

1 **Time to monitor livestock carcasses for biodiversity conservation and public**
2 **health**

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12 **Running head:** Carcass monitoring for conservation

13 **Article Impact Statement:** On-ground monitoring of livestock carcasses for effective
14 integration of conservation issues into sectorial policies for preserving biodiversity and public
15 health.

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17

18 **Abstract**

19 1. Law enforcement and integration of environmental issues into other policies able to
20 affect species and ecosystems are cornerstones for effective protection of biodiversity.

21 We illustrate the necessity of monitoring and improving such enforcement and
22 integration using as an example the European sanitary policies for managing livestock
23 carcasses after the “mad cow disease” outbreak while supporting scavengers’
24 conservation.

25 2. Continuous updates of EU sanitary regulations for reconciling scavenger conservation
26 and public health have led to actions whose implementation and monitoring rely on
27 delineating scavenger feeding zones (SFZs) and estimating livestock mortality and
28 scavenger feeding requirements (SFRs).

29 3. However, the lack of clear and homogeneous criteria to calculate SFRs results in
30 remarkable variations (e.g. of up to >450 % in some regions). Though we offer a
31 prospective approach to improve SFR calculations, we show here the high levels of
32 uncertainty in these estimates based on the imperfect information available regarding
33 scavengers’ ecology.

34 4. We recommend policy-makers to establish a systematic on-ground carcass monitoring
35 for detecting implementation gaps (e.g. food shortages compromising scavenger
36 conservation, potential risks of disease transmission), and to modify EU sanitary
37 regulations accordingly. This monitoring would increase knowledge on scavenging
38 ecology and epidemiological surveillance while enhancing cross-compliance.

39 5. The multiple socioeconomic and ecological impacts of sanitary crisis such as the “mad
40 cow disease” underpin the need for high-level political commitments to guarantee

41 public health, food security and biodiversity conservation. Lessons learned in Europe
42 may help to integrate conservation issues into other sectorial policies worldwide.

43

44 **Keywords:** environmental policy integration, human-mediated carcasses, Natura 2000,
45 sanitary regulations, scavenging, large carnivores, vultures

46 **Introduction**

47 Law enforcement and integration of conservation issues into sectorial policies not specifically
48 focused on conservation but able to affect species and ecosystem persistence are cornerstones
49 to guarantee the effective protection of biodiversity and ecological processes (Ripple et al.,
50 2016, Trouwborst et al., 2017). Important achievements have been made through multiple
51 regulatory legal instruments, from regional to international scales, such as the Endangered
52 Species Act of 1973 in USA, the European Birds and Habitats Directive of 1979 and 1992,
53 respectively, the Convention on the Conservation of Migratory Species of Wild Animals of
54 1983 and the Convention on Biological Diversity of 1993 (Trouwborst et al., 2017). The
55 integration of environmental concerns into other sectorial policies has also been set as a
56 priority by multiple governments. For example, since the Cardiff Process in 1998, the
57 European policy-making agenda prioritizes the integration of environmental concerns into
58 major policies, from agriculture to fisheries or transport, to name a few; such as in the case of
59 the European Union Common Fishery Policy (Ribeiro, 2017).

60 However, although law enforcement and policy integration may be fit for the purpose
61 of conservation, several pitfalls, such as unsuitable integration schemes, compliance or
62 transposition failures, still jeopardize their effectiveness (Trouwborst et al., 2017, López-Bao
63 & Margalida, 2018). Here, we take a step further and show how the lack of clear guidelines in
64 the implementation process, and a limited ecological knowledge to inform them, can also
65 hinder the integration of environmental concerns into other sectorial policies. We use as an
66 illustrative example the European sanitary policies that manage livestock carcasses affecting
67 scavenger conservation. To address the shortfalls in this integration process, we propose the
68 systematic on-ground monitoring of livestock carcasses for detecting policy implementation
69 gaps and adaptation of the EU sanitary regulations accordingly.

70

71 **The example of European sanitary policies**

72 The past twenty years of European sanitary policies managing livestock carcasses provide a
73 sound example on the importance of a continuous update of legal instruments to comply with
74 conservation laws (e.g. European Birds and Habitats Directives) and commitments (e.g. halting
75 biodiversity loss by 2020 under the European Biodiversity Strategy; European Union, 2011).
76 After the outbreak of Bovine Spongiform Encephalopathy (BSE or “mad cow disease”) in the
77 late 1980s, EU sanitary regulations prohibited the abandonment of livestock carcasses in the
78 field to prevent potential risks for animal health that could in turn compromise public health.
79 The initial lack of commitment with scavenger conservation in the regulations adopted at the
80 beginning of 2000s (i.e. Decision 2000/418/EC, Regulation EC 1774/2002 and Decision
81 2003/322/EC; Tella, 2001; Mateo-Tomás, 2009; López-Bao & Margalida, 2018) was changed
82 with the enforcement of Regulation EC 1069/2009, a sanitary policy that considered, for the
83 first time, the natural consumption patterns of avian and mammalian scavengers, a major
84 outcome expected to benefit these species (López-Bao & Margalida, 2018; Mateo-Tomás, Olea
85 & López-Bao, 2018).

86 To guarantee food supply from livestock carcasses to wildlife, the subsequent
87 Regulation EU 142/2011 (Official Journal of the European Union, 2011a) guides the
88 implementation of the new sanitary legislation allowing carcasses of extensive livestock to be
89 left uncollected in geographically defined scavenger feeding zones (SFZs) designated by
90 Member States. The approval of Regulations EC 1069/2009 and EU 142/2011 is heralded
91 therefore as an outstanding advance towards reconciling biodiversity conservation and public
92 health (Mateo-Tomás, Olea & López-Bao, 2018). However, the effectiveness of these

93 regulations is still compromised by several implementation gaps (López-Bao & Margalida,
94 2018; Mateo-Tomás, Olea & López-Bao, 2018). Among them, the lack of consistent and sound
95 criteria for guiding the designation of SFZs has been already highlighted (see Supporting
96 Information; Mateo-Tomás, Olea & López-Bao, 2018). For example, in Spain, it has been
97 shown how depending on the criteria used for designing these feeding zones, the size of SFZs
98 can change up to 72 % (Mateo-Tomás et al., 2018). Similarly, remarkable variations (e.g. of up
99 to >450 %) relying on the criteria used have also been noted for the other key factor supporting
100 the implementation and monitoring of Regulation EU 142/2011, i.e. the estimates of scavenger
101 feeding requirements (SFRs; Mateo-Tomás et al., 2018). Since this regulation obligates
102 competent authorities to approximate mortality rates of extensive livestock and SFRs to be “*a*
103 *basis for the assessment of the potential risks of disease transmission*” (Official Journal of the
104 European Union, 2011a), this outcome urges a comprehensive examination of how SFRs are
105 estimated, and an assessment of their usefulness for the intended purpose of monitoring the
106 implementation of these EU sanitary policies.

107

108 **Guidelines for estimating and using scavenger feeding requirements (SFRs)**

109 Though no additional guidance on how to conduct the assessment of the potential risk of
110 disease transmission is provided in the text of the Regulation EU 142/2011, a straightforward
111 interpretation (that some Member States, such as for example Spain, have already used;
112 Spanish Government 2011) is to compare the estimates of livestock mortality and SFRs to
113 anticipate potential mismatches between the carrion consumed by scavengers and the carcasses
114 authorized to be left within SFZs that could compromise public health.

115 However, similarly to that already reported for SFZs (Mateo-Tomás, Olea & López-
116 Bao, 2018; Mateo-Tomás et al., 2018), the lack of clear guidelines and homogeneous criteria
117 on how to estimate SFRs lead to estimates with both high bias (i.e. distance between estimated
118 and “true” values) and uncertainty (i.e. variability around the estimated value). Bias in SFR
119 estimates can be reduced by progressively adding ecological parameters that approximate
120 calculations to the real “true” values; yet, by doing so, the uncertainty around of the estimates
121 increases. Figure 1 illustrates to what extent improving the ecological soundness of SFRs – e.g.
122 by progressively adding parameters describing the species demography and feeding ecology
123 such as breeding success, floating population or percentage of carrion in the species’ diet –
124 increases the accumulated uncertainty from simpler (i.e. “Daily Food Intake (DFI)”) to more
125 complex (i.e. “percentage of carrion in the diet”) scenarios (see details in Supporting
126 Information). Furthermore, knowledge gaps in key elements of scavengers’ ecology (e.g. from
127 accurate population size estimates to theoretical individual metabolic needs; Mateo-Tomás et
128 al., 2017) can add some bias to the SFR estimates. Consequently, resulting over and/or under-
129 estimates may contribute to hinder the expected impact of the EU 142/2011 regulation on
130 scavenger conservation. While underestimating SFRs may result in food shortages
131 compromising the conservation of scavenging species (Tella 2001), their over-estimation could
132 exert negative impacts on threatened species and ecosystems (e.g. local increases of generalist
133 predators; Oro et al., 2013).

134 Therefore, although estimated SFRs could be useful in the implementation of sanitary
135 regulations in Europe (see some examples below), we argue that the above mentioned pitfalls
136 preclude their use for the intended purpose of assessing potential sanitary risks that could
137 compromise public health. Indeed, the obligation of estimating SFRs poses an additional risk

138 of using them as real figures to set the number of carcasses authorized within SFZs. For
139 example, at least 6 (out of 17) Spanish autonomous regions (competent for implementing
140 Regulation EU 142/2011 in Spain) explicitly state in their legislation the use of SFR estimates
141 to guide the quantity of carrion biomass left uncollected within SFZs, a recommendation
142 included also in the implementation guidelines elaborated by the Spanish Government (2011).
143 However, besides generic requirements of recording the type and estimated body mass of the
144 fallen stock uncollected within SFZs – which implies proactive actions to monitor livestock
145 carcass availability –, clear criteria on how to estimate SFRs are lacking across European and
146 domestic laws (see Supporting Information; Mateo-Tomás et al., 2018).

147 Clear guidance on how to estimate SFRs should be included within the enforced
148 regulations. Though we use “Equation (1)” in Supporting Information just to illustrate the
149 associated bias and high variability of SFR estimates, it offers a prospective approach to
150 perform these calculations. However, although the inclusion of parameters such as, for
151 example, the species’ breeding success or the percentage of carrion in its diet may result in
152 more ecologically-sound estimates of SFRs, as previously highlighted, they are not exempt
153 from uncertainty, which increases cumulatively with the addition of parameters (Figure 1). In
154 order to minimize the potential consequences of these issues of bias and uncertainty during
155 their implementation and monitoring, EU sanitary regulations should clearly state the intended
156 (e.g. comparison of scenarios within and/or among regions; Mateo-Tomás et al., 2018) and
157 non-intended (e.g. exact figures of scavenger feeding needs) uses of SFRs estimates.

158

159 **The need for systematic on-ground carcass monitoring**

160 Considering the high bias and uncertainty when estimating SFRs, we argue that the
161 systematic on-ground monitoring of livestock carcasses left within SFZs may be the most
162 effective and reliable approach to evaluate the correct implementation of the above mentioned
163 EU sanitary regulations. On-ground monitoring would enhance the cross-compliance with
164 sanitary regulations, promoting policy integration and building public trust in managing
165 authorities (e.g. through establishing reciprocal obligations, not only for farmers to dispose
166 livestock carcasses in compliance with sanitary policies but also for competent authorities to
167 deploy in-situ surveillance that guarantees the correct achievement of the regulation
168 objectives). This approach would allow the detection of implementation gaps in terms of i)
169 food shortages compromising scavenger conservation (e.g. increasing inter- or intraspecific
170 trophic competition, unusual foraging behaviors; Margalida, Campión & Donázar 2011;
171 Mateo-Tomás et al., 2017) and ii) potential risks of disease transmission related to scavenging
172 and/or unconsumed carrion. For instance, carcass consumption by some facultative scavengers
173 such as wild boars (*Sus scrofa*) seems to play a role in the transmission of tuberculosis;
174 contacts between mammals at carcasses increase with carrion persistence, maximizing the
175 probability of disease spread; human health costs from rabies increased dramatically in India
176 apparently due to population increases of feral dogs and rats feeding on persistent carcasses
177 (Markandya et al., 2008; Ogada et al., 2012; Barron et al., 2015). Noteworthy, although many
178 works highlight the role of scavenging in disease dynamics, major knowledge gaps persist
179 regarding the underlying mechanisms as well as the epidemiological consequences of carcass
180 presence in ecosystems, which are in turn highly context-dependent (Vicente & VerCauteren,
181 in press).

182 In the long term, the on-ground monitoring of livestock carcasses would also provide
183 valuable information on scavenging ecology in order to guide other measures that competent

184 authorities must state in compliance with European regulations (e.g. targeting species of
185 conservation concern, minimizing disease transmission risks; Official Journal of the European
186 Union, 2011). For example, monitoring carcasses allows for the identification of species,
187 seasons and places where carrion is consumed (and where not), as well as the spatiotemporal
188 evaluation of changes in key ecosystem functions supported by scavenger communities, such
189 as carrion consumption (Mateo-Tomás et al., 2017). This information would facilitate the
190 adaptation on when, where and how carcass disposal in the field should be authorized and
191 prioritized. Parallel monitoring of scavenger populations (e.g. census, estimation of breeding
192 parameters, habitat use) would allow assessment of the response of target scavenger
193 populations to changes in carrion availability. Similarly, on-ground carcass monitoring may
194 support the implementation of disease surveillance and monitoring programs needed to delve
195 into the role of carrion in the maintenance and transmission of diseases (Vicente &
196 VerCauteren, in press), while complementing the epidemiological surveillance already in place
197 (e.g. Transmissible Spongiform Encephalopathies (TSEs) control system; Official Journal of
198 the European Union, 2011a; European Food Safety Authority (EFSA) et al., 2016). This
199 information will be also paramount to avoid misleading management actions (e.g. Tella 2001).

200 Although undertaking the on-ground monitoring of livestock carcasses can be
201 challenging (e.g. time-consuming, budgetary and logistical constraints), the severe
202 socioeconomic (e.g. >200 human deaths since 1996, ~180,000 cattle affected, 4.4 million cows
203 killed, and £3.5 billion costs in 1996-1999 only in UK; Atkinson, 1999; U.S. Department of
204 Health & Human Services, 2017) and ecological (e.g. altered foraging behaviors and local
205 declines of up to 50% in breeding success in some European griffon vulture *Gyps fulvus*
206 populations; Mateo-Tomás 2009; Margalida, Campión & Donazar, 2011) impacts of the BSE

207 outbreak in Europe, underpin the need for high-level political commitments to guarantee public
208 health, food security and biodiversity conservation associated with the ecological process of
209 scavenging and the presence of livestock carcasses in the field. Similar efforts are already
210 demanded regarding other ecological processes strongly related to human wellbeing, with
211 monitoring schemes underway for fisheries and pollination (Official Journal of the European
212 Union, 2011b; Dicks et al., 2016). Moreover, although focused on a few number of feeding
213 stations, on-ground monitoring of scavengers through remote cameras is already in place in
214 ~20 locations in France (Ligue pour la protection des oiseaux, LPO & Fondation Nature &
215 Découvertes, 2013). Effective collaboration among sanitary and environmental authorities
216 (encouraged by Regulation EU 142/2011; Official Journal of the European Union 2011a),
217 especially at local scales (e.g. local veterinarians, wildlife rangers), would improve the
218 implementation of the proposed on-ground carcass monitoring to address the major regulation
219 objectives of biodiversity conservation and public health.

220 A multiple-legal framework already supports on-ground monitoring of carcasses from
221 sanitary and conservation perspectives. While Regulation EU 142/2011 requests authorities to
222 undertake estimates of SFRs and a regular surveillance of potential disease risks (Official
223 Journal of the European Union 2011a), Birds and Habitats Directives oblige Member States to
224 periodically assess (every 3-6 years) the conservation status of the species listed in their
225 annexes, – which include in turn the scavengers targeted by Regulation EU 142/2011.
226 Furthermore, some key countries for scavenger conservation, such as Spain (home of >90% of
227 European vultures; Mateo-Tomás, 2009; López-Bao & Margalida, 2018) have transposed the
228 European law into specific domestic legislation (i.e. RD 1632/2011, see Supporting
229 Information; BOE 2011). Under this national regulation, the 17 Spanish autonomous regions

230 and farmers are responsible to track the amount of carrion biomass provided to scavengers
231 within SFZs. Furthermore, at least 4 Spanish subnational legislations oblige farmers to
232 communicate livestock deaths soon after detection (within 24 hours in one case), enabling
233 some traceability to support on-ground carcass monitoring. A similar obligation exists in
234 Sardinia (Italy) to communicate livestock deaths within SFZs to both sanitary authorities and
235 local researchers (Regione Autònoma de Sardigna, 2016).

236 Since European (i.e. Regulation EU 142/2011) and national (e.g. Spanish RD
237 1632/2011) sanitary legislations prioritize Natura 2000 network sites for scavenger
238 conservation, the area under this network emerges as a priority location for on-ground
239 monitoring of livestock carcasses at SFZs. This choice would not only reinforce the weak
240 transboundary coordination detected when implementing European sanitary regulations
241 (López-Bao & Margalida, 2018; Mateo-Tomás, Olea & López-Bao, 2018; Mateo-Tomás et al.,
242 2018), but also the relevance of the Natura 2000 network for conservation among stakeholders.

243 While meaningful achievements in biodiversity conservation have been reached in
244 recent decades, the effective integration of scavenger conservation into European sanitary
245 policies remains an issue and provides an illustrative example within a global context of rising
246 conservation concerns for scavengers. Contrasting with the severe vulture declines taking place
247 in Asia (Oaks et al., 2014) and Africa (Ogada et al., 2016) and the prevailing negative trends of
248 the world's megafauna (Ripple et al., 2016), Europe harbors important recovering populations
249 of obligate (i.e. vultures) and facultative scavengers (e.g. large carnivores; Chapron et al.,
250 2014; López-Bao & Margalida, 2018). If Europe aims to continue leading the conservation of
251 scavengers, effective implementation of European regulations, and better integration of
252 biodiversity conservation into sectorial policies must be considered a priority. Europe may thus

253 become an example for integrating conservation needs into sectorial policies, providing
254 guidance to other world regions with scavengers threatened by poor management policies
255 (Mateo-Tomás & Olea, 2018).

256

257 **Authors' contributions**

258 PMT conceived the idea and did the analysis; PMT and JVLB collected the data; all authors
259 did the writing of the manuscript, contributed critically to the drafts and gave final approval for
260 publication.

261

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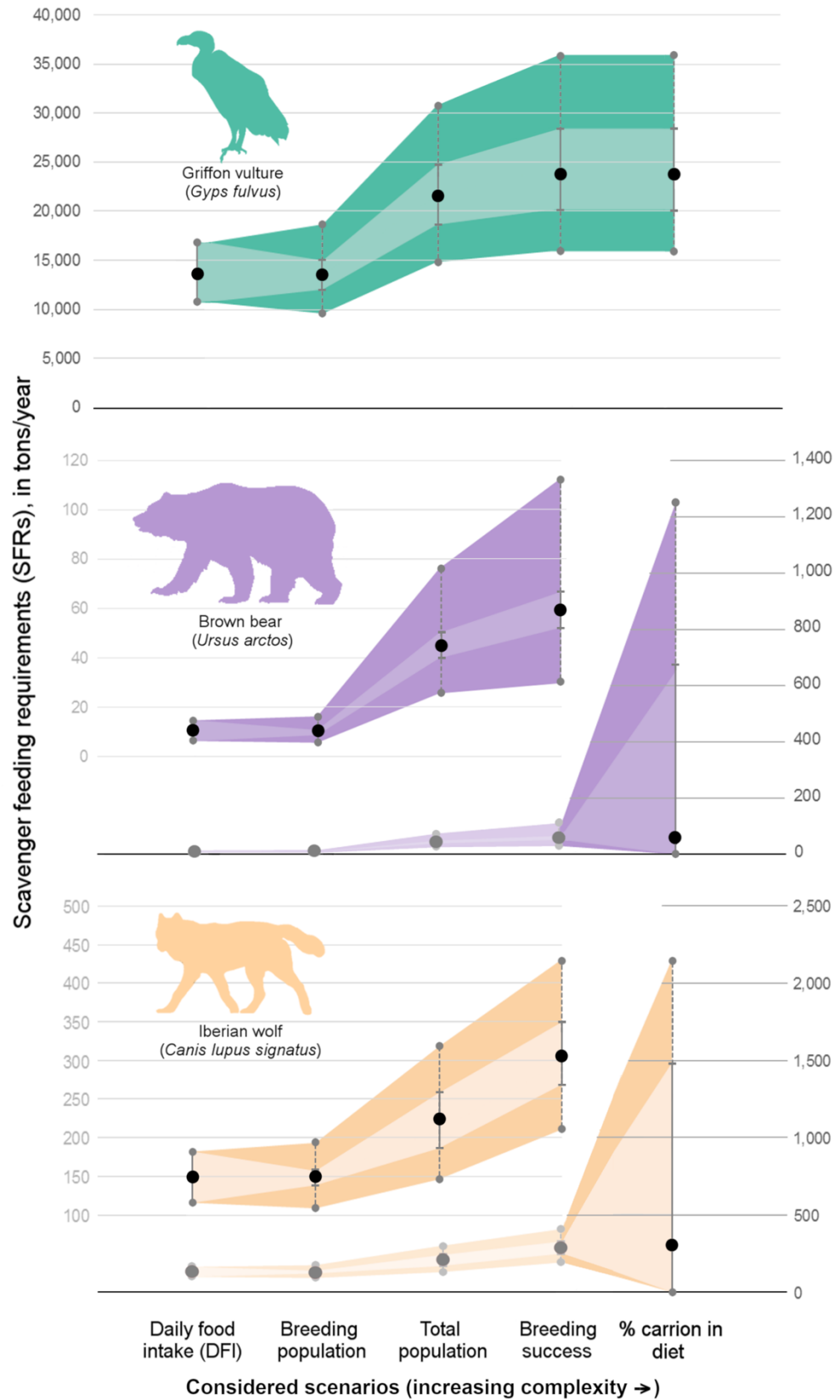
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353

354 **Figure 1. Bias and uncertainty in estimating scavenger feeding requirements (SFRs).**
355 Estimated SFRs (mean: black dot \pm minimum-maximum range: error bars in tons/year on the
356 x-axis) for the Spanish populations of an obligate (griffon vulture *Gyps fulvus*) and two
357 facultative (brown bear *Ursus arctos* and wolf *Canis lupus*) vertebrate scavengers targeted by
358 European sanitary regulations. Calculations of SFRs from simple (i.e. “Daily food intake
359 (DFI)”, the quantity of food that an individual should ingest per day to keep its basic metabolic
360 functions; see Mateo-Tomás et al. 2017) to more complex (i.e. “% carrion in diet”) scenarios
361 (on the x-axis) result from progressively incorporating various parameters into Equation (1)
362 (see details in Supporting Information). The progressive incorporation of more information on
363 the species demography and feeding ecology is expected to improve the ecological soundness
364 (i.e. reducing bias) of the SFRs estimates (black dot), but it would also increase total
365 uncertainty (shaded background) around such estimates due to the accumulation of the inherent
366 uncertainty of the new incorporated parameters (light-colored background). Zoomed data are
367 provided, on the left axis, for bear and wolf populations to better show the increase of
368 uncertainty in the estimates. Note that SFRs here provided are based on the best evidence
369 available but are not exact figures; this is rather intended as a representation of the uncertainty
370 in the estimates.



372 **Supporting Information**

373 Appendix S1: main criteria for estimating scavenger feeding requirements (SFRs) and
374 designating scavenger feeding zones (SFZs) across Europe. Appendix S2: detailed calculations
375 of SFRs. Appendix S3: legislations enforced in EU Member States for implementing
376 Regulation EU 142/2011. The authors are solely responsible for the content and functionality
377 of these materials. Queries (other than absence of the material) should be directed to the
378 corresponding author.

379

1 **Appendix S1.** Main criteria used to estimate scavenger feeding requirements (SFRs) for the implementation and monitoring of
 2 Regulation EU 142/2011 in the eight Member States included in Annex VI (Chapter II, Section 2, 1.a.i) of the regulation and in the 17
 3 Spanish autonomous regions (competent for biodiversity conservation in Spain). We considered approved regulations (N = 19) and drafts
 4 available at official websites (N = 2; Balears and Murcia Spanish autonomous regions). Note that the same territory can use several
 5 criteria simultaneously. Only criteria explicitly referred to in the approved/drafted legislation were included. See Appendix S1 for the
 6 complete list of legislations considered per country and autonomous region. Although already assessed in previous works (e.g. Mateo-
 7 Tomás, Olea and López-Bao 2018; Mateo-Tomás et al., 2018), criteria for designating scavenger feeding zones (SFZs) are also listed
 8 for allowing further comparisons.
 9

Criteria	Territory
Scavenger feeding requirements (SFRs)	
<i>EU Member States in Annex VI of EU Regulation 142/2011 (N = 8)</i>	
Authorized farmers must register the quantity of livestock carcasses annually provided for feeding scavengers	France, Italy (Sardinia), Spain (37.5 %)
Spanish autonomous regions (% from total, N = 15)	
Abundance estimations of scavengers of European conservation concern	All but Andalucía and Canarias ^d (87 %)
Breeding parameters of scavengers of European conservation concern	Asturias, Castilla-La Mancha, Castilla y León (20 %)
Scavenger Feeding Zones (SFZs)	
<i>EU Member States in Annex VI of EU Regulation 142/2011 (% from total, N = 8)</i>	
Areas where extensive farming of animals takes place	All ^a (100 %)
Natura 2000 protected areas declared because of the presence of scavengers of European conservation concern (i.e. according to Annex VI of Regulation 142/2011).	Spain, Italy (Sardinia) (25 %)
Conservation/recovery areas for scavengers of European conservation concern officially declared by regional governments	Spain, Italy (Sardinia) (25 %)
Priority feeding areas for scavengers of European conservation concern	France, Spain (25 %)
Only within concrete holdings authorized after application by the interested party	France (13 %)

Appendix S1 (cont.)

<i>Spanish autonomous regions (% from total, N = 15)</i>	
Breeding areas for scavengers of European conservation concern	All but Balears ^b , Cataluña and Comunidad Valenciana (80 %)
Foraging areas for scavengers of European conservation concern	All but Cataluña and Comunidad Valenciana (87 %)
Breeding and/or foraging areas of other scavengers not listed in Regulation 142/2011	Castilla y León (wolf) and Balears (raven <i>Corvus corax</i>) (13 %)
Natura 2000 protected areas declared because of the presence of scavengers of European conservation concern	Aragón, Cantabria, Castilla-La Mancha, Castilla y León, Comunidad Valenciana, Extremadura, La Rioja, Murcia ^b , País Vasco (60 %)
Conservation/recovery areas for scavengers of European conservation concern officially declared by regional governments	Aragón, Cantabria, Castilla-La Mancha, Castilla y León, Extremadura, País Vasco (40 %)
Other (e.g. mountain areas ^c , municipalities according to livestock rearing types ^d , public terrains)	Cataluña, La Rioja, Aragón, Cantabria (27 %)

^aAs stated in Regulation EU 142/2011; ^bDrafted regulations; ^cCriteria used as a surrogate for identifying extensive farming and excluding intensive farming; ^dOnly considered if explicitly referred in the legislations.

Appendix S2. Estimates of annual scavenger feeding requirements (SFRs) for griffon vulture, brown bear and Iberian wolf.

Calculations of SFRs from simple (i.e. “Daily food intake (DFI)”) to more complex (i.e. “% carrion in diet”) scenarios by modifying “equation (1)”. We illustrate to what extent improving the ecological soundness of SFRs estimates (i.e. by including more detailed information on the species demography and feeding ecology) increases the accumulated uncertainty associated by progressively incorporating key parameters (in bold) into “equation (1)”, through the steps shown in Figure 1. Our most basic calculation takes into account the daily food intake (i.e. DFI, the quantity of food that an individual should ingest per day to keep its basic metabolic functions; see Mateo-Tomás et al. 2017 for complete details on its calculation) of each individual of the considered species, which can vary from minimum to maximum values (in brackets after the mean value). The remaining parameters (i.e. $\%carrion_m$: percentage of carrion in the species diet, and Abb_m : abundance of the breeding population) are kept constant at their mean values (denoted with “m” subscript). The “Breeding population” scenario adds to the previous equation (i.e. “Daily food intake (DFI)”) the variation in abundance of the breeding population (Abb), keeping constant the percentage of carrion in the species diet. In the next scenario (i.e. “Total population”), the species population estimates are improved by accounting for the entire population (i.e. breeders and non-breeders; Abt). To further approach reality, the “Breeding success” scenario incorporates to the previous equation the number of breeding units (i.e. pairs, females with cubs and dens, respectively; bu), breeding success (i.e. offspring size per breeding unit; bsc) and length of the breeding season ($bsdays$, in days) of the considered species. Finally, the “% carrion in diet” scenario uses the entire “equation (1)”, i.e. it accounts also for changes in the percentage of carrion in the species’ diet. Note that no variation occurs in the griffon vulture under the “% carrion in diet” scenario

since the species is an obligate scavenger, i.e. feeds exclusively on carrion, which represents 100 % of the species DFI. All equations retrieve tons of carrion needed by each species per year (tons/year).

$$\sum_{i=1}^{N_{spp}} (DFI_i * \%carrion_i * ((Abt_i * 365days/year) + (bu_i * bsc_i * bsdays_i))) \quad \text{Equation (1)}$$

Scenario	Equation used	Griffon vulture (<i>Gyps fulvus</i>)	Brown bear (<i>Ursus arctos</i>)	Iberian wolf (<i>Canis lupus signatus</i>)
Daily food intake (DFI)	$\sum_{i=1}^{N_{spp}} (DFI_i * \%carrion_{mi} * Abb_{mi} * 365days/year)$	DFI = 0.669 kg (0.532; 0.834)^a <i>Abb_m</i> = 55,257 <i>%carrion_m</i> = 100	DFI = 3.70 kg (2.37; 5.62)^a <i>Abb_m</i> = 80 <i>%carrion_m</i> = 9	DFI = 1.60 kg (1.26; 1.98)^a <i>Abb_m</i> = 1,262 <i>%carrion_m</i> = 20
Breeding population	$\sum_{i=1}^{N_{spp}} (DFI_i * \%carrion_{mi} * Abb_i * 365days/year)$	<i>Abb</i> = 55,257^b (49,216; 61,298)	<i>Abb</i> = 80^c (72; 88)	<i>Abb</i> = 1,262^f (1,184; 1,341)
Total population	$\sum_{i=1}^{N_{spp}} (DFI_i * \%carrion_{mi} * Abt_i * 365days/year)$	<i>Abt</i> = 177,427 (152,570; 202,283)	<i>Abt</i> = 371 (328; 413)	<i>Abt</i> = 1,793 (1,521; 2,203)
Breeding success	$\sum_{i=1}^{N_{spp}} (DFI_i * \%carrion_{mi} * ((Abt_i * 365days/year) + (bu_i * bsc_i * bsdays_i)))$	<i>bu</i> (breeding pairs) = 27,682 (24,608; 30,649) <i>bsc</i> = 0.67 (0.39; 0.94) <i>bsdays</i> = 214	<i>bu</i> (females with cubs) = 80 (72; 88) <i>bsc</i> = 1.9 (1; 3)^d <i>bsdays</i> = 275	<i>bu</i> (breeding packs) = 263 (263; 263) <i>bsc</i> = 4.8 (4.5; 5.1)^g <i>bsdays</i> = 214
% carrion in diet	$\sum_{i=1}^{N_{spp}} (DFI_i * \%carrion_i * ((Abt_i * 365days/year) + (bu_i * bsc_i * bsdays_i)))$	<i>%carrion</i> = 100	<i>%carrion</i> = 9 (0; 100)^e	<i>%carrion</i> = 20 (0; 100)^h

^aMean (minimum; maximum) species' daily food intake (i.e. DFI) calculated following Mateo-Tomás et al. (2017); ^bMean (minimum; maximum) values of abundance and breeding parameters for the Griffon vulture obtained from the last Spanish census (i.e. 24,608-30,649 breeding pairs; Del Moral 2009); ^cMean (minimum; maximum) values of abundance for the brown bear were estimated by applying to the census data of the two Spanish populations – i.e. Cantabrian mountains (i.e. 80 breeding females; Principado de Asturias et al. 2016, 2017) and Pyrenees (i.e. 39 individuals; Palazón 2017) – the adult females/total population ratios available for other protected brown bear populations (i.e. 0.27-0.28; Nawaz et al. 2008; Eberhardt and Breiwick 2010) and considering a proportion of 0.22 non-breeding females/adult females, as calculated for the Italian brown bear population of the Apennines (Tosoni et al. 2017); ^dBreeding parameters for brown bear were directly obtained from Principado de Asturias et al. (2016, 2017); ^eThe mean percentage of carrion in the brown bear diet (i.e. 9 %) was obtained from Naves et al. (2006), we assumed that carrion could vary from 0 to 100 % of the species DFI depending on individuals, seasons and locations; ^fMean (minimum; maximum) values of abundance for the wolf were calculated from the Spanish census data (i.e. 297 packs; MAPAMA 2012-2014) and the estimates of breeding packs from the total (i.e. 80 %), mean pack size (i.e. 4.5-5.1 individuals)^g and percentage of floaters (i.e. 16-25 % of individuals in the population are not linked to any pack) in Spain (Fernández-Gil et al. 2010; Llana et al. 2012; López-Bao et al. 2018); ^hThe mean percentage of carrion in the wolf diet (i.e. 20 %) was obtained from Palacios et al. (2014), we assumed that carrion could represent from 0 to 100 % of the species DFI depending on individuals, seasons and locations.

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Appendix S3. Legislations enforced in the EU Member States listed in Annex VI (Chapter II, Section 2, 1.a.i) of Regulation EU 142/2011 and in Spanish autonomous regions for implementing the European Regulation EU 142/2011 on feeding scavengers:

EUROPEAN UNION (EU)

COMMISSION REGULATION (EU) No 142/2011 of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive.

Date of document: 25th February 2011

Date of publication: 26th February 2011 in the EU official journal (Official Journal of the European Union, vol. 54)

Date of effect: 4th March 2011

Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2011.054.01.0001.01.ENG&toc=OJ:L:2011:054:TOC

Bulgaria

Law amending the Veterinary Law.

Да се обнародва в „Държавен вестник“ Законът за изменение и допълнение на Закона за ветеринарномедицинската дейност, приет от XLI Народно събрание на 11 януари 2013 г. Издаден в София на 18 януари 2013 г.

Date of publication: 18th January 2013 in the Bulgarian official journal (State Gazette)

Available at: <http://extwprlegs1.fao.org/docs/pdf/bul164355.pdf>

National legislation amending existing veterinary law according to Regulation EU 142/2011. No specific guidelines for feeding wildlife with animal by-products has been found in this document.

Cyprus

No specific legislation found for guiding the implementation of Regulation EU 142/2011

France

Arrêté du 8 décembre 2011 établissant des règles sanitaires applicables aux sous-produits animaux et produits dérivés en application du règlement (CE) n° 1069/2009 et du règlement (UE) n 142/2011.

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Date of document: 8th December 2011

Date of publication: 30th December 2011 in the French official journal (Journal Officiel de la République Française, num. 0302)

Date of effect: 31st December 2011

Available at:

<https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000025056078&dateTexte=20180406>

National legislation transposing EU Regulation 142/2011 and amending existing legislation (i.e. Arrêté du 28 février 2008 relatif aux modalités de délivrance de l'agrément sanitaire et de l'autorisation des établissements visés par le règlement (CE) n° 1774/2002 du Parlement européen et du Conseil du 3 octobre 2002 établissant des règles sanitaires applicables aux sous-produits animaux non destinés à la consommation humaine; available at

<https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000018217605>).

Greece

Law 4235/2014. Administrative measures, procedures and sanctions in the implementation of EU and national legislation in the fields of food, feed and health and animal welfare and other provisions by the Ministry of Rural Development and Food.

NΟΜΟΣ ΥΠ' ΑΡΙΘ. 4235 Διοικητικά μέτρα, διαδικασίες και κυρώσεις στην εφαρμογή της ενωσιακής και εθνικής νομοθεσίας στους τομείς των τροφίμων, των ζωοτροφών και της υγείας και προστασίας των ζώων και άλλες διατάξεις αρμοδιότητας του Υπουργείου Αγροτικής Ανάπτυξης και Τροφίμων.

Date of publication: 11th February 2014 in the Greek official journal (Official Government Gazette num. 32)

Available at: <http://www.et.gr/index.php/f-e-k>

National legislation amending and merging existing EU and national legislation, including Regulation EU 142/2011. No specific guidelines for feeding wildlife with animal by-products has been found in this document.

Italy

Legislative Decree No. 186 laying down penalties to be applied in case of infringement of Regulation (EC) No. 1069/2009 laying down health rules as regards animal by-products and derived products

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not intended for human consumption, and in case of infringement of Regulation (EU) No. 142/2011 implementing Regulation (EC) No. 1069/2009.

DECRETO LEGISLATIVO 1 ottobre 2012, n. 186. Disciplina sanzionatoria per la violazione delle disposizioni di cui al regolamento (CE) n. 1069/2009 recante norme sanitarie relative ai sottoprodotti di origine animale e ai prodotti derivati non destinati al consumo umano e che abroga il regolamento (CE) n. 1774/2002, e per la violazione delle disposizioni del regolamento (UE) n. 142/2011 recante disposizioni di applicazione del regolamento (CE) n. 1069/2009 e della direttiva 97/78/CE per quanto riguarda taluni campioni e articoli non sottoposti a controlli veterinari in frontiera. (12G0206)

Date of document: 1st October 2012

Date of publication: 31st October 2012 in the Italian official journal (Gazzetta Ufficiale num. 255)

Date of effect: 15th November 2012

Available at: <http://www.gazzettaufficiale.it/eli/id/2012/10/31/012G0206/sg>

No specific guidelines for feeding wildlife with animal by-products has been found in this document.

Only in Sardinia (Italy)

Procedura per l'autorizzazione in deroga all'uso di talune categorie di sottoprodotti di origine animale per l'alimentazione di uccelli necrofagi in stazioni di alimentazione (carnai aziendali) di cui al punto 1.2 dell'art. 14 dell'Allegato 1 alla determinazione del Servizio prevenzione della G Sanità n. 464 del 16/05/2013.

Date of document: 19th October 2016

Available at: <http://www.lifeundergriffonwings.eu/export/sites/default/.galleries/doc-notizie/Det.-n.-1199-2016.pdf>

Regional legislation authorizing the use of livestock carcasses for Griffon vulture feeding at light feeding stations, i.e. within individual farmlands.

Portugal

No specific legislation found for guiding the implementation of Regulation EU 142/2011 through designation of SFZs.

Slovakia

Decree on collection, transportation and disposal of animal by-products and the use of animal by-products for special feeding purposes.

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Predpis č. 148/2012 Z. z. Vyhláška Ministerstva pôdohospodárstva a rozvoja vidieka Slovenskej republiky, ktorou sa ustanovujú podrobnosti o výnimkách pri zbere, preprave a odstraňovaní vedľajších živočíšnych produktov a o použití vedľajších živočíšnych produktov na osobitné krmné účely.

Date of document: 9th May 2012

Date of publication: 23th May 2012 in the Slovak official journal (Collection of Laws SR, num. 37)

Date of effect: 1st June 2012

Available at: <http://www.zakonypreludi.sk/zz/2012-148>

National legislation transposing Regulation EU 142/2011.

Spain

Real Decreto 1632/2011, de 14 de noviembre, por el que se regula la alimentación de determinadas especies de fauna silvestre con subproductos animales no destinados a consumo humano.

Date of document: 14th November 2011

Date of publication: 25th November 2011 in the Spanish official journal (Boletín Oficial del Estado, num. 284)

Date of effect: 26th November 2011

Available at: <https://www.boe.es/buscar/doc.php?id=BOE-A-2011-18536>

National legislation transposing Regulation EU 142/2011 regarding the feeding of scavengers with animal by-products.

SPANISH AUTONOMOUS REGIONS

Andalucía

Orden de 2 de mayo de 2012, conjunta de las Consejerías de Agricultura y Pesca y Medio Ambiente, por la que se desarrollan las normas de control de subproductos animales no destinados al consumo humano y de sanidad animal, en la práctica cinegética de caza mayor de Andalucía.

Date of document: 2nd May 2012

Date of publication: 21st May 2012 in the official journal of the region (Boletín Oficial de la Junta de Andalucía, num.98 p. 13)

Date of effect: 1st June 2012

Orden de 30 de julio de 2012, por la que se establecen y desarrollan las normas para el proceso de retirada de cadáveres de animales de las explotaciones ganaderas y la autorización y Registro de los

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Establecimientos que operen con subproductos animales no destinados al consumo humano en Andalucía.

Date of document: 30th July 2012

Date of publication: 13th August 2012 in the official journal of the region (Boletín Oficial de la Junta de Andalucía, num.158 p. 10)

Date of effect: 14th August 2012

Aragón

DECRETO 170/2013, de 22 de octubre, del Gobierno de Aragón, por el que se delimitan las zonas de protección para la alimentación de especies necrófagas de interés comunitario en Aragón y se regula la alimentación de dichas especies en estas zonas con subproductos animales no destinados al consumo humano procedentes de explotaciones ganaderas.

Date of document: 22nd October 2013

Date of publication: 4th November 2013 in the official journal of the region (Boletín Oficial de Aragón, num.217)

Date of effect: 5th November 2013

Asturias

Resolución de 25 de mayo de 2017, de la Consejería de Desarrollo Rural y Recursos Naturales, por la que se declaran zonas de protección para la alimentación de especies necrófagas de interés comunitario en el Principado de Asturias y se establecen requisitos específicos para el uso de subproductos no destinados a consumo humano en estas zonas.

Date of document: 25th May 2017

Date of publication: 6th June 2017 in the official journal of the region (Boletín Oficial del Principado de Asturias, num.129)

Date of effect: 26th June 2017

Baleares

Esborrany de l'Avantprojecte de decret _/20__, d__ d____ de 20__, pel qual es regula a les Illes Balears l'ús de determinats subproductes animals no destinats al consum humà per a l'alimentació d'espècies necròfagues d'interès comunitari

Drafted regulation available at <http://www.caib.es/sites/proteccioespecies/ca/portada-46282/>. Last accessed 27th May 2018

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Canarias

ORDEN de 17 de abril de 2014, por la que se delimitan las islas de Fuerteventura, Lanzarote y La Graciosa como zonas de protección para la alimentación de especies necrófagas de interés comunitario en la Comunidad Autónoma de Canarias.

Date of document: 17th April 2014

Date of publication: 28th April 2014 in the official journal of the region (Boletín Oficial de Canarias, num.81)

Date of effect: 18th May 2014

Cantabria

Orden MED/2/2017, de 20 de febrero, por la que se regula las zonas de protección autorizadas para la alimentación de la fauna silvestre necrófaga con cadáveres de animales pertenecientes a explotaciones ganaderas, en la Comunidad Autónoma de Cantabria.

This regulation amends Orden GAN/30/2012, de 4 de mayo.

Date of document: 20th February 2017

Date of publication: 1st March 2017 in the official journal of the region (Boletín Oficial de Cantabria, num.42)

Date of effect: 2nd March 2017

Castilla-La Mancha

Decreto 120/2012, de 26/07/2012, por el que se crea la red de alimentación de especies necrófagas de Castilla-La Mancha y se regula la utilización de subproductos animales no destinados a consumo humano para la alimentación de determinadas especies de fauna silvestre en el ámbito territorial de Castilla-La Mancha.

Date of document: 26th July 2012

Date of publication: 1st August 2012 in the official journal of the region (Diario Oficial de Castilla-La Mancha, num.150)

Date of effect: 2nd August 2012

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Castilla y León

DECRETO 17/2013, de 16 de mayo, por el que se desarrolla en Castilla y León el uso de determinados subproductos animales no destinados al consumo humano para la alimentación de especies necrófagas de interés comunitario.

Date of document: 16th May 2013

Date of publication: 29th May 2013 in the official journal of the region (Boletín Oficial de Castilla y León, num.101)

Date of effect: 30th May 2013

Cataluña

ORDENAAM/387/2012, de 23 de noviembre, relativa a la alimentación de especies necrófagas de interés comunitario.

Date of document: 23th November 2012

Date of publication: 29th November 2012 in the official journal of the region (Diari Oficial de la Generalitat de Catalunya, num.6264)

Date of effect: 30th May 2013

Comunidad Valenciana

RESOLUCIÓN de 28 de noviembre de 2014, de la directora general de Medio Natural, por la que se delimitan las zonas de protección para la alimentación de aves necrófagas.

Date of document: 28th November 2014

Date of publication: 5th January 2015 in the official journal of the region (Diari Oficial de la Comunitat Valenciana, num.7436)

Date of effect: 25th January 2015

This regulation amends RESOLUCIÓN de 18 de junio de 2012.

Extremadura

DECRETO 38/2015, de 17 de marzo, por el que se regula la alimentación de determinadas especies de fauna silvestre con subproductos animales no destinados a consumo humano en la Comunidad Autónoma de Extremadura.

Date of document: 17th March 2015

Date of publication: 23rd March 2015 in the official journal of the region (Diario Oficial de Extremadura, num.56)

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Date of effect: 24th March 2015

Galicia

DECRETO 72/2016, de 9 de junio, por el que se autorizan y se regulan determinados sistemas de eliminación de subproductos animales no destinados al consumo humano en Galicia y se concretan determinados aspectos sanitarios de las explotaciones porcinas.

Date of document: 9th June 2016

Date of publication: 22nd June 2016 in the official journal of the region (Diario Oficial de Galicia, num.118)

Date of effect: 23rd June 2016

This regulation authorizes only the abandonment of carcasses of grazing horses in remote areas where collection would be impossible or too costly; the process should be done under official surveillance. It does not designate SFZs.

La Rioja

Decreto 25/2014, de 13 de junio, por el que se establecen en la Comunidad Autónoma de La Rioja las condiciones para la alimentación, dentro de las zonas de protección, de determinadas especies de fauna silvestre necrófaga con subproductos animales no destinados a consumo humano procedentes de explotaciones ganaderas y se regula el procedimiento de autorización.

Date of document: 13th June 2014

Date of publication: 18th June 2014 in the official journal of the region (Diario Oficial de La Rioja, num.75)

Date of effect: 19th June 2014

This regulation amends Resolución nº 489, de fecha 22 de mayo de 2012.

Navarra

Orden Foral 46/2014, de 25 de febrero, del Consejero de Desarrollo Rural, Medio Ambiente y Administración Local, por la que se regula el aporte de alimento para determinadas especies de la fauna silvestre con subproductos animales no destinados al consumo humano, el funcionamiento de los muladares de la Comunidad Foral de Navarra, se establece la zona de protección para la alimentación de especies necrófagas de interés comunitario y se dictan normas para su funcionamiento.

Date of document: 25th February 2014

Supporting Information for Time to monitor livestock carcasses for biodiversity conservation and public health

Date of publication: 7th March 2014 in the official journal of the region (Boletín Oficial de Navarra)

Date of effect: 8th March 2014

Madrid

No regulation enforced or drafted but in progress, i.e. initial documents under public consultation until 2nd February 2019.

Initial documents for consultation available at: <https://participa.madrid.org/content/proyecto-decreto-regula-alimentacion-determinadas-especies-fauna-silvestre-subproductos>

Last accessed 7th February 2019.

Murcia

Proyecto de decreto, por el que se regula la alimentación de determinadas especies de fauna silvestre con subproductos animales no destinados al consumo humano procedentes de explotaciones ganaderas en zonas de protección de la comunidad autónoma de la Región de Murcia.

Drafted regulation available at <http://transparencia.carm.es/-/proyecto-de-decreto-por-el-que-se-regula-la-alimentacion-de-determinadas-especies-de-fauna-silvestre-con-subproductos-animales-no-destinados-a-consu-1>

Last accessed 27th May 2018

País Vasco

Orden Foral 229/2015, de 22 de mayo, por la que se aprueba el Plan Conjunto de Gestión de las aves necrófagas de interés comunitario de la Comunidad Autónoma del País Vasco, redactado conjuntamente por la Administración General del País Vasco y las Diputaciones Forales de Álava-Araba, Bizkaia y Gipuzkoa.

Date of document: 22nd May 2015

Date of publication: 1st July 2015 in the official journal of the region (Boletín Oficial del Territorio Histórico de Álava, num. 77)

Date of effect: 2nd July 2015

DECRETO FORAL de la Diputación Foral de Bizkaia 83/2015, de 15 de junio, por el que se aprueba el plan conjunto de gestión de las aves necrófagas de interés comunitario de la Comunidad Autónoma del País Vasco.

Date of document: 15th June 2015

Supporting Information for Time to monitor livestock carcasses for biodiversity conservation and public health

Date of publication: 24th June 2015 in the official journal of the region (Boletín Oficial de Bizkaia, num. 119)

Date of effect: 25th June 2015

References

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