SCIENTIFIC OPINION

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

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

European Food Safety Authority (EFSA), Parma, Italy

Rev 18 version 22-09-2014

ABSTRACT

This scientific opinion on sheep welfare is the result of a scoping exercise which included a systematic literature review, construction of a risk model (conceptual model) by the Working Group and ranking of welfare consequences through expert knowledge elicitation that involved an on-line survey and technical hearing. Sheep farmed for three different production purposes -wool, meat and milk - were identified as target population, focusing the attention on ewes and lambs as animal categories. Sheep management systems were characterised for the purpose of this opinion as shepherding, intensive, semi-intensive, semi-extensive, extensive, very extensive and mixed system. The conceptual model proposed 17 main animal welfare consequences and associated risk factors in farming of sheep under different management systems. These animal welfare consequences were based on four principles identified in the Welfare Quality project: good feeding, good housing and environment, good health and appropriate behaviour. The results of the on-line survey on the 17 main animal welfare consequences helped identification of the main welfare consequences for ewes and lambs kept under each management system. The technical hearing of experts facilitated consensus on the major risk factors associated with the most important welfare consequences of ewes and lambs under the studied management systems and production purposes. In addition, some of the measures used to assess animal welfare consequences for ewes and lambs were also elucidated.

KEY WORDS

(Max. seven key words)

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[1] On request from the European Commission, Question No EFSA-Q-2013-00580, adopted on DD Month YYYY.

[2] Panel members: Edith Authie, Charlotte Berg, Anette Bøtner, Howard Browman, Ilaria Capua, Aline De Koeijer, Klaus Depner, Mariano Domingo, Sandra Edwards, Christine Fourichon, Frank Koenen, Simon More, Mohan Raj, Liisa Sihvonen, Hans Spoolder, Jan Arend Stegeman, Hans-Hermann Thulke, Ivar Vågsholm, Antonio Velarde, Preben Willeberg and Stéphan Zientara. Correspondence: alpha@efsa.europa.eu Correspondence: alpha@efsa.europa.eu

[3] Acknowledgement: The Panel wishes to thank the members of the Working Group on sheep welfare: Cathy Dwyer, Sandra Edwards, Fabio Napolitano, Hans-Hermann Thulke, Mohan Raj, Antonio Velarde for the preparatory work on this scientific opinion and the hearing experts: Gustavo Levrino, Alison Small, Dino Gavojdian, George Fhtenakis, Lindsay Mathhews, David Henderson, Frank Langrish, Luc Mirabito, Antonello Cannas, and EFSA staff: Denise Candiani, Maria Ferrara, Matthew Watts for the support provided to this scientific opinion.

Suggested citation: EFSA ACRONYM Panel (EFSA Panel Name) [or] Scientific Committee, 20YY. Scientific Opinion on title of the opinion. EFSA Journal 20YY;volume(issue):NNNN, 119 pp. doi:10.2903/j.efsa.20YY.NNNN

Available online: www.efsa.europa.eu/efsajournal

SUMMARY

Following a request from [the requesting party], the EFSA [Panel Name] (Acronym)/Scientific Committee was asked to deliver a scientific opinion on [subject].

Note: the summary should not include tables, footnotes, graphs or pictures.

Note: Following a decision from the management, the following elements should be included in the summary: the requestor, the request, the methods used or approach and the conclusions and/or recommendations.

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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 guide 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

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 on the identification of the animal-based measures to evaluate the main welfare consequences identified. 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 were considered since 2004, initially through literature reviews and afterwards trough risk assessment methodology; in particular, several risk assessment for welfare on the farm were carried out for a number of species including calves (EFSA, 2006), beef cattle (EFSA, 2012a), dairy cows (EFSA, 2009), pigs (EFSA, 2007 a, b and c) and broilers (EFSA, 2010). However, this is the first time that EFSA aims to assess the welfare of sheep on the 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, 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, 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 for EFSA to address the welfare of sheep and, following the methodological frame of the EFSA Guidance on risk assessment for animal welfare, 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.

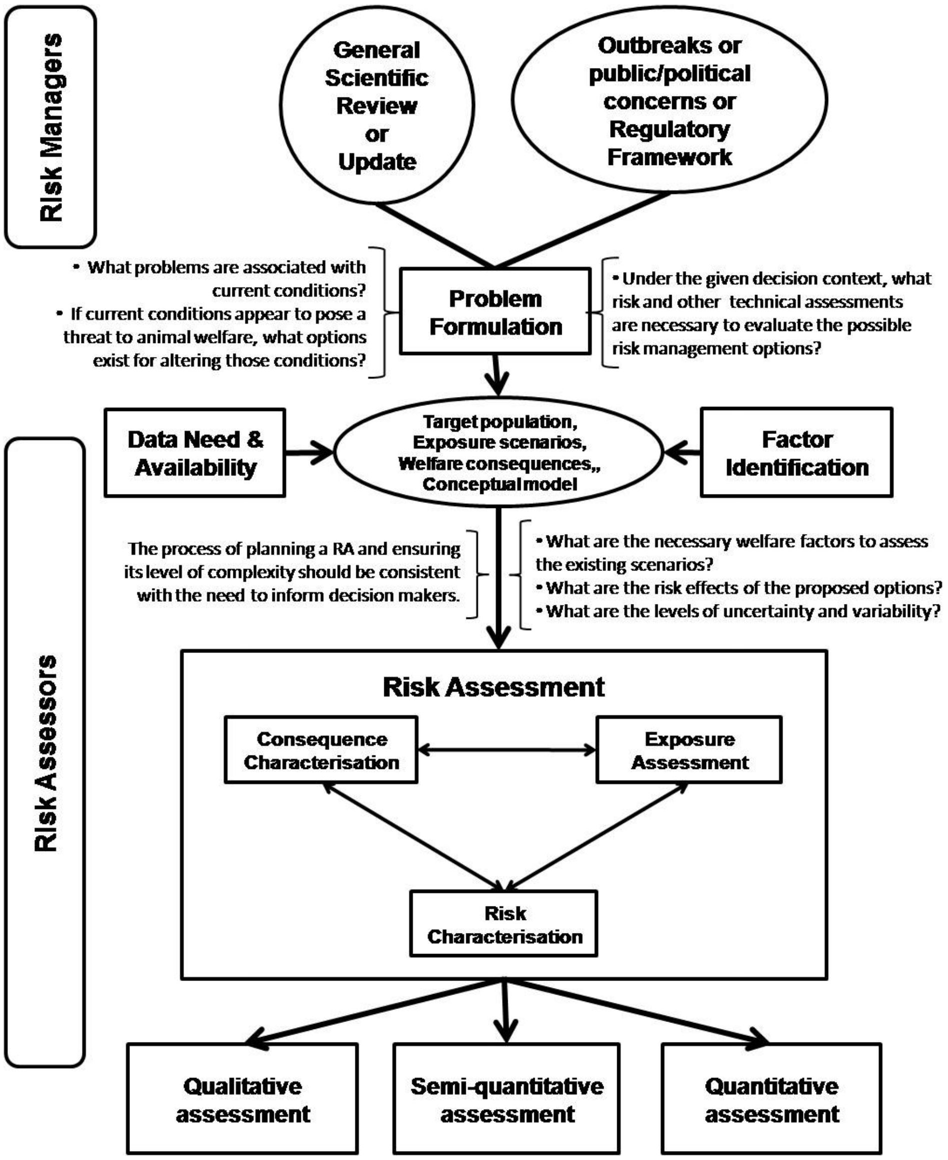

Figure 1. Workflow to conduct a risk assessment (EFSA, 2012)

1.1. Distribution of sheep population in the world

FAO data (FAOSTAT.fao.org) indicate that the overall world sheep population is 1,167 million in 2012 with a slight increase to 1,173 million in the preliminary 2013 data. 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), United Kingdom (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 EU, 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 Survey, a total of 979,180 agricultural holdings[5] produced sheep within the surveyed countries (see Table 4 and Figure 2). Romania had the most sheep producing agricultural holdings, followed by Greece, Bulgaria, United Kingdom, Spain, France and Portugal (Table 1).

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

Table 1: FSS countries with the most sheep producing agricultural holdings. Source: Eurostat, 2010

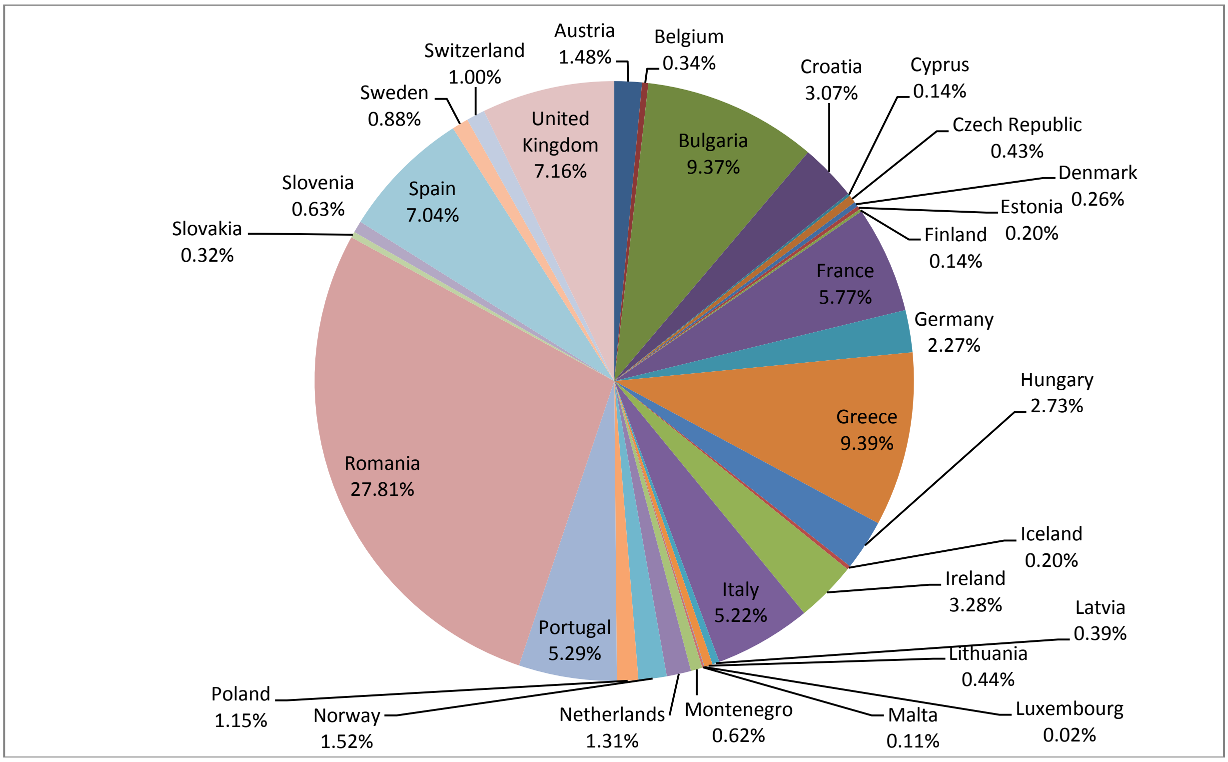

Figure 2: Proportion of sheep holdings by FSS country. Source: Eurostat, 2010

[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." http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Farm_structure_survey_(FSS)

[5] "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.

The total population of sheep in the 32 surveyed countries was 99,421,850 (Table 4 and Figure 3). The United Kingdom had the largest population of sheep, followed by Spain, Greece, Romania, France, Italy and Ireland (Table 2).

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

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

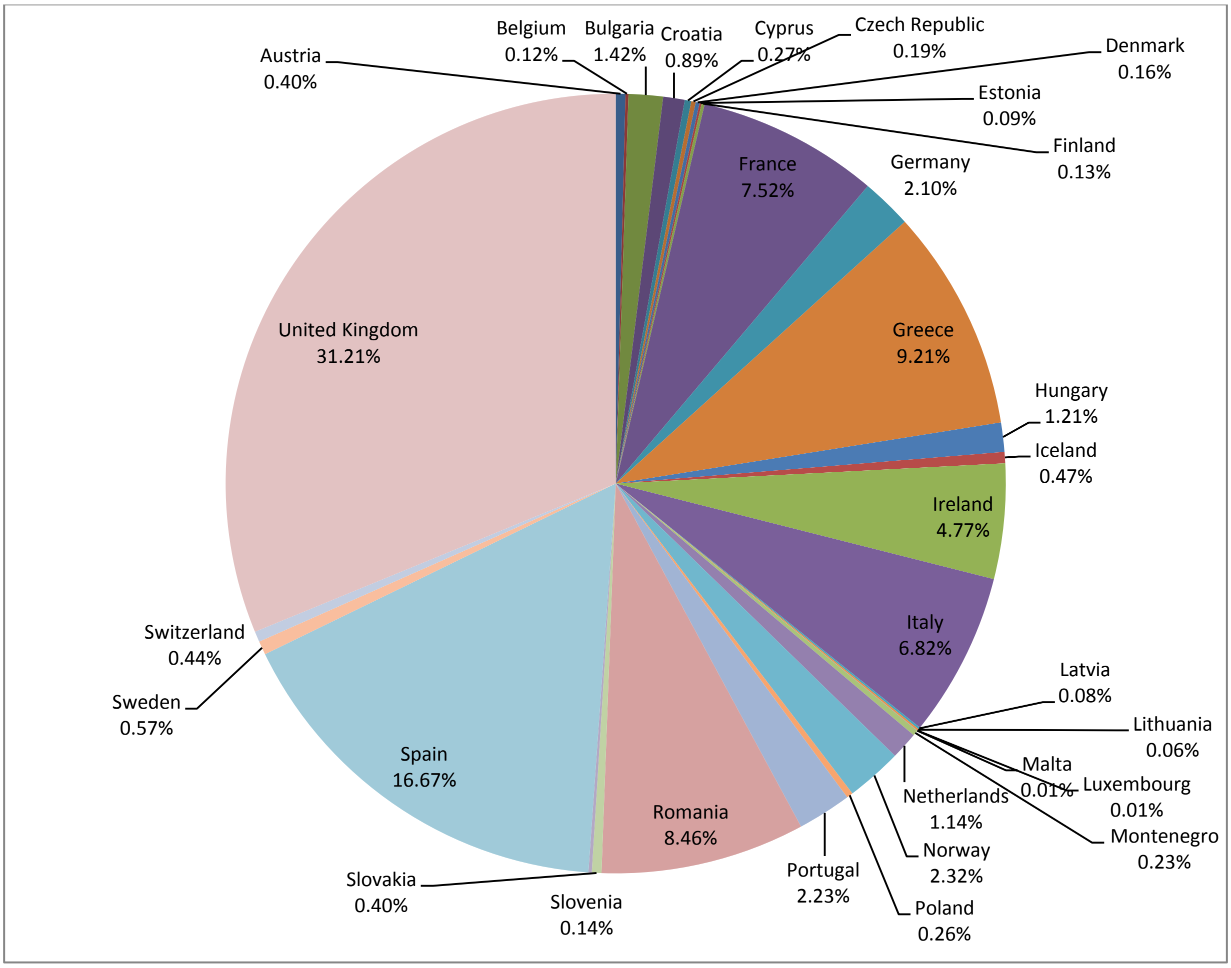

Figure 3: Proportion of sheep by FSS country. Source: Eurostat, 2010

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

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

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

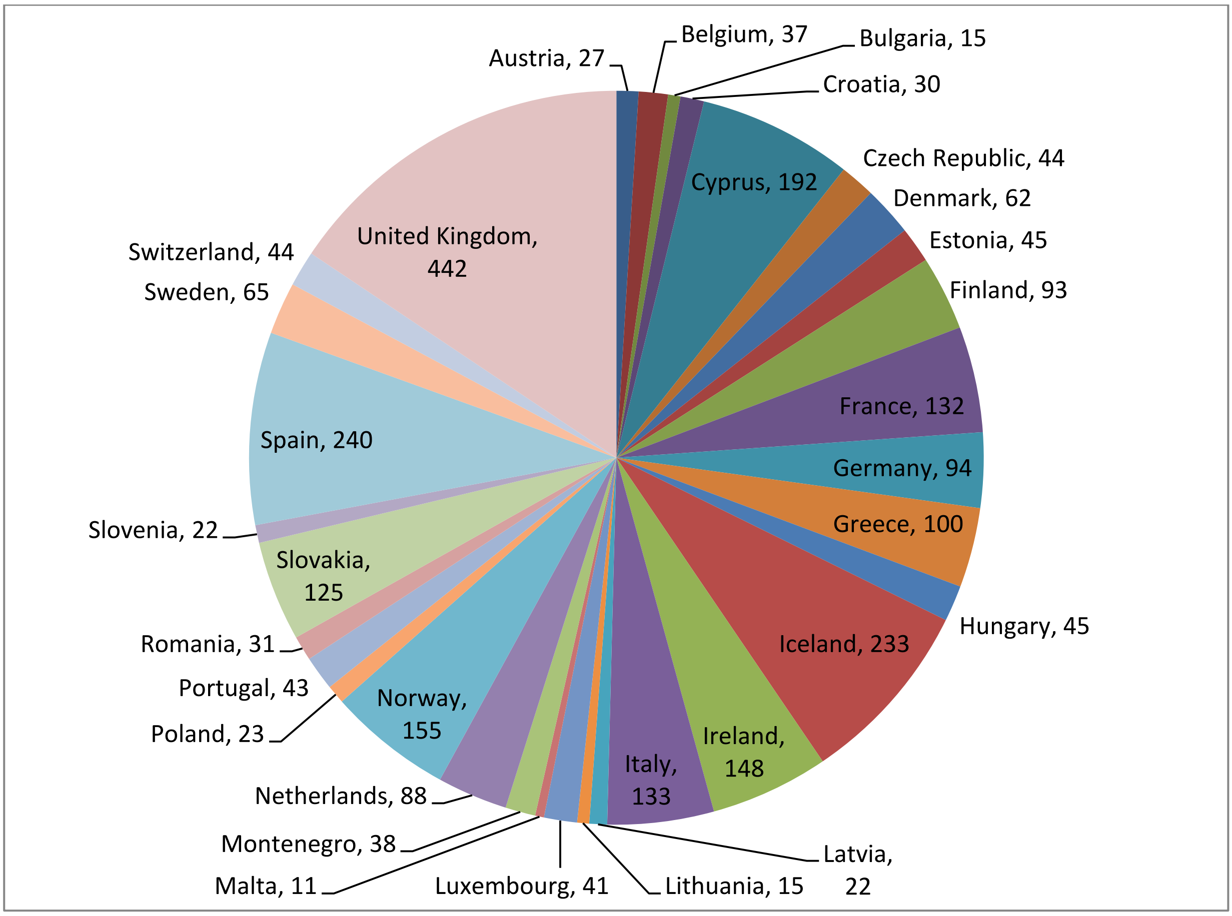

Figure 4: Average Sheep per holding for FSS countries: Source: Eurostat, 2010

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

Country	**Number of sheep**	**Number of holding**	**Average 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
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

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

Regional distribution of sheep is provided in number of animals per EU-country. However, to our knowledge, data on geographical distribution by management system and production purpose are not available.

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 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 population might be defined, ewe for reproductive, milk and wool production purposes and lamb for meat.

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 the 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 keeps a certain relationship with the geographical area: in northern regions temperate breeds of sheep are kept for meat and wool, 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 (for example 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. Thus 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) Mountain, 'rustic' and primitive breeds (e.g. Herdwick, Scottish Blackface, Ripollesa): 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) Downs breeds (e.g. Texel, Suffolk, Merino): larger, temperate, thin-tailed sheep breeds generally subjected to more intensive selection pressure for production traits (meat or wool).

Animals may be more likely to be kept in flatter pastures with access to grazing of a better quality 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) Longwool breeds (e.g. Bluefaced Leicester): 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) Northern desert sheep (e.g. Awassi, Karakul): locally adapted to hot, arid climates and harsh terrain, these breeds are kept for milk production, and for meat.

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 1. 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, 2012). The multidimensional approach of the Welfare Quality 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, Keeling, Gavinelli, & Serratosa, 2008). Within these principles, the project highlighted twelve 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 5 as follows:

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 neither be 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)

Table 5. The four principles and twelve criteria of animal welfare according to the Welfare Quality project.

A hazard is a risk factor with the potential to impair one or more welfare consequences.

1.5. Animal-Based Measures (ABMs)

Animal-based measures (see glossary) are necessary to assess 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, Capdeville, Gebresenget, Hörning, & Roiha, 2003). Reliability assessment included: 1) inter-observer reliability, 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). 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. Feasibility means the possibility to carry out the measure under practical conditions.

The *Animal Welfare Indicators Project* (AWIN) 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 Welfare Quality®. The AWIN project uses similar methods to those developed by Welfare Quality, and the 4 Principles and 12 Criteria developed in this project and shown above. The work for sheep focuses on extensively managed adult ewes. 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, 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) with an increase in health-related disorders (e.g. low body condition score, breech soiling) in summer months when ewes were lactating.

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

Welfare Quality criteria as a framework to identify welfare problems which might be experienced by sheep in any system. A systematic 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 more focussed technical meeting, as detailed in the following sections. Finally 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 to identify the main factors and welfare consequences for sheep raised for the production purpose of wool, meat and milk. The mandate also requested to consider 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. It should, however, 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 on Risk Assessment for Animal Welfare. ToR 3 was addressed separately after identification of the risk factors and welfare consequences.

2.1. Addressing TOR 1 and 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)

Sheep raised for wool, meat and milk production were identified as the target population, focusing attention in particular on ewes and lambs because of the higher number of animals exposed to given risk scenarios. Although in most 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 factors 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 2).

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, as well as the links among them. A table summarising this conceptual model is given in Appendix 3.

The welfare consequences of the different factors are mainly related to sheep biology (therefore common to the 3 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 Welfare Quality 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 Welfare Quality Project were used as the starting point. In considering the appropriate welfare consequences for further analysis, it was felt necessary to sub-divide the criterion of good health into specific categories of disease because these would have different risk factors. Furthermore, the report will deal only with risk factors (negative risk factors) and not with factors that have positive effect on welfare (benefits), as these require further conceptual and methodological refinement (EFSA, 2012b).

Therefore, finally 17 welfare consequences were retained in the conceptual model and considered for further assessment through an expert elicitation process (see paragraph 2.1.4). Each of these welfare consequences could be expressed with different degrees of severity which are included in the conceptual model.

From the conceptual model, the working group prepared a list of the main factors related to each welfare consequences, as the starting point for a systematic literature review (see next paragraph).

2.1.3. Systematic literature review

A systematic review of the literature was first run. The methodology for the systematic literature review is detailed in an external report from O’Connor et al (O’Connor et al, in press). A first 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), 8 main welfare determinants adapted from the 12 Welfare Quality principles (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 EFSA WG.

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

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As follow-up to the mapping, a systematic review was performed on “The effect of extensive/outdoor/migratory management on lameness in intensive/indoor management systems 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. The WG considered it appropriate to evaluate first 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. As second step, main risk factors were identified and characterized for the most important welfare consequences that resulted from the first step.

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The first phase of the expert elicitation was carried out through an electronic survey, in which experts were provided with the 17 main welfare consequences and with their definition (see below) that was considered by the EFSA Working Group as point at which the welfare problem becomes significant from the animal point of view.

For the purpose of the questionnaire animal categories were defined as below:

- Ewe: adult sheep kept for breeding and/or milking and female lambs kept for breeding purposes
- Lamb: young sheep - between birth and slaughter – kept for meat

For the purpose of the questionnaire welfare consequences were defined as below:

- 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 due to 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, inflammed 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 inappetance, 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, prolapsed uterus.
- Mastitis: the animal has inflammation of the udder, indicated by altered colour, temperature and consistency, and reluctance to allow contact to 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 due to management procedures such as castration, tail docking and shearing): the animal shows altered posture, vocalization, 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 unrestricted environment. These can include sucking, biting or chewing non-food items and stereotypic behaviours such as pacing.
- Chronic fear (fearfulness due to e.g. predation, poor handling, disturbed social behaviour): the animal shows exaggerated signs of anxiety such as escape attempts, increased vigilance, excitability, 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 paragraph 3.1.1.).

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 importance of each of the welfare consequences separately for ewes and lambs, according to the average amount of suffering an animal will experience in that system in 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 system, causing different degrees of suffering depending on how frequently they happen during the lifetime of the animal, how long they last and how intense is 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 and were defined in more specific way depending on the specific management system.

The on-line survey was launched on 7 May and was open till 27 June. 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 questionnaire was therefore distributed to 6 main categories of stakeholders with relevant expertise:

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

The organisations and technical groups contacted were asked to identify and distribute the 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 questionnaire 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. In addition, the WG checked how influential certain replies were, by reassessment when outliers were excluded. Finally, for respondents who did not disclosed their identity, the WG checked if their replies were different from those who disclosed their identity.
Methodology and general criteria were also defined to select the main welfare consequences from the overall survey replies. For each management system and for ewes and lambs, the prevalence value of each consequence was multiplied by its score of severity so as to result in an overall value of importance that allowed ranking of all the consequences. The same exercise was repeated for all responses for ewes and lambs, each grouped together depending on their production purpose. As the aim of the on-line survey was to identify the main welfare consequences for ewes and lambs depending on the management system, from the above-mentioned lists the WG decided to include at least 3 consequences, and always selected the top 3 ranked consequences for both ewes and lambs.
Furthermore, additional consequences were included following the specific criteria for lambs and ewes. For lambs, when there was a clear separation of scores for welfare consequences, the 3 highest scored ones were chosen plus the ones that could not be excluded as being clearly different from the top 3 (1 score difference). In addition, any of the 4 highest scoring overall consequences for lambs were also included if they were next highest ranking for that category.
For ewes, the 3 highest scored consequences were chosen plus the ones that could not be excluded as being clearly different from the top 3 (1 score difference). In addition the top ranking consequence for each purpose within the system was added if not yet present.
The 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.

On the basis of these results and in order to identify the main risk factors associate 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 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 is the relation between the risk factor and the consequence, how many animals are exposed to this factor and for how much of their life.

3. To discuss mixed system possibilities/components mostly reported in the questionnaire

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 chapter 2.2).

10 hearing experts were invited to participate at this meeting and they were selected on the basis of the following 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:

1) 4 scientists with field /farm experience on sheep welfare and production
2) 2 veterinary practitioners with commercial field experience on sheep production, sheep health and sheep welfare
3) 4 researchers representing farmers' organisations, with practical sheep production experience across a range of systems.

The results of such activities are reported in chapter 3.1.4 and a summary table is presented in Appendix 4.

2.2. Addressing ToR3: Identification of the animal based measures

In the conceptual model, 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 affecting (as a factor) 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, 2011).

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 therefore does not aim at fully covering all the existing and varied farming systems and their comprehensive elements, but it aims instead at characterizing, 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 is 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. In 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.

The following Table 6 was developed by the EFSA WG as model to identify the elements and factors characterizing the main system typologies and to outline definitions suitable for the risk assessment process. In particular, the elements considered for the definition of the different scenarios are: shepherding, no outdoor access, housing, keeping of sheep in fenced pastures and supplementation.

While the continuous presence of the stockperson (shepherding) 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 shepherding and sheep have continuous outdoor access (seasonal housing may occur), the keeping of sheep in fenced pastures characterizes semi-extensive systems. Supplementation is instead the main differentiating element in extensive systems, where there is no shepherding and sheep are kept outside in unfenced pastures. No supplementation differentiates very-extensive from extensive systems.

Table 6: Model to define the main elements and factors characterizing the most commonly applied management systems

	Shepherding (continuous presence of the stockperson with the sheep)	**No outdoor access**	**Housing**	**Kept in fenced pastures (including rotational grazing)**	**Supplementation**
1.**Shepherding**	YES				
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)**					

Empty boxes indicate “not relevant to system characterisation”

The following sections describe each management systems in more detail (see also Appendix 2)

3.1.1.1. Shepherding

Shepherding 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 movements 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 either by 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 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 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 West 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 are usually separated from the ewes within their first days of life and are artificially reared prior to fattening, 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 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 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 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 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 fenced pastures and are housed over night 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 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 are systems where the stockperson is almost never with the sheep, sheep 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 both for meat and wool production (e.g. 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 high 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. Rams remain in the extensive system the entire year, in separate groups to ewe groups outside the breeding season. 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 the size of high hundreds 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. Also 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 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 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). Rams remain in the extensive system the entire year, usually in separate groups to ewe groups outside the breeding season, with low replacement. 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 the size up to thousands 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 are various combinations of the above 6.

The following examples are commonly practiced types of mixed systems:

a. **Seasonal mix of very extensive (during summer) and intensive (during winter) for dual purpose (meat and wool)**

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 7 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, they store forage for winter from more intensive fields which often need irrigation. The sheep usually spend four months inside.

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

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 at 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 Working group 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 comprehensive literature review which can be found in other publications such as Dwyer 2008.

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 nutritients 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 (Argot 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),

Absence of hunger: 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 (Boe et al., 2010). This is exacerbated in conditions of even minor feed restriction (Boe et al., 2012). 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. Where 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 be increased 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 in 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 gastrointestinal 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 sulfur and molybdenum resulting in anemia, bone disorders, neonatal ataxia, cardiovascular disorders, diarrhea, and increased susceptibility to infections (Underwood and Suttle, 1999). Similarly, an excess of potassium may impair Mg 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), whist 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. 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 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. Water supplies may also 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 (Boe et al., 2011). The absence of emergency reservoirs, for use when 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 to other types of flooring (Bøe 1990; Gorden & 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 dry and smooth surface to rest and competition for space due to limited availability of shade, shelter and comfortable surface would cause distress.

Thermal confort: 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. In extensive management systems, provision of shelter and shade are important for protection from solar radiation and inclement weather conditions. For example, with shade, sheep are able to maintain body temperature in ambient temperatures of up to 50◦C (Johnson 1987). 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, lactating ewes and shorn sheep, Alexander et al. 1979; Pollard et al. 1999). Under intensive management systems, heat stress may result from poor ventilation, inadequate housing and due to high stocking density. Under extensive conditions, particularly in the tropics, non-adapted, exotic breeds of animals may suffer an increased risk of heat stress. 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 (undernutrition, poor body condition, lack of shelter, for example), 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 particular, poor ventilation due to inappropriate temperature and humidity caused by

inadequate ventilation rate, air speed, ventilation cycles, in housing systems causes increased respiration rate and rectal temperature in lactating ewes kept under Mediterranean climatic conditions (Sevi et al., 2002; Caroprese et al. 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 subclinical 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; Sevi et al., 2009; Kilic et al., 2013).

Ease of movement, 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, in this sense, a greater proportion of ewes housed in low stocking density and access to outdoor displayed standing and drinking behaviours than ewes in low stocking density without access to outdoor, and a greater proportion of ewes in low stocking density was observed walking than ewes in high stocking density (Caropresе et al., 2009). 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 due to 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 & 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.

Absence of injuries: 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 sheep normal behaviour. The vast majority of lameness cases can be attributed to scald, also known as inter-digital dermatitis (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, animals can be hardly identified, in the second one animals are overtly lame and some of them can even walk on 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. spirochetes). 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 (2006), 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, Merinos sheep have been reported to be more susceptible to foot-rot as compared with British breeds in UK (Emery et al., 1984). However, genetic selection for resistance to foot-rot remains challenging, as resistance to the disease is most likely polygenic, with genomic selection likely to be more effective than selection on a small number of markers (Bishop, 2014). 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 less studied than in cattle, rumen acidosis caused by sugar rich diets and leading to alteration of the bloodstream at foot level 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 (Morgante, 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 the attached external scientific report (Annex I) as prepared by O'Connor et al. (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. 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), 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 due to 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 the 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 due to 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). Due to mite bites and reaction to saliva, mange is connected with scabs and severe itching (pruritus), which in turn causes damage of the integument due to 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 remain often unnoticed until wool loss becomes manifest, which means that the whole flock is probably already infested. The most important parasitic mite species of sheep are listed below. *Psoroptes ovis* is the agent of the 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, 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 the move on grazing sheep. Preventing 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 due to rubbing and scratching, blood loss, disease transmission (bacteria, viral or protozoan), paralysis (sometimes induced by the toxin containing saliva) and predispose to other harmful conditions, such as blowfly strike (trough 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 (mallophage), which feed on exfoliated epithelium and skin debris, and sucking lice (anoplura) feeding 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. Even though 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. 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 both of the environment and the flee, shearing, mulesing, tail docking. The latter two however can have detrimental effects on sheep welfare (see paragraph on *Absence of pain induced by management procedures)*.

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 at 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 grounds may also increase the risk of injuries and integument alterations by physical agents.

Absence of disease. Absence of disease is a basic requisite for good welfare. Diseases can cause pain and may interfere with normal behaviour. Chronic diseases often have a debilitating effect on the animal and may lead to it being culled.

Even though to a lesser extent as compared with dairy cows, a common metabolic disease in ewes is milk fever. A shortage of calcium (hypocalcaemia) in parturient ewes, either related to an excess of calcium ingested during the pre-parturition period or consequent to low supply during the parturition period, can cause this disease, also known as parturient paresis, which occurs especially 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 the animal's death if it is left untreated.

Rumen acidosis can be caused by elevated consumption of concentrates (grain in particular) or 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 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 and clover, as these legumes can be easily digested in fine particles trapping the gas. The same can occur when animals are fed high 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 micro-organisms, 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 preventing the occurrence of this disease as well as dystocia. This latter reproductive disorder occurs when ewes have difficult 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 subclinical 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 range between 600,000 and 800,000 per ml (Berthelot et al., 2006). Subclinical mastitis appears to be less 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 lead the ewes to death 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. (2007b) reported a higher resistance against mastitis of an indigenous Greek sheep breed (Karagouniko) compared to an improved high-production breed (Friesarta) and attributed that to more efficient local defense 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. *Dricocoelium 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 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 programs 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. Gastrointestinal parasites can cause diarrhoea, dehydration, loss of appetite and loss of weight (or reduced weight gains), reduced productivity, 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. The round worms are one of the major cause 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*. Teniasis can affect the sheep under the form of adults or larvae.

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 left on the ground with faeces. The intermediary host is a dwarf pond snail, *Limnea truncatula*, known as *Galba truncatula*. The intermediate stage of this parasite (*cercariae*) leaves the snail and encysts on the grass as *metacercariae*, where they can be ingested by sheep to start a new life cycle. Most of the damages are caused by fluke migrating through the liver. In acute and subacute cases liver necrosis can cause sudden death or death in 1-2 weeks, respectively. Chronic forms determine abdominal pain, anaemia and weight loss, while biochemical and haematological parameters are altered. Chronic forms can also cause death due to anaemia, cachexia, metabolic disorders and concurrent infections. Warm and humid climates can favour the development of this disease as the snail as intermediate host is necessary. 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 mostly affecting the intestine of lambs with marked effects including diarrhea (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).

Paratuberculosis (Johne's Disease) is caused by *Mycobacterium paratuberculosis,* also known as *Mycobacterium avium* subspicies *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.

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) to that in an improved high-production breed (Friesarta, 70%). Differences were associated to a toll like receptor 9 polymorphism (Sarafidou et al., 2013). 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 to human. 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 death. 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 programs (Turnbull, 1991) and burning of infected carcasses.

Bluetongue is a viral disease (BTV) 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 USA. 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 cause of death. Vaccination is only effective on a reduced number of serotypes existing in Europe and the USA, does not prevent the disease to occur 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 characterized 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. Generally, affected animals recover within 4 weeks from the start of the disease. Lip papules may cause reduced milk intakes in young lambs.

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 enterotoxemias caused by *Clostridium perfringens* types C and D. Sudden changes in the diet of young lambs and concentrate-based diets in fast growing lambs can predispose to enterotoxemia 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, being the average mortality in developed countries of 15-20% with nearly 50% of these lamb deaths occurring within the first 3 days of life. The main causes of lamb deaths are: a) pre- or peri-parturient disorders (30-40%); b) weakly lamb/exposure/starvation (25-30%); c) infectious disease and gastrointestinal problems (20-25%); d) congenital disorders (5-8%); e) 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 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.

<u>Absence of pain induced by management procedures</u>*:* Several procedures that are routinely carried out in sheep farming can cause pain. These include de-horning, 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. Though 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, 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 fly-strike 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 (Rhodes et al., 1989). Surgical removal appears to be less so than the use of rubber rings (Kent et al., 1991). 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 due to 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 fly-strike, particularly in Merino sheep. It consists in 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/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 fly-strike. Breeding for traits giving resistance to fly-strike (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 fly-strike) has also been suggested as a genetic alternative to mulesing (James, 2006).

De-horning and disbudding is 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 ant-inflammatory treatments to reduce pain and stress.

Ear tags can be the source of injuries, infections 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.

3.1.2.4. Appropriate Behaviour

The principle of appropriate behaviour consists of four criteria as identified by Welfare Quality (Blokhuis et al., 2008): expression of social behaviours, expression of other behaviours (often taken to mean stereotypic behaviours); the quality of the human-animal relationship and an absence of general fear. The latter criterion may also be labelled "positive emotional state". The likely welfare consequences for each of these 4 criteria, and the factors contributing to these will be discussed.

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. Secondly, 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). Generally, therefore, sheep are able to perform much of their social behavioural repertoire of associating with preferred companions, forming subgroups for grazing and resting and expressing flocking responses. Sheep are, however, 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 & Bornett, 2004), high vocal activity (except when in the presence of a predator e.g. sheep dog; Torres-Hernandez & Hohenboken 1979), and a robust activation of the hypothalamic-adrenal stress axis (Guesdon et al., 2012; Apple *et al* 1993; Minton *et al* 1992; Niezgoda *et al* 1987). 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 6 months after birth (Arnold et al., 1979). Thus 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 (Dwyer, 2008; Binns et al., 2002; Snowder & Knight, 1995). Abrupt weaning is also associated with elevated plasma cortisol (Mears & Brown 1997; Rhind *et al* 1998; Orgeur *et al* 1999), depressed growth rates (Jagush *et al* 1977; Watson 1991; Napolitano *et al* 1995) and increased susceptibility to disease (Jagush *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 to unrestrained animals, and is associated with higher salivary cortisol and heart rate (Ward, 2012, PhD thesis, University of Northampton, UK). 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 (also see below) 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 4 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, and these can involve butting, kicking, pushing, chasing and persistent displacements. For subordinate animals, this may result in frequent displacements from accessing feed, so 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 & Johnson 1987; Deag 1996) and, where there is limited shade or shelter, may experience greater thermal challenges than more dominant animals. Subordinate animals are generally at the back of any movement order (Lynch & Alexander 1973), which during management gathers, means these animals are more likely to experience human and sheep dog close contacts.

Factors disposing to an increase in social tension and negative welfare consequences for sheep particularly include housing at high stocking density and when resources (access to food, lying areas or shade and shelter) are restricted (e.g. Bøe et al., 2006). Housing at densities of 1 or 1.5m^2 in comparison to 3 m^2 results in increases in both overtly negative social interactions (Caroprese et al., 2009) and more subtle social interactions (such as nose-to nose contacts or nudging, Averos et al., 2014a:), and in decreased activity, increased time feeding and reduced resting (Caroprese et al., 2009; Averos 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, 1975). When placed in the same enclosure sheep of the same breed but unfamiliar to one another sheep will initially remain segregated but_become integrated into a single flock after a period of time (Lynch & Alexander 1973; Arnold & Pahl 1974). However, sheep of different breeds, even after being maintained in the same environment for a number of months, do not integrate (Winfield & Mullaney 1973; Arnold & Pahl 1974; Shillito-Walser & Hague 1981; Dwyer & 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 & Rushen 1993). This may be due to the lower frequency with which sheep are kept in the type of housing that appears to elicit stereotypy. Individually-housed sheep, for experimental purposes, have, however, 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 & Alexander 1973; Done-Currie *et al* 1984; Marsden & Wood-Gush 1986a, b; Fordham *et al* 1991; Cooper *et al* 1994; 1995; Cooper & Jackson 1996; Yurtman *et al* 2002). Indoor housed ewes in groups have also been reported to show stereotypic licking, star-gazing (arching the head and neck over the back), and floor kicking (Averos 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 & 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 & Wood-Gush 1986a; Cooper et al 1994; Yurtman et al 2002). Providing hay or increased fibre in the diet reduce oral stereotypy (Done-Currie et al 1984; Cooper et al 1995), and increase lying and rumination (Cooper & 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 & Broom 1990), and disappear when the sheep are turned out. Wool-pulling is generally performed by the most dominant sheep on subordinates (Fraser & Broom 1990; Lynch *et al* 1992), is most frequent at high stocking density and eliminated by increasing space per animal (Fraser & Broom 1990). Redirected sucking occurs in artificially reared lambs where lambs suck the navels and scrotums of other lambs (Stephens & 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 2 months of age (Markowitz *et al* 1998). Some lambs also chew and suck bedding, and stone sucking (pica) occurs in early-weaned lambs (Jagush *et al* 1977).

<u>Human-animal relationship</u>: 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). The quality of the human-animal interaction, therefore, 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, 1988; Jones, 1996). 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 learnt 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 (Duncan, 1990; 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 (Hemsworth and Coleman, 1988; Jones, 1997). 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, 1988; Jones, 1996) but is often not feasible in modern farming. In systems where the 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 & Shutt 1989; Boivin *et al* 1997), and retain memory for individual recognition for at least 2 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). The amount of distress that sheep suffer during movement and handling is, therefore, likely to be affected by the quality of the stockperson working with the sheep (reviewed by Rushen & de Passillé 1992; Hemsworth & Coleman 1998; Hutson 2000). The learning abilities of sheep suggest this may be so even if the animals are handled infrequently.

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. It should be noted, however, 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, ACTH and heart rates, above those seen on sudden exposure to humans and noise (Harlow *et al.*, 1987; Baldock and Sibley, 1990; Cook, 1996; Komesaroff *et al.*, 1998). Dogs also elicit greater aversive responses than unfamiliar humans in a variety of experimental testing situations (e.g. Beausoleil et al., 2012). In on farm or slaughthouse 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). Thus 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 need 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; Jones, 1998; Faure and Jones, 2004). Fear and anxiety are two emotional states induced by the perception of a danger or a potential danger, respectively, that threaten the integrity of the animal (Jones, 1987; Boissy, 1995). 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), either through 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 ar associated with increased locomotor activity (Sevi et al., 2001; Fell et al., 1991). However, moving sheep indoors from pasture reportedly causes inactivity (Casamassima et al 2001), raised plasma cortisol that takes several weeks to normalise (McNatty & Young 1973; Pearson & Mellor 1976), and a reduction in circadian rhythm (Tobler et al., 1991).

For extensively managed animals, particularly in regions with 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 avoidance of areas of high risk resulting in reduced diet quality (Altendorf et al., 2001; Laundre et al., 2001; Hernandez & Laundre, 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 occur here also. 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 Merinos 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 & 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. Ile-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 are 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 identifying and mapping 679 citations relevant to sheep welfare. Those citations were mapped according to the study population, 8 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 EFSA WG. Such mapping supported the WG in identifying gaps of knowledge and data that further led to seeking for experts' knowledge, as well as to identify areas where a systematic literature process could be performed. The scoping exercise identified minimal literature relevant to establishing a clear relationship between the risk factors and welfare consequences, except for lameness.

As follow-up to the mapping, a systematic review was therefore performed on the effect of 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 footrot and other lameness related conditions such as inter-digital dermatitis (IDD), measured only during non out-break 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 either 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 used in any analyses.

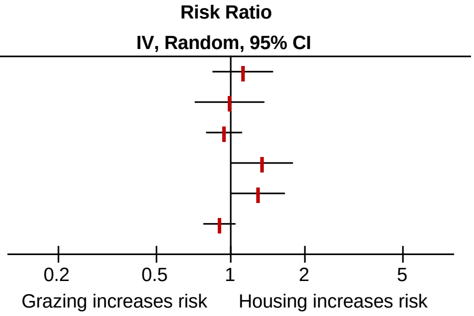
A forest plot was created to display the data for both exposure variables. Variables that were related to management system (pasture access) were grouped together. As the exposure categories were not truly equivalent across the studies and some animals were used for multiple measures, a summary effect 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 5. 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. Also 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 as occurred in many of these studies.

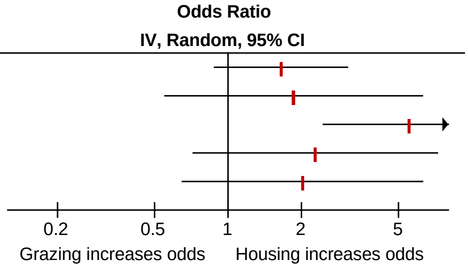
The results for studies that assessed stocking density and lameness are reported in Figure 6. Although few studies have evaluated this outcome, the finding was reasonably consistent that higher stocking density was associated with more lameness.

Figure 5a-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 to 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.

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]



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]
Wassnick-IDD lambs 04	0.7031	0.5785		2.02 [0.65, 6.28]



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]

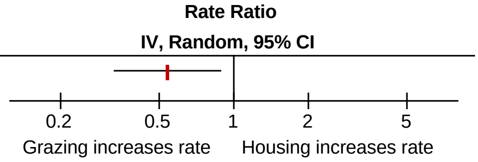
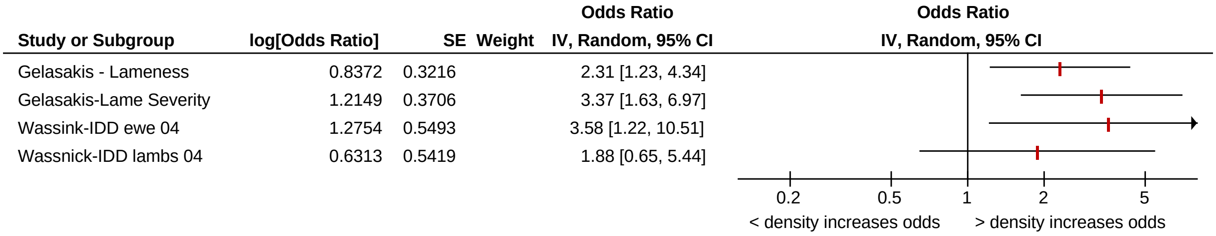
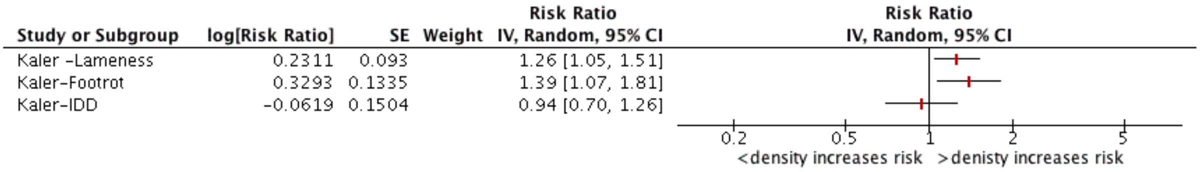
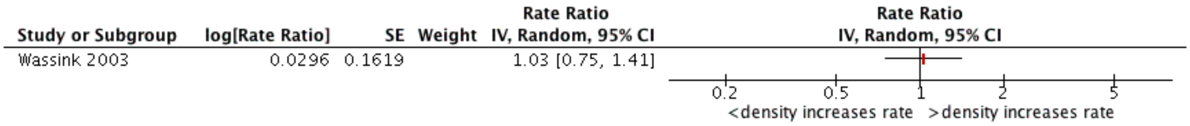


Figure 6a-c: Forest plots of association between different measures of lameness and variables that describe stocking density. All data are organized such that the numerator of the association represents the high density compared to the denominator which refers to animals with lower density. A ratio greater 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 to inform the scoping exercise of this opinion. However, the sample of experts was not random, neither 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 only reflect 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 5. The results of the survey only identify 2 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 consequences) for each individual management system would apply to the period when sheep were in that system within a mixed system. Additionally some interactions would occur and also the transition period was considered very critical. Concerns were raised about additional hazards 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 not covered in this opinion (see previous scientific opinion of EFSA, 2012 for details about sheep transport).

The expert elicitation process allowed identification, according to the experience of the experts, of the main welfare consequences for ewes and lambs in the different management systems, as well as the risk factors giving rise to these welfare problems and the exposure assessment for different systems.

The most important welfare consequences within each management system were identified using a calculated impact score. 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 (a) the affected population proportion (prevalence percentages were converted to a score between 0 and 1), and (b) the severity classification (the 4 classes: low, medium, high and very 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. Thus the uncertainty rating (Low +/-12.5%; Medium +/-25%; High +/-50%) was translated into the accountable probability mass of L: 2*0.125, M: 2*0.25, H: 2*0.5 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) * (prevalence rating)/(accountable probability mass)
= (severity rating) * (prevalence rating)/(2*0.125*{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 0.3 *0.66= 0.198; and an uncertainty corrected impact score of (0.66*0.3)/(2*0.125*2)=0.396.

For sensitivity evaluation three different methods of data aggregation were applied and the resulting ranking of consequences provided: (i) average of raw impact score values, (ii) median of raw impact score values and (iii) average of uncertainty corrected impact score values are presented in the appendix 5, with results of the third approach summarised in the following main text.

Figure 7 shows for ewes, the 3 highest scored consequences in each management system plus the ones that could not be excluded as being clearly different from the top 3 (see score diagrams in Appendix 5). Table XX shows in addition for ewes in each management system the next highest scored welfare consequences.

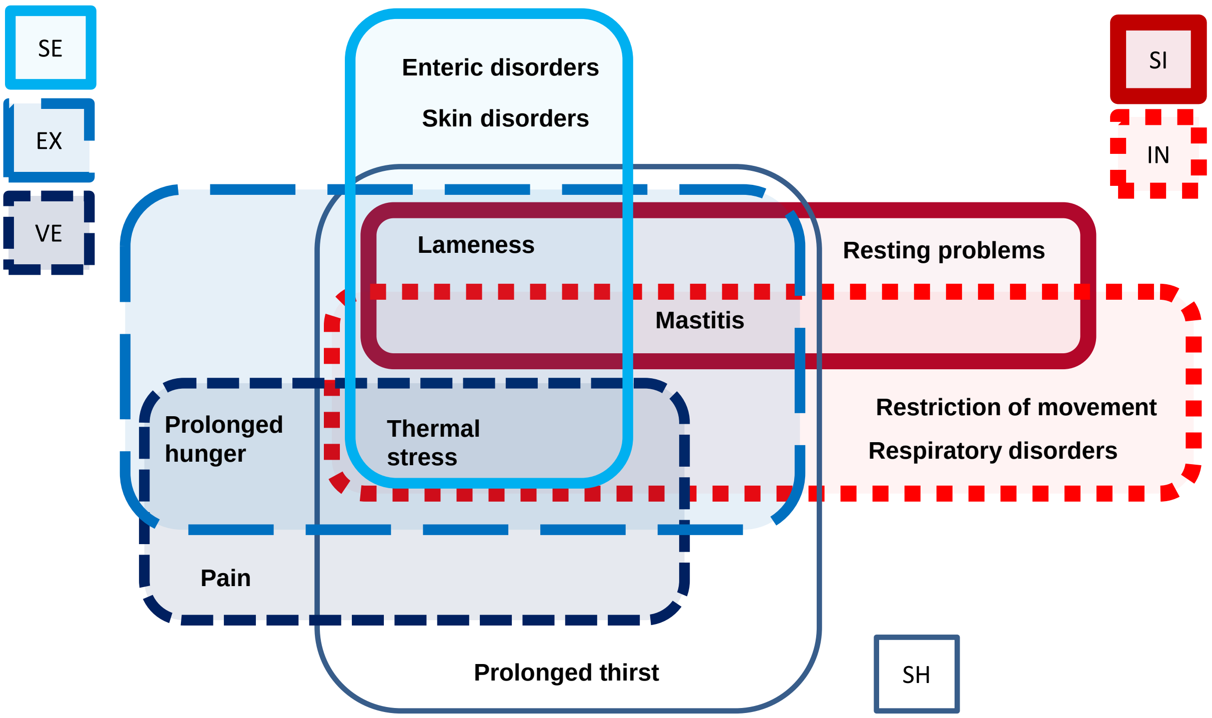


Figure 7: Main welfare consequences identified for ewes, according to the online survey, for the management systems represented by different boxes (SH: shepherding; IN: Intensive; SI: Semi-intensive; SE: Semi-extensive; EX: Extensive; VE: Very extensive; see Table 5 and Appendix 2 for definition). Consequences ranking highest across the management systems (bold text) are overlapped by multiple boxes. The data are equivalent to the black cells in Table 7 (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 3.

Table 7: Main 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) consequences with the highest impact scores plus the ones that could not be excluded as being clearly different from the top 3 (5) (SH: shepherding; IN: Intensive; SI: Semi-intensive; SE: Semi-extensive; EX: Extensive; VE: Very extensive; see Table 6 for definition).

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

Figure 8 shows for lambs, the 3 highest scored consequences in each management system plus the ones that could not be excluded as being clearly different from the top 3 (see score diagrams in Appendix 5). Table 8 shows in addition for lambs in each management system the next highest scored welfare consequences.

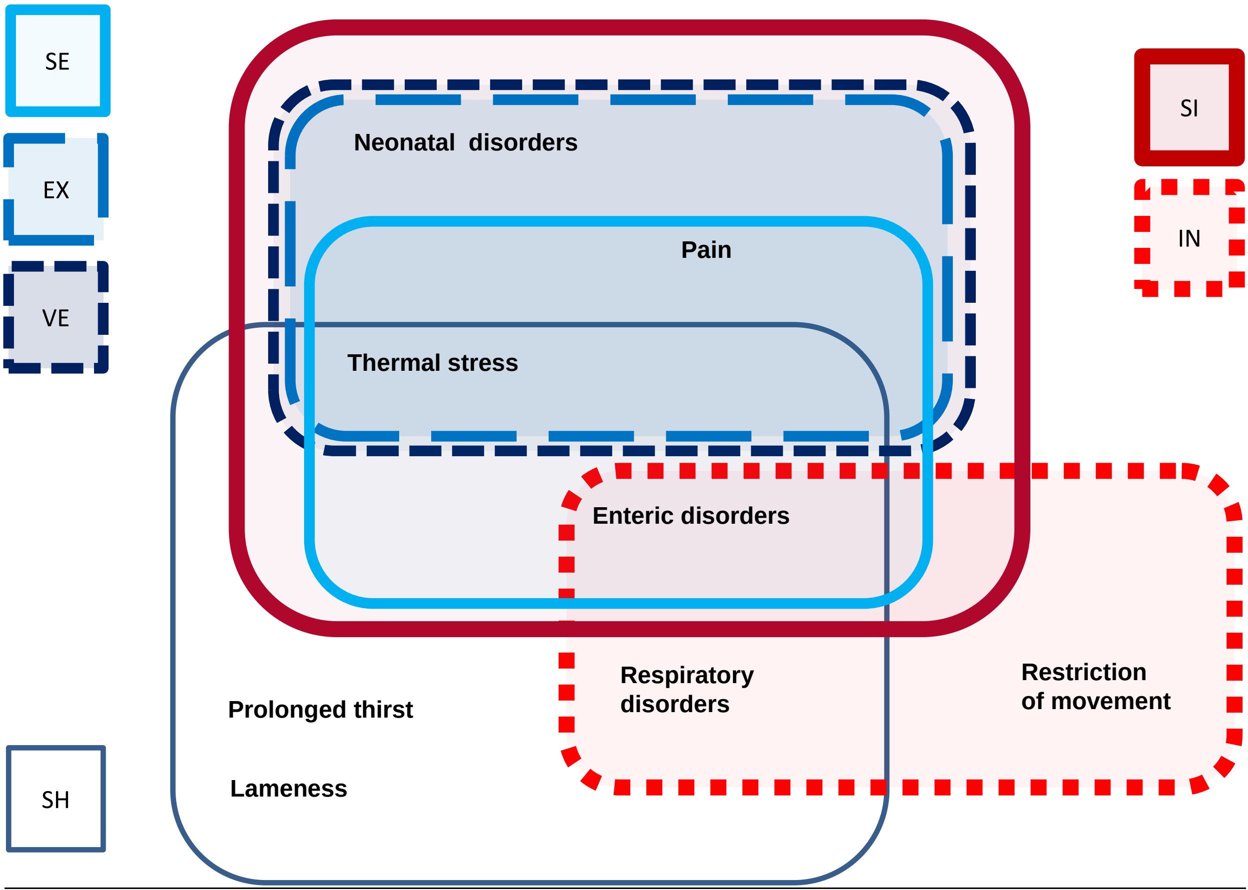


Figure 8: Main welfare consequences identified for lambs, according to the online survey, for the management systems represented by different boxes (SH: shepherding; IN: Intensive; SI: Semi-intensive; SE: Semi-extensive; EX: Extensive; VE: Very extensive; see Table 5 and Appendix 2 for definition). Consequences ranking highest across the management systems (bold text) are overlapped by multiple boxes. The data are equivalent to the black cells in Table 8 (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 3.

Table 8: Main 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 plus the ones that could not be excluded as being clearly different from the top 3 (5). (SH: shepherding; IN: Intensive; SI: Semi-intensive; SE: Semi-extensive; EX: Extensive; VE: Very extensive; see Table 6 for definition).

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

3.1.4.2. Description of welfare consequences and risk factors among the different management systems

The major welfare consequences summarised in this section are derived from Tables 7 and 8, and are linked to the principal risk factors presented in Table 9-20.

Ewes

As shown in table 7, prolonged hunger was considered to be a major animal welfare consequence for ewes kept under extensive and very extensive systems. No risk factor was identified by the respondents but the WG inferred that lack of availability of pasture / appropriate grazing land was the main risk factor.
Prolonged thirst was judged a major welfare consequence in shepherding, with hot and dry summer and lack of access to water as the risk factors.
Thermal stress was considered to be major welfare consequences in all the management systems. The most common risk factors were judged to be lack of shade, shelter or bedding, extreme climate and winter shearing for ewes kept under extensive systems, and stocking density (overcrowding), inappropriate housing (microenvironment & ventilation) conditions and delayed shearing for ewes kept under intensive systems.

Resting problems were considered to be a major welfare consequence in semi intensive systems. The risk factors were inadequate space available when housed as well as the floor and bedding quality. Furthermore, restriction of movement was judged as a major welfare consequence in intensive systems.

Lameness was considered to be major welfare consequences in all the management systems, except very extensive. Improper hoof care was identified as the risk factor for lameness common to the management systems. Inappropriate nutrition and soil conditions were considered to be risk factors for ewes kept under intensive as well as extensive systems. Poor biosecurity was considered to be a risk factor associated with shepherding, semi-intensive and semi-extensive systems, whereas poor flooring conditions was considered to be a risk factor for ewes kept under intensive system.

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. Teat lesions and inappropriate management of the ewes in the drying off period were considered to be the major risk factors for ewes kept for all production purposes, and poor udder hygiene in shepherding, intensive and semi-intensive. The risk factors for ewes kept for milk production under shepherding, intensive and semi-intensive systems were considered to be poor udder hygiene, inappropriate milking procedures, poor udder confirmation in relation to milking by machine and maintenance of the milking systems. 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 only highlighted 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. The main risk factors causing gastro-enteric disorders were considered to be poor grazing management, antihelminthic resistant parasites and chronic diseases (e.g. pTB). Improper feeding (transition and excess of proteins) was also reported as a main factor in semi-intensive systems. The main factors provoking skin disorders were considered to be poor biosecurity (introduction and transmission of ectoparasites), lack of preventive measures (eg dipping), and micronutrient deficiency.

Reproductive disorders was judged as a major consequence for ewes kept under S and the risk factors were poor lambing intervention, nutrition (toxaemia, hypocalcaemia) and high pathogen load.

Respiratory disorder was considered as a major welfare consequence in intensive and extensive management systems. For ewes kept in intensive system, the risk factors were poor air quality (micro-environment, ventilation, stocking density, ammonia level) and increased exposure to pathogens (poor hygiene, resistant pathogen strains).

Pain was judged a serious animal welfare consequence for ewes kept under very extensive systems and the risk factors were tail docking and ear tagging / notching.

Chronic fear (fearfulness due to e.g. predation, poor handling, disturbed social behaviour) was reported to be an animal welfare consequence in ewes kept under very extensive systems only and the risk factors were lack of exposure and acclimation to perceived threats, e.g. human handling) and predation.

<u>Lambs</u>

Prolonged thirst was considered to be a serious welfare consequence for lambs kept under shepherding only and the risk factors were hot and dry summer, lack of access to water and reduced suckling opportunities.

Thermal stress was reported to be common welfare consequence for lambs kept under all the management systems. The risk factors for lambs kept under SH, SE, E & VE systems were lack of shade, shelter or bedding, extreme climate, feed quality and quantity during cold weather and genotype unable to cope with heat. The risk factors for lambs kept in I and SI systems were inappropriate housing (micro-environment, ventilation), stocking density (overcrowding), **extreme climate** and lack of shade / shelter when outdoors.

Restricted movement was judged to be a major problem only in intensive management systems and the main risk factors causing this consequence were increased stocking density and poor housing conditions (e.g flooring).

Gastro-enteric disorders were also considered to be a major welfare consequence in all management systems and the risk factors were reduced immune competence, increased exposure to pathogens and malnutrition or unbalanced diet.

Respiratory disorders were considered to be a serious welfare consequence for lambs kept in all systems where lambs are housed for some period of time. The risk factors were poor air quality (microenvironment, ventilation, stocking density, ammonia level), increased exposure to pathogen (poor hygiene, resistant pathogen strains) and reduced immune competence (inadequate colostrums, vaccination and anti-parasitics).

Neonatal disorders were judged to be a major welfare consequence for lambs kept under all management systems, except shepherding. The risk factors were lack of shelter (exposure to rain and wind) and deficiency of ewe nutrition during pregnancy and dystocia. They were not reported as a major problem in shepherding, due to the closer presence of the stockperson in this management system, allowing intervention during lambing if necessary.

Pain was reported to be a major welfare consequence for lambs kept under all the management systems, except shepherding, where the number of respondents was low. The risk factors were castration, tail docking and ear tagging / notching.

Chronic fear (fearfulness due to e.g. predation, poor handling, disturbed social behaviour) was reported to be an animal welfare consequence in lambs kept under extensive and very extensive systems only and the risk factors were presence of dogs and predators.

3.1.4.3. Main welfare consequences and risk factors within management systems and production purposes for ewes

The ranking of the welfare consequences for each management system from the online survey has been analysed using the average impact score corrected by uncertainty rating (see the analysis of results from the online survey in appendix 5). The welfare consequences per production purpose are described only in the management systems with sufficient number of respondents of different production purpose.

Table 9. 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 - SHEPERDING		
Average uncertainty corrected impact score	**Welfare consequence**	**Risk factors leading to the welfare consequence**
> 0.05	Thermal stress	Lack of shade/ shelter/bedding Extreme climate
	Prolonged thirst	Hot and Dry Summer Lack of access to water
	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

0.03-0.05		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 or incorrect treatment when needed)
	Reproductive disorders (including dystocia and metritis)	Poor lambing intervention Nutrition (toxaemia, hypocalcaemia) High pathogen loading Inappropriate breeding (eg large lambs or litter size)

Table 10. 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		
Average uncertainty corrected impact score	**Welfare consequence**	**Risk factors leading to the welfare consequence**
> 0.05	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)
	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	Improper hoof care (incorrect trimming) Inappropriate nutrition (SARA) Poor flooring (poor litter quality or plastic, slatted floor causing lameness)
0.03-0.05	Resting problem	High stocking density (specially at time of lambing) Floor and bedding quality
	Occurrence of abnormal behaviours (e.g. inter-sucking, wool pulling, biting or chewing non-food items)	Lack of grazing Nutritional deficiencies Social instability

Table 11. 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		
Average uncertainty corrected impact score	**Welfare consequence**	**Risk factors leading to the welfare consequence**
> 0.05	Resting problem	Inadequate space available when housed 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
	Lameness	Improper hoof care (incorrect trimming) Poor biosecurity (introduction of contaminated animals) Inappropriate nutrition (SARA, mineral deficiency and excess of protein at grazing)
0.03-0.05	Gastro-enteric disorders (including infections, endoparasites or toxins)	Poor pasture and grazing management Antihelmintic resistant parasites 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
	Skin disorders (including infections, allergens, ectoparasites)	Poor biosecurity (introduction and transmission of ectoparasites) Lack of preventive measures (eg dipping) Micronutrient deficiency
	Reproductive disorders (including dystocia and metritis)	Poor lambing intervention Nutrition (toxaemia, hypocalcaemia) High pathogen loading Inappropriate breeding (eg large lambs or litter size)

Table 12. 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		
Average uncertainty corrected impact score	**Welfare consequence**	**Risk factors leading to the welfare consequence**
>0.05	Lameness	Soil conditions (wet and stony) Poor biosecurity (introduction of contaminated animals) Improper hoof care (lack or incorrect treatment when needed)
0.03-0.05	Gastro-enteric disorders (including infections, endoparasites or toxins)	Poor pasture and grazing management Antihelmintic resistant parasites Chronic diseases (e.g. pTB
	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 (eg dipping) Nutritional photosensitisation
<0.03	Mastitis (genotype susceptibility)	All production purposes Teat lesions Inappropriate management of the ewes at drying-off Poor udder hygiene (related to suckling and resting)

Table 13. 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		
Average uncertainty corrected impact score	**Welfare consequence**	**Risk factors leading to the welfare consequence**
>0.05	Thermal stress	Extreme climate Lack of shade/ shelter Winter shearing
0.03-0.05	Lameness	Soil conditions (wet and stony) Improper hoof care (lack of treatment when needed) Inappropriate nutrition (mineral deficiency)
	Mastitis (genotype susceptibility)	All production purposes Teat lesions Inappropriate management of the ewes at drying-off Poor udder hygiene (related to suckling and resting)
	Skin disorders (including infections, allergens, ectoparasites)	Lack of preventive measures (eg dipping) Micronutrient deficiency Nutritional photosensitisation

Table 14. 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		
Average uncertainty corrected impact score	**Welfare consequence**	**Risk factors leading to the welfare consequence**
>0.05	Thermal stress	Extreme climate Lack of shade/ shelter Winter shearing
	Pain (including due to management procedures such as castration, tail docking and shearing)	Tail Docking Ear tagging/notching Mulesing Poor handling
0.03-0.05	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 preventive measures (eg dipping) Micronutrient deficiency Nutritional photosensitisation

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

Similarly to the above subchapter on ewes, here below risk factors and welfare consequences ranked by their average impact score corrected by uncertainty are presented for all management systems for lambs.

Table 15. 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 - SHEPERDING		
Average uncertainty corrected impact score	**Welfare consequence**	**Risk factors leading to the welfare consequence**
>0.05	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
0.03-0.05	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) Malnutrition (lack of nutrients, proteins, fibre)
<0.03	Pain (including due to management procedures such as castration, tail docking and shearing)	Ear tagging/notching Poor handling

Table 16. 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		
Average uncertainty corrected impact score	**Welfare consequence**	**Risk factors leading to the welfare consequence**
>0.05	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)
	Thermal stress	Inappropriate housing (micro-environment, ventilation) Stocking density (overcrowding) Extreme climate
0.03-0.05	Chronic fear (fearfulness due to e.g. predation, poor handling, disturbed social behaviour)	Presence of dogs Presence of rats
<0.03	Occurrence of abnormal behaviours (e.g. inter-sucking, wool pulling, biting or chewing non-food items)	Lack of environmental enrichment Lack of grazing Early weaning Lack of environmental enrichment

Table 17. 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		
Average uncertainty corrected impact score	**Welfare consequence**	**Risk factors leading to the welfare consequence**
>0.05	Pain (including due to management procedures such as castration, tail docking and shearing)	Ear tagging/notching 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)
0.03-0.05	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

Table 18. 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		
Average uncertainty corrected impact score	**Welfare consequence**	**Risk factors leading to the welfare consequence**
>0.05	Pain (including due to management procedures such as castration, tail docking and shearing)	Castration Tail Docking Ear tagging/notching
	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
0.03-0.05	Neonatal disorders (including starvation/mis-mothering/exposure complex)	Deficiency of ewe nutrition during pregnancy Dystocia Prolificity

Table 19. 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		
Average uncertainty corrected impact score	**Welfare consequence**	**Risk factors leading to the welfare consequence**
>0.05	Thermal stress	Lack of shade/ shelter/bedding Extreme climate Feed quality and availability during cold weather genotype unable to cope with heat
	Pain (including due to management procedures such as castration, tail docking and shearing)	Castration Tail Docking Ear tagging/notching
	Neonatal disorders (including starvation/mis-mothering/exposure complex)	Lack of shelter (exposure to rain and wind) Deficiency of ewe nutrition during pregnancy Dystocia
0.03-0.05	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 20. 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 – EXTENSIVE SYSTEMS		
Average uncertainty corrected impact score	**Welfare consequence**	**Risk factors leading to the welfare consequence**
>0.05	Pain (including due to management procedures such as castration, tail docking and shearing)	Castration Tail Docking Ear tagging/notching
	Thermal stress	Lack of shade/ shelter/bedding 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
0.03-0.05	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

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 causes 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 consequence may be underestimated in extensive systems due to lack of routine inspections. The impact of chronic-viral diseases such as Maedi-VISNEA 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 stock people 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 include 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 identified into 3 categories: birth to 3 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

The AWIN Project has validated a number of ABMs for extensive and intensive management system for adult animals. However, animal-based measures 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 adult sheep in a number of other studies and in young lambs (Phythian et al., 2013).

The ABMs are described for ewes and lambs for each welfare consequence and summarised in table 21.

FEEDING:

Prolonged hunger:

<u>Sheep:</u>

Body condition score (BCS: 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 both in farming practice and in experimental settings to monitor fatness and as a measure of hunger (Morgan-Davies et al., 2008; Caroprese et al., 2009; Napolitano et al., 2009; Phythian et al., 2012; Stubsjoen et al., 2011). Recent research 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 good reliability has been found for full and half points (Phythian et al., 2012). 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). Thus the AWIN project uses a simplified version: emaciated (A), thin (B), ok (C), fat (D) which has very good agreement between assessors.

Dental health: and the assessment of the presence and condition of molar and incisor teeth can act as predictors for the likelihood that ewes will subsequently show a decline in BCS. In AWIN studies tooth loss is scored on 3 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 2 non-vital teeth are missing; whether the bite is correct i.e. vital teeth meet the hard palate) and is highly correlated with BCS. 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, where there is little grazing, is not known.

Lambs:

Body condition: the BCS score used for adults is not appropriate for young lambs but Phythian et al. (2013a) suggest an alternative method for lambs involving visual inspection and palpation over the ilial crest, ribs and sternum to determine fat and muscle cover. An ‘appropriate’ body condition was described as where the skeletal structures were distinguishable but not sharp or prominent, and an ‘inappropriate’ body condition with poor cover and prominent bones. Observer agreement was good (Fleiss κ0.7) but this score may be affected by the age of lamb at inspection.

Visual inspection of gut fill (also used by Phythian et al., 2013a) may also be relevant 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).

Prolonged thirst

Sheep and lambs

For both ages of sheep there are no reliable and tested ABMs for this welfare consequence which, in AWIN as in Welfare Quality, 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.

HOUSING/ENVIRONMENT*:*

Resting problem

Sheep and lambs:

Coat cleanliness has been used by a number of studies, including AWIN, as a welfare measure (Napolitano et al., 2009; Caroprese et al., 2009; Stubsjoen 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. The AWIN project scores sheep on a 5 point scale as: 1 (clean and dry); 2 (dry or only slightly damp due to 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 in both handled animals and at a distance when undisturbed animals are at pasture and observer reliability for coat cleanliness is very good.

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.

Thermal stress

Sheep

Panting and an elevated respiration rate as an measure of thermal discomfort has been reviewed (Cockram, 2004) and has been assessed by several studies (Lowe et al., 2002; Caroprese et al., 2009; Phythian et al., 2012), 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 an measure of thermal stress.

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 or newborn lambs; Terrill & 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 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. Overall, however, lying behaviour of lambs has not been investigated with a view to acting as a measure of thermal stress.

Restriction of movement

Sheep:

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 (Averos et al., 2014a, b) where movement and resting may be restricted. The reliability of these measures for on-farm welfare assessment is still being tested in AWIN.

Hoof overgrowth has also been suggested as a measure of restriction of movement in sheep (Napolitano et al., 2009; Caroprese et al., 2009) and in housed goats in AWIN. For welfare assessment this may be relevant in housed animals but can also indicate lack of wear due to lameness in some conditions (Abbott & Lewis, 2005).

HEALTH:

Lameness

Sheep:

Locomotion or gait scores for sheep have been developed by several authors mainly using numerical rating scales (Welsh & Nolan, 1995; Otto et al., 2000; Guedes et al., 2006; Hemsworth et al., 2009; Colditz et al., 2011; Kaler et al., 2009; 2011). The score of Kaler et al (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 reliability both in the field and whilst handling.

Lambs:

In lambs lameness assessments could use a similar locomotion score as for ewes. However, these have only been conducted in 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.

Injuries

Sheep and lambs

Clinical assessment of the presence of injuries to eyes, body and legs have been reported in several studies (Napolitano et al., 2009; Caroprese et al., 2009; Lovatt, 2010; Stubsjoen et al., 2011; Phythian et al., 2012) 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, Stubsjoen et al., 2011; Phythian et al., 2012).

Skin disorders (including infections, allergens, ectoparasites)

Sheep

Skin or integument condition (presence of lesions or irritation) and fleece quality have been reported in several welfare assessment studies, including AWIN (Napolitano et al., 2009; Caroprese et al., 2009; Stubsjoen et al., 2011; Phythian et al., 2011). Fleece quality can be assessed from a distance for even coverage with no significant loss or shedding. 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 reliability of assessments of skin condition vary between studies with some reporting excellent agreement (e.g. Stubsjoen et al., 2011) and others low to moderate agreement (Phythian et al., 2012, 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.

Respiratory disorders

Sheep

Nasal discharge, scored as present/not present, is used in the AWIN protocol, and in Phythian et al. (2012), with good inter-observer reliability.

Assessment of respiration, 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; Stubsjoen et al., 2011; Phythian et al., 2012). In general this occurs at low incidence which makes assessment of inter-observer reliability difficult.

<u>Lambs</u>

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).

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

<u>Sheep</u>

Dag score (a score of breech soiling) is used in some studies (Phythian et al., 2012) and in AWIN as a potential measure of endoparasites (as it shows good correlation with faecal egg counts in AWIN studies), 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-observer reliability.

Mucosa colour, using the FAMACHA© 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 (Lovatt, 2010). In the AWIN project this measure has moderate to good inter- and intra-observer reliability.

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, due to the fact that sheep are not observed frequently, bloat is usually detected under the form of sudden death.

<u>Lambs</u>

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.

Metabolic disorders (e.g. acidosis and ketosis)

<u>Sheep and Lambs</u>

To date no studies have suggested ABMs to assess these disorders without collection of blood samples (e.g. to determine β-hydroxy butyrate concentration). Although not specific for these disorders, assessment of *animal demeanour, or Qualitative Behavioural Assessment* (QBA), may be a useful measure that animals may be experiencing ill health that 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).

Reproductive disorders (including dystocia and metritis)

Sheep

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.

Mastitis:

Sheep

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

Presence of lesions on the udder or teat lesions can also be readily assessed and showed good observer agreement in AWIN studies.

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

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 3 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 only be recorded at very specific times of year.

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

Sheep:

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 likely 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.

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.

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 likely pain experienced by the lamb as pain associated with these procedures has been extensively studied (e.g. 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 likely 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.

BEHAVIOUR:

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

<u>Sheep</u>

Wool pulling, biting or chewing are abnormal oral behaviours typically seen only in housed sheep at high stocking density (Dwyer & 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 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.

<u>Lambs</u>

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 & Bornett, 2004). The presence and frequency of these behaviours could be used as a measure of abnormal behaviours but requires assessment of reliability.

Chronic fear (fearfulness due to e.g. predation, poor handling, disturbed social behaviour):

<u>Sheep</u>*:*

Response to human tests of various forms have 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 & Hutson, 1990) is the most practical measure of response to humans, and shows some convergent validity with other measures in AWIN data.

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) are 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, as developed for AWIN, contains assessment terms related to fear and anxiety (fearful, agitated, wary, tense) and high scores on these terms indicate increased fearfulness.

<u>Lambs</u>*:*

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 only relevant to lambs which are exposed without the mother present.

Table 21: Summary of animal based measures associated with different welfare consequences in ewes and lambs

Welfare Quality Criteria	**Welfare Consequence**	**Animal based measures**	
		Ewes	**Lambs**
1. Absence of prolonged hunger	Prolonged hunger	Body condition score Dental health	Body condition score Gut fill
2. Absence of prolonged thirst	Prolonged thirst	Resource based measures only	Resource based measures only
3. Comfort around resting	Resting problems	Coat cleanliness Lying behaviour	Coat cleanliness Lying behaviour
4. Thermal comfort	Thermal stress	Panting Respiration rate Shivering	Panting Respiration rate Shivering Huddling behaviour
5. Ease of movement	Restriction of movement	Displacement Activity Frequency of social interaction Overgrown hoof	No animal based measures reported in literature
6. Absence of injuries	Lameness	Locomotion score (lameness)	Locomotion score (lameness)
	Injuries	Clinical assessment	Clinical assessment
7. Absence of disease	Skin disorders	Skin conditions Fleece quality	Skin conditions
	Respiratory disorders	Nasal discharge Respiration quality	Nasal discharge Respiration quality
	Gastro-enteric disorders	Dag score Mucosal colour	Dag score Mucosal colour Gut fill
	Metabolic disorders	Bloat	Bloat
	Reproductive disorders	Farmer records of abortion and dystocia incidences.	
	Mastitis	Udder consistency Teat lesions Somatic Cells Count	
	Neonatal disorders		Farmer records of mortality

			Vigour
8. Absence of pain induced by management procedures	Pain induced by management procedures	Presence of full tail Ear damage Presence of breech scar Facial expression	Presence of full tail Presence of testicles in males Ear damage Facial expression
10. Expression of other behaviours	Abnormal behaviour	Wool pulling Stereotypic behaviour Social isolation	Inter-sucking Pica
9. Expression of social behaviour 11. Good human-animal relationship 12. Positive emotional state	Chronic fear	Flight distance Startle response Vigilance behaviour Qualitative behavioural assessment Facial expression	Flight distance Startle response Qualitative behavioural assessment Facial expression

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Not applicable (this section is not under public consultation)

RECOMMENDATIONS

Not applicable (this section is not under public consultation)

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To be completed

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GLOSSARY

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.

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

Measurement: The result of this evaluation as scored for an individual animal or group of animals.

For example, the welfare consequence of prolonged hunger can be indicated by e.g. loss of body tissue reserves (the indicator), which can be evaluated by e.g. 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. 40 Kg: the measurement).

Furthermore, the indicator could be indirectly assessed with a resource based measure, e.g. the amount of feed given to the animal relative to its maintenance requirements, using MJ of energy per day as the measurement.

APPENDICES

APPENDIX 1. 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	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	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 Veenden	Intensively selected, under controlled conditions, for lamb growth and carcass traits.
3. Semi-intensive	Churra Lacaune Castellana Latxa Awassi	Rams are intensively selected under controlled conditions, for milk yield and quality traits.	Seldom primary breed criteria		Ripollesa Castellana Rasa Aragonesa Segurena	Rams are intensively selected, under controlled conditions, for meat traits.

	Chios Sarda Comisana	Ewes are selected for milk yield and quality traits under local environmental conditions.			Bleu de Maine	Ewes are typically crossed-bred from breeds selected for prolificacy, lambs survival and weaning weight.
4. Semi-Extensive	Seldom primary breed criteria		Merino Karakul Corriedale	Pure-bred rams 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.	Bleu de Maine Dorset Scottish Blackface Romanov Finnsheep Veenden Merino And cross-bred animals	Pure-bred rams are selected for lamb growth and carcass traits. Pure or crossed-bred ewes are selected for lambs survival and weaning weight in local environmental conditions. Ewes may also be selected for prolificacy.
5. Extensive	Seldom primary		Merino Karakul	Pure-bred rams are selected from	Scottish Blackface	Pure-bred rams are selected for adaptation to local

	breed criteria		Corriedale Polwarth Romney	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.	Rough fell Swaledale Welsh Montain Cheviot Dorset Clun Forest Finnsheep Herdwick Karakul Bluefaced Leicester Lleyn Merino Corriedale Polwarth Romanov Romney	conditions of themselves and offspring. Rams may also be selected for lamb carcass traits. Pure or crossed-bred ewes selected for adaptation to local conditions of themselves and offspring. Ewes may also be selected for prolificacy and lamb weaning weight.
6. Very extensive	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	Scottish Blackface Rough fell Welsh Mountain Cheviot Herdwick Merino 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 crossed-bred ewes selected for adaptation to local conditions of themselves and offspring.

				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.		Ewes may also be selected for prolificacy and lamb weaning weight.
7. Mixed system (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 2. MAIN ELEMENTS OF A GIVEN MANAGEMENT SYSTEM

Primary purpose	**Management system**	**Lamb management**	**Ewe management (milking)**	**Adult male management**	**Nutrition**	**Human-animal relationship (this referes general management during the year, excluding lambing)**	**Genetic lines**	**Environmental conditions**
Milk	Shepherding	Temporary separation on daily basis	Hand or machine milking (once a day or twice); Always kept in a group of small numbers; 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 to 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 hundred;	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

			High replacement; Year old animals enter into breeding; (remind to revisit the welfare consequences).					
Milk	Semi-intensive	Separation could happen within few days and weeks, until weaning for replacement and heavy lambs, or until slaughter.	Machine milking (twice a day); Both natural and artificial insemination are practiced; Kept in mixed groups with size in hundred; High replacement; Year old animals enter into breeding; (remind to revisit the welfare consequences).	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 environment.	Usually carried out in temperate and Mediterranean regions.
Meat	Shepherding	Temporary	Always kept in	As ewes, they	Pasture, depending	No physical contact	Diverse,	Usually carried

		separation on daily basis.	a group of small numbers; Low replacement.	remain in the group.	on the environmental resources available; Possibility of supplementation.	necessary (sheep can avoid the physical contact); Continuous contact, at group level; Absence of fear to stockperson; High opportunity to recognise and treat welfare and health problems.	variable and with different degrees of adaptation to the environment;	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 low hundreds; Artificial insemination practiced; High replacement; Year old animals enter into breeding.	Intensively managed; Outside the mating season, may be moved to extensive systems with minimal supervision.	No pasture; Roughage and concentrates, provided by feeding.	No physical contact necessary; Daily contact at group level; High opportunity to recognise and treat welfare and health problems.	Highly selected for meat traits, including growth rate	West and Northern European regions
Meat	Semi-intensive	Reared by mothers, weaning at 8 to 12 weeks, fattening under intensive conditions possible	Kept in mixed groups with size in hundreds; Relatively high	Kept in low numbers and expected to be only with the ewes during	Improved and unimproved pasture and provision of feed (roughage, silage and	No physical contact necessary; Daily contact at group level;	Ewes selected for mothering traits and prolificity, crossed with	Regions/areas with good pasture quality.

			replacement; Year old animals enter into breeding.	the breeding season; Outside the mating season, may be moved to extensive systems with minimal supervision.	concentrate) during housing	High opportunity to recognise and treat welfare and health problems.	meat traits sire.	
Meat	Semi-extensive	Reared by mothers, weaning at 8 to 12 weeks, fattening under intensive conditions possible	Kept in mixed groups with size in 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 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 meat traits sire.	Regions/areas with good pasture quality.
Meat	Extensive	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 as separate ram groups in the extensive system, or in fenced areas, the entire year; Low replacement.	Access to some improved and unimproved pastures (continuous grazing). Infrequent 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	Very-extensive	Reared by mothers,	Kept in groups	Rams remain	Access to	No physical contact	Ewes selected	Regions/areas

		weaning at 12 to 16 weeks, fattening under intensive conditions possible	with size in high hundreds up to thousands; Relatively low replacement.	in separate ram group in the very extensive system, or in fenced areas, the entire year; Low replacement.	unimproved pastures. No supplementation	necessary; Intermittent contact at group level;	for mothering traits, crossed with diverse breeds; Adaptation to local environmental conditions.	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 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.
Meat	Seasonal mix of semi-extensive and extensive/very	Reared by mothers, weaning at 12 to 16 weeks, fattening under intensive	Kept in groups with size in high hundreds up to thousands;	Rams remain in the extensive system the	During the semi-extensive phase, improved pasture and provision of	No physical contact necessary; Intermittent contact at	Ewes selected for mothering traits and prolificity,	Regions/areas with natural pastures.

	extensive production for dual purpose (wool and meat) (e.g. New Zealand, UK)	conditions possible	Relatively low replacement.	entire year; Low replacement.	feed (supplementation) During the extensive phase, access to some improved and unimproved pasture and infrequent supplementation.	group level Less opportunity to recognise and treat welfare and health problems.	crossed with meat traits sire.	
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 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-breed 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 intensive conditions possible	Kept in groups with size in high hundreds; Relatively low replacement.	Castrated males remain in the group.	Access to some improved and unimproved pastures; Possibility of supplementation.	No physical contact necessary; Intermittent ocntact at group level; Less opportunity to recognise and treat welfare and health problems.	Selected for wool traits.	Regions/areas with natural pastures.
Wool	Very extensive	Reared by the	Kept in groups	Castrated	Access to	No physical contact	Selected for	Regions/areas

		mothers, weaning at a later stage, fattening under intensive conditions possible	with size up to thousands; Relatively low replacement.	males remain in the groups;	unimproved pastures; Infrequent supplementation.	necessary; Minimal contact, at group level; Low opportunity to recognise and treat welfare and health problems.	wool traits	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 3. CONCEPTUAL MODEL

Principles	Welfare Quality Criteria		Negative Welfare Consequence if criteria not met	Animal-based indicators These might be primary ABIs which have a direct relationship with the welfare consequence, or secondary ABIs which 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[6]: 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 affect 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	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) System 2, 3 n) Systems 1-4, 7

[6] For the description of farming/management systems, please refer to the accompanying draft working document "Description of the management systems for sheep"

					i) Imbalanced diet (specific nutrient deficiencies) j) Competition for feed resources (including feeding space) k) Low seasonal feed availability (winter snow, summer drought, floods) l) Lack of supplementation in hard periods (winter storms or summer droughts, floods) m) Poor drying off practices after lactation (leaving animals without eating 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 affect 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 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	a-g) Systems 1-7 h) Systems 4-7 i-j) Systems 1-7

					freezing, summer drought) i) Lameness j) Maternal desertion/agalactia (lambs)	
	3	**Comfort around resting**	Resting problems including: 1)Reduced comfort around resting 2) fatigue due to reduced resting time	1. Reduced resting time 2. Abnormal gait 3. Injury 4. Soiled / matted wool 5. Competition for limited suitable areas 6. Symptoms of respiratory problems 7. Shivering (impaired thermogenesis) 8. Loss of body condition 9. Decreased reproductive performance 10. Increased lambs mortality 11. 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) 1 -7 a-f) System 2, 3, 7 b) Systems 1- 7 c) 2, 3, 7 d) 2, 3, 7
Housing/Environment	4	**Thermal comfort**	Thermal discomfort including: 1)Heat stress 2)Reduction in heat tolerance 3)Cold stress 4) Lamb mortality	1. Bunching / grouping 2. Panting 3. Increased respiratory rate 4. Shivering 5. Reduced feed intake 6. Increased water intake 7. Loss of body condition 8. Physical inactivity during heat stress 9. Increased competition for thermally desirable areas 10. Clinical signs of udder infections 11. 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 at wet conditions, 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	c-f) System 1 a, b, g to i) System 2 a, b, g to i) System 3 c to f) System 4 c to f) System 5 c to f) System 6 a to i) System 7

	5	Ease of movement	Restriction of movement including: 1) Slipping and falling 2) Physical restraint 3)Overgrown hoof 4)Crushing /smothering 5)Bullying	1. Increased incidence of slipping and falling 2. Overgrown hoof 3. Abnormal gait 4. Reluctance to move 5. Increased aggression from enforced proximity 6. Overcrowding 7. Soiled / matted wool 8. Occurrence of injuries 9. Occurrence of abnormal behaviours	a) Inappropriate flooring/material/design/construction b) High stocking densities c) Physical restraint c d) Selection of sheep not adapted to the conditions encountered in the field e) Not adequate hoof trimming f) Poor walking tracks	a to f) System 2 a to f) System 3 e & f) Systems 4,5 and 6 a to f) System 7 d) - 1-7
Health	6	**Absence of injuries**	Lameness including: 1) wound 2)fractures Injuries (others) including: 1) Wounds 2) Fractures	1. Abnormal gait 2. Occurrence of lesions and/or swelling 3. Reluctance to move 4. Teeth grinding 5. Abnormal posture 6. Apathy 7. 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 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) Not adequate hoof trimming	
	7	**Absence of disease**	Lameness including: 1)Foot infection Skin disorders Respiratory disorders Gastro-enteric disorders including: 1) Cachexia 2) poisoning (e.g endotoxemia) Metabolic disorders including: 1) acidocis 2)ketosis Reproductive disorders Mastitis Neonatal disorders including: a) lamb mortality b)Perinatal infection c) Conjunctivitis in lambs d) Lamb mortality	1. 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,enterotoxemia -clostridium..) i) Poor handling (e.g. bad shearing practices) j) Lack of biosecurity k) Inappropriate nutrition (acute and chronic) l) No inspection during lambing m) No cleaning and disinfection of shearers and contractors n) Use of not 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 in environmental impacts (blizzards, snow)	

					s) Not adequate drying of sheep t) Over explotation of landscape u) Inadequate management of the drinking points (overcrowding	
	8	**Absence of pain induced by managemen t procedures**	Pain including: a) acute pain b)chronic pain	1. Abnormal gait 2. Head shacking 3. Visible lesions and/or swelling 4. Reluctance to move 5. Teeth grinding 6. Abnormal posture 7. Apathy 8. Social isolation 9. Tremor 10. Frequent high pitched bleats 11. Facial expression	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 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 displacements from lying areas	i) Increased negative social interactions ii) Increased behavioural activity iii) Reduced behavioural synchrony iv) Frequent displacements at feeder v) Frequent displacements at resting vi) Frequent high pitched bleats vii) Frequent vigilance postures vii) Refusal to eat viii) Low body condition x) Immune suppression xi) Poor growth in lambs xii) Apathy Anxious demeanour xiii) Escape behaviours xiv) Lamb mortality xv) Broken horns (if present)	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 for	a) Systems 2, 3, 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) System 2, 3 greatest, lower for 4 and 7 lowest for 1, 4-6 f) System 2 & 3, 7 g) System 1-7, greatest risk for 2-3, 7 h) Systems 3 & 7 i) Systems 1-7

			Prolonged hunger included 1) frequent displacement from feeders 2)Weaning stress in lambs 3) Abandoned neonatal lambs	12. xvi) Facial expression including ear position	allowing antipredator behaviour k) Inadequate escape terrain (such as cliffs with high slopes) for allowing antipredator behaviour	j) Systems 1-4, 7 k) Systems 5, 6, 7
	10	**Expression of other behaviours**	Abnormal behaviour	1)Wool pulling 2)Bar biting 3)Star gazing 4)Route tracing/pacing 5)Pica 6) Poor fleece quality 7) 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) System 2, 7 d) Systems 2 & 3, 7
	11	**Good human-animal relationship**	Chronic fear of human Pain Injury	1) Frequent high pitched bleats 2) Escape behaviours 3) High behavioural activity 4) Avoidance of humans 5) Bunching, pushing and riding each other 6) Slipping, falling, baulking 7) Injury from collision with handling facilities 8) Increased flight distance 9) Slow recovery after being startled 10) Panting 11) High respiration rate 12) Kicking, flinching or increased stepping at milking 13) Broken horns (if present) 14) Fleece condition (pulls or bare patches)	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

				13. Facial expression including ear position 15)		
	12	**Positive emotional state**	Chronic fear	1) Frequent high pitched bleats 2) Escape behaviours 3) High behavioural activity 4) Avoidance of humans/dogs 5) Avoidance of areas of pasture following predator presence 6) Bunching, pushing and riding each other 7) Increased flight distance 16) Slow recovery after being startled 8) Bite wounds 9) High vigilance behaviours 10) Low behavioural synchrony 11) Refusal to eat 14. 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 3-6, 7 b) Systems 1, 4, 5,6, 7 c) Systems 2 & 3, 7 d) Systems 4-6, &b, 7

APPENDIX 4: RESULTS FROM EXPERT KNOWLEDGE ELICITATION.

1. Responses:

1.1. Statistics

322 **experts** started the survey providing

347 data **records** (1x6; 1x4; 20x2)

248 data records describe the system for evaluation and were compatible to the sheep farming culture relevant for the assessment

220 data records provide some frequency ratings (194 are completed)

175 data records provide some impact ratings (163 are completed)

163 record were included in all analyses (additional were used when appropriate i.e. selected ratings available)

1.2. Identity

149 records are associated with personal identity and background while 14 are not. The latter distribute to SE & MX (6 each) and EX & VE (1 each). It is not suggested to separate both groups of respondents. E.g. in SE the average frequency estimate of the 17 consequences provided by respondents without identity was 8 times smaller and 8 times higher than those with revealed identity (one equal).

1.3. Technical background

The respondents were asked to indicate the nature of 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, NGO, 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.

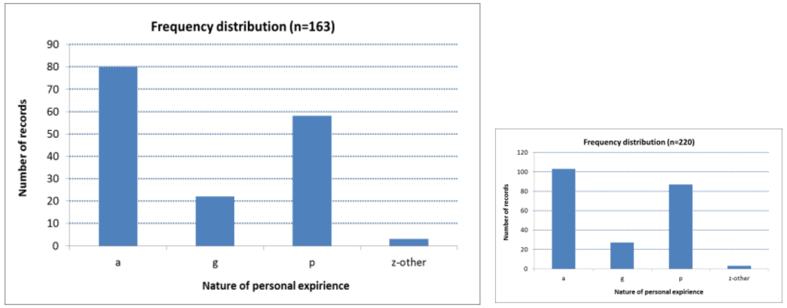


Fig. 1.1: Nature of technical experience of respondents (n= 163; left) and all respondents with any estimate (n=220; right)

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

1.4. Country of sheep system for which ratings were provided

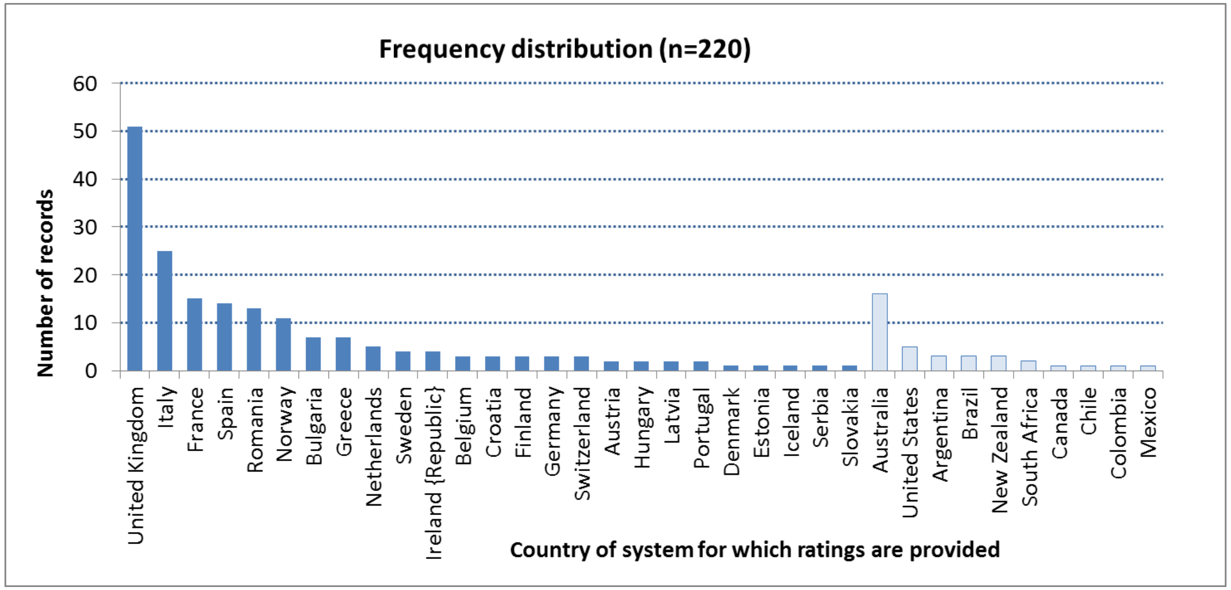


Fig. 1.2: Records on systems with data (n=220) by the country where the respondent assigned the system

1.5. Flock size by country

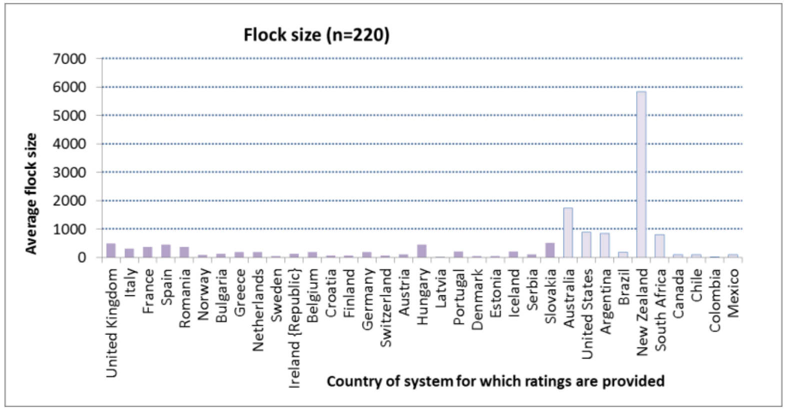


Fig. 1.3: Average flock size by country (n=220; ordered by the number of records, Fig. before).

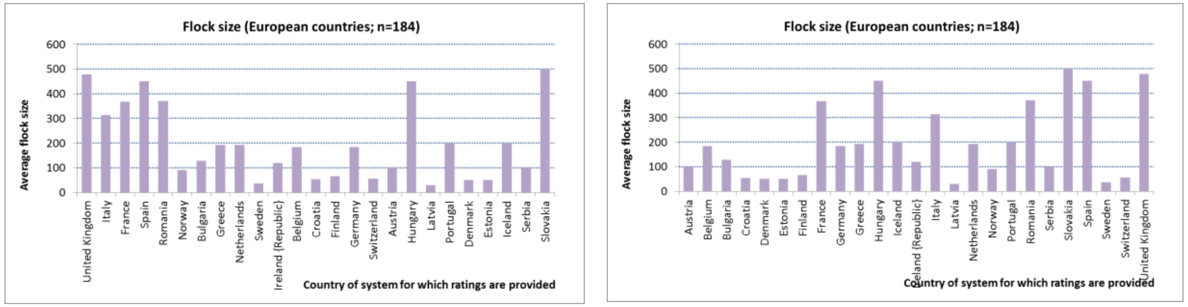


Fig. 1.4: Average flock size by country for Europe (n=184; left - ordered by number of records; right –alphabetical order)

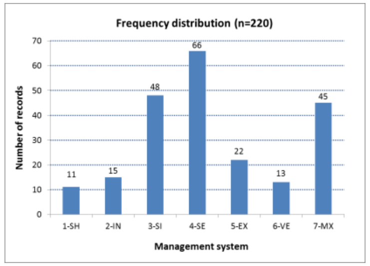
2. Description of sets of responses

The description is provided by management system or by production purposes.

2.1. Description of responses by management system

The following categories are applied to identify 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) 

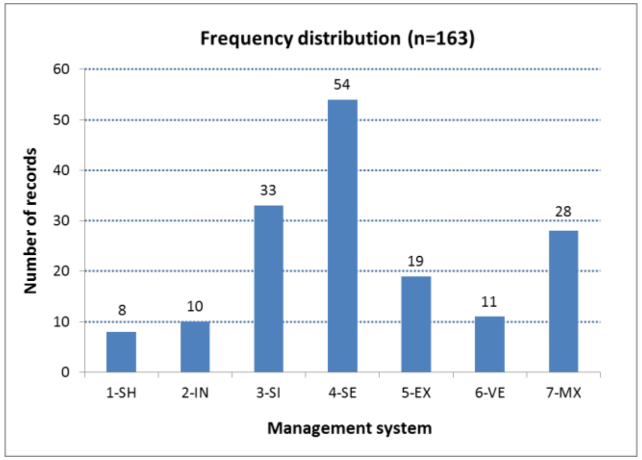
b) 

Fig. 2.1: Distribution of management system in a) all records with ratings (n=220); b) only records with complete data (n=163)

NB: Any interpretation of result about SH, IN, VE should be read with caution and if appropriate cross-checked against the set of the individual responses.

2.1.1. Mixed systems – Details

Table: Abbreviations of different categories for mixed systems.

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	Any Extensive	Mixture of than four systems

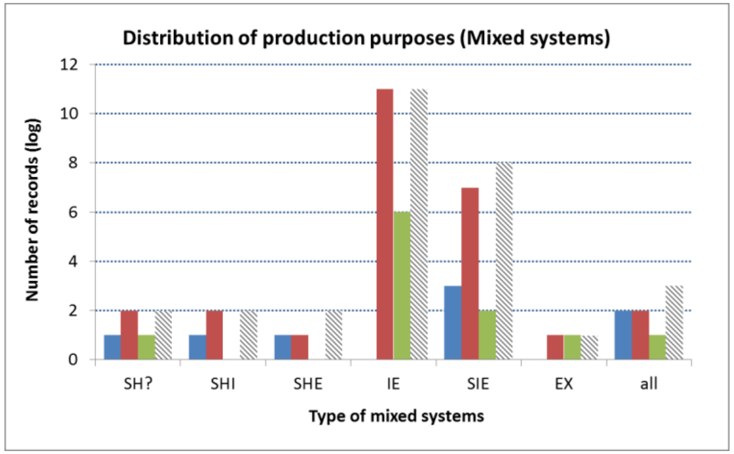


Fig. 2.1.2: Distribution of production purposes across the mixed systems. The number of records is shown by the grey-dashed bars. Milk = blue, Meat = red, Wool = green. For example all eleven systems mixing intensive and any extensive were Meat by purpose while six of these also served for wool production.

2.2. Description of responses by production purpose

The following categories are applied to identify production purposes:

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

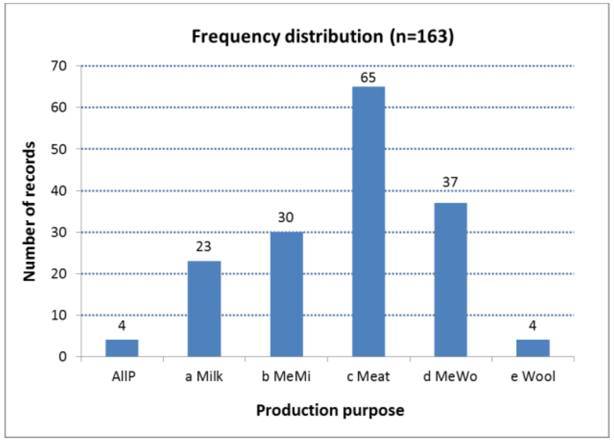


Fig. 2.2: Distribution of production purpose in records with complete data (n=163).

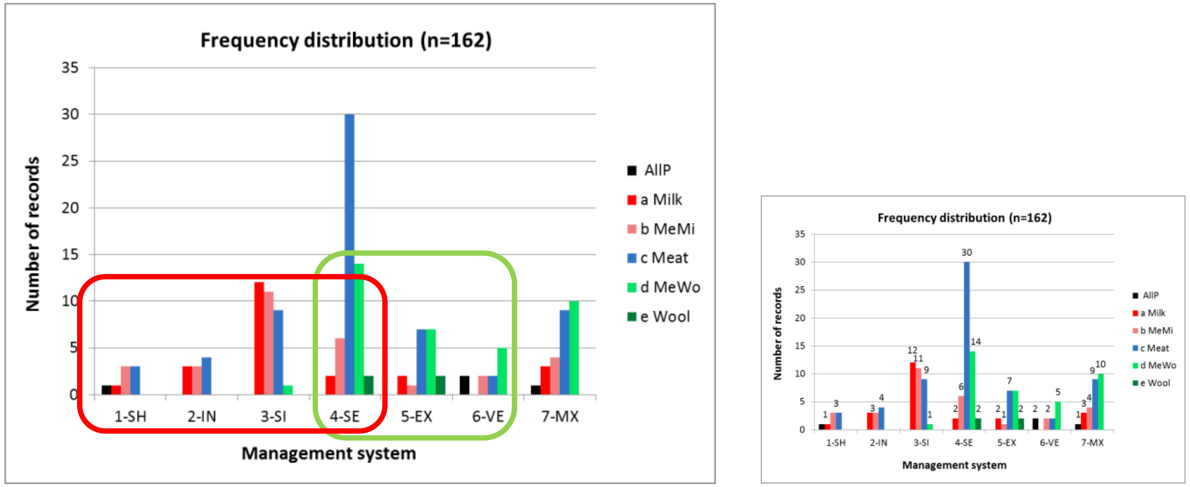


Fig. 2.3: Distribution of production purpose across the management systems (n=163). Milk or meat in combination with milk is concentrated to SH, IN, SI, and SE. Whereas Wool production or meat in combination with wool is concentrated within the extensive sector i.e. SE, EX, and VE

(NB: the 163rd record was 7-MX Meat)

2.2.1. Production purpose – Special requests

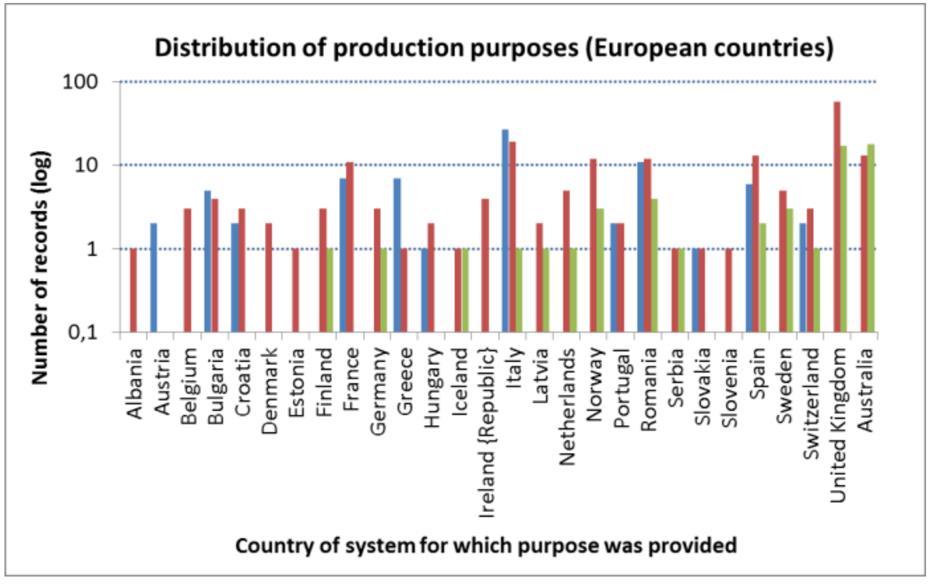


Fig. 2.4: Log-scale distribution of production purpose(s) assigned to the system per record as shown for Europe plus Australia. Records with multiple purposes are represented more than once. Milk = blue; Meat = red; Wool = green series. For example wool (green) is assigned as purpose to systems in the countries FI, DE, IS, IT, LV, NL, NO, RO, RS, ES, SE, CH, UK, (AU).

Table. Data details as shown in Figure 2.4 above.

	Milk	Meat	Wool
Albania		1	
Austria	2		
Belgium		3	
Bulgaria	5	4	
Croatia	2	3	
Denmark		2	
Estonia		1	
Finland		3	1
France	7	11	
Germany		3	1
Greece	7	1	
Hungary	1	2	
Iceland		1	1
Ireland {Republic}		4	
Italy	27	19	1
Latvia		2	1
Netherlands		5	1
Norway		12	3
Portugal	2	2	
Romania	11	12	4
Serbia		1	1
Slovakia	1	1	
Slovenia		1	
Spain	6	13	2
Sweden		5	3
Switzerland	2	3	1
United Kingdom		58	17
Total	**73**	**186**	**55**

	Milk	Meat	Wool
Australia		13	18
New Zealand		4	2
Canada		1	
United States	1	4	2
Mexico		2	
Argentina		3	3
Brazil		3	
Chile		1	
Colombia	1	1	
Uruguay		1	1
South Africa		2	2
South Sudan	1	1	
Total	**3**	**36**	**28**

3. Main consequences by management system

3.1. Analysis

The main consequences were identified using the impact score (approximating the risk to the particular dimension of animal welfare). The impact score was defined as multiplicative combination of two or three ratings. The ratings were standardised between 0 and 1. The ratings were (a) the affected population proportion (prevalence; between 0 and 1), (b) the severity classification (ordinal 0, 0.33, 0.66, 1) and (c) the uncertainty rating of the proportion (Low +/-0.125; Medium +/-0.25; High +/-0.5). For sensitivity evaluation three different methods of data aggregation were applied and the resulting ranking of consequences provided: (i) average of raw impact score values, (ii) median of raw impact score values and (iii) average of uncertainty corrected impact score values. For the latter the uncertainty rating was translated into the accountable probability mass of L: 2*0.125, M: 2*0.25, H: 2*0.5 and the corresponding rating weighed with the respective likelihood of being observed: (proportion rating)/(length of certainty interval) = (proportion rating)/(2*0.125*{L=1; M=2;H=3}).

3.2. Ewes

3.2.1. Ewes – Summary

Table. Comparison Average (upper row) vs. Uncertainty corrected (middle row) vs. Median (bottom row) impact score. Items highlighted by colour were high-ranked across the management systems providing more general main consequences for sheep production. Inclusion of uncertainty has minor impact on the ranking results (cf. row 2 vs. row 1) which indicates that extreme frequency ratings are dominantly stated very certain. The consequence items marked red in the first (average) or last row (median) were not ranked high in terms of the median or the average of the records, respectively. The reason was the different perspective in the ratings by background (i.e. academic vs. practitioner, see detailed analysis). Academia e.g. emphasised behavioural items. Because both groups by numbers are 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 measures is identical. Italic items are sequential after the first clear tie subsequent to the third consequence item (see detailed analysis).

1-SH	2-IN	3-SI	4-SE	5-EX	6-VE	7-MX
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 f Thermal Mastitis *Pain* *Skin* *Hunger* *Resting*
Thermal Thirst Mastitis Lameness Reproduct Chronic f Hunger	Restriction Thermal Respiratory Mastitis Lameness Pain Resting Abnormal b Chronic f	Resting Mastitis Lameness Enteric Thermal Skin Reproduct Chronic f	Lameness Enteric Thermal Skin	Thermal Hunger Lameness Mastitis Thirst Respiratory Skin Chronic f	Thermal Hunger Pain Chronic f Lameness Skin Resting	Enteric Lameness Mastitis Skin Chronic f Pain

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*

3.2.2. Ewes – Details

3.2.2.1. Ewes: Raw average

Table: Main consequences for ewes by management system based on average impact score. Colours mark commons across all management systems. First row: maximum rank. Second row: subsequent rank (usually selected at ratings between 0.3-0.4)

1-SH	2-IN	3-SI	4-SE	5-EX	6-VE	7-MX
Thermal Thirst	Thermal Restriction Mastitis Respiratory Abnormal b	Mastitis Resting Lameness Thermal Enteric Reproductive Skin	Lameness Enteric Thermal	Thermal Hunger Mastitis Lameness	Hunger Thermal Pain	Enteric Lameness Chronic f Thermal Mastitis
Lameness Mastitis	Lameness Resting Chronic f	Chronic f Restriction Metabolic Respiratory	Skin Pain Mastitis	Skin Chronic f Respiratory Thirst	Skin Chronic f Lameness Resting	Pain Skin Hunger Resting

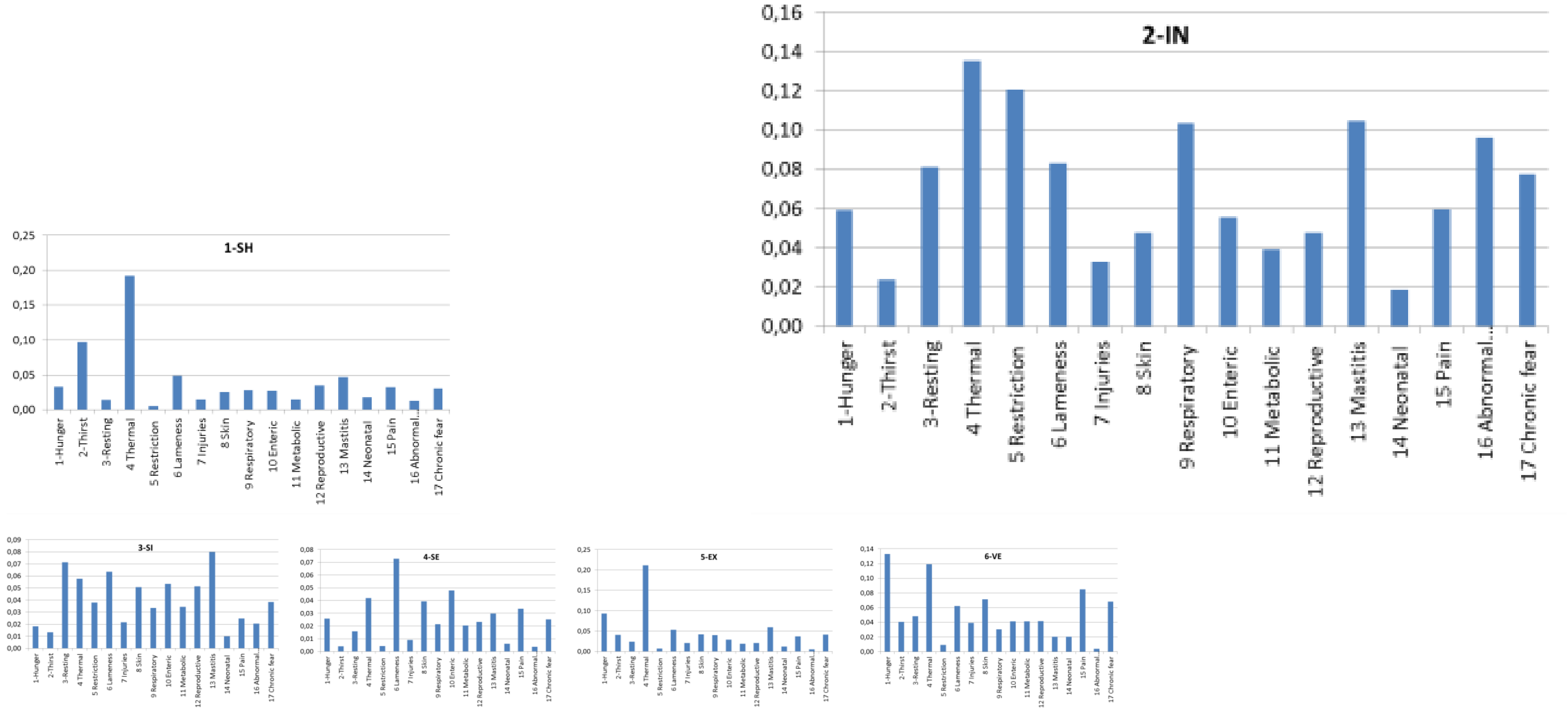


Fig. a-f: Average impact score for the 17 selected consequences (summary see Table above)

3.2.2.2. Ewes: Uncertainty corrected average

Table: Main consequences for ewes by management system based on average impact score **corrected by uncertainty rating**. Colours mark commons across all management systems. First row: maximum rank (above 0.5). Second row: subsequent rank (usually with rating between 0.3-0.4)

Score	1-SH	2-IN	3-SI	4-SE	5-EX	6-VE	7-MX

> 0.05	Thermal 0.17 Thirst	Restriction .08 Thermal Respiratory Mastitis Lameness	Resting .06 Mastitis Lameness	Lameness .06	Thermal 0.18 Hunger	Thermal .11 Hunger 0.11 Pain	Enteric .08
0.03-0.05	Mastitis Lameness Reproduct Chronic f	Pain Resting Abnormal b Chronic f *Enteric* *Hunger* *Skin* *Reproduct*	Enteric Thermal Skin Reproduct Chronic f	Enteric Thermal Skin	Lameness Mastitis Thirst Respiratory Skin Chronic f	Chronic f Lameness Skin Resting	Lameness Mastitis Skin Chronic f Pain
< 0.03	Hunger			*Pain* *Mastitis*			Thermal

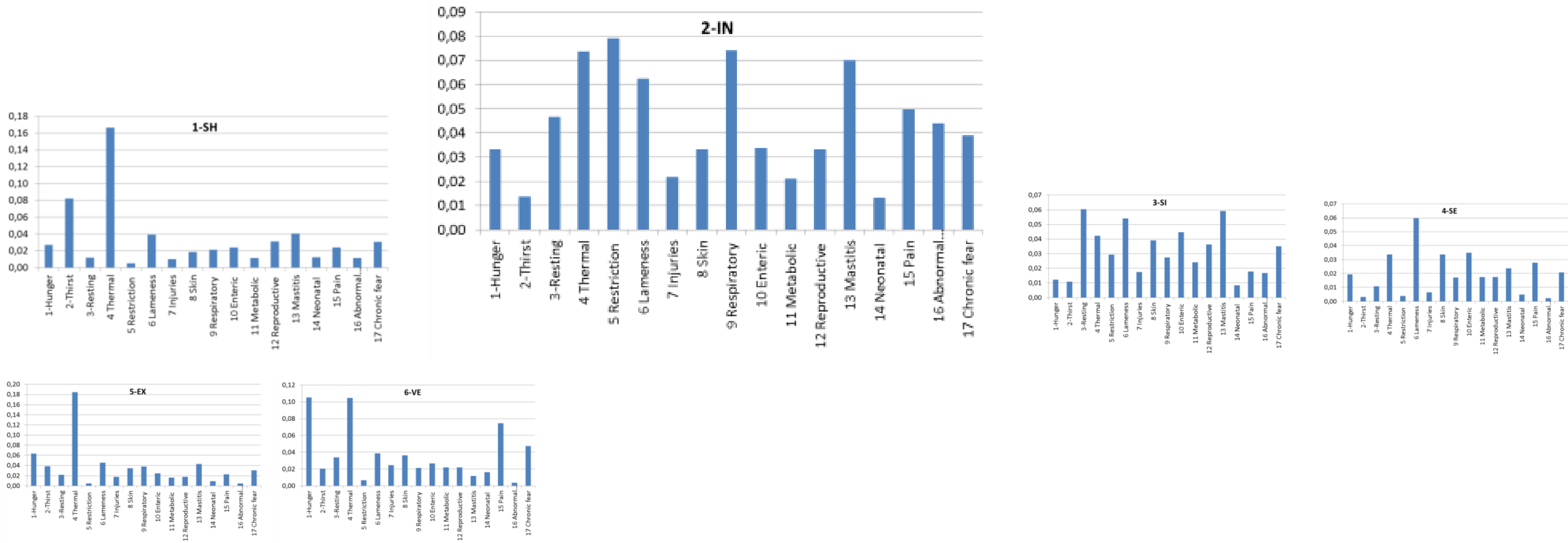
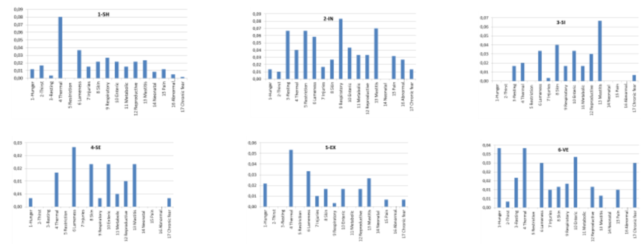


Fig. a-f: Average impact score **adjusted by uncertainty value** for the 17 selected consequences (summary see Table above)

3.2.2.3. Ewes: Median

Table. Main consequences for ewes by management system based on **median impact score**. Colours mark commons across all management systems. Bold items: maximum rank (above 0.5). Italic items: subsequent ranks.

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



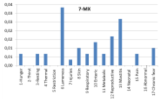
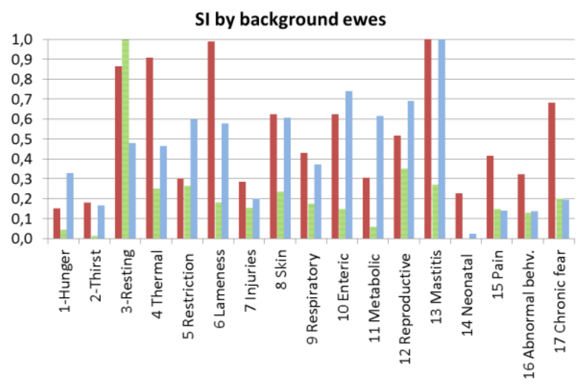


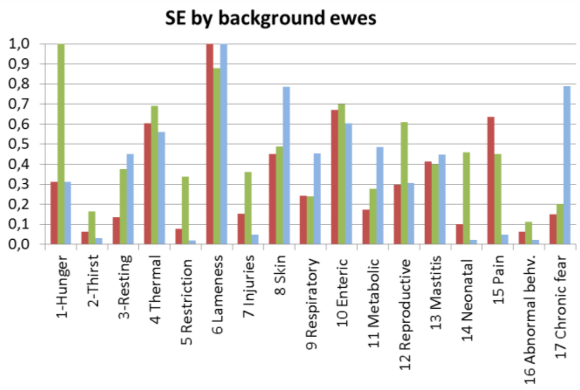
Fig. a-f: Median impact score for the 17 selected consequences

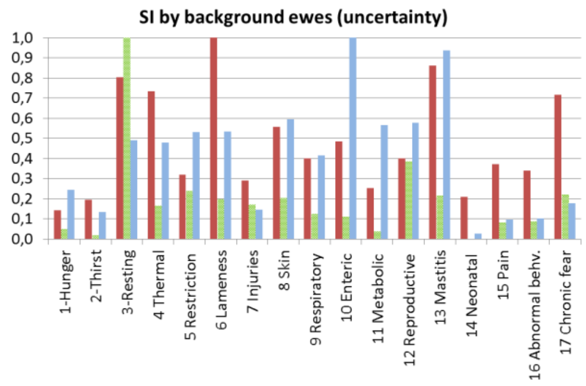
3.2.2.4. Comparison of background effect

Table: Main consequences for ewes by background of respondents. Colours mark commons across all six management systems (see summary Table above). First row: ranking for 3-SI. Second row: ranking for 3-SI uncertainty corrected. Third row: ranking for 4-SE. (Items stop at level 0.5 but are lower until the coloured commons in Table above are appended). Red items were disselceted in the

	Academia (18/21)	Governmental (3/7)	Practitioner (11/28)	overall
3-SI	Mastitis Lameness Thermal Resting Chronic f Enteric Skin Reproductive	Resting	Mastitis Enteric Reproductive Metabolic Skin Restriction Lameness Resting Thermal	Mastitis Resting Lameness Thermal Enteric Reproductive Skin
3-SI (uncertainty) (threshold 0.5)	Lameness Mastitis Resting Thermal Chronic f Skin	Resting	Enteric Mastitis Skin Reproductive Metabolic Restriction Lameness *Resting* *Thermal*	
4-SE	Lameness Enteric Pain Thermal Skin Mastitis	Hunger Lameness Enteric Thermal Reproductive Skin Neonatal Pain Mastitis	Lameness Skin Chronic f Enteric Thermal Metabolic Resting Respiratory Mastitis	Lameness Enteric Thermal Skin Pain Mastitis





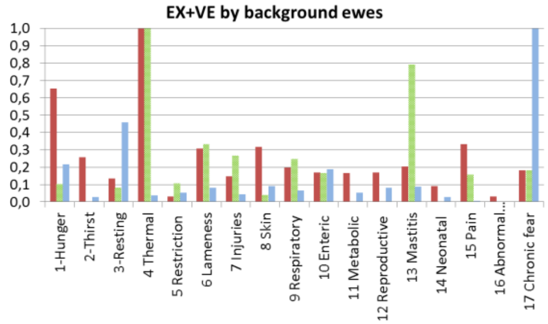


3.2.2.4.1. Special request on Lameness for EX+VE

Table. Average consequence impact score by background.

	Academia (20)	Governmental (3)	Practitioner (7)	All (average)	All (median)
5-EX + 6-VE	Thermal Hunger Pain Skin Lameness *Thirst*	Thermal Mastitis Lameness Injuries Respiratory	Chronic f Resting Hunger Enteric Mastitis Skin	Thermal Hunger Lameness Pain Skin *Chronic f*	Thermal Hunger Lameness *Mastitis* *Skin* *Enteric*

	Mastitis *Respiratory*		Lameness Reproductive	*Mastitis* *Thirst*	*Chronic f*



Lameness is perceived as issue in extensive management systems. However, only academia (fifth) and governmental (third) expert rank the consequence as important. Practitioners don't rank Lameness as main consequence (seventh).

3.3. Lambs

3.3.1. Lambs - Summary

Table. Comparison Average (upper row) vs. Uncertainty corrected average (middle row) vs. Median (lower row) importance score. The consequence items in red are not ranked high in terms of the median of the records. Italic items are sequential after the first clear tie subsequent to the third consequence item (see Fig. above).

1-SH	2-IN	3-SI	4-SE	5-EX	6-VE	7-MX
Thermal Thirst Enteric Respiratory *Pain* ← *Lameness* *Neonatal*	Respiratory Restriction Thermal Enteric Abnormal *Chronic f* *Neonatal* *Resting* *Pain*	Pain Enteric Thermal *Neonatal* *Resting* *Respiratory*	Pain Enteric Thermal *Neonatal* *Skin*	Pain Thermal Neonatal *Chronic f* *Enteric* *Hunger* *Thirst*	Pain ← Thermal Neonatal Hunger Chronic f *Enteric* *Resting* *Skin*	Pain Enteric Chronic f Neonatal *Thermal* *Lameness*
Thermal Thirst *Enteric* *Lameness* *Respiratory* *Neonatal* *Pain*	Respiratory Restriction Enteric Thermal Pain *Neonatal* *Chronic f* *Resting*	Pain Enteric *Thermal* *Neonatal* *Resting*	Pain Thermal Enteric *Skin* *Neonatal*	Thermal Pain Neonatal *Chronic f* *Thirst* *Skin* *Enteric* *Hunger*	Pain Thermal *Enteric* *Hunger* *Resting* *Chronic f* Neonatal	Pain Enteric Neonatal *Chronic f*
Thermal **Enteric** **Neonatal** **Respiratory** *Hunger* *Lameness*	**Enteric** **Respiratory** **Thermal** **Restriction** **Neonatal** *Pain* *Resting*	**Enteric** **Thermal** **Neonatal** **Respiratory** *Pain* *Lameness*	**Pain** **Enteric** **Thermal** **Neonatal** *Lameness* *Respiratory*	**Pain** **Thermal** **Neonatal** *Enteric*	**Thermal** **Neonatal** **Enteric** **Hunger** *Resting* *Injuries* *Skin* *Chronic f*	**Neonatal** **Enteric** **Pain** *Chronic f* *Lameness* *Skin* *Thermal*

3.3.2. Lambs – Details

3.3.2.1. Lambs: Raw average

Table: Main consequences for lambs by management system. Colours mark commons across all management systems. First row: maximum rank. Second row: subsequent rank (usually with rating between 0.3-0.4)

1-SH	2-IN	3-SI	4-SE	5-EX	6-VE	7-MX
Thermal Thirst Enteric Respiratory	Respiratory Restriction Thermal Enteric Abnormal	Pain Enteric Thermal	Pain Enteric Thermal	Pain Thermal Neonatal	Pain Thermal Neonatal Hunger Chronic f	Pain Enteric Chronic f Neonatal
Pain Lameness Neonatal	Chronic f Neonatal Resting Pain	Neonatal Resting Respiratory	Neonatal Skin	Chronic f Enteric Hunger Thirst	Enteric Resting Skin	Thermal Lameness

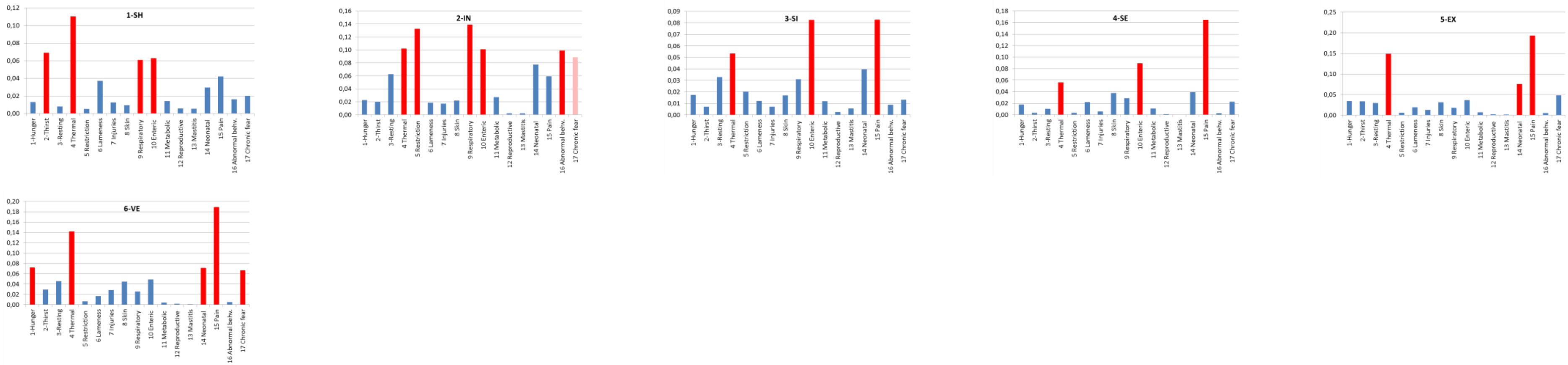


Fig. a-f: Average importance score for the 17 selected consequences (summary see Table above)

3.3.2.2. Lambs: Uncertainty corrected average

Table: Main consequences for lambs by management system based on average impact score **corrected by uncertainty rating**. Colours mark commons across all management systems. First row: maximum rank (above 0.5). Second row: subsequent rank (usually with rating between 0.3-0.4)

Score	1-SH	2-IN	3-SI	4-SE	5-EX	6-VE	7-MX
> 0.5	Thermal Thirst	Respiratory Restriction Enteric Thermal Pain	Pain Enteric	Pain Thermal Enteric	Thermal Pain Neonatal	Pain Thermal Neonatal	Pain Enteric Neonatal
0.3- 0.5	Enteric Lameness Respiratory	Neonatal Chronic f Resting	Thermal Neonatal Resting	Skin Neonatal	Chronic f Thirst Skin Enteric Hunger	Enteric Hunger Resting Chronic f	Chronic f
< 0.3	Neonatal Pain	Abnormal b Metabolic	Respiratory	Respiratory	Resting		Lameness

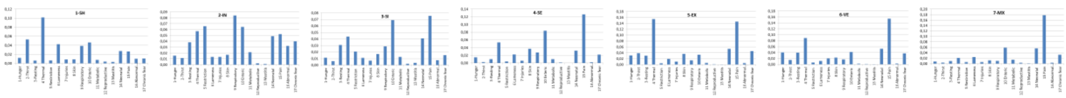


Fig. a-f: Average importance score **adjusted by Uncertainty rating** for the 17 selected consequences (summary see Table above)

3.3.2.3. Lambs: Median

Table. Median impact score. Italic items are sequential after the first clear tie subsequent to the third consequence item (see Figs. below).

1-SH	2-IN	3-SI	4-SE	5-EX	6-VE	7-MX
Thermal **Enteric** **Neonatal** **Respiratory** *Hunger* *Lameness*	**Enteric** **Respiratory** **Thermal** **Restriction** **Neonatal** *Pain* *Resting*	**Enteric** **Thermal** **Neonatal** **Respiratory** *Pain* *Lameness*	**Pain** **Enteric** **Thermal** **Neonatal** *Lameness* *Respiratory*	**Pain** **Thermal** **Neonatal** *Enteric*	**Thermal** **Neonatal** **Enteric** **Hunger** *Resting* *Injuries* *Skin* *Chronic f*	**Neonatal** **Enteric** **Pain** *Chronic f* *Lameness* *Skin* *Thermal*

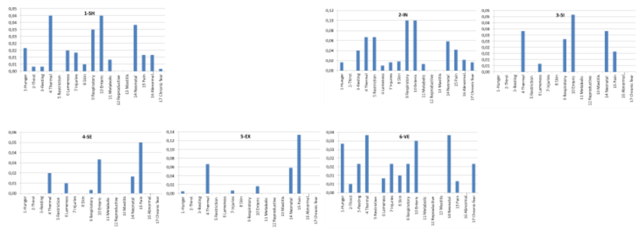
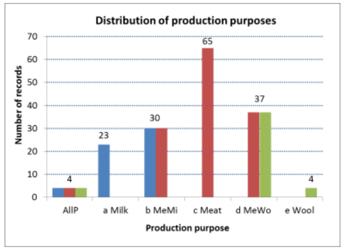


Fig. a-f: Median importance score for the 17 selected consequences (summary see Table above)

4. Main consequences by purpose

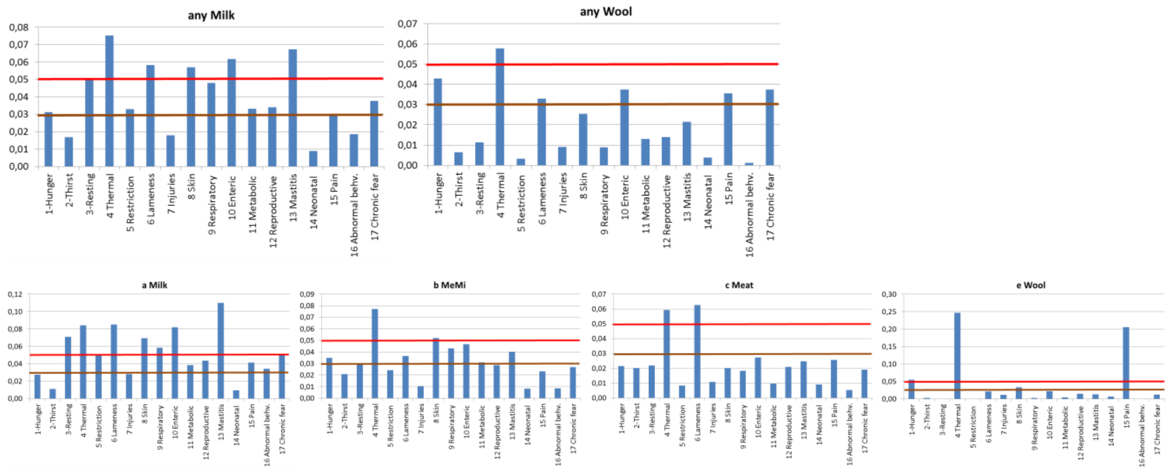


Q	Value
1	0,247
0,8	0,05(0,047)
0,6	0,030
0,5	0,024
0,4	0,019
0,2	0,009
0,001	0,000

4.1. Ewes

Score	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.
> 0.05 (Q80)	Mastitis_0,11 Lameness_,085 Thermal_,084 Enteric_,082 Resting Skin Respiratory	Thermal_,08 Skin	Thermal_,075 Mastitis Enteric Lameness Skin	Lameness_,06 Thermal	Thermal_,06		Thermal Pain Hunger
0.03-0.05 (Q60-Q80)	Restriction Chronic f Reproduct Pain Etc.	Enteric Respiratory Mastitis Lameness Hunger	Resting Respiratory *< 0,038* *Chronic f* *Reproduct* *Metabolic* *Restriction* *Hunger*		Hunger *< 0,038* *Enteric* *Chronic f* *Pain* *Lameness*	Hunger Chronic fear Thermal Enteric Lameness	Skin
< 0.03				Enteric Pain		Skin Mastitis	Injuries

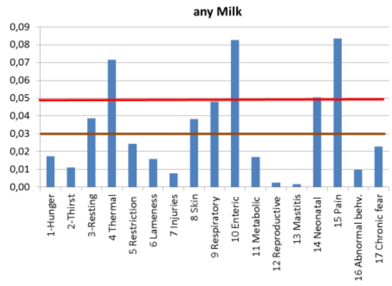
(Q60)				Mastitis Resting			

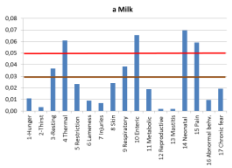


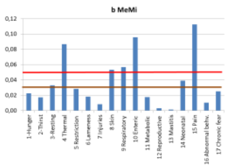
4.2. Lambs

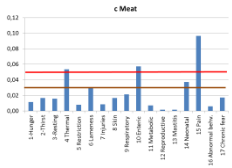
Score	Milk (n=23)	Milk+Meat (n=30)	*Any* milk (n=57)	Meat (n=65)	*Any* wool (n=45)	Meat+Wool (n=37)	Wool (n=4) n.a.
> 0.05 (Q80)	**Neonatal** **Enteric** **Thermal** **Pain**	**Pain**_,11 **Enteric** **Thermal** *Respiratory* *Skin*	**Pain**_,084 **Enteric** **Thermal** **Neonatal**	**Pain**_,10 **Enteric** **Thermal**	**Pain**_,19 **Thermal**	**Pain**_,19 **Enteric** Chronic fear	**Pain**_,39 Thermal Skin
0.03-0.05 (Q70-Q80)	Respiratory *Resting*	***<0,04*** ***Neonatal*** *Resting*	Respiratory *< 0,04* *Resting*	***<0,04*** ***Neonatal*** *Lameness*	Chronic f **Neonatal**	**Neonatal**	**Neonatal**

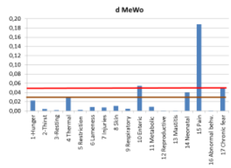
			Skin				
< 0.03 (Q70)						**Thermal** Hunger	Hunger

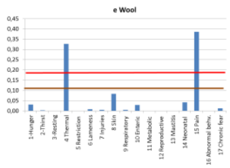












GLOSSARY [AND/OR] ABBREVIATIONS

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