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Review
Environmental enrichment in ruminants and equines: Introduction

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Preliminary note

The concept of environmental enrichment applies to any species. As far as possible, examples given in the present review concern ruminants or equines. When knowledge is lacking in ruminants or equines we mention findings obtained in other species.

1 Executive summary

In natural habitats, animals receive many stimuli that vary in place and time. In such habitats, they can express a wide range of behaviours that define the species' "behavioural repertoire". Farming or captive environments are designed to meet their basic biological needs (e.g. for rest, feeding), but are far less complex than natural habitats. Animals thus may not be able to express some of the behaviours from their repertoire and as a consequence experience boredom. The concept of environmental enrichment refers to a wide range of modifications to the environment of captive or farmed animals that offer adequate stimulation and facilitate the expression of highly motivated behaviour, thereby promoting positive emotions and improving animal welfare. Environmental enrichment can be divided into five (non-exclusive) categories: relational, feeding, occupational, physical and sensory enrichments. A good knowledge of the behaviour and the biology of the species is essential for the design of relevant enrichments. The benefits and drawbacks of enrichments need to be assessed in both short and long term by studying the use of enrichments in terms of occupancy value, the preference and motivation of animals to use them and the impact on welfare. To support positive animal welfare, high quality enrichment that engages animals over a long period of time should be seriously considered.

2 Foreword

Domestic ruminants and equines are kept in a wide range of environments with varying complexity, from individual housing in barren pens to rearing in large groups in semi-natural environments. The richness of the environment has an impact on animal welfare. EURCAW *Ruminants & Equines* proposed to review the available knowledge on environmental enrichment for the species covered by the Centre. The first review introduces the issue of environmental enrichment in general: What does a enriched environment mean? What are the various types of enrichment and what are the main consequences of a poor vs. enriched environment? Then separate reviews address the various types of enrichment: occupational and physical enrichment; sensory and feeding enrichment; and relational enrichment (including the impact of the presence of conspecifics and that of other species including humans). The goal is to understand the underlying mechanisms and how they impact on the various animal types. Directive 98/58/EC for the protection of farmed animals mentions ethological (behavioural) needs, but not positive emotions or enrichment. Directive 2008/119/EC for the protection of farmed calves further specifies that calves must have visual and tactile contacts and must be kept in group from the age of 8 weeks. Directive 2010/63/EU for the protection of animals used for scientific purposes mentions enrichment, in reference to the expression of behaviour and the reduction of negative emotions (stress). For the purpose of EURCAW *Ruminants & Equines* the reviews on enrichment will therefore mainly address enrichment relevant to behavioural or sensorial needs and will make no distinction between animals used for farming or scientific purposes.

3 Definitions

Natural habitats are often very rich: animals receive many stimuli that vary in place and time; they can express a wide range of behaviours, defining the so-called "behavioural repertoire" of their species. The behavioural repertoire includes various activities which can be species-specific (e.g. social interactions, sexual behaviour, foraging). It allows the species to be adapted to its habitat. Farmed or captive environments are designed to cover animals' basic biological needs (e.g. for rest, for feeding), however they are far less complex than natural habitats. Despite generations of breeding in non-natural habitats, domestic, farmed and captive animals still display behaviours of their original repertoire (Sluyter & Van Oortmerssen, 2000). The possibility for the animal to perform such behaviours can be rewarding, apart from the strict fulfilment of its biological needs. For instance, in natural conditions young calves take their food by suckling their dam. Nutritional needs can be fulfilled in calves drinking milk from buckets; calves fed milk from buckets are nevertheless motivated to suck and they can redirect sucking towards inanimate objects (a dry teat for instance) or other calves (in so called 'cross-sucking') (Rushen & de Passillé, 1995). Behavioural needs refer to behaviours that are performed whatever the environment (Weeks & Nicol, 2006). Animals generally experience suffering when they cannot fulfil behavioural needs (Jensen & Toates, 1993). The term behavioural priority has been introduced to refer to a behaviour the animal is motivated to perform (e.g. in operant conditioning settings) (Nicol, 2011; Weeks & Nicol, 2006). The degree of suffering due to not performing the behaviour depends on the strength of its priority (measured by the amount of work the animal is ready to produce to obtain a reward). In addition to be denied the possibility to express some behaviours, animals may lack stimulation and experience boredom when they are in barren environments, which can manifest as stereotypies (Wemelsfelder, 1993).

It is now widely acknowledged that animals not only have biological needs but also behavioural and sensorial needs. Not expressing a behaviour for which there is a need results in frustration, with e.g. signs of stress or over-expression later when the behaviour is possible ('rebound' behaviour). In addition, some behaviours are particularly pleasant to animals and procure positive emotions, e.g. positive interactions with peers or the dam, play behaviour, having control on the environment (Mellor, 2016).

The concept of environmental enrichment refers to a wide range of modifications to the environment of captive or farmed animals that offer adequate stimulation and facilitate the expression of highly motivated behaviour thus promoting positive emotions and improving animals' welfare.

Directive 98/58/EC for the protection of farmed animals mentions ethological (behavioural) needs, but not positive emotions or enrichment. Directive 2008/119/EC for the protection of farmed calves further specifies that calves must have visual and tactile contacts and must be kept in group from the age of 8 weeks. Directive 2010/63/EU for the protection of animals used for scientific purposes mentions enrichment, in reference to the expression of behaviour and the reduction of negative emotions (stress). For the purpose of EURCAW *Ruminants & Equines* the

reviews on enrichment will therefore mainly address behavioural or sensorial needs and will make no distinction between animals used for farming or scientific purposes.

Environmental enrichment starts from "housing supplementation" with few elements added to very poor environments and can go up to rearing in complex environments close to natural habitats (Benefiel et al., 2005; Boissy et al., 2007; Duncan & Olsson, 2001; Newberry, 1995). Basic enrichments ("housing supplementation") added to a poor environment may improve animal welfare but are insufficient to promote good animal welfare since the environment remains too constrained to allow the animals to express their full behavioural repertoire. For instance, groups of five calves housed in 9 m² slatted-floor pens are enriched compared to calves housed in individual crates because it facilitates social interactions, but overall it does not provide a rich environment.

Environmental enrichments may provide additional opportunities for different facets of the animal's life, e.g. food-related, housing, social, spatial and / or cognitive exercise (Newberry, 1995). Environmental enrichments can be classified into five (non-exclusive) categories (adapted from Bloomsmith et al., 1991; Mandel et al., 2016):

- **physical enrichments** that include the complexity of the animal's enclosure and the provision of additional elements (e.g. hiding places);
- **occupational enrichments** that promote physical and/or psychological activities by providing opportunities to exercise or to engage in cognitive tasks;
- **sensory enrichments**, designed to stimulate one or several senses of the animal, and include visual, auditory, olfactory, tactile and taste stimulations.
- **feeding enrichments** that promotes foraging and feeding behaviour by providing new or varied foods, or feed delivery methods or tools;
- **relational enrichments** that embrace social contacts, development of feeling safety, facilitation or learning in diverse situation and specific bonds with conspecifics or individuals of other species (including humans);

These categories are not exclusive: e.g. new food items can provide both a feeding and a sensory enrichment, a new food-delivery system can provide both a feeding and a cognitive enrichment, the possibility to see conspecifics can provide both a sensory (visual) and a relational enrichment.

Enrichment aims at improving the welfare of animals. Any solution nevertheless to improve welfare is not necessarily an enrichment. For instance, adjusting the diet of an animal to cover its metabolic needs cannot be considered an enrichment, especially if the animal does not perceive changes (e.g. micro-nutrient composition of a diet is not perceived by the animal in the short term at least). In turn any enrichment designed by humans may not improve animal welfare if it does not correspond to animal needs or preferences. Typically, enrichment should promote positive welfare and not only prevent negative welfare.

4 Identification of animals' needs

Enriching the environment requires facilitation of the animals' needs, which depends on their perceptual world (Rørvang & Nawroth, 2021; Uexküll & Kriszat, 2013). A good knowledge of the species, its behaviour and biology is thus essential to implement relevant enrichment (e.g. Würbel, 2009). Also needs may differ between individuals within species, depending for instance on their development stage. Examples are provided below. The species in the scope of EURCAW *Ruminants & Equines* are herbivorous. In a natural habitat they spend a large proportion of the day eating grass, leaves, bushes etc. Depending on the resource availability, equines spend 60-75% (up to 80% for lactating mares) of their time feeding while slowly walking (1 step/s) (e.g. Waring, 2003). Feeding bouts are distributed throughout the 24-h period so that their gut remains relatively full. At pasture, cattle spend approximately 1/3 of their time grazing and 1/3 ruminating motionless in a quiet environment (Neave et al., 2021). In a comparative study on feeding behaviour, horses spent up to 3 times more grazing than sheep, but when adding rumination bouts of the sheep, the time spent feeding was similar (Dulphy et al., 1997). When fed with diets that can be rapidly ingested (like concentrate feed), the animals may develop abnormal behaviour (Aziz ur Rahman et al., 2019; Waters et al., 2002), as if they compensate for the lack of feeding behaviour. For instance, calves denied the possibility to eat solid foods spend more time in non-nutritive oral activities (Veissier et al., 1998). Under domestic or farming conditions, feeding conditions are often constrained in terms of distribution over time (restricted number of meals) and diversity (mostly single roughage and concentrates, and sometimes provided in a total mixed ration) (cattle: Gomez & Cook, 2010; horses: Thorne et al., 2005), leading to potential behavioural disorders (e.g. stereotypies, cattle: Seo et al., 1998; horses: Ninomiya et al., 2004). For both ruminants and equines, the provision of feeds that are slowly ingested, e.g. roughage, allows them to spend a large part of the day feeding. This may be even more important for equines (see below) due to their natural patterns of feeding behaviour. Ruminants should also benefit from a quiet place where they can ruminate undisturbed.

The social organisation, as can be observed in natural or semi-natural habitats, varies with species, but with a common trait: the majority of ruminants and equines are gregarious, living in social groups (except some reproductive males). Horses live in stable family groups (Waring, 2003). Young male horses form separate 'bachelor groups'. Donkeys may live in stable family groups as horses or in large females groups with males in close proximity (McDonnell, 1998). Cattle reside in large multi-female groups with their offspring, and small groups of young male or solitary males in close proximity (Bouissou et al., 2001). Goats and sheep are also organised into groups of related females with their offspring and groups of males, the size of the groups depending on the habitat, with larger groups in open habitat with a risk of predation (Shackleton & Shank, 1984). Deer species that are farmed such as red and fallow deer show seasonal sexual segregation typically with groups consisting of females and their offspring and a separate bachelor herd. These groups congregate during the reproduction period (Mysterud, 1998; Wang & Schreiber, 2001).

Social isolation is a source of stress for gregarious species (cattle: Rushen et al., 1999; goats and sheep: Price & Thos, 1980; rabbits: Chu et al., 2003; horses: Rivera et al., 2002) and can lead to the development of undesired behaviours (Benhajali et al., 2010; Costa et al., 2016; Visser et al., 2008). In order to alleviate these negative effects, social enrichments may be set up. In addition, in most species, the presence of adults with young animals improves the development of the behaviour and decreases the prevalence of abnormal behaviours, including stereotypies (horses: Henry et al., 2012; sheep: Nowak et al., 2018). Mixing animals i.e. changing the group composition, can also be stressful (Proudfoot & Habing, 2015). The impacts vary depending on the social organisation of the species and the development stage of the animals. Indeed repeatedly mixing of 11-15 months old heifers reduced stress but had the opposite effects on calves that were a few months old, probably due to the development of social behaviour around puberty (Boissy et al., 2001; Raussi et al., 2006; Veissier et al., 2001). Both isolation, mixing and overcrowding can induce social stress and may impair health (Proudfoot & Habing, 2015).

Some species, like sheep, show a high level of group behavioural synchronisation (social facilitation), so that enrichment may be more effective if it can be done at group level (allowing all animals to perform the same activity at the same time). Other species like goats display more individual behaviours, they are probably more likely to explore their environment alone and are considered more inquisitive.

The behavioural needs and time-budgets are often different between adults and young of the same species. In some species, play is a strictly juvenile behaviour under natural conditions (Burghardt, 2005; Waring, 2003) and is considered to help the ontogeny of behaviour. For instance, social play is crucial for the development of behaviour of horses (Waring, 2003) and cattle (Jensen et al., 1998). Play in adults is rarely observed and may have a different role from play in juveniles (Burghardt, 2005; Oliveira et al., 2010). In horses, the most playful adults are those responding more intensively to humans and to tactile stimulation, so that in these animals play can be interpreted as a sign of suboptimal welfare (Blois-Heulin et al., 2015; Hausberger et al., 2012). Enrichments stimulating play behaviour will therefore be of importance for young animals and not necessarily for adults.

5 Present situation

Among ruminants and equines in the European Union (EU), cattle and sheep largely dominate in terms of the number of animals, followed by goats, equines, deer, buffaloes and other animals (camelids and bison) (*Annexe 1*). Cattle by far predominate the other species in terms of equivalent Livestock Units (LSU) and number of farms (*Annexe 2*). The most current conditions for their management – especially housing – are described below.

5.1 Cattle

Bovines, almost entirely cattle, represent 79.4 million animals for 57.4 million LSU; they are distributed throughout the EU (*Annexe 2 & Annexe 4*, Eurostat, 2016). In the EU, most cattle are outdoors at pasture during the grazing season and indoors in winter. The duration of each period depends on weather conditions and grass availability. In Ireland where the oceanic climate makes grass growing for a large part of the year, beef cattle may overwinter outdoors or indoors (in colder regions and or to prevent 'poaching' of the grass) whereas dairy cattle overwinter indoors. By contrast, in Nordic countries cattle may only be kept outdoors for a few months, if at all. Zero grazing is also practiced in some EU member states, e.g. in Netherlands where canals surround pastures, cattle may be housed all year, mainly to avoid pollution by manure leaching. When indoors, cattle are generally housed in group pens, with a straw-yard or cubicles to rest. Tethering is decreasing in the EU and is most often seen in mountainous areas or in some countries (Germany, Poland). For beef bulls, straw-yards are more common than other types of housing and they are turned out onto pasture less often during summer. According to EU legislation calves can be housed in individual stalls, not tethered, up to 2 months of age. Calves from beef breeds are generally suckled by their dams: when outdoors, they are maintained in the same pasture as adult cows whereas indoors they can be grouped in pens and separated from the dams except for suckling (generally twice a day). Most dairy calves are separated from the dam soon after birth, they drink milk from buckets with or without a teat dispenser (bucket fixed with a teat or automatic milk feeder). The vast majority of dairy calves do not have outdoor access, they are kept in group pens at least after 2 months of age.

5.2 Sheep and goats

Sheep and goat farming, which represents just 3.6% of the total value of meat production in the EU, is considered to be the most vulnerable livestock sector (increasing aging and poor retention of farmers, health crises, attacks by predators, decline in sheep meat consumption) (European Parliament, 2018). Despite the low economical value of sheep and goat production there are currently about 75 million sheep and goats in the EU27 (85% sheep and 15% goats), often kept in economically vulnerable areas such as mountain regions, mainly in southern Europe (*Annexe 2, Annexe 3 & Annexe 5*, European Commission, 2022). In the sheep sector, meat is the most important production from an economic point of view, despite the fact that it is going through a phase of strong contraction due to the increase of dairy production, in response to consumer demand. In the goat sector, there is an increase in dairy products and exports of goats to third countries.

Overall, the sheep and goat supply chain is characterised by a marked heterogeneity of the farm type, with a predominance of extensive and semi-extensive farming, with some countries relying on intensive farming. Four types of farming systems may be described. In intensive farming systems, animals are kept indoor, with no grazing and rare access to an outdoor exercise area. In semi-intensive systems, animals are kept indoors but have access to outdoor paddocks or pasture during the day for a few months. In semi-extensive farming, animals are kept indoors overwinter, and at pasture during the rest of the year. Finally, in extensive systems, animals are kept almost permanently outdoors at pasture and generally benefit from natural shelters.

5.3 Equines

In Europe (EU and non-EU countries), the equid population is around 7 million of horses, ponies, mules and donkeys but figures are probably underestimated (Eurogroup4Animals, 2015). A significant proportion of equines are kept by private owners, non-farmers (which explains the difference with figures presented in *Annexe 2 & Annexe 6*). The European equine industry is divided into several sectors differing in terms of management and working constraints for the animal. Sport and leisure horses represent most of the population, followed by racehorses. The breeding, working and production horses are far less numerous. Donkeys are mostly distributed between leisure, equine assisted activities, working and production sectors. Mules are mostly used for leisure and working purposes. Strong differences exist between sectors concerning the housing, feeding and working conditions of equines.

Sport and racehorses as well as stallions are mostly housed (>80% of their time) in single boxes or tied in individual stalls with no or little access to social and spatial resources, they are fed two to three meals of high energy concentrate food per day and a limited amount of hay. A large proportion of these horses leave their stalls only for training and events, they are thus not allowed to exercise freely. Restrictions at social, spatial and feeding levels differ markedly compared to natural conditions. Leisure equines are more likely to be housed in groups, with or without daily access to paddocks or pastures. They are often fed larger amount of grass and roughage, with occasional provision of concentrate food. They may be involved in physically challenging activities. Production, breeding and working (draught) equines, including those used in tourism and equine assisted activities are mostly kept in fairly stable groups, outdoors with stabling/shelter in adverse weather conditions. They are mainly fed grass or roughage with concentrate supplementation when necessary. Breeding horses and those reared for meat (weaner) are mostly housed outdoors in more or less stable groups, with few physical constraints, whilst production horses reared for their blood (to produce hormones) or those reared for meat (fattener) may be subjected to conditions that restrict their behavioural activity. Working equines (including donkeys and mules) may undertake challenging physical activities.

5.4 Deer

According to the Federation of European Deer Farmers Associations (FEDFA, 2022), the EU has approximately 310,000 farmed deer, mainly fallow deer (76%), followed by red deer (20%) and Sika deer (4%) (*Annexe 8*). The figures are underestimated because FEDFA membership is on a voluntary basis and does not include all of EU27 countries (only 16 EU member states, of which

only 11 provide figures). Furthermore, reindeer are not in the scope of the FEDFA although they are farmed in Sweden (250,000 heads) and Finland (204,000 heads) (EFSA, 2012). Fallow, Red and Sika deer can be reared in artificial groups in fenced outdoor paddocks or in a more extensive form with natural groups and less human contact. They may be housed overwinter depending on climate and the age of the animals, indoor housing for mature deer is sometimes practiced but not recommended for welfare reasons (Hanlon & Griffin, 2022; Mattiello, 2009). Reindeer are managed in open-range systems in northern forests and mountains.

5.5 Buffaloes

The EU population of buffaloes represents less than 1% of the world population with about 460,000 head (Eurostat, 2019; FAO, 2013), mainly in Italy, Romania, Bulgaria, and Greece (*Annexe 7*). Farming systems can be extensive, but are mainly intensive, with animals loose housed with outdoor paddocks or with no access to pasture such as in Italy or in tied stalls such as in Romania and Bulgaria. In Greece, buffaloes are reared in small herds with access to pasture (Borghese, 2005).

5.6 Camelids

The number of camelids (camels, dromedaries, llamas, alpacas) kept in zoological gardens, circuses and farms is estimated at 5,000-6,000 animals in Europe (Faye, 2020). Camels can be used to produce meat, milk, wool or hides in farming systems or for cultural and recreational purposes (Faye, 2014). No information was found on how they are farmed.

5.7 Bison

No information was found on the number of farmed bison in the EU nor on enrichment. They will thus not be addressed in the EURCAW reviews on enrichment.

Farming conditions for ruminants and equines can vary from very restrictive housing (e.g. horses in individual stall with no opportunity for free physical exercise) to extensive production systems (e.g. sheep in large flocks on meadows with mixed vegetation). Restrictive environments do not allow animals to meet their behavioural needs as defined above. These gaps between animal needs and opportunities offered by the environment requires that the environment is enriched.

6 Checking the efficiency of environmental enrichment

Environmental enrichments should support positive behavioural, emotional and cognitive states and thus increase welfare. The expression of natural behaviour for which the animals are motivated is indeed likely to promote positive emotions (Boissy et al., 2007). If adapted to the needs of animals, enrichments should have beneficial effects. If not adapted, an enrichment may be inefficient (Stachurska et al., 2013) or even harmful (e.g. more stereotypic behaviours in presence of "toys" in horses, Luescher et al., 1998). In any case, it is necessary to check the efficiency of an enrichment before it is deployed. A combination of several components has to be

considered: Is the enrichment used by animals? Are animals motivated by the enrichment? Does the enrichment have either positive or negative impacts on the animals?

6.1 Use of an enrichment

A first step to determine the efficiency of an environmental enrichment is to assess whether or not it is used by the animals. Goats placed in an enriched environment (with haynets, chewing disks, platforms, logs, brushes) can, during the day, interact with the enrichments for 25% of their time (De Almeida et al, *in prep*) whereas horses spend little time interacting with non-edible enrichments (0.33% in Bulens et al., 2015; Jørgensen et al., 2011). The proportion of the population using the enrichment should also be considered (Wilson et al., 2002) since preferences may vary between individuals. The effectiveness of an enrichment may be considered lower if used a lot by a few individuals rather than scarcely but by all individuals. In case the enrichment is used by only a few animals, additional enrichments have to be considered to reach the other animals. How long the interest for an enrichment lasts (the 'occupancy value') must also be taken into consideration: the interest may be strong but short lasting for some items whereas the interest may not fade with time with other items (Mandel et al., 2016; Wilson et al., 2002). If the interest is short-lasting, the enrichment items should be replaced on a regular basis. However, active interaction with items is not essential for assessing the efficiency of enrichment, as no interaction can still reduce stress and improve welfare (e.g. humans often seek to be in natural environment with trees without physically interacting with it) (Decker et al, 2023).

6.2 Preference for and motivatin to get an enrichment

An animal's preference for the type of enrichment can be measured by comparing their use in a free choice situation or by conducting preference tests with only one enrichment accessible at a time. When placed in a multi-enriched environment, goats spent 20.3% time using "climbing" enrichment vs. 2.8% time using brushes (de Almeida et al, *in prep*). When facing a choice in a preference test, calves prefer entering a room with a human brushing them than an empty room (Westerath et al., 2014). Dairy cows prefer automatic brushes to fixed ones (Gutmann, 2010), and brushes to scent release devices (Wilson et al., 2002). When given the choice, horses prefer having access to food or to a paddock with conspecifics, followed by the access to an empty paddock, and returning to their stall. Forced exercise conditions (similar to a treadmill) were avoided by horses (Lee et al., 2011). Duncan & Young (2002) showed that when given the choice, goats actively preferred mixed food rather than a single food. When trained to use a light switch, both adult sheep and calves chose to have longer periods of light vs. darkness (sheep: 77% of the day, calves: 67% of the day, Baldwin et al., 1981).

The motivation for an enrichment can be assessed by the work an animal is ready to perform to obtain it (*e.g.* Kilgour et al., 1991; Mendl & Paul, 2020). Comparing the motivation displayed towards several enrichments allows the identification of the most significant enrichment from the animal's point of view (Dawkins, 1990). For instance, horses are very motivated to access food (even when fed with an adequate diet) and to have contacts with conspecifics whereas access to a barren large enclosure is less important to them (Lee et al., 2011; Søndergaard et al., 2011). Calves also are very motivated to obtain full contact with conspecifics rather than head-only

contact (Holm et al., 2002). The frustration of not having enrichment can also be measured by the level of stress when the access to an enrichment is denied or by the over-expression of a previously prevented behaviour. For example, cortisol increases in fur-farmed minks when they are denied access to a water pool after they have been used to use it for 6 weeks (Mason et al, 2001), and cattle tethered indoors for 6 days over-express locomotion (running, jumping) when moved to a paddock (Nakayama & Ninomiya, 2018).

6.3 Impact of an enrichment on animal welfare

The ultimate aim of environmental enrichment is to improve animal welfare. It is therefore crucial to evaluate the impact of enrichments on the animals' behaviour, stress level, health or overall fitness. Adding platforms was shown to have positive impacts on feeding, resting and social behaviour of goats (Aschwanden et al., 2009). In turkeys, the addition of environmental enrichment was tested in order to replace the conventional solution of "beak trimming" to prevent injuries. The results showed that adding straw and platforms decreased the proportion of injured animals in both males and females (Mirabito & Michel, 2003). The results are nevertheless not always positive: when adding platforms in rabbits' environment, the behavioural repertoire was closer to the natural one, but injuries were more frequent (Trocino et al., 2019), suggesting that the design of platforms or their access should be improved. In horses, providing a mobile food delivery system for concentrates increased the time spent eating, but it was also associated with the development of frustration and stereotypic behaviours (Goodwin et al., 2007). On the contrary, using slow-feeders (Rochais et al., 2018) or increasing hay diversity (Goodwin et al., 2002; Thorne et al., 2005) increased the time spent feeding, resting and decreased the prevalence of stereotypic behaviours. Impacts on the behavioural and physiological reactivity of animals can also be observed. For instance, heifers that regularly meet other heifers react less to unusual stimuli and habituate to them more quickly than heifers that always stay with the same pen mates, they also react less (i.e. release less cortisol) to a pharmacological challenge (CRF injection to stimulate the release of cortisol in blood) suggesting a lower chronic stress state (Raussi et al. 2006).

It is of prime importance to comprehensively assess the impact of an enrichment on animals in all animal welfare dimensions, to ensure that potential negative impacts are identified. Focusing on the occupancy value, differentiating between short-term (e.g. exploration of a new device) and longer term effects (e.g. prolonged use of a device, variety of behaviours expressed for a long period) will improve the effectiveness and beneficial impacts on animals.

7 Environmental enrichments: what and how?

Examples of enrichments used in farming conditions are provided below. The usefulness of such enrichments depends on the rearing conditions of animals: environments such as pastures in semi-natural habitats with a variety of plants, including bushes and trees may not need to be enriched whereas indoor housing in barren pens certainly requires enrichments.

7.1 Physical enrichments

Physical enrichments consist of providing more space and additional elements to offer more diversity of the environment and more freedom of behaviour.

The environment has to provide sufficient space for animals to avoid or escape in case of social conflict. The addition of supplementary space, either by increasing the size of the enclosure (cattle: Veissier et al., 2008; horses: Lesimple et al., 2020; Visser et al., 2008) or by adding elements such as platforms (goats: Aschwanden et al., 2009; rabbits: Trocino et al., 2019) decreases agonistic and stereotypic behaviours and increases the time spent feeding and the resting quality (time and posture). Depending on the species' needs, the provision of nesting material, "refuge" areas or observation points increases positive social relationships and the time spent resting, improves feeding behaviour, and decreases aggression and stereotypic / abnormal behaviours (Aschwanden et al., 2009; Proudfoot et al., 2014).

7.2 Occupational enrichments

The possibility for the animals to engage in physical or cognitive activities when reared in farmed or domestic conditions can be limited, whilst it is considered that captive/domestic animals should be given opportunities for stimulating activities comparable to those performed by their wild counterparts (Spinka & Wemelsfelder, n.d.; Swaisgood & Shepherdson, 2008). Occupational enrichments provide the opportunity to perform biologically relevant physical or cognitive tasks. Allowing animals reared indoors to access an outdoor area increases the possibilities for locomotion and exploration (cattle: Castro et al., 2011; Veissier et al., 2008; horses: Lesimple et al., 2011, 2019) and reduces body and joint lesions (Keil et al., 2006; Loberg et al., 2004; Popescu et al., 2013; Regula et al., 2004). Occupational enrichment can also be achieved by stimulating the cognitive abilities of the farmed / captive animals by making them "work" to access a resource thanks to instrumental learning devices (e.g. goats: Langbein et al., 2009; horses: Lee et al., 2011). Including small challenges in the animals' daily environment may help preserve their psychological wellness (Rasmussen et al., 2020). In addition, having to work to access a resource gives control on the environment, which is perceived positively by animals (Greiveldinger et al., 2009).

7.3 Sensory enrichments

Sensory enrichment may include a wide range of stimuli that affect one or several senses (Bloomsmith et al., 1991; Wells, 2009). Not all stimuli constitute appropriate enrichment. Indeed, loud and unnatural noises like metallic sounds, or artificial light may be perceived negatively by animals (e.g. human shouting: Pajor et al., 2000; noise: Waynert et al., 1999).

Music diffusion in barns was tested with mixed results (reviewed by Ciborowska et al., 2021). Dairy cows are more willing to approach milking systems in the presence of music (country music in this study) (Uetake et al., 1997), and the diffusion of auditory stimuli (country and classical music, audiobooks) decreases the prevalence of stereotypic behaviours (Crouch et al., 2019). The exposure to slow music seems to have positive consequences (reduced stress in dogs: Bowman et al., 2015; better sleep and decrease stereotypic behaviours in horses: Hartman & Greening, 2019, Huo et al., 2021), with variations between species: increased performance in pigs (Ekachat & Vajrabukka, 1994) and koi carp (Vasantha et al., 2003), no impact on rats (Pfaff & Stecker, 1976) or cows (Kıyıcı et al., 2013) (see Alworth & Buerkle, 2013; Wells, 2009 for reviews). In contrast, silence may be preferred to music by some animals: tamarins and marmoset monkeys prefer silence to slow or fast music (McDermott & Hauser, 2007) and cows produce less milk when exposed to various music (country, rock, opera, jazz, reggae, pop, lullaby, classical, rap, heavy metal, and hip-hop) (Kemp, 2020). Despite some beneficial effects on ruminants' behaviour, the use of music as an enrichment remains to be further investigated. The diffusion of odours in the environment can impact the animals' behaviour either by increasing activity (e.g. Powell, 1995) or on the contrary by having an anxiolytic / calming effect (e.g. Bradshaw et al., 1998; Graham et al., 2005). The impacts differ between odours and species, and have to be cautiously checked before application. The application of flavour in the food (concentrates : Goodwin et al., 2005) or water (Van Diest et al., 2021) impacts consumption by the animals, e.g. increased consumption in case of sweet flavours (horses: Goodwin et al., 2005). In addition, animals often seek for diversity in food flavour (active choice for food diversity: sheep: Provenza et al., 1996; horses: Thorne et al., 2005, see Favreau-Peigne et al 2013 for review). Animals are also able to discriminate between foods of different nutritional characteristics and to adapt their behaviour accordingly e.g. when fed rapidly digestible food in the morning, lambs prefer slowly digestible food in the evening (Early & Provenza, 1998). Sensory enrichment could also include visual stimulation (e.g. pictures) and tactile stimulation (e.g. brushes).

7.4 Feeding enrichments

Feeding enrichments should provide the animal with food diversity as well as the opportunity to spend more time feeding (e.g. by providing roughage). Different strategies can be adopted, e.g. providing several types of roughage at the same time or alternating between roughages (Garrett et al., 2021; Hutchings et al., 2003; Meagher et al., 2017; Thorne et al., 2005), increasing the access time or changing the temporal distribution of access to forage (Benhajali et al., 2008) or spacing out the feeding points to enlarge the individual feeding space (DeVries et al., 2004). These strategies increase the time spent eating/foraging, reduce aggressivity, decrease the time spent performing abnormal / stereotypic behaviours (DeVries et al., 2004). They can also reduce health disorders (colic / laminitis: Jonsson & Egenvall, 2006; Tinker et al., 1997). In addition to the provision of supplementary roughage, favouring edible litters can facilitate a more natural pattern of feeding behaviour (Baumgartner et al., 2020) and decrease the prevalence of stereotypic / abnormal behaviours (Tuyttens, 2005).

7.5 Relational enrichments

Relational enrichment refers to contacts and bonds with partners of the same or different species. It has many advantages: not only interactions between preferential animals can provide positive emotions but also the presence of partners can favour a feeling of safety, help coping with stressors, facilitate learning (by imitation), and improve emotionality or cognitive traits (Veissier et al., 1998). Group housing improves animals' social skills (Costa et al., 2016; Fureix et al., 2012), and is beneficial provided that attention is paid to group composition and maintaining stability over time. On the contrary, social instability or inappropriate group composition can induce stress-related behaviours and increase aggression (Christensen et al., 2011; Fureix et al., 2012; Proudfoot & Habing, 2015). In case of individual housing, favouring physical and visual contacts with close neighbours (e.g. by open stalls, grid, mirrors) results in cattle being calmer (Piller et al., 1999) and horses displaying less stereotypic behaviours and also being calmer (Cooper et al., 2000; Lesimple et al., 2019; McAfee et al., 2002). If contact with conspecifics is not possible, providing contacts with individuals from other species (sometimes referred to as 'stable companions') may mimic social interactions. For example, a lamb can be adopted by a goat and a kid by a ewe (Kendrick et al., 1998). Finally, promoting positive interactions between animals and their handlers decrease stress related to human presence and to handling, reassure animals and can generate positive emotions (cattle: Lürzel et al., 2016; goats: Boivin & Braastad, 1996; horses: Fureix et al., 2009, Rault et al, 2018).

Furthermore, selecting a distribution modality to better align with the species' natural feeding time-budget can improve welfare. For instance, using tools such as hay nets or slow-feeders for roughage delivery increases the time spent feeding (Correa et al., 2020; Rochais et al., 2018).

The possibility to choose enrichments – whatever their type – seems of high value. Not only does choice increase the probability to obtain a desirable resource and allow some control over their environment, the act of choosing *per se* seems rewarding. Compared to being offered a desirable resource, the act of choosing is preferred by monkeys (Suzuki, 1999; Perdue et al, 2014). In humans choosing seems highly rewarding, with brain activity modified in regions involved in reward processing (Arana et al, 2003; Sharot et al, 2009; Leotti and Delgado, 2011). However, there is a lack of research concerning the impact of choice of enrichments on ruminants and equines.

For detailed knowledge about the different types of enrichment in ruminants and equines, see reviews on physical and occupational enrichment (Botreau et al., 2023), sensory and feeding enrichment (Ginane & Rørvang, 2023) and relational enrichment (de Oliveira & Boivin, 2023).

8 Designing environmental enrichments

We propose a 3-step approach for the design of enrichments (*Figure 1*):

1. identification of potential enrichments
2. assessment of benefits and drawbacks of enrichments
3. refinement of enrichments

This approach is suggested to those producing knowledge on enrichment or testing enrichment solutions. Policy-makers should check that the enrichment solutions recommended on farms have been validated according to such an approach. We do not expect official inspectors to use such an approach during farm inspections.

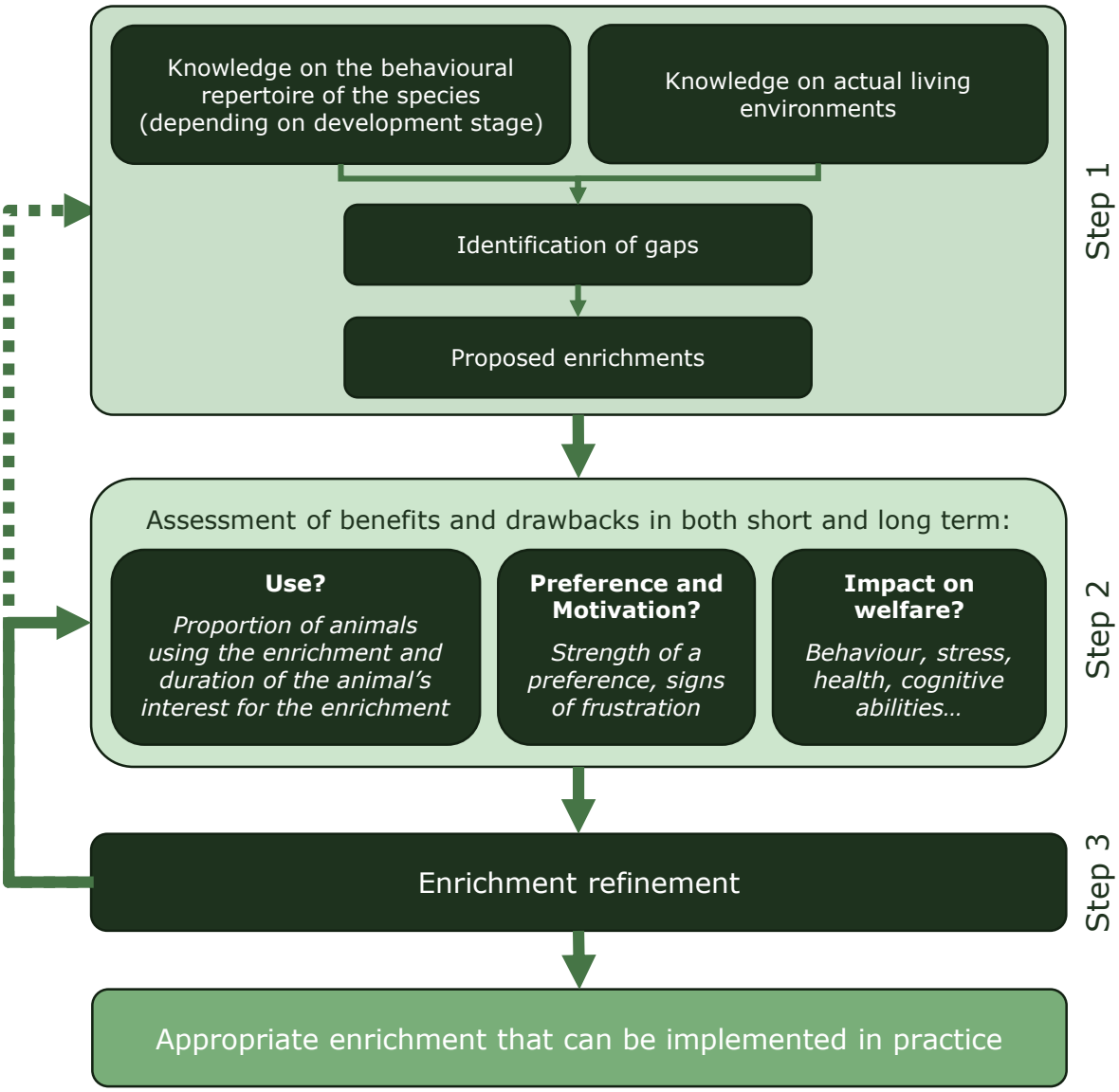


Figure 1: 3-step approach for the design of enrichments

8.1 Step 1 – Identification of potential enrichments

A first step is to identify the needs of animals. This is often done by considering the "natural" niche of animals and their behavioural repertoire depending on their development stage. The literature on preferences, for various components of the environment, of the different types of herbivore livestock, will be helpful as well as to identify potential enrichments. The actual environment of animals should then be analysed to identify potential deficiencies that prevent the fulfilment of behavioural or sensorial needs. For instance, gregarious animals housed individually probably lack the company of other animals. Then the means to enrich the environment can be proposed. For instance, pair or group housing for gregarious animals. Such an exercise should be performed regarding the suitability of the environment to implement the relevant enrichment type(s): relational, occupational and cognitive, physical, sensorial, feeding enrichment. A proposed enrichment can include one or more items to cover several components of the environment.

8.2 Step 2 – Assessment of benefits / drawbacks

8.2.1 Enrichment use and animals' preferences

- Measuring the time spent using the enrichment, including changes over time
- Measuring the proportion of animals using the enrichment
- Identifying the type of interactions with the enrichment and between individuals
- Conducting choice tests to identify the preferences of the animals
- Measuring the work an animal is willing to produce to get an enrichment or measuring potential signs of frustration in absence of the enrichment

8.2.2 Impact on animal welfare

- Evaluating changes in behaviour: reduction of undesirable behaviours (e.g. stereotypic behaviours, aggression) and increase of positive behaviours (e.g. exploration, play in young animals, resting)
- Evaluating the impact on behavioural reactivity (towards new environment or human for example)
- Evaluating the impact on physiological parameters, especially chronic stress (e.g. activity of the corticotropic axis)
- Evaluating the impact on health status (e.g. increased risk of injuries, spread of diseases)
- Evaluating the impacts on production when appropriate (e.g. growth or milk or production)

The use of an enrichment use, the preferences and motivations of the animals and the impact on animal welfare must be assessed in both the short and long term.The overall impact of an enrichment must be positive. In some cases, this may require trade-offs between positive and negative effects (e.g. positive effects on activity, reduction of stereotypies and improvement of cognitive abilities but some risk of injury).

8.3 Step 3 – Refinement of enrichments

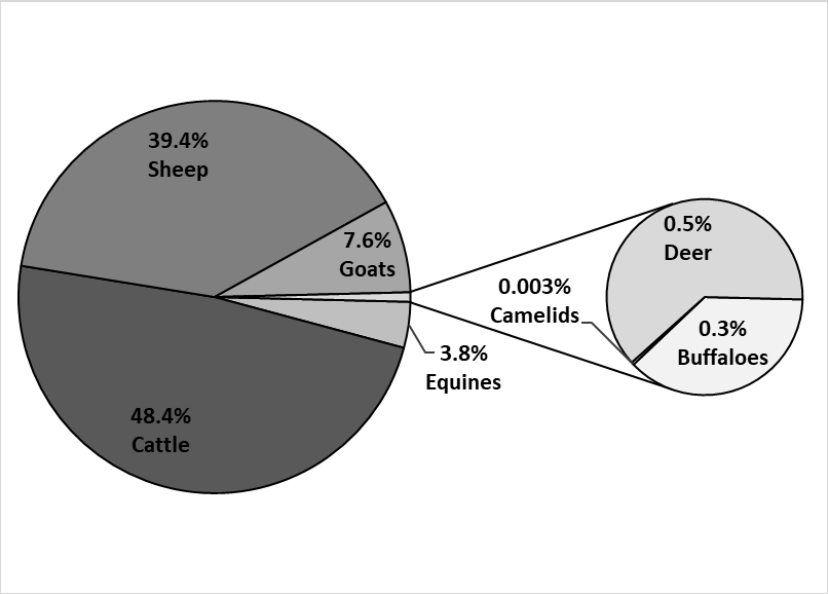
The assessment of the impacts of an enrichment can help to refine its implementation. Observing how animals use an enrichment can help to improve its design and functionality. Detection of drawbacks should result in design solutions. Then a feedback to Step 2 is required to test the appropriateness of the refined enrichment.

In addition, the impact of an enrichment can help to improve the understanding of the needs of species or individuals. For instance, although cattle are gregarious animals, it seems that their need to interact with social partners varies with age, e.g. young calves preferring stable partnerships. In that case, a feedback to Step 1 is required to refine needs and/or knowledge on the environment so as to propose a more adequate enrichment. The refinement may differ between individuals or groups of individuals of similar characteristics.

9 Conclusions

Farm animals often live in environments that are far simpler than their natural habitat would be. This can result in a lack of stimulation and restrict their behaviours. Enrichments should help to reduce the gap between farmed and natural environments in terms of stimulation and behavioural opportunities. When investigating the impact of enrichments on animals, it is crucial to adopt the animals' point of view by matching the enrichments to their behavioural priorities and needs and assess the long-term consequences. Both benefits and drawbacks should be taken into account to ensure that the final balance is positive to animals.

10 Annexes

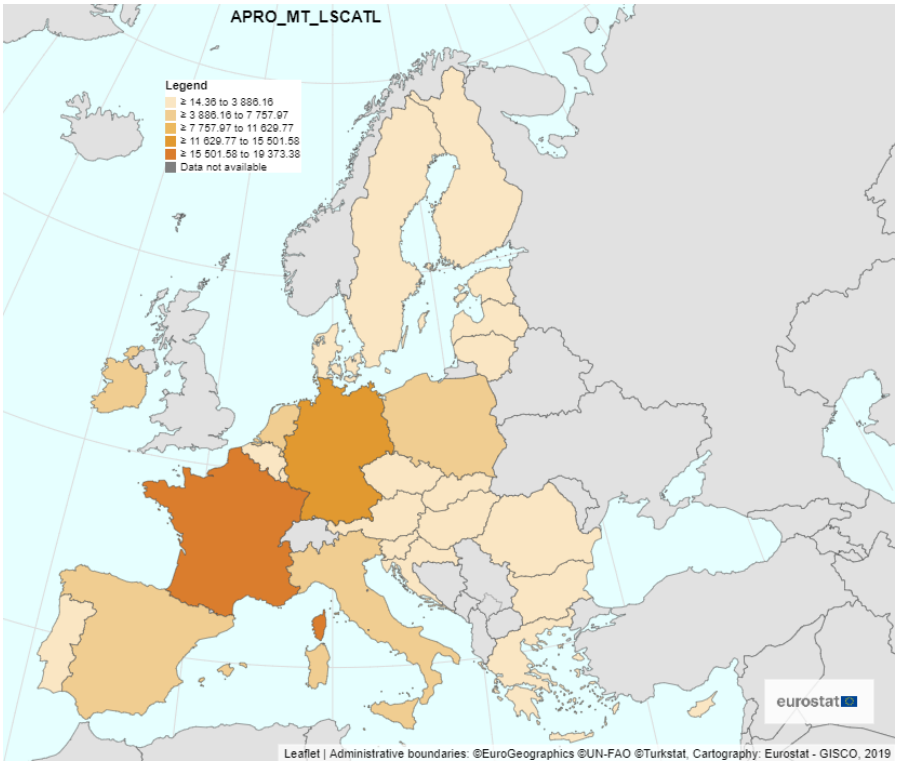


Annexe 1: Estimated percentage of captive ruminants and equines in EU27 (in heads, UK not included). Data for equines, deer, buffaloes and camelids are approximative and may be underestimated. Data for bison and other ruminant species are not available and thus not represented. Wild populations are excluded. Sources: British Equestrian Trade Association, 2019; EFSA, 2012; Eurogroup4Animals, 2015; Eurostat, 2019; Faye, 2020; FEDFA, 2022.

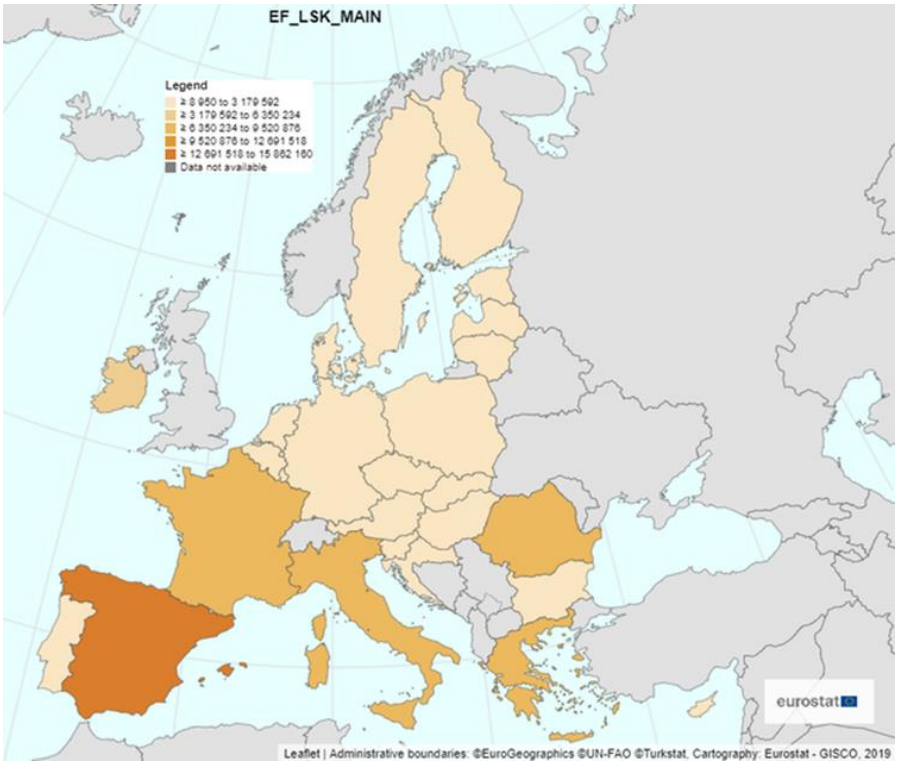
Annexe 2: Number of animals (heads and LSU) reared in farms and number of farms in EU27 (UK not included) in 2016, data from the agricultural census. Source: Eurostat, 2016.

LIVE ANIMALS IN TOTAL EU27	Equines	Bovines (including buffaloes)	Sheep	Goats
No. (per head)	2 583 390	79 361 330	63 311 060	11 399 440
No. LSU[1]	2 066 710	57 433 300	6 331 110	1 139 940
No. farms	671 160	1 925 480	715 460	378 420

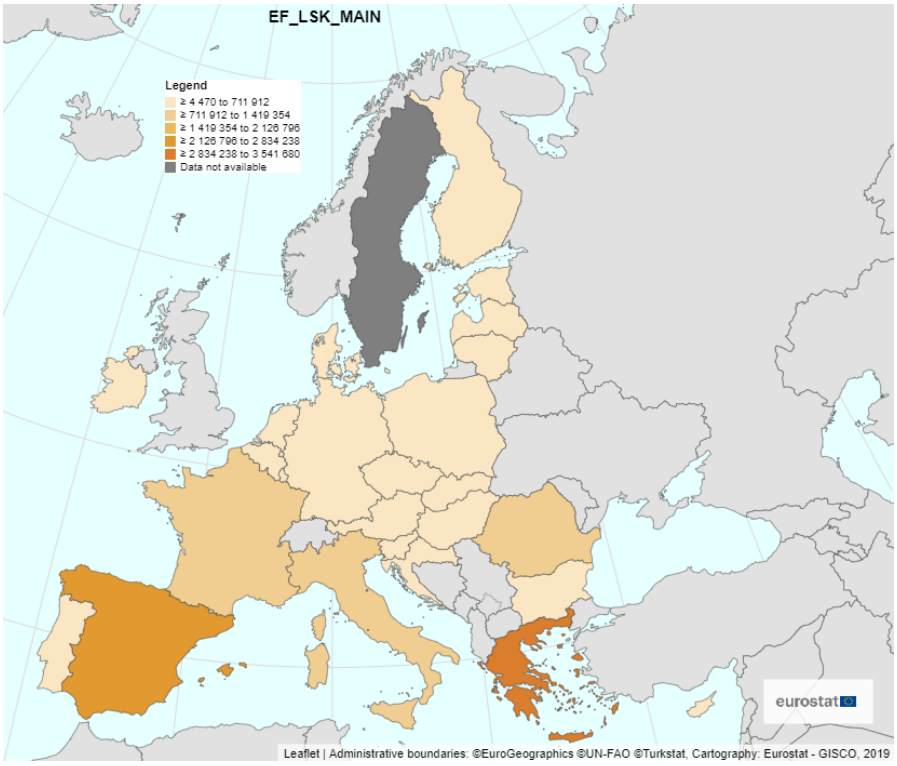
[1] LSU: Livestock Unit



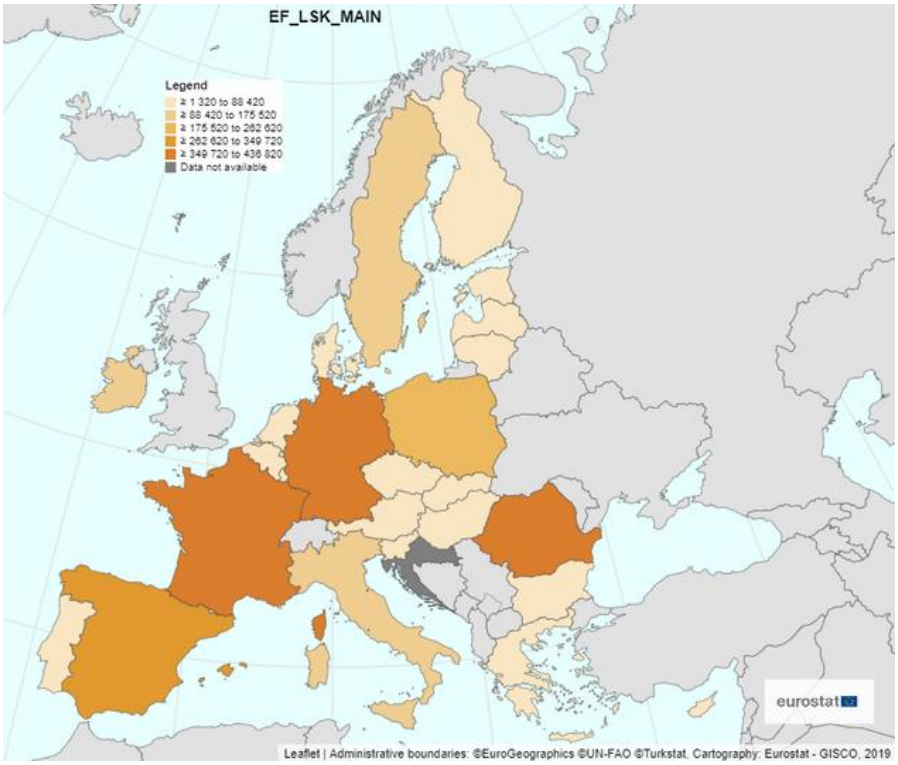
Annexe 4: Geographical distribution of cattle in EU27, year: 2016, unit: thousands of heads. Source: Eurostat, annual data.



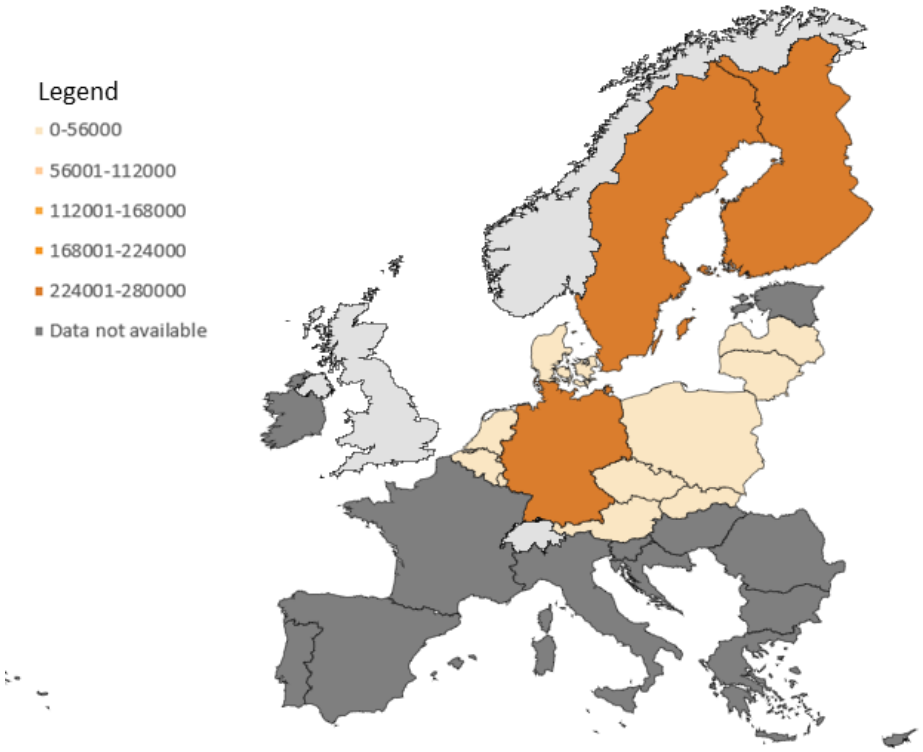
Annexe 3: Geographical distribution of sheep in EU27, year: 2016, unit: heads. Source: Eurostat, agricultural census.



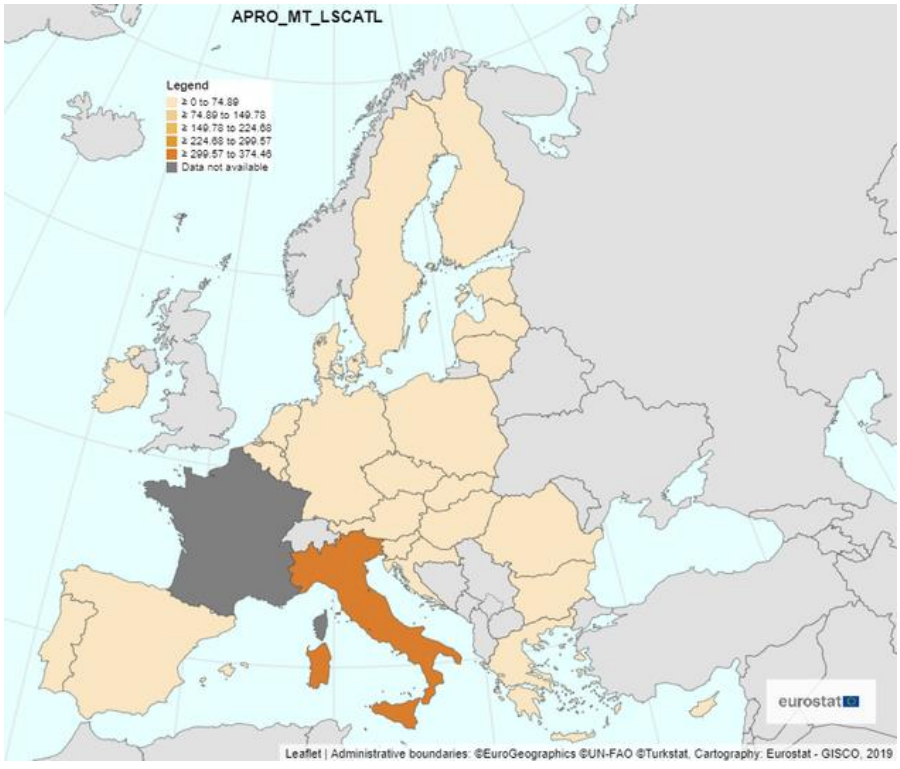
Annexe 5: Geographical distribution of goats in EU27, year: 2016, unit: heads. Source: Eurostat, agricultural census.



Annexe 6: Geographical distribution of equines in EU27, year: 2016, unit: heads. Source: Eurostat, agricultural census.



Annexe 8: Geographical distribution of deer (fallow deer, red deer, Sika deer and reindeer) in EU27, approximative figures, year: estimations covering the 2010-2022 period, unit: heads. Sources: FEDFA (2022) and EFSA (2012).



Annexe 7: Geographical distribution of buffaloes in EU27, year: 2015, unit: thousands of heads. Source: Eurostat, annual data.

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EURCAW *Ruminants & Equines* is the third European Union Reference Centre for Animal Welfare. It focuses on ruminant and equine welfare and legislation, and covers the entire life cycle from birth to the end of life. EURCAW *Ruminants & Equines*' main objective is a harmonised compliance with EU legislation regarding welfare in EU Member States. This includes:

- Directive 98/58/EC concerning the protection of animals kept on farms;
- Regulations 1/2005/EC and 1099/2009/EC concerning their protection during transport and slaughter;
- Directive 2010/63/EU concerning the protection of animals used for scientific purposes;
- Directive 2008/119/EC laying down minimum standards for the protection of calves.

EURCAW *Ruminants & Equines* supports:

- Inspectors of Competent Authorities (CAs);
- Ruminant and equine welfare policy workers;
- Bodies supporting CAs with scientific expertise, training, and communication.

Website and contact

EURCAW *Ruminants & Equines*' website offers relevant and actual information to support enforcement of ruminant and equine welfare legislation.

We offer a 'Questions to EURCAW' service for official inspectors, policy workers, and other personnel providing advice or support for official controls of ruminant and equine welfare in the EU. For more information go to https://www.eurcaw-ruminants-equines.eu/questions-to-eurcaw/.

Activities of EURCAW *Ruminants & Equines*

- Coordinated Assistance
  Providing support, networking and Questions to EURCAW;
- Welfare indicators, Assessment & Best Practice
  Identifying animal welfare indicators, including animal based, management based and resource based indicators, that can be used to verify compliance with the EU legislation;
- Scientific and technical studies
  Preparing Scientific Reviews of knowledge on welfare topics and identify research needs;
- Training
  Developing training materials and training standards for official inspectors;
- Communication and Dissemination
  Increasing awareness of our outputs via the website, twitter, and newsletter;

Partners

EURCAW *Ruminants & Equines* receives funding from DG SANTE of the European Commission and represents a collaboration between the following six partner institutions:

- Swedish University of Agricultural Sciences, Sweden
- Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise "G. Caporale", Italy
- French National Institute for Agriculture, Food, and Environment, France
- University of Natural Resources and Life Sciences, Vienna, Austria
- University College Dublin, Ireland
- Ellinikos Georgikos Organismos-Dimitra/Veterinary Research Institute, Greece