 901,656 sheep movements and 40,495,551; 40,999,165 and 37,400,780 animals moved in Great Britain in 2009, 2010 and 2011 respectively, where one movement may constitute several batches of animals, and each batch may contain many animals. The number of movements, and number of animals moved, peaked during the late summer/ autumn (September and October) for all years, while the number of animals per movement was lower during the summer months (May-July). Number of movements varied between months ($p<0.05$), but were not significantly different between years. Number of animals moved varied between months ($p<0.05$) and years ($p<0.05$), with median numbers of animals moved per month of 3,034,779; 2,979,180; and 2,668,367 in 2009, 2010, and 2011, respectively. Number of animals per movement varied significantly between years and months ($p<0.05$), with means of 45.7, 44.1 and 41.6 animals per movement in 2009, 2010 and 2011, respectively.

Estimates of Euclidean distances were calculated for all movements in all years. The majority of movements (54.3%, 57%, and 58% in 2009, 2010 and 2011, respectively) were between 6 miles and 31 miles. 1.0%, 0.5% and 0.4% of movements in 2011, 2010 and 2009, respectively, are recorded as having been of zero distance. Zero distance movements are discussed in Upton (2009), and are likely the result of farmers taking their sheep to markets and then home again, or moving them within farm. In total 0.12%, 0.10% and 0.09% of movements in 2011, 2010 and 2009, respectively were estimated to be over 311 miles. Finally, a very small proportion, 0.01%, 0.004% and 0.002% of movements in 2011, 2010 and 2009, respectively, were estimated to be over 472 miles.

Distances were also estimated using GIS road networks, and the transport data subset from 2009 and 2010 (73,300 movements). In this dataset 2.56% movements were over distances estimated to be greater than 311 miles, while just 0.74% movements were over distances greater than 472 miles. Overall only 1.65% journeys were estimated to have exceeded 8 hours. Since Euclidean distances assume a straight line between the start and end point of a journey, while GIS networks estimate actual journeys, accounting for a variety of road types and indirect routes (i.e. not straight line) estimates using GIS road network information are likely to be more reliable. This suggests that Euclidean calculations may underestimate journey times; however, in both cases the proportion of movement estimates which exceed 8h is small. However, both estimates are presented as the GIS estimate is based on a smaller sample size due to the reduced size of the vehicle type dataset (75,601 movements) from the Department of Transport.

Although the short journeys with which this project is concerned are defined as journeys less than 8h, all movements were included in summaries for completeness, since our methods of estimating journey distance and time are not sufficiently accurate to confidently estimate a cut-off for eight hour journeys, and since we cannot estimate a full journey length. The location and purpose of both departure points and destinations were examined for all movements in 2010 and 2011. Note that the location type definitions changed between 2009 and 2010, thus only figures for 2010 and 2011 are discussed. The majority of movements, and the majority of animals moved, *departed* from agricultural premises. In 2010 and 2011 the next most common departure type was a 'Gathering'; this location type is common because when a farmer with animals from different fields is preparing to send animals away somewhere (e.g. another holding, market or slaughter) he will gather his animals from different places at a local gathering point with a defined County Parish Holding Number (CPH) e.g. common land. The haulier then picks them up and takes them to their next destination. Gathering points are not subject to standstill rules, rather they are a transitional location prior to a journey; however, they are still recorded. The third most common departure type was markets. Similarly the *destination* type associated with the highest number of movements and the highest number of animals moved was agricultural premises. Other common destination types were markets, slaughterhouses and gatherings, all receiving a similar proportion of movements (21%-23%). In terms of the number of animals moving destination type slaughterhouse received a higher proportion of animals relative to the proportion of movements (26-30% of animals moved to slaughter compared with markets and gatherings which both received 14%-15% of animals), suggesting that the number of animals per movement was greater for those movements going to slaughter.

Table 3 shows the percentage of movements and animals which arrived at slaughter via a market or collection premises. Data were not available for collection centres in 2009. The lower percentage of movements via market in 2009 compared with 2010 and 2011 are likely due to changes in how market locations are calculated in this report.

Table 3. *The percentage of movements to slaughter which arrived from a market or a collection centre in 2009, 2010 and 2011.*

To slaughter via:	Percentage of:	2009	2010	2011
Market	Movements	12.0	20.4	22.4
	Animals	29.9	24.0	27.4
Collection Premises	Movements	-	0.4	0.3
	Animal	-	1.8	0.9

The lengths of movements to markets, from market to slaughter, to collection premises, and from collection premises to slaughter were compared with the lengths of movements direct to slaughter (i.e. those movements to slaughter which did not originate in a market or collection centre). Since data were not available for collection centres from 2009, comparisons are made using only data from 2010 and 2011 (Tables 4a and 4b). During these years 21.3% of movements to slaughter went via a market (25.5% of animals) and 0.3% via collection premises (1.4% of animals). It is important to note that movements to and from markets cannot be matched; that is animals recorded as moving to a market cannot be traced in a movement from that market. The same is true of journeys to and from collection centres. Thus total journey time cannot be exactly estimated.

Table 4a. *The number of movements, animals, animals per movement, mean movement distance and 95% confidence intervals for movements to market, from market to slaughter, to collection premises, from collection premises to slaughter, and direct to slaughter in 2010 (i.e. movements to slaughter from any premises other than markets or collection premises).*

	All Premises to Market	Market to Slaughter	All Premises to Collection Premises	Collection Premises to Slaughter	Everything but markets and collection to slaughter
Number of movements	212858	42741	5195	734	166193
Number of animals moved	6181220	2920925	240965	216833	9044405
Average no. animals per movement	29.0	68.3	46.4	295.4	54.42

Average distance moved (miles)	12.8	62.1	9.7	78.9	38.5
CI distance moved	12.7, 12.9	61.6, 62.6	9.4, 10.0	76.0, 81.7	38.2, 38.7
CI animals per movement	28.9, 29.2	67.4, 69.3	44.7, 48.1	269.7, 321.1	54, 54.9

Table 4b. *The number of movements, animals, animals per movement, mean movement distance and 95% confidence intervals for movements to market, from market to slaughter, to collection premises, from collection premises to slaughter, and direct to slaughter in 2011 (i.e. movements to slaughter from any premises other than markets or collection premises).*

	All Premises to Market	Market to Slaughter	All Premises to Collection Premises	Collection Premises to Slaughter	Everything but markets and collection to slaughter
Number of movements	196748	42172	4735	506	145796
Number of animals moved	5697118	2692265	170786	90780	7025163
Average no. animals per movement	28.96	63.85	36.07	179.41	48.19
Average distance moved (km)	13.7	63.1	9.7	79.0	41.0
CI distance moved	13.6, 13.7	62.6, 63.6	9.3, 10.0	74.9, 83.0	40.7, 41.3
CI animals per movement	28.8, 29.1	63.0, 64.7	35.1, 37.1	168.8, 190.1	47.8, 48.6

However, if we assume that lengths of journeys to market and lengths of journeys from markets are not correlated (i.e. a longer journey to a market does not mean that journey from the market should also be longer) we may make estimates of the total lengths of journeys, including stopovers. The same assumption may be made for collection premises. Given these assumptions we can add the means and variances for the two parts of these journeys to give an estimated mean and confidence interval for the overall journey distance. Mean distance of movement to slaughter via market was estimated at 75.8 miles (95% CI: 75.6, 76.0) and mean movement distance to slaughter via collection premises was estimated at 88.5 miles (95% CI: 87.4, 89.7). In comparison the mean transport distance for journeys which went directly to slaughter during the same period was 39.6 miles (95% CI: 39.4, 39.9). Assuming an average speed of 40mph, the transit times for these distances would be approximately 1.9h, 2.2h and 1.0h, respectively. Note that journey lengths are estimated using Euclidean methods; consequently actual journey lengths and journey times are likely to be underestimated.

As well as loading and unloading times, and rest stops (for drivers) these estimates also do not take into account the time spent at markets or collection centres. Although such data are not recorded in AMLS, the University of Bristol (for Objective 1) collected data from 86 batches of animals which arrived at slaughter via a market, and 11 batches which arrived at slaughter via a collection premises. They recorded time at these stop points either from paperwork associated with each batch of animals (8/86 for markets and 0/11 for collection premises), or from estimations using calculated journey lengths, and arrival times at markets and slaughter plants (78/86 for markets and11/11 for collection premises). Median stop-over time was calculated from these figures: mean stop-over in markets was 288 minutes (4.8h), while mean stop-over time in collection premises was 45 minutes (0.75h).

Discussion

Large numbers of movements of sheep annually took place through the duration of this project. The data showed seasonal variation, with September and October being the peak times for sheep movements, and May to July the months when numbers of sheep per movement were at a minimum. Fewer animals in total were moved in 2011 and the average number of animals per movement also decreased.

Estimates of movement lengths and transit times suggest that a very small proportion of movements in Great Britain exceed 8h in duration. The majority of movements were estimated to be between 6 miles and 31 miles (or between 0.16h and 0.78h, assuming an average speed of approximately 40mph). When estimates using Euclidean methods and GIS network analysis were compared, it seemed that Euclidean calculations did underestimate journey lengths and transit times. In addition, both these estimates of journey length/transit time cannot take into account loading and unloading times, thus in reality time spent on road vehicles will be much longer for most animals.

A large proportion of movements to slaughter, and animals moved to slaughter go via markets and collection centres. Between 2009 and 2011 27-30% of sheep which were moved to slaughter went via a market, and 1-2% via collection centres. Thus any welfare issues which may arise as a result of these stopovers will affect large numbers of animals. On average, journeys from markets or collection premises to slaughter alone were considerably longer than direct journeys to slaughter.

Using data collected by the University of Bristol, median stop-over time was 4.8h for markets, and 0.75h for collection centres. Our work suggests a conservative estimate of 6.7h average total transit time including a stopover in a market. This is likely to be an underestimate of actual journey time, since Euclidean estimates of distance are used, and doesn't account for loading and unloading times, multiple pick-ups, and rest stops. Therefore, total time from farm to slaughter for two stage journeys which include markets is likely, on average, to be considerably longer than 8h.

Objective 4 (Cranfield University)

To integrate the approach and results from Objectives 1 &3 to evaluate the economic and environmental impact of the different types of journey and to provide a holistic evaluation of the benefits and costs, with recommendations for the most sustainable options.

Economic Impact of Different Types of Journey

Introduction

Public auction markets have developed and evolved over time, shaped by changing social and economic circumstances. As such, these markets have become unique to the UK. It is useful to understand their role in maintaining a viable sheep industry and supporting EU welfare and environmental targets. This is effectively done by contrasting public auction markets to the alternative marketing options. This comparative evaluation of marketing for slaughter will also help understand some of the costs and benefits of intra-agricultural sheep movements that form part of the stratified industry, but it will not calculate the agronomic benefits of specialised breeds in hill, upland, and lowland or the three to four generations of hybrid vigour accumulating in the terminal generation of finished lambs.

Aim

To provide a holistic evaluation of the benefits and costs of the different marketing and transport systems involved with the movement of sheep, with recommendations for sustainable options

Two major activities are required. The first activity is to develop an understanding of the sheep transport network with its origins, destinations, and aggregation/redistribution nodes at markets and collection centres. This activity defines in detail the system and its boundaries for further study. The second activity is to consider the costs and benefits of the stages in these systems

Developing a conceptual model of sheep transport networks

From Objective 3, AHVLA provided a sample of animal movement data which was related to vehicle data. The data provided was a subset of the full set of sheep movement records in England, Wales, and Scotland for the years 2009 and 2010, checked for representativeness against the whole dataset for these years. The data subset contains 66,292 movement records. Essentially these data describe movements of batches of animals from origin to destination, in terms of estimates journey length and time, number of animals in the batch, and type of vehicle. For example 30 animals are moved from farm to market using a goods vehicle of a given type.

To understand the structure of the industry we used a Markov Chain analysis to follow the flow of animals leaving a farm and the probability that they will end up at another farm, an abattoir, a market, or a collecting centre. Markets and collecting centres are transient locations and we can follow the probability that the sheep will move on to a farm, abattoir, market, or collection centre. Eventually sheep will arrive at a final destination for an overall movement chain. This analysis only examines the journeys required in one episode of a sheep's life: either the movement from last farm to slaughter or (in the case of stores and breeding stock) the movement from one farm to the next.

Using Markov Chain analysis we have found that roughly 2/3 of sheep leaving farms will use one transport step to get to their next farm or into an abattoir. The remaining sheep require two journeys, stopping at markets or collection centres before moving on again to a farm or abattoir. Markets and collecting points appear to be handling similar numbers of sheep. However, there is a degree of ambiguity about the classification of each in the dataset. Less than 0.05% of sheep require three or more transport steps between leaving a farm and getting to a final destination, which if this is to a farm, means at least a 6 day standstill or if an abattoir then death.

Roughly, half of all sheep movements return to a farm. With the current data we are unable to follow the movement histories of individual sheep. These movements are an important part of the functioning of a stratified sheep industry that allows locally specialised breeds in different habitats with two or three generations of hybrid vigour in the finished lambs arising from the movement and crossbreeding of blood stock. We have not quantified the costs and benefits of stratification *per se.* This study restricts itself to the final movement sequence that ends at the abattoir. However, many of the assumptions and analysis will apply to the movement of sheep around the farming industry.

Of those arriving at an abattoir, two thirds came from a farm, 20% from a market, and 15% from a collecting point. Nationally 50-60% of finished sheep are sold at market (EBLEX, 2012). Therefore, it seems likely that many of those arriving from a farm have recently passed through a market before being resold by a farmer/dealer after a required six day standstill.

A lot of vehicle types seem to move sheep, but overall there are a few very dominant ones. These can be broken down into commercial goods vehicle and farmer vehicles. The commercial vehicles are represented by 44t articulated tractor and trailer units, 26t rigid axle vehicles, and 7.5t rigid axle vehicles. The farmer vehicles are either tractor and livestock trailer or car/4x4 and livestock trailer. The most extensive use of farmer vehicles is delivering stock to markets and collecting points. Commercial vehicles, especially the high capacity ones, are very dominant (95+%) between markets and collecting points and abattoirs. Markets and collecting points play an important logistical role by allowing small and remote batches of sheep to come together for onward transit.

It is important to note that if markets take a smaller role then it is not simply a case of more direct farm-abattoir trade. The direct farm abattoir movement data currently will be indicative of opportunities where there are large batches of sheep and the transport links are good thus making a relatively strong economic case over trade via livestock auction markets. Expansion will have to take into account the costs of bringing an increasing proportion of small rural batches in either directly or via collecting points.

Economic costs and benefits of the sheep transport networks

In practice individual transport operations can vary widely in price due to a plethora of factors such as backloads, profit margins, accessibility, etc. (DFF International Ltd 2012). We have used standard models to allow us to average out many of these variables by considering the national industry as a whole. However, important variables remain that are not readily quantified. The bodywork for sheep transporters will involve additional costs beyond the standard vehicle. The exact nature of the sheep transport job is important and includes factors such standstill times, loading, back loads, and access times to reach pickup points.

The cost models contain many assumptions that may well have an important impact on the predicted costs of sheep haulage. To test this, sensitivity analysis has been conducted on the farm 4x4 + trailer model and the 26t rigid axle vehicle model. Sheep per movement is the most important assumption in both cases and it is also a non-linear response increasing rapidly as the load falls. Many fixed cost items feature near the top such as driver employment and vehicle purchase price, meaning that any dead time (standstill) will be relatively expensive.

The data imply that 50% of movements seem to involve vehicles at less than 1/3 capacity. Part loading weighs heavily on the average costs of moving a sheep. It may be the case that vehicles are in fact more fully loaded because sheep are transported in lots or batches from different farms and internally separated in the vehicle. This would make sense for bio security reasons, but the data subset does not contain the information to identify this. The transport models have been calculated to consider both cases where either each movement record represents a unique vehicle movement or that all vehicles operate at 80% of maximum capacity. The results are shown in Table 5 and indicate that the average costs per sheep per leg fall between 30 and 60%. This fall is most evident between markets and collection points and abattoirs, which logistically would make a lot of sense. These averages mask the heterogeneity of the transport network and that the comparative costs for any one farm might be very different depending on distances, accessibility, and load sizes.

Table 5 Shows the effect on transport costs per leg of assuming vehicles operate at 80% loading revealing a market reduction in costs (30-60%) especially between markets and collection points and abattoirs.

	Destinations							
	Abattoir		Agricultural		Collection point		Market	
Origins	Av. £/head	Av. £/head (80% loading)	Av. £/head	Av. £/head (80% loading)	Av. £/head	Av. £/head (80% loading)	Av. £/head	Av. £/head (80% loading)
Agricultural	£2.83	£1.98	£3.09	£2.14	£2.20	£1.51	£2.03	£1.35
Collection point	£5.56	£2.61	£3.95	£2.39				
Market	£5.49	£2.33	£4.33	£2.40				

Economic costs and benefits of the sheep marketing

To determine the costs of the various marketing options we have used publically available data sources augmented by personal insights from the trade. Sheep sold via public auction are traded on a liveweight basis and the others are traded on a deadweight basis. The costs and outcome of livestock auction markets are public domain whereas the costs of collection centres and the prices of the sheep sold deadweight are not. Markets charge 2-4% commission to the farmer with 40-50% of that going on labour, with utilities and regulatory compliance accounting for an increasing share of the remainder. A £90 finished lamb transported to market would cost a farmer £2.88 commission (3.2%) and the transport to market costs £1.35-£2.03 on average (Table 5). Transport from market to abattoir adds a further £0.35 - £2.66. A tentative estimate of the cost to farmers of shipping lambs via collecting points to abattoirs is £0.50-£1.50 (Palmer 2013). The pricing of collecting points is less transparent and arranged privately within deadweight sales between farms and abattoirs, however, it is likely to be less, as sheep are there for considerably less time (see Objective 1), and fewer staff are required, as there is no auction process.

Regardless of marketing route the producer has the Agriculture and Horticulture Development Board (AHDB) levy to pay (£0.60 /head). The AHDB also collects as £0.20 head levy from the slaughterer (or exporter). Farmers selling via markets can sometimes be charged a promotional levy (£0.13 /head) and a bad debt levy. Abattoirs can also try to pass back to the producers, via the markets, charges for Ante Mortem Inspection (AMI), Specified Risk Material (SRM) disposal, as well as penalties where carcass quality proved worse than assumed at sale. Producers selling on a deadweight basis (direct and collection centre) can face the AMI and SRM charges as well as charges for classification, residue testing, and rejection insurance.

The straight economic comparison between liveweight and deadweight trading is not simple. Even to compare prices, one has to attempt to take into account different killing out percentages and carcass dressing specification. Additionally, markets provide numerous socio-economic benefits and prices respond directly, openly and competitively, whereas deadweight trades are determined *a priori*. The variable and heterogeneous nature of sheep meat demand, combined with numerous highly rural producers makes it neither wise nor feasible to exclusively have a 'lean' deadweight sheepmeat supply chain based on contractual partnerships. Lean supply chains focus on adding value to the customer by sharing information and eliminating all other costs as waste. They work best where the quantity and quality of demand are consistent and the power between customer and producer is even and have found application in the automotive and UK pig industry. Livestock markets have a vital role to play in creating the agility and opportunism necessary to fully balance supply and demand as well as prevent the producers from being overwhelmed by the power and leverage of the relatively few multiple retailers and abattoirs (Cox, Chicks and Palmer 2007).

There is an argument that farmers who sell deadweight will get explicit feedback to enhance their production practices whereas farmers trading at markets will only get this information indirectly by seeing what other stock sell for relative to their own. Within Objective 1 carcass quality data were collected for a small sample from across the different marketing routes. For new season Lambs there is some evidence to suggest more over-fat lambs (graded 3H or higher) go through markets (37% compared with direct deadweight sales to abattoir at 19% or deadweight sales going via collecting points at 34%). If electronic tagging improved traceability of sheep, then it might be possible for markets to give farmers better feedback. Nationally, 46% of lambs are 3H or over. If just 1% of lambs were reared to 2H/3L instead of 3H or over it would be worth £230,000 a year.

Livestock markets are multifunctional hubs within the agricultural and local community. Regardless of finished stock, the markets have a role in the trade of sheep breeding stock and stores for finishing, with farmers much preferring to inspect the stock in person that they wish to buy. Livestock markets were closed for 13 months during the foot and mouth outbreak. If they did not have an economically important role to play they would not have recovered once the farmers had broken the habit of using markets and had to trade directly with the slaughterhouse. The markets are providing the cash flow buffer, and taking the bad debt risk, between the farmer and trade purchasers who typically pay in arrears. The livestock markets provide added value services to the local community by providing car parking on off days, bringing people into town, often providing a café, and providing non-agricultural auction services, such as household goods. They also supply added value benefits to the agricultural community in terms of chartered surveying and property services as well as providing trading outlets for specialist organic, small holder, and rare breed producers. To farmers, a day at the markets can be an important social opportunity (in a very isolated profession) and a chance to evaluate the comparative quality of their stock against the stock of peers and to put a price on it. Good market operators will know the farmers and more importantly their growing stock and will advise on their finishing and sale.

Discussion

Overall in terms of the supply chains of sheep to slaughter the different transport and marketing routes provide different, often non-commensurate, economic costs and benefits. There is a strong argument that the system is more sustainable given this variety of routes allowing the trade to be agile and opportunistic to variations in demand without placing any of the various parties at a permanent commercial disadvantage. There are many additional non-financial advantages and disadvantages between the marketing routes. Such a decision, in the end, involves each farmer making multiple judgements and trade-offs. The heterogeneity of the industry and variations in comparative costs of transport routes will mean that one marketing choice is not optimal for all farmers. The above economic description helps elucidate some of the costs and benefits of intra-agricultural sheep movements as part of the stratified industry, but it cannot easily factor in rather intangible agronomic benefits, for example, of specialised breeds in hill, upland, and lowland or the three to four generations of hybrid vigour accumulating in the terminal generation of finished lambs.

Environmental Impact of Different Types of Journey

Introduction

The environmental effects of transporting sheep to abattoirs (and within agriculture) are mainly expected to be fuel use by vehicles, water use for cleaning vehicles and associated effluent management as well as cleaning market premises and providing feed and bedding for sheep in markets. This was considered in the wider context of sheep production *per se* and was analysed using Life Cycle Assessment (LCA). This is based on quantifying all of the environmental burdens of producing the functional unit of 1 t of expected edible carcass weight at the abattoir entrance (i.e. liveweight multiplied by the killing out percentage). The main burdens of interest are greenhouse gas emissions (GHGE), energy use and blue (i.e. abstracted) water use. LCA is a systematic, holistic approach for quantifying the impact on the environment resulting from the production and delivery of goods or services. This work is an extension of that described for sheep by Williams et al (2006).

Hypothesis: The hypothesis to test is that there is no significant environmental effect from marketing sheep through markets compared with direct sales to abattoirs.

Methods

Assumptions and simplifications: We need to simplify the actual complexity of sheep transport and sales in order to model it. So, some smaller routes and activities were ignored. The major routes to slaughter analysed are in Table 6.

Table 6. Main alternative routes from farm to slaughter.

Stage 1	Stage 2
From Farming to Abattoir	None
From Farming to Collection point	From Collection point to Abattoir
From Farming to Market	From Market to Abattoir

Transport: The subset of data supplied by AHVLA was scrutinised and transport types were aggregated into four main functionally similar groups.

- Quad bike (all-terrain vehicle), used for driving sheep in agriculture or possibly towing sheep in a trailer.
- 4x4 (typically used to tow a trailer to or from market)
- Agricultural vehicle (assumed to be a tractor and trailer)
- HGV (assumed proportion of journeys: 35% 7.5 t rigid, 35% 26 t rigid or 30% articulated lorry)

Movements of large numbers of sheep not within agriculture: Where an individual vehicle might appear to be overloaded, it was assumed that the sheep were repeatedly moved between the same locations. So, the distance was scaled accordingly using values derived from the industry for vehicle types.

Fuel consumption: The fuel consumptions of light goods vehicles (for 4x4) and HGV were derived from the DFF International Ltd (2012) guidance on reporting GHGE from transport and assumed that when loaded, each vehicle was laden with the national average for freight transport. Tractor fuel use was from Williams et al. (2006). The life cycle inventory (LCI) data for fuel use came from the ECLD database (JRC, 2012).

Water use and effluents: Water is provided as drinking water at markets and used for cleaning. Cleaning water for lorries was estimated from expert opinion at 5 l per sheep. In a market, the volume was higher at about 50 l/sheep. Drinking water consumption it is known to be small and was estimated from (King, et al. 2006) at 0.11 and 0.043 l per ewe or lamb respectively. The LCI data for water came from Leinonen et al. (2012).

Effluent management: Effluents may be managed in several ways, but all incur energy costs and lead to specific GHGE. Some may be applied to agricultural land from which a fertiliser credit may be obtained. The arising of excreta from sheep and fertiliser benefits were derived from the Cranfield systems LCA model (Williams et al., 2006). An LCI of effluent treatment was taken from the ECLD database (JRC, 2012).

Analysis of transport data: The journey types (i.e. between each destination type) were analysed using a Monte Carlo method (a technique involving random sampling from within the entire data space) to establish the uncertainties. The best fit of data to a distribution in all cases was lognormal.

Results

The mean use of fuel via a market (liveweight sales) was superficially about 2 litres higher per sheep slaughtered than by direct marketing (deadweight sales), but this was not statistically significant (p=0.05), whether via a market or collection point.

Blue water use via a market was about 55 litres higher per sheep slaughtered than by direct marketing ($p>0.05$). This increases the overall blue water use to raise sheep for slaughter (baseline of 49 m^3/t expected carcass weight, Chatterton et al., 2010) by 3% (0.3% for direct). This is without the 125 m^3/t incurred at the slaughter stage (Williams et al., 2009).

The effects of primary energy demand and greenhouse gas emissions (GHGE) of transport to slaughter were dominated by transport fuel use, which accounted for over 99.8%, and effluent management and water use the remainder. Transport to slaughter (mean fuel use) increases the cumulative primary energy demand for sheep carcass at the abattoir entrance by 9% and 27% for direct and market routes respectively. The effect on GHGE (or the carbon footprint) is much smaller at 1.6% and 3% (Table 7).

Table 7. *Burdens of primary production and transport to abattoir directly and via markets.*

Stages	Cumulative primary energy demand, GJ/t expected carcass	GHGE, t CO_2e/t expected carcass
Sheep carcass to Farm Gate	27.0	22.6
Transport direct to abattoir *	2.5	0.22
Total with direct	29.4	22.8
Increase between farm gate and abattoir	9%	1%
Transport to abattoir via market *	7.3	0.65
Total via market	34.3	23.3
Increase between farm gate and abattoir	27%	2.9%

* includes fuel, water etc.

The variation in fuel use per sheep journey was high and the distribution was skewed. The median values were about 35% to 50% of the mean values. There is much apparent scope for improvement in efficient fuel use.

Discussion

The results show that there is an increase in the burdens of primary energy use and GHGE from transport by either main route to the abattoir, but these were not significantly different from each other, given the high variance in fuel use. The effects of water use and effluent management on these two burdens are trivial compared with primary production. Blue water use is significantly higher via markets, although this is a relatively small increase in overall pre farm gate water and abattoir use.

It is self-evident that introducing the extra stage of a market imposes additional environmental burdens in the overall cycle of sheep production. These all appear, however, to be relatively small compared with primary production and operations in the abattoir.

There are apparent opportunities for improving environmental performance in transport, but a more detailed understanding of the reasons for inefficient transport practices is needed. These may, for example, just be for pragmatic reasons, but there must some win-win opportunities.

Objective 5 (University of Bristol)

To hold a Stakeholders meeting towards the end of the project.

The stakeholder meeting had several key aims; to disseminate the findings of our work, to gain input on the work and to carry out workshops establishing what the stakeholders felt were key outstanding welfare issues and how they might be tackled.

A meeting was organised for 17th December 2012 and a range of stakeholders were invited, representing sheep farmers, haulage companies, auctioneers, abattoirs and other interested parties. In total 49 people participated in the meeting on the day.

Presentations were given to summarise the work and findings of each Objective within the project. Following each presentation the participants were given the opportunity to ask questions and give feedback. From this we gained an insight into those areas that the stakeholders felt were important to investigate further and several specific requests have been included in this final report.

During the workshop participants were asked the question, “What are the possible problems with sheep marketing in the UK today, both actual and perceived?” The answers covered a broad range of topics which can be broadly clustered under the following headings: Fitness to travel, sheep characteristics, transport time and distance, training and stockman standards, market facilities, vehicle standard and issues, stocking density (transport, market, lairage and generally), poor and unnecessary handling, haulage issues, biosecurity, traceability, emergencies, lairage issues, communication, market issues, noise stress and young animals.

The main themes were then listed and stakeholders were asked to vote on which issues they felt were most important, with the results shown in Table 8.

Table 8. *Number of votes allocated to each welfare concern by participants in the workshop.*

Heading	Number of votes
Transport of Unfit Animals	39
Space Allowance / Stocking Density in Markets	24
Vehicle Fitness for Purpose (Tailoring to Breed / Weather / Design)	20
Inefficient Handling / Penning in Markets	15
Water Availability and Encouraging Drinking in Markets	12
Space Allowance / Stocking Density in Abattoir Lairage	9
Extended Time in Lairage	4

Groups were then allocated an issue and asked to discuss 'Who is responsible for addressing the problem as an organisation, and as an individual?' They were also asked 'what would be the difficulties in achieving a solution?'. This stimulated much interesting discussion amongst participants, a brief summary of which will be provided here. The transport of unfit animals was obviously considered a major concern by stakeholders and it was felt that drivers may be put under pressure to take animals which are not fit to travel. It was felt that this issue is unlikely to improve in the near future due to the decrease in monitoring at markets and that records are needed to trace regular offenders. That this issue was raised by so many of the external participants as one of primary concern is important as the topic had not been mentioned within any of the project presentations! This strongly suggests that further research in this area should take place.

Stocking densities were discussed at length and considerable concerns were raised regarding changes in regulations that will require maximum stocking densities to be listed on pens. It was felt that a good stockman would vary the stocking density according to a number of factors and that specifying numbers of animals could lead to more problems rather than fewer. There seemed to be a general feeling that a number of the issues at auction markets could be eased by farmers booking their animals in, as this would enable better planning of penning of animals.

Emergency planning was also raised as an issue with respect to transporting animals, lairage of animals during line breakages and disease outbreaks. Finally it was suggested that animal welfare could be improved with more checks of vehicles being used to transport animals, particularly of those used for small loads, as these are generally not owned by full-time, professional transporters. In summary the stakeholder meeting was a forum for an exchange of information and ideas and seemed to be very positively received.

Overall Conclusions From Objectives 1 to 5

Objectives 1 & 2: The amount of time that sheep were held in lairage at the abattoir was bimodal reflecting the practice of delivering sheep that were often then held overnight for slaughter the next day. This led to lairage times that could extend to just over 24 hours (and in a small number of cases, for additional reasons, to several days); this pattern of lairage times being common across all of the slaughterhouses visited. Forty per cent of sheep were held for less than 12 hours and 94 per cent for less than 24 hours.

The majority of road journeys recorded within this Objective were under 8 hours per leg and as such fall within the current definition of a short journey. Initial journeys to both auction market and to collection centre were almost all less than 1.5 hours. Within our relatively small sample the time spent at a collection centre was always less than 2 hours. A larger sample was collected from animals passing through auction markets and the time spent at auction for the majority of animals was less than 7 hours, however, a small number of batches were held for longer; up to 24 hours. The distribution of journey times from auction, collection centre and farm to abattoir were similar with very few over 8 hours, the majority taking less than 5 hours. A complete breakdown of the distributions of different stage times is shown in the accompanying full report. Overall time in transit (not including time in lairage) is shown above in Figure 2. Sheep transported direct from farm to abattoir tended to have short overall times, the distribution being strongly right skewed and all below 8 hours. Sheep transiting through an auction market had longer journey times, mostly due to the time for which they were held at the market, the distribution of total times being strongly left skewed with the greater proportion of times between 5 to 12 hours and a small number extending beyond this. Total time in transit for sheep passing through collection centres was intermediate.

Overall, the more mature sheep (ewes and rams) showed less marked physiological changes in response to transport than the more immature new season lambs, the old season lambs being intermediate. It is not possible to say whether this was because the different types of animals find transport more or less 'stressful' or whether their responses are 'naturally' dissimilar.

The physiological measurements made on the sheep following transport indicated that generally sheep did not appear to have eaten or drunk when passing through an auction market: as a result of the greater total time in transit they had drawn upon body reserves to a greater extent and were slightly more dehydrated. Data from markets (Objective 2) showed that very few (≤10%) markets made water available to any animals during their stay. Furthermore 42.9% of markets did not allow any access to feed or edible bedding, while 23.8% provided only a small proportion of animals with access to feed or edible bedding.
However, physiological effects tended not to be extreme and could also be found in a smaller number of animals

transported direct or through collection centres. The extended time in auction markets also appeared to have allowed greater recovery from the physical demands of the initial stages of transport to take place. However, there will be a small number of animals that are at the extreme of the physiological measurements before their entry into a market (for example those that should have been classed as unfit to travel), for whom the extension of transport times due to passing through a market will have more serious welfare consequences.

Behavioural data collected at markets showed little evidence for discomfort in the animals observed: rates of vocalisation were low (0.19 per sheep per hour) and panting was rarely observed. Analyses of behavioural data suggest that high stocking densities and high frequencies of disturbance both impinge on animals' ability to rest at markets, with both reducing likelihood of observing lying or ruminating. In our observations stocking densities ranged from 0.42 to 7.8 sheep per m^2; 10.1% of pens had insufficient space for any animals to lie, according to observer scores. In total 50.2% of pens experienced disturbance from passers-by, with a further 5.8% experiencing disturbance from handling during our observations. Thus circumstances which may reduce animals' ability to rest during their time at market appear relatively frequent. If time in market were to be considered as 'neutral' time it is suggested that there should be a requirement for sheep to have sufficient space for lying and, in order for sheep to rest during their stay at market, they should experience a reasonable period of time during which their resting behaviour (e.g. lying) in not disturbed by activity in the market around them.

Quality of rest time at market, and thus ability to cope with onward transport, may be improved by limiting stocking densities. When penned for protracted periods, sheep with sufficient room to move would be able to adapt their behaviour to greater preserve both energy and moisture and to lessen the detrimental effects of extended transport times. More and better rest may also be facilitated by managing markets so that there is as little disturbance as possible to sheep during their time in market. For example, filling pens furthest away from the point of entry to the market first, so that, once in their pen, sheep are left undisturbed by the movements of market personnel. Similar principles could be applied to abattoir lairages, where relatively high densities were also observed.

It may also be that better identification of sheep 'unfit' to travel at source and improved enforcement at destination (see below, Objective 5 and Further Research) would improve the welfare of animals travelling both through market and direct to abattoir.

<u>Objective 3</u>: Annual movements of sheep ranged between 890 thousand, and 934 thousand over the three years of this study, with numbers of animals moved ranging from 37 million to 41 million. Data from 2009 were patchy, regarding the purpose of the origin and destination of movements, but when 2010 and 2011 were examined together 21.3% of movements to slaughter went via a market (25.5% of animals moved to slaughter). Thus issues associated with the use of auction markets, as described for Objectives 1 and 2, may affect more than a quarter of animals going to slaughter.

Overall journey distance was estimated to be 75.8 miles on average, although this is likely an underestimate, since distances were calculated 'as the crow flies'. Assuming an average speed of 40mph the time taken to cover this distance will be 1.9h. However, this time estimate does not make any allowance for loading and unloading times, nor for rest stops for the driver. Consequently this too is likely an underestimate. The mean length of movements direct to slaughter (i.e. those which came neither from a market, nor from a collection centre) was 39.6 miles, with at transit time of 1h at an average speed of 40mph. This will be similarly underestimated, for the reasons outlined above, although journeys direct to slaughter will have two loading/unloading events, compared to four for those via a market. On average journeys via market carried batches of 66 animals, while those direct to slaughter carried batches of 52 animals. Thus, in summary, it seems that animals travelling to slaughter via a market, travel further, and for longer, in larger groups, which may exacerbate any outcomes associated with this system.

A much smaller number of movements go via collection premises (0.3% of movements or 1.4% of animals). However, journey lengths for these movements are estimated to be longer still at 88.5 miles (with a transit time of 2.2h, at an average speed of 40mph) and carry considerably larger groups of animals (mean 248.1 animals per movement). Thus although relatively few animals may be affected, there may be a greater potential for impact on welfare, particularly for those animals mentioned above, that are already at physiological extremes, and perhaps could have been regarded as 'not fit for travel'.

<u>Objective 4:</u> Overall in terms of the supply chains of sheep to slaughter the different transport and marketing routes provide different often non-commensurate economic costs and benefits. The heterogeneity of the industry and comparative transport costs means that one marketing route will not be financially optimal for all farmers. There is a strong argument that the system is more sustainable given this variety of routes allowing the trade to be agile and opportunistic to variations in demand without placing any of the various parties at a permanent commercial disadvantage.

The environmental burdens of sheep transport to slaughter have been quantified including the optional use of markets. These are dominated by fuel use for all burdens, except blue (abstracted) water. There was no statistically significant difference in fuel use per sheep between direct and indirect transport to slaughter. The variation was considerable, so that there appears to be a substantial opportunity for improvement in environmental performance. There may, however, be programmatic reasons why some of this inefficiency occurs and a further detailed study of behaviour and motivation is required to understand why.

Objective 5: The transport of unfit animals was highlighted as a major concern by stakeholders and was an issue that they felt needed to be tackled in the future. Stocking densities in markets was also deemed important by the workshop participants. It was felt that some of the problems at markets could be reduced by farmers booking animals in, allowing markets to plan the penning of animals. Concerns were expressed about changes to regulations requiring maximum stocking densities to be listed on pens.

Further research

The results within Objective 1 suggest that sheep were not eating and drinking when held at auction market pens, during the day time. Future studies should investigate whether it is possible to provide an environment at market in which sheep, when provided with water and feed, will be settled enough to drink and eat and under what circumstances it is desirable to provide such an environment. Even when food and water were present (a minority of observations) sheep did not appear to take advantage of the opportunity to eat and drink.

If it is possible to provide sheep at market with food and water in an environment in which they will consume both, it will be necessary to monitor and consider the consequences of freshly fed and watered sheep arriving for slaughter. Abattoirs prefer a period of food withdrawal to ensure that they have less rumen and gut content to deal with. The actual consequences for hygiene within the abattoir are less clear and studies are still required to investigate optimum feed withdrawal times. It is likely that some feed withdrawal times result in poorer hygiene as a consequence of changes in the liquidity of gut contents and changes to the gut micro flora.

Avoiding crowding in pens at market, in collection centres and in lairage at abattoir would allow sheep the space to use behavioural adaptations to reduce physical, physiological and social stress. We suggest that work on how best to implement this, through engagement with abattoirs and auction markets should be carried out.

A majority of delegates at the stakeholder conference identified the transport of unfit sheep as their primary concern for welfare during transport. This was a surprise to the organisers as this suggestion was completely unprompted and the subject had not arisen within any of the project team's presentations. The concern of the stakeholders strongly suggests that work is required to properly quantify this potential problem, and, if it exists at a sufficient level, to investigate how unfit sheep can be better identified at source and possibly, enforcement improved at destination.

The study has highlighted considerable issues with traceability of individual sheep, even in cases where EIDs have been fitted. Improved traceability of sheep would have a considerable number of benefits including enhancing the ability to track diseases, providing feedback to farmers on carcass scores and enhancing the UK GHG inventory for agriculture to help understand sheep populations, locations, age at slaughter and production system. Increasing the accuracy of the inventory means that improvements over time can be tracked and will help the industry meet its own targets, e.g. in the GHG Action Plan. A system which improved traceability of sheep could benefit the industry which would be able offer consumer reassurance about the source of their meat. Work to investigate the feasibility of implementing schemes to improve traceability would be recommended.

In terms of environmental performance, there are clearly opportunities for improving fuel use in transport. A detailed study of farmer operated vehicles, in particular, would be needed to improve the analysis substantially, but it would help to be coupled with commercial haulier operation. Water use will cause more stress in some geographic areas than others. Further research could show how these vary across the country and highlight opportunities for reducing water use.

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

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