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SCIENTIFIC OPINION

Scientific Opinion on the welfare risks related to the farming of sheep for wool, meat and milk production[1]

EFSA Panel on Animal Health and Welfare (AHAW)[2,3]

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ABSTRACT

This scientific opinion is the outcome of a scoping exercise aimed to identify the main welfare consequences and associated risk factors for sheep across, and within, categories of management systems and production types. The exercise included the construction of a risk (conceptual) model, a literature review and an expert knowledge elicitation, involving an online survey and a technical hearing, in order to rank the welfare consequences on the basis of the amount of suffering and prevalence. Sheep farmed for wool, meat and milk production were the target population, focusing on ewes and lambs. Based on the degree of human contact, use of housing, nature of pasture management and provision of supplementary feeding, sheep management systems were characterised as: shepherding, intensive, semi-intensive, semi-extensive, extensive, very extensive and mixed. The conceptual model proposed seventeen welfare consequences. In ewes, the importance of the welfare consequences was rated differently in different management systems; however, across all systems, the most important welfare consequences were: thermal stress, lameness and mastitis. Prolonged hunger was rated to be more frequent in extensive and very extensive management systems, and mastitis in ewes reared for milk production. For lambs, there were few differences among management systems with thermal stress, pain due to management procedures, gastro-enteric disorders and neonatal disorders rated as main welfare consequences. Respiratory disorders were more frequent in intensive management systems. The technical hearing of experts facilitated consensus on the major risk factors for ewes and lambs. Animal-based measures exist for most welfare consequences in ewes and lambs, but many require further validation. The identified currently available validated ABMs for assessing the main welfare consequences in ewes are: body condition score, locomotion score, udder consistency and somatic cell count in milk; and in lambs: shivering, evidence of painful husbandry procedures and dag score (score of breech soiling).

KEY WORDS

welfare consequences, animal-based measures, farming systems, sheep, risk assessment, risk factors

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SUMMARY

Following a request from the European Commission, the EFSA Animal Health and Welfare (AHAW) Panel was asked to deliver a scientific opinion on the main welfare risks related to the farming of sheep for wool, meat and milk production. The request consisted of the identification of the main welfare consequences and risk factors for which a risk assessment should be performed, as well as on the identification of the animal-based measures (ABMs) to evaluate the welfare consequences. Consequences and factors should be identified for sheep (ewes and lambs) farmed for the three production purposes (meat, wool and milk) and depending on the management systems used and the sheep breed typologies.

This scientific opinion on sheep welfare is the outcome of a scoping exercise for the identification of the main welfare consequences and associated risk factors across and within categories of management systems and specific production types. It provides a first broad assessment that could be followed-up by more specific and targeted welfare risk assessments. The scoping exercise, conducted by the Working Group, included the construction of a risk model (conceptual model), a literature review and ranking of welfare consequences through expert knowledge elicitation. Owing to the scarcity of scientific literature, from which to derive data for quantitative risk assessment relating risk factors to welfare consequences in sheep production, a qualitative approach was employed to rank welfare consequences and identify risk factors within management systems. The importance of the welfare consequences was calculated on the basis of the amount of suffering and prevalence. The amount of suffering was defined as a combination of the severity of the problem, its duration and how often it is repeated during the lifetime of the sheep. Such expert knowledge elicitation involved an online survey and a technical hearing meeting with external experts.

Sheep farmed for three different production purposes – wool, meat and milk – were identified as the target population, focusing the attention on ewes and lambs as animal categories. Evidence of welfare consequences and associated risk factors for breeding rams is particularly scarce, allowing no formal risk assessment. Sheep management systems were characterised for the purpose of this opinion as shepherding, intensive, semi-intensive, semi-extensive, extensive, very extensive and mixed systems. Such categorisation was based on the degree of human contact, use of housing, quality, availability and management of pasture and provision of supplementary feeding.

The conceptual model proposed 17 main animal welfare consequences and associated risk factors in the farming of sheep under the different management systems and production purposes. These animal welfare consequences were based on the four principles identified in the Welfare Quality® project: good feeding, good housing and environment, good health and appropriate behaviour. The results of the online survey on the 17 main animal welfare consequences helped identify of the main welfare consequences for ewes and lambs kept under each management system and production purpose. The welfare consequences for ewes were rated to differ in importance in different management systems. Across all the management systems the most frequently identified important welfare consequences for ewes were: thermal stress, lameness and mastitis. Prolonged hunger was rated to be more frequent in extensive and very extensive management systems. Mastitis was identified as an important welfare consequence in sheep maintained for milk purposes, being also affected by genetic factors.

For lambs, there were few differences among management systems with thermal stress, pain due to management procedures, gastro-enteric disorders and neonatal disorders rated as main welfare consequences. Respiratory disorders were rated to be more frequent in intensive management systems.

It is recommended that, to build on the scoping exercise produced in this opinion, risk assessment should be formulated on specific welfare consequences, management systems and production purposes. Systematic data collection should be carried out to identify the welfare problems in different management systems and production purposes for sheep, including rams. Data should allow quantification of their severity and prevalence, together with the associated risk factors. In addition,

the interaction between different welfare consequences, which might occur concurrently or consecutively, should be investigated further.

The technical hearing of experts facilitated consensus on the major risk factors and their association with the most important welfare consequences of ewes and lambs under the studied management systems and production purposes. Risk factors tend to be specific to the welfare consequences but are often common across management systems where that consequence is important. Tables presenting the risk factors leading to the major welfare consequences for both ewes and lambs under the identified management systems are presented in the scientific opinion. Geographical differences in risk factors within a given management system, should be taken into consideration.

Animal-based measures (ABMs) exist for most welfare consequences in ewes and lambs, but many require further validation. Some of these measures used to assess animal welfare consequences for ewes and lambs were also elucidated during the technical hearing meeting.

The identified currently available ABMs that are considered to have validity, reliability and feasibility to be used for ewes are: body condition score, locomotion score, clinical assessment of injuries, dag score (score of breech soiling), mucosal colour, udder consistency, somatic cells count (for dairy sheep), evidence of painful husbandry procedures (tail docked, ear damage, mulesing) and qualitative behavioural assessment (QBA). Among these, the ones that can be used for assessing the identified main welfare consequences are: body condition score, locomotion score, udder consistency and somatic cell count in milk.

In addition, ABMs that are believed to be promising but require further scientific evaluation for ewes are: coat cleanliness, panting, respiration rate, displacement, skin conditions, fleece quality, nasal discharge, social isolation, and flight distance.

The ABMs that are considered to have validity, reliability and feasibility to be used for lambs are: shivering, locomotion score, clinical assessment of injury, dag score, and evidence of painful husbandry procedures (tail docked, ear damage, castration). Among these, the ones that can be used for assessing the identified main welfare consequences are: shivering, evidence of painful husbandry procedures, and dag score.

In addition, ABMs that are believed to be promising but require further scientific evaluation for lambs are: evaluation of body condition, coat cleanliness, panting, skin conditions, nasal discharge, mucosal colour, qualitative behavioural assessment, respiration quality, and gut fill.

Moreover, ABMs based on farmer records of mortality and diseases have good potential but necessitate accurate farm recording which cannot currently be guaranteed. It is recommended that a systematic data collection should include reliable farm records in addition to direct animal-based measures to take into account the variation associated with season and reproductive state.

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BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION

Sheep farming for milk, meat and wool production is of increasing importance worldwide, including in the EU and particularly in Eastern European countries.

Council Directive 98/58/EC concerning the protection of animals kept for farming purposes lays down minimum standards for the protection of animals kept for farming purposes, including sheep. Recommendations concerning sheep, under the European Convention on the protection of animals kept for farming purposes were adopted back in 1992.

While no specific EU rules on farming of sheep exist, the EU Strategy for the protection and welfare of animals 2012-2015 foresees a revised animal welfare framework, introducing the use of animal-based welfare indicators to simplify the legal framework and to enhance the applicability of general principles to all farm animals.

Meanwhile international organisations, global stakeholders and Third Countries Governments are moving towards more sustainable livestock production policies and farming practices, developing guidelines and codes of practices addressing the welfare of sheep. This includes the recent joint initiative of the Commission (DG SANCO) and the International Wool and Textile Organisation (IWTO) to support the elaboration of a guideline for best practices for welfare of wool producing animals.

Production systems can be very different across regions, including within the EU. Sheep can be reared in different conditions also within the same farm: from free range grazing exposed to natural hazards and surveillance depending exclusively on the availability of pasture resources, to full time indoors management and relatively high-tech facilities.

In the case of dairy sheep farming, systems can vary from very extensive (such as pastorals with practices such as manual milking, seasonal breeding and one lactation/year) to very intensive (with machine milking, concentrate supplementation, year around breeding with three lactations in two years, etc.). Breeds and related welfare problems can also vary in the different regions and in connection with factors such as nutrition and environment.

The IWTO is currently working on its Good Wool Sheep Welfare Guidelines which will aim to clearly define and widely promote good animal welfare practices in wool production, relevant to the wide diversity of production environments around the globe. While specifically relevant to the global wool sheep production industry, these good welfare practices are closely aligned with the World Animal Health Organisation (OIE) Terrestrial Animal Health Code.

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

The Commission therefore considers it opportune to request the EFSA to give an independent view on the main welfare risks related to the farming of sheep for wool, meat and milk production.

1. To identify the main factors and welfare consequences and perform the risk characterisation for the farming of sheep for wool, meat and milk production, taking into account differences in genetic lines, local production systems, environmental conditions and nutrition.

2. Based on the risk assessment carried out following point 1 and on the analysis of breeds' distribution, to identify the main welfare risks common to the different production typologies and main breeds in order to develop a matrix linking breeds/common risks/welfare consequences/risk characterization.

3. Based on the outcome of the above terms of reference, to identify the animal-based measures that can be used to assess the welfare of sheep and the main welfare risks identified.

ASSESSMENT

1. Introduction

The European Food Safety Authority (EFSA) has been requested to provide a scientific opinion on the main welfare risks related to the farming of sheep for wool, meat and milk production. The request consisted of the identification of the main welfare consequences and risk factors for which a risk assessment should be performed, as well as the identification of the animal-based measures (ABMs) to evaluate the welfare consequences. Consequences and factors should be identified for sheep (ewes and lambs) farmed for the three production purposes (meat, wool and milk) and depending on the management systems used and the sheep breed typologies.

The risks for animal welfare in EFSA scientific opinions have been considered since 2004, initially through literature reviews and subsequently through risk assessment methodology; in particular, several risk assessments for welfare on farm were carried out for a number of species including pigs (EFSA, 2004, 2005a, 2007a, b, c), laying hens (EFSA, 2005b), calves (EFSA, 2006; EFSA AHAW Panel, 2012a), dairy cows (EFSA, 2009a, b, c, d, e, f), broilers (EFSA AHAW Panel, 2010a, b), and beef cattle (EFSA AHAW Panel, 2012a). However, this is the first time that EFSA aims to assess risks to the welfare of sheep on farm.

A self-mandate was launched by EFSA in September 2007 (EFSA-Q-2007-168) to develop the Risk Assessment Guidelines for Animal Welfare, where three main animal welfare issues were identified, namely: Stunning and Killing, Transport, and Housing and Management. The technical report on "Animal welfare risk assessment guidelines on housing and management" (Wageningen UR Livestock Research, 2010), presents the description of the main housing and management systems for cattle, pigs, sheep, goats, laying hens, broilers, broiler breeders, turkeys, ducks and geese. The report included the hazard identification, hazard characterisation and exposure assessment related to housing and management conditions of farm animals, as well as a risk assessment methodology for evaluating the welfare.

In 2012, EFSA published "Guidance on Risk assessment for Animal Welfare" (EFSA AHAW Panel, 2012b). The document provides a structured methodological framework for the assessment of risks for animal welfare and it is intended to be applicable to all types of welfare consequences and factors that affect welfare, all types of husbandry systems, management procedures and all animal categories. The problem formulation is the starting point and prerequisite for any risk assessment, which includes the description of the exposure scenario, the target population and the conceptual model linking the relevant factors of animal welfare concern (Figure 1). The formal risk assessment consists of three steps: exposure assessment, consequence characterisation and risk characterisation. Exposure assessment provides a qualitative or quantitative evaluation of the strength, duration, frequency and patterns of exposure for the factors relevant to the exposure scenarios developed during the problem formulation. Consequence characterisation involves assessing the magnitude (intensity and duration) of the consequences for welfare and the probability of their occurrence at the individual level. Risk characterisation is the final step of risk assessment and is the qualitative or quantitative estimation of the probability of occurrence and magnitude of the welfare consequence (known or potential) in a given population.

Uncertainty and variability in risk assessment, as well as all assumptions used in problem formulation and risk assessment, need to be clearly expressed. Quality of risk assessment includes the quality of the data input, the relevance of the assumptions and the quality of the final assessment in relation to uncertainty and variability. Quantitative data should be used whenever possible. However, when these data are not available in the scientific literature, qualitative information and expert knowledge might be used as an alternative.

This is the first time that EFSA has addressed the welfare of sheep and, following the methodological frame of the EFSA Guidance (EFSA AHAW Panel, 2012b), to identify, as requested by the mandate, the main welfare consequences for the different production and management systems as well as the issues common to all productions and scenarios.

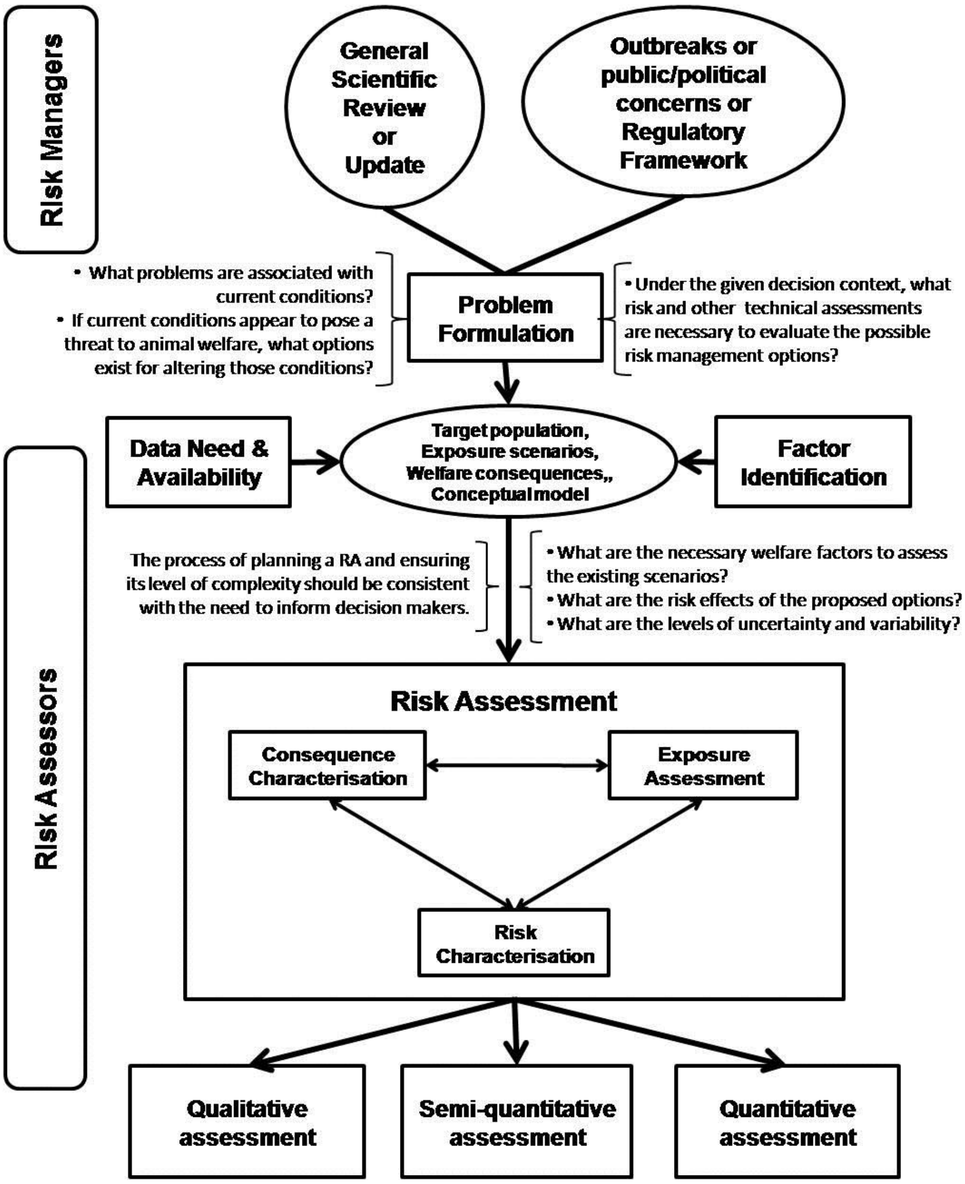


Figure 1: Workflow to conduct a risk assessment (EFSA AHAW Panel, 2012b)

1.1. Distribution of sheep population in the world

Data from the Food and Agriculture Organization of the United Nations (FAO; FAOSTAT.fao.org) indicate that the overall world sheep population was 1,167 million in 2012 with a slight increase to 1,173 million in preliminary data for 2013. The largest number of sheep are found in Asia (524 million) followed by Africa (321 million), Europe (129 million), Oceania (106 million) and the Americas (86 million). The largest sheep-producing country in the world is mainland China with 183 million head of sheep. Other significant sheep-producing nations (more than 20 million head of sheep) are India (75 million), Australia (74.7 million), the former Sudan (52.5 million), Iran (50 million), Nigeria (38 million), the United Kingdom (UK; 32.2 million), New Zealand (31.3 million), Pakistan (28 million), Turkey (25 million), South Africa (24 million), Ethiopia (25.5 million), Algeria (25 million) and Russia (20.7 million).

1.2. Distribution of sheep population and holdings in the European Union, Norway, Switzerland, Iceland and Montenegro

In 2010, a Farm Structure Survey (FSS)[4] was carried out by the EU-27 Member States and Croatia, Norway, Switzerland, Iceland, and Montenegro. According to the FSS, a total of 979,180 agricultural holdings produced sheep within the surveyed countries (for details, see Appendix A, Table A.4 and Figure A.2), and the total population of sheep in the 32 surveyed countries was 99,421,850 (see Table A.4 and Figure A.3 of Appendix A).

In the FSS, the regional distribution of sheep is provided in number of animals per European Union (EU)-country. However, to our knowledge, data on geographical distribution by management system and production purpose are not available.

Figure 2 shows the sheep populated areas in Europe.

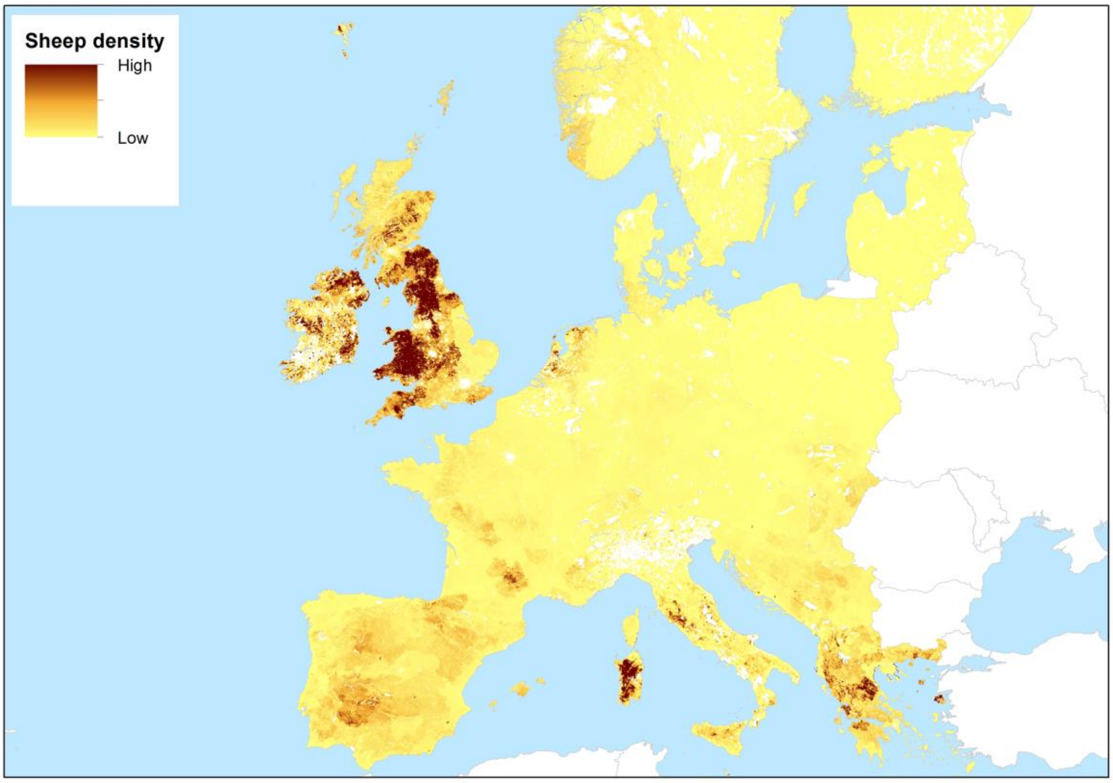


Figure 2: Sheep distribution in Europe in 2010 (1-km resolution; data source: FAO GeoNetwork[5])

1.3. Purposes of sheep production (for meat, milk and wool), breed typologies and management systems

The first step of the risk assessment, the problem formulation, requires the identification of the target population and the exposure scenarios. The population is defined by a set of common characteristics in relation to the risk question. The current mandate proposes to define the target population by the

[4] "The basic Farm Structure Survey, abbreviated as FSS and also known as Survey on the structure of agricultural holdings, is carried out by all European Union (EU) Member States. The FSS are conducted consistently throughout the EU with a common methodology at a regular base and provides therefore comparable and representative statistics across countries and time, at regional levels (down to NUTS 3 level). Every 3 or 4 years the FSS is carried out as a sample survey, and once in the ten years as a census. The 2000 census FSS covers only the EU-15 countries, while the 2010 census covers EU-27 Member States and Norway, Switzerland, Iceland, Croatia and Montenegro". Available online: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Farm_structure_survey_(FSS)

[5] http://faostat.fao.org/

production purpose (meat, milk or wool), geographical area and genetic line. In most cases sheep, are raised for dual (e.g. meat and wool or milk and meat) or multiple purposes. Therefore, in the flock, two different target populations might be defined, ewes for reproductive, milk and wool production purposes and lambs for meat. Breeding ewes and lambs (as breeding replacements or prior to slaughter for meat) are the dominant sheep types present on farm. Breeding rams, for all three production purposes, are also present, in much smaller numbers. Although their welfare is important, there is a scarcity of information in the literature, and elsewhere, to allow rams to be included in the problem formulation as a third target population.

Worldwide, there are in excess of 850 breeds of sheep, with exact numbers varying with definition and the development of new strains. Sheep breeds can be broadly classified by geographical/environmental adaptations as: temperate (a broad classification including mountain, longwool and downs sheep found in Europe, the Americas, Australia and New Zealand), Northern desert sheep (found in Mediterranean regions, North Africa, Iran, Syria and Afghanistan) and Southern desert sheep of sub-Saharan Africa and India. Sheep breeds can also be classified by morphology (essentially "tail-type" and fleece quality). Here, breeds are divided into thin-tail (e.g. most European temperate breeds), fat-tail, fat-rump, short- and long- tail and by hair, coarse-, medium- and fine-wool types. Temperate, thin-tail sheep are the predominant type of sheep breeds in Europe. They are moderate in size, short-limbed and compact with thick coats. Northern desert sheep are less compact, with thinner necks, longer legs, markedly longer ears and are often fat-tailed (e.g. Awassi). They have woolly coats, which are coarser and less dense than temperate breeds. Southern desert sheep have elongated extremities, long ears and tails and are hair sheep (e.g. Djallonké), and are infrequent in Europe. At the European level, the main purpose of sheep breeds varies greatly but maintains some relationship with geographical area: in northern regions, temperate breeds of sheep are kept for meat and woo; in southern regions, dairy sheep, often of Northern desert sheep breeds, are more common. Although many sheep are kept for a primary purpose, commonly other products will also be harvested, some of which may have near to equal economic importance to the producer (e.g. most meat sheep also produce wool; milk sheep produce lambs which are reared and sold for meat). Even within Europe numerous sheep breeds are raised commercially (e.g. in the UK alone more than 80 breeds and cross-breeds are in commercial production), and many sheep breeds may be locally adapted to geography and climate. Therefore, defining the risk assessment within genetic line or breed is largely impossible. However, European sheep can be broadly classified into a smaller number of main types:

1) <u>Mountain, "rustic" and primitive breeds (e.g. Herdwick, Scottish Blackface, Ripollesa)</u>: generally small, temperate, thin-tailed sheep breeds locally adapted to harsh conditions of low food availability and climatic extremes. Breeds are often horned in both sexes, show behavioural adaptations to the environment and are low producing (typically rearing single lambs). In addition to being kept for production purposes these breeds may be kept by hobbyists, used for vegetation and landscape management or farmed for their pelts.

2) <u>Downs breeds (e.g. Texel, Suffolk, Merino)</u>: larger, temperate, thin-tailed sheep breeds generally subjected to more intensive selection pressure for production traits (meat or wool). Animals are more likely to be kept in flatter pastures with access to better quality grazing than mountain breeds. Ewes, or both sexes, are frequently polled and animals are more productive than mountain breeds (e.g. raising twin lambs, producing heavier, more muscular carcases or wool of a finer quality).

3) <u>Longwool breeds (e.g. Bluefaced Leicester)</u>: somewhat intermediate between mountain and downs sheep, these are larger temperate sheep, which are locally adapted and often raised for their wool or used as crossing breeds to improve size and productivity whilst retaining hardy and adaptive traits.

4) <u>Northern desert sheep (e.g. Awassi, Karakul)</u>: locally adapted to hot, arid climates and harsh terrain, these breeds are kept for milk production and for meat.

5) Dairy sheep (e.g. Sarda, Comisana, Delle Langhe): a group of dual-purpose breeds primarily kept for the production of milk to be used for cheese-making and secondarily raised for meat or wool production. These breeds are able to give larger quantities of milk and have longer lactations than other sheep.

The exposure scenario can be classified by the different management systems that include information on housing, nutrition, breeds, and husbandry and management procedures. The management of sheep varies depending on the product to be harvested from the animals and the country in which they are raised. Examples of breeds used in different management systems and production purposes are presented in Appendix B. Within different countries, financial, cultural and climatic differences affect such management factors as the numbers of animals supervised by one person and whether the sheep are kept outdoors all year round or spend some time indoors (Kilgour et al., 2008).

1.4. Welfare consequences and risk factors

The identification of the welfare consequences and risk factors is also a main element of the problem formulation. Welfare consequences are changes in any welfare aspect that result from the effect of a factor or factors, defined as any aspect of the environment in relation to housing and management (EFSA AHAW Panel, 2012b). The multidimensional approach of the Welfare Quality® (WQ®) project proposed to break down the welfare into four principles according to how they are experienced by animals: good feeding, good housing, good health and appropriate behaviour (Blokhuis et al., 2008). Within these principles, the project highlighted 12 distinct but complementary animal welfare criteria (Botreau et al., 2007). Each criterion represents a separate aspect of animal welfare. In detail, the 12 criteria are indicated in Table 1.

Table 1: The four principles and twelve criteria of animal welfare according to the Welfare Quality® (WQ®) project.

Principles	Criteria
Good feeding	1. Absence of prolonged hunger (animals should not suffer from prolonged hunger, i.e. they should have a suitable and appropriate diet)
	2. Absence of prolonged thirst (animals should not suffer from prolonged thirst, i.e. they should have a sufficient and accessible water supply)
Good housing	3. Comfort around resting (animals should have comfort when they are resting)
	4. Thermal comfort (animals should have thermal comfort, i.e. they should be neither too hot nor too cold)
	5. Ease of movement (animals should have enough space to be able to move around freely)
Good health	6. Absence of injuries (animals should be free of injuries, e.g. skin damage and locomotory disorders)
	7. Absence of disease (animals should be free from disease, i.e. animal unit managers should maintain high standards of hygiene and care)
	8. Absence of pain induced by management procedures (animals should not suffer pain induced by inappropriate management, handling, slaughter, or surgical procedures, e.g. castration, dehorning)
Appropriate behaviour	9. Expression of social behaviours (animals should be able to express normal, non-harmful, social behaviours, e.g. grooming)
	10. Expression of other behaviours (animals should be able to express other normal behaviours, i.e. it should be possible to express species-specific natural behaviours such as foraging)
	11. Good human-animal relationship (animals should be handled well in all situations, i.e. handlers should promote good human-animal relationships)
	12. Positive emotional state (negative emotions such as fear, distress, frustration or apathy should be avoided whereas positive emotions such as security or contentment should be promoted)

1.5. Animal-based measures (ABMs)

Animal-based measures (ABMs; see glossary) are the form of evaluation of the welfare consequences. Potential measures can be identified and evaluated based on their validity, reliability and feasibility. Validity is the main criterion and is defined as the extent to which the measure is meaningful in terms of providing information on the welfare of an animal or a group of animals (Winckler et al., 2003). Reliability assessment include: 1) inter-observer reliability (reproducibility), which refers to agreement between two or more observers after they have received reasonable training (Dalmau et al., 2010); 2) intra-observer reliability or repeatability which requires that results are largely the same when the same observer repeats assessments (e.g. using video clips or pictures); 3) test–retest reliability to assess the robustness of the measure to external factors, such as time of day or weather conditions (i.e. repeated tests with the same subjects yield similar data; for definitions of the essential characteristics of ABMs, see also EFSA AHAW Panel, 2012c). This means that results must be representative of the longer-term farm situation and not too sensitive to changes in the farm conditions or the internal states of the animals as long as the situation has not changed significantly. At the same time, a measure should be sensitive enough to detect variations in welfare state between farms (Temple et al., 2013). Feasibility means the ability to carry out the measure under practical conditions.

The "Animal Welfare Indicators Project" (AWIN, online[6]) includes sheep in its list of target species (with goats, horses, donkeys and turkeys). The aim of this project is to produce a protocol for the on-farm assessment of these species using animal-based measures, as was previous completed for pigs, poultry and cattle in WQ®. The AWIN project uses similar methods to those developed by WQ® and the four principles and 12 criteria developed in this project are shown in Table 1. The work for sheep focuses on extensively managed adult ewes. The principle "Good housing" was expanded to include "environment" as most sheep spend at least a proportion of their productive lives outdoors. A list of measures has been developed, following literature review and expert panel assessment, representing at least one indicator for each criterion, for further research to investigate validity, reliability and feasibility. Although most measures are animal-based, for some criteria resource-based measures are used (e.g. absence of prolonged thirst was evaluated by the number and cleanliness of water sources) where there were no acceptable animal-based measures. The measures selected are described further in section 3.2 of the main text, along with the evidence in support of their validity, reliability and feasibility for on-farm assessment. Measures consist of those that can be collected in undisturbed sheep (largely behavioural and physical measures such as coat condition that can be observed from a distance) and those that require sheep to be gathered and handled for assessment. Most measures showed significant seasonal variation (Dwyer et al., 2014; Richmond et al., 2014).

2. Materials and methods

Against this background, the opinion was developed using the EFSA risk assessment framework. The initial step of problem formulation, and definition of risk assessment scenarios, was followed by the development of a conceptual model. Initially, this was based on generic sheep biology, using the 12 WQ® criteria as a framework to identify welfare problems which might be experienced by sheep in any system. A literature review was then used to inform the further development of this model by consideration of risk factors and exposure assessment for different management systems and production purposes. Since this confirmed the paucity of relevant scientific information which was available, a decision was taken to utilise expert opinion for this purpose. This took the form of both a widely based survey and a more focused technical meeting, as detailed in the following sections. Finally animal-based welfare measures were identified for the most important outcomes, using AWIN as the basis from which to start.

As the first step, the EFSA Working Group (WG) clarified the scope of the risk question (problem formulation), which requested the identification of the main factors and welfare consequences for sheep raised for the production of wool, meat and milk. The mandate also requested the consideration

[6] www.animal-welfare-indicators.net

of different scenarios, taking into account different management systems, genetic characteristics, environmental conditions and nutrition.

The management systems were the main pillars on which to build the risk assessment. However, it should be noted that, while the management systems constituting the risk assessment scenarios are broad categories aimed at characterising the main aspects of the most commonly applied systems, specific data corresponding to each system category were missing and evaluations were broadly based on the opinion of experts.

The outcome of the current opinion therefore has to be viewed as a scoping exercise which permits identification of the main welfare issues and risk factors across and within categories of management systems and specific production types. This scoping therefore provides a first broad assessment which could be followed-up by more specific and targeted risk assessments.

The first and second terms of reference (ToRs) were addressed in parallel and following the approach of the EFSA Guidance (EFSA AHAW Panel, 2012b). ToR 3 was addressed separately after identification of the risk factors and welfare consequences.

2.1. Addressing ToR 1 and ToR 2: EFSA's methodology on risk assessment for animal welfare and the WG approach

2.1.1. Characterisation of the target population and management systems (definition of the scenarios)

The main elements of a given management system are detailed in Appendix C. Sheep farmed for wool, meat and milk production were identified as the target population, focusing attention, in particular, on breeding ewes and lambs because of the greater number of animals exposed to given risk scenarios. Breeding rams, for all three production purposes, are also present, in much smaller numbers. Although their welfare is important, there is a scarcity of information in the literature, and elsewhere about their main welfare consequences and risk factors, to allow rams to be included in the risk assessment as a third target population.

Although in many cases sheep are currently raised for dual (e.g. meat and wool) or multiple purposes, the main welfare consequences for ewes were analysed for each production purpose within a given management system.

In terms of definition of the exposure scenarios, the WG initially considered it appropriate to identify the management systems and the genetic types as the main two elements defining the risk assessment scenarios. It was agreed to consider aspects such as environment and nutrition as risk factors within each scenario, as they are mainly associated with the management system and do not constitute a scenario per se. For each scenario, elements related to production and management, housing, animal health, nutrition, geographical and environmental conditions were considered.

Following an assessment of the breed distribution, the extensive number of sheep breeds and cross-breeds for each country did not allow for consideration of breeds as a main element of the risk assessment scenarios. In addition, in expert consultation individual breeds were not considered to be main risk factors and therefore breed typologies for each production type were instead described as part of the scenarios. A separate consideration of the extent to which breed is a risk factor for different welfare consequences was included in addition to the analysis by scenarios.

The risk assessment scenarios were therefore built primarily around the management systems, which were classified in broad categories, aimed at characterising the main aspects of the most commonly applied systems for the different production purposes which impact on sheep welfare (Appendix C).

2.1.2. Construction of a risk model (conceptual model)

A conceptual model was subsequently built to identify the main welfare consequences and related risk factors relevant to specific management system, as well as the links among them. A table summarising this conceptual model is given in Appendix D.

The welfare consequences of the different factors are mainly related to sheep biology (therefore common to the three production purposes). In contrast, the exposure to given factors (exposure assessment) and the intensity and duration of the welfare consequences may change according to the different management systems and scenarios. The conceptual model was therefore built around the sheep biology, rather than the production systems, and in particular around the 4 principles and 12 criteria developed by the WQ® project. As sheep are also reared in extensive and very extensive conditions without any housing facilities, the term "environment" was integrated with the WQ® principle of "housing".

In the conceptual model, 12 welfare criteria, as defined by the WQ® project, were used as the starting point. In considering the appropriate welfare consequences for further analysis, it was considered necessary to sub-divide the criterion of good health into specific categories of disease because these would have different risk factors.

Therefore, 17 welfare consequences were retained in the conceptual model and considered for further assessment through an expert elicitation process (see section 2.1.4 of the main text). Each of these welfare consequences could be expressed with different degrees of severity which are included in the conceptual model. There is a concern, however, that this gives the impression that the opinion is too focused on negative welfare. Such a view tends to emerge as a result of the change in emphasis when discussing welfare from provision of resources (meeting animal needs) to the identification of welfare outcomes (often deficiencies). Whilst welfare also has positive aspects, these outcomes are more difficult to quantify from present scientific knowledge, placing the emphasis when describing good welfare more on the absence of negative aspects. The risk assessment process therefore tends to give a more negative impression since it requires identification of all situations in which welfare of individual animals might be compromised. This allows their practical importance to be assessed for effective management of predisposing factors. Therefore, even problems with very low prevalence are initially considered and receive mention in the process even if they seldom cause negative welfare. Therefore, the report will deal with risk factors (hazards) only and not with factors that have positive effects on welfare (benefits), as these require further conceptual and methodological refinement (EFSA, 2012b).

From the conceptual model, the WG prepared a list of the main risk factors related to each welfare consequence, as the starting point for a systematic literature review (see section 2.1.3 of the main text).

2.1.3. Literature review

A review of the literature was first conducted. The methodology for the literature review is detailed in an external report "Preparatory work for the development of a Scientific Opinion on the main welfare risks related to the farming of sheep for wool, meat and milk production" (O'Connor et al., in press).An initial part of the project allowed a scoping of the existing scientific literature relating risk factors and welfare consequences for sheep. The citations were mapped according to the study (observational or experimental studies), eight main welfare determinants adapted from the 12 WQ® criteria (management, environment, genetics, nutrition/feeding/watering, behaviour, health, housing and handler traits/human-animal bond) and outcomes, following the structure of the conceptual model developed by the WG.

Such mapping supported the WG in identifying gaps of knowledge and data that further led to seeking for experts' knowledge (see section 2.1.4 of the main text), as well as to identify areas where a systematic literature process could be performed.

As follow-up to the mapping, a systematic review was performed on the effect of extensive/outdoor/migratory management on lameness in sheep raised for the production of meat, milk or wool in Europe (O'Connor et al., in press).

2.1.4. Experts' knowledge elicitation (online survey and technical meeting with experts)

Given the lack of data in scientific literature for the assessment of factors exposure and characterization of the consequences, data for the above-mentioned steps of the risk assessment were obtained by carrying out an online survey for elicitation of expert knowledge and a follow-up technical meeting. As a first step, and following the same approach as the conceptual model, EFSA elicited experts' knowledge to score by importance the 17 welfare consequences identified by the WG, and thus select the main ones for each management system. First the WG considered it appropriate to evaluate the importance of welfare consequences and consequently of risk factors, as usually risk factors are not thought on their own but always in association to a given welfare consequence. Second, main risk factors were identified and characterized for the most important welfare consequences that resulted from the first step.

The first phase of the expert elicitation was carried out through an electronic (online) survey, in which experts were provided with the 17 welfare consequences of the conceptual model and with their definition (see below) that was considered by the WG as the point at which the welfare problem becomes significant from the animals' point of view.

For the purpose of the survey, animal categories were defined as:

- Ewe: adult sheep kept for breeding and/or milking or wool purposes. When assessing life time experience, this also includes female lambs kept for breeding purposes.

- Lamb: young sheep-between birth and slaughter if kept for meat, or between birth and recruitment if destined for breeding.

For the purpose of the survey, welfare consequences were defined as:

- Prolonged hunger: the animal has been unable to get enough food to meet its maintenance requirements for energy, proteins or specific nutrients. This has resulted in failure to grow, loss of body condition such that, palpating the lumbar spine, the bones are prominent and easy to feel (condition score 2 or below), or impaired bodily functions (micro-nutrient deficiency).

- Prolonged thirst: the animal has been unable to get enough water to satisfy its daily needs, resulting in dehydration.

- Resting problem: the animal is unable to lie comfortably because of insufficient amount of space or space of inadequate quality in terms of surface texture, dryness and hygiene. This has resulted in reduced lying time, callus or coat soiling.

- Thermal stress: the animal is unable to maintain constant body temperature by behavioural adaptation alone. This has resulted in panting, bunching or shivering.

- Restriction of movement: the animal is unable to move freely because of physical restraint or lack of space resulting in impeded movements, or is unable to walk comfortably because of inappropriate flooring resulting in slipping and falling.

- Lameness: the animal has impaired gait seen as uneven posture, reduced weight bearing on one or more limbs, visible nodding of the head when walking.

- Injuries: the animal has physical damage to the bones, muscles or organs, or open wounds of the skin.

- Skin disorders (including infections, allergens, ectoparasites): abnormal condition of the skin, fleece or coat seen as excessive rubbing and scratching, fleece loss, inflamed scabs or exuding skin.

- Respiratory disorders: the animal has impaired function of the lungs or airways seen as laboured breathing, chronic coughing, sneezing or nasal discharge.

- Gastro-enteric disorders (including infections, endoparasites or toxins): the animal has impaired function of the gastro-intestinal tract resulting in inappetence, abnormal faeces consistency, tucked posture or bloated rumen or rectal prolapse.

- Metabolic disorders (e.g. acidosis and ketosis): the animal has disturbed metabolism resulting in inappetence, weakness, recumbency or altered bodily functions.

- Reproductive disorders (including dystocia and metritis): the animal has a disorder of the reproductive tract resulting from physical injury or infection, seen as lambing difficulties, uterine discharge and prolapsed uterus.

- Mastitis: the animal has inflammation of the udder, indicated by altered colour, temperature and consistency and reluctance to allow contact of the udder.

- Neonatal disorders (including starvation/mis-mothering/exposure complex): the newborn lamb shows compromised functions, seen as weakness, which results in death or would lead to death without intervention.

- Pain (including that due to management procedures such as castration, tail docking and shearing): the animal shows altered posture, vocalisation or specific pain-related behaviour such as teeth grinding, foot stamping, head shaking, restlessness or apathy.

- Occurrence of abnormal behaviours (e.g. inter-sucking, wool pulling, biting or chewing non-food items): the animal shows non-functional behaviours not normally exhibited by healthy animals in an unrestricted environment. These can include sucking, biting or chewing non-food items and stereotypic behaviours, such as pacing.

- Chronic fear (fearfulness due to, for example, predation, poor handling and disturbed social behaviour): the animal shows exaggerated signs of anxiety such as escape attempts, increased vigilance, excitability and flightiness. This results in difficulties in handling and approaching sheep and easily stimulated panic.

A summary description of the management systems was also provided (see section 3.1.1 of the main text).

With the overall aim of identifying the main welfare consequences for ewes and lambs for each management system, the specific objectives of the first step of the experts' knowledge elicitation (online survey) were:

1. to identify for each management system that the respondents were experienced with, the percentage of sheep (ewes and lambs) in a typical flock that will experience the welfare consequence to the significant degree, as indicated in its definition, over a year period;

2. to score the amount of suffering for each of the welfare consequences separately for ewes and lambs, as a combination of the severity of the problem, its duration and how often it is repeated during its lifetime;

3. to gather information on the typologies and components of mixed management systems mostly reported by respondents;

4. to gather information on the sheep breeds commonly seen in the mostly reported management systems.

In order to allow standardised estimates of prevalence of the welfare consequences, the WG set the above-mentioned threshold level which was deemed to represent significant suffering for sheep. In addition, respondents were also asked to rate their level of certainty about the prevalence value they gave.

Welfare consequences may have a different impact for the sheep concerned in a given management system, causing different degrees of suffering depending on how frequently they happen during the lifetime of the animal, how long they last and the intensity of the suffering that they cause while they last. Therefore, to score the importance of those consequences, experts were asked to give an integrated scoring for the overall amount of suffering, considered as a combination of the severity of the problem, its duration and how often it is repeated during the lifetime of the sheep. To this end, welfare consequences were presented as to avoid definitive end-points, which would not allow experts to think of the suffering of the animal over time.

The online survey was launched on 7 May 2014 and was open till 27 June 2014. In order to have a relevant number of replies covering all the management systems addressed by the opinion, the WG considered it appropriate to ensure a broad distribution of the survey, while defining the profiles of the expertise required for participation in the survey.

The survey questionnaire was therefore distributed to six main categories of stakeholders with relevant expertise:

- Academics and field researchers on sheep welfare and sheep production researchers,
- Food Safety Agencies of Member States, which are members of the EFSA Animal Health and Welfare Network,
- Farmers' organisation representatives and private sectors,
- EU and international veterinary practitioners,
- International organisations such the Food and Agriculture Organization of the United Nations (FAO),
- Non-governmental organisations (NGOs) engaged in sheep welfare and in developing sheep standards.

The organisations and technical groups contacted were asked to identify and distribute the survey questionnaire to their members and experts, recognised as having scientific and/or technical field expertise on sheep welfare and sheep production.

In order to analyse the survey replies, the WG established a data validation procedure and criteria for exclusion of replies/respondents from the analysis. In particular, if the respondent was identified as a significant outlier in that particular management system, which on further investigation was explained by geographically based factors making that system atypical of other reported elements (for more details see Appendix E).

In addition, the WG checked how influential certain replies were, by reassessment when outliers were excluded. Finally, for respondents who did not disclose their identity, the WG checked if their replies were different from those who disclosed their identity.

The survey questionnaire analysis allowed identification of the main welfare consequences for the different management systems for ewes and lambs in the experience of the experts involved. Methodology and general criteria were also defined to select the main welfare consequences from the overall survey replies. For each management system or production purposes, and for ewes and lambs, the prevalence value of each consequence was multiplied by its score of severity, resulting in an overall value of importance that allowed ranking of all the consequences. The WG selected the top three ranked consequences, plus the ones that could not be excluded as being clearly different from the top three.

On the basis of these results, and in order to identify the main risk factors associated with the main welfare consequences, the WG carried out a second step of the expert knowledge elicitation through a technical meeting with hearing experts organised on 26 June 2014.

The objectives of this second step were:

1. to discuss the survey questionnaire analysis results and reach consensus on main welfare consequences for ewes and lambs, depending on the management system and production purpose;

2. to discuss and reach consensus on the main risk factors causing the main welfare consequences per management system and production purpose. For the identified main systems, discussion focused on how strong the relation between the risk factor and the consequence is, and how many animals are exposed to this factor and for how much of their lives;

3. to discuss mixed system possibilities/components most frequently reported in the survey replies;

4. to discuss whether and to what extent breed is a risk factor for sheep welfare;

5. to discuss if within a system, flock size has an impact on welfare consequences of sheep and if risk factors are different for different flock sizes;

6. to collect information on measures used to assess the welfare consequences for ewes and lambs (as part of ToR 3, see section 2.2 of the main text).

Ten hearing experts were invited to participate at this meeting and they were selected on the basis of the stated criteria, set by the WG and to cover practical experience for the management systems being considered by the opinion. Experts were also selected to cover experience of the EU countries with highest sheep production, and experience from other international sheep producing countries:

- Four scientists with field /farm experience on sheep welfare and production.

- Two veterinary practitioners with commercial field experience on sheep production, sheep health and sheep welfare.

- Four experts representing farmers’ organisations, with practical sheep production experience across a range of systems.

The results of such activities are reported in section 3.1.4 of the main text, and a summary table is presented in Appendix E.

2.2. Addressing ToR 3: Identification of the animal-based measures (ABMs)

In the conceptual model (Appendix D), the WG prepared a list of ABMs related to each welfare consequence. The ABMs were classified as primary if they measure the outcome of the welfare consequences or as secondary if they measure the outcome of a different welfare consequence affected by the studied welfare consequence. The WG decided to further discuss and recommend only the primary ABMs.

The main source for the identification of the ABMs was the AWIN project and the paper “Validating indicators of sheep welfare through a consensus of expert opinion” (Phythian et al., 2011). The measures were reviewed by the WG and selected according to their validity, reliability and feasibility.

For each ABM, the WG assigned a rating for validity, reliability and feasibility, based on literature, when available, or working group opinion, when scientific studies were lacking (see Tables 17 and 18).

The rating for validity was given as “high” if supported by experimental validation or strong face validity. A rating of “moderate” was given when the only validation was by expert opinion or the experimental evidence was less strong. “Low” rating was given where there was little information in the literature despite some expert view. In the majority of studies, data did not allow for calculation of sensitivity and specificity of the ABMs.

The rating for reliability was based on the outcome of statistical assessment of intra- and inter-observer comparison, using accepted boundary criteria appropriate for each statistical method to differentiate between ratings.

The rating for feasibility was based on field experience of experts reported in the scientific literature or arising from the expert elicitation exercise.

Furthermore, during the technical meeting organised on 26 June 2014, the hearing experts were asked for information on measures used to assess the welfare consequences for ewes and lambs.

3. Results and discussion

3.1. Addressing ToR 1 and ToR 2 of the mandate

3.1.1. Characterization of the management systems (definition of the scenarios)

The following description of the management systems for sheep was developed with the main purpose of defining the scenarios for a risk assessment exercise. It aims to characterise, in broad categories, the main aspects and the most commonly applied management systems that impact on sheep welfare in the EU and in other sheep production areas and regions. As the management systems may vary greatly according to geographical areas, production typology and breeds, the current classification is not intended to be comprehensive of all the possible sub-systems and sub-typologies.

Three major management systems are used for sheep production: extensive systems for wool and meat production, intensive for dairy production and traditional pastoralism or shepherding (Kilgour et al., 2008) for meat and milk production (dual purpose). Among these farming systems, there are a wide range of mixed systems such as summer pasture/winter indoors or alternatively indoors/outdoors subject to climatic circumstances. For each of these systems, the level of intensification is very variable; for example, in pasture systems based on cultivated/improved pasture versus poor rangelands. As regards to indoor systems, the level of intensification is tightly linked with the nutritive value of fodders, as well as the quantity of distributed concentrates.

Table 2 was developed by the WG as model to identify the elements and factors characterizing the main management systems and to outline definitions suitable for the risk assessment process. In particular, the elements considered for the definition of the different scenarios are: continuous presence of the stockperson with the sheep, no outdoor access, housing, keeping of sheep in fenced pastures and supplementation.

While the continuous presence of the stockperson with the sheep is the main element characterizing shepherding/pastoralism systems, this constant factor is absent in all the other systems. The main element characterizing an intensive system is that sheep have no outdoor access and are always kept inside. Housing during night and part of the day is the main distinguishing element of semi-intensive systems; when the flock is outdoor the stockperson is not constantly with the sheep. Where there is no continuous presence of the stockperson and sheep have continuous outdoor access (seasonal housing may occur), the keeping of sheep in fenced pastures characterizes semi-extensive systems. Feed supplementation is instead the main differentiating element in extensive systems, where there is no continuous presence of the stockperson and sheep are kept outside in unfenced pastures. No supplementation differentiates very-extensive from extensive systems.

Table 2: Model to define the main elements and factors characterizing the most commonly applied management systems.

	Continuous presence of the stockperson with the sheep	**No outdoor access**	**Housing** (during night and part of the day)	**Kept in fenced pastures** (including rotational grazing)	**Supplementation**
1.**Shepherding**	Yes	[(a)]			
2.**Intensive system**	No	Yes			
3. **Semi-intensive**	No	No	Yes		
4. **Semi-extensive**	No	No	No	Yes	
5**. Extensive system**	No	No	No	No	Yes
6. **Very extensive system**	No	No	No	No	No
7. **Mixed system (combination of 1 to 6 in periods)**					

Note: [(a)] Empty boxes indicate "not relevant to management system characterisation".

The following sections describe each management system in more detail. In addition, Appendix C details the main elements of each management system.

3.1.1.1. Shepherding

Shepherding (SH) or pastoralism is a management system of marginal areas, such as mountains or semi-arid open rangelands, where pastures are of low quality or not sufficient and require movement of the management groups, during the day or for a period of time. These pastures are away from the farm where animals sometimes may return at night for shelter. These marginal areas have unpredictable climates, determined by either rainfall or elevation, and are unfavourable for agricultural cropping, so allowing pastoralism to compete. Nomadic or migrant forms of pastoralism, by exploiting the inherent variability in these areas, allow sustainable livestock production and support more people than would be possible by other strategies.

The movements depend on the environmental resources available, with possibility for supplementation. The main characteristic of this management system is that the stockperson (and dogs if used) is constantly with the sheep while they are grazing and the human-animal relationship is at individual sheep level. The role of the stockperson is to guide the animals to pastures, provide protection and perform necessary husbandry tasks.

Shepherding can be practiced for sheep reared for milk or meat production as primary purposes, but it is not normally practiced for sheep kept primarily for wool production. For both production systems (milk and meat), ewes are always kept in management groups constituted by a number of animals as low as can be managed by one or more stockpersons and with low replacement rate; in case of milk production, ewes are milked manually or by machine once or twice a day. The genetic lines are diverse, variable and with different degrees of adaptation to the environment. Lambs may be temporarily separated from their mothers on a daily basis and adult males remain in the management group.

Shepherding or pastoralism can be categorised by the degree of movement into three main classes, which are the most traditional typologies (Kilgour et al., 2008):

- Nomadic: is a highly mobile and flexible system of seasonal migration with no established home base. Movements are opportunistic, following pasture and water availability, so are highly dependent on the growth cycles of different plant species.

- Transhumance: this form of migration involves regular movement about fixed points. Transhumance can consist of vertical migrations in mountain areas, which tend to be ancient routes associated with high rainfall regions. Horizontal transhumance tends to be more opportunistic, and can be altered by climate as well as economic or political change along the migration routes.

- Agropastoralism: this differs from the other two not only by the degree of movement, but also because other forms of pastoralism occur at the subsistence level, where the animal products maintain the family group and are not kept for commercial profit, although some trade may occur. The other main differences are a greater provision of supplementary feeding, fenced ranges and land tenure.

Only the general “shepherding system” will be considered by EFSA in its scenarios to assess the related welfare risks and consequences.

3.1.1.2. Intensive systems

Intensive systems (IN) are management systems where the stockperson is not constantly with the sheep, which are kept in permanent housing with no access to pasture, and are fed with roughage, silage and concentrate. The role of the stockperson is to provide food and carry out husbandry tasks.

The most common intensive system that sheep may be managed under occurs in dairy sheep and it is practiced primarily in south-eastern Europe and Mediterranean regions; its intensiveness can vary greatly in different regions. The intensive management system can also be carried out for meat production, as the main purpose, in Mediterranean western and northern European regions. This system is not usually practiced for wool production.

In **intensive systems for milk production**, ewes usually enter into breeding at one year of age and are kept in separate management groups for different stages of the production cycle, with a high rate of replacement. Ewes are highly selected for milk yield, they may be artificially inseminated and are usually machine-milked twice a day. Lambs stay for few weeks with the ewes or are separated from them within their first days of life and artificially reared prior to slaughter (for light lambs) or fattening (for heavy lambs), while adult males are kept in low numbers in separate groups. During the time that the stockperson is on the farm, the human-animal relationship is daily at animal level, allowing for daily inspection and easy intervention, and physical contact cannot be avoided by the sheep during milking.

In **intensive systems for meat production**, as for dairy production, ewes usually enter into breeding at one year of age and are kept in mixed management groups of around a hundred animals of different ages, with a high rate of replacement. Ewes are highly selected for meat traits, including growth rate, and may be subjected to advanced reproductive technologies (artificial insemination, embryo transfer). Lambs are reared by their mothers and are weaned at 8 to 12 weeks prior to slaughter or fattening. Fattening can be carried out in housed systems or feed lots. Lambs may be reared intensively while ewes and rams may be managed under different systems. In intensive meat production, daily supervision usually takes place at group level with good access to all animals, although no physical contact and no involvement of dogs are normally necessary.

3.1.1.3. Semi-intensive system

Semi-intensive systems (SI) are management systems where animals are kept intensively during night and some part of the day and are moved to fenced or unfenced owned or rented pastures during some period of the day. Sheep are fed with roughage, silage and concentrate, in combination with improved or unimproved grazing. The role of the stockperson is to provide food and carry out husbandry tasks, and to move the animals daily to the pasture. The stockperson and the dog (if used) may stay with the sheep at pasture.

Semi-intensive management systems occur in dairy and meat sheep and are practiced primarily in Mediterranean regions and France. This system is not usually practiced for wool production. In **semi-intensive systems for milk production**, ewes usually enter into breeding at one year of age and are kept in mixed management groups of around a hundred animals of different ages, with a high rate of replacement. Ewes are highly selected for production traits and for local adaptation to the environment, and they can be either naturally or artificially inseminated. Ewes spend part of the day on pastures and are housed overnight and for milking, which is carried out by machine twice a day. Lambs stay for few weeks with the ewes until weaning for replacement and heavy lambs, or until slaughter (for light lambs), during which time ewes are not milked. During the day in the pre-weaning period, the lambs are temporarily separated from the ewes and remain in the house. Human contacts are daily at animal level, and cannot be avoided by sheep during milking. In **semi-intensive systems for meat production,** lambs are also raised intensively by keeping them permanently housed, and are weaned at 8 to 12 weeks. Daily contacts between the stockperson and sheep usually take place at group level and no physical contact is necessary.

3.1.1.4. Semi-extensive systems

Semi-extensive systems (SE) are management systems where the stockperson (and dogs if used) is not continuously with the sheep. The role of the stockperson is to manage pasture availability and carry out husbandry tasks. Sheep are moved to fenced pastures where they stay continuously for several days/weeks. They can be moved between different fenced pastures (including rotational grazing) or they may be housed during lambing. They can be provided with supplementary feed in addition to pastures.

This system is usually carried out for meat production in temperate and Mediterranean regions with good quality pastures. It is not usually practiced for wool production.

In **semi-extensive systems for meat production**, sheep are usually kept on improved pastures and provided with supplementary feed. Ewes usually enter into breeding at one year of age and are kept in mixed management groups of up to several hundred animals of different adult ages, with a relatively high rate of replacement. Ewes are highly selected for mothering traits and prolificity, crossed with meat trait sires. Lambs are reared by the mothers and weaned at 8 to 12 weeks. Daily contacts between the stockperson and sheep usually take place at group level and no physical contact is necessary.

3.1.1.5. Extensive systems

Extensive systems (EX) are systems where the stockperson is almost never with the sheep, that are constantly kept on unfenced pastures or ranges (continuous grazing), with no housing. The role of the stockperson (and dogs if used) is to move the sheep to suitable areas of the range and to carry out necessary husbandry tasks, usually following gathering. Sheep can have access to some improved and unimproved pastures, where they may also be provided with supplementation.

Extensive farming is carried out in regions/areas with natural pastures and for both meat and wool production (e.g. the UK, New Zealand), as primary purposes. It is not usually practiced for milk production.

In extensive systems for **meat production**, ewes are kept in management groups of many hundreds of sheep. Ewes are usually selected for mothering traits, crossed with diverse breeds and for adaptation to local environmental conditions. Ewe replacement rates are relatively low and older animals may be drafted to semi-extensive systems. Lambs are reared by the mothers and weaned at 12 to 16 weeks. Visual contacts between the stockperson and sheep usually take place at group level, and physical contact only if necessary.

In extensive systems for **wool production**, as for meat production, ewes are kept in management groups of many hundreds of sheep with relatively low replacement and lambs are reared by the mothers and weaned at 12 to 16 weeks. Ewes are selected for wool traits; males are castrated and kept in the groups. In addition, in this case, visual contacts between stockperson and sheep usually take place at group level, and physical contact only if necessary.

3.1.1.6. Very extensive systems

Very extensive systems (VE) are systems where the stockperson is almost never with the sheep, which are kept in unfenced pastures or ranges (continuous grazing) with no housing. They never have access to improved pastures and they are not provided with routine supplementation. The role of the stockperson is to carry out necessary husbandry tasks, normally following gathering.

This system is practiced for both meat and wool production in regions and areas with unimproved natural pasture of low quality (e.g. parts of the UK, Australia, South Africa) where supplementation is infrequent. This system is not practiced for milk production.

In **very extensive systems for meat production**, ewes are kept in big groups of up to thousands of sheep with relatively low replacement and are selected for adaptation to local environmental conditions. Lambs are reared by their mothers for a long period of time (more than 16 weeks). Usually, no physical contact between the stockperson and sheep is necessary, visual contacts are minimal and at group level.

In **very extensive systems for wool production** and as for meat production, ewes are kept in big groups of up to thousands of sheep with relatively low replacement but they are selected for wool traits. Lambs are reared by their mothers for a long period of time (more than 16 weeks) and males are castrated and remain in the groups. As for meat production, no physical contact between the stockperson and sheep is necessary, visual contacts are minimal and at group level.

3.1.1.7. Mixed systems

Mixed systems (MX) are various combinations of the above six.

The following examples are commonly practiced types of mixed systems.

<u>Seasonal mix of very extensive (during summer) and intensive (during winter) for dual purpose (meat and wool)</u>

These systems are usually practiced in regions with extreme winter environments but where summers are mild (e.g. in Scandinavia, Canada, some mountain regions like Cantabria and the Pyrenean mountains). During the winter months, animals are housed continually for up to seven months of the year and managed as described for intensive meat production. During the summer months, animals are moved to extensive or very-extensive pastures to graze and are then managed as described for these types of systems. The main feature of this system is the movement between continuous prolonged housing, with a high degree of supervision for some part of the year, to extensive systems where a low degree of visual contact is possible for the remainder of the year.

An example of this type of farming system is the “dry hill sheep system”. In dry hilly areas of Provence or Languedoc-Roussillon regions, those systems are characterized by grazing extensively in summer on low fertility fields or in oak woods (similar in some way to the Spanish Dehesa systems). To reach forage self-sufficiency, farmers store forage for winter from more intensive fields which often need irrigation. The sheep usually spend four months inside.

<u>Seasonal mix of semi-extensive and extensive/very extensive production for dual purpose (wool and meat; e.g. New Zealand, the UK)</u>

In these systems, although animals are maintained outside all year round, they may move seasonally between extensive, unfenced rangeland pastures, which typically offer nutritionally poor grazing, to fenced extensive pastures that provide either improved grazing or forage crops (e.g. brassicas), and may be fed supplements. Movements of sheep between different systems generally depend on forage availability and quality, matching of available nutrition and changing sheep nutritional requirements (e.g. when pregnant or lactating) and the need for particular management actions such as greater supervision during outdoor lambing.

3.1.2. Conceptual model: identification of main welfare consequences by system and production type (problem definition and risk factor characterization)

For each welfare criterion, the WG considered the available information about the possible impact on sheep welfare and the major risk factors. This was illustrated by examples from the scientific literature, but the following section does not give a comprehensive literature review, which can be found in other publications such as Dwyer (2008). A table of the conceptual model, summarising the welfare consequences, and related risk factors relevant to specific management system is given in Appendix D.

3.1.2.1. Good feeding

Good feeding includes two elements or criteria: absence of prolonged hunger and absence of prolonged thirst. Hunger may result from malnutrition, undernutrition or both. Malnutrition occurs when nutrients are not balanced, whereas undernutrition reflects insufficient supply. There are several reasons why prolonged hunger results in poor welfare. First, both malnutrition and undernutrition cause stress and, if sufficiently prolonged or severe, this can lead to debilitation, loss of body condition, immunosuppression and disease. Consequently, prolonged hunger results in inadequate biological functioning and it is likely to be an unpleasant emotional state (Webster, 1995; Kyriazakis and Savory, 1997). Ruminants are adapted to withstand short-term nutrient deprivation, and sheep have evolved in environments where food quality and availability show seasonal and climatic variation. As an adaptation to this, pronounced seasonal changes in appetite are evident in many traditional breeds of sheep (Argo et al., 1999). However, the fact that sheep will invest significant work to obtain food suggests that hunger generates a negative affective state that the animal seeks to alleviate (Verbeek et al., 2011). There is also supporting evidence from cognitive bias studies that the consumption of a food reward generates a positive affective state (Verbeek et al., 2014a), whilst physiological changes associated with hunger generate a negative state (Verbeek et al., 2014b) . The effects of inadequate feed supply may also exacerbate the adverse effects of cold challenge (Verbeek et al., 2012a).

<u>Absence of hunger</u>: Undernutrition may be a consequence of neglect, poor husbandry and/or circumstance. Where sheep are housed or kept in feedlot conditions with no natural vegetation, their nutrition is fully dependant on human carers and inadequate food provision, for reasons of unavailability or ignorance of requirement, pose a serious welfare compromise. One stage where undernutrition, through ignorance, may be deliberate is in the drying off period, where feed (and

water) restriction may be believed to aid the process of terminating lactation. Undernutrition of some individuals can also occur, even if adequate feed for the group is provided, if social competition for spatially limited access prevents less dominant animals from feeding, or if the feeders are poorly designed and physically impair access (Bøe and Andersen, 2010). This is exacerbated in conditions of even minor feed restriction (Bøe et al., 2012a). Where sheep are pastured in fenced areas, they have some ability to forage for themselves, but poor assessment of herbage availability and feeding value by the carers, and failure to provide supplementation in times of need, will have the same consequence. Restriction of the daily time available for grazing can also limit herbage intake unless sward availability is high (Iason et al., 1999). In extensive conditions, grazing ruminants are dependent on the natural availability and quality of forage, and thus subject to uncontrolled effects of season and climate. Feed availability and quality can be reduced in summer drought conditions, particularly in southern European countries, or by winter cold, particularly in northern climates. Other natural or extreme climatic conditions, such as deep snow or floods, may prevent access to herbage for extended periods of time, while simultaneously hindering ability of carers to provide supplementary feed. When digestibility is reduced by seasonal changes in plant growth stage and structure, physiological constraints may mean that the animals may be unable to consume and process sufficient low quality herbage to meet nutrient demands, even if it is available to them (Jarrige et al., 1986; Avondo et al., 2002).

Hunger will increase when animals are in reproductive states which generate higher metabolic demand (Kenyon et al., 2007). Research suggests that feeding motivation in pregnant sheep may be relatively high, even when sufficient energy intake and body reserves are available, and is significantly increased when they are under-nourished (Verbeek et al., 2012b). In the case of high-yielding milk sheep, metabolic demand will be even greater and risk of metabolic disease increased (see section 3.1.2.3). Undernutrition, even when food availability is apparently adequate, may also result from health disorders of the animal. As sheep age, their incisor teeth wear out and are lost, and this ”broken mouth” condition can prevent consumption of grazed herbage (McGregor, 2011). Equally, severe lameness, which reduces locomotory ability, may prevent animals from competing at a feed resource, from ranging far enough to obtain adequate grazed nutrients if pasture availability is poor, or from grazing for long enough during the day if standing is too painful.

Malnutrition results from a mismatch between the nutrient composition of the feed supplied and an individual animal’s nutritional requirements, which are a consequence of its sex, age, stage of growth or reproduction, and previous nutritional history. It can arise through natural deficiencies in herbage composition, and lack of necessary supplementation to compensate, or poor formulation of diets supplied in controlled feeding regimes. Protein-limited diets, common in extensive production systems, can impair host resistance to gastro-intestinal parasites (Athanasiadou et al., 2008). Dietary mineral imbalances can arise because of the nature of soils where sheep are grazed. For example, a copper secondary deficiency can be caused by an excess of sulphur and molybdenum resulting in anaemia, bone disorders, neonatal ataxia, cardiovascular disorders, diarrhoea and increased susceptibility to infections (Underwood and Suttle, 1999). Similarly, an excess of potassium may impair magnesium absorption and lead to a specific secondary deficiency followed by a metabolic disease (grass tetany). Malnutrition may also be induced by consumption of anti-nutritive factors in plants, such as tannins (Min et al., 2002), whilst toxins in plants may cause poisoning (see section 3.1.2.3).

<u>Absence of thirst</u>: Thirst is the sensation that accompanies dehydration. Prolonged thirst causes stress and, if long-lasting or severe, leads to debilitation, loss of body condition and disease. In ruminants, the water content of the rumen may buffer short-term lack of drinking water and some wild ruminants have evolved various behavioural and physiological strategies that apparently enable them to survive long periods without drinking (Silanikove, 1994). The ability to survive in hot conditions without drinking for long periods is diminished in domestic ruminants from temperate areas, although breeds indigenous to arid lands have greater capacity to withstand prolonged periods of water deprivation. Thirst also reduces food intake which, in turn, may lead to the welfare problems associated with prolonged hunger (Legel et al., 1987).

Thirst may arise in extensive systems because of a lack of natural water during summer drought, or freezing of water during severe winter weather. If the distance to water is too great, or physical barriers exist in the landscape, animals with weakness from poor health or locomotory impairment may be unable to travel the necessary distances between feed and water supplies. In addition, water supplies may be polluted, or of high salt concentration, thus inhibiting intake. Herbage species with higher salt concentration, as a result of growth on saline soils, will increase water demand and may give rise to unsatisfied thirst if water supply is limited, or itself of high salt concentration. For housed animals, or those kept in more intensive grazing systems where water must be artificially supplied, prolonged thirst can occur when animals are given water of poor quality or when drinking facilities are insufficient or inadequate. The effects of competition for water resources under housed conditions require more research (Bøe et al., 2012b). The absence of emergency reservoirs, for use when a water supply is disrupted by freezing or distribution malfunction for substantial periods, can also exacerbate problems. As with feeding, animals with increased metabolic demand for water will be at greater risk of thirst. This may be because of higher need for production, as in the case of high-yielding lactating ewes, or for thermoregulation when animals have high evaporative heat loss.

3.1.2.2. Good housing and environment

Housing and environmental conditions can have a major impact on the welfare of sheep and includes three major elements: comfort around resting, thermal comfort and ease of movement.

Comfort around resting: lack of comfort around resting could occur in all the management systems as a consequence of excessive stocking density (overcrowding), lack of suitable ground surface or bedding material. Research has shown that sheep prefer to lie on straw in comparison with other types of flooring (Bøe, 1990; Gorden and Cockram, 1990; Faerevik et al., 2005), and spend more time lying on straw bedding. This preference is particularly expressed in shorn ewes, but less apparent in ewes with thick fleeces. In general, many of the dairy breeds of ewe have thinner fleeces than meat breeds, suggesting that these ewes are more likely to require straw bedding for adequate thermoregulation, particularly during cold weather. Sheep kept under extensive management systems would at least require a dry and smooth surface to rest and competition for space because of limited availability of shade, shelter and comfortable surface would cause distress. Sheep have also been shown to have a preference for lying against a solid wall (Jørgensen and Bøe, 2009).

Thermal comfort: Sheep are homeothermic, i.e. they are able to maintain a relatively constant deep body temperature that differs from the environmental temperature within certain limits. A relatively constant deep body temperature means that heat production and heat loss are equal. Lower environmental temperature leads to higher heat losses, which have to be compensated by a higher heat production. Thermal comfort and the relationship between animals and their thermal environment are explained using the concept of thermoneutral zone. Sheep are well adapted to coping with both extremes, and have a wide thermoneutral range. Owing to this, sheep are able to adapt physiologically and behaviourally to regulate heat loss and to cope with thermal extremes, provided the husbandry practices, such as shearing, provision of bedding or supplementary feeding, are carried out appropriately. Adult, fully fleeced sheep can thrive in temperatures far below 0 °C. In northern Europe, many sheep are housed in open buildings (three walls) in winter or have free access from the barn to outdoor areas during winter, and prefer to stay outdoors at - 20 to - 30 °C (Jørgensen and Bøe, 2011).

In extensive management systems, provision of shelter and shade are important for protection from solar radiation and inclement weather conditions.

For example, with shade, some sheep breeds are able to maintain body temperature in ambient temperatures of up to 50 °C (Johnson, 1987), while Mediterranean dairy sheep breeds can tolerate ambient temperatures up to 30 °C when shaded (Sevi et al., 2001). The temperature-humidity index (THI) can be used to measure the combined impact of air temperature and humidity on physiological responses and welfare status of sheep. There is evidence showing that Mediterranean dairy sheep breeds can tolerate a THI up to 80 when kept in shaded areas (Sevi et al., 2001).

It is worth noting that heat stress increases the amount of water required and can therefore increase the risk of prolonged thirst if water supply is limited. During cold exposure sheep increase feed intake, flock more closely together and make use of shelter, particularly if they are likely to be more susceptible to hypothermia (e.g. lambs and shorn sheep; Alexander et al., 1979; Pollard et al., 1999; Jørgensen and Bøe, 2011). Under intensive management systems, heat stress may result from poor ventilation, inadequate housing and high stocking density. Under extensive conditions, particularly in the tropics, non-adapted, exotic breeds of animals may suffer an increased risk of heat stress. Extensively kept animals are exposed to relatively greater environmental challenges than animals maintained in temperature and humidity-controlled housing. This environmental variability is not, of itself, likely to cause poor welfare. However, prolonged exposure to extreme environmental conditions, particularly if they are accompanied by other challenges (e.g. undernutrition, poor body condition, lack of shelter) may be a source of chronic stress.

Research has clearly demonstrated that different micro-environmental conditions influence thermoregulatory mechanisms with effects on the productivity and on the welfare of ewes (Pennisi et al., 2010). In confinement, poor ventilation causing inappropriate temperature and humidity because of inadequate ventilation rate, air speed and ventilation cycles, causes increased respiration rate and rectal temperature in lactating ewes kept under Mediterranean climatic conditions (Sevi et al., 2002; Caroprese, 2008). It also leads to increased air concentration of ammonia and carbon dioxide and impaired humoral immune responses and elevated plasma cortisol levels. Exposure to direct solar radiation also produced similar effects and ewes exhibited inactivity. The volume of airspace per animal has been reported to determine the air quality and inadequate air spaces are associated with increased microbial count and higher incidence of sub-clinical mastitis. Insufficient air space per animal in combination with poor ventilation system is responsible for higher incidence of mastitis and foot infection and respiratory disease (Sevi et al., 2001, 2009; Kilic et al., 2013).

<u>Ease of movement</u>: i.e. the ability of animals to turn round, groom, get up, lie down and stretch their legs has long been considered a basic requisite for good welfare. Housing conditions and space allowance significantly affected sheep behavioural activities; at low stocking density sheep provided with outdoor access were more often observed standing and drinking than at low stocking density without outdoor access, whereas at low stocking density sheep walked more than at high stocking density (Caroprese et al., 2009a). These movements are part of the behavioural repertoire of all species, and animals are highly motivated to perform them. They are also important to maintain the adequate functioning of the body. Difficulty of movement may be caused by a lack of space in the home environment. Too high a stocking density may also prevent animals from moving normally. Inadequate design of housing facilities may prevent animals from lying down and getting up normally. The presence of dominant individuals, particularly when stocking density is high or housing facilities are inadequate, may further curtail the movement of subordinate animals. Agonistic interactions increase in sheep because of overcrowding and limited availability of resources (McBride et al., 1967), and when moved from pastures to houses (Done-Currie et al., 1984). Subordinate animals may also be frequently displaced from shelter and shade during conditions of thermal extremes if space is limited, leading to chronic stress (Sherwin and Johnson, 1987).

3.1.2.3. Good health

Good health is an important component of animal welfare and it can be defined as the absence of injuries, disease and pain (Keeling, 2009). These negative states can have many causes, including certain management procedures. Injuries and diseases can cause acute and/or chronic pain. Pain is defined as an aversive emotional experience and is therefore a welfare problem.

<u>Absence of injuries</u>: the legs and the feet are the parts of the body that are most frequently injured in sheep. These injuries interfere with normal behaviour and locomotion, and may have a debilitating

effect by preventing the animal from feeding normally. This aspect is particularly relevant in sheep as most of the farms present pasture based management systems. Sheep often graze low-quality upland pastures, thus they have to walk long distances to gain access to a sufficient amount of food.

Lameness is the most common sign of limb injury, which compromises the animals' welfare by causing long-term pain and impairing normal sheep behaviour. The vast majority of lameness cases can be attributed to scald, also known as inter-digital dermatitis (IDD; infection with *Fusobacterium necrophorum*, a naturally occurring environmental pathogen, particularly on wet pasture), and foot-rot (infection with *Dichelobacter nodosus*). Foot-rot may follow an initial inter-digital infection and can be classified as benign, if lesions are limited to the inter-digital space with little involvement of the horn, or virulent if extensive separation of horn from deeper structures occurs (Winter, 2008). In the first case, lame animals can be difficult to identify. In the second case, animals are overtly lame and some of them walk on their knees to alleviate the weight from the feet. Foot diseases may be also induced by other causal or synergic microbial pathogens such as viruses, fungi and bacteria (e.g. spirochaetes). Other foot lesions leading to lameness are white line lesions (causal agent unknown) with reported high prevalence (up to 75 % of sheep) by Winter and Arsenos (2009), foot abscesses leading to severe and acute lameness and permanent deformation of the claw (Winter, 2004) and granulomas generally caused by over-trimming. Genetic, nutritional and environmental aspects have been recognised as predisposing factors. For instance, Merino sheep have been reported to be more susceptible to foot-rot than British breeds in the UK (Emery et al., 1984). However, genetic selection for resistance to foot-rot remains challenging, as resistance to the disease is probably polygenic, with genomic selection likely to be more effective than selection on a small number of markers (Bishop, in press). Many studies have assessed the heritability of foot-rot, with consensus values for resistance generally being in the range 0.15 to 0.25 for foot-rot (Conington et al., 2008; Nieuwhof et al., 2008; Raadsma and Dhungyel, 2013) or related hoof issues (e.g. Conington et al., 2010). Although not as well studied in sheep than in cattle, rumen acidosis caused by a sugar-rich diet and lead to alteration of the bloodstream at foot level and is considered a predisposing factor along with high levels of dietary protein and lack of minerals such as zinc, which is fundamental for the maintenance and growth of foot tissues (Pulina, 2001). As to environmental factors, wet and muddy grounds, average temperatures above 10 °C, sharp stones in the pasture, high stocking density and dirty floors are all predisposing factors. Lame sheep are less able to graze and compete for feed and this affects productivity (inadequate body condition, increased predisposition to disease, reduced fertility, reduced milk yield, etc.). In addition to the effects on productivity, lame sheep show physiological responses of pain and stress. Sheep with foot-rot have elevated vasopressin and prolactin, and elevated plasma cortisol with severe lesions. Sheep with both mild and severe foot-rot show elevated plasma adrenaline and noradrenaline, suggesting activation of the sympathetic adreno-medullary system (Roger, 2008). For a systematic review of the literature evaluating the effect of management system on lameness in sheep see relevant sections (sections 2.1.3 and 3.1.3 of the main text) and the scientific report of O'Connor (in press).

Mouth lesions may also hamper feeding. Chewing low-quality forages (i.e. rough vegetation) or picking leaves from shrubs with thorns and other lignified parts may make sheep prone to non-infectious lesions of the mouth. However, mouth wounds can become infected and reduce feed intake with consequent debilitating effects.

Injuries may be caused by abuse or rough handling, thus related with low quality human-animal relationship (see also section 3.1.2.4. in the main text on appropriate behaviour). When properly handled, habituation can reduce the fear response of sheep to humans through repeated exposures. However, in shepherding, intensive and semi-intensive systems stock-people may frequently change, whereas in more extensive systems human-animal contacts are rare. In both cases, habituation may be hampered thus making the sheep more reactive to the human presence. Injuries can result from accidents, such as when animals become entangled in wire or run into a fence or other obstacles. Such accidents are often seen if animals are frightened and become panicked. Sheep are defenceless, gregarious animals and if they feel threatened (presence of unknown people, dogs, noise, etc.) then they tend to become agitated and flee as a group (Wemelsfelder and Farish, 2004), which may increase the risk of injuries, particularly in enclosed or rough areas. Poor flooring and inadequate design or maintenance of housing facilities (e.g. slippery floors, sharp protrusions) may also cause injuries, particularly to intensively farmed sheep. Although ewes are described as social tolerant animals (Dwyer, 2009), resource scarcity can induce aggression and injuries (see also section 3.1.2.4. in the main text on appropriate behaviour). In addition, rams can fight with other males and cause severe injuries of the weaker animal as a consequence of repeated clashing. This is more common if adult males are mixed with unacquainted individuals (i.e. during the non-breeding season) in enclosed areas with low space allowance and consequent short flight distance availability.

Integument alterations may be caused by different causes, and poor nutrition may, additionally, play a role with regard to hair condition and to a possible predisposition for lesions. In particular, infestations with ectoparasites are enhanced by malnutrition and often by humid housing conditions resulting in higher numbers of more severely infested animals. Young animals and animals with long hair are more likely to be affected by ectoparasites. Some skin diseases of sheep caused by ectoparasites are listed below.

Mange (scabies) is caused by mites (class *Acarina*). The mites either burrow and feed on epidermal layers (sarcoptic mange) or live at the skin surface and feed on epidermal debris or tissue fluids by sucking (psoroptic mange) or biting (chorioptic mange). Owing to mite bites and reaction to saliva, mange is connected with scabs and severe itching (pruritus), which in turn causes damage of the integument because of rubbing and licking. Advanced lesions are described as hairless, scaly and scabby areas and crusts. Lesions often affect the back, the flanks and the shoulders of the sheep. Although mites are not vectors of other diseases, lesions can be infected with secondary bacteria and lead to weight loss and wool loss, reduced milk production and general weakness that makes the affected sheep more susceptible to other diseases. If left untreated mange can cause the death of the animals, particularly in young lambs. In addition, at slaughter, hides of affected animals can be downgraded or rejected. Infestations often remain unnoticed until wool loss becomes manifest, which indicates that the whole flock is probably already infested. The most important parasitic mite species of sheep are: *Psoroptes ovis* is the agent of psoroptic mange, also called sheep scab, which affects sheep worldwide; *Sarcoptes scabiei* var. *ovis* causes sarcoptic mange, also called scabies, which affects sheep worldwide; *Chorioptes ovis* causes chorioptic mange, also called leg mite or foot scab, which affects sheep worldwide; *Psorergates ovis* is responsible for psorergatic mange, also called itch mite, which is more common in Australia, New Zealand, South Africa and North and South America. Mites are more common in cold climates and winter indoor overcrowding can favour the spread of these parasites along with confinement and poor body condition, also common in winter, as a consequence of stress and reduced immune-responsiveness.

Ticks (class *Acarina*) are bloodsucking ectoparasites affecting sheep in warm climates. The most common species belong to the genus *Ixodes*. The life cycle includes four main development stages. Adults stay on herbaceous plants, from which they move onto grazing sheep. Preventive management practices therefore include rotational grazing and grass mowing. Negative effects on the animals include severe itching (pruritus), which in turn causes damage of the integument because of rubbing and scratching, blood loss, disease transmission (bacterial, viral or protozoan), paralysis (sometimes induced by the toxin-containing saliva) and predispose to other harmful conditions, such as blowfly strike (through the wounds caused by ticks).

Lice affect sheep worldwide (pediculosis). Prevalence in a given region depends more on the abundance of sheep, herd management and breeds, and less on climatic or ecological conditions. As a general rule, sheep lice tend to be more abundant during the cold season. Most lice species affecting sheep and goats are species specific, and consequently there is no risk of transmission from one species to the other (e.g. from sheep to cattle, from dogs to cats or humans, etc.). However, sheep lice may survive on goats and vice versa, but usually do not reproduce off their specific host. Distinction is drawn between chewing and biting lice (Mallophaga), which feed on exfoliated epithelium and skin debris, and sucking lice (Anoplura), which feed on blood and tissue fluid. Depending on degree of infestation, hairless patches, skin irritation and chronic dermatitis in association with itching can be observed. Similar to mange, consequential injuries through self-inflicted trauma can be found. Although pediculosis is supposed to be harmful only when infestation is heavy, hide damage and decreased growth even at lower levels indicate welfare relevance already at this point. Favoured sites of infestation are the neck and the area around the withers.

Cutaneous myiasis in sheep (blowfly strike) can be caused by a number of flies belonging to the family of Calliphoridae. Some of the most common species belong to the genus *Lucilia*. Although these insects can affect sheep in colder climates (e.g. the UK), they are common in warmer countries and are favoured by humid weather conditions, whereas windy conditions are unfavourable. Females can lay eggs on wounds or other injuries on a sheep's body. Poor hygienic conditions of the body are also attractive to female flies, thus faeces dangling from the fleece or stuck on the wool and lumpy wool are all predisposing factors. These insects tend to affect hindquarters, flanks and the back. Some preventing management practice include good hygienic conditions of both environment and flee, i.e. shearing, mulesing and tail docking. However, mulesing and tail-docking can have detrimental effects on sheep welfare (see paragraph on "Absence of pain induced by management procedures" of this section).

Indoors alterations of the integument are often caused by repeated collisions or contact with housing structures. They are mostly prevalent at leg joints (carpus, fetlock joints, stifle and tarsus), withers, neck (often caused by the feeding rack), hip and spine/backbone, as well as brisket and shoulders. However, protruding and sharp-edged parts of equipment in the housing system may cause injuries to any part of the body. In addition, skin lesions can occur outdoors if fences and hedges are not well-maintained and unable to prevent entanglement. Mesh and electric fencing can be particularly dangerous for horned sheep. Natural pastures with closely growing shrubs or bushes, as well as stony ground may also increase the risk of injuries and integument alterations by physical agents.

In extensive systems, injuries may result from predator attacks. Predator species, depending on the geographic area, include lynx, wolverine, wolf, feral dogs, brown bear, eagle and red fox (taking young lambs). Ewes and lambs are often severely injured, especially by bears and wolves, and it may take several days before they are found and euthanized or treated.

Absence of disease: absence of disease is a basic requisite for good welfare for individual sheep. Diseases can cause pain and may interfere with normal behaviour. Chronic diseases often have a debilitating effect.

A common metabolic disease in ewes is milk fever, but occurrence in sheep is not as common as dairy cows. A shortage of calcium (hypocalcaemia) in parturient ewes, either related to an excess of calcium ingested during the pre-parturition period because of a low supply during the parturition period, can cause this disease, also known as parturient paresis, which occurs, in particular, in older subjects and high-producing dairy ewes. It can be also triggered by stress, such as group mixing, or a sudden change of diet. Animals with milk fever become restless, loose their appetite, show muscle tremors, starting from the shoulders, and paresis, with animals unable to stand. The disease can cause death if left untreated.

Rumen acidosis can be caused by elevated consumption of concentrates (grain in particular), grazing on fresh pasture or when sheep are given access to grain stubble after harvest or as a consequence of an abrupt change to a grain-based diet. All these conditions can result in high levels of acid produced in the rumen as a consequence of intense bacterial demolition of dietary sugars leading to high production of volatile fatty acids and lactic acid. Affected sheep appear depressed and lethargic and may have abdominal pain. Acidosis can increase morbidity and mortality and can markedly reduce weight gains in young animals and milk production in adults. Prevention is based on the provision of an adequate amount of fibre to stimulate salivation, which in turn is able to buffer rumen pH, and to a gradual adaptation to starch-reach diets.

Tympanism is the over-distension of the rumen and reticulum with gases produced by fermentation which are not eliminated by physiological eructation (bloat). Primary tympanism can occur in animals grazing on pastures rich in alfalfa (luceme) and clover, as these legumes can be easily digested in fine particles trapping the gas. The same can occur when animals are fed a large quantity of grains, particularly when they are finely ground. Secondary tympanism can occur in any conditions impeding eructations of free gas (e.g. abscesses, tumors, foreign bodies).

Most of sheep management systems are pasture-based, which means that the animals have a certain degree of freedom in selecting the plants to be ingested. As a consequence, poisoning can occur, especially in periods of low availability of normal forage, as the animals are induced to ingest less palatable or unknown plants, which can potentially contain toxins.

Reproductive disorders include a number of different pathologies. Metritis can be observed in ewes after parturition when uterus can be contaminated by a variety of microorganisms, or as a consequence of placental retention or presence of a macerated foetus in the uterus. Symptoms include vulvar discharge and reproductive failure. Assistance at parturition may help prevent the occurrence of this disease, as well as dystocia. Dystocia occurs when ewes have difficulty lambing as a consequence of abnormal presentation of the lamb(s), large lambs and ewe fatness or pelvic conformation. In addition to non-infectious traumatic agents, late-term abortion and foetal abnormalities in sheep can be welfare problems caused by a number of infectious agents.

Dairy ewes are at risk of developing production-related diseases such as mastitis. The incidence of clinical intra-mammary infections in sheep is relatively low, at or below 5 % (Kilgour et al., 2008). However, the incidence of sub-clinical mastitis varies from 4 % to more than 40 %. Mastitis is associated with an increment in somatic cell count (SCC): 20 to 30 % of new infections occur in a year when SCC ranges between 600,000 and 800,000 per ml (Berthelot et al., 2006). Sub-clinical mastitis appears to occur less frequently with machine milking than hand milking, which suggests that hygiene during milking may reduce the spread of infection. The main infective agent of clinical mastitis in ewes is *Staphylococcus aureus*. The udder of ewes with acute mastitis may be discoloured and dark, swollen, very warm and in severe cases can evolve to gangrenous mastitis with toxaemia and loss of condition while the gangrenous tissue can necrotise, causing the loss of part of the udder and leave a large granulating wound characterised by secondary bacterial infections. Gangrenous mastitis can sporadically cause death of ewes but it always represents a relevant welfare concern. Sub-clinical mastitis is more often induced by *Staphylococcus epidermidis*, *Streptococci bacteria* and *Escherichia coli* (Olechnowicz, 2012). When machine milking is adopted, a proper maintenance is necessary for substitution of worn parts (e.g. teat cup liners) or regular tuning of the equipment (e.g. vacuum level, pulsation ratio, etc.). Poor maintenance of the milking machine leads to increased mastitis incidence (Olechnowicz, 2012). Genetic factors may possibly be involved in increased susceptibility of ewes to mastitis. High-producing breeds seem more prone to mastitis than local low-producing animals. Fragkou et al., (2007) reported a higher resistance against mastitis of an indigenous Greek sheep breed (Karagouniko) than an improved high-production breed (Friesarta) and attributed that to more efficient local defence mechanisms in the teat of ewes of the indigenous breed. In sheep, genomic selection has been shown to have a potential for improvement of mastitis resistance (Duchemin et al., 2012). A genetic background to increased susceptibility in mastitis in dairy ewes has also been reported by Barillet et al. (2001) in France and by Bramis et al. (2014) in Greece. Contagious agalactia is caused by *Mycoplasma agalactiae*. Three main symptoms have been described: mastitis, arthritis and keratoconjunctivitis. The disease is more common in warm climates and leads to a marked reduction and even suppression of milk production. Vaccines represent the main preventive measure along with good hygienic condition at milking, as ewes can be infected through the udder (Khezri et al., 2012).

Internal parasites are a major health problem for many flocks, particularly in areas characterised by high rainfall levels, although there are parasites that do not require humid environments (e.g. *Dicrocoelium dendriticum*). The life cycle of the main sheep internal parasites involves the presence of infectious larvae on the forages grazed by the animals and the presence of adult parasites in the animals. Therefore, strategies that interrupt the life cycle and reduce pasture contamination are the most successful. De-wormers (anthelmintic treatments) are more effective when used in combination with pasture management strategies. Resistance of worms to anthelmintic treatments is becoming a serious problem in many countries. Parasite-management programmes should take into account the best strategies to minimise both the impact of the infection on the flock and the risk of development of parasite anthelmintic resistance. Gastro-intestinal parasites can cause diarrhoea, dehydration, loss of appetite, loss of weight (or reduced weight gains), reduced productivity and death, and represent a serious welfare problem in sheep. Sheep internal parasites can be divided into three main groups: strongyles or round worms, cestodes or tapeworms and trematodes or liver flukes. Round worms are one of the major causes of production losses in sheep. These worms generally invade the abomasum (e.g. *Haemonchus contortus*), the intestines (e.g. *Trichostrongylus colubriformis*) or the lungs (e.g. *Dictyocaulus filaria*). Examples of tapeworms in sheep are: *Taenia ovis*, *Moniezia expansa*, *Echinococcus granulosus*. Adults or larvae the abovementioned parasites can cause teniasis in sheep.

Fascioliasis, is caused by a flatworm trematode (*Fasciola hepatica*). Adults live in the bile ducts where eggs are laid. Eggs migrate to the intestine and are deposited on the ground with faeces. The intermediary host is a dwarf pond snail, *Lymnaea truncatula*, known as *Galba truncatula*. The intermediate stage of this parasite (the cercaria) leaves the snail and encysts on the grass as a metacercaria, which can be ingested by sheep and start a new life cycle. Most of the damage caused by this parasite is the result of flukes migrating through the liver. In acute and subacute cases, liver necrosis can result in sudden death or death in one week and two weeks, respectively. Chronic forms cause abdominal pain, anaemia and weight loss, while biochemical and haematological parameters are altered. Chronic forms can also cause death owing to anaemia, cachexia, metabolic disorders and concurrent infections. Warm and humid climates can favour the development of this disease as the snail is a necessary intermediate host. Prevention is based on pasture improvement through drainage and removal of snail habitats.

Coccidiosis (*Eimeria spp.*) is an important sheep disease in systems where animals are managed at high stocking density. It is caused by a small protozoan parasite that mostly affects the intestine of lambs with marked effects, including diarrhoea (containing blood or mucus), dehydration, fever, loss of appetite, weight loss, anaemia and death. Fly-strike and secondary bacterial enteric infections may accompany coccidiosis in lambs. Sheep nose bot is caused by *Oestrus ovis*, a cosmopolitan fly that in its larval stage affects the nasal cavity and paranasal sinuses of the animals. The main effects are annoyance, consequent reduction in grazing time and loss of body condition.

Sheep pulmonary adenomatosis can cause a long insidious disease leading to slow deterioration and death of the animals (Sharp and De Las Heras, 2007). Maedi-visna is another viral disease characterised by long incubation leading to pneumonia and death (Pritchard and McConnell, 2007). Leginagoikoa et al. (2006) in Spain found a seroprevalence of small ruminant *Lentivirus* infection (a significant cause of respiratory problems in sheep) of 77 %, 25 % and 5 % in intensively managed Assaf sheep, semi-intensively managed Latxa sheep and extensively managed Manchega flocks, respectively. In another study, it was found that seroprevalence of *Lentivirus* infection in two indigenous sheep breeds (Boutsko in Greece, Comisana in Italy) was significantly smaller (41 %, 7 %, respectively) than that observed in an improved high-production breed (Friesarta, 70 %). Differences were associated with a toll-like receptor 9 polymorphism (Sarafidou et al., 2013).

Paratuberculosis (Johne's disease) is caused by *Mycobacterium paratuberculosis*, also known as *Mycobacterium avium* subsp. *paratuberculosis*. In sheep, weight loss, hypo-proteinemia and poor fleece conditions are the primary symptoms, whereas diarrhoea is less frequent. This bacterium is excreted in large numbers in faeces by infected animals and less in colostrum and milk. It is resistant to various environmental factors and can survive on pasture for more than one year.

A common bacterial pulmonary disease is pasteurellosis, which occurs in two forms (pneumonic and systemic) by *Mannheimia haemolytica*, whereas *Pasteurella multocida* can cause septicaemia in lambs, and marked symptoms such as fever, coughing and nasal discharge. Treatment of the disease is not effective, whereas preventive measures such as vaccination are often successful (Watson and Davies, 2002).

Scrapie is a chronic, progressive prion disease leading to the degeneration of the central nervous system and death. It is a spongiform encephalopathy caused by a prion. Symptoms include itchiness, nibbling and evident tremors and fear of humans. There is no therapy available and prevention is based on selection of scrapie-resistant animals.

Bacillus anthracis is the causative agent of anthrax. This bacterium can form spores, which remain vital and infective for decades in the soil where they are discharged and disseminated after the death of the infected animal. Contaminated forages and hay can induce the spread of the disease through ingestion, but spores can be also breathed in, or enter the body through damaged skin. They quickly spread through the body, causing cell destruction and bleeding. Some of the symptoms of acute anthrax include fever, cardiac and pulmonary distress. In sheep, an acute course of the disease usually leads to a sudden death. Sporulation is induced by oxygenation, which in turn can be favoured by scavengers (e.g. dogs), bloating and post-mortem examination. Prevention is based on vaccination programmes (Turnbull, 1991) and burning of infected carcasses.

Bluetongue virus (BTV) is transmitted by insects (*Culicoides,* biting midge). BTV is not contagious and it is widespread in warm climates including southern Europe, Africa and the southern states of the USA, but has also reached northern Europe. Fever, nasal discharge often becoming purulent, congestion of mouth, swollen tongue which may become cyanotic, are all symptoms of the disease that, in acute cases, can be the cause of death. Vaccination is effective on only a reduced number of serotypes existing in Europe and the USA, and does not prevent disease occurrence and shows marked adverse effects (Mahrt and Osburn, 1986) including abortion and neonatal malformation.

Soremouth is a very contagious viral disease also known as contagious ecthyma, orf and scabby mouth, and is characterised by the formation of papules, vesicles and scabs on the skin of the lips and other organs (Buddle and Pulford, 1984). Treatment is unsuccessful and vaccines should be used only in flocks where the virus is already present. In general, affected animals recover within four weeks from the start of the disease. Lip papules may cause reduced milk intakes in young lambs.

The viral disease Schmallenberg, causing congenital malformations, is also emerging in several EU countries (EFSA, 2014).

Clostridial diseases are caused by organisms mostly found in the soil. They include a number of different diseases (tetanus, lamb dysentery by *Clostridium perfringens,* type B, botulism, etc.) although the most common is represented by the enterotoxaemia caused by *C. perfringens* types C and D. Sudden changes in the diet of young lambs and concentrate-based diets in fast-growing lambs can predispose to enterotoxaemia types C and D, respectively. Gradual diet changes and vaccination of pregnant ewes are regarded as the main preventive measures.

Lamb mortality is a significant welfare concern; the average mortality in developed countries is 15-20 %, with nearly 50 % of these lamb deaths occurring within the first three days of life. The main causes of lamb deaths are: 1) pre- or peri-parturient disorders (30-40 %); 2) weakly lamb/exposure/starvation (25-30 %); 3) infectious disease and gastro-intestinal problems (20-25 %); 4) congenital disorders (5-8 %); 5) predation, misadventure and unknown causes (5 %) (Roger, 2008). The risks of lambs succumbing to any of the causes of death will vary somewhat by management. For example, outdoor lambing systems may have higher deaths from dystocia (as the risks of a ewe experiencing difficulties and not being assisted are greater) and exposure/starvation, whereas indoor lambing systems face greater risks of infectious diseases and abortions.

The welfare consequence of disease is influenced by both the risk of infection and the speed of detection and effectiveness of treatment when infection occurs. Sheep maintained in more extensive systems, may have a lower risk of contracting diseases influenced by stocking density, albeit biosecurity protocols are more difficult to implement. Because extensively kept sheep are inspected less frequently and are more difficult to handle individually, the consequences of any disease or injury may, however, be more severe than for those kept under management systems of greater intensity.

Absence of pain induced by management procedures: several procedures that are routinely carried out in sheep farming can cause pain. These include dehorning, castration, tail docking and mulesing. The pain associated with these procedures normally lasts a few days, but in some cases chronic pain may also result. Although these management procedures are often carried out on young animals they too can feel pain.

Unlike in the Mediterranean region where lambs are slaughtered at an early age or in countries where this is prohibited (e.g. Norway), in many other countries lambs are castrated and their tails are docked. Castration is performed to prevent unwanted mating and meat taint. A range of techniques for castration are applied. Common ones include bloodless techniques, such as the use of rubber rings (elastrator) to restrict the blood supply to the scrotum and its contents or castration clamp, and surgery using a knife to incise the scrotum and allow the testicles to be removed by traction. Pain alleviation strategies should include the use of anaesthetics and anti-inflammatory treatments (Mellor and Stafford, 2000).

Tail-docking is practiced routinely on most sheep operations in order to prevent flystrike and, in dairy breeds, to facilitate routine milking procedures. Docking can be carried out using a rubber ring, a cautery iron or a sharp knife. Whatever the technique is, tail-docking is stressful (Kent et al., 1993). Surgical removal appears to be less stressful than the use of rubber rings (Kent et al., 1993). The use of a heated cautery iron produces the least changes in behaviour and cortisol levels (Graham et al., 1997); however, it is not the preferred method of tail-docking because of the incidence of subsequent chronic infections. The use of local anaesthetic significantly reduces behavioural signs of pain, but it is not common due to the fact that it is time consuming.

Mulesing is performed, in some countries outside the EU, to prevent flystrike, particularly in Merino sheep. It consists of cutting away skin from the perianal region using wool-trimming shears, which causes the formation of scar tissue less prone to get dirty. A range of alternative non-surgical approaches to mulesing are currently being developed and evaluated. For instance, Playford et al. (2012) suggested that polypropylene clips applied to the breech of lambs produce scar tissue by necrosis and may reduce the risk of flystrike. Breeding for traits giving resistance to flystrike (e.g. reduced breech wrinkle, increased area of bare skin in the perineal area, reduced tail length and wool cover on and near the tail, increased shedding of breech wool, reduced susceptibility to internal parasites and diarrhoea, increased immunological resistance to flystrike) has also been suggested as a genetic alternative to mulesing (James, 2006).

De-horning and disbudding are less common in sheep than in other species such as cattle and goats. These management procedures may be performed to prevent injuries to the animals and to make handling safer through hot-iron cauterisation. These procedures should be accompanied by anaesthetic and anti-inflammatory treatments to reduce pain and stress.

Ear tags can be a source of injury, infection and pain in sheep. Edwards and Johnston (1999) reported on the incidence of injuries associated with six types of ear tags. The shape of the tag was more important than the material in causing injuries. Loop tags resulted in more injuries. The least injuries were caused by plastic two-piece tags made of flexible polyurethane. The size of the tag relative to the thickness of the ear might also be a risk factor for infection.

3.1.2.4. Appropriate behaviour

The principle of appropriate behaviour consists of four criteria as identified by WQ® (Blokhuis et al., 2008): expression of social behaviours, expression of other behaviours (often taken to mean stereotypic behaviours); quality of the human-animal relationship and absence of general fear. The latter criterion may also be labelled “positive emotional state”.

Social behaviours: positive social interactions can have a desirable effect on welfare for at least two reasons. First, they have been shown to elicit physiological responses known to be pleasant. Second, they reduce the negative effects of stressful events; this is known as “social buffering” of the stress response (Kikusui et al., 2006). However, negative social interactions, such as aggression, impair animal welfare. Aggression may result in injuries, pain and, in extreme cases, the death of the animal. Furthermore, aggression leads to fear and stress within the whole group (Fraser and Rushen, 1987). In almost all sheep farming systems, sheep are kept in social groups, usually by sex and age group, and are rarely, if ever, confined in social isolation (exceptions might be short periods of restraint to induce a parturient ewe to accept a lamb (fostering), or quarantine management of recently purchased rams). Therefore, sheep are generally able to perform much of their social behavioural repertoire of associating with preferred companions, forming sub-groups for grazing and resting and expressing flocking responses. However, sheep are very gregarious and have a very strong reaction to being separated from the flock, particularly if they are unable to make visual or auditory contact with other sheep, and to being separated from particular companions (separation of ewes and lambs for example). Flocking and the social group play a fundamental role in the evasion of predators by sheep, and their wild ancestors, and this social tendency remains a very strong part of the sheep behavioural biology (Dwyer, 2004). Separation of the sheep from the flock has been shown to cause a fear or panic reaction in sheep, expressed as excessive movement and escape attempts (Dwyer and Bornett, 2004), high vocal activity (except when in the presence of a predator, e.g. sheep dog; Torres-Hernandez and Hohenboken, 1979), and a robust activation of the hypothalamic-adrenal stress axis (Niezgoda et al., 1987; Minton et al., 1992; Apple et al., 1993; Guesdon et al., 2012). Attempts to escape may also result in injury as animals may collide with walls or pen fixtures. Likewise, exclusive attachments between ewe and lambs form immediately after birth and ewe and lambs are rarely separated for long in a natural situation, and never in a threatening situation, until at least six months after birth (Arnold et al., 1979). Therefore, separation of ewe and lambs may engender similar anxiety reactions to social isolation (Napolitano et al., 2008). For ewes, these attachments generally wane within a few days of separation, in line with the reduction in a lactation response. In lambs, the timing of separation from the ewe is likely to be important, affecting whether the lamb is able to form effective relationships with others (e.g. human caregivers, peers), although separated lambs rarely perform as well as lambs raised by their mothers (Snowder and Knight, 1995; Binns et al., 2002; Dwyer, 2008). Abrupt weaning is also associated with elevated plasma cortisol (Mears and Brown, 1997; Rhind et al., 1998; Orgeur et al., 1999), depressed growth rates (Jagusch et al., 1977; Watson, 1991; Napolitano et al., 1995) and increased susceptibility to disease (Jagusch et al., 1977; Watson 1991).

Few studies have investigated the welfare consequences of housing in isolation or close confinement, largely as this rarely occurs except for experimental purposes or fostering. Preliminary data suggest that restraint fostering (where recently lambed ewes are held by the neck in stocks for a number of days to induce acceptance of a lamb) increases the amount of butting, stamping, escape attempts and high-pitched bleating in parturient ewes in comparison with unrestrained animals, and is associated with higher salivary cortisol and heart rate (Ward, 2012). In experimental housing of sheep in close confinement, alterations in ingestive behaviour, activity, depression of circulating cortisol, a blunting of the circadian rhythm for behaviour and cortisol secretion, a reduced attention to environmental features and an increase in stereotypic behaviours have been reported (Done-Currie et al., 1984; Fordham et al., 1991; Tobler et al., 1991).

With the exception of the early establishment of ewe-lamb contact, sheep do not often engage in social grooming or licking, and even between ewes and lambs this is relatively infrequent after the first four hours after birth. Affiliative social contacts are generally subtle and expressed as close contacts and lying preferences rather than overt social interactions. Likewise, negative social interactions, in a natural grazing environment, are mainly subtle eye contacts, intentional movements and displacements (such as resting the chin on the back or nudging with the front leg) rather than overt aggression. However, more aggressive interactions can occur, either between entire males or when competition for resources occurs (Bøe and Andersen, 2010), and these can involve butting, kicking, pushing, chasing and persistent displacements. For subordinate animals, this may result in frequent displacements from accessing feed, leading to poor growth or weight gain, and in pasture situations may mean that subordinates can only access less preferred grazing that may be more likely to be contaminated with parasites. Subordinates may also be displaced from preferred lying areas (Sherwin and Johnson 1987; Deag, 1996) and, where there is limited shade or shelter, they may experience greater thermal challenges than more dominant animals. Subordinate animals are generally at the back of any movement order (Lynch and Alexander, 1973), which, during management gathers, means these animals are more likely to experience human and sheep dog close contacts.

Particular factors disposing to an increase in social tension and negative welfare consequences for sheep include housing at high stocking density and restricted resources (access to food, lying areas or shade and shelter; Bøe et al., 2006). Housing at densities of 1 or 1.5 m^2 in comparison with 3 m^2 results in increases in both overtly negative social interactions (Caroprese et al., 2009a) and more subtle social interactions (such as nose-to-nose contacts or nudging; Averós et al., 2014a), and in decreased activity, increased time feeding and reduced resting (Caroprese et al., 2009a; Averós et al., 2014a). Re-grouping of animals into new social groups may also result in an increase in aggression and negative social interactions, particularly if space is limited. Sheep maintain social cohesion through olfactory cues and visual assessments (Arnold and Pahl, 1974). When placed in the same enclosure, sheep of the same breed but unfamiliar to one another will initially remain segregated but_become integrated into a single flock after a period of time (Lynch and Alexander, 1973; Arnold and Pahl, 1974). However, sheep of different breeds, even after being maintained in the same environment for a number of months, do not integrate (Winfield and Mullaney, 1973; Arnold and Pahl, 1974; Shillito-Walser and Hague, 1981; Dwyer and Lawrence, 1999). If space is limited, sheep may be forced into close proximity with unfamiliar animals (Averos et al., 2014b) resulting in fearful responses and aggressive social contacts.

<u>Other behaviours</u>: animals are strongly motivated to perform particular behaviour patterns. In some circumstances, the inability to perform such behaviour patterns may cause distress and lead to the development of damaging behaviours. Stereotypic, or repetitive, functionless behaviours, are seen less frequently in ruminants, and sheep in particular, than other species (Houpt, 1987; Lawrence and Rushen, 1993). This may be because of the lower frequency with which sheep are kept in the type of housing that appears to elicit stereotypy. However, individually housed sheep, for experimental purposes, have been shown to demonstrate stereotypical oral behaviours, such as mouthing bars, chewing slats or chains, rattling or chewing buckets, biting and chewing pen fixtures, mandibulation (licking lips and mouthing air), and repetitive licking (Lynch and Alexander, 1973; Done-Currie et al., 1984; Marsden and Wood-Gush, 1986; Fordham et al., 1991; Cooper and Jackson 1996; Cooper et al., 1996; Yurtman et al., 2002). Ewes housed indoors in groups have also been reported to show stereotypic licking, star-gazing (arching the head and neck over the back) and floor kicking (Averós et al., 2014a) although not apparently related to stocking density. Locomotor stereotypies have also been reported, including rearing against the pen, repetitive butting, star-gazing, leaping vertically up and down, weaving and route-tracing (Done-Currie et al., 1984; Marsden and Wood-Gush, 1986). These studies suggest that sheep do perform stereotypies, although they may not be as frequent as in other species.

Feed restriction increases the frequency of abnormal oral behaviours (Done-Currie et al., 1984; Marsden and Wood-Gush, 1986a; Cooper et al., 1996; Yurtman et al., 2002). Providing hay or increasing fibre in the diet, reduces oral stereotypy (Done-Currie et al., 1984; Cooper et al., 1996), and increases lying and rumination (Cooper and Jackson, 1996) although not in all studies (Yurtman et al., 2002). Sheep also show other forms of abnormal oral behaviours including wool-biting or pulling (generally nibbling, biting or chewing behaviours directed at the wool of another ewes) and redirected sucking. Wool-pulling occurs exclusively in indoor-housed sheep within restrictive enclosures (although there may also be a component of dietary deficiency (Fraser and Broom, 1990), and disappear when the sheep are turned out. Wool-pulling is generally performed by the most dominant sheep on subordinates (Fraser and Broom, 1990; Lynch et al., 1992), is most frequent at high stocking density and eliminated by increasing space per animal (Fraser and Broom, 1990). Redirected sucking occurs in artificially reared lambs where lambs suck the navels and scrotums of other lambs (Stephens and Baldwin, 1971). This can persist until weaning, and seems to occur most frequently in lambs that have been disturbed during feeding. Lambs separated from their dams for 48 hours in the first few days of birth, before being raised by their dams, also show a propensity to re-directed sucking even at two months of age (Markowitz et al., 1998). Some lambs also chew and suck bedding, and stone sucking (pica) occurs in early-weaned lambs (Jagusch et al., 1977).

Human-animal relationship: the quality of the human-animal relationship can be one of the most important factors in determining the welfare of an animal. The nature and frequency of this relationship can vary markedly in different sheep farming systems and the descriptors given above partially characterise sheep farming systems on the basis of human contacts. These range from daily close physical contact (shepherding, intensive dairy) to infrequent visual contacts (extensive and very extensive). Therefore, the quality of the human-animal interaction is composed of both the behaviour of the human when in contact with the sheep (and hence the amount of fear that the sheep may experience) and the knowledge and skills of the stockperson in recognising animal needs and managing the sheep to achieve those, whether in direct contact with the sheep or not. The term "stockmanship", therefore covers the way that animals are handled, the quality of their daily management and health care and how well problems, other than disease, are recognised and solved (Waiblinger and Spoolder, 2007). At least three factors underlie individual differences in the quality of stockmanship: personality, attitude and behaviour (Hemsworth and Coleman, 1998). Personality, which can be defined as a person's unique combination of traits that affects how he/she interacts with the environment, is relatively stable over time. Attitudes (including those towards animals) are learned and can be modified through experience; they are often seen as the most important factor explaining how a person interacts with social objects, including animals (Waiblinger and Spoolder, 2007).

The welfare consequence of a poor human relationship with sheep is chiefly excessive fear when humans are present (Jones, 1997). Not surprisingly, the problem is exacerbated by exposure to rough, aversive and/or unpredictable handling. Many human-animal interactions in current sheep farming practice are frightening to the sheep; these include restraint, shearing, veterinary treatment, etc., while few, other than feeding, are positively reinforcing. In some sheep farming systems, the infrequency of human contact provide very reduced opportunities for sheep to habituate to people. Chronic fear of humans is a major welfare problem that can lead to handling difficulties, injury and stress as well as impaired growth, reproductive performance and product quality (Jones, 1997; Hemsworth and Coleman, 1998). Conversely, the regular experience of positive human-animal interactions can decrease the animals' general level of stress (Seabrook and Bartle, 1992) and enhance reproductive performance (Waiblinger et al., 2006), and the presence of a familiar person can calm the animal in potentially aversive situations (Waiblinger et al., 2006). Regular gentle handling reduces stress and fear of humans in sheep (Hemsworth and Coleman, 1998) but is often not feasible in modern farming. In systems where sheep have daily physical contact with humans an absence of any fear is an important part of sheep welfare and animals that are willing to approach the human voluntarily should be encouraged. For more extensive systems this may not be appropriate or desirable, for example if sheep may also encounter other humans in open-grazing areas, although the ability of the stockperson to approach close enough to properly inspect the sheep is important.

Despite what is often believed, sheep have an excellent memory for place and can rapidly learn to associate place with particular aversive experiences and can retain this information for up to a year (Hutson, 1985). Sheep are also able to discriminate between human handlers on the basis of their previous experience of pleasant or unpleasant treatment from the handler (Fell and Shutt, 1989; Boivin et al., 1997), and retain memory for individual recognition for at least two years (Kendrick, 2008). Recent evidence suggests that sheep can discriminate individual handlers when handled gently, but tend to generalise responses to all humans when handled poorly (Destrez et al., 2013a). Together, these data suggest that sheep are capable of retaining memories of poor handling and are likely to be more reactive to humans when they have been poorly handled in the past, although there is some preliminary evidence that infrequently handled sheep show similar avoidance of humans to sheep that have experience of poor handling (Richmond et al., 2013).

Movement of sheep for handling is usually brought about by the use of fear-evoking stimuli (Gonyou 2000; Hutson, 2000), and handling procedures are often aversive. Sheep movement is often achieved by the use of dogs, in concert with other frightening stimuli, to elicit a flight response. As animals move towards the place of treatment, particularly if they already associate that place with negative experiences (Rushen, 1990, 1996), the effectiveness of fear stimuli in forcing movement declines as the competing aversion of the place increases (Hutson, 2000). Use of greater fear or force causes behaviours such as: freezing, fleeing, baulking, sitting, turning, reversing and jumping or escape attempts. Plasma cortisol in moved sheep, albeit at a slaughterhouse, was influenced by the intensity of dog use to bring about movement, and the frequency of human touches, pushing and whistling (Hemsworth et al., 2011). Therefore, the amount of distress that sheep suffer during movement and handling is likely to be affected by the quality of the stockperson working with the sheep (reviewed by Rushen and de Passillé, 1992; Hemsworth and Coleman, 1998; Hutson, 2000). The learning abilities of sheep suggest this may be so even if the animals are handled infrequently. In addition, behavioural reactivity to humans may be affected by breed (Caroprese et al., 2011).

In many farm systems, dogs are used to move sheep; therefore it is also pertinent to consider the influence of dogs on sheep welfare as well as stockpeople. However, it should be noted that in some systems guardian dogs are used, which live with and are "bonded" to the flock from a young age, to protect sheep from predation, thus interactions with dogs should not always be considered negative for all systems. However, the presence of a dog, or recorded dog barking, is often used as a stressor in experimental studies and causes elevated plasma cortisol, adrenocorticotropic hormone and heart rates, above those seen on sudden exposure to humans and noise (Harlow et al., 1987; Baldock and Sibly, 1990; Cook, 1996; Komesaroff et al., 1998). Dogs also elicit greater aversive responses than unfamiliar humans in a variety of experimental testing situations (Beausoleil et al., 2012). In on-farm or slaughterhouse situations, exposure to dogs used for movement, and the intensity of that use, influences the cortisol response of handled animals (Terlouw et al., 2008; Hemsworth et al., 2011). Vigorous movement by dogs and aggressive behaviour (biting) by the dog also caused elevated plasma cortisol and reduced ovulation, particularly in young ewes (Kilgour and de Langen, 1970). Therefore, exposure to dogs and the behaviour of those dogs are important considerations in the assessment of stockperson behaviour.

An inability to understand animal needs (e.g. through poor training, lack of empathy or incompetence), infrequent inspection to assess whether animal needs are being met, inspections where animals cannot be properly observed or too many animals per stockworker can all lead to poor management decisions that may impact on sheep welfare. This poor decision making can influence all aspects of welfare (e.g. provision of supplementary feed affecting good feeding, decisions about provision of shelter or housing affecting good environment, decisions about prophylactic treatment or recognition of diseases states affecting good health) so will not be discussed in detail here. In a study of UK hill sheep farmers and farm management nearly half of all farmers (42 %) thought it acceptable to allow their dogs to bite the sheep (Dwyer, 2009). As 90 % of all farmers trained their own dogs, this attitude may influence the likelihood of exposure of sheep to dog bites. The same survey demonstrated that only 5 % of farmers believed that the sheep were afraid of their dogs, suggesting a widespread lack of understanding of some aspects of sheep behaviour or needs.

General fear: fear is an aversive emotional state and, although fear behaviour can be adaptive in ideal circumstances, its sudden, intense or prolonged elicitation (and the consequences thereof) is a major welfare problem (Jones, 1997). Fear and anxiety are two emotional states induced by the perception of danger or potential danger, respectively, that threaten the integrity of the animal (Boissy, 2005). Fear and anxiety both involve physiological and behavioural changes that prepare the animal to cope with the danger. Although fear and anxiety have not always been clearly differentiated, fear can be operationally defined as states of apprehension focusing on isolated and recognisable dangers while anxieties are diffuse states of tension that magnify the illusion of unseen dangers (Rowan, 1988). As a prey animal, a sheep is generally cautious of novelty and may experience short-term fear or anxiety regularly in response to many acute stressors. These behaviours may well be adaptive, promoting survival, especially in outdoor managed animals, and are not generally considered a welfare concern.

General fear becomes a problem particularly when animals encounter new or unexpected stimuli (e.g. a sudden noise or movement, an unfamiliar animal) or situations (e.g. a new housing facility). These may become more serious if fear of, for example, novel foods, leads to inanition and weight loss or failure to grow. In addition, excessive fear of humans or dogs can lead to short-term issues with handling sheep involving escape behaviours, and risk of injury through bunching, smothering and collisions (as covered above). However, sheep may also be in a constant heightened state of chronic fear, such that it impinges on their ability to feed, reproduce or rest adequately. This state can occur when animals are exposed to multiple concurrent or consecutive stressors and a high degree of unpredictability when, in addition to increased expression of fear, sheep also show depressed leukocyte concentrations, heart rate and circulating cortisol indicative of chronic stress (Destrez et al., 2013b). Chronic stress will also inhibit the normal secretion of luteinising hormone and interfere with reproductive behaviours (Pierce et al., 2008).

For intensively managed animals the most likely sources of chronic stress and increased fearfulness are through interactions with conspecifics (as discussed above in social behaviour), through either the presence of dominant individuals or high stocking density leading to constantly disrupted behaviour, or through fear of humans (also discussed above). Other sources of chronic stress may be mediated through various unpredictable or uncontrollable environmental challenges as covered above. Sheep may also experience chronic stress and increased fearfulness when moved between environments, particularly movement indoors from pasture. This is likely to be a combination of increased social interactions and the novelty of a new environment and probably new foods. Frequent changes in environment or movement to feed lots from pasture are associated with increased locomotory activity (Fell et al., 1991; Sevi et al., 2001). However, moving sheep indoors from pasture reportedly causes inactivity (Casamassima et al., 2001), raised plasma cortisol that takes several weeks to normalise (McNatty and Young, 1973; Pearson and Mellor, 1976) and a reduction in circadian rhythm (Tobler et al., 1991).

For extensively managed animals, particularly in regions with a high predator density where domestic sheep can form a substantial proportion of wild carnivore diets (e.g. 64 % of lynx kills in Norway during the summer; Gervasi et al., 2014), this may be a source of chronic stress. In wild populations, high predator density and reintroduction of predators causes increased vigilance in elk and deer, reduces foraging behaviour and causes avoidance of areas of high risk resulting in reduced diet quality (Altendorf et al., 2001; Laundre et al., 2001; Hernández and Laundré, 2005). These so-called “landscapes of fear” have also been shown to operate in free-ranging domestic goats having similar impacts on foraging behaviour and habitat use as seen in wild ungulates (Shrader et al., 2008). Anecdotal evidence (reported in van Liere et al., 2013) from farmers where fenced sheep populations have experienced wolf attacks suggest that behavioural changes and avoidance of areas where attacks took place also occur here. Wild sheep use environmental features to evade predators, making use of the more rocky and inaccessible parts of their home range (escape terrain) where they can more successfully avoid predator attacks (reviewed by Dwyer, 2004). Domestic sheep are kept in a variety of different outdoor environments ranging from small, relatively feature-less fenced paddocks, to open range. The physical environment has been shown to influence sheep behaviour as the frequency of alarm behaviours in Merino sheep decreased in more complex physical environments (Stolba et al., 1990), presumably as the sheep perceived an open, barren paddock as more threatening.

Fear has a strong genetic component and some breeds or individuals within breeds are likely to be more easily frightened than others. Breed influences on fearfulness have been investigated by tests measuring sheep responses to surprise effects, the presence of a human or novel object, exposure to an open-field or an unfamiliar environment (Romeyer and Bouissou, 1992; Boissy et al., 2005) and feeding behaviour in the presence of a human intruder (Le Neindre et al., 1993; Lankin, 1997). Taken together, these data suggest that less selected and specialised breeds of sheep (e.g. Romanov, Karakul) are more fearful than more specialised breeds (e.g. Île-de-France, Merino, East Friesian). Fearfulness was shown by a higher incidence of withdrawal from humans, immobilisations, low pitched bleats, escape attempts and unwillingness to interact with novel objects. In other studies, Scottish Blackface lambs were found to have higher heart rates and plasma cortisol following an open-field test than lambs of a more highly selected meat breed, the Texel (Goddard et al., 2000).

3.1.3. Literature review

The mapping of the available literature allowed the identification of 679 citations relevant to sheep welfare. Those citations were mapped according to the study population, eight main welfare determinants (management, environment, genetics, nutrition/feeding/watering, behaviour, health, housing, handler traits/human-animal bond) and outcomes, following the structure of the conceptual model developed by the WG. Such mapping supported the WG in identifying gaps of knowledge and data that further led to seeking of experts' knowledge. In addition, areas where a systematic literature process could be performed were also identified. The scoping exercise identified minimal literature relevant to establishing a clear relationship between the risk factors and welfare consequences, except for lameness.

As a follow-up to the mapping, a systematic review was performed on the effect of the management system on lameness in sheep raised for the production of meat, milk or wool in Europe (O'Connor et al., in press). Lameness included foot-rot and other lameness-related conditions such as IDD, measured only during non-outbreak periods. Information sources included both observational and experimental studies. From an initial scrutiny of 21 full-text papers, only six proved to be relevant to the review and suitable for the final analysis. These papers allowed an evaluation of the effect of two aspects of management systems: housing vs. grazing, and degree of stocking density.

The six papers used in the evaluation reported prevalence ratios, odds ratios or rate ratios. The log of the measure of association and standard error used for graphing were back-calculated from the extracted point estimates and 95% confidence intervals using RevMan (RevMan, 2012). When authors conducted a multivariable analysis the adjusted measure of association was reported in preference to the unadjusted. However when only an unadjusted estimate was available, this was extracted, reported and analysed.

A forest plot was created to display data for both exposure variables. Variables that were related to management system (pasture access) were grouped together. As the exposure categories were not truly equivalent across the studies and some animals were used for multiple measures, a summary effect size was not calculated. It was not possible to conduct statistical tests to assess if clinical or methodological factors might be associated with heterogeneity because insufficient independent studies were available.

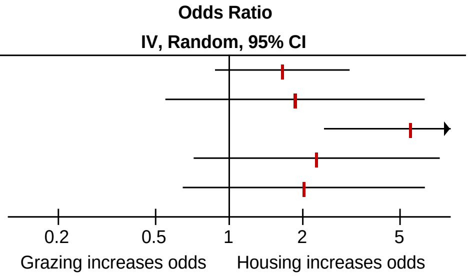
The results for studies that assessed exposure to pasture and lameness are reported in Figure 3 (O'Connor et al., in press). Overall, the studies suggest either no association or an increased lameness in animals that spend more time indoors. The studies that report odds ratios show stronger associations based on the point estimates. However, this is potentially misleading, as all but one study report a confidence interval that includes one. In addition, the odds ratio is always further from the null than the risk ratio and the difference between the risk (prevalence) ratio and odds ratio is larger when the disease is common, which occurred in many of these studies.

The results for studies that assessed stocking density and lameness are reported in Figure 4 (O'Connor et al., in press). Although few studies have evaluated this outcome, the finding was reasonably consistent that higher stocking density was associated with more lameness.

Therefore, the Systematic literature review showed that whereas outdoor or indoor keeping has no consistent effect on the prevalence of lameness, the stocking density does.

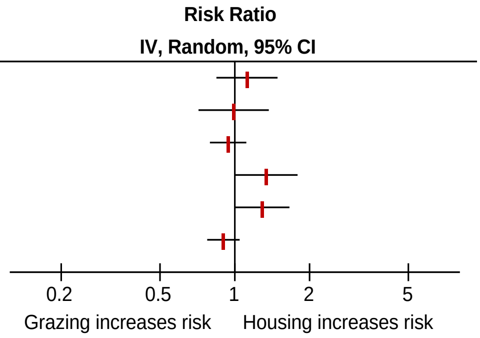
a)

Study or Subgroup	log[Odds Ratio]	SE	Weight	Odds Ratio IV, Random, 95% CI
Gelasakis - Lameness	0.5	0.32		1.65 [0.88, 3.09]
Gelasakis - Lame Severity	0.62	0.62		1.86 [0.55, 6.27]
Green 2004	1.7084	0.4124		5.52 [2.46, 12.39]
Wassink - IDD ewe 04	0.8242	0.5881		2.28 [0.72, 7.22]
Wassink - IDD lambs 04	0.7031	0.5785		2.02 [0.65, 6.28]



b)

Study or Subgroup	log[Risk Ratio]	SE	Weight	Risk Ratio IV, Random, 95% CI
Kaler -Lameness	0.1133	0.1407		1.12 [0.85, 1.48]
Kaler-Footrot	-0.0101	0.1625		0.99 [0.72, 1.36]
Kaler-IDD	-0.0619	0.0823		0.94 [0.80, 1.10]
Kaler2-Footrot	0.2927	0.1442		1.34 [1.01, 1.78]
Kaler2-IDD	0.2546	0.1248		1.29 [1.01, 1.65]
Kaler2-Lame	-0.1054	0.073		0.90 [0.78, 1.04]



c)

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Random, 95% CI
Wassink 2003	-0.6162	0.2513		0.54 [0.33, 0.88]

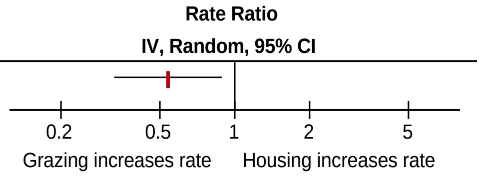


Figure 3: **a-c:** Forest plots of association between different measures of lameness and variables that describe access to pasture. All data are organized such that the numerator of the association represents the animals housed or housed more frequently compared with the denominator which refers to animals with more access to pasture (less housing). A ratio greater than one suggests the numerator is a risk factor.

a)

Study or Subgroup	log[Odds Ratio]	SE	Weight	Odds Ratio IV, Random, 95% CI
Gelasakis - Lameness	0.8372	0.3216		2.31 [1.23, 4.34]
Gelasakis - Lame Severity	1.2149	0.3706		3.37 [1.63, 6.97]
Wassink - IDD ewe 04	1.2754	0.5493		3.58 [1.22, 10.51]
Wassink - IDD lambs 04	0.6313	0.5419		1.88 [0.65, 5.44]

b)

Study or Subgroup	log[Risk Ratio]	SE	Weight	Risk Ratio IV, Random, 95% CI
Kaler -Lameness	0.2311	0.093		1.26 [1.05, 1.51]
Kaler-Footrot	0.3293	0.1335		1.39 [1.07, 1.81]
Kaler-IDD	-0.0619	0.1504		0.94 [0.70, 1.26]

c)

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Random, 95% CI
Wassink 2003	0.0296	0.1619		1.03 [0.75, 1.41]

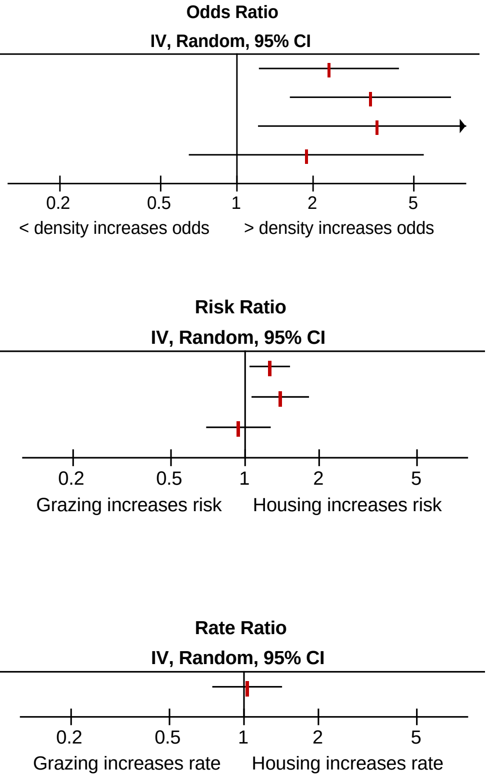


Figure 4: a-c: Forest plots of association between different measures of lameness and variables that describe stocking density. All data are organized such that the numerator of the association represents the high density compared with the denominator which refers to animals with lower density. A ratio greater than one suggests the numerator is a risk factor.

3.1.4. Expert’s knowledge elicitation (online survey and technical meeting with experts): main welfare consequences and risk factors for sheep welfare

The survey of experts was important for informing the scoping exercise of this opinion. However, the sample of experts was not random, that is not by management system, country or background (academia, organisations and practitioners). Comparative evaluations therefore should not be used to conclude demonstration of differences in the described systems, since they reflect only differences according to the judgement of responding experts.

Complete replies were received from 163 responders. The overall results from the analysis of the online survey are reported in Appendix E. The results of the survey identify only two predominant mixed farming systems which were already included in the systems described by the EFSA WG, and which corresponded to combinations of intensive and extensive, and semi intensive and extensive systems. The expert group agreed that the consequence characterization (factor identification+welfare consequence) for each individual management system would apply to the period when sheep were in that system within a mixed system. In addition, some interactions would occur and the transition period was also considered to be very critical. Concerns were raised about additional risk factors associated with transportation or locomotion between systems, about the sudden change in environment and feeding and about the challenges of genetic suitability to cope with contrasting environments. However, the welfare consequences associated with transportation are outside the scope of this opinion (see previous scientific opinion of EFSA AHAW Panel, 2011 for details about sheep transport).

Out of the 17 welfare consequences proposed in the conceptual model, the expert elicitation process allowed identification, according to the experience of the experts, of the most relevant ones for ewes and lambs in the different management systems (see Tables 3 and 4), as well as the risk factors giving rise to these welfare problems and the exposure assessment for different systems (see Tables 5-16 and Appendix F).

By ranking the welfare consequences the most important ones for ewes and lambs were identified within each management system by using a calculated impact score (see Figures 5 and 6). This was achieved in 2 steps:

1. The raw impact score was calculated by multiplying the prevalence and severity ratings, standardised between 0 and 1. The ratings were: 1) the affected population proportion (prevalence percentages were converted to a score between 0 and 1), and 2) the severity classification (the four classes: none, low, medium and high were assigned ordinal values of 0, 0.33, 0.66, 1).

2. In a second step the degree of uncertainty was included in the impact score. The prevalence rating was assigned a weight according to the probability interval corresponding to the uncertainty rating. Therefore, the uncertainty rating (low (L) +/– 12.5 %; medium (M) +/– 25 %; high (H) +/– 50 %) was translated into the accountable probability mass of L: 2X0.125, M: 2X0.25, H: 2X0.5 and the corresponding rating weighed with the respective likelihood of observing any particular value. This uncertainty corrected prevalence value was multiplied by the severity rating to give an uncertainty corrected impact score:

Uncertainty corrected impact score = (severity rating) X (prevalence rating)/(accountable probability mass)
= (severity rating) X (prevalence rating)/(2X0.125X{L=1; M=2;H=4}).

For example, a welfare consequence with a prevalence of 30 %, medium uncertainty (±25 %) and a medium severity (2) will have a raw impact score of 0.3X0.66=0.2; and an uncertainty corrected impact score of (0.66X0.3)/(2X0.125X2)=0.4.

For sensitivity evaluation three different methods of data aggregation were applied and the resulting ranking of consequences provided: 1) average of raw impact score values, 2) median of raw impact score values, and 3) average of uncertainty corrected impact score values, presented in the Appendix E, with results of the third approach summarised in the following main text.

Figure 5 shows for ewes the most important welfare consequences resulting from online survey (see also black cells of Table 3); the three highest scored welfare consequences in each management system plus the ones that could not be excluded as being clearly different from the top three (see score diagrams in Appendix E). In addition, Table 3 shows for ewes in each management system the next highest scored welfare consequences (grey cells).

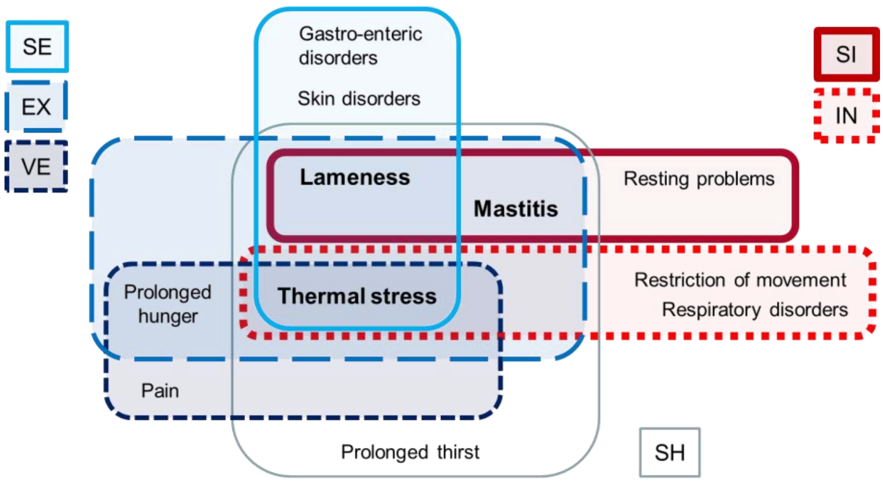


Figure 5: Most important welfare consequences identified for ewes, according to the online survey, for the management systems represented by different boxes (SH: shepherding; IN: Intensive; SI: Semi-intensive; SE: Semi-extensive; EX: Extensive; VE: Very extensive; see Table 2 and Appendix C for definition). Welfare consequences ranking highest across the management systems (bold text) are overlapped by multiple boxes. These data are equivalent to the black cells in Table 3 (ewes) for each management system reflecting three welfare consequences with the highest impact scores supplemented with additional consequences that could not be excluded as being clearly different from the top three.

Table 3: Most relevant welfare consequences identified for ewes by management system according to the online survey. The cells of the table are coloured for consequences with highest uncertainty corrected impact score: Black cells (black+grey cells) identify per management system those three (five) welfare consequences with the highest impact scores (black cells) plus the ones that could not be excluded as being clearly different (grey cells) from the top three (five) (SH: shepherding; IN: Intensive; SI: Semi-intensive; SE: Semi-extensive; EX: Extensive; VE: Very extensive; see Table 2 and Appendix C for definition).

Consequences	SH	IN	SI	SE	EX	VE
Good feeding						
Prolonged hunger						
Prolonged thirst						
Good housing and environment						
Thermal stress						
Restriction of movement						
Resting problems						
Good health						
Mastitis						
Lameness						
Gastro-enteric disorders						
Skin disorders						
Respiratory disorders						
Reproductive disorders						
Pain						
Appropriate behaviour						
Chronic fear						

Figure 6 shows for lambs the most important welfare consequences resulting from online survey (see also black cells of Table 4); the three highest scored welfare consequences in each management system plus the ones that could not be excluded as being clearly different from the top three (see score diagrams in Appendix E). In addition, Table 4 shows for lambs in each management system the next highest scored welfare consequences (grey cells).

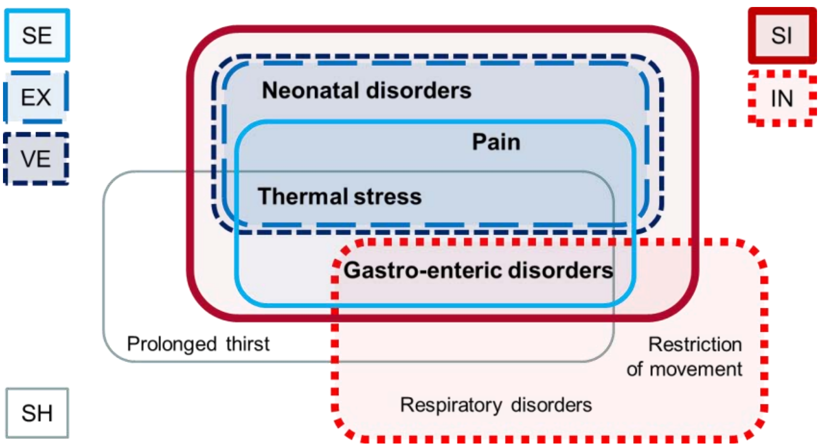


Figure 6: Most important welfare consequences identified for lambs, according to the online survey, for the management systems represented by different boxes (SH: shepherding; IN: Intensive; SI: Semi-intensive; SE: Semi-extensive; EX: Extensive; VE: Very extensive; see Table 2 and Appendix C for definition). Consequences ranking highest across the management systems (bold text) are overlapped by multiple boxes. These data are equivalent to the black cells in Table 4 (lambs) for each management system reflecting three welfare consequences with the highest impact scores supplemented with additional consequences that could not be excluded as being clearly different from the top three.

Table 4: Most relevant welfare consequences identified for lambs by management system according to the online survey. The cells of the table are coloured for consequences with highest uncertainty corrected impact score: Black cells (black+grey cells) identify per management system those three (five) consequences with the highest impact scores (black cells) plus the ones that could not be excluded as being clearly different (grey cells) from the top three (five). (SH: shepherding; IN: Intensive; SI: Semi-intensive; SE: Semi-extensive; EX: Extensive; VE: Very extensive; see Table 2 and Appendix C for definition).

Consequences	SH	IN	SI	SE	EX	VE
Good feeding						
Prolonged hunger						
Prolonged thirst						
Good housing and environment						
Thermal stress						
Restriction of movement						
Resting problems						
Good health						
Lameness						
Gastro-enteric disorders						
Skin disorders						
Respiratory disorders						
Neonatal disorders						
Pain						
Appropriate behaviour						
Chronic fear						

Ewes

Across all the management systems the most frequently identified important welfare consequences for ewes were thermal stress, lameness and mastitis. Prolonged hunger was assessed to be more frequent in EX and VE management systems. These differ in importance in different management systems.

Mastitis was reported as an important welfare consequence in all management systems, except in semi-extensive and very extensive systems. The reason for this is because mastitis is more frequent in sheep maintained for milk purposes, and these animals are not managed in very extensive conditions. However, for ewes kept under more extensive systems and never milked the consequence of mastitis may not be detected or underestimated.

Gastro-enteric disorders were considered important in semi-extensive and semi-intensive management systems, while skin disorders were highlighted only for semi-extensive. Parasites causing gastro-enteric and skin disorders are present in pasture. Therefore, lower stocking density in extensive systems reduces level of challenge whilst intensive management systems allow a closer and permanent supervision of the animals.

Lambs

For lambs, there were few differences among management systems with thermal stress, pain due to management procedures, gastro-enteric disorders and neonatal disorders rated as the main welfare consequences. Respiratory disorders were rated to be more frequent in IN management systems, and, to a lesser extent, in SI and SH systems.

Neonatal disorders and pain were judged to be a major welfare consequence for lambs kept under all management systems, except shepherding, where the number of respondents was low.

3.1.4.1. Main welfare consequences and the associated risk factors within management systems and production purposes for ewes and lambs

The main welfare consequences summarised in this section are derived from Tables 3 and 4, and are linked to the principal risk factors presented in Tables 5-16.

The welfare consequences per production purpose are described only in the management systems with sufficient number of respondents of different production purpose.

The risk factors shown in Tables 5-16 are those which were identified as most important for that welfare consequence in each of the management system during the technical hearing meeting, utilising suggestions arising from online survey.

Table 5: The main welfare consequences, ranked by the uncertainty corrected impact score, and their associated risk factors for ewes kept under shepherding, based on the expert opinion.

EWES – SHEPHERDING		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
Top three consequences plus the ones not clearly different	Thermal stress	Lack of shade/shelter/bedding Extreme climate
	Prolonged thirst	Hot and dry summer Lack of access to water
	Mastitis (genotype susceptibility)	All production purposes Poor udder hygiene (related to flooring, resting) Teat lesions Inappropriate management of the ewes at drying-off Sheep for milk Poor udder hygiene (related to milking) Inappropriate milking procedure Udder conformation in relation to machine milking Maintenance of milking system
	Lameness	Pasture conditions (rough vegetation and wet and stony soil) Poor biosecurity (introduction of contaminated animals) Improper hoof care (lack of, or incorrect, treatment when needed)
Top five consequences plus the ones not clearly different	Prolonged hunger	Poor pasture quality Lack of supplementary feed
	Reproductive disorders (including dystocia and metritis)	Poor lambing intervention Nutrition (toxaemia, hypocalcaemia) High pathogen loading Inappropriate breeding (e.g. large lambs or litter size)
	Chronic fear	Predation Presence of dogs Lack of exposure and acclimation to perceived threats (e.g. human handling)

Table 6: The main welfare consequences, ranked by the uncertainty corrected impact score, and their associated risk factors for ewes kept in intensive systems, based on the expert opinion.

EWES - INTENSIVE SYSTEMS		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
Top three consequences plus the ones not clearly different	Restriction of movement	Increased stocking density Poor housing conditions (e.g. flooring)
	Thermal stress	Inappropriate housing (micro-environment, ventilation) Stocking density (overcrowding) Extreme climate Delay in shearing
	Respiratory disorders	Poor air quality (micro-environment, ventilation, stocking density, ammonia level) Increased exposure to pathogen (poor hygiene, resistant pathogen strains) Reduced immune competence (inadequate vaccination and anti-parasitics)
Top five consequences plus the ones not clearly different	Mastitis (genotype susceptibility)	<u>All production purposes</u> Poor udder hygiene (related to flooring, resting) Teat lesions Inappropriate management of the ewes at drying-off <u>Sheep for milk</u> Poor udder hygiene (related to milking) Inappropriate milking procedure Udder conformation in relation to machine milking Maintenance of milking system
	Lameness	Improper hoof care (incorrect trimming) Inappropriate nutrition (sub-acute ruminal acidosis-SARA) Poor flooring (poor litter quality or plastic, slatted floor causing lameness)

Table 7: The main welfare consequences, ranked by the uncertainty corrected impact score, and their associated risk factors for ewes kept in semi-intensive systems, based on the expert opinion.

EWES – SEMI- INTENSIVE SYSTEMS		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
Top three consequences plus the ones not clearly different	Resting problem	Inadequate space available when housed Floor and bedding quality
	Mastitis (genotype susceptibility)	<u>All production purposes</u> Poor udder hygiene (related to flooring, resting) Teat lesions Inappropriate management of the ewes at drying-off <u>Sheep for milk</u> Poor udder hygiene (related to milking) Inappropriate milking procedure Udder conformation in relation to machine milking Maintenance of milking system
	Lameness	Improper hoof care (incorrect trimming) Poor biosecurity (introduction of contaminated animals) Inappropriate nutrition (sub-acute ruminal acidosis-SARA, mineral deficiency and excess of protein at grazing)
Top five consequences	Gastro-enteric disorders (including infections,	Poor pasture and grazing management Anthelmintic-resistant parasites

EWES – SEMI- INTENSIVE SYSTEMS		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
plus the ones not clearly different	endoparasites or toxins)	Improper feed (transition and excess of proteins)
	Thermal stress	Inappropriate housing (micro-environment, ventilation) Stocking density (overcrowding) Delay in shearing Lack of shade/shelter when outdoors

Table 8: The main welfare consequences, ranked by the uncertainty corrected impact score, and their associated risk factors for ewes kept in semi-extensive systems, based on the expert opinion.

EWES – SEMI-EXTENSIVE SYSTEMS		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
Top three consequences plus the ones not clearly different	Lameness	Soil conditions (wet and stony) Poor biosecurity (introduction of contaminated animals) Improper hoof care (lack of, or incorrect, treatment when needed)
	Gastro-enteric disorders (including infections, endoparasites or toxins)	Poor pasture and grazing management Anthelmintic-resistant parasites Chronic diseases (e.g. pulmonary tuberculosis)
	Thermal stress	Extreme climate Lack of shade/shelter Winter shearing
	Skin disorders (including infections, allergens, ectoparasites)	Poor biosecurity (introduction and transmission of ectoparasites) Lack of preventive measures (e.g. dipping) Nutritional photosensitisation
Top five consequences plus the ones not clearly different	Pain (including that due to management procedures such as castration, tail docking and shearing)	Tail-docking Ear notching-poor practice when ear tagging or use of inappropriate tags Mulesing (Australia only) Poor handling

Table 9: The main welfare consequences, ranked by the uncertainty corrected impact score, and their associated risk factors for ewes kept in extensive systems, based on the expert opinion.

EWES – EXTENSIVE SYSTEMS		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
Top three consequences plus the ones not clearly different	Thermal stress	Extreme climate Lack of shade/shelter Winter shearing
	Prolonged hunger	Poor pasture quality Lack of supplementary feed
	Lameness	Soil conditions (wet and stony) Improper hoof care (lack of treatment when needed) Inappropriate nutrition (mineral deficiency)
	Mastitis (genotype susceptibility)	<u>All production purposes</u> Teat lesions Inappropriate management of the ewes at drying-off Poor udder hygiene (related to suckling and resting)
Top five consequences	Prolonged thirst	Hot and dry summer Lack of access to water

EWES – EXTENSIVE SYSTEMS		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
plus the ones not clearly different	Respiratory disorders	Lack of preventative measures (vaccination, anti-parasitics) Reduced immune competence (inadequate vaccination and anti-parasitics)
	Skin disorders (including infections, allergens, ectoparasites)	Lack of preventative measures (e.g. dipping) Micronutrient deficiency Nutritional photosensitisation

Table 10: The main welfare consequences, ranked by the uncertainty corrected impact score, and their associated risk factors for ewes kept in very extensive systems, based on the expert opinion.

EWES – VERY EXTENSIVE SYSTEMS		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
Top three consequences plus the ones not clearly different	Prolonged hunger	Poor pasture quality Lack of supplementary feed
	Thermal stress	Extreme climate Lack of shade/shelter Winter shearing
	Pain (including that due to management procedures such as castration, tail docking and shearing)	Tail-docking Ear notching-poor practice when ear tagging or use of inappropriate tags Mulesing (Australia only) Poor handling
Top five consequences plus the ones not clearly different	Chronic fear	Predation Lack of exposure and acclimation to perceived threats (e.g. human handling)
	Lameness	Inappropriate nutrition (mineral deficiency) Soil conditions (wet and stony) Improper hoof care (lack of treatment when needed)
	Skin disorders (including infections, allergens, ectoparasites)	Lack of preventative measures (e.g. dipping) Micronutrient deficiency Nutritional photosensitisation

3.1.4.2. Main welfare consequences and risk factors within management systems and production purposes for lambs

Similarly to the above section on ewes (see Tables 5 to 10), in the following Tables 11 to 16 risk factors and welfare consequences ranked by their average impact score corrected by uncertainty are presented for all management systems for lambs.

Table 11: The main welfare consequences, ranked by the uncertainty corrected impact score, and their associated risk factors for lambs kept in shepherding, based on the expert opinion.

LAMBS – SHEPHERDING		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
Top three consequences plus the ones not clearly different	Thermal stress	Lack of shade/shelter/bedding Extreme climate Feed quality and availability during cold weather Genotype unable to cope with heat
	Prolonged thirst	Hot and dry summer Lack of access to water Reduced sucking opportunities
	Gastro-enteric disorders	Reduced immune competence (inadequate colostrum,

LAMBS – SHEPHERDING		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
	(including infections, endoparasites or toxins)	vaccination and anti-parasitics) Increased exposure (stocking density, hygiene) to pathogen (parasites, bacteria) Malnutrition (lack of nutrients, proteins, fibre)
Top five consequences plus the ones not clearly different	Lameness	Pasture conditions (rough vegetation and wet and stony soil) Poor biosecurity (introduction of contaminated animals Inappropriate nutrition (mineral deficiency) Soil conditions (wet and stony)
	Respiratory disorders	Poor air quality (micro-environment, ventilation, stocking density, ammonia level) Increased exposure to pathogen (poor hygiene, resistant pathogen strains) Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics)

Table 12: The main welfare consequences, ranked by the uncertainty corrected impact score, and their associated risk factors for lambs kept in intensive systems, based on the expert opinion.

LAMBS – INTENSIVE SYSTEMS		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
Top three consequences plus the ones not clearly different	Respiratory disorders	Poor air quality (micro-environment, ventilation, stocking density, ammonia level) Increased exposure to pathogen (poor hygiene, resistant pathogen strains) Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics)
	Restriction of movement	Increased stocking density Poor housing conditions (e.g. flooring)
	Gastro-enteric disorders (including infections, endoparasites or toxins)	Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics) Increased exposure (stocking density, hygiene) to pathogen (parasites, bacteria) Unbalanced diet (frequency concentrate supply, lack of fibre)
Top five consequences plus the ones not clearly different	Thermal stress	Inappropriate housing (micro-environment, ventilation) Stocking density (overcrowding) Extreme climate
	Pain	Ear notching-poor practice when ear tagging or use of inappropriate tags Poor handling Castration Tail-docking
	Neonatal disorders (including starvation/mis-mothering/exposure complex)	Deficiency of ewe nutrition during pregnancy Dystocia Prolificity Mis-mothering due to crowding or ewe stress at parturition

Table 13: The main welfare consequences, ranked by the uncertainty corrected impact score, and their associated risk factors for lambs kept in semi-intensive systems, based on the expert opinion.

LAMBS – SEMI-INTENSIVE SYSTEMS		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
Top three consequences	Pain (including that due to management procedures such	Ear notching-poor practice when ear tagging or use of inappropriate tags

plus the ones not clearly different	as castration, tail docking and shearing)	Poor handling
	Gastro-enteric disorders (including infections, endoparasites or toxins)	Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics) Increased exposure (stocking density, pasture management, hygiene) to pathogen (parasites, bacteria) Unbalanced diet (frequency concentrate supply, lack of fibre)
	Thermal stress	Inappropriate housing (micro-environment, ventilation) Stocking density (overcrowding) Lack of shade/shelter outdoors
	Neonatal disorders (including starvation/mis-mothering/exposure complex)	Deficiency of ewe nutrition during pregnancy Dystocia Prolificity
Top five consequences plus the ones not clearly different	Resting problems	Inadequate space available when housed Floor and bedding quality
	Respiratory disorders	Poor air quality (micro-environment, ventilation, stocking density, ammonia level) Increased exposure to pathogen (poor hygiene, resistant pathogen strains) Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics)

Table 14: The main welfare consequences, ranked by the uncertainty corrected impact score, and their associated risk factors for lambs kept in semi-extensive systems, based on the expert opinion.

LAMBS – SEMI-EXTENSIVE SYSTEMS		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
Top three consequences plus the ones not clearly different	Pain (including due to management procedures such as castration, tail docking and shearing)	Castration Tail-docking Ear notching-poor practice when ear tagging or use of inappropriate tags
	Gastro-enteric disorders (including infections, endoparasites or toxins)	Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics) Increased exposure (stocking density, pasture management, hygiene) to pathogen (parasites, bacteria) Malnutrition (lack of nutrients, proteins, fibre) and unbalanced diet (frequency concentrate supply, lack of fibre)
	Thermal stress	Lack of shade/shelter/bedding Extreme climate Feed quality and availability during cold weather Genotype unable to cope with heat
Top five consequences plus the ones not clearly different	Skin disorders (including infections, allergens, ectoparasites)	Poor biosecurity (introduction and transmission of ectoparasites) Lack of preventive measures (e.g. dipping) Nutritional photosensitisation
	Neonatal disorders (including starvation/mis-mothering/exposure complex)	Deficiency of ewe nutrition during pregnancy Dystocia Prolificity

Table 15: The main welfare consequences, ranked by the uncertainty corrected impact score, and their associated risk factors for lambs kept in extensive systems, based on the expert opinion.

LAMBS – EXTENSIVE SYSTEMS		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
Top three consequences plus the ones not clearly different	Thermal stress	Lack of shade/shelter/bedding Extreme climate Feed quality and availability during cold weather Genotype unable to cope with heat
	Pain (including that due to management procedures such as castration, tail docking and shearing)	Castration Tail-docking Ear notching-poor practice when ear tagging or use of inappropriate tags
	Neonatal disorders (including starvation/mis-mothering/exposure complex)	Lack of shelter (exposure to rain and wind) Deficiency of ewe nutrition during pregnancy Dystocia
Top five consequences plus the ones not clearly different	Chronic fear	Presence of dogs Predation Lack of exposure and acclimation to perceived threats (e.g. human handling)
	Prolonged thirst	Hot and dry summer Lack of access to water
	Skin disorders (including infections, allergens, ectoparasites)	Lack of preventive measures (e.g. dipping) Micronutrient deficiency Nutritional photosensitisation
	Gastro-enteric disorders (including infections, endoparasites or toxins)	Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics) Increased exposure (pasture management, hygiene) to pathogen (parasites, bacteria) Malnutrition (deficient trace elements, toxic plants)

Table 16: The main welfare consequences, ranked by the uncertainty corrected impact score, and their associated risk factors for lambs kept in very extensive systems, based on the expert opinion.

LAMBS – VERY EXTENSIVE SYSTEMS		
Main welfare consequences according to the average uncertainty corrected impact score		**Risk factors leading to the welfare consequence**
Top three consequences plus the ones not clearly different	Pain (including that due to management procedures such as castration, tail docking and shearing)	Castration Tail-docking Ear notching-poor practice when ear tagging or use of inappropriate tags
	Thermal stress	Lack of shade/shelter Extreme climate Feed quality and availability during cold weather Genotype unable to cope with heat
	Neonatal disorders (including starvation/mis-mothering/exposure complex)	Lack of shelter (exposure to rain and wind) Deficiency of ewe nutrition during pregnancy Dystocia
Top five consequences plus the ones not clearly different	Gastro-enteric disorders (including infections, endoparasites or toxins)	Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics) Increased exposure (pasture management, hygiene) to pathogen (parasites, bacteria) Malnutrition (deficient trace elements, toxic plants)
	Prolonged hunger	Poor pasture quality Lack of supplementary feed
	Resting problems	Wet, boggy or stony pasture

	Chronic fear	Presence of dogs Predation Lack of exposure and acclimation to perceived threats (e.g. human handling)

A comparison of the risk factors associated with each main welfare consequence for ewes and lambs kept in the different management systems is given in Appendix F.

3.1.5. Expert discussion during technical meeting

A common comment from the experts was that geographical differences between the risk factors for a given management system existed. For example, lameness due to infection was identified as a significant welfare consequence for lambs at pasture in northern Europe (semi-extensive system) but was not considered a major problem in southern Europe with drier climate. In the survey lameness in semi-extensive system was given greater emphasis by practitioners than by academics respondents.

Experts highlighted the fact that the prevalence of some welfare consequences may be underestimated in extensive systems because of lack of routine inspections. The impact of chronic-viral diseases, such as Maedi-visna and viral mastitis and viral respiratory diseases on welfare were underestimated. In addition, the experts felt that these chronic diseases may predispose animals to other welfare consequences or bacterial diseases.

The experts emphasised the importance of management and stockmanship within all systems in alleviating the risks for poor welfare. The mitigation option for stockpeople to accomplish good welfare was much greater in more intensive systems where frequent contact and greater control was possible. In extensive systems, natural environmental conditions were therefore more influential.

Although in this opinion the definition of lamb includes all the animals from birth to slaughter or for recruitment for breeding, the experts reported that there are differences between the management of lambs destined for meat or breeding and as a consequence the risk factors and welfare consequences are different. In addition, lambs were reported to be classified into three categories: birth to three days of age as neonatal, up to weaning as young lambs and weaning to slaughter as fattening lambs.

Whilst it is accepted that each of the issues is important in the consideration of sheep welfare, it was not possible to address this level of detail in the current scoping exercise. However, if future opinions build on this work, these should be taken into consideration.

3.2. Addressing ToR 3 of the mandate

A small number of ABMs for sheep have already been validated and assessed for repeatability, e.g. lameness (Kaler and Green, 2009) and body condition score (Verbeek et al., 2012b; Phythian et al., 2012a). The AWIN Project is currently validating a number of ABMs for extensive and intensive management system for adult animals.

However, ABMs are likely to be a direct reflection of the actual welfare state and they permit to evaluate the welfare by directly observing the animal, regardless of how and where it is kept. Therefore, they are applicable to all management systems; although the nature of extensive systems may limit some types of measures being readily applied (e.g. those requiring close contact or monitoring of animals). In addition, some measures have been developed and tested in young lambs (Phythian et al., 2013a).

Based on these different sources of information Tables 17 and 18 describe the ABMs for ewes and lambs for each welfare consequence.

3.2.1. Feeding

3.2.1.1. Prolonged hunger

Ewes

Body condition score (BCS) is a method of assessing back fat through palpation of the lumbar spine, on a scale of 0 (emaciated) to 5 (obese; Russell et al., 1969) is widely used in both farming practice and experimental settings to monitor fatness and as a measure of hunger (Morgan-Davies et al., 2008; Caroprese et al., 2009b; Napolitano et al., 2009; Stubsjøen et al., 2011; Phythian et al., 2012a). Recent research to validate the use of BCS experimentally as an indicator of hunger has shown that BCS is associated with feed motivation in ewes (Verbeek et al., 2012a), a reduced ability to respond to cold challenge (Verbeek et al., 2012b) and is a predictor of ewe survival through the winter (Morgan-Davies et al., 2008). Although for on-farm nutritional management of ewes BCS may be assessed to quarter points, for welfare assessment with trained assessors better repeatability and reproducibility has been found for scores as full and half points (Stubsjøen et al., 2011; Phythian et al., 2012a). For welfare assessment the main aim is to discriminate animals that are too thin or too fat from ewes that are of an adequate body composition (generally between 2.5 and 4 on the BCS scale). Therefore, the AWIN project uses a simplified version: emaciated (A), thin (B), ok (C) and fat (D) which has shown very good agreement between assessors (Ruiz et al., 2014).

Tooth loss is the assessment of the presence and condition of molar and incisor teeth, which can act as predictors for the likelihood that ewes will subsequently show a decline in BCS. Tooth loss was considered a valid indicator of hunger from expert opinion (AWIN). In AWIN studies, tooth loss is scored on a three-point scale (full mouth where all teeth are present; minor tooth loss, where only non-vital teeth are missing; significant tooth loss where any vital teeth are missing or more than two non-vital teeth are missing; whether the bite is correct i.e. vital teeth meet the hard palate) and is highly correlated with BCS. Repeatability and reproducibility of tooth loss scores is also very high (AWIN, unpublished data). This is likely to be very important, particularly the loss of vital teeth, in animals that rely on grazing to obtain the bulk of their nutritional intake as this will be severely impaired without these teeth present. Thus this measure is relevant in SH, SI, SE, EX, VE, but whether this is as important in IN and circumstances of concentrate supplementation where there is little grazing, is not known.

Lambs

Evaluation of body condition, which involves visual inspection and palpation over the iliac crest, ribs and sternum to determine fat and muscle cover, has been suggested as a more appropriate method to assess body condition in lambs (Phythian et al., 2013a), An “appropriate” body condition describes a situation where the skeletal structures were distinguishable but not sharp or prominent, whereas an “inappropriate” body condition is characterised by poor cover and prominent bones. This measure has face validity but has not been addressed experimentally. Reproducibility is good (Fleiss κ0.7; Phythian et al., 2013a) but age may be a confounding factor because the body conformation changes.

Visual inspection of gut fill (also used by Phythian et al., 2013a) may also be relevant for assessing either bloating (defined as ballooning of the flank, which may indicate gastro-enteric disease) or a hollow, sunken abdominal appearance likely to indicate poor gut fill. However, observer agreement for this measure was only moderate, and this may not always indicate hunger *per se* but could be related to other health issues in the lamb (see below for metabolic disease and gastro-intestinal disorders).

3.2.1.2. Prolonged thirst

Ewes and lambs

For both ages of sheep there are no reliable and tested ABMs for this welfare consequence which, in AWIN as in WQ®, is assessed primarily by resource-based measures. Although skin pinch tests have been used in other species (e.g. horses) this is not feasible in sheep. Other measures include assessment of *eye condition* with sunken eyes believed to indicate dehydration. This measure still requires validation and testing for reliability.

3.2.2. Housing/environment

3.2.2.1. Resting problem

Ewes and lambs

Coat cleanliness has been used by a number of studies, including AWIN, as a welfare measure (Caroprese et al., 2009a; Napolitano et al., 2009; Stubsjøen et al., 2011). A soiled or wet fleece can indicate there is insufficient dry lying area for all sheep to lie in comfort, and a wet coat can also be a cause of physical and thermal discomfort. Validation of the measure is currently restricted to expert opinion (Phythian et al., 2011) and face validity. The AWIN project scores sheep on a 5-point scale as: 1 (clean and dry); 2 (dry or only slightly damp because of current weather conditions, slight mud or dirt that may have been acquired during recent handling in pens); 3 (very damp or wet, coat contaminated with mud or dung from fields); 4 (very wet, heavily soiled in mud or dung); 5 (filthy, the animals is completely soiled in mud or dung). This ABM can be readily assessed both in handled animals and at a distance when undisturbed animals are at pasture and observer reproducibility for coat cleanliness is very good (Napolitano et al., 2009; Phythian et al., 2012b; AWIN unpublished data).

Lying behaviour can also indicate whether sheep are able to lie in comfort, and the proportion of sheep lying and lying time has been suggested by some authors (Bøe et al., 2006; Pines et al., 2007) to indicate resting comfort, although this is largely only relevant to housed sheep. Assessment of the validity and repeatability of this measure requires further work.

3.2.2.2. Thermal stress

Ewes

Panting and an elevated respiration rate as a measure of thermal discomfort has been reviewed (Cockram, 2004) and has been assessed by several studies (Lowe et al., 2002; Caroprese et al., 2009a; Phythian et al., 2012b), including AWIN. Open-mouthed panting is an obvious expression of severe thermal distress, but increase in respiration rate is also seen with increased thermal load and indicates elevated effort to dissipate heat. Sheep also show a typical behaviour where animals stand in close proximity with heads together and lowered when hot; however, the occurrence of this posture has not been validated as a measure of thermal stress. However, this measure does occur at low rates, which has precluded assessment of repeatability and reproducibility in experimental studies.

Shivering is a visible expression of the physiological response to cold stress, and the main adaptation used to respond to cold stress in sheep. However, adult sheep with adequate fleece cover can have a very low thermal threshold to elicit shivering (less than 0 °C in fully fleeced adult sheep, although it is considerably higher in shorn animals; Terrill and Slee, 1991), and this was discounted in the AWIN project as it occurred at such a low rate as to be unobservable. Other studies also do not appear to include this measure.

Lambs

Panting and an elevated respiration rate are also seen in thermally stressed lambs. However, this does not appear to have been used in any assessment scheme to look at the welfare of lambs.

Shivering is more common in lambs than in adult sheep and, after the initial perinatal period, the main heat generation mechanism of young lambs. Shivering (defined as observable rapid muscular contractions and/or trembling) has been used in welfare assessment of young lambs and shows good inter-observer reliability (reproducibility) and specificity (Phythian et al., 2013a).

Huddling behaviour, as seen in other young animals such as pigs, or lying in close proximity to other young animals, is also seen in lambs. However, it is not clear if this represents a mechanism to deal with low temperatures or social facilitation and has not been validated for lambs. Lambs also lie in contact with their mothers when resting, and tend to lie to the leeward side of their mother where she can act as a shelter from windchill. However, overall lying behaviour of lambs has not been investigated with a view to acting as a measure of thermal stress.

3.2.2.3. Restriction of movement

Ewes

Displacements, high movement activity and an increased frequency of social interactions have been shown to occur in ewes housed at high stocking density or with limited space allowance (Averós et al., 2014a, b) where movement and resting may be restricted, suggesting these are valid ABMs for space restriction in sheep. The reliability and feasibility of these measures for on-farm welfare assessment are still being tested in AWIN. In lambs, high movement activity and frequency of social interactions may also indicate restricted movements. However, these have not been studied.

Hoof overgrowth has also been suggested as a measure of restriction of movement in sheep (Caroprese et al., 2009b; Napolitano et al., 2009). For welfare assessment this may be relevant in housed animals where it has good reproducibility and can be readily assessed (Napolitano et al., 2009), but can also indicate lack of wear because of lameness in some conditions (Abbott and Lewis, 2005). Studies of repeatability and feasibility at pasture have not been conducted.

3.2.3. Health

3.2.3.1. Lameness

Ewes

Locomotion or gait scores for sheep have been developed by several authors mainly using numerical rating scales (Welsh et al., 1993; Otto et al., 2000; Guedes et al., 2006; Hemsworth et al., 2009; Kaler and Green, 2009; Colditz et al., 2011; Reader et al., 2011), and good association with foot lesions has been reported suggesting these are valid indicators of lameness for sheep. The score of Kaler and Green (2009) has 7 points ranging from 0 (normal locomotion) to 6 (unable to move and stand), and has high inter- and intra-observer reliability. Although this score is accurate for experimental purposes, in practice for welfare assessment there is not always a flat concrete surface on which to assess gait. Therefore, for AWIN, a modified version with only 4 points was used (0 = even weight bearing or shortened stride on one side without head nodding; 1 = visible shortening of the gait accompanied by head nodding or flicking; 2 = unable to bear weight on the foot when standing, discomfort when moving; 3 = more than 1 limb affected or inability to stand or move) which could be scored with good observer repeatability and reproducibility both in the field and whilst handling (Phythian et al., 2012b; AWIN, unpublished data).

Lambs

In lambs, lameness assessments could use a similar locomotion score as for ewes. However, these have been conducted in only one study (Phythian et al., 2013a) using a 1-0 scale where lameness was classified as one or a combination of measures (three-legged gait, holding foot off the ground, a stiff or stilted gait, head nodding whilst walking, a large and inflamed joint). This scale had good inter-observer reliability and specificity.

3.2.3.2. Injuries

Ewes and lambs

Clinical assessment of the presence of injuries to eyes, body and legs have been reported in several studies (Caroprese et al., 2009b; Napolitano et al., 2009; Lovatt, 2010; Stubsjøen et al., 2011; Phythian et al., 2012b) and used in the AWIN protocol. Injuries, damage or alterations to ears are considered under "Pain due to management procedures", and to skin are considered under "Skin disorders", so will not be discussed here. In all assessments, the presence of any concurrent or healing eye damage or discharge is scored on a presence/absence scale for each eye and has good inter-observer reliability. For lambs in particular, eye condition has very high inter-observer reliability (Phythian et al., 2013a). Injuries to legs are recorded as evidence of lesions or callus (hairless patches, lesions or swellings on knees or hocks and has only moderate observer agreement (κ = 0.40-0.46; Stubsjøen et al., 2011; Phythian et al., 2012b).

3.2.3.3. Skin disorders (including infections, allergens, ectoparasites)

Ewes

Skin or integument condition (presence of lesions or irritation) and fleece quality have been reported in several welfare assessment studies (Caroprese et al., 2009b; Napolitano et al., 2009; Phythian et al., 2011, 2012b; Stubsjøen et al., 2011; AWIN, unpublished data). Fleece quality can be assessed from a distance for even coverage with no significant loss or shedding. A reduced staple-strength and increased wool shedding has been shown to be associated with nutritional stress and elevated circulating cortisol (Schlink et al., 2002) suggesting fleece loss is a valid indicator of reduced welfare. At close quarters the fleece can be parted and further inspected for lumpiness, scurf, bald or rubbed patches and evidence of ectoparasites or maggot infestation (myiasis). The reproducibility of assessments of skin condition vary between studies with some reporting excellent agreement (e.g. Stubsjøen et al., 2011) and others low to moderate agreement (Phythian et al., 2012b; although specific scoring of myiasis had very good agreement), which may reflect generally a low incidence of poor skin condition.

Lambs

There are no published studies investigating the scoring or reliability of these measures in lambs. Although fleece quality is likely to be influenced by lamb breed and age, the presence of skin lesions, ectoparasites, and myiasis can also be assessed in young lambs.

3.2.3.4. Respiratory disorders

Ewes

Nasal discharge has face validity and has been suggested by expert opinion as a welfare indicator in sheep (Phythian et al., 2011). It is scored as present/not present, when used in the AWIN protocol, with good reproducibility.

Respiration quality (e.g. breathing normal, hampered respiration, coughing or obviously noisy/"rattly" breaths) is also used in the AWIN protocol and coughing has been reported in others studies (Lovatt, 2010; Stubsjøen et al., 2011; Phythian et al., 2012b). The measures have face validity only and have not been tested experimentally for agreement with underlying conditions. In general, this measure occurs at low incidence which makes assessment of inter-observer reliability difficult.

Lambs

There are no published studies investigating the scoring or reliability of these measures in lambs. However, the presence of nasal discharge and respiration quality can also be readily assessed in young lambs (preliminary AWIN data).

3.2.3.5. Gastro-intestinal disorders (including infections, endoparasites or toxins)

Ewes

Dag score (a score of breech soiling) is used in some studies (Phythian et al., 2012b) and in AWIN as a potential measure of endoparasites (as it shows good correlation with faecal egg counts in AWIN studies; unpublished data), and as a risk factor for myiasis. Animals are scored on the degree of breech soiling from 0 (no soiling) to 4 (extensive soiling and lumps of faecal material or dags extending to the hocks) with good inter- and intra-observer reliability (Phythian et al., 2012b; Ruiz et al., 2014).

Mucosa colour, using the FAMACHA© (Faffa Malan chart) anaemia guide, can determine where animals have pale mucosa which can indicate the presence of some blood-feeding endoparasites (e.g. *Haemonchus contortus* or liver fluke), and have been validated against red blood cell counts (Kaplan et al., 2004; Lovatt, 2010). In the AWIN project this measure has moderate to good inter- and intra-observer reliability.

Lambs

There are no published studies investigating the scoring or reliability of these measures in lambs. However, dag scoring can be readily assessed in young lambs (preliminary AWIN data), and assessment of mucosa colour is also possible.

Gut fill has been assessed in young lambs both visually and with palpation (Phythian et al., 2013a). Distension or ballooning of the abdomen and flank may indicate gastro-enteric disorders in lambs, and has good inter-observer reliability and specificity.

3.2.3.6. Metabolic disorders (e.g. acidosis and ketosis)

Ewes and Lambs

To date, no studies have suggested ABMs to specifically assess these disorders without collection of blood samples (e.g. to determine β-hydroxy butyrate concentration). Although not specific to these disorders, assessment of *animal demeanour, or Qualitative Behavioural Assessment* (QBA), may be a useful measure for animals that may be experiencing ill health and can be further investigated with physiological assessments. Demeanour or QBA assessments have been developed for sheep in the AWIN project and show excellent inter- and intra-observer reliability in adult sheep (Phythian et al., 2013b; Richmond et al., 2014) and in lambs (Phythian et al., 2013a), and to correlate with other welfare measures (preliminary AWIN data).

In both ewes and lambs, bloated rumen can be defined as abdominal distension primarily occurring on the left side of the animal (where the rumen is located), but with the progression of the disease the entire abdomen can become distended. Although no studies on inter- and intra-observer reliability are available, the clinical signs can be easily identified. As the disease is characterised by a short course, when available the measure should be taken from farm records, particularly for animals kept in extensive conditions where, because sheep are not observed frequently, bloat is usually detected under the form of sudden death.

3.2.3.7. Reproductive disorders (including dystocia and metritis)

Ewes

Farm records of abortion and dystocia incidence and presence of *vaginal discharge* can act as measures of reproductive disorders. These data are difficult to collect during inspection visits and rely on farmer records for their assessment.

3.2.3.8. Mastitis

Ewes

Udder consistency by palpation for the presence of fibroids has been used in the AWIN project with good inter-observer reproducibility. Other tested mastitis measures (udder symmetry, udder colour, udder temperature) have also been tested with moderate reliability.

Somatic cell count data for dairy ewes, as with cows, are potentially useful measures of mastitis where these data are available.

3.2.3.9. Neonatal disorders (including starvation/mis-mothering/exposure complex)

Lambs

Mortality records can provide good information about the frequency of neonatal disorders but do rely on adequate record keeping by farmers.

In studies where farm visits were made during the period that young lambs were present additional measures of *demeanour, standing ability* (on a three point scale: standing without difficulty; weak and stands with difficulty; recumbent and unable to stand) and *response to stimulation* (scored as responsive or not) have been reported (Phythian et al., 2013a). Although good observer agreement was achieved for all measures, it is likely that standing ability and response to stimulation will be influenced by the age of lambs observed, and can be recorded only at very specific times of year.

3.2.3.10. Pain (including that due to management procedures such as castration, tail docking and shearing)

Ewes

Presence of full or docked tail serves as a measure that sheep have experienced tail docking earlier in life. Information on the method used, whether analgesia was used and the age of the lamb at tail docking can be informative of the probable pain experienced by the lamb as pain associated with these procedures has been extensively studied (Kent et al., 1998, 2004). The length of the docked tail can also provide some indication of potential for underlying problems if docked too short.

Ear damage associated with notching, poor tagging practice (leading to current or healed rips and tears in the ears) or associated with multiple tags is recorded in AWIN. Although tagging is mandatory in the EU, multiple tags, holes, tears or other damage to ears suggest tags may not be properly applied and placed, or that the type of tag used may not be correct.

Skin lesions and scars can be measures of shearing injuries, but can be reliably assessed only when carried out soon after shearing whilst the fleece is short. In countries that permit mulesing (outside the EU) the presence of smooth scar tissue in the breech area indicates that animal has previously experienced this procedure.

Grimace scales have been validated in several species (mice: Langford et al., 2010; rabbits: Keating et al., 2014; horses: Dalla Costa et al., 2014), and are being developed for sheep (in AWIN) and lambs.

Preliminary AWIN data suggest that similar facial action patterns are expressed by adult sheep in pain (e.g. from lameness) as in other species and that this has good repeatability (McLennan et al., 2014).

Lambs

Presence of castrated males can be used as a measure that animals will have experienced castration earlier in life. Information on the method used, whether analgesia was used and the age of the lamb at castration can be informative of the probable pain experienced by the lamb as pain associated with these procedures has been extensively studied (Molony et al., 2002).

Presence of full or docked tail serves as a measure that sheep have experienced tail docking earlier in life. Information on the method used, whether analgesia was used and the age of the lamb at tail docking can be informative of the probable pain experienced by the lamb as pain associated with these procedures has been extensively studied (Kent et al., 1998, 2004). The length of the docked tail can also provide some indication of potential for underlying problems if docked too short.

Ear damage associated with notching, poor tagging practice (leading to current or healed rips and tears in the ears or floppy ears where lambs have experienced cartilage damage) or associated with multiple tags is recorded in AWIN. Although tagging is mandatory in the EU, multiple tags, holes, floppy or torn ears suggest tags have not be properly placed, or that the type of tag used may not be correct.

Facial expression: preliminary studies are underway in lambs investigating the existence of a 'pain face' but no published data are currently available.

3.2.4. Behaviour

3.2.4.1. Occurrence of abnormal behaviours (e.g. inter-sucking, wool pulling, biting or chewing non-food items)

Ewes

Wool pulling, biting or chewing are abnormal oral behaviours typically seen only in housed sheep at high stocking density (Dwyer and Bornett, 2004). Other forms of stereotypic responses (star-gazing, rearing, weaving route-tracing) are seen only under very restrictive isolation housing conditions in experimental settings and may not occur on farm. Scoring of the presence and frequency of these behaviours forms is part of the AWIN assessment protocol.

Separation from the flock occurs very rarely in the highly social sheep and may serve as a measure of abnormal responsiveness, except when this occurs in ewes with a lamb at foot. However, this still requires validation to be used reliably as a measure of abnormal behaviour.

Lambs

Inter-sucking and chewing non-food items (pica) have been reported solely in artificially reared lambs or lambs that have been temporarily separated from their mothers in early life (Dwyer and Bornett, 2004). The presence and frequency of these behaviours could be used as a measure of abnormal behaviours but requires assessment of reliability.

3.2.4.2. Chronic fear (fearfulness due to predation, poor handling, disturbed social behaviour, etc.)

Ewes

Response to human tests of various forms has been used to assess fear of humans in sheep (reviewed by Waiblinger et al., 2006). In the AWIN project, the response to a stationary human test (carried out in the home pen) had some validity for housed animals, but the responses following neutral or negative handling could not be discriminated from one another, although positive handling did reduce responsiveness. For pasture managed sheep assessment of flight distance or response to a moving human (Hutson 1982; Hargreaves and Hutson, 1990) is the most practical measure of response to humans, and shows some convergent validity with other measures in AWIN data. The repeatability and reproducibility of these measures requires further work. In intensive systems, avoidance distance at the manger proved to be valid and reliable (Napolitano et al., 2011).

Startle response tests also can be indicative of underlying fearfulness (measured from the distance the animal fled following startle, and time taken to resume maintenance behaviours; Dwyer, 2004) and show good correlation with response to human tests in AWIN data.

High frequency vigilance behaviour (indicated by frequent expression of the "head up" posture where the animal stands rigidly immobile with the head raised above the level of the back, with eyes and ears pointing in the direction of the perceived threat) is indicative of increased fear or level of threat exposure in wild ungulates (reviewed by Dwyer, 2004). The reliability and validity of this measure is currently being tested in the AWIN project.

Qualitative Behavioural Assessment (QBA), as developed for AWIN, contains assessment terms related to fear and anxiety (fearful, agitated, wary, tense), and QBA assessments show excellent correlation with physiological measures of stress or nutritional challenge. The repeatability and reproducibility of these measures have also been shown to be very good (Richmond et al., 2014).

Facial expression: aspects of sheep facial expression have been shown to be associated with stress or fear states (e.g. ear posture: Reefmann et al., 2009; Boissy et al., 2011; percentage eye white: Kendrick, 2008; Reefmann et al., 2009). These have, however, not been tested for repeatability and reproducibility for use as a welfare indicator.

Lambs

Response to humans and *startle response* tests are also relevant for lambs. However, the response of dam-reared lambs will be largely dictated by that of their mothers, so are relevant only to lambs which are exposed without the mother present.

Play behaviour is often interpreted as an expression of positive mental state indicating good welfare (reviewed by Boissy et al., 2007; Held and Spinka, 2011). In lambs, play is reduced following painful stimuli (for example castration, see Thornton and Waterman-Pearson, 2002), or when nutrition is limited (Berger, 1979; Reale et al., 1999), although play is also affected by lamb genotype (Dwyer and Lawrence, 2000). However, play is a difficult phenomenon to record reliably (Held and Spinka, 2011) and absence of observable play is not a reliable indicator of poor welfare, although presence of play may indicate good welfare.

Qualitative behavioural assessment (QBA) has not yet been applied to young lambs as an indicator of welfare, although "dull demeanour" was included in the assessment of welfare for young lambs by Phythian et al. (2013a). This measure had good reproducibility between observers, although the validity of the measure is still undergoing testing.

Facial expression: the validity and repeatability of aspects of facial expression, such as changes in ear posture and percentage eye white, have not been tested in young lambs.

Table 17: Summary of animal-based measures (ABMs) associated with different welfare consequences in ewes. Estimates of validity, reliability and feasibility, are based on published evidence or preliminary indications from the AWIN project (see also main text, section 3.2).

Welfare Quality® criteria	**Welfare consequences**	**Animal-based measures**			
		Ewes	**Validity**	**Reliability**	**Feasibility**
1. Absence of	Prolonged	Body condition	High	High	High[(a)]

Welfare Quality® criteria	Welfare consequences	Animal-based measures			
		Ewes	**Validity**	**Reliability**	**Feasibility**
prolonged hunger	hunger	score (BCS) Tooth loss	 Moderate	 High	 High(a)
2. Absence of prolonged thirst	Prolonged thirst	Skin pinch Sunken eyes	Not known Not known	Not known Not known	Low(a) Moderate(a)
3. Comfort around resting	Resting problems	Coat cleanliness Lying behaviour	Moderate Moderate	High High	High Low
4. Thermal comfort	Thermal stress	Panting Respiration rate Shivering	High High Low	Not known Not known Not known	Moderate Moderate Low
5. Ease of movement	Restriction of movement	Displacement Activity Frequency of social interaction Overgrown hoof	High Moderate High Low	Not known Not known Not known Not known	Moderate Moderate Low Low to high(b)
6. Absence of injuries	Lameness	Locomotion score (lameness)	High	High	Moderate
	Injuries	Clinical assessment	High	Moderate	High(a)
7. Absence of disease	Skin disorders	Skin conditions Fleece quality	High High	Inconsistent information (High to low) Inconsistent information (Moderate to low)	High(a) High(a)
	Respiratory disorders	Nasal discharge Respiration quality	Moderate Moderate	High Not known	High(a) Moderate
	Gastro-enteric disorders	Dag score Mucosal colour	High High	High Inconsistent information (Moderate to high)	High High(a)
	Metabolic disorders	Bloat Demeanour	High Moderate	Not known High	High to Low(b) High
	Reproductive disorders	Farmer records of abortion and dystocia incidences.	Moderate	Not known	High to Low(c)
	Mastitis	Udder consistency Somatic Cells Count (SCC)	High High	High High	High(a) Low to High(b)
8. Absence of pain induced by management procedures	Pain induced by management procedures	Presence of docked tail Ear damage Presence of breech scar Grimace scale	 High High High Moderate	 High High High Moderate	 High High(a) High Low
9. Expression of other behaviours	Abnormal behaviour	Wool pulling Stereotypic behaviour Social isolation	High High Moderate	Not known Not known Not known	Low Low Moderate
10. Expression of social behaviour		Flight distance Startle response	Moderate Moderate	Not known Not known	Moderate Low

Welfare Quality® criteria	Welfare consequences	Animal-based measures			
		Ewes	Validity	Reliability	Feasibility
11. Good human-animal relationship 12. Positive emotional state	Chronic fear	Vigilance behaviour Qualitative behavioural assessment (QBA) Facial expression	Moderate High High	Not known High Not known	Low High Low

[(a)] These indicators require handling or close monitoring of animals which may not be feasible in some management systems without gathering the animals.
[(b)]These indicators have high feasibility in intensively managed or indoor systems and low feasibility in pasture-based systems.
[(c)] The feasibility of using farmers' records depends on availability and accuracy of record keeping.

Table 18: Summary of animal-based measures associated with different welfare consequences in lambs. Estimates of validity, reliability and feasibility, are based on published evidence or preliminary indications from the Animal Welfare Indicators (AWIN) project (see also main text, section 3.2).

Welfare Quality® criteria	Welfare consequences	Animal-based measures			
		Lambs	Validity	Reliability	Feasibility
1. Absence of prolonged hunger	Prolonged hunger	Evaluation of body condition Gut fill	Moderate Moderate	High Moderate	Moderate[(a)] Moderate
2. Absence of prolonged thirst	Prolonged thirst	Skin pinch Sunken eyes	Not known Not known	Not known Not known	Low[(a)] Moderate[(a)]
3. Comfort around resting	Resting problems	Coat cleanliness Lying behaviour	Moderate Low	High Not known	High Low
4. Thermal comfort	Thermal stress	Panting Respiration rate Shivering Huddling behaviour	High High High (in neonates) Low	Not known Not known High Not known	Moderate Low Moderate Moderate
5. Ease of movement	Restriction of movement	Activity Frequency of social interaction	Moderate Moderate	Not known Not known	Moderate Low
6. Absence of injuries	Lameness	Locomotion score (lameness)	High	High	Moderate
	Injuries	Clinical assessment	High	High (eye conditions); others not known	High[(a)]
7. Absence of disease	Skin disorders	Skin conditions	Moderate	Not known	High[(a)]
	Respiratory disorders	Nasal discharge Respiration quality	Moderate Moderate	Not known Not known	High[(a)] Moderate
	Gastro-enteric disorders	Dag score Mucosal colour Gut fill Demeanour	High High Moderate Moderate	High Not known Moderate High	High High[(a)] Moderate High
	Metabolic disorders	Bloat	High	High	Low
	Neonatal disorders	Farmer records of mortality Response to stimulation	Moderate Low	Not known High	High to Low[(b)] Low
8. Absence of pain	Pain induced by	Presence of docked	High	High	High

Welfare Quality® criteria	Welfare consequences	Animal-based measures			
		Lambs	**Validity**	**Reliability**	**Feasibility**
induced by management procedures	management procedures	tail			
		Absence of testicles in males	High	High	High
		Ear damage	High	High	Moderate[a]
		Facial expression	Moderate	Not known	Low
9. Expression of other behaviours	Abnormal behaviour	Inter-sucking	High	Not known	Low
		Pica	High	Not known	Low
10. Expression of social behaviour	Chronic fear	Flight distance	Low	Not known	Moderate
11. Good human-animal relationship		Startle response	Moderate	Not known	Low
12. Positive emotional state		Qualitative behavioural assessment	Not known Not known	Moderate	High
		Facial expression	Low	Not known	Low
		Play behaviour		Not known	Low

[a] These indicators require handling or close monitoring of animals which may not be feasible in some management systems without gathering the animals.

[b] The feasibility of using farmers' records depends on availability and accuracy of record keeping.

As summary of the table, the ABMs that have validity, reliability and feasibility to be used for ewes (rated high in validity and high/moderate in reliability and feasibility) are: BCS, locomotion score, clinical assessment of injuries, dag score, mucosal colour, udder consistency, SCC (for dairy sheep), evidence of painful husbandry procedures (tail docked, ear damage, mulesing) and QBA.

Animal-based measures that are believed to be promising but require further scientific evaluation of validity or reliability for ewes are: coat cleanliness, panting, respiration rate, displacement, skin conditions, fleece quality, nasal discharge, social isolation, flight distance.

Among these, the ones that can be used to assess the main welfare consequences in ewes are indicated in Table 19.

Table 19: ABMs that can be used to assess the main welfare consequences, in ewes.

Main welfare consequences in ewes	Currently usable ABMs in ewes	Potential usable ABMS in ewes
Prolonged hunger	Body condition score (BCS)	
Thermal stress		Panting Respiration rate
Lameness	Locomotion score	
Mastitis	Udder consistency Somatic cells count (SCC; for dairy sheep)	

As summary of the table, the ABMs that have validity, reliability and feasibility to be used for lambs (rated high in validity and high/moderate in reliability and feasibility) are: shivering, locomotion score, clinical assessment of injury, dag score, evidence of painful husbandry procedures (tail docked, ear damage, castration).

Animal-based measures that are believed to be promising but require further scientific evaluation of validity or reliability for lambs are: evaluation of body condition, coat cleanliness, panting, skin conditions, nasal discharge, mucosal colour, QBA, respiration quality and gut fill.

Animal-based measures based on farmer records of mortality and diseases have good potential but necessitate accurate farm recording which cannot currently be guaranteed.

Among these, the ones that can be used in lambs to assess the main welfare consequences are indicated in Table 20.

Table 20: ABMs that can be used to assess the main welfare consequences, in lambs.

Main welfare consequences in lambs	Currently usable ABMs in lambs	Potential usable ABMS in lambs
Thermal stress	Shivering	Panting
Pain due to management procedures	Evidence of painful husbandry procedures (tail docked, ear damage, castration).	
Gastro-enteric disorders	Dag score	Mucosal colour Gut fill
Neonatal disorders		Farmer record of mortality and disease
Respiratory disorders		Nasal discharge Respiration quality

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

ToR 1 and ToR 2: EFSA's methodology on risk assessment for animal welfare and the WG approach

Characterization of the management systems (definition of the scenarios)

1. Worldwide there are more than 850 breeds of sheep. The choice of breed depends on production purposes and local environmental conditions and cross breeds are very widely used. Therefore, categorisation by genetic lines is not practical for risk assessment purposes.

2. Sheep are kept in a very wide range of farming systems according to the production purpose, local, climatic, topographic and socio-economic circumstances. Therefore, only a broad categorisation of management systems can be adopted for risk assessment purposes.

3. Categorisation can be based on the degree of human contact, use of housing, nature of pasture and provision of supplementary feeding, giving seven defined management systems: shepherding, intensive, semi-intensive, semi-extensive, extensive and very extensive. The seventh category of mixed systems incorporates any diurnal or seasonal combinations of the first six management systems.

4. In many cases, sheep are reared for dual or multiple production purposes (milk, meat and wool). These purposes do not clearly map to geographic regions or management systems and can therefore not be used in risk assessment without consideration of the management system in which they occur.

Identification of main welfare consequences by system and production type

5. Given the diversity of management systems, a risk assessment approach using welfare consequences identified from generic sheep biology provides the best possible theoretical approach.

6. Seventeen welfare consequences for sheep can be identified using the Welfare Quality® principles and criteria as a framework

7. There is scarcity of scientific literature from which to derive data for quantitative risk assessment relating risk factors to welfare consequences in sheep production. Therefore, a qualitative approach using expert elicitation to rank welfare consequences and identify risk factors within management systems has to be adopted.

8. Evidence of welfare consequences and associated risk factors for breeding rams are particularly scarce, allowing no formal risk assessment.

9. Different risk factors might pertain to lambs destined for meat production and those retained as breeding replacement.

10. In view of these limitations only a general scoping exercise can be initially carried out.

11. The welfare consequences for ewes were rated to differ in importance in different management systems. Across all the management systems, the most frequently identified important welfare consequences for ewes were: thermal stress, lameness and mastitis. Prolonged hunger was assessed to be more frequent in extensive and very extensive management systems, compared to the other systems.

12. Mastitis was identified as an important welfare consequence in sheep maintained for milk purposes, being also affected by genetic factors. However, for ewes kept under more extensive systems and not milked, the consequence of mastitis may be underestimated or not detected. .

13. For lambs, there were few differences among management systems with thermal stress, pain due to management procedures, gastro-enteric disorders and neonatal disorders rated as main welfare consequences. Respiratory disorders were rated to be more frequent in intensive management systems.

14. Risk factors tend to be specific to the welfare consequences and are often common across management systems.

ToR 3: Identification of the ABMs

15. Animal-based measures exist for most welfare consequences in ewes and lambs, but many require further validation. The sensitivity and specificity of the ABMs have rarely been investigated.

16. The identified main welfare consequences for ewes all have currently available validated ABMs (BCS, locomotion score, udder consistency and SCC in milk) except for thermal stress, where potential ABMs require further scientific study (panting, respiration rate).

17. Some of the identified main welfare consequences for lambs currently have available validated ABMs (shivering, evidence of painful husbandry procedures, dag score). Potential ABMs requiring further scientific study also exist for these and the other main welfare consequences (panting, mucosal colour, gut fill, farmer record of mortality and disease, nasal discharge, respiration quality).

RECOMMENDATIONS

ToR 1 and ToR 2: EFSA's methodology on risk assessment for animal welfare and the WG approach

1. To build on the scoping exercise produced in this opinion, systematic data collection should be carried out to identify the welfare consequences in different management systems for sheep, including rams. Data should allow quantification of their severity and prevalence, together with the associated risk factors.

2. Systematic data collection for risk assessment purposes should include reliable farm records in addition to direct ABMs to take into account variation which might be associated with season and reproductive state.

3. Risk assessment should be formulated on specific welfare consequences, management systems and production purposes.

4. For the risk assessment purposes, geographical differences in risk factors within a given management system, should be taken into consideration.

5. Evaluation should be made of the particular issues involved in the transitions which occur in mixed management systems.

6. The interaction between different welfare consequences, which might occur concurrently or consecutively, merit further study.

7. The impact of poor welfare as a predisposing factor to poor animal health should be investigated.

ToR 3: Identification of the ABMs

8. Further research is necessary to identify and validate protocols for ABMs for welfare consequences where none are currently suitable for on-farm assessment (e.g. prolonged thirst in ewes and lambs, restriction of movements in lambs)

9. In ewes, further scientific assessment for validation and/or reliability testing should be carried out for panting and respiration rate.

10. In lambs, further scientific assessment for validation and/or reliability testing should be carried out for panting, mucosal colour, gut fill, nasal discharge and respiration quality.

11. Harmonised methods to implement and maintain accurate and verifiable farmer records of mortality, incidence of diseases and welfare outcomes should be actively developed, in order to facilitate a systematic data collection.

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APPENDICES

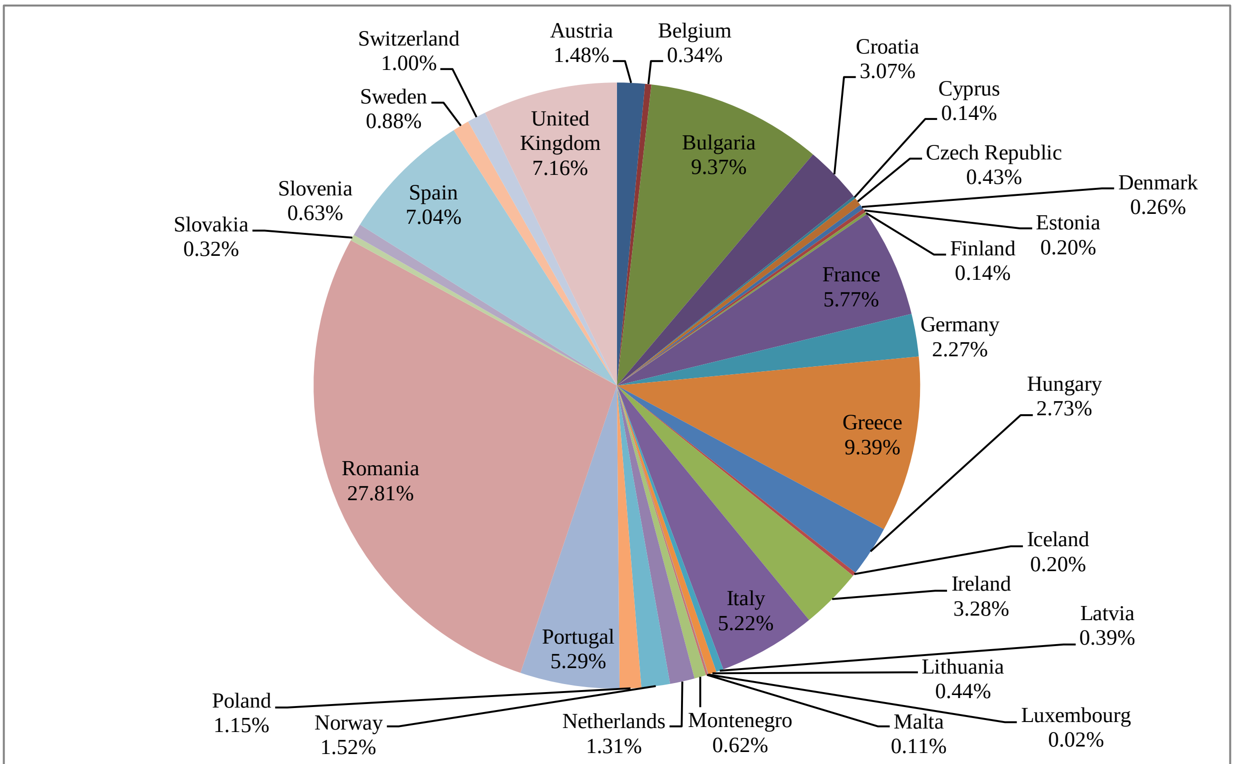
Appendix A. Distribution of sheep population and holdings in the EU, Norway, Switzerland, Iceland and Montenegro from the 2010 Farm Structure Survey

In 2010, a Farm Structure Survey (FSS) was carried out by the EU-27 Member States and Croatia, Norway, Switzerland, Iceland, and Montenegro. According to the survey, a total of 979,180 agricultural holdings[7] produced sheep within the surveyed countries (see Table A.4 and Figure A.1 of this appendix).

Romania had the most sheep producing agricultural holdings, followed by Greece, Bulgaria, the UK, Spain, France and Portugal (see Table A.1).

Table A.1: Farm Structure Survey (FSS) countries with the most sheep-producing agricultural holdings. Source: Eurostat, 2010.

Country	Number of holdings
Romania	272,280
Greece	91,930
Bulgaria	91,790
United Kingdom	70,120
Spain	68,980
France	56,480
Portugal	51,790



[7] "Agricultural holding" or "holding" means a single unit, both technically and economically, which has a single management and which undertakes agricultural activities listed in Annex I to the European Parliament and Council Regulation (EC) No 1166/2008 within the economic territory of the European Union, either as its primary or secondary activity.

Figure A.1: Proportion of sheep holdings by FSS country. Source: Eurostat, 2010

The total population of sheep in the 32 surveyed countries was 99,421,850 (see Table A.4 and Figure A.2 of this appendix).

The UK had the largest population of sheep, followed by Spain, Greece, Romania, France, Italy and Ireland (Table A.2).

Table A.2: FSS countries with the largest sheep populations. Source: Eurostat, 2010.

Country	Number of sheep
United Kingdom	31,027,810
Spain	16,574,220
Greece	9,156,820
Romania	8,412,170
France	7,475,000
Italy	6,782,180
Ireland	4,745,420

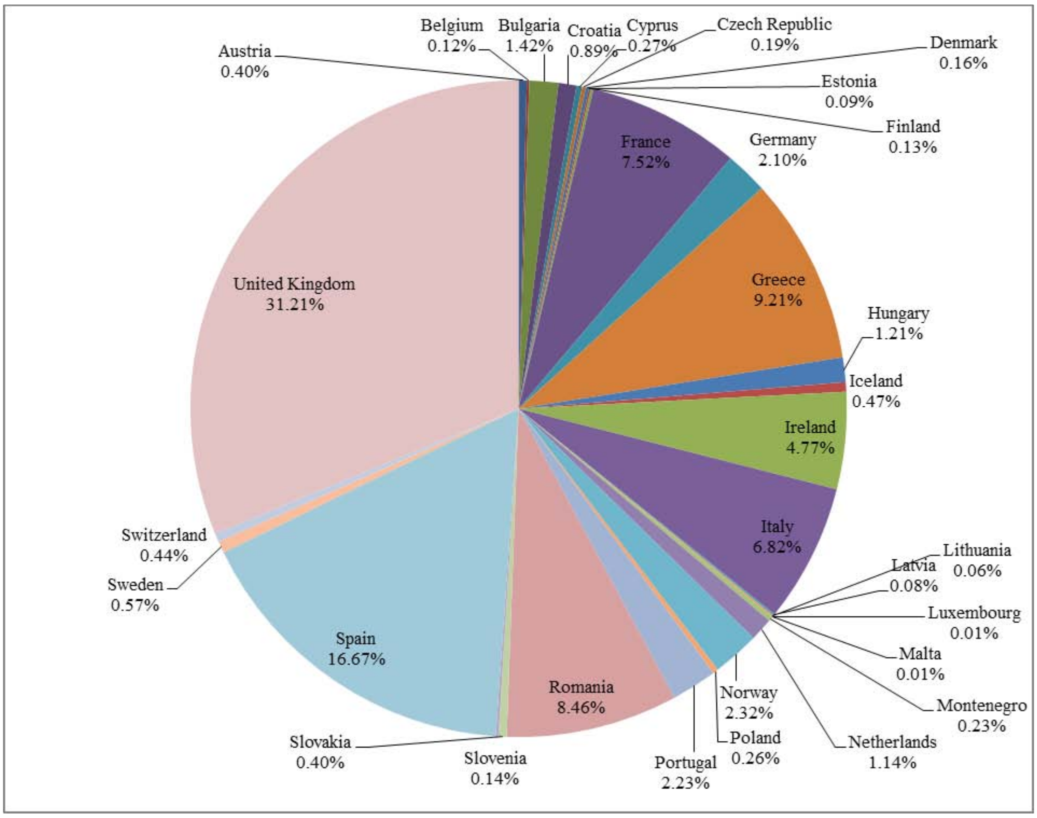


Figure A.2: Proportion of sheep by FSS country. Source: Eurostat, 2010

The average number of sheep per agricultural holding in the surveyed countries was 99.94 (see Table A.4 and Figure A.3 of this appendix). The UK had the highest number of sheep per holding, followed by Spain, Iceland, Cyprus, Norway, Ireland, Italy and France (Table A.3).

Table A.3: FSS Countries with the highest average number of sheep per agricultural holding. Source: Eurostat 2010.

Country	Average number of sheep per holding
United Kingdom	442.50
Spain	240.28
Iceland	232.85
Cyprus	192.44
Norway	154.92
Ireland	147.79
Italy	132.72
France	132.35

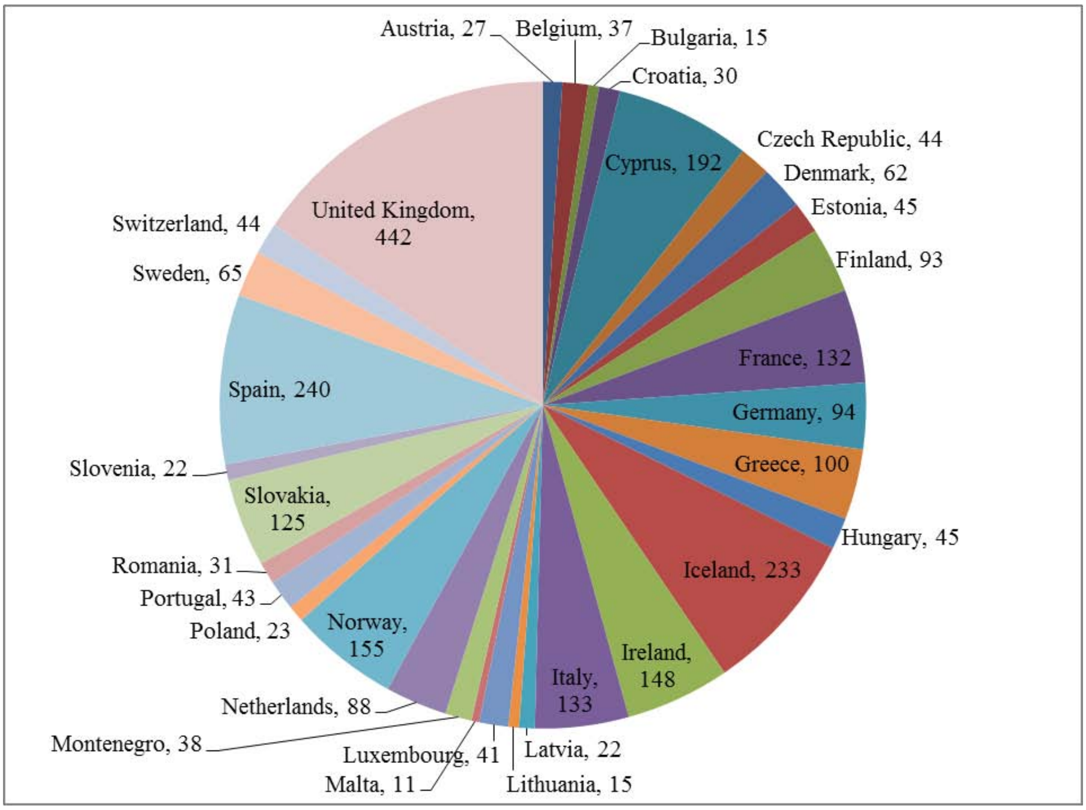


Figure A.3: Average number of sheep per holding for FSS countries: Source: Eurostat, 2010

A summary table showing sheep population, number of sheep holdings and average number of sheep per holding in the EU Norway, Switzerland, Iceland and Montenegro is presented in Table A.4.

Table A.4: Sheep population, number of sheep holdings and average number of sheep per holding in the EU, Norway, Switzerland, Iceland and Montenegro. Source: Eurostat, FSS 2010.

Country	Number of sheep	Number of holdings	Average number of sheep per holding
Austria	397,620	14,500	27.42
Belgium	120,460	3,300	36.50
Bulgaria	1,415,180	91,790	15.42
Croatia	886,200	30,030	29.51
Cyprus	267,490	1,390	192.44
Czech Republic	184,030	4,190	43.92
Denmark	159,630	2,570	62.11
Estonia	87,140	1,950	44.69

Country	**Number of sheep**	**Number of holdings**	**Average number of sheep per holding**
Finland	125,670	1,350	93.09
France	7,475,000	56,480	132.35
Germany	2,088,540	22,270	93.78
Greece	9,156,820	91,930	99.61
Hungary	1,204,350	26,780	44.97
Iceland	463,380	1,990	232.85
Ireland	4,745,420	32,110	147.79
Italy	6,782,180	51,100	132.72
Latvia	84,280	3,800	22.18
Lithuania	64,530	4,320	14.94
Luxembourg	9,080	220	41.27
Malta	11,870	1,080	10.99
Montenegro	229,040	6,090	37.61
Netherlands	1,129,500	12,870	87.76
Norway	2,308,290	14,900	154.92
Poland	261,080	11,230	23.25
Portugal	2,219,640	51,790	42.86
Romania	8,412,170	272,280	30.90
Slovakia	394,490	3,150	125.23
Slovenia	137,740	6,180	22.29
Spain	16,574,220	68,980	240.28
Sweden	564,920	8,660	65.23
Switzerland	434,080	9,780	44.38
United Kingdom	31,027,810	70,120	442.50
Total	99,421,850	979,180	101.54

Appendix B. Allocation of the primary production purpose and breed characteristics to the management systems

	Milk production		Wool production		Meat production	
	Example breeds	**Breed characteristics**	**Example breeds**	**Breed characteristics**	**Example breeds**	**Breed characteristics**
1.Shepherding (SH)	Sarda Tsigai Racka Akkaraman	Selected for survival and production under local environmental circumstance; often multi-purpose traditional breeds	Seldom primary breed criteria		Tsigai Racka Akkaraman	Selected for survival and production under local environmental circumstance; often multi-purpose traditional breeds
2.Intensive (IN)	Lacaune Awassi Asaf Comisana Sarda	Intensively selected, under controlled conditions, for milk yield and quality.	Seldom primary breed criteria		Suffolk Texel Charollais Ile de France Asaf Berrichon du Cher Hampshire Oxford Down Rouge de l'Ouest South Down Vendéen	Intensively selected, under controlled conditions, for lamb growth and carcass traits.
3. Semi-intensive (SI)	Churra Lacaune Castellana Latxa Awassi Chios Sarda Comisana	Rams are intensively selected under controlled conditions, for milk yield and quality traits. Ewes are selected for milk yield and quality traits under local environmental conditions.	Seldom primary breed criteria		Ripollesa Castellana Rasa Aragonesa Segurena Bleu de Maine	Rams are intensively selected, under controlled conditions, for meat traits. Ewes are typically crossed-bred from breeds selected for prolificacy, lambs survival and weaning weight.
4. Semi-extensive (SE)	Seldom primary breed criteria		Merino Karakul Corriedale	Pure-bred rams selected from specialist lines for premium quality wool production. Pure-bred ewes are	Bleu de Maine Dorset Scottish Blackface Romanov Finnsheep Vendéen	Pure-bred rams are selected for lamb growth and carcass traits. Pure or cross-bred ewes are selected for lambs survival and weaning weight under local environmental conditions.

	Milk production		Wool production		Meat production	
	Example breeds	**Breed characteristics**	**Example breeds**	**Breed characteristics**	**Example breeds**	**Breed characteristics**
				selected for wool yield and quality traits under local environmental conditions. Most wool production now comes from dual purpose breeds selected for characteristics of wool yield and quality in combination with meat traits. The balance of these traits depends on prevailing market economics.	Merino and Cross-bred animals	Ewes may also be selected for prolificacy.
5. Extensive (EX)	Seldom primary breed criteria		Merino Karakul Corriedale Polwarth Romney	Pure-bred rams are selected from specialist lines for premium quality wool production. Pure-bred ewes are selected for wool yield and quality traits under local environmental conditions. Most wool production now comes from dual-purpose breeds selected for characteristics of wool yield and quality in combination with meat traits. The balance of these traits	Scottish Blackface Rough Fell Swaledale Welsh Mountain Cheviot Dorset Clun Forest Finnsheep Herdwick Karakul Bluefaced Leicester Lleyn Merino Corriedale Polwarth Romanov Romney	Pure-bred rams are selected for adaptation to local conditions of themselves and offspring. Rams may also be selected for lamb carcass traits. Pure or cross-bred ewes selected for adaptation to local conditions in terms of themselves and their offspring. Ewes may also be selected for prolificacy and lamb weaning weight.

	Milk production		Wool production		Meat production	
	Example breeds	**Breed characteristics**	**Example breeds**	**Breed characteristics**	**Example breeds**	**Breed characteristics**
				depends on prevailing market economics.		
6. Very extensive (VE)	Seldom primary breed criteria		Merino Polwarth Romney	Pure-bred rams are selected from specialist lines for premium quality wool production. Pure-bred ewes are selected for wool yield and quality traits under local environmental conditions. Most wool production now comes from dual purpose breeds selected for characteristics of wool yield and quality in combination with meat traits. The balance of these traits depends on prevailing market economics.	Scottish Blackface Rough fell Welsh Mountain Cheviot Herdwick Merino Polwarth Romanov Romney	Pure-bred rams are selected for adaptation to local conditions in terms of themselves and their offspring. Rams may also be selected for lamb carcass traits. Pure or cross-bred ewes selected for adaptation to local conditionsin terms of themselves and thir offspring. Ewes may also be selected for prolificacy and lamb weaning weight.
7. Mixed system (MX) (combination of 1 to 6 in periods)	Dependent on the component systems	Animals are selected for milk production in diverse conditions	Dependent on the component systems	Animals are selected for wool production in diverse conditions	Dependent on the component systems	Animals are selected for lamb survival and growth in diverse conditions.

Appendix C. Main elements of a given management system

Primary purpose	Management system	Lamb management	Ewe management (milking)	Adult male management	Nutrition	Human-animal relationship (this refers to general management during the year, excluding lambing)	Genetic lines	Environmental conditions
Milk	Shepherding	Temporary separation on daily basis	Hand or machine milking (once or twice a day) Always kept in a small group Low replacement	As ewes, they remain with the group.	Pasture, depending on the environmental resources available Possibility of supplementation	Continuous, at animal level Absence of fear of stockperson High opportunity to recognise and treat welfare and health problems	Diverse, variable and with different degrees of adaptation to the environment	Usually carried out in marginal areas such as mountains or semi-arid open rangelands Low pasture quality
Milk	Intensive	Separation within first days+artificial rearing, fattening	Automatic milking (twice a day) Artificial insemination may be practiced Kept in mixed groups with size in the hundreds High replacement Year-old animals enter into breeding	Kept in low numbers	No pasture Roughage and concentrates, provided by feeding	Continuous, at animal level Daily unavoidable contact High opportunity to recognise and treat welfare and health problems	Highly selected for milk yield	South-eastern Europe
Milk	Semi-intensive	Separation could happen within a few days or weeks, until weaning for	Machine milking (twice a day) Both natural and artificial insemination are	Kept in low numbers.	Improved or unimproved pasture and provision of feed.	Frequent, at animal level Daily unavoidable contact	Highly selected for milk yield and for local adaptation to the	Usually carried out in temperate and Mediterranean regions

Primary purpose	Management system	Lamb management	Ewe management (milking)	Adult male management	Nutrition	Human-animal relationship (this refers to general management during the year, excluding lambing)	Genetic lines	Environmental conditions
		replacement and heavy lambs, or until slaughter	practiced Kept in mixed groups with size in the hundreds High replacement Year-old animals enter into breeding				environment	
Meat	Shepherding	Temporary separation on daily basis	Always kept in a small group Low replacement	As ewes, they remain in the group	Pasture, depending on the environmental resources available Possibility of supplementation	No physical contact necessary (sheep can avoid physical contact) Continuous contact, at group level Absence of fear of stockperson High opportunity to recognise and treat welfare and health problems	Diverse, variable and with different degrees of adaptation to the environment	Usually carried out in Mediterranean and Balkan areas Low pasture quality
Meat	Intensive	Reared by mothers, weaning at 8 to 12 weeks, fattening	Kept in mixed groups with size up to the low hundreds Artificial insemination practiced	Intensively managed Outside the mating season, may be moved to extensive systems with	No pasture Roughage and concentrates, provided by feeding	No physical contact necessary Daily contact at group level High opportunity to recognise and treat	Highly selected for meat traits, including growth rate	Western and northern European regions

Primary purpose	Management system	Lamb management	Ewe management (milking)	Adult male management	Nutrition	Human-animal relationship (this refers to general management during the year, excluding lambing)	Genetic lines	Environmental conditions
			High replacement Year-old animals enter into breeding	minimal supervision		welfare and health problems		
Meat	Semi-intensive	Reared by mothers, weaning at 8 to 12 weeks, fattening under intensive conditions possible	Kept in mixed groups with size in the hundreds; Relatively high replacement; Year-old animals enter into breeding	Kept in low numbers and expected to be with the ewes only during the breeding season; Outside the mating season, may be moved to extensive systems with minimal supervision	Improved and unimproved pasture and provision of feed (roughage, silage and concentrate) during housing	No physical contact necessary; Daily contact at group level; High opportunity to recognise and treat welfare and health problems	Ewes selected for mothering traits and prolificity, crossed with a sire selected for meat traits	Regions/areas with good pasture quality
Meat	Semi-extensive	Reared by mothers, weaning at 8 to 12 weeks, fattening under intensive conditions possible	Kept in mixed groups with size in the hundreds Relatively high replacement Year-old animals enter into breeding	Rams are kept in low numbers and with ewes during breeding season, usually pastured separately as a ram group outside this period	Improved pasture (including rotational grazing) and provision of feed (supplementation)	No physical contact necessary; Intermittent contact at group level Less opportunity to recognise and treat welfare and health problems	Ewes selected for mothering traits and prolificity, crossed with a sire selected for meat traits	Regions/areas with good pasture quality
Meat	Extensive	Reared by mothers, weaning at 12 to 16 weeks, fattening	Kept in groups with size in the high hundreds up to thousands	Rams remain as separate ram groups in the extensive system, or in	Access to some improved and unimproved pastures (continuous	No physical contact necessary; Intermittent contact at group level	Ewes selected for mothering traits, crossed with diverse breeds	Regions/areas with natural pastures.

Primary purpose	Management system	Lamb management	Ewe management (milking)	Adult male management	Nutrition	Human-animal relationship (this refers to general management during the year, excluding lambing)	Genetic lines	Environmental conditions
		under intensive conditions possible	Relatively low replacement	fenced areas, the entire year Low replacement	grazing) Infrequent supplementation		Adaptation to local environmental conditions	
Meat	Very-extensive	Reared by mothers, weaning at 12 to 16 weeks, fattening under intensive conditions possible	Kept in groups with size in the high hundreds up to thousands Relatively low replacement	Rams remain in separate ram group in the very extensive system, or in fenced areas, the entire year Low replacement	Access to unimproved pastures No supplementation	No physical contact necessary Intermittent contact at group level	Ewes selected for mothering traits, crossed with diverse breeds Adaptation to local environmental conditions.	Regions/areas with natural pastures
Meat	Seasonal mix of very extensive (during summer) and intensive for dual-purpose (meat and wool)	Reared by the mothers, fattening under intensive conditions possible	During the very extensive phase, kept in groups with size in the high hundreds up to thousands Artificial insemination practiced High replacement during the intensive period Year-old animals enter into breeding	During the very extensive phase, rams remain in the extensive system the entire year Intensively managed during the intensive phase; mating occurs indoors and may involve “hand-mating” Low replacement	During the extensive phase, access to unimproved pastures and no supplementation During the intensive phase, no pasture and provision of roughage and concentrates, by feeding	During the extensive phase, no physical contact necessary and intermittent contact at group level During the intensive phase, no physical contact necessary; daily contact at group level; high opportunity to recognise and treat welfare and health problems	Mostly selected for and adapted to local environment	Regions/areas with extremes of climatic conditions

Primary purpose	Management system	Lamb management	Ewe management (milking)	Adult male management	Nutrition	Human-animal relationship (this refers to general management during the year, excluding lambing)	Genetic lines	Environmental conditions
Meat	Seasonal mix of semi-extensive and extensive/very extensive production for dual-purpose (wool and meat) (e.g. New Zealand, the UK)	Reared by mothers, weaning at 12 to 16 weeks, fattening under intensive conditions possible	Kept in groups with size in high hundreds up to thousands Relatively low replacement	Rams remain in the extensive system the entire year Low replacement	During the semi-extensive phase, improved pasture and provision of feed (supplementation) During the extensive phase, access to some improved and unimproved pasture and infrequent supplementation	No physical contact necessary; Intermittent contact at group level Less opportunity to recognise and treat welfare and health problems	Ewes selected for mothering traits and prolificity, crossed with a sire selected for meat traits	Regions/areas with natural pastures.
Wool	Semi-extensive (wool as secondary purpose)	Reared by mothers, weaning at 8 to 12 weeks, fattening under intensive conditions possible	Kept in mixed groups with size in the hundreds Relatively high replacement Year-old animals enter into breeding	Rams are kept in low numbers, separate from the ewes outside the mating period	Improved pasture and provision of feed (supplementation)	No physical contact necessary Intermittent contact at group level Less opportunity to recognise and treat welfare and health problems	Pure-bred ewes selected for wool yield and quality traits under local environmental conditions	Regions/areas with good pasture quality
Wool	Extensive	Reared by mothers, weaning at 12 to 16 weeks, fattening under	Kept in groups with size in the high hundreds Relatively low replacement	Castrated males remain in the group	Access to some improved and unimproved pastures Possibility of	No physical contact necessary Intermittent contact at group level	Selected for wool traits	Regions/areas with natural pastures

Primary purpose	**Management system**	**Lamb management**	**Ewe management (milking)**	**Adult male management**	**Nutrition**	**Human-animal relationship** (this refers to general management during the year, excluding lambing)	**Genetic lines**	**Environmental conditions**
		intensive conditions possible			supplementation	Less opportunity to recognise and treat welfare and health problems		
Wool	Very extensive	Reared by the mothers, weaning at a later stage, fattening under intensive conditions possible	Kept in groups with size up to the thousands Relatively low replacement	Castrated males remain in the groups	Access to unimproved pastures Infrequent supplementation.	No physical contact necessary Minimal contact, at group level Low opportunity to recognise and treat welfare and health problems	Selected for wool traits	Regions/areas with natural pastures of low quality
Wool	Mixed (see lines on mixed meat and wool production: i) mix of very extensive (during summer) and intensive for dual-purpose; and ii) seasonal mix of semi-extensive and extensive production for dual-purpose)							

Appendix D. Conceptual model

Principles	Welfare Quality® criteria	Negative welfare consequence if criteria not met	Animal-based indicators These might be primary ABIs that have a direct relationship with the welfare consequence, or secondary ABIs that reflect the outcome of a different welfare consequence arising from the studied welfare consequence	Main factor related to the identified consequence (factor that, if present, causes the identified welfare consequence or affects the level of that consequence)	Main factors relevant to a specific farming system Farming systems[(a)]: 1. Shepherding 2. Intensive system 3. Semi-intensive 4. Semi-extensive system 5. Extensive system 6. Very extensive system 7. Mixed system
Feeding	**1. Absence of prolonged hunger**	Prolonged hunger including: 1) Unpleasant effect of hunger 2) Weakness and lethargy 3) Clinical signs specific deficiency syndromes (e.g. micronutrients) 4) Poor health 5) Death (extreme cases) 6) Metabolic disorders (please refer to health section for details and risk factors)	Poor body condition Reduced activity Clinical signs of micronutrient deficiency Increased aggression from food competition Reduced immune response Increased health problems Increased mortality	The factors listed below are related to all the negative welfare consequences listed (1-6): a) Feed of low digestibility or nutrient content (e.g. poor quality of forage) b) High metabolic demand (genetic or production stage related, for example pregnancy or lactating stage) c) Broken mouth d) Health disorders, e.g. lameness e) Maternal agalactia/desertion (lambs) f) Physical barriers preventing food access g) Lack of access to water h) Inadequate food quantity provided i) Imbalanced diet (specific nutrient deficiencies) j) Competition for feed resources (including feeding space) k) Low seasonal feed availability (winter snow, summer drought, floods)	a) Systems 1-7 b) Systems 1-7 c) Systems 1-7 d) Systems 1-7 e) Systems 1-7 f) Systems 1-7 g) Systems 1-7 h) Systems 2-4, 7 i) Systems 1-7 j) Systems 1-7 k) Systems 1, 5-7 l) Systems 1, 4-7 m) Systems 2, 3 n) Systems 1-4, 7

Principles	**Welfare Quality® criteria**	**Negative welfare consequence if criteria not met**	**Animal-based indicators** These might be primary ABIs that have a direct relationship with the welfare consequence, or secondary ABIs that reflect the outcome of a different welfare consequence arising from the studied welfare consequence	**Main factor related to the identified consequence** (factor that, if present, causes the identified welfare consequence or affects the level of that consequence)	**Main factors relevant to a specific farming system** Farming systems[(a)]: 1. Shepherding 2. Intensive system 3. Semi-intensive 4. Semi-extensive system 5. Extensive system 6. Very extensive system 7. Mixed system
				l) Lack of supplementation in hard periods (winter storms or summer droughts, floods) m) Poor drying off practices after lactation (leaving animals without food or only drinking water) n) Lack of knowledge of a technique for assessing condition scoring to know body reserves	
	2. Absence of prolonged thirst	Prolonged thirst including: 1) Unpleasant effect of thirst 2) Dehydration 3) Hunger (from reduced feed intake 4) Weakness and lethargy 5) Death	Increased haematocrit Reduced skin pliability Increased aggression from water competition Reduced body condition Increased health problems Increased mortality	a) Absence of, or inappropriate, drinking supply b) High evaporative heat loss c) High metabolic demand (genetic or production stage related) d) Inappropriate food type (high mineral) e) Lack of emergency water supply f) Physical barriers preventing water access g) Water of poor quality (high mineral content) h) Seasonal availability (winter freezing, summer drought) i) Lameness j) Maternal desertion/agalactia (lambs)	a-g) Systems 1-7 h) Systems 4-7 i-j) Systems 1-7

Principles	Welfare Quality® criteria	Negative welfare consequence if criteria not met	Animal-based indicators These might be primary ABIs that have a direct relationship with the welfare consequence, or secondary ABIs that reflect the outcome of a different welfare consequence arising from the studied welfare consequence	Main factor related to the identified consequence (factor that, if present, causes the identified welfare consequence or affects the level of that consequence)	Main factors relevant to a specific farming system Farming systems[(a)]: 1. Shepherding 2. Intensive system 3. Semi-intensive 4. Semi-extensive system 5. Extensive system 6. Very extensive system 7. Mixed system
Housing/Environment	**3. Comfort around resting**	Resting problems including: 1) Reduced comfort around resting 2) Fatigue due to reduced resting time	Reduced resting time Abnormal gait Injury Soiled / matted wool Competition for limited suitable areas Symptoms of respiratory problems Shivering (impaired thermogenesis) Loss of body condition Decreased reproductive performance Increased lambs mortality Clinical signs of udder infections	a) Inappropriate flooring b) Wet lying area c) Poor air quality-ammonia and airborne particulates d) Lack of litter material (straw or coarse sawdust/wood shavings) e) High stocking density (space per animal) f) Lack of or poor ventilation (to find justification)	a) Systems 1- 7 b-f) Systems 2, 3, 7
	4. Thermal comfort	Thermal discomfort including: 1) Heat stress 2) Reduction in heat tolerance 3) Cold stress 4) Lamb mortality	Bunching / grouping Panting Increased respiratory rate Shivering Reduced feed intake Increased water intake Loss of body condition Physical inactivity during heat stress Increased competition for thermally desirable areas Clinical signs of udder infections Decreased reproductive performance	a) Selection for high yield resulting in high metabolic heat production b) Low genetic heat tolerance c) Contingency for extreme weather conditions (temperatures, wind speed, floods) d) Inappropriate shearing practice (no shearing or shearing during wet conditions or severe cold) e) Inappropriate shade and shelter f) Inappropriate water supply g) High and low effective temperature (THI, including adequate ventilation) h) Stage of production in ewes i) Inappropriate bedding, floor type, etc.	a-i) System 7 a, b, g-i) Systems 2, 3 c-f) Systems 1, 4, 5, 6

Principles	Welfare Quality® criteria	Negative welfare consequence if criteria not met	Animal-based indicators These might be primary ABIs that have a direct relationship with the welfare consequence, or secondary ABIs that reflect the outcome of a different welfare consequence arising from the studied welfare consequence	Main factor related to the identified consequence (factor that, if present, causes the identified welfare consequence or affects the level of that consequence)	Main factors relevant to a specific farming system Farming systems[(a)]: 1. Shepherding 2. Intensive system 3. Semi-intensive 4. Semi-extensive system 5. Extensive system 6. Very extensive system 7. Mixed system
	5. Ease of movement	Restriction of movement including: 1) Slipping and falling 2) Physical restraint 3) Overgrown hoof 4) Crushing /smothering 5) Bullying	Increased incidence of slipping and falling Overgrown hoof Abnormal gait Reluctance to move Increased aggression from enforced proximity Overcrowding Soiled / matted wool Occurrence of injuries Occurrence of abnormal behaviours	a) Inappropriate flooring/material/design/construction b) High stocking densities c) Physical restraint d) Selection of sheep not adapted to the conditions encountered in the field e) Inadequate hoof trimming f) Poor walking tracks	a-f) System 2, 3, 7 d) Systems 1-7 e, f) Systems 4, 5, 6
Health	**6. Absence of injuries**	Lameness including: 1) wounds 2) fractures Injuries (others) including: 1) wounds 2) fractures	Abnormal gait Occurrence of lesions and/or swelling Reluctance to move Teeth grinding Abnormal posture Apathy Social isolation	a) Use of inappropriate ear-tags b) Restriction of movement c) Presence of horns d) Poor handling (inadequate shearing) e) Untrained dogs f) Inappropriate flooring/housing/husbandry practices g) Inappropriate milking equipment and practices h) Fly strike i) Lack of supervision/treatment j) Dystocia k) Predation l) No presence of escape terrain for allowing antipredator behaviour m) Inadequate escape terrain (such	

Principles	Welfare Quality® criteria	Negative welfare consequence if criteria not met	Animal-based indicators These might be primary ABIs that have a direct relationship with the welfare consequence, or secondary ABIs that reflect the outcome of a different welfare consequence arising from the studied welfare consequence	Main factor related to the identified consequence (factor that, if present, causes the identified welfare consequence or affects the level of that consequence)	Main factors relevant to a specific farming system Farming systems[(a)]: 1. Shepherding 2. Intensive system 3. Semi-intensive 4. Semi-extensive system 5. Extensive system 6. Very extensive system 7. Mixed system
				as cliffs with high slopes) for allowing antipredator behaviour n) Use of inadequate fences and hedges o) No regular inspection of the flock p) Presence of wild predators or feral dogs q) Inadequate hoof trimming	
	7. Absence of disease	Lameness including: Foot infection Skin disorders Respiratory disorders Gastro-enteric disorders including: 1) cachexia 2) poisoning (e.g endotoxaemia) Metabolic disorders including: 1) acidocis 2) ketosis Reproductive disorders Mastitis Neonatal disorders including:	Specific clinical signs relevant to the disease	a) Poor hygiene b) Inappropriate milking management (milking practices, drying practices) c) Genetic susceptibility to diseases d) Poor pasture quality or management e) Lack of ecto- and endoparasite control f) Inappropriate or lack of foot care g) Overstocking of the pen h) Inadequate prevention and treatment of infections (e.g. paratubercolosis, visna maedi,enterotoxaemia-clostridium) i) Poor handling (e.g. bad shearing practices) j) Lack of biosecurity	

Principles	Welfare Quality® criteria	Negative welfare consequence if criteria not met	Animal-based indicators These might be primary ABIs that have a direct relationship with the welfare consequence, or secondary ABIs that reflect the outcome of a different welfare consequence arising from the studied welfare consequence	Main factor related to the identified consequence (factor that, if present, causes the identified welfare consequence or affects the level of that consequence)	Main factors relevant to a specific farming system Farming systems[(a)]: 1. Shepherding 2. Intensive system 3. Semi-intensive 4. Semi-extensive system 5. Extensive system 6. Very extensive system 7. Mixed system
		a) lamb mortality b) perinatal infection c) conjunctivitis in lambs		k) Inappropriate nutrition (acute and chronic) l) No inspection during lambing m) No cleaning and disinfection of shearers and contractors n) Use of un-dewormed dogs o) No regular inspection of the flock p) No removing of unfit sheep from the flock q) Not regular inspection of udder function r) Lack of shelter from environmental impacts (blizzards, snow) s) Inadequate drying of sheep t) Over-exploitation of landscape u) Inadequate management of the drinking points (overcrowding)	
	8. Absence of pain induced by management procedures	Pain including: a) acute pain b) chronic pain	Abnormal gait Head shaking Visible lesions and/or swelling Reluctance to move Teeth grinding Abnormal posture Apathy Social isolation Tremor	a) Use of rubber rings b) Tail docking c) Surgical castration d) Dehorning e) Lambing intervention f) Ear tagging g) Mulesing h) Inappropriate genetic selection i) Poor handling (lifting or dragging	

Principles	Welfare Quality® criteria	Negative welfare consequence if criteria not met	Animal-based indicators These might be primary ABIs that have a direct relationship with the welfare consequence, or secondary ABIs that reflect the outcome of a different welfare consequence arising from the studied welfare consequence	Main factor related to the identified consequence (factor that, if present, causes the identified welfare consequence or affects the level of that consequence)	Main factors relevant to a specific farming system Farming systems[(a)]: 1. Shepherding 2. Intensive system 3. Semi-intensive 4. Semi-extensive system 5. Extensive system 6. Very extensive system 7. Mixed system
			Frequent high-pitched bleatings Facial expression	sheep by the fleece, tail, ears, horns or legs) j) Inappropriate milking practices and equipment	
Behaviour	**9. Expression of social behaviours**	Chronic fear from disturbed social behaviour including: 1) High behavioural activity 2) Aggression and fighting/bullying (especially rams) 3) Stress and frustration Resting problems including: 1) Frequent displacement from lying areas Prolonged hunger including 1) Frequent displacement from feeders 2) Weaning stress in lambs	Increased negative social interactions Increased behavioural activity Reduced behavioural synchrony Frequent displacement at feeder Frequent displacement at resting Frequent high-pitched bleating Frequent vigilance postures Refusal to eat Low body condition Immune suppression Poor growth in lambs Apathy Anxious demeanour Escape behaviours Lamb mortality Broken horns (if present) Facial expression including ear position	a) Regrouping of animals in an established group b) Close confinement (e.g. lambing) c) Stocking densities d) Separation of lambs from mothers (mis-mothering) e) Weaning f) Social isolation g) Resources competition h) Housing of sheep from extensive systems, even for a short period i) Segregation of sheep on the basis of age and sex j) No presence of escape terrain to allow antipredator behaviour k) Inadequate escape terrain (such as cliffs with high slopes) to allow antipredator behaviour	a) Systems 2-4, 7 b) Systems 1-3, 7 c) Systems 1-3, 7 d) Systems 2-7, greatest risk for 2, 3, 7, lower for 4-6, e) Systems 2, 3 greatest risk, lower for 4, 7, lowest for 1, 4-6 f) Systems 2, 3, 7 g) Systems 1-7, greatest risk for 2-3, 7 h) Systems 3, 7 i) Systems 1-7 j) Systems 1-4, 7 k) Systems 5, 6, 7

Principles	Welfare Quality® criteria	Negative welfare consequence if criteria not met	Animal-based indicators These might be primary ABIs that have a direct relationship with the welfare consequence, or secondary ABIs that reflect the outcome of a different welfare consequence arising from the studied welfare consequence	Main factor related to the identified consequence (factor that, if present, causes the identified welfare consequence or affects the level of that consequence)	Main factors relevant to a specific farming system Farming systems[(a)]: 1. Shepherding 2. Intensive system 3. Semi-intensive 4. Semi-extensive system 5. Extensive system 6. Very extensive system 7. Mixed system
		3) Abandoned neonatal lambs			
	10. Expression of other behaviours	Abnormal behaviour	Wool pulling Bar biting Star gazing Route tracing/pacing Pica Poor fleece quality Sucking/chewing conspecifics	a) Nutritional inadequacy b) Barren housing c) Close confinement d) Social isolation	a) Systems 1-3, 7 b) Systems 1-3, 7 c) Systems 2, 7 d) Systems 2, 3, 7
	11. Good human-animal relationship	Chronic fear of humans Pain Injury	Frequent high-pitched bleatings Escape behaviours High behavioural activity Avoidance of humans Bunching, pushing and riding each other Slipping, falling, baulking Injury from collision with handling facilities Increased flight distance Slow recovery after being startled Panting High respiration rate Kicking, flinching or increased stepping at milking Broken horns (if present) Fleece condition (pulls or bare patches) Facial expression, including ear position	a) Poor or rough handling (e.g. restraint and inversion) b) No regular inspection of the flock c) Lack of training d) Lack of competence e) Lack of empathy f) High animal to labour unit ratio	a) Systems 1-7 b) Systems 2, 3, 4, 5, 6, 7 c) Systems 1-7 d) Systems 1-7 e) Systems 1-7 f) Systems 4, 5, 6, 7

Principles	Welfare Quality® criteria	Negative welfare consequence if criteria not met	**Animal-based indicators** These might be primary ABIs that have a direct relationship with the welfare consequence, or secondary ABIs that reflect the outcome of a different welfare consequence arising from the studied welfare consequence	**Main factor related to the identified consequence** (factor that, if present, causes the identified welfare consequence or affects the level of that consequence)	**Main factors relevant to a specific farming system** Farming systems[(a)]: 1. Shepherding 2. Intensive system 3. Semi-intensive 4. Semi-extensive system 5. Extensive system 6. Very extensive system 7. Mixed system
	12. Positive emotional state	Chronic fear	Frequent high-pitched bleating Escape behaviours High behavioural activity Avoidance of humans/dogs Avoidance of areas of pasture following predator presence Bunching, pushing and riding each other Increased flight distance Slow recovery after being startled Bite wounds High-vigilance behaviour Low behavioural synchrony Refusal to eat Facial expression, including ear position	a) Dogs b) Predators c) Environmental issues (e.g. milking machine, lack of escape route) d) Presence of hunter in the area	a) Systems 3-7 b) Systems 1, 4-7 c) Systems 2, 3, 7 d) Systems 4-7

Appendix E. Results from expert knowledge elicitation

This appendix reflects the analysis of the data gathered through the online survey. The document is structured in the following units: (1) descriptive overview of the data set and background data of the respondents; (2) description of the respondents' expertise regarding management system and production purpose; (3) analysis and aggregation of respondents' ratings (i.e. consequence prevalence, including uncertainty and severity) providing the aggregated scores to rank the 17 welfare consequences proposed in the conceptual model for ewes and lambs in either management system or production purpose; and (4) sensitivity considerations using ranking scores of alternative aggregation methods or peculiar aspects of the data.

NB: The final identification of main consequences is documented in the opinion, and, although based on the ranking order generated below, the procedure is outside the scope of this appendix.

1. Descriptive overview of the data set and background data of the respondents

1.1 Descriptive overview of the data set

A total of 319 **respondents** started the survey providing:

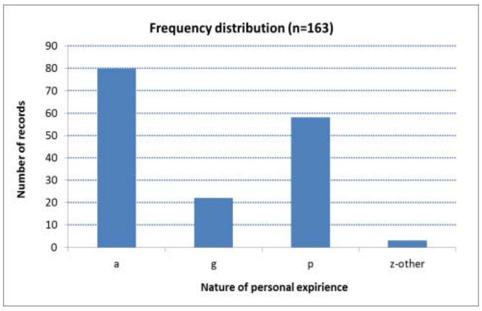
- 347 data **records** (one respondent provided six systems responses; one provided four; 20 provided two, and the rest provided only one system response);
- 248 data records describe the system for evaluation and were compatible with the sheep farming culture relevant for the assessment;
- 220 data records provide some prevalence ratings (194 are completed);
- 175 data records provide some impact ratings (163 are completed);
- <u>163 record were included in all analyses</u> (additional were used when appropriate i.e. selected ratings available).

1.2. Identity of respondents

One hundred and forty-nine records were associated with personal identity and background while 14 were not. The latter distribute to SE and MX (six each; for acronyms see Table E.1 below in this appendix) and EX and VE (one each). The data do not suggest separating both groups of respondents; for example, in SE the average prevalence rating of the 17 welfare consequences provided by respondents without identity was eight times smaller and eight times higher than those with revealed identity (one equal).

1.3. Technical background of respondents

The respondents were asked to indicate the nature of their technical experience with sheep production by ticking one of three categories: academic research on sheep, e.g. universities, research institutes (**a**); policy or standardisation on sheep production, e.g. standards organisation, non-governmental organisation, retailers, market organisations, inter-governmental organisation, governmental organisation (**g**); involved in sheep production, e.g. farmers or farmers' organisation, breed societies, veterinary practitioner, technical consultant (**p**); or others.

a) 

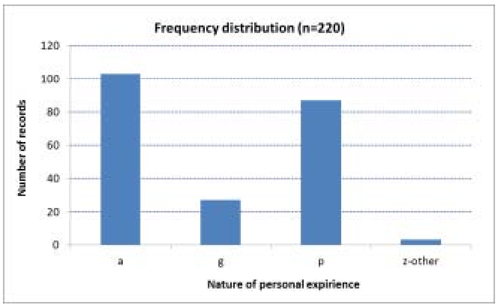
b) 

Figure E.1: Nature of technical background of respondents experience of: a) records with complete data (n=163); b) any records with ratings (n=220)

The sub-sets of responses differed for certain welfare aspects between the a), g) and p) groups. However, as the survey questionnaire was addressing an overview, the comparative evaluation was provided for only dedicated aspects. In general, the three groups are pooled for the analysis.

1.4. Country of sheep system for which respondents provided ratings

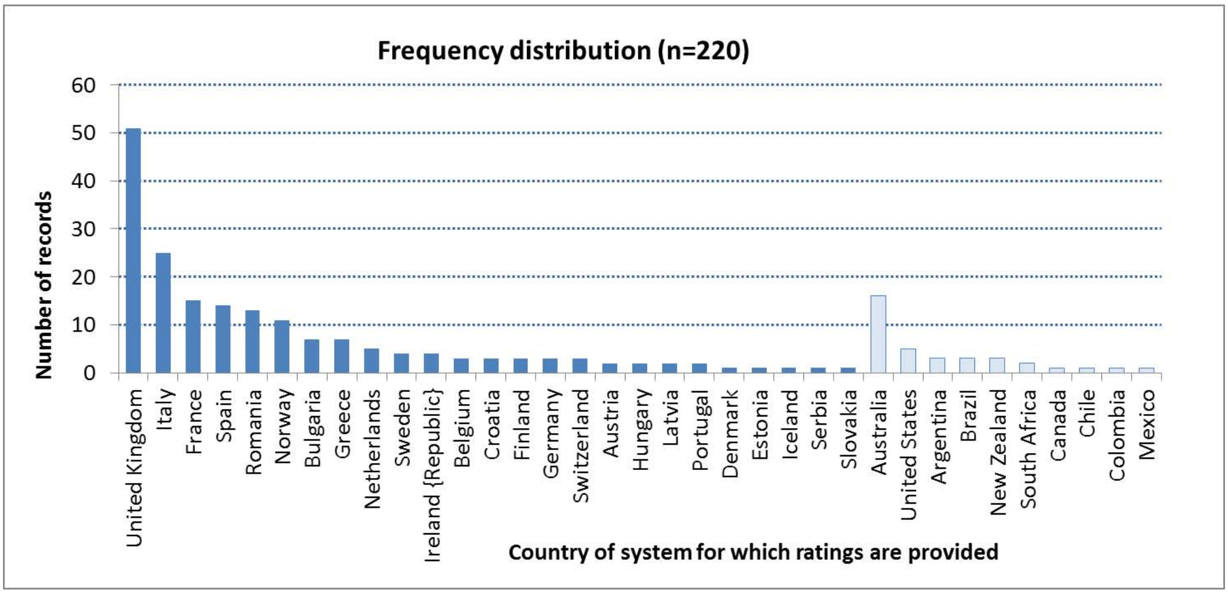


Figure E.2: Number of records on systems with data (n=220) by the country of the system as specified by the respondent. Blue histograms: European countries; light blue histograms: non-European countries

2. Description of respondents' expertise

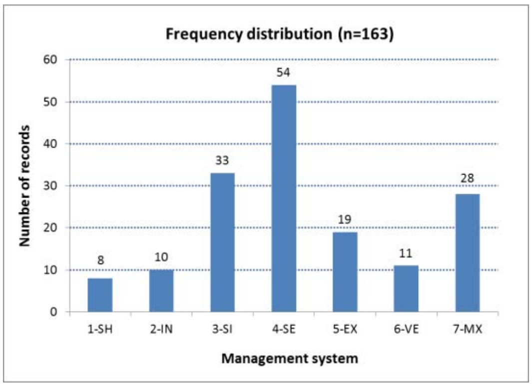
The description is provided by management system or by production purposes summarizing the respondents' expertise.

The large sheep-breeding countries are proportionally represented in the survey sample.

2.1. Description of respondents' expertise by management system

Table E.1: Abbreviations of different categories of management systems.

1-SH	**2-IN**	**3-SI**	**4-SE**	**5-EX**	**6-VE**	**7-MX**
Shepherding	Intensive	Semi-intensive	Semi-extensive	Extensive	Very extensive	Mixed

a) 

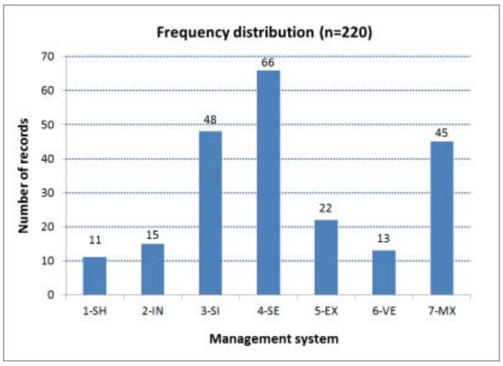
b) 

Figure E.3: Frequency distribution of respondents' expertise by management system of a) records with complete data (n=163); b) any records with ratings (n=220)

NB: Any interpretation of results relating to SH, IN and VE should be made with caution and, if appropriate, cross-checked against the set of individual responses.

2.2. Details of management system category mixed system (7-MX)

Table E.2: Abbreviations of different categories for mixed systems (number of records in brackets).

SH? (2)	SHI (2)	SHE (2)	IE (11)	SIE (8)	EX (1)	All (3)
Shepherding + Unknown	Shepherding + Any intensive	Shepherding + Any extensive	Intensive + Any extensive	Semi-intensive + Any extensive	Extensive + Very extensive	Mixture of more than four systems

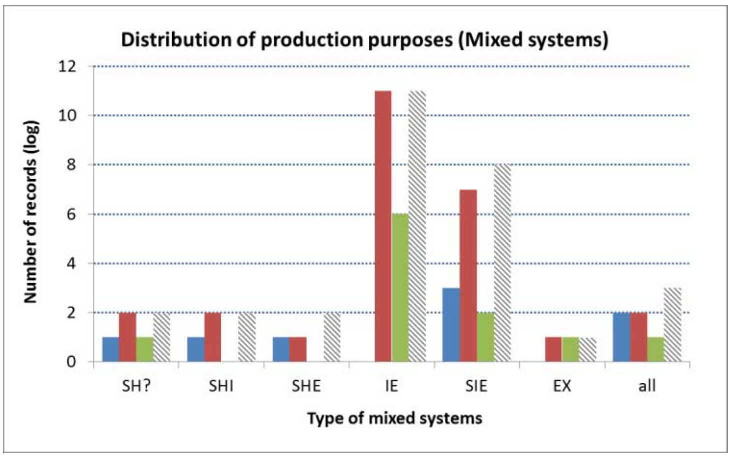


Figure E.4: Frequency distribution of production purpose category across the records rating on a mixed system. Milk = blue; meat = red; wool = green. The absolute number of records is shown by the grey-dashed bars. For example all 11 mixed systems mixing intensive and any extensive management category (IE) assigned meat as purpose (11 red) while six of these also served for wool production (six green)

2.3. Description of respondents' expertise by production purpose

Table E.3: Abbreviations of different categories of production purposes.

a Milk	b MeMi	c Meat	d MeWo	e Wool	AllP
milk only	meat and milk	meat only	meat and wool	wool only	meat and milk and wool

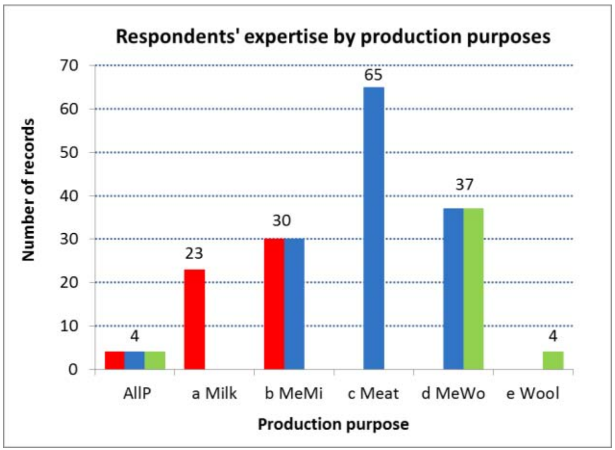


Figure E.5: Frequency distribution of respondents expertise by production purpose in those records with complete data (n=163). Milk = red; Meat = blue; wool = green series

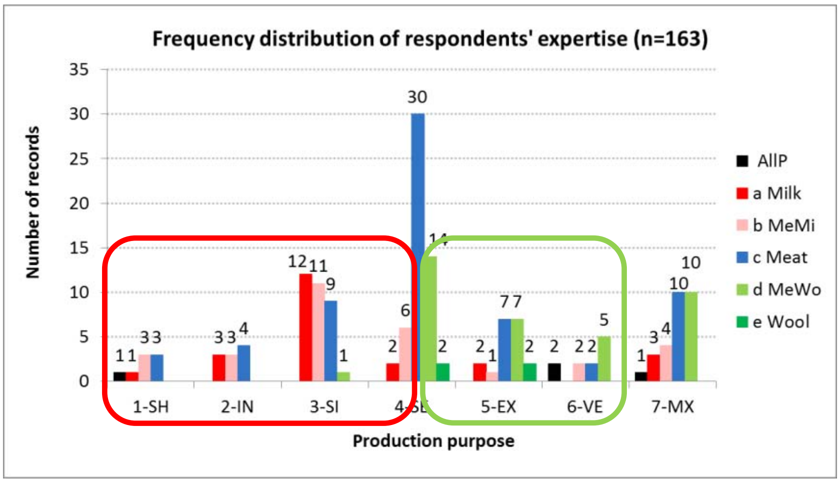


Figure E.6: Frequency distribution of respondents' expertise regarding production purpose by the management systems (n=163). Milk or meat in combination with milk is concentrated in SH, IN, SI, and SE, whereas wool production or meat in combination with wool is concentrated within the extensive sector, i.e. SE, EX, and VE

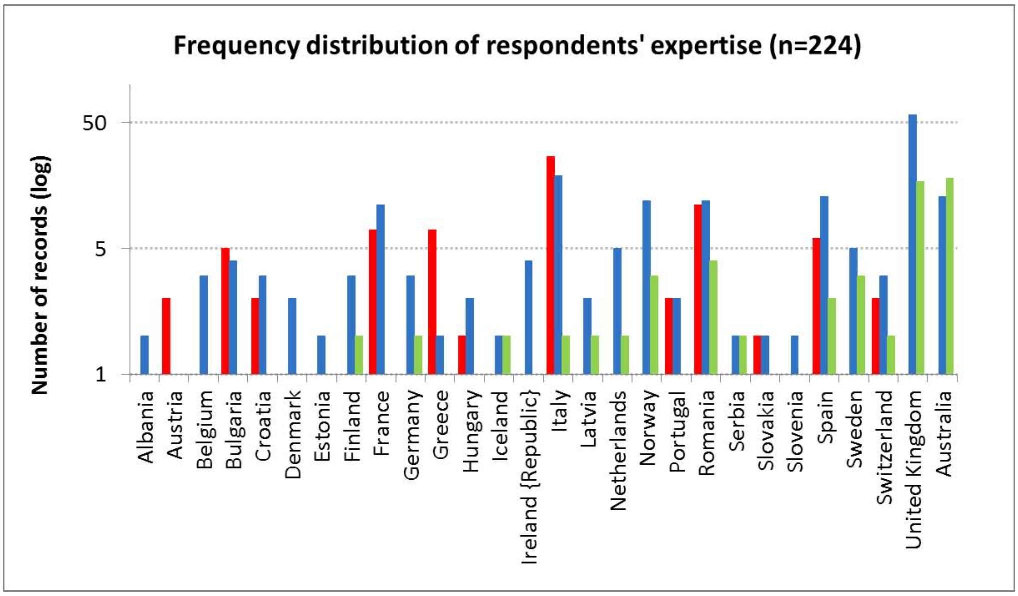


Figure E.7: Frequency distribution (log-scale) of respondents' expertise by production purpose(s) by the geographical region assigned, i.e. European countries and Australia. Records with multiple purposes assigned are counted more than once. Milk = red; meat = blue; wool = green series. For example wool (green) as production purpose was assigned by respondents rating systems from the countries FI, DE, IS, IT, LV, NL, NO, RO, RS, ES, SE, CH, UK, (AU)

3. Analysis and aggregation of respondents' ratings

3.1. Methods of aggregation

The ranking of consequences was performed using the impact score. The individual impact score was defined as multiplicative combination of two respondents' ratings, i.e. prevalence and severity.

The raw ratings were transformed between 0 and 1. In detail, these ratings were: (a) the proportion of population affected by the consequence (prevalence rating/100; between 0 and 1); and (b) the severity category (none, low, medium, high; 0, 0.33, 0.66, 1).

The individual scores were aggregated over all respondents. Three different methods of data aggregation were tested to evaluate sensitivity: (i) average of impact score values; (ii) median of impact score values; and (iii) weighted average of impact score values.

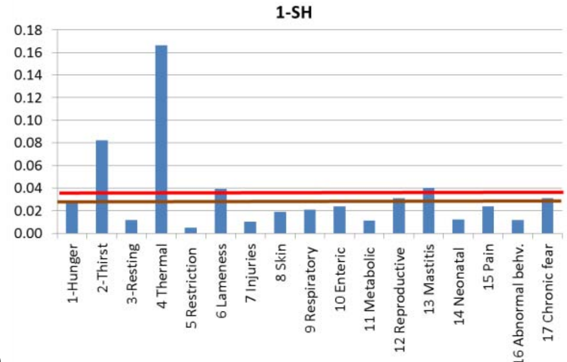
For the latter the uncertainty ratings were applied as weights. The uncertainty rating (i.e. ULow ±0.125; UMedium ±0.25; UHigh ±0.5) specifies an interval of values around the respondent's precise rating which are also considered likely. The broader the interval, the greater the uncertainty, the less weight will be given to the particular value of the individual rating. To achieve this, the inverse uncertainty rating was used as weight, or in other words the rating was divided by the length of the interval reflecting the chance to pick one particular value out if it. The calculation therefore applies the respondents uncertainty rating, UL: 0.125, UM: 0.25=0.125X2, UH: 0.5=0.125X4 as the weights: 1/(0.125X{UL=1; UM=2;UH=4}).

The aggregation of scores to rank the consequences was performed for every management system or production purpose and ewes and lambs. The following sub-sections present the uncertainty-adjusted impact scores for ewes and lambs per management system (3.2.1) and per production purposes (3.2.2). Furthermore, in section 3.3, the results of other aggregation methods (averaging raw impact scores, or using the median) are presented for ewes and every management system. Finally, more detailed investigations are presented in section 3.4.

3.2. Resulting impact scores for welfare consequences

3.2.1. Resulting impact scores by management system

3.2.1.1. Resulting impact scores by management systems-Ewes



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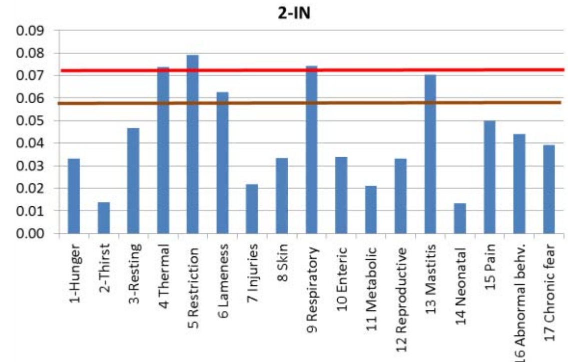

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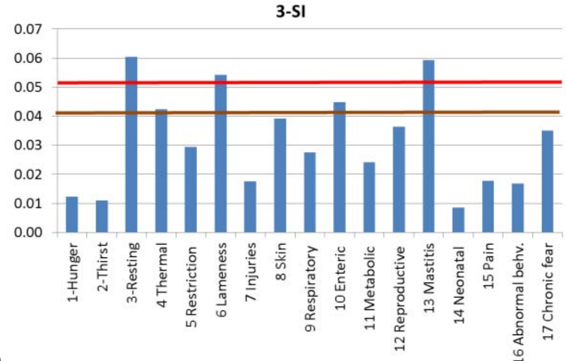

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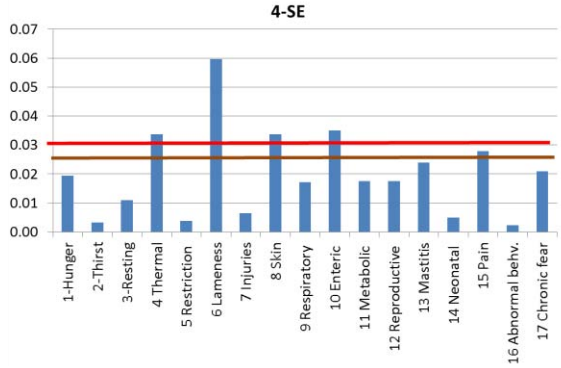

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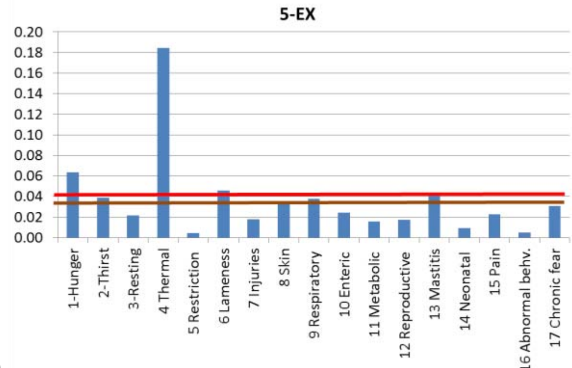

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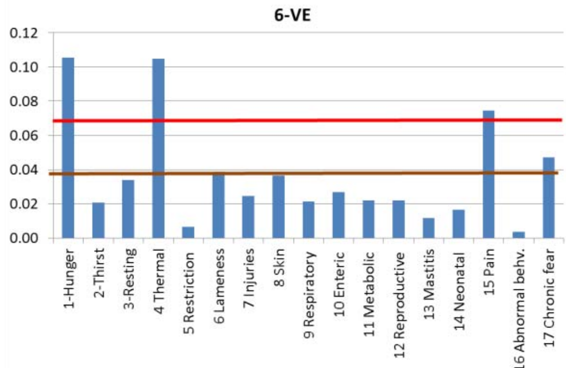

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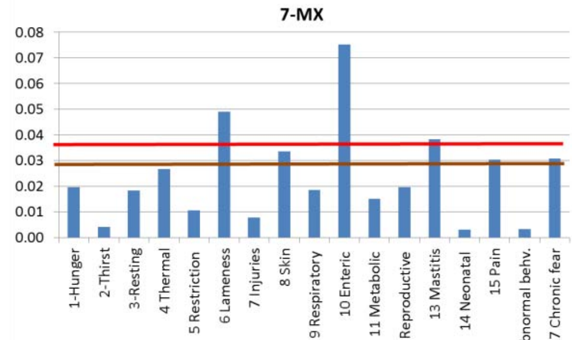
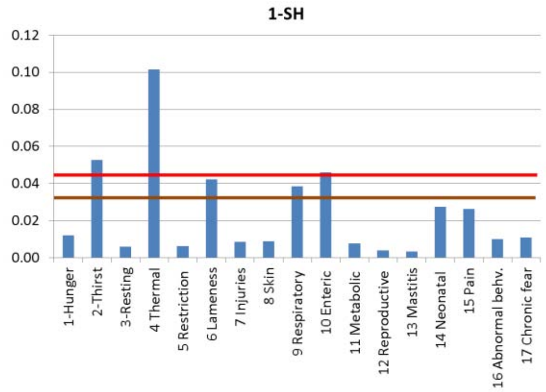


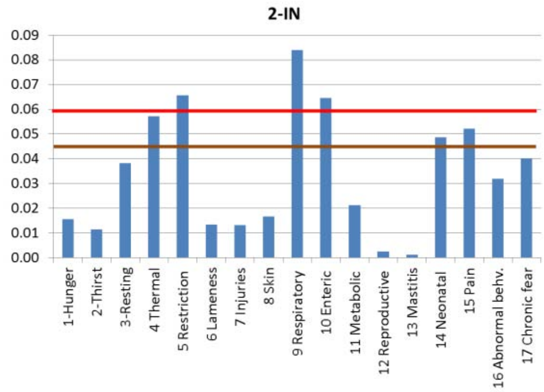
g)

Figure E.8 a-g: Uncertainty-weighted average impact scores for the 17 welfare consequences selected in the conceptual model for **ewes** by **management systems**. Red lines (brown lines) identify those three (five) consequences with the highest weighted average impact scores plus the ones that could not be excluded as being clearly different from the top three (five). Welfare consequences left-right: 1_Hunger, 2_Thirst, 3_Resting, 4_Thermal, 5_Restriction, 6_Lameness, 7_Injuries, 8_Skin, 9_Respiratory, 10_Enteric, 11_Metabolic, 12_Reproductive, 13_Mastitis, 14_Neonatal, 15_Pain, 16_Abnormal behaviour, 17_Chronic fear

3.2.1.2. Resulting impact scores by management systems–Lambs



a)



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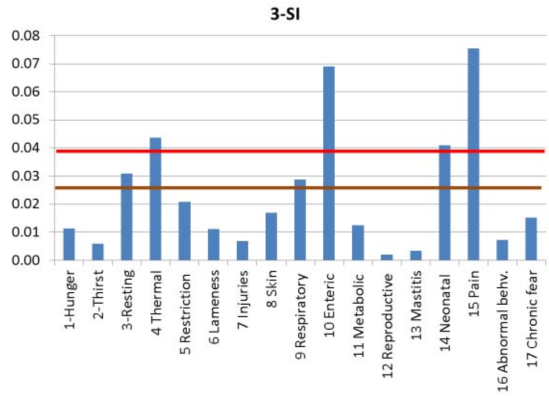

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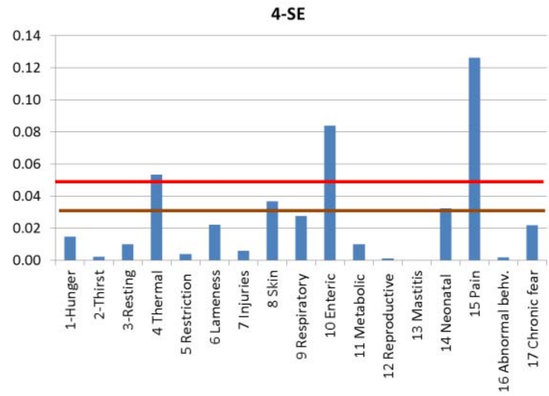

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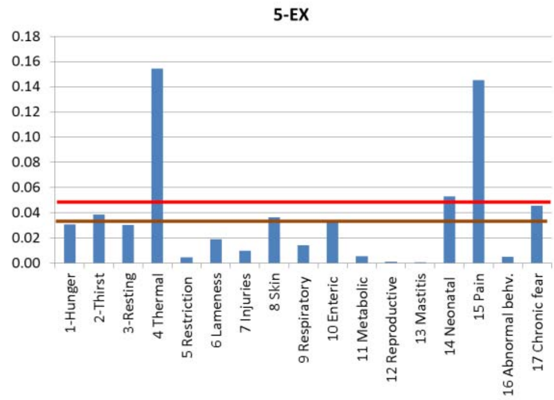

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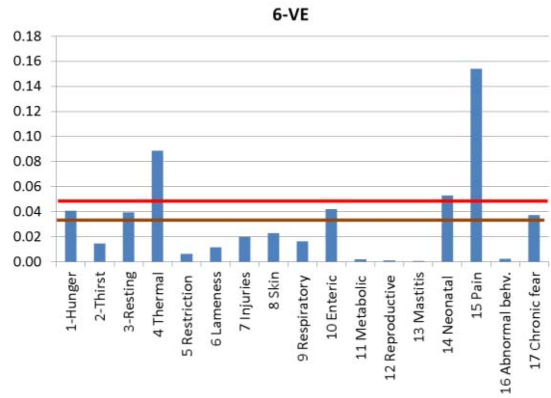

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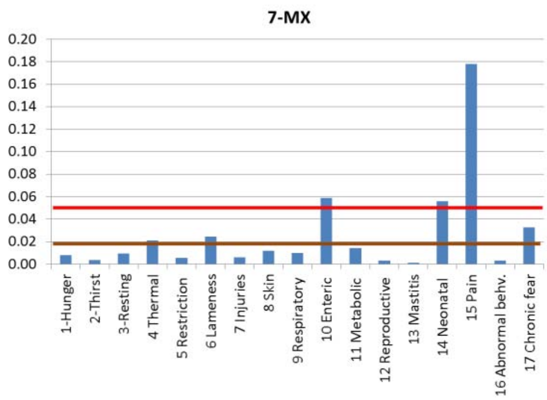


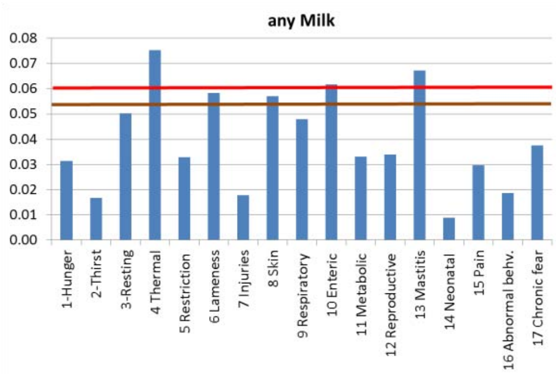
g)

Figure E.9 a-g: Uncertainty-weighted average impact scores for the 17 welfare consequences selected in the conceptual model for **lambs** by **management systems**. Red lines (brown lines) identify those three (five) consequences with the highest weighted average impact scores plus the ones that could not be excluded as being clearly different from the top three (five). Welfare consequences left-right: 1_Hunger, 2_Thirst, 3_Resting, 4_Thermal, 5_Restriction, 6_Lameness, 7_Injuries, 8_Skin, 9_Respiratory, 10_Enteric, 11_Metabolic, 12_Reproductive, 13_Mastitis, 14_Neonatal, 15_Pain, 16_Abnormal behaviour, 17_Chronic fear

3.2.2. Resulting impact scores by production purpose

3.2.2.1. Resulting impact scores by production purpose–Ewes

Milk (n=23)	Milk+meat (n=30)	Any milk (n=57)	Meat (n=65)	Any wool (n=45)	Meat+wool (n=37)	Wool (n=4) n.a.



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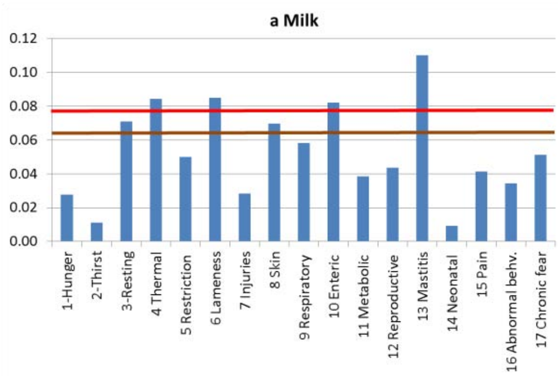

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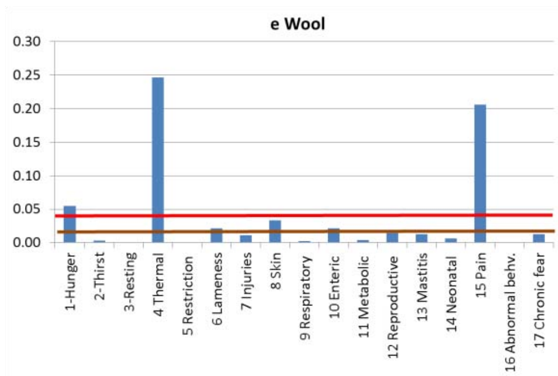

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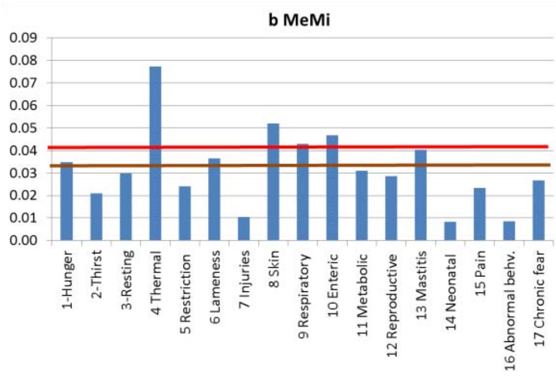

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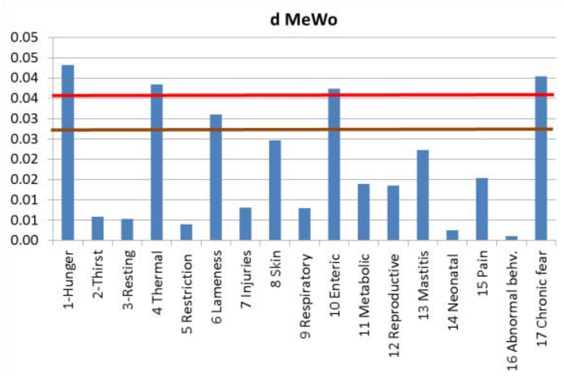

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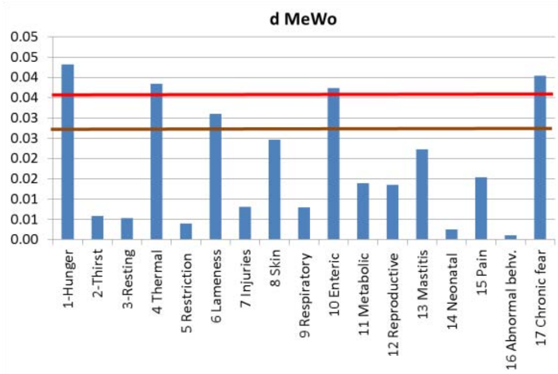
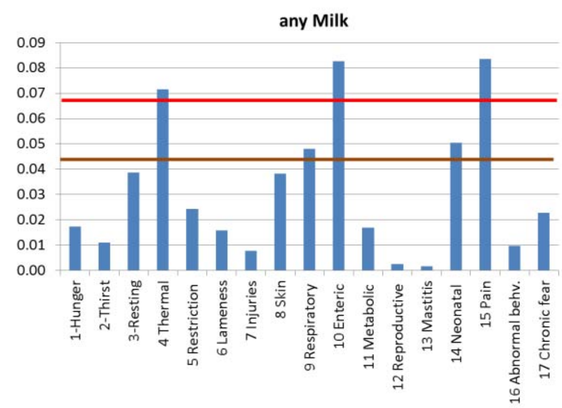


g)

Figure E.10 a-g: Uncertainty-weighted average impact scores for the 17 welfare consequences selected in the conceptual model for **ewes** by **production purpose**. Red lines (brown lines) identify those three (five) consequences with the highest weighted average impact scores plus the ones that could not be excluded as being clearly different from the top three (five). Welfare consequences left-right: 1_Hunger, 2_Thirst, 3_Resting, 4_Thermal, 5_Restriction, 6_Lameness, 7_Injuries, 8_Skin, 9_Respiratory, 10_Enteric, 11_Metabolic, 12_Reproductive, 13_Mastitis, 14_Neonatal, 15_Pain, 16_Abnormal behaviour, 17_Chronic fear

3.2.2.2. Resulting impact scores by production purpose-Lambs

Milk (n=23)	Milk+Meat (n=30)	Any milk (n=57)	Meat (n=65)	Any wool (n=45)	Meat+Wool (n=37)	Wool (n=4) n.a.



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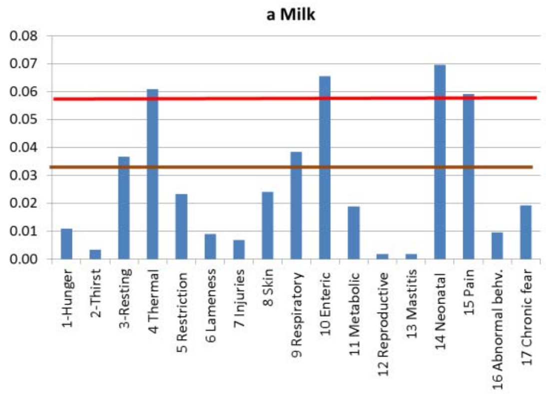

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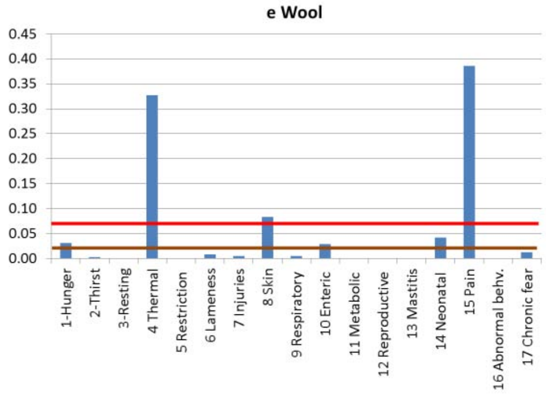

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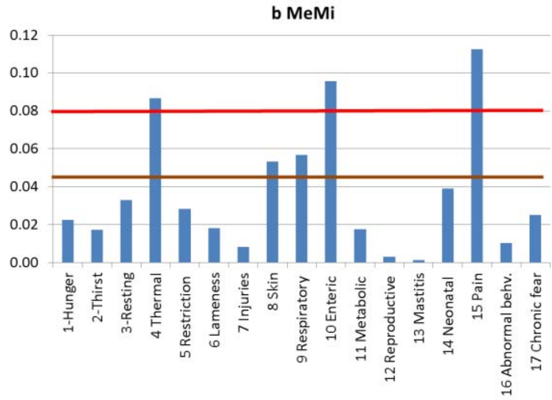

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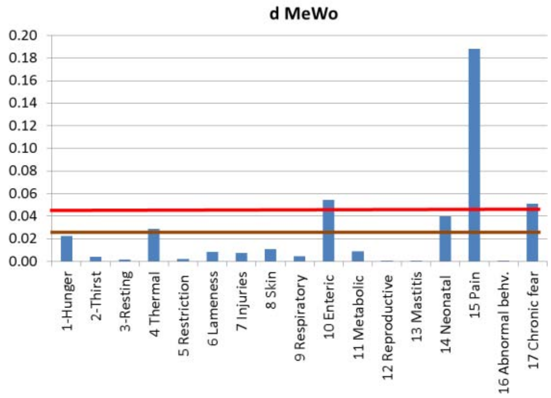

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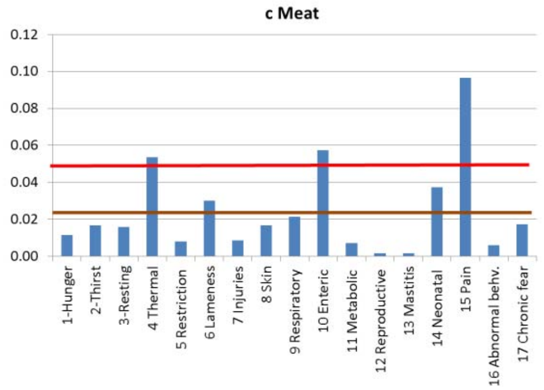

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Figure E.11 a-g: Uncertainty-weighted average impact scores for the 17 welfare consequences selected in the conceptual model for **lambs** by **production purpose**. Red lines (brown lines) identify those three (five) consequences with the highest weighted average impact scores plus the ones that could not be excluded as being clearly different from the top three (five). Welfare consequences left-right: 1_Hunger, 2_Thirst, 3_Resting, 4_Thermal, 5_Restriction, 6_Lameness, 7_Injuries, 8_Skin, 9_Respiratory, 10_Enteric, 11_Metabolic, 12_Reproductive, 13_Mastitis, 14_Neonatal, 15_Pain, 16_Abnormal behaviour, 17_Chronic fear

3.3. Comparison of alternative calculations to rank impact scores of welfare consequences

This and the following section are methodologically motivated. The information generated did contribute to the background understanding of the results but was not immediately used in the opinion.

The approach to integrate uncertainty ratings into the weighted average impact score was developed to exploit the distributional response (i.e. rating% ± 12.5%X{L:1,M:2,H:3}). Usually such interval ratings are interpreted as a certain percentile range of the full distribution of the uncertain estimate.

Because of the survey questionnaire methodology, it was not feasible to adjust that percentile interval across the respondents. Therefore, the weighting approach might not sufficiently balance the average for uncertainty of the respondents. We provided alternative aggregation methods, which are deemed simpler to interpret and which may give certain orientation about the valid tendency of the weighted score. Nevertheless, only the weighted average allows integrating ratings stated with a very narrow uncertainty interval with those providing very weak information, i.e. ±50% and thus the weighted approach was applied further in the opinion.

Distribution of uncertainty weighted impact scores across all ratings:

Percentile	Value
1	0.247
0.8	0.047
0.6	0.030
0.5	0.024
0.4	0.019
0.2	0.009
0.001	0.000

Table E.4. Comparison of results from alternative aggregation. Uncertainty-weighted average (upper row) vs. average (middle row) vs. median (bottom row) impact score. Inclusion of uncertainty has a minor impact on the ranking results (cf. row 1 vs. row 2) which indicates that extreme frequency ratings are dominantly stated very certain. The welfare consequence items marked red in the third row (median) were not ranked highly in terms of the average of the impact scores. The reason was the different perspective in the ratings by background (i.e. academic vs. practitioner; see detailed analysis). Academia, for example, emphasised behavioural items. Because both group samples are sized nearly 1:1, the median is dominated by the lower ratings of practitioners, while the average is dominated by the higher ratings of academia. A good exception is 3-SI, where 21 a+g are opposed to 11 p only–thus the outcome of both calculations is identical. Italic items are sequential after the first clear tie subsequent to the third consequence item (see main text).

method	**1-SH**	**2-IN**	**3-SI**	**4-SE**	**5-EX**	**6-VE**	**7-MX**
Uncertainty-weighted average impact score	Thermal Thirst Mastitis Lameness *Reproductive* *Chronic fear* *Hunger*	Restriction Thermal Respiratory Mastitis *Lameness* *Pain* *Resting* *Abnormal b* *Chronic fear*	Resting Mastitis Lameness *Enteric* *Thermal* *Skin* *Reproductive* *Chronic fear*	Lameness Enteric Thermal Skin *Pain*	Thermal Hunger Lameness Mastitis *Thirst* *Respiratory* *Skin* *Chronic fear*	Thermal Hunger Pain *Chronic fear* *Lameness* *Skin* *Resting*	Enteric Lameness Mastitis Skin Chronic fear Pain
Average impact score	Thermal Thirst Lameness Mastitis	Thermal Restriction Mastitis Respiratory Abnormal b *Lameness* *Resting* *Chronic f*	Mastitis Resting Lameness Thermal Enteric Reproductive Skin *Chronic f* *Restriction* *Metabolic* *Respiratory*	Lameness Enteric Thermal *Skin* *Pain* *Mastitis*	Thermal Hunger Mastitis Lameness *Skin* *Chronic f* *Respiratory* *Thirst*	Hunger Thermal Pain *Skin* *Chronic f* *Lameness* *Resting*	Enteric Lameness Chronic fear Thermal Mastitis *Pain* *Skin* *Hunger* *Resting*

method	1-SH	2-IN	3-SI	4-SE	5-EX	6-VE	7-MX
Median impact score	Thermal Lameness Respiratory Mastitis *Skin* *Enteric* *Reproductive*	Respiratory Mastitis Restriction Resting *Lameness* *Enteric* *Thermal*	Mastitis Skin Lameness Enteric Reproductive *Thermal*	Lameness Skin Enteric Mastitis Thermal *Reproductive*	Thermal Lameness Mastitis Hunger *Skin* *Enteric* *Reproductive*	Hunger Thermal Enteric Lameness Chronic f *Resting*	Lameness Mastitis Reproductive Enteric *Skin* *Chronic f*

3.3.1.1. Raw average

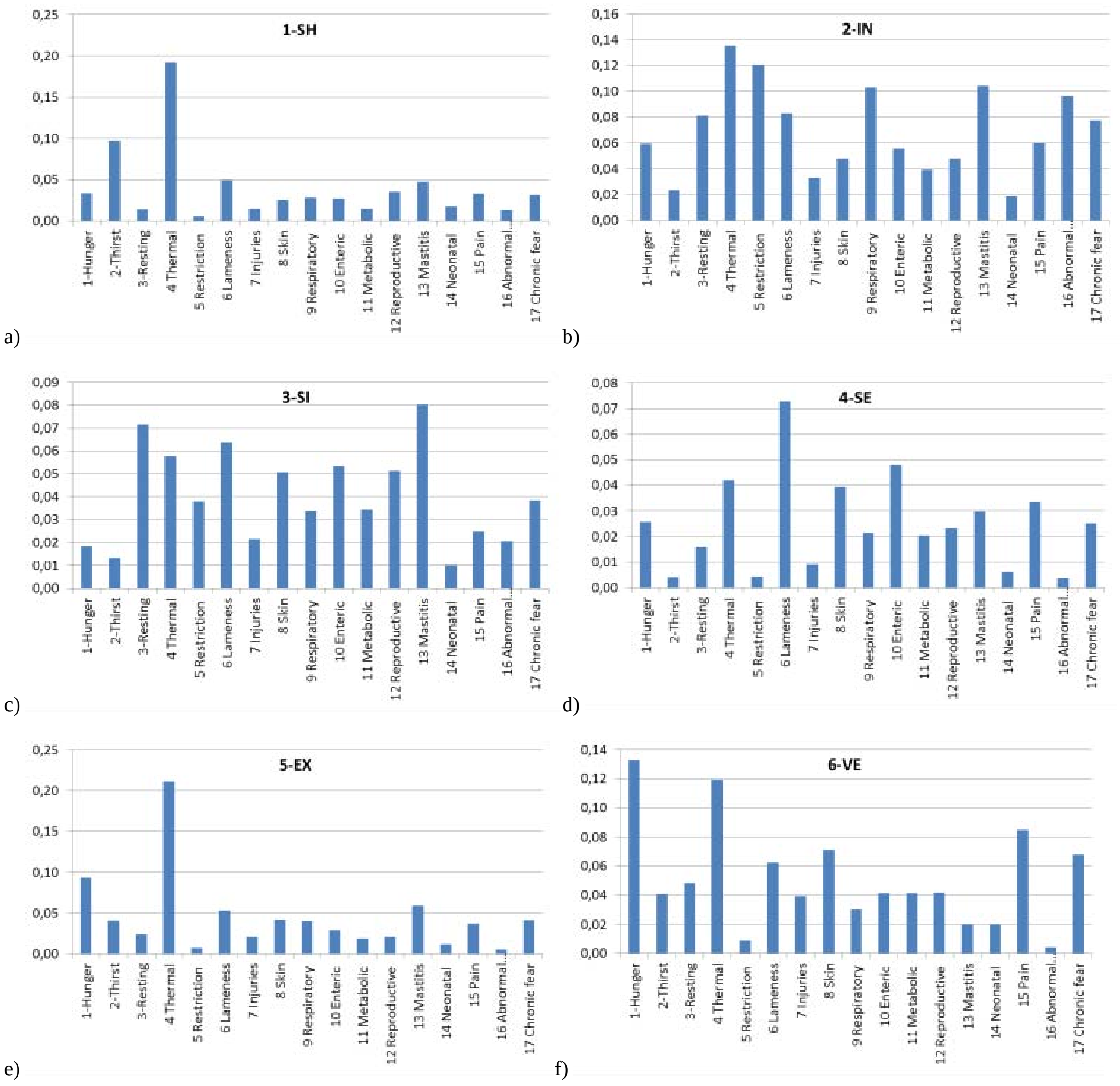


Figure E.12 a-f: Average impact scores for the 17 welfare consequences selected in the conceptual model for ewes by management system. Welfare consequences left-right: 1_Hunger, 2_Thirst, 3_Resting, 4_Thermal, 5_Restriction, 6_Lameness, 7_Injuries, 8_Skin, 9_Respiratory, 10_Enteric, 11_Metabolic, 12_Reproductive, 13_Mastitis, 14_Neonatal, 15_Pain, 16_Abnormal behaviour, 17_Chronic fear

3.3.1.2. Median

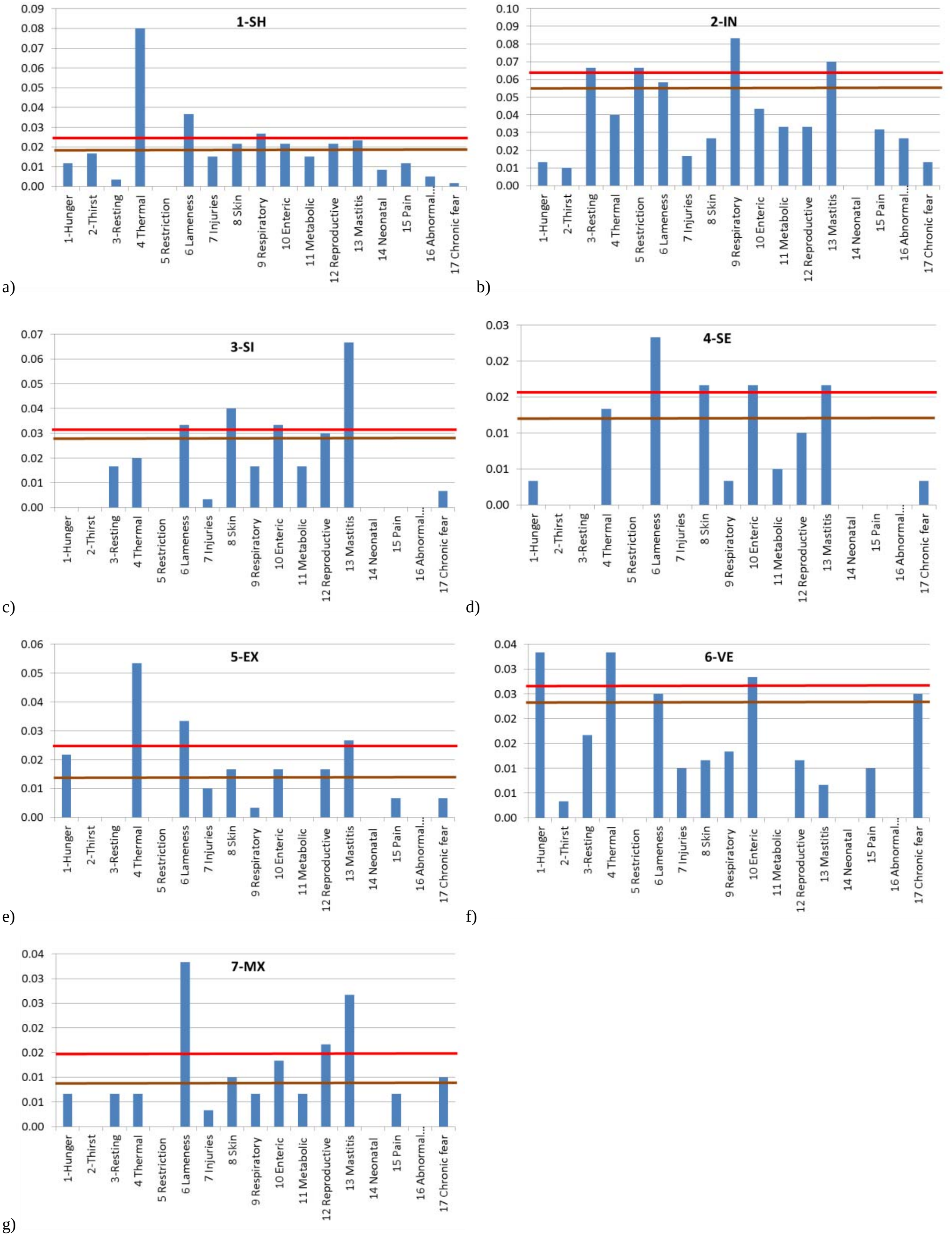


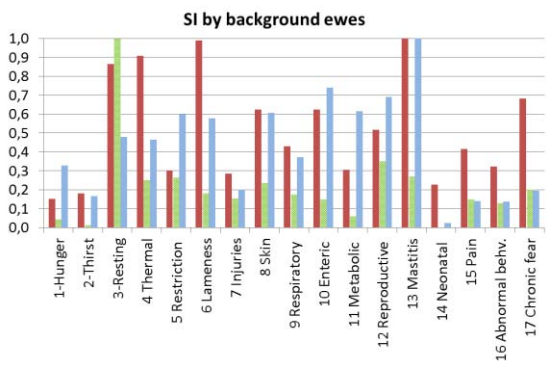
Figure E.13 a-g: Median impact scores for the 17 welfare consequences selected in the conceptual model for ewes by management system. Red lines (brown lines) identify those three (five) consequences with the highest weighted average impact scores plus the ones that could not be excluded as being clearly different from the top three (five). Welfare consequences left-right: 1_Hunger, 2_Thirst, 3_Resting, 4_Thermal, 5_Restriction, 6_Lameness, 7_Injuries, 8_Skin, 9_Respiratory, 10_Enteric, 11_Metabolic, 12_Reproductive, 13_Mastitis, 14_Neonatal, 15_Pain, 16_Abnormal behaviour, 17_Chronic fear

3.4. Detailed investigations

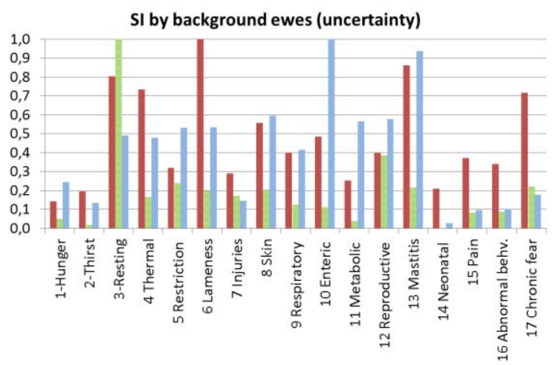
3.4.1. Comparison of background effect

Table E.5: Main welfare consequences for ewes by background of respondents in semi-intensive and semi-extensive systems. In brackets the number of records (n 3-SI/n 4-SE). First row: ranking for 3-SI using uncertainty-weighted average score. Second row: ranking of 3-SI average score. Third row: ranking of 4-SE average score. Red items were deselected in the other groups (row wise). Interpretation of differences between governmental and other groups needs care owing to the limited number of respondents.

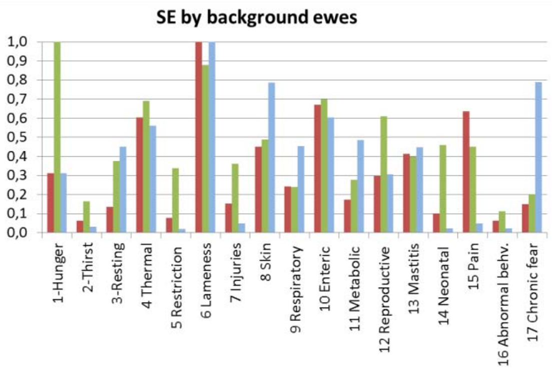
	Academia (18/21)	**Governmental (3/7)**	**Practitioner (11/28)**	**overall**
3-SI (uncertainty weighted average impact score)	Lameness Mastitis Resting Thermal Chronic fear Skin	Resting	Enteric Mastitis Skin Reproductive Metabolic Restriction Lameness Resting Thermal	Resting Mastitis Lameness Enteric Thermal Skin Reproductive Chronic fear
3-SI (average impact score)	Mastitis Lameness Thermal Resting Chronic fear Enteric Skin Reproductive	Resting	Mastitis Enteric Reproductive Metabolic Skin Restriction Lameness Resting Thermal	Mastitis Resting Lameness Thermal Enteric Reproductive Skin
4-SE (average impact score)	Lameness Enteric Pain Thermal Skin Mastitis	Hunger Lameness Enteric Thermal Reproductive Skin Neonatal Pain Mastitis	Lameness Skin Chronic fear Enteric Thermal Metabolic Resting Respiratory Mastitis	Lameness Enteric Thermal Skin Pain Mastitis



a)



b)



c)

Figure E.14 a-c: Average impact scores for the 17 welfare consequences selected in the conceptual model for ewes in semi-intensive and semi-extensive management systems. To allow comparison between the three series they all were standardised to the maximum, i.e. the highest rank in every group is set to 1. Coloured bars represent the score as calculated only for different educational background groups (red= academia; green= governmental; blue= practitioners). Welfare consequences left-right. 1_Hunger, 2_Thirst, 3_Resting, 4_Thermal, 5_Restriction, 6_Lameness, 7_Injuries, 8_Skin, 9_Respiratory, 10_Enteric, 11_Metabolic, 12_Reproductive, 13_Mastitis, 14_Neonatal, 15_Pain, 16_Abnormal behaviour, 17_Chronic fear

3.4.2. Detailed investigation on welfare consequences for the two most extensive management systems, i.e. extensive (EX) and very extensive (VE), by background of the respondents

There were differences of opinion between different background categories of respondents. For example, Lameness was perceived as an issue in extensive management systems. However, only academia (top fifth) and governmental (top third) experts rank the consequence as important. Practitioners did not rank lameness as a main consequence (top seventh; see Figure E.15 below). Other striking different perspectives are highlighted by the average ratings on thermal stress and chronic fear.

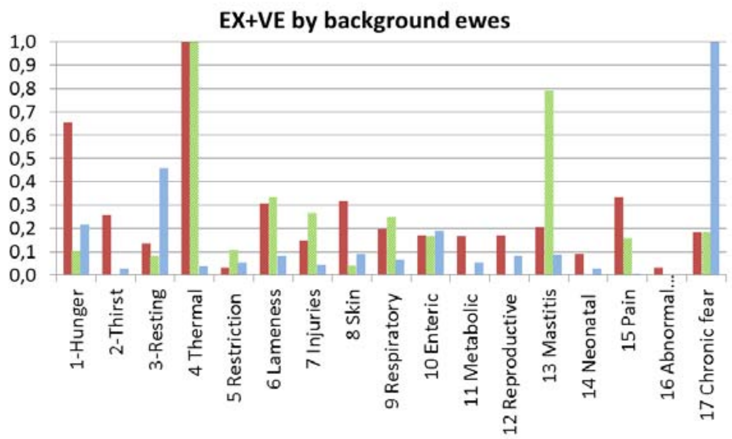


Figure E.15: Average impact scores for the 17 welfare consequences selected in the conceptual model for ewes in extensive and very extensive management systems. To allow comparison between the three series they all were standardised to the maximum i.e. the highest rank in every group is set to 1. Coloured bars represent the score as calculated for different educational background groups (red= academia; green= governmental; blue= practitioners). Welfare consequences left-right: 1_Hunger, 2_Thirst, 3_Resting, 4_Thermal, 5_Restriction, 6_Lameness, 7_Injuries, 8_Skin, 9_Respiratory, 10_Enteric, 11_Metabolic, 12_Reproductive, 13_Mastitis, 14_Neonatal, 15_Pain, 16_Abnormal behaviour, 17_Chronic fear

Appendix F. Comparison of the risk factors associated with each main welfare consequence for ewes and lambs kept in the different management systems

Table F.1: Most important welfare consequences and associated risk factors in ewes. The main welfare consequences identified are highlighted. For references, see Table 3 of the main text (section 3.1.4).

Welfare consequences	Management systems					
	SH	**IN**	**SI**	**SE**	**EX**	**VE**
Prolonged hunger	Poor pasture quality Lack of supplementary feed				Poor pasture quality Lack of supplementary feed	Poor pasture quality Lack of supplementary feed
Prolonged thirst	Hot and Dry Summer Lack of access to water				Hot and dry summer Lack of access to water	
Thermal stress	Lack of shade/shelter/bedding Extreme climate	Inappropriate housing (micro-environment, ventilation) Stocking density (overcrowding) Extreme climate Delay in shearing	Inappropriate housing (micro-environment, ventilation) Stocking density (overcrowding) Delay in shearing Lack of shade/ shelter when outdoors	Extreme climate Lack of shade/shelter Winter shearing	Extreme climate Lack of shade/shelter Winter shearing	Extreme climate Lack of shade/shelter Winter shearing
Restriction of movement		Increased stocking density Poor housing conditions (e.g. flooring)				
Resting problems			Inadequate space available when housed			

Welfare consequences	Management systems					
	SH	IN	SI	SE	EX	VE
			Floor and bedding quality			
Mastitis (genotype susceptibility)	All production purposes: Poor udder hygiene (related to flooring, resting) Teat lesions Inappropriate management of the ewes at drying-off Sheep for milk: Poor udder hygiene (related to milking) Inappropriate milking procedure Udder conformation in relation to machine milking Maintenance of milking system	All production purposes: Poor udder hygiene (related to flooring, resting) Teat lesions Inappropriate management of the ewes at drying-off Sheep for milk: Poor udder hygiene (related to milking) Inappropriate milking procedure Udder conformation in relation to machine milking Maintenance of milking system	All production purposes: Poor udder hygiene (related to flooring, resting) Teat lesions Inappropriate management of the ewes at drying-off Sheep for milk: Poor udder hygiene (related to milking) Inappropriate milking procedure Udder conformation in relation to machine milking Maintenance of milking system		All production purposes: Teat lesions Inappropriate management of the ewes at drying-off Poor udder hygiene (related to suckling and resting)	
Lameness	Pasture conditions (rough vegetation and wet and stony	Improper hoof care (incorrect trimming)	Improper hoof care (incorrect trimming)	Soil conditions (wet and stony)	Soil conditions (wet and stony)	Inappropriate nutrition (mineral deficiency)

Welfare consequences	Management systems					
	SH	IN	SI	SE	EX	VE
	soil) Poor biosecurity (introduction of contaminated animals) Improper hoof care (lack of, or incorrect, treatment when needed)	Inappropriate nutrition (SARA) Poor flooring (poor litter quality or plastic, slatted floor causing lameness)	Poor biosecurity (introduction of contaminated animals) Inappropriate nutrition (SARA, mineral deficiency and excess of protein at grazing)	Poor biosecurity (introduction of contaminated animals) Improper hoof care (lack of, or incorrect, treatment when needed)	Improper hoof care (lack of treatment when needed) Inappropriate nutrition (mineral deficiency)	Soil conditions (wet and stony) Improper hoof care (lack of treatment when needed)
Gastro-enteric disorders (including infections, endoparasites or toxins)			Poor pasture and grazing management Anthelmintic-resistant parasites Improper feed (transition and excess of proteins)	Poor pasture and grazing management Anthelmintic-resistant parasites Chronic diseases (e.g. pTB)		
Skin disorders (including infections, allergens, ectoparasites)				Poor biosecurity (introduction and transmission of ectoparasites) Lack of preventative measures (e.g. dipping) Nutritional photosensitisation	Lack of preventative measures (e.g. dipping) Micronutrient deficiency Nutritional photosensitisation	Lack of preventative measures (e.g. dipping) Micronutrient deficiency Nutritional photosensitisation
Respiratory disorders		Poor air quality (micro-environment, ventilation, stocking density, ammonia level)			Lack of preventive measures (vaccination, anti-parasitics)	

Welfare consequences	Management systems					
	SH	IN	SI	SE	EX	VE
		Increased exposure to pathogen (poor hygiene, resistant pathogen strains) Reduced immune competence (inadequate vaccination and anti-parasitics)			Reduced immune competence (inadequate vaccination and anti-parasitics)	
Reproductive disorders	Poor lambing intervention Nutrition (toxaemia, hypocalcaemia) High pathogen loading Inappropriate breeding (e.g. large lambs or litter size)					
Pain (including that due to management procedures such as castration, tail docking and shearing)				Tail-docking Ear notching-poor practice when ear tagging or use of inappropriate tags Mulesing (Australia only)		Tail-docking Ear notching-poor practice when ear tagging or use of inappropriate tags Mulesing (Australia only)

Welfare consequences	Management systems					
	SH	IN	SI	SE	EX	VE
				Poor handling		Poor handling
Chronic fear	Predation Presence of dogs Lack of exposure and acclimation to perceived threats, e.g. human handling					Predation Lack of exposure and acclimation to perceived threats, e.g. human handling

Table F.2: Most important welfare consequences and associated risk factors in lambs. The main welfare consequences identified are highlighted. For references, see Table 4 of the main text (section 3.1.4).

Welfare consequences	Management systems					
	SH	**IN**	**SI**	**SE**	**EX**	**VE**
Prolonged hunger						Poor pasture quality Lack of supplementary feed
Prolonged thirst	Hot and dry summer Lack of access to water Reduced sucking opportunities				Hot and dry summer Lack of access to water	
Thermal stress	Lack of shade/ shelter/bedding Extreme climate Feed quality and availability during cold weather Genotype unable to cope with heat	Inappropriate housing (micro-environment, ventilation) Stocking density (overcrowding) Extreme climate	Inappropriate housing (micro-environment, ventilation) Stocking density (overcrowding) Lack of shade/shelter outdoors	Lack of shade/ shelter/bedding Extreme climate Feed quality and availability during cold weather Genotype unable to cope with heat	Lack of shade/ shelter/bedding Extreme climate Feed quality and availability during cold weather Genotype unable to cope with heat	Lack of shade/ shelter/bedding Extreme climate Feed quality and availability during cold weather Genotype unable to cope with heat
Restriction of movement		Increased stocking density Poor housing conditions (e.g. flooring)				
Resting			Inadequate space available			Wet, boggy or stony

Welfare consequences	Management systems					
	SH	**IN**	**SI**	**SE**	**EX**	**VE**
problems			when housed Floor and bedding quality			pasture
Lameness	Pasture conditions (rough vegetation and wet and stony soil) Poor biosecurity (introduction of contaminated animals Inappropriate nutrition (mineral deficiency) Soil conditions (wet and stony)					
Gastro-enteric disorders	Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics) Increased exposure (stocking density, hygiene) to pathogen (parasites, bacteria) Malnutrition (lack	Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics) Increased exposure (stocking density, hygiene) to pathogen (parasites, bacteria) Unbalanced diet (frequency concentrate supply, lack of fibre)	Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics) Increased exposure (stocking density, pasture management, hygiene) to pathogen (parasites, bacteria) Unbalanced diet (frequency concentrate supply, lack of fibre)	Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics) Increased exposure (stocking density, pasture management, hygiene) to pathogen (parasites, bacteria) Malnutrition (lack of nutrients, proteins, fibre) and unbalanced diet	Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics) Increased exposure (pasture management, hygiene) to pathogen (parasites, bacteria) Malnutrition (deficient trace elements, toxic plants)	Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics) Increased exposure (pasture management, hygiene) to pathogen (parasites, bacteria) Malnutrition (deficient trace

Welfare consequences	Management systems					
	SH	IN	SI	SE	EX	VE
	of nutrients, proteins, fibre)			(frequency concentrate supply, lack of fibre)		elements, toxic plants)
Skin disorders				Poor biosecurity (introduction and transmission of ectoparasites) Lack of preventive measures (eg dipping) Nutritional photosensitisation	Lack of preventive measures (eg dipping) Micronutrient deficiency Nutritional photosensitisation	
Respiratory disorders	Poor air quality (micro-environment, ventilation, stocking density, ammonia level) Increased exposure to pathogen (poor hygiene, resistant pathogen strains) Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics)	Poor air quality (micro-environment, ventilation, stocking density, ammonia level) Increased exposure to pathogen (poor hygiene, resistant pathogen strains) Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics)	Poor air quality (micro-environment, ventilation, stocking density, ammonia level) Increased exposure to pathogen (poor hygiene, resistant pathogen strains) Reduced immune competence (inadequate colostrum, vaccination and anti-parasitics)			
Pain (including due to		Ear notching-poor practice when ear tagging or use of	Ear notching-poor practice when ear tagging or use of inappropriate tags	Castration Tail-docking	Castration Tail-docking	Castration Tail-docking

Welfare consequences	Management systems					
	SH	IN	SI	SE	EX	VE
management procedures such as castration, tail docking and shearing)		inappropriate tags Poor handling Castration Tail-docking	Poor handling	Ear notching-poor practice when ear tagging or use of inappropriate tags	Ear notching-poor practice when ear tagging or use of inappropriate tags	Ear notching-poor practice when ear tagging or use of inappropriate tags
Chronic fear					Presence of dogs Predation Lack of exposure and acclimation to perceived threats, e.g. human handling	Presence of dogs Predation Lack of exposure and acclimation to perceived threats, e.g. human handling
Neonatal disorders (including starvation/ mis-mothering/ exposure complex)		Deficiency of ewe nutrition during pregnancy Dystocia Prolificity Mis-mothering due to crowding or ewe stress at parturition	Deficiency of ewe nutrition during pregnancy Dystocia Prolificity	Deficiency of ewe nutrition during pregnancy Dystocia Prolificity	Lack of shelter (exposure to rain and wind) Deficiency of ewe nutrition during pregnancy Dystocia	Lack of shelter (exposure to rain and wind) Deficiency of ewe nutrition during pregnancy Dystocia

GLOSSARY

Conceptual model: a written description and visual representation of predicted relationships between factors that affect welfare and the animal welfare aspects that are being considered in a problem formulation.

Expert elicitation: a multi-disciplinary survey of expert opinion that can inform decision making by characterising uncertainty and filling data gaps where traditional scientific research is not possible or data are not yet accessible or available

Feasibility: capacity to be applicable to different housing systems and at least have the potential to be applied on-farm. These requirements excluded some physiological parameters that need experimental equipment (e.g. heart rate recordings) or laboratory analyses (e.g. hormone assay) as well as complex behavioural tests that could not be integrated into the farm routine (e.g. open-field tests). In terms of the feasibility of the whole assessment protocol, the assumption that has been taken was that it should be possible for a single observer to carry out a farm assessment during a one-day visit.

Hazard: risk factor with the potential to impair one or more welfare consequences.

Indicator: an occurrence which has a proven relationship to the welfare consequence of concern. This could be an absolute state or change in state of an animal or the circumstances which it is kept[8].

Measure: a form of evaluation of the indicator used in the animal welfare assessment, which can be animal-, management- or resource-based[8].

Measurement: the result of this evaluation as scored for an individual animal or group of animals[8].

Reliability: includes intra-observer reliability (repeatability) which requires that results are largely the same when the same observer repeats assessments, inter-observer reliability (reproducibility), which refers to agreement between two or more observers after they have received reasonable training, and test-retest reliability, i.e. repeated tests with the same subjects yield similar data. A somewhat special but often neglected case of test-retest reliability is the repeatability (consistency) of assessments over time at farm level.

Validity: the extent to which a measure is meaningful in terms of providing information on a specific welfare consequence of an animal or a group of animals.

Welfare consequence: the change in welfare that results from the effect of a factor or factors defined as any aspect of the environment in relation to housing and management[8].

[8] For example, the welfare consequence of prolonged hunger can be indicated by, for example, loss of body tissue reserves (the indicator), which can be evaluated by, for example, visual inspection/ manual palpation (body condition score e.g. on the scale 1-5; the measure), and recorded for the individual sheep as a number (e.g. score 2: the measurement). Alternatively the indicator can be evaluated by body weight (the measure), and recorded for the individual sheep as a number (e.g. 40Kg: the measurement).
Furthermore, the indicator could be indirectly assessed with a resource-based measure, for example, the amount of feed given to the animal relative to its maintenance requirements, using megajoule of energy per day as the measurement.