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Big Game Waste Production: Sanitary and Ecological Implications

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1. Introduction

Big game hunting has been anciently practiced by the humanity as an essential event to survival (Nitecki et al. 1988), and although nowadays man continues to hunt meat, big hunting has expanded to sport. Species included as big game vary with geographical areas and the general range includes mainly medium to large size hoofed ungulates and predators. Such diverse group of species plays essential roles in the ecological dynamics of natural or semi-natural systems (e.g. Putman 1986). Also big game species can often cause conflict with human interests, for example abundant ungulate species damaging to agriculture and conservation habitats or transmitting disease to livestock (e.g. Ammer 1996, Ferroglio et al. 2011).

Big game waste consists of solids generated mainly after hunting activity. This waste comprises the whole body of the animals or parts of them, such as the viscera and heads (when are not used as trophies). Much of this ungulate biomass becomes solid waste after hunting events following the removal of the internal and external offal (head, feet, all intestines as well as all internal organs). These materials play an important role in ecosystems, maintaining complex faunal communities extending from invertebrates to large carnivores (DeVault et al. 2003). Therefore a premise is that big game waste must be properly managed to protect the continuation of natural ecological processes (for example just leaving it *in situ* may be an option), which poses great conservation value. These remains may also be managed to reduce their effect on animal/human health and the environment under certain circumstances, and to a lesser extent, for aesthetics purposes or to recover resources from them. Although there is increasing interest on the ecological role of these materials, the hunting generation and impacts of big game waste has received little attention compared with management of other solid waste. In some contexts this waste may potentially be hazardous for the animal community (including species of high conservation interest), the livestock or the general public. This situation specially arises as a consequence of human interventions in habitats and the natural regulation of wildlife populations (Gortazar et al. 2006). Changes in population density and/or wild host behavior through solid waste may help new pathogens; new hosts or new hazards emerge, favouring disease spread and maintenance. Here we compile existing information on big game waste generation, ecological value, problems and management options under current regulations, remarking the sanitary and environment conservation dilemmas when managing this waste.

2. Big game waste production

Big game is a significant economic resource through the production of recreational hunting and game meat. Among big game, generation of waste from wild ungulates is relevant because ungulate species are abundant and widespread. For instance, there are some 20 species within Europe (Cervidae, Bovidae, Ovidae and Suidae) adding up to 15 million and representing a standing biomass of more than 0.75 billion kg (Apolonio et al. 2010a). Ungulate post-hunting generation may reach considerable figures but this abundance may strongly vary at short scales. More than 5.2 million animals are harvested each year in Europe (Apolonio et al. 2010a), which resembles a potential of more than 0.1 billion kg of solid waste. The distribution of big game population densities and standing biomass are all strongly influenced by natural factors (Ogutu & Owen-Smith 2003, Acevedo et al. 2011), as well as human's (Gortazar et al. 2006). Ungulate populations may build biomasses exceeding 1500 kg per km^2 in Europe (most due to Cervidae), with high spatial variability even at small scales. This indicates the strong influence of human management on ungulates distribution and abundance, and subsequent standing biomass and post-hunting waste generation. As indicative, North America may harbour approximately 80 million of deer (the main wild ungulate group, including several species, Crête & Manseau 1996) and combining all species biomass may range from 28 to 900 kg per km^2. Africa has ungulate communities of unique diversity with high spatial variability (McNaughton & Georgiadis 1986), and the biomass density in different National Parks may vary across from 100 to 20,000 kg per km^2 (e.g. Coe et al. 1976, Fritz & Duncan 1994). Large ungulate biomasses are also common in tropical ecosystems, although supporting lower quantity than other habitats because most of the primary production occurs in the canopy, well out of the reach of terrestrial herbivores (Bodmer 1989). For instance, wild ungulate biomass ranged from 1900 kg per km^2 to 3290 kg per km^2 in study sites from India (Khan et al. 1996).

A high proportion of ungulate biomass is annually converted in solid waste as a consequence of hunting activities. Nonetheless this proportion varies as a function of the prevalent big game extraction planning. In a context of increasing waste production, mainly due to the population growth of big game (Apolonio et al. 2010b), marked temporal variations between years may occur because hunting exploitation usually is reactive to game population changes, there is a strong effect of stochastic factors on populations (i.e., climatic conditions as hard winters in the Northern areas or droughts in other zones) and hunting actions conveys a degree of randomness (Milner et al. 2006). We estimate that 20-25% of the total population of deer (fallow *Dama dama*, roe *Capreolus capreolus* and red deer *Cervus elaphus*), the most abundant and widespread ungulate species in Europe, are annually shot in average. In the case of the wild boar (*Sus scrofa*), above 30% of the total population may be hunted on a yearly basis in this continent. These hunter kills (and subsequent waste) are usually aggregated in both time and space, as hunting takes place in a tightly circumscribed area over a narrow period of time. When the hunting systems yield the kill of multiple individuals just in a journey, becomes what is called gut piles. This regime of solid waste production has an impact on its posterior use (see below). The availability of ungulate offal piles can be high in some regions. For example, the 10-year mean (1992–2001) of 676,739 white-tailed deer (*Odocoileus virginianus*) annually harvested by rifle hunters in Wisconsin would have produced an average density of about 5 offal piles per km^2 for the area of the entire state (Dhuey 2004), and the harvest of elk (*Cervus elaphus nelsoni*) in other area (Bailey

1999) results in an approximately 70 kg gut pile left at the kill location, which represents 2.5 gut piles per km^2, a 5-fold increase since the 50ies.

Much of this ungulate biomass becomes solid waste after hunting events following the removal of the internal and external offal (head, feet, all intestines as well as all internal organs). In practice, there may be slight differences in the final presentation of the dressed carcass due to local cultural practices, type of trophy and final carcass use. Trophy hunters hunt majorly for the trophy (generally the antlers or horns) and in this case the whole body usually remains as waste (although meat may be consumed by the local "natives" or commercialized by the hunting event organizer or commercial). It can be generated also as a consequence of sanitary confiscations after inspection, ranging from the whole body to specific parts and due to several causes: traumatisms (such as dog bites, bullet-caused massive damages to meat), infectious hazards, unpleasant aspect (i.e. caquectic carcasses) or putrefaction (associated to environment high temperatures, excessive time lapse from the shooting to evisceration, digestive content contamination of the meat, etc.).

The quantity of remains is also variable among taxonomic groups because each presents particular foraging digestive morphology and size. Ruminants, the more numerically important ungulate group among big game, have a large digestive system which conveys a high production of hunting waste: for most of the ruminants the offal weight ranges between 40 and 50% of the total live body weight (Van Zyl & Ferreira 2004). The destination given to big game remains, while following legislative imperatives, may vary in part due to differences in species present, their relative abundance, cultural particularities, conflicts experienced between wild ungulates populations and other land-use interests (i.e. sanitary risks), and whether management is primarily directed towards control, conservation or exploitation (by hunting). Box 1 resumes the solid big game waste production in Ciudad Real, a province of Castilla-La Mancha Region (Spain), a typical big game production area for recreational purposes, attending to temporal, spatial, hunting management and social aspects. Detailed updated figures for national hunting bags for big game (which is mainly due to ungulates) and subsequent production of solid waste can be seen in Apolonio et al. (2010b), but see also Milner et al. (2006).

Box 1. The example of solid big game waste production in South Central Spain

Big game capture volume in Spain (which includes red deer, roe deer, Iberian wild goat *Capra pyrenaica*, fallow deer, Pyrenean chamois *Rupicapra pyrenaica*, Barbary sheep *Ammotragus lervia*, mouflon *Ovis aries*, wild boar and the Iberian wolf *Canis lupus signatus*) has increased during last decades. A conservative estimation of the total captures is over 300,000 per year (Forestal Annuary 2007), the higher figures belonging to wild boar (over 160,000) and red deer (over 100,000). This represents approximately a total of 950,000 kg and an estimated value of over 29,000,000 Euros. Hunting activity in Castilla-La Mancha Region has a great importance, by generating business. Ciudad Real province (19,813 km^2) is a rich big hunting area, which is predominantly red deer and wild boar. To ensure the sustainable use of game species, each estate has its technical plan of hunting, and a compulsory inspection of animal carcasses and remains is done by authorised veterinarians after hunting events. The Mediterranean woodlands and scrublands predominates in the north, west and south borders of the province, and are constituted by largely independently managed private or public hunting estates. The densities of big game populations are highly variable owing to game management practices, but densities often are above the natural carrying capacity (Acevedo et al. 2008), which associates with high disease prevalences (e.g. Vicente et al. 2006, Gortazar 2008, see Box 2). This is also an area of conservation value for species such as the Iberian lynx (*Lynx pardinus*), wolves, the Iberian imperial eagle (*Aquila adalberti*) and the cinereous vulture (*Aegypius monachus*), a specialized scavenger. Vulture species distribution overlaps with the Mediterranean habitats where big game is the prevalent activity. We show the figures of hunting extraction and subsequent generation of big game solid waste. Data presented here come from official statistics (veterinarian inspection) and own elaboration (period 1998-2007). Over 95% of hunting events (and average of per regular hunting season, from October to February) correspond hunting systems with multiple captures (predominantly hunting drives), and correspond to an average number of reserves (public or privates) of 331 per year (range 315-345 per season). During the study period, up to a maximum of 26,014 red deer and 10,126 wild boar per hunting season where shot. This represents a production of 2.3 (approximately 60 kg) and 0.7 (approximately 10 kg) individual gut piles per km^2 and year, for red deer and wild boar, respectively (3 per km^2 and 70 kg both together). The generation of deer gut remains may reach up to 15 (approximately 400 kg) per km^2 and hunting season in some high density estates. Overall, about 1000 mouflons, fallow deer, Barbary sheep and roe deer are also shot per yearly regular season. Big game waste is produced very aggregately in time and space in this area. About 30% of hunting events are concentrated just in two fortnights (in the middle-beginning and the middle-end of the season) in a given season. The average number of hunting event organized by estate is 2.1 per year (ranging from 1 to 17), which is mainly a function of the size of the estate. Figures 1a and 1b show the capture effort (average number of shot animals per hunting and year) for red deer and wild boar at the different Municipalities, respectively. Although red deer is hunted in 57% of the province area, and wild boar in 73%, the production of game waste per hunting event is much aggregated, firstly by Municipalities, resembling the natural conditions for big hunting, but also the intensity of big game management and subsequent densities. Also the data reveals a highly aggregation at the Estate level, since practices such a fencing makes management and densities very variable even at local scale for close Estates. The mean number of red deer shot per hunting event and year per Estate is 14.23 ±14.83 (ranging between 0-65, over 48% of estate shot an average of over 11 red deer per hunting event and year) and for wild boar 18.36 ± 21.99 (ranging between 0-111, 50% of estates shot an average of over 11 wild boar per hunting event and year). These figures are also indicative of the large volume of big game waste generated per hunting event. It is compulsory compiling all the remains at the inspection point (usually close to the hunter meeting site), which determines large gut piles (see Figure 2), which should thereafter be managed according to normative. The mapping of the production of big game solid waste may help optimizing the logistic of treatment programs (such the collecting of the remains) or the design of a net of feeding points for vultures.

3. Ecological value of big game waste

Big game carcasses greatly contribute to the total available carrion that is consumed by scavengers and decomposers in many ecosystems and areas (e.g. Magoun 1976, Hewson 1984, Wallace & Temple 1987, Selva et al. 2003, 2005, Wilmers et al. 2003a, b). Since extensive cattle farming is in serious decline mainly in many areas of developed countries (e.g. Bernues et al. 2005), wild ungulates may be able to or have already occupied this vacuum. They generate naturally a significant amount of carrion (e. g. Blázquez et al. 2009, Blázquez & Sánchez-Zapata 2010) which originates from the kill remains of large predators

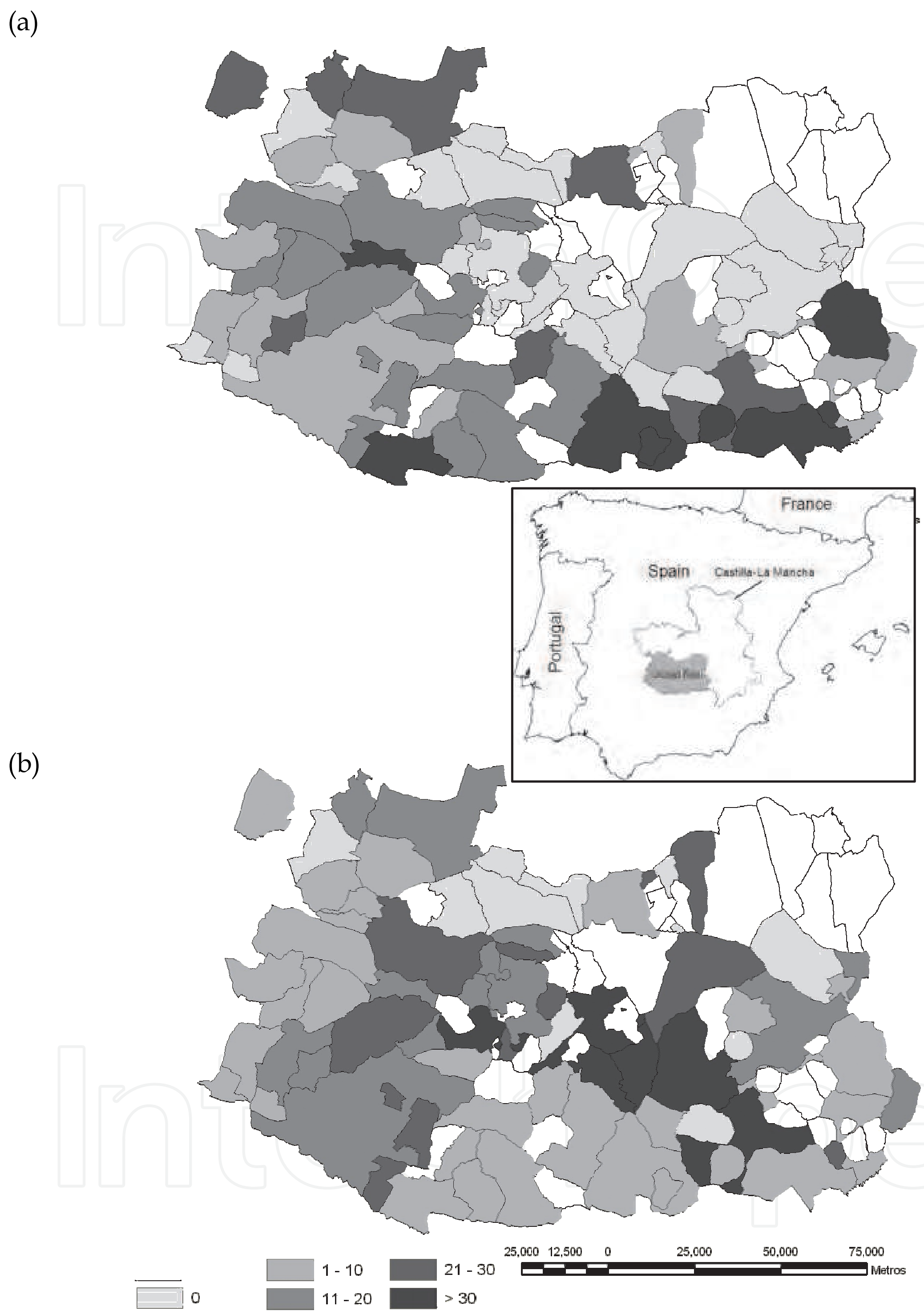

Fig. 1. The capture effort (average yearly value of shot animals, per hunting event and hunting estate), which equates to the individual big game offal generated, for red deer (a) and wild boar (b) at municipality level, respectively (red deer hunted in the 57 % of the province area, wild boar in 73 %) in the province of Ciudad Real (Castilla-La Mancha Region, South Central Spain, location is depicted in the inset). No data for municipalities in white

(although predator strategies either rapidly consume most of them or hide prey remains make them not to be available for scavengers, DeVault et al. 2003) and natural deaths (malnourish or diseased animals). In Bialowieza primeral forest (Poland), for example, a wolf pack kills an ungulate every two days and annually wolves kill on average 72 red deer, 16 roe deer, and 31 wild boar over a 100 km^2 area (Jedrzejewsky et al. 2002). These processes maintain complex faunal communities extending from decomposers and invertebrates to large carnivores (DeVault et al. 2003), and improve soil nutrient quality (Towne et al. 2000). Human hunters probably provide a larger food resource (hunting waste) to scavengers in many areas. This supply occurs in landscapes and periods of time with limited food availability for scavengers, reason for which is very valuable. In many cases the amount of carrion in the form of big game waste is much more abundant than that of natural origin because large predators are not longer present in many areas and/or human promotes large abundances of ungulates for hunting purposes. Solid waste originated from wild animals represents an important part of the diets of avian scavengers in areas devoted to big hunting (Blazquez & Sanchez-Zapata 2009). For example, in South Central Spain (Vicente et al. 2006), the country where inhabits the majority of European vultures, hunting remains are key to the maintenance of this endangered and rich avian scavenging community.

There exists a certain degree of competence between vertebrate scavengers and arthropods and decomposing microbial. Microorganisms are generally the first in colonizing the carrion or waste, using enzymes and toxins to degrade the tissues, in some cases monopolizing the use of this resource (Janzen 1977, Braack 1987), especially in hot weather areas. Nonetheless microbial hardly ever colonize all the biomass, although they have the potential to transform the carrion or waste into a unpleasant even toxic mass that is not further used by vertebrate scavengers. At the same time, substances derived from the decomposing process will signal vertebrate scavengers (DeVault & Rhodes 2002a). The range of scavenging species primarily may vary as a consequence of the availability of biomass found in particular regions. The scavenging community includes obligate (vultures) and facultative scavengers (avian or mammal), each of the species either uses different parts of the carcass, or locates different types of carcass or has a distinct geographical range. Whatever the origin, ungulate carrion represents the principal source of food for obligate scavengers. In spite that vultures tend to concomitantly exploit the resources, there exists certain degree of specialization among them. Although the available food supply is utilized very efficiently by the obligate avian scavengers, the status of many vulture populations is of acute conservation concern as several show marked and rapid decline (e. g. Donazar et al. 2002). Also most carnivorous and omnivorous vertebrates can be considered to be facultative scavengers (DeVault et al. 2003), although the tendency to consume ungulate carrion varies widely from frequent (e.g. Gasaway et al. 1991, Green et al. 1997) to limited consumption (Delibes 1980, O´Sullivan et al. 1992, DeVault & Krochmal 2002b). In general, where abundant specialized scavengers are present, facultative scavengers may proportionally account for a smaller proportion of the scavenging activity than they would do in the absence of vultures. Nonetheless, since human activities have an influence on endangered and unmanaged wildlife, as the loss of certain habitats or food resources, different species has been lead to exploit ungulate carrion as alternative resource (e.g. Iberian lynx feeding on ungulate carrion, Perez et al. 2001). Facultative scavengers may locally specialize on the exploitation of the hunting solid waste exploitation due to the large amount produce that in not fully consumed by vultures (see below). Different studies have revealed active guilds of vertebrate scavengers in wild ungulate carcases all over the world and some of them have quantified this use and the factors involved in the consumption (e. g. Selva et al. 2003, Blázquez & Sanchez-Zapata 2009). For example, the effect of habitat on the quantitative consumption of the carcasses also may differ between habitats and prevalent scavenging communities. Very few studies have attended the interactions (direct or indirect) occurring between different scavengers, for example between nocturnal (most of which are mammals) and diurnal species, so as the competence and dominance relationships occurring among them, and how they specialize in exploiting the resource.

The unpredictable availability of natural carrion has probably inhibited the strict evolving towards strict scavenging specialization in vertebrates (Houston 1979). The carrion provided by natural enemies (predators and diseases) arrives consistently over the course of year (Selva 2004), but the generation and mode of disposal of big game waste differ from the natural regime of carrion pulses along time and space. Because of the high temporal and spatial overlap of carrion at hunter kills, especially in the form of large gut piles, scavengers from the local area surrounding the gut piles may become super-saturated with resource. How beneficial result to scavengers the temporal resource patterns of hunter kills depends on a trade off between an ability to assimilate and/or cache large amounts of resource quickly and/or tracking that resource over time (Wilmers et al. 2003b). Such super-saturation reduces competition and allows far ranging species to gather in high numbers, not always with beneficial results. Even facultative scavenging individuals in the proximity get used to exploit this resource at predictable sites. Scavenger feeding stations, which are designed to favour vulture supply of resources, provide carrion regularly in time and space, and therefore are predictive, with consequences that may not meet always the original conservational objectives. From 2002, a number of dispositions to the EU regulations (discussed below) enabled conservation managers the creation of vulture feeding stations aimed at satisfying the food requirements of vultures, but these conservation measures may seriously modify habitat quality and have indirect detrimental effects on avian scavenger populations and communities (e.g. Donazar et al. 2010).

4. Hazards potentially present in big game waste

Big game carcass and waste may bear infectious, toxinfectious or toxicological hazards primarily for scavengers. Often, once it has been confirmed a health problem in a given population, community or environment, studies focus on the role of scavenging on wildlife carrion/solid waste to favour the spread and perpetuation of such problem, in many cases usually confirming the initial suspects. For example, we can mention the case of scavenging on possums (*Trichosurus vulpecula*) by ferrets (*Mustela furo*) and the bovine tuberculosis problem in New Zealand (Ragg et al. 2000, Lugton et al. 1997). Wildlife disease surveillance and monitoring is a necessary first step to identify risks and develop adequate management schemes of big game waste. The use and management of such waste must be based on scientific knowledge in order policy makers develop equilibrate regulations and decisions, balancing sanity and conservation priorities, while avoiding alarmism on the risks for disease transmission coming from big game solid waste disposal.

Sanitary risks posed by big game are dependant upon the prevalence, incidence, and magnitude of disease agent carriage in the animal, the degree of interaction between the animals and the environment, and animal behaviour and ecology (Morris et al. 1994). Usually the most abundant big game species in a particular region are of the greatest concern as the risk of exposure by these animals remains may be the highest. Under certain circumstances big game waste disposal may contribute to the establishment and subsequent maintenance of pathogens and disease in scavengers, the rest of the animal community and the environment. In order this to occur, pathogens must be present and viable in accessible-to-scavenger waste. The scavenging species in turn must be susceptible to infection and be able to, somehow, transmit the pathogen to favour its persistence. A particular scavenger, although not being the most affected species in terms of prevalence or disease severity, may play a key factor in maintaining the problem because of its epidemiological role as reservoir of disease.

To briefly describe infection dynamics, an infected animal population can be classed as either a maintenance or spillover host, depending on the dynamics of the infection. In a maintenance (true reservoir) host, infection can persist by intraspecies transmission alone, and may also be the source of infection for other species. In a spillover host, infection will not persist indefinitely unless there is re-infection from another species or the environment. The presence of a disease and reservoir may involve the maintenance of disease may pose management implications in relation to big game waste. Fenton and Pedersen (2005) proposed a conceptual framework based on the pathogen's between- and within-species transmission rates to describe possible configurations of a multihost-pathogen community that may lead to disease emergence. Spill over and apparent multihost situations are those where, without between-species transmission (for example inter-specific scavenging), the disease would not persist in the target host. In true multihost situations the pathogen can independently persist in either host population in the absence of the other. One example of multihost situation is bovine tuberculosis (bTB), caused by *Mycobacterium bovis*.

Bovine tuberculosis is mainly a disease of domestic cattle and goats, but can affect many other domestic and wild species, as well as humans. Also some species of conservation interest have resulted affected, such as the Iberian lynx in their last two strongholds in southern Spain (e.g. Perez et al. 2001). Consumption of infected prey or infected carcass or game waste is also a suspected as the way of transmission (Vicente et al. 2006). The existence of wildlife bTB reservoirs is the main limiting factor for controlling this disease in livestock. Major problems with wildlife bTB occur in areas with a high density of susceptible host species (de Lisle et al. 2001), such as the possum in New Zealand, the buffalo (*Syncerus caffer*) in South Africa, and the badger (*Meles meles*) in the UK and Ireland, white-tailed deer in North America, and transmission may get magnified when scavengers of infected gut piles become infected (Bruning-Fann et al. 2001, Gortazar et al. 2001, 2008, Renwick et al. 2007). In contrast, some pathogens do exclusively infect a single host species. These pathogens are frequently specialized; highly coevolved parasites with limited effect on the primary host’s population (Crawley 1992), or the possible secondary hosts are just unknown. Then, big game consumption may become a risk for the transmission of these pathogens when it involves cannibalism (e. g. wild boar, although carrion consumption by ruminant ungulates has been extraordinary detected). These pathogens are generally, in the absence of environmental changes, considered less relevant from the wildlife management and conservation and domestic animal perspective. Emerging infectious diseases include those where the pathogen will become self-sustaining in the new host once the initial (environment, host- or pathogen-related) barrier to infection has been crossed, for example, by big game waste ingestion. Wild animals are the most likely source of new emerging infectious diseases that put at risk the health of human beings and livestock.

Human impacts on natural processes favour that some species contributes to maintenance of diseases, for which game waste may play a role. In Europe, as in many other parts of the world, the changes occurring across the last 40 years have had a pronounced effect on the environment, creating a dynamic situation where pathogens or new hosts emerge o re-emerge. In particular, there have important been changes in big game population density and/or host behaviour (management favouring aggregation, Acevedo et al. 2007), which affect disease prevalence and, in some cases, may allow disease agents to boost their virulence and widen their host range (Ferroglio et al. 2010). Big game becomes often reservoir of disease as a consequence of overabundance. According to Caughley (1981), overabundance ("overpopulation") of a given wildlife species occurs, among other premises, when it causes dysfunctions in the ecosystem. This occurs also in form of disease spread and maintenance in the population that otherwise would not occur. In fact, the most obvious cases of relationships between overabundance and diseases occur among wild ungulates. The European wild boar is a good example. This species is increasing its range, reaching levels previously unrecorded (Geisser & Reyer 2004). This has contributed to the spread of many diseases, including classical swine fever, Aujeszky´s disease, Porcine Circovirus type 2, and bTB (see Box 2 and Figure 2), among others. It has also been shown that the increased density and spatial aggregation of wild boar in fenced hunting estates increases the risk of getting in contact with multiple disease agents (Ruiz-Fons et al. 2006). These situations are good examples of how overabundance affects animal health through the consumption of gut piles from fall ungulates in overabundance situations. In many cases, big game gut piles are left in the own hunting place or at meeting points, and remain available not only for obligate scavenger species but also can be used by the facultative scavenger, such as terrestrial carnivorous and omnivorous mammals. Under such circumstances, big game waste consumption by facultative scavengers (among which many are mammals) favours the feed back on the transmission chain and the maintenance of diseases (Bruning-Fann et al. 2001, Renwick et al. 2007, Jenelle et al. 2009, see Box 2 for the scavenging activity of wild boar). Therefore care should be taken with ungulate waste, especially in overabundance situations, since susceptible facultative scavengers may access to waste, which includes endangered species that scavenge to some extent (Perez et al. 2001). This situation secondary increases the risk of disease transmission from wildlife to the domestic flock and humans, which can also undermine conservation efforts if wildlife is seen as the source of a disease affecting livestock or human health (Brook & McLachlan 2006). Obligate scavengers effectively remove infectious tissue, thus decreasing the load of pathogens from the environment. It is therefore desirable that legislation be applied in a way that would allow for the selective access of vultures to the abandoned carcasses and gut piles that appear during the hunting season (see below). Although sanitary authorities should consider the removal of infected hunted animals and viscera to limit potential pathogen contamination where facultative scavengers can access, the conservation of obligate scavengers and other birds requires of selective disposal that guarantees their food supply (see bellow). In view of the potential risks of big game waste for the food chain, diseases that benefit from wildlife overabundance are of special concern, affecting public health, livestock health, and the conservation of endangered species.

A large number of infectious agents have been found in big game species. For example, foodborne pathogens may be present in the gut and faeces of wild ungulates without causing outward signs of illness or disease, making it difficult, if not impossible, to determine by visual inspection if an animal is carrying a specific pathogen. Following we briefly review some of the most relevant ungulate diseases that may be transmitted via big game waste. Along with the nematodes of the genus *Trichinella*, the cestode and *Echinococcus* *granulosus* are some of the parasitic helminths of greatest zoonotic concern. *E. granulosus* has a domestic dog – sheep (and other livestock) cycle, but also a sylvatic wolf – wild ruminant (and other herbivores) one. These cycles may get linked through dogs consuming carcass remains of hunted game and wolves consuming livestock as carrion or as prey (e.g. Sobrino et al. 2006). Although is illegal, feeding wildlife or domestic pigs with wild boar offal still occurs, which increases risk for human trichinellosis outbreaks. Furthermore, where absent, programs are needed that emphasize the necessity of ensuring testing for *Trichinella* spp. infection in all wild boar intended for human consumption and promoting education of humans regarding thorough cooking of meat to guarantee food safety. In general, any infectious disease that is prevalent in a given area that affect also other species than big game, either zoonotic or not, have the potential to be present in the carcass, which justifies the need of rigorous inspection by well-qualified people. Obviously, any animal showing disease symptoms or lesions suggestive of such diseases (for example during an outbreak of disease) should be out from the food chain, and in some cases when the destination are avian scavengers and there are suspects that they may be affected or may act as vectors of disease (e. g. Bullock 1956 concerning vultures as disseminators of anthrax).

Aujeszky´s disease (AD), a viral disease of swine and wild boar that can affect most mammals except man and primates, has been proposed as a risk for carnivore. AD causes fatal infection in non suid species including carnivores such as the Florida panther (*Felis concolor corii*) or the European brown bear (*Ursus arctos*) (Glass et al. 1994, Zanin et al. 1997). In Europe, endangered carnivores such as the Iberian lynx, the brown bear, or the Iberian wolf may include wild boars among their prey species (Clevenger et al. 1992), and thus may eventually be at risk due to AD. Cannibalism after wild boar AD outbreaks has been related to disease transmission (Gortazar et al. 2002). Rabies is the most classical wildlife related zoonosis. Data suggest that oral transmission of rabies virus among scavenger species may be a common occurrence (Schaefer 1983). In Europe, the red fox (*Vulpes vulpes*) is the main reservoir of this viral disease. Rabid foxes can transmit the virus to wild and domestic mammals and humans, or infect pets or livestock that can in turn infect humans. Hepatitis E virus also circulates actively among red deer and wild boar (Boadella et al. 2010).

Apart from bTB (commented above) other bacterial disease such as brucellosis are of concern when disposing big game waste. Brucellosis, is endemic in elk and bison using winter feed grounds of western USA presumably because of increased animal density, duration of attendance, and subsequent contact with aborted foetuses (foetuses, placentas, and fluids). Similar hazard could occur from game remains. The bacteria *Brucella* exists in the reproductive tissues, yet elk, bison and deer are hunted every year, and hunters leave gut piles all over the landscape. It have been seen that several eight species of scavengers consumed foetuses, and therefore protection of scavengers on and adjacent to feed grounds would likely reduce intraspecific transmission risk of brucellosis (Maichak et al. 2009). *Escherichia coli* O157 has become an important cause of illness attributed to food born contamination. Ruminant animals are among the most common reservoir species for this pathogen. In studies of free-ranging deer, the faecal prevalence of *E.coli* O157:H7 was estimated to range from zero to less than 3% (e. g. Fisher et al. 2001, Dunn et al. 2004, Branham et al. 2005). Among wild ungulates, apparently low prevalence of *Salmonella* faecal shedding occurs (Renter et al. 2001), although *Salmonella* were detected in 8% of rumen samples from white tailed deer (Renter et al. 2006). Finally, it should be noted that hunters and contaminated equipment may also be vehicles by which pathogens are transferred from contaminated locations to the growing field.

Chronic wasting disease (CWD) is a transmissible spongiform encephalopathy (TSE) of North American cervids. As suggested for CWD in high-risk regions from North America (Jenelle et al. 2009), recent laws on TB endemic areas have considered the removal of hunted animals (including viscera) to limit potential TB deposition near a kill site that mammals, and particularly wild boar, can access. Carcasses infected with CWD are an important source of infectious prions to susceptible cervids and may expose vertebrate scavengers (Miller et al. 2004, 2006). Agents that cause TSEs can remain viable in the environment for many years (Seidel et al. 2007). During decomposition, ungulate carcasses release nutrients into surrounding soils, stimulate subsequent biomass production that attracts herbivores, and serve as a potential source of infectious material (Towne 2000, Miller et al. 2004). It has not been demonstrated transmission of CWD to other species, but it has anecdotally been reported that deer may consume animal tissues, including flesh and bone of dead conspecifics (Cook et al. 2004). Avian scavengers also are consumers of ungulate carrion (Wilmers et al. 2003a, Cook et al. 2004), but birds are not susceptible to mammalian TSEs (Wopfner et al. 1999). It may be possible, however, for avian and mammalian scavengers to consume TSE-infected materials and spread prions, or other infectious agents, through deposition of feces in the environment (Houston & Cooper 1975, European Commission 2002) or by transport of infectious carrion during food-caching or young-provisioning. Interestingly Jenelle (2009) found that the daily rate of deer contacts with gut piles was greater than with whole carcasses, suggesting a higher daily risk of potential exposure for susceptible deer. However, the total risk of exposure will also depend on the persistence and abundance of gut piles *versus* carcasses in the environment.

The bovine spongiform encephalopathy (BSE, commonly known as mad-cow disease) is a TSE of cattle. The disease may be most easily transmitted to human beings by eating food contaminated with the brain or spinal cord or digestive tract of infected carcasses. In the EU, farmed and free ranging deer were almost certainly exposed to BSE infected in proprietary feeds prior to legislation banning its inclusion. The European red deer are susceptible to intra-cerebral challenge with BSE positive cattle brain pool material and the clinical signs are indistinguishable to those reported in deer with CWD, and one of six red deer orally dosed with BSE developed clinical disease (Martin et al. 2005, 2009) although no BSE wild deer has been diagnosed. By 2002, BSE crisis led to prohibition on abandoning the carcasses of extensively grazed animals in the wild in the EU, and subsequently, led to a scarcity of this type of carrion. EU regulations distinguish between carcasses that are safe and those that may be a potential source of BSE transmission /EU regulations: EU999/2001, EU1774/2002, EU32272003, EU830/2005), despite the lack of any evidence to suggest that dead animals left in the wild suppose any risk of BSE transmission (CMIEET 2001, Crozet & Lehmann 2007). Over 90% of European vultures live in Mediterranean areas (e.g. Donazar et al. 2009a), most on them in the Iberian Peninsula, and these species are of conservation interest. As a result, avian scavengers have been forced to congregate at artificial feeding points (fenced 'vulture restaurants') supplied with carcasses from stabled animals under intensive exploitation that are thought not to represent a risk BSE transmission. In theory this is a good system for avoiding public health problems caused by the ingestion of carcasses of animals that can be vectors for the spread of disease, such as generalist carnivores. This feeding strategy has led secondly to the obligate concentration of birds at a small number of feeding points supplied with carrion originating from stabled animals, which are though not to be at risk in the transmission of BSE. It can be counterproductive in certain aspects, such as avian behaviour and dynamics, and impact in local habitat quality. Additionally, as changes in commented below, this management conveys infectious and toxicological risks to scavengers (Lemus et al. 2008, Blanco et al. 2009). Because of the dilemma between the application of sanitary and conservation strategies, managers and policy makers must solve a problem of lack of food in one of the most threatened wildlife groups and at the same time Being compatible with food security policies. Wild ungulate waste may mitigate these effects; although this does not mean encouraging at the same time their densities, because overabundance (and its consequences) is already a serious concern. A sufficient amount of natural of carrion originating from big game is already generated in large areas (in Mediterranean areas from Spain may reach about 40% of obligate scavenger diet, and nearly 100% during hunting season), and the question is how ensuring the supply of big game waste management with not sanitary risks for other groups of animals and humans. In fact, vultures are sanitary filters because they clean up the environment by eating carrion.

An additional problem is that wild ungulate remains left by hunters may result in lead-shot poisoning with harmful effects on individuals and populations (e. g. Hernández & Margalida 2009). There are possible measures that have not yet been developed which should be implemented by the regional authorities. It appears advisable for the networks of vulture restaurants to be well spaced out and include a large number of feeding points, to promote them in big game exploitations, always implemented and assessed on the basis of scientific evidence. These feeding points should be adequately managed in order to avoid excessive spatial and temporal concentration of avian scavengers and big game remains, which is produced as large pulses in time and space in many hunting areas (see Box 1).

Interestingly, and contrary to extensive livestock, it has been found that the presence of carcasses originating from intensive livestock (especially pigs and chickens) carry a high number of pathogens and pharmaceutical products that can be transmitted via carrion consumption to avian scavengers at feeding sites (Lemus et al. 2008, Blanco et al 2009). If sanitary programs are applied in the same way in some game farms, attention should be paid to the remains originated from these animals. Carcasses originating from extensive livestock and natural big hunting left in the wild should be prioritised by management and conservation programmes targeting avian scavengers as a strategy that does not put the health of birds or the environment in general at risk. Nonetheless this situation may present particularities in wild ungulates. This is so because overabundance situation conveys high prevalence of disease in populations that are not under sanitary programs as extensive livestock is, this remarks the importance of the veterinary inspection of the carcasses and hunting remains. Similar to intensive livestock, pharmaceutical products used in farmed big game might have negative consequences for the health of avian scavengers and population dynamics (Oaks et al. 2004 concerning the collapse in avian scavenger populations in South-east Asia, Lemus et al. 2008, Blanco et al. 2009 concerning non-steroidal anti-inflammatory and anti-parasitic agents and Iberian vultures that feed predominantly at feeding points supplied with animal remains). As a consequence, the pathogenic and bacterial flora may develop resistance to these products. It has been found that the presence in the blood of the residues of antibiotics coming form intensive livestock carrion is associated with the infection by opportunistic pathogens of the nestlings and damage to internal organs in vultures from Spain (Lemus et al. 2008, Blanco et al. 2009). Scavengers may also encounter metal toxics in big game carrion, for example metals derived from bullets. Metals (Pb, Hg, Cd) belong to the most toxic substances present in the natural environment. Lead, as a metal characterized by a very high accumulation rate in the environment, presents a particular strong threat of disturbing the chemical equilibrium in the biosphere. A serious problem is presented by bullet-derived lead contamination of large game carcasses. Monitoring of lead contents in tissues of large game frequently shows high lead levels, exceeding the admissible contents several tens or—on occasion—several hundred-fold (e.g. Dobrowolska & Melosik 2008). Careless removal of tissues from around the bullet pathway in the animal body results in elevated lead doses being ingested by humans. Lead-shot poisoning may harms scavengers, as has been demonstrated for avian scavenger (Hernandez & Margalida 2009). For example, bullet fragments in rifle-killed deer (*Odocoileus* spp.) carrion and offal have been implicated as agents of lead intoxication and death in bald eagles (*Haliaeetus leucocephalus*), golden eagles (*Aquila chrysaetos*), California condors (*Gymnogyps californianus*), and other avian scavengers (Craighead & Bedrosian 2006, Hunt et al. 2006). For example, 94% of deer samples killed with lead-based bullets contained fragments, and 90% of 20 offal piles showed fragments: 5 with 0–9 fragments, 5 with 10–100, 5 with 100–199, and 5 showing 200 fragments (Hunt et al. 2006). In contrast the authors counted a total of only 6 fragments in 4 whole deer killed with copper expanding bullets. These findings suggest a high potential for scavenger exposure to lead. Mammalian carnivores in areas of high hunting density may exhibit the same temporal pattern of lead exposure from ingestion of rifle bullet fragments during the hunting season as avian scavengers, for example grizzlies feasting eating the remains of the hunt in the Greater Yellowstone on gut piles get lead and show blood elevated levels of toxic lead (Rogers et al. 2008). Finally, bullet-derived lead in game food products is also an important source of human contamination. In summary, research is needed on big game remains that are left for scavengers without any previous toxicological control

Box 2. The example of wild ungulate waste consumption by vertebrate scavengers in Mediterranean areas: ecological, conservation and sanitary implications

The carcasses and gut piles of wild ungulates are becoming gradually more available in the Iberian ecosystems, and may constitute an important food source of feeding for the vertebrate scavengers (see Box 1). This is because overabundant ungulate populations (mainly wild boar and red deer) do exist in many areas, where hunting is an important socio-economic activity, and this contributes to generate large amounts of available carrion. Overabundance consequences, due to big game industry, in form of diseases (Gortazar et al. 2006, Acevedo et al. 2007) occur, and subsequently the consumption of infected ungulate carrion may contribute to disease maintenance and spread in the wildlife reservoir, especially if facultative scavengers have access and are directly exposed to potentially infectious ungulate material. The importance given to the management of big game waste when is capable of transmitting diseases depend on whether wildlife has a high probability of substantially affecting regional disease status, and the disease has a strong impact on human health, economy, wildlife management and conservation. One case is bTB in Spain. Carcasses from individuals with chronic bTB are particularly infective owing to the large extension of infected tissues (Martin-Hernando et al. 2007). In South Central Spain bTB averages 45% of prevalence based on macroscopic lesions in wild boar (ranged up to 100% in local populations of wild boar, Vicente et al. 2006), reaching prevalences that has been estimated up to 60% based on culture (Gortazar et al. 2008). The importance of the intraspecific transmission of bTB may be especially relevant in areas with absence of vultures (Gortazar et al. 2008), and the fact that wild boar, the main carriers of the bTB in Spain (Naranjo et al. 2008) are the principal ungulate carrion consumers (see below). Figures for deer in south-central Spain are also high, averaging 15% prevalence (Vicente et al. 2006), and about 30% and 20% in red deer and fallow deer, respectively, in Doñana National Park, South Spain (Gortazar et al. 2008). The isolation of bTB strains from these estates strongly suggests that the *M. tuberculosis* complex is able to survive in these high-density wildlife populations in the absence of livestock hosts (Gortazar et al. 2005). Cannibalism may be one mechanism by which TB is transmitted within wild boar populations (Ragg et al. 2000, Gortazar et al. 2002). Predators in Spain, such as the endangered Iberian lynx, the badger and the fox, have been considered to be possibly infected by TB as a result of their consuming infected prey or carrion (Perez et al. 2001, Millan et al. 2008, Sobrino et al. 2008). As long as bovine bTB exists in ungulate populations (the main reservoirs in many areas), there will be some risk to local wildlife species that feed on bovine bTB-infected carcasses or gut piles.

As a basis through which to determine the ecological, conservational and sanitary relevance of ungulate carrion and waste for the vertebrate scavenging community (specialized and facultative) in European Southwest Mediterranean areas during 2007, we describe the guild of vertebrate scavengers. We compared one site on which obligate scavengers (vultures) were absent during the study period (Doñana National Park) with another area in which they were present and abundant all year round (Central Spain). By using automatic photo-trapping on 47 carcasses (Figure 2), the frequencies of scavenging for different species per carrion and study area are shown in Table 1. As expected, vultures were only detected in Central Spain. We evidenced that, even in the presence of abundant specialized scavengers, wild boar, red fox and facultative scavengers accounted for a relevant proportion of the scavenging activity, to the extent of becoming locally predominant in the absence of vultures. Also, own data on the frequency of scavenging on gut piles generated after big hunting events in Central Spain evidence that remains left in habitats with high vegetation cover are more often scavenged by facultative scavenger (wild boar and foxes) than by vultures. The high occurrence of wild boar and foxes at carrion throughout our study areas is indicative of their ubiquity and abundance, whereas for other species the low and/or solely local occurrence would reflect their more restricted distribution and/or abundance (e. g. Imperial eagle, kite, Egyptian vulture, Egyptian mongoose, etc.). Wild boar are frequently managed in order to promote high densities on hunting Estates in South Central Spain, and also reach considerably high densities in protected areas (Acevedo et al. 2007). The communal feeding by facultative scavengers on ungulate carrions may facilitate the intraspecific and interspecific transmission of diseases, since scavengers are directly exposed to potentially infectious ungulate material. This risk is increased by the sanitary consequences of overabundance caused by intensive management in South Central Spain, which favour the transmission of disease and its persistence in ungulates (Gortazar et al. 2006, Acevedo et al. 2007). The importance of the intraspecific transmission of TB may be especially relevant in certain areas because of the absence of vultures, and the fact that wild boar, the main carriers of the disease in Spain (Naranjo et al. 2008), are the principal ungulate carrion consumers. This example provides support for the influence on the environment on carcass consumption and the direct or indirect competitive relationships between scavengers, and focuses the discussion on ecological, conservational and disease management considerations. The consumption of infected ungulate carrion and waste may subsequently contribute to the spread and persistence of bTB in wildlife with regard to carnivorous and omnivorous species rather than avian scavengers, which effectively remove infectious sources. In this context, controversy has arisen concerning vulture conservation, since current European policies encourage the destruction of domestic animal carcasses, rather than their being left in the open (Donazar et al. 2009b), and this could also apply to the management of big game carcasses and hunting remains. Table 2 describes the guild of vertebrate scavengers present during the monitoring of 18 gut piles in the South Central area, during the 2008-2009 hunting seasons. Gut piles where obtained from hunting were constituted by non-trophy heads, hoofs and thoracic and abdominal viscera (red deer and wild boar).

Visitant species	Total (n=47)	Doñana N. P. (n=10)	Central Spain (n=37)
	%Pres/%Scav[1]	%Pres/%Scav	%Pres/%Scav
Wild boar	80.9/55.3	100/90	80/50
Red fox	85.1/55.3	80/30	90/70*
Griffon vulture	40.4/40.4	0/0	65/65
Monk vulture	36.2/31.9	0/0	55/55
Raven	12.8/6.4	40/20	0/0
Magpie	12.8/6.4	30/20	15/5
Jackdaw	8.5/2.1	30/0	0/0
Kite	14.9/10.6	70/50	0/0
Egyptian mongoose	2.1/2.1	10/10	0/0
Imperial eagle	2.1/2.1	0/0	5/5
Egyptian vulture	2.1/0	0/0	5/0
Eurasian jay	2.1/0	0/0	0/0
Red deer	6.4/0	0/0	0/0
Cattle	8.5/0	40/0	0/0
Horse	4.3/0	20/0	0/0

Table 1. Percentages of presence and scavenging occurrence per carcass (%) of the scavenging community. [1]Percentage of carrions at which the species was detected/Percentage of carrions at which scavenging by the species was detected.

Species detected	Nº of gut piles visited		Nº of gut piles scavenged		Mean group size (± SD)
	open	woodland	open	woodland	
Griffon vulture	9	1	9	1	36.03 ± 22.67
Monk vulture	7	0	7	0	4.15 ± 2.94
Raven	8	2	6	1	4.29 ± 3.51
Magpie	2	0	2	0	6.14 ± 4.09
Azure-winged magpie	5	1	5	1	4.24 ± 3.09
Egyptian vulture	1	0	0	0	1
Imperial eagle	2	0	2	0	1.26 ± 0.45
Golden eagle	1	0	1	0	1
Wild boar	4	4	4	3	1.58 ± 0.88
Red fox	9	5	7	4	1.02 ± 0.12
Common genet	0	1	0	0	1
Dog	3	1	3	1	1.02 ± 0.15
Red deer	2	0	2	0	1

Table 2. Scavenging community and general parameters of activity detected in 18 gut piles from South Central Spain.

5. Normative

Here we briefly expose and update the current normative that applies to big game waste management from a European point of view, from the EU Regulation to some regional normative that is exemplified with particular cases given the current diversity occurring among countries and regions. Regulation (EC) No 1774/2002 introduced the classification of animal by-products into three categories according to the degree of risk involved. Pursuant to that Regulation, only material from animals which have undergone veterinary inspection is to enter the feed chain. In addition, it lays down rules for processing standards which ensure the reduction of risks. The regulation (EC) no 1069/2009 of the European Parliament and of the Council of 21 October 2009 lays down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation). In order to prevent risks arising from wild animals, bodies or parts of bodies of such animals suspected of being infected with a transmissible disease should be subject to the rules laid down in this Regulation. This inclusion should not imply an obligation to collect and dispose of bodies of wild animals that have died or that are hunted in their natural habitat. If good hunting practices are observed, intestines and other body parts of wild game may be disposed of safely on site. Such practices for the mitigation of risks are well-established in Member States and are in

Fig. 2. This figure illustrates big game waste production; handling and gut pile disposal after a hunting event (top right and left) in south central Spain. Research on carcass and waste use by scavengers can be done by means of automatic recording systems after the carcass or gut pile is disposed. Pictures illustrate carrion and gut pile consumption (either deer or wild boar origin) by wild boar in south central Spain. Facultative scavengers may proportionally account for a proportion of the scavenging activity and under certain circumstances; big game waste consumption by them favours the feed back on the transmission chain and the maintenance of diseases, such as bovine tuberculosis. Observe bovine tuberculosis compatible lesions in the liver of the gut pile obtained from the deer (top left).

some cases based on cultural traditions or on national legislation which regulates the activities of hunters. This Regulation shall not apply to the following animal by-products: (a) entire bodies or parts of wild animals, other than wild game, which are not suspected of being infected or affected with a disease communicable to humans or animals, except for aquatic animals landed for commercial purposes; (b) entire bodies or parts of wild game which are not collected after killing, in accordance with good hunting practice, without prejudice to Regulation (EC) No 853/2004; (c) animal by-products from wild game and from wild game meat referred to in Article 1(3)(e) of Regulation (EC) No 853/2004. Community legislation Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin, lays down rules for handling of meat and animal by-products from wild game. Those rules also place the responsibility for the prevention of risks on trained persons such as hunters. In view of the potential risks for the food chain, animal by-products from killed wild game should only be subject to this Regulation in so far as food hygiene legislation applies to the placing on the market of such game and involves operations carried out by game-handling establishments. Following with the example at regional scale, the Castilla-La Mancha regional normative 14607 from may 2008, complete regulation (CE) nº 852/2004, and normative lay down specific regulations on the collection, transport, inspection and sanitary control of game (big sands mall) intended to commercialization for human consumption. Concerning the inspection, before transport of the carcass to an authorized processing plants it is compulsory a first inspection by an authorized veterinarian (private in this cases, in other Spanish region the veterinarian must be official). It lay down that all the shot animals must be presented to the veterinarian in an authorized evisceration place, and there will be auxiliary staff to eviscerate and mark the carcasses. Even for big hunting intended for self-consumption, it is not allowed that the responsibility for the prevention of risks falls on not veterinarian persons, such as hunters, and it laid down the conditions that are required for big game authorized inspection locals (D65/2008 from 6 May 2008). The examination of the animals must include the body and the offal.

Animal by-products are classified into three categories, in accordance with their potential risk to public and animal health. Thus, depending on their age (due to BSE risk), despite the lack of any evidence to suggest that dead animals left in the wild suppose any risk of BSE transmission (CMIEET 2001, Crozet & Lehmann 2007), the carcasses of domestic ruminants are mainly classified as belonging to Category 1, the carcasses of monogastric species belong to a lower risk category (Category 2 materials) and Category 3 materials are those intended for human consumption but which are not used for this purpose. The Regulation considers as an exception the possibility of authorizing animal by-products in Categories 2 and 3 for the feeding of wild animals and, in the case of necrophagous birds, also authorizes the feeding of carcasses that are classed as Category 1 materials (cows, goats and sheep). Traditionally, gut piles are left in the own hunting states and remain available not only for obligate scavenger species but can also be used by the facultative scavenger, such as terrestrial carnivorous and omnivorous mammals. Nonetheless there is a variety of national traditions, legislative framework and regulations, ownership, which have a profound effect on the organisation and integration of management activities. Game management and hunting in Spain is regulated by autonomous regional governments. As a result there are 15 distinct regulatory and legal frameworks within continental Spain with little or no coordination at the level of the country. Due sanitary concerns (see Box 2), some Spanish regions have recently developed legislation concerning the disposal of big game remains. In

Castilla-La Mancha region, the options to manage big game by-products generated alter hunting activities (Resolution 10/02/2009 on the management of big hunting by-products) are (i) burial of gut piles in the same hunting place under certain conditions (location, deep o burial, cal, burial registration book, and authorisation previous visit an inspection by the Animal heath authorities), (ii) the move of them to be processed and destructed in authorised plants by special authorised vehicles and (iii) the move of them to legal vulture restaurant (fenced places with a constant carcass supply), laying dawn the conditions that these feeding points must meet. There are also national and regional normative creating a net of modern feeding points for vultures and regulating the feeding of necrophagous birds with animal by-products not intended to human consumption (regional: D108/2006, national: RD664/2007).

Since Regulation (EC) No. 1774/2002, all dead livestock had to be removed, using specially authorized vehicles, in order to be transformed or destroyed at approved, designated plants. This affected big game waste use because it has been seen as an alternative food supply for avian scavenger, especially in Southern Europe where this endangered animal community is more abundant. Conservation strategies (dispositions 2003/322/CE, 2005/830/CE, in Spain RD 342/2010 which modifies RD664/2007) regulating the use of animal by-products as food for necrophagous birds have been incorporated into European Commission regulations since the 2002 BSE crisis, in order to be more flexible and trying to make compatible sanitary and environmental interests. All these legal derogations aimed granting exemption from removing certain animal by-products from the carcasses, once a series of specific conditions have been met. One requirement is that the animal by-products have to be made available to animals within fenced-in sites, although in our experience there are administrative restrictions on the creation of feeding stations and numerous small feeding sites are needed to avoid excessive concentration of waste in just a few places (see comments above on the repercussions of these changes on individuals, populations and communities of avian scavengers.

6. Management

Big game waste must be properly managed to protect the continuation of natural ecological processes, to reduce their effect on animal/human health and the environment under certain circumstances, and to a lesser extent, for aesthetics purposes or to recover resources from it (such as composting). Management to control hazards associated to waste disposal in the wild starts at a pre-harvest phase. First we must known the prevalence, spatial and temporal distribution of big game pathogens (and quantifying any other hazard) in the area, what is called surveillance and monitoring (Wobeser 1994, 2002, Artois 2001, 2003). In Europe, wildlife disease surveillance is addressed by a series of regional, national and international schemes. Currently, parts of Europe benefit from wildlife surveillance efforts (frequently limited to a few diseases), while in other parts no surveillance is done at all. Proper implementation of a complete surveillance effort must be a priority of the Veterinary Authorities, since it is accepted that those countries which conduct disease surveillance of their wild animal populations are more likely to detect the presence of infectious and zoonotic diseases and to swiftly adopt counter measures (Mörner et al. 2002). We need identifying risk factors of relevant wildlife diseases (i.e. those affecting animal and human health) to effectively manage them and reduce the generation of hazardous solid waste from big game. Among risk factors, the most frequent one is the introduction of diseases through movements or translocations of wild or domestic animals. Examples include food and mouth disease in the UK (involuntary disease translocation). Introduction of exotic species (i.e. wapiti and Barbary sheep in Europe), conveys important risks of introduction of previously inexistent diseases, especially when foreign species range in or share habitats with native susceptible species, leading to situations where the native big game species become endangered (McInnes et al. 2006). For example, this is the case of the North American wapiti (carrying the trematode *Fascioloides magna*, highly pathogenic in the red deer, Novobilsky et al. 2006). Finally, the expansion or introduction of hosts has been linked to disease risks in several occasions. For example the newly established (escaped) wild boar populations in the UK and tuberculosis (Williams & Wilkinson 1998). Overabundance of wildlife is a second relevant risk factor for wildlife diseases. We above highlighted the relationship between overabundance and disease in big game species, and therefore control of the situation will lead to limiting the associated risks. The assessment of overabundance and the available management tools have been discussed recently (Gortazar et al. 2006). Management tools to estimate big game overabundance are needed for legislative purposes and for the monitoring of wildlife populations. A multidisciplinary approach is needed to diagnose if a given wildlife population is overabundant, which includes signs such as adverse effects on the soil, vegetation or fauna, poor body condition scores, low reproductive performance or increased parasite burdens infectious disease prevalences. A close monitoring of wildlife densities and diseases, the establishment of reference values for all signs of overabundance, and the mapping of the disease and density hotspots will be needed to design adequate management for each particular situation.

In addition to surveillance and monitoring, three basic forms of disease management strategies for wildlife are known: prevention of introduction of disease, control of existing disease or almost impossible eradication (Wobeser 2002). Preventive veterinary medicine is a key discipline in the prevention and control of disease in the wild and at wildlife/domestic livestock/human interface. Among the preventive actions, the most important one is by restricting translocation of wild animals to prevent movement of disease (Wobeser 2002). This includes the movement and release of farm-bred "wildlife", an increasingly popular game management tool that needs a careful sanitary control (Fernández de Mera et al. 2003). But even the movements of domestic animals can easily cause the introduction of new diseases or new vectors. A close monitoring of both wildlife densities and wildlife diseases and the mapping of the disease and density hotspots will be needed to design adequate risk control measures for each particular situation. In addition, it must be noted that any risks are not necessarily directly related to actual population size because aggregation of animals, usually due to human activities (i.e. artificial feeding), can increase the risk of pathogen transmission even in populations with a not particularly high density (Acevedo et al. 2007). European examples include bTB in wild boar, red and fallow deer (Vicente et al. 2007) and classical swine fever (Rossi et al. 2005) in wild boar, where an increase in transmission rates has been associated with artificial feeding. In many cases bans on supplementary feeding (Miller et al. 2003) can reduce the carrying capacity for ungulates and reduce population density and, just as significant, aggregation, two key factors in infectious disease transmission (Acevedo et al. 2007, Vicente et al. 2007). Once a given wildlife population is defined as overabundant, and even if there is specific evidence for disease problems, it is difficult to establish corrective management actions. One future direction is to convince hunters and wildlife managers of the benefits of management for quality, with lower densities and less detrimental consequences on habitat, wildlife and animal and human health. Moreover wildlife managers and the public may perceive animal health authorities as purveyors of bad news with no positive counterpart (Ferroglio 2003). Concerning the problem of the use of lead gunshot in terrestrial ecosystems, and particularly in big game, copper bullets have been trialled, and their accuracy and killing power compared to that of traditional lead bullets, which suggest that copper bullets are a viable alternative to lead bullets (e.g. Knot et al. 2009). In problematic areas, it can be considered restrictions on the use of lead ammunition, designed to encourage a switch to non-toxic ammunition across terrestrial habitats, to be a proportionate response to the problems associated with lead ingestion.

Attempts to control disease in wildlife populations have been based on a variety of methods. These include setting up barriers, improving hygienic measures, culling, habitat management and feeding bans, vector control, treatments, and vaccination (Wobeser 2002, Artois et al. 2003, Karesh et al. 2005, Gortazar et al. 2006). Wildlife culling is almost never an effective means of controlling a wildlife-related disease. Moreover, it is a subject of intense scientific and social debate (e.g. badger culling for TB control, Donnelly et at. 2006). Only in the case of island populations, when geographical barriers limit animal dispersal, or in the case of introduced species (pest species, where legal and social constraints to culling are minimal), or to cope with a point-source wildlife disease outbreak (centering culling on the disease focus, plus an outer ring of vaccination), is culling and eradication an option. By contrast, population reduction is a goal in many disease control efforts. This is a temporary measure, except if habitat modification is used to reduce host density more permanently, or to alter host distribution or exposure to disease agents (Wobeser 2002, Gortazar et al. 2006, Acevedo et al. 2007). Selective culling is limited to situations in which affected individuals are readily identifiable (Wobeser 2002). This has been used in several attempts to control mange in wild ungulates, but obviously with little success since not all individuals with visible lesions are detected and not all infected individuals show visible lesions. Social structure disruption with increased movement and therefore increased contact rate (at intra or interspecific level, Donnelly et al. 2006) may be counter-productive consequences of depopulation, which could be followed by rapid recovery of population size, even with increased population turnover through compensatory reproduction (e. g. wild boar and swine fever after high hunting pressure, Guberti et al. 1998). Recently, wildlife contraception has been considered, but there is still little information on the reliability of this method under field conditions (Ramsey et al. 2007). Ultimately the best management choice must run in parallel with intense campaigns that convince and inform the society (hunters, wildlife managers, etc.). Habitat management to cope with diseases may have opposite goals. For example, feeding bans can reduce the habitat carrying capacity for ungulates and eventually reduce population density and aggregation, two key factors in infectious disease transmission (Acevedo et al. 2007, Vicente et al. 2007). The identification and correction of overabundance situations is a key action in the control of many infectious diseases (Gortazar et al. 2006). Vector control has sometimes proven helpful in field experiments, but vector diversity and other factors may limit the effectiveness of this management in more complex environments. Treatment of wildlife is increasingly frequent, especially against parasites in economically valuable game species. For example, Iberian wild goats have been treated against sarcoptic mange with ivermectin (León Vizcaino et al. 2001). Anthelminthic treatments are frequent in ungulates (Fernández-de-Mera et al. 2004, Rodríguez et al. 2006). In many cases however, the actual effectiveness of these treatments is unclear and ethical and public health issues need to be addressed. For example, the use of antibiotics in game species may affect meat hygiene. Wildlife vaccination is exceptional, and it is normally limited to the most relevant diseases (those that cause serious economic losses, are almost under control in domestics, and where wildlife reservoirs are paramount). In Europe, this is the case of fox rabies (Artois et al. 1993), classical swine fever (Kaden et al. 2002), and probably soon bTB. In contrast to culling, oral vaccination has the advantages of being painless, thus avoiding animal welfare problems, and does not cause behavioural problems such as increased dispersal or immigration. Vaccination makes sense if the huge investment is the only way to control a disease in its wildlife reservoir, if the costs are clearly outbalanced by the costs of remaining passive, and provided the effectiveness and safety of the vaccine have been tested in captivity. In most cases, vaccination needs to be combined with other management measures, and the ecology of the host species needs to be considered carefully.

In summary, management of diseases and subsequent reduction in the generation of hazardous big game waste usually require a change in human activities (Wobeser 2002), and a sound scientific basis is strongly needed before suggesting any corrective measures that can create or increase conflicts between the different stakeholders: veterinary authorities, hunters, conservationists, livestock breeders and the general public. Moreover, the success of any wildlife disease and subsequent hazardous waste management action must be assessed critically, including an analysis of the costs, of the ecological consequences, and of the animal and human health and welfare benefits.

Post harvest operations occurs once big game waste is generated, we can firstly act by inspecting and identifying any hazard present in such remains. Then, the uses that can be given to the waste should depend on that. Harvest and post-harvest actions are mainly responsibility of hunters, hunting managers and land owners, with supervision of wildlife and sanitary authorities. Big game waste not suspected of being infected with a transmissible disease can also be managed in order to favour conservation and ecological processes. The disposal in the wild must meet sanitary and ecological/conservation interests and therefore the question that arise is how it should be done. Big game management is consubstantial to the production of solid residues and its destruction or disposal depends on practical, cultural, conservation, sanitary and legislative considerations. For non-hazardous big game waste the responsibility is usually of the generator. In order to prevent risks arising from wild animals, bodies or parts of bodies of such animals suspected of being infected with a transmissible disease should be subject to the rules laid down in regulations. Under certain regulations, for example those of the UE, this inclusion should not imply an obligation to collect and dispose of bodies of wild animals that have died or that are hunted in their natural habitat. Such practices for the mitigation of risks are well-established on national and regional legislation in the UE. Another consideration is that waste from hunter kills is highly aggregated in time and space, and usually takes place in a tightly circumscribed area over a narrow period of time. This very often conveys that a large amount of biomass residues have to been managed safety and efficiently in a short time and the accumulation of large amount of decomposed material environmental, sanitary or aesthetical problems. The spatial distribution of feeding stations has to be very patchy and with numerous small feeding sites, to avoid being predictable because of the repercussions of aggregated food availability changes on individuals, populations and communities of avian scavengers (Carrete et al. 2006). Future legislation should encourage the opening of numerous feeding stations supplied with low quantities of food to mimic the original condition of temporal and spatial unpredictability of carcasses and to maintain ecological relationships within the scavenger guild as suggested by Cortes-Avizanda et al. (2010), who propose: (i) carcass-size manipulation may be a valuable tool for directing supplementary feeding towards species of interest, (ii) the spatial position of the feeding station must also be taken into account in any attempt to increase the probabilities of use by breeding threatened species, (iii) diversifying the time at which carrion is left at feeding sites may be an efficient way of avoiding direct competition and small scavengers may benefit from food supplied when the predominant vultures are less active. Finally, we remark that cost studies suggest that the economic cost of this type of conservation measure is high (the creation of a new feeding station will cost between 30000 and 50000 Euros), to which must be added the running and maintenance costs of the site of around 20000 Euros/year (Donazar et al. 2009b, Margalida et al. 2010). The abandonment of safety livestock carcasses (once demonstrated that risks for BSE) is more recommendable than favours populations of wild herbivores to help to maintain populations of avian scavengers given the consequence of overpopulation discussed along this chapter.

Hygienic measures, such as correct disposal of the hunting carcasses and carcass remains should become compulsory in every country and for every hunting modality. Leaving it *in situ* is an option when big game animals that are hunted in their natural habitat are not suspected of being infected with disease transmissible to humans or animals or affected with any potential hazard ad good hunting practices are observed. This is recommendable to protect natural ecological processes, although it should follow previous veterinarian inspection of the offal. In this case, it becomes especially essential disease surveillance and monitoring of big game diseases (see above), and in general of wildlife in the area. Completely limiting access to this material would probably have important conservation consequences (Donazar et al. 2009a). We therefore need research assessing which disposal regime is most beneficial to obligate scavengers, guaranteeing their food supply, while reducing the exposure of susceptible animals to potentially infectious material. One solution that is being tested is the use of mammal proof enclosures or other effective barriers, although fences can injure birds, especially during landing and take-off, and therefore the feeding point should have a minimum area high game fences should be sufficiently separated from the disposal site.

7. Conclusion

This review shows that management hazards associated to big game waste production require a change in human activities, and a sound scientific basis is strongly needed before suggesting any corrective measures that can create or increase conflicts between the different stakeholders. Big game solid waste is produced in large amounts and worldwide. The production of high ungulate biomass is in many cases aggregated in space and time, and ususally associated to overabundance situations, which involves among others infectious hazards for scavengers, animals and humans. Proper implementation of a complete wildlife disease surveillance, monitoring and risk assessment efforts must be a priority of the sanitary authorities. Countries which conduct disease surveillance of their wild animal populations are more likely to detect the presence of infectious diseases and to swiftly adopt counter measures to effectively manage and reduce the effects of hazardous solid waste from big game. Hazardous big game waste disposal may contribute to the establishment and subsequent maintenance of pathogens and disease. Scientific knowledge (epidemiological and ecological) is essential to support equilibrated regulations and decisions on big game waste use, balancing sanity and conservation priorities. A mayor problem worldwide is bovine tuberculosis, for which transmission may get magnified among scavengers (especially vertebrate facultative ones when) due to infected gut pile disposal. This kind of situations secondary increases the risk of disease transmission from wildlife to the domestic flock and humans, which can also undermine conservation efforts if wildlife. Because obligate scavengers effectively remove infectious tissue from big game it is therefore desirable that legislation be applied in a way that allows for the selective access of avian scavengers to the resource. We need assessing which disposal regime is most beneficial to obligate scavengers while reducing the exposure of susceptible animals to potentially infectious/hazardous material. One solution that is currently being tested is the use of mammal proof enclosures or other effective barriers. At the same time, sanitary authorities should consider the removal of infected hunted animals and viscera to limit potential pathogen contamination. This arises the question on whether rigorous inspection compatible with food security policies can be done by not veterinarian persons, at least in vast areas where the prevalence of relevant diseases in many wild ungulate recommend a proper veterinary inspection. There is need also at international and national level of coordinating distinct regulatory and legal frameworks (e. g. presence of some diseases in boundary areas). Hygienic measures, such as correct disposal of the hunting carcasses and carcass remains should become compulsory in every country and for every hunting modality. Leaving it *in situ* is an option when big game animals that are hunted in their natural habitat are not suspected of being infected with disease transmissible to humans or animals or affected with any potential hazard ad good hunting practices are observed. This is recommendable to protect natural ecological processes, although it should follow previous veterinarian inspection of the offal.

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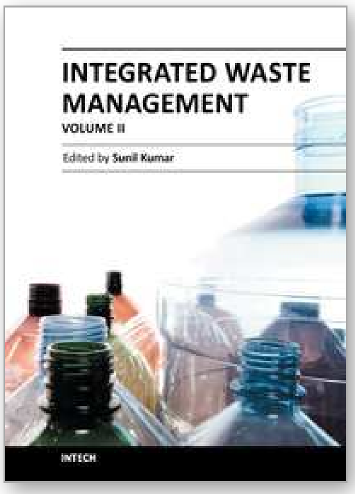

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