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# Are all conservation measures for endangered species legitimate? Lines of thinking with the European hamster

Florian Kletty<sup>1\*</sup>, Marie Pelé<sup>1</sup>, Fabrice Capber<sup>2</sup>, Caroline Habold<sup>1</sup>

<sup>1</sup>UMR7178 Institut pluridisciplinaire Hubert Curien (IPHC), France, <sup>2</sup>Other, France

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In review

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### *Author contribution statement*

FK and MP equally contributed to this work as the first author.

All authors brought constructive thoughts and participated in the elaboration and the redaction of this review.

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### *Keywords*

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### *Abstract*

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When dealing with the protection of an endangered species, it appears more and more important to address the ethical limits and the societal perception of the implemented conservation measures. This will be illustrated here through the example of conservation programs of the European hamster (*Cricetus cricetus*) in France. The main threats for this rodent are the impoverishment and fragmentation of its habitat due to recent changes in agricultural practices and urbanisation. Thus, the status of this species changed from harmful to endangered in only a few decades. This must lead to acceptance of the species by citizens and especially farmers paid to destroy this species until the 1990s while nowadays to protect it. To stem the decline, several measures have been taken through the last twenty years including population reinforcement, wild animal tracking, and implementation of suitable habitats. One can, therefore, discuss the efficiency of these measures and their integration in the entire socio-ecosystem. Population reinforcement and the questions that can arise from it will first be addressed. Secondly, in situ animal monitoring and implications of the methods used will be discussed. Third, we will deal with agricultural practices favourable to the species. Finally, we will highlight the links between European hamster conservation measures and wider problematics.

### *Contribution to the field*

To cope with biodiversity decline, conservation measures are currently taken by policymakers. In this review, we address the ethical limits and the societal perception of such measures through the example of the conservation of the European hamster (*Cricetus cricetus*) in France. The main threats for this rodent are the impoverishment of its habitat due to recent changes in agricultural practices and spatial fragmentation. It is also important to point out that the status of this species shifted recently from a pest to a protected species. This leads to mentality changes and acceptance of the species by citizens and especially farmers. In practice, several measures are still taken to stem the decline: some hamsters are bred in captivity and released in the field, wild animals are captured and marked to be monitored. This implies stress and invasive procedures and the risks and benefits of such approaches need to be discussed. Then, we deal with the importance to modify the agricultural practices conducted in Alsace to make them favourable to the species. Finally, we highlight why European hamster conservation measures are not only a solution of species' protection but an entire improvement of the whole socio-ecosystem, including farmers.

# Are all conservation measures for endangered species legitimate? Lines of thinking with the European hamster

1

2 **Florian Kletty<sup>†\*1</sup>, Marie Pelé<sup>†2</sup>, Fabrice Capber<sup>3</sup>, Caroline Habold<sup>1</sup>**

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4 <sup>†</sup> These authors contributed equally to this work

5 <sup>1</sup> Université de Strasbourg, CNRS, IPHC UMR 7178, F-67000 Strasbourg, France

6 <sup>2</sup> ETHICS EA 7446, Lille Catholic University, Lille, Hauts-de-France, France

7 <sup>3</sup> Clinique Vétérinaire, 68000 Colmar, France

8 **\* Correspondence:**

9 Florian Kletty

10 florian.kletty@iphc.cnrs.fr

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12 **animal ethics, environmental ethics, *Cricetus cricetus***

13 **Abstract**

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27 species. Finally, we will highlight the links between European hamster conservation measures and  
28 wider problematics.

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31

## 32 1 Introduction

### 33 1.1 Conservation measures for animal populations' protection

34 Human beings currently impose a very strong selection pressure on organisms, forcing them to  
35 adapt, move away or die. The impact of our species on the environment is particularly visible among  
36 other things by the creation of urban areas (Alberti *et al.*, 2017), the fragmentation of the territory  
37 (Cheptou *et al.*, 2017), the increase in global temperatures (Beaumont *et al.*, 2011), the introduction of  
38 pathogens (Rogalski *et al.*, 2017) or the loss of native biodiversity by the introduction of invasive  
39 species (Colautti *et al.*, 2017). Thus, *Homo sapiens* become the main evolutionary force at the global  
40 level (Palumbi, 2001; Hendry *et al.*, 2017). We have entered the sixth mass extinction crisis with a  
41 higher rate ever compared to earlier mass extinctions. The acceleration of the disappearance of fauna  
42 and flora caused by human activities is an assertion often used to alert people. Then, every informed  
43 people agree that protecting biodiversity in all forms is a priority, just like reducing global warming.

44 Protecting the habitat of species, in particular by reducing the threats that affect it, is a first so-  
45 called *in situ* conservation measure. It aims at maintaining populations in the environment where the  
46 distinctive characteristics of the species have developed and in which they can continue to evolve with  
47 their prey or food resources, predators and parasites. In addition, by reinforcing populations in their  
48 environment, conservation measures appear to allow a long-term success. Their importance was  
49 underlined in international conventions and legislation (e.g. Convention on Biological Diversity, Rio  
50 Earth Summit of 1992).

51 However, in theory as in practice, whether natural or encouraged by humans, the restoration of  
52 biodiversity is not always self-evident. Indeed, when considering the animals and the ethics devoted to  
53 it, two concepts emerge. *Animal ethics* itself considers the animal as an individual and will then refer  
54 to the study of the moral responsibility of humans regarding animals taken as beings. It therefore poses  
55 “the classic questions of human duties towards animals, possible animal rights and, more generally,  
56 moral judgements to be made on our current treatment of animals” (Vilmer, 2008). Next comes  
57 *environmental ethics* which consider animal species as a whole, as building blocks of the ecosystems  
58 in which they live (Vilmer, 2008). These two ethics devoted to animals are different and are often  
59 brought to clash. Indeed, in a lot of situations, the interests of the individual appear to be opposed to  
60 the interests of the collective (e.g. population, species or ecosystem), since the protection of habitat  
61 may be the cause of deleterious actions on individuals. A perfect example is the plan of the Australian  
62 government to kill about 2 million feral cats by 2020 to preserve the native Australian fauna from a  
63 high level of predation due to felines. On the other hand, we cannot minimize the suffering of these  
64 cats that are shot, poisoned or trapped. The case of Australia is extreme but protecting biodiversity  
65 often lead to conflicts of interest between different social groups or ecosystem users. In France, a  
66 striking example of such conflicts is the return of the grey wolf (*Canis lupus*) from Italy, which has  
67 become a real ‘sensitive case’ in the light of a very strong public opinion on this issue. Indeed, the  
68 French grey wolf case is a natural recovery and was not the subject of any reintroduction or population  
69 support plan. From an ecological point of view, a return to equilibrium is possible but some believe  
70 that wolf has not its place any longer because of its role of top-level predator and thus, possible human

71 competitor. Some lobbies do not hesitate to blame the carnivores for livestock slaughters leading to the  
72 rise of authorized shoots to 19% of the population of wolves in 2020.

73 Another example of ethics disagreement -and purpose of this paper- is the captive breeding of  
74 endangered species for the preservation of biodiversity. In Alsace (Northeast of France), several  
75 programs have been launched to preserve, reinforce or reintroduce animal emblematic species (white  
76 stork (*Ciconia ciconia*), Eurasian lynx (*Lynx lynx*), Western capercaillie (*Tetrao urogallus*), European  
77 otter (*Lutra lutra*)) of the region including the European hamster (*Cricetus cricetus*). Its case perfectly  
78 illustrates the gradient of consideration that humans can apply towards animals, from animal ethics to  
79 environmental ones. On one hand, the conservation plan aims at obtaining the recovery of the wild  
80 populations thanks to the release of hundreds of individuals bred in captivity –such action irrefutably  
81 affects the individuals- and the improvement of their living conditions by the establishment of  
82 ‘hamster-friendly’ cultures. On the other hand, these actions need to be sustainable by implementing  
83 practices that can reconcile environmental but also economic interests. However, the stakeholders here  
84 are numerous (scientists, NGO’s, policymakers, farmers, citizens) and accession is not always easy.  
85 Thus, the ethical or environmental concerns of some may come up against others’ view of the world  
86 that differed from the one they would have wished to promote more locally, notably within rural areas.

87 Through the European hamster case, we will here question different points to determine whether  
88 all conservation measures for endangered species are legitimate. At first, we will address population  
89 reinforcement and the questions that can arise from it. Secondly, *in situ* animal monitoring and  
90 implication of the methods used will be discussed. Third, we will deal with favourable agricultural  
91 practices that can be developed and the elements that can slow them. Finally, we will expose the  
92 interconnections of conservation measures for endangered species with other problematics and the  
93 benefits we can expect from them.

94

### 95 **1.2 The European hamster case: from agricultural pest to flagship species of Alsatian** 96 **biodiversity**

97 The European or common hamster is a small hibernating rodent found from Russia to the East  
98 of France, and more precisely in Alsace. European hamsters live in burrows dug in agricultural fields.  
99 It is a solitary species that only shows social interactions for the reproduction period from April to  
100 August. At the end of the summer, European hamsters prepare their next hibernation period – from  
101 October to April- hoarding food in their burrows.

102 Since the 1990 Bern Convention on the Conservation of European Wildlife and Natural  
103 Habitats, the European hamster is a strictly protected species (Annex II of Bern Convention). The  
104 common hamster was also included in the Annex IV of Habitats Directive (92/43/EEC) in 1993. Listed  
105 as Least Concern at the global level in the IUCN’s red list of Threatened Species, European scientists  
106 urgently requested its reclassification as Vulnerable species for many years (24<sup>th</sup> International Hamster  
107 Workgroup meeting; Surov et al., 2016). It is only in 2020 that the common hamster obtained the status  
108 of Endangered Species (Banaszek et al., 2020). Indeed, its range has declined in almost all areas it was  
109 present during the last century, especially in western Europe but also more recently in central and  
110 eastern Europe (Stubbe and Stubbe, 1998; Surov *et al.*, 2016). This is for example the case in Poland

111 and the Czech Republic where populations have already significantly decreased (Ziomek and  
 112 Banaszek, 2007; Tkadlec et al., 2012). The common hamster has already disappeared or regressed in  
 113 many provinces of Eastern Europe and Russia where it was present, and if the evolution of populations  
 114 continues in the same way, more than 70% of the population could disappear in these provinces (see  
 115 Surov *et al.*, 2016). In the western part, for example in the territory regrouping Belgium, the  
 116 Netherlands and the German land of North Rhine-Westphalia, the hamster has declined by more than  
 117 99% in recent decades (La Haye et al., 2012). Agricultural practices, habitat's fragmentation, fur  
 118 trapping but also the impact of climate change and urban pollutions on the rate of reproduction of  
 119 females have been identified as possible causes of such decline, even if the mechanisms are still  
 120 difficult to identify for some (Stubbe and Stubbe, 1998; Monecke, 2014; Surov et al., 2016).  
 121 ~~(Stubbe and Stubbe, 1998; Monecke, 2013; Surov et al., 2016).~~

122 In France, the common hamster is only present in Alsace where hamsters' trapping and killing  
 123 were common until the 1990's. Since one individual can hoard up to more than ten kilograms of food  
 124 in its burrow for hibernation (Nechay *et al.*, 1977) and with the explosion of population documented  
 125 during the 20<sup>th</sup> century, one may understand that the European hamster was considered as an  
 126 agricultural pest causing crop damage. At this time, farmers' children even earned pocket money for  
 127 hamsters' fur. But during the 1970s, the habitat of the European hamster in Alsace began to change:  
 128 agricultural practices evolved to single-crop farming, small villages expanded their urbanization plans,  
 129 and more and more roads infrastructures appeared dividing the landscape. All of these factors  
 130 converged to disastrous consequences on hamsters' populations in Alsace. The common hamster has  
 131 disappeared from the vast majority of its historical Alsatian range and is now only present in 18  
 132 municipalities compared to the 329 municipalities in 1972 (Figure 1).

133 Moreover, the plans of protection (breeding programme and two National Action Plans)  
 134 implemented in France at the beginning of the 2000s were considered as not sufficient by the European  
 135 Union Court of Justice (EUCJ) which condemned France in 2011 for the non-respect of Habitats  
 136 Directive (Case C-383/09). Indeed, as a Directive's State Member, France has the obligation to take  
 137 all the measures necessary to establish a system of strict protection in their natural range of the animal  
 138 species listed in this annex (O'Brien, 2015). Then, from the most hated animal in Alsace, the European  
 139 hamster became the most protected one by international (Bern Convention), European (Habitats  
 140 Directive) and national legislations in only a few decades. The European hamster was and is still the  
 141 target of National Action Plans (NAP): a total of four NAPs cumulating 21 years of actions of  
 142 conservation from 2000 to 2028 (Figure 1). Moreover, the status reversal of the common hamster has  
 143 been so radical that feelings of human populations living with the hamster (farmers and citizens) were  
 144 hatched leading the European hamster to become without any doubt the most controversial species in  
 145 Alsace (Losinger et al., 2006; Méchin, 2007, 2011, 2013).

146 Alsace is one of the most agricultural regions of France counting 40% of exploited lands  
 147 (Agreste, 2020). The maize culture is one of the most important, not only for alimentation or seeds but  
 148 also for biofuel or bioplastic (Méchin, 2011). Yet, it has been shown that maize as monoculture  
 149 negatively impacts the survival of European hamsters by a lack of protective cover part of the year, but  
 150 also the behaviour of mothers who killed their pups at parturition because of a lack of vitamin B3 and  
 151 essential amino acids (Tissier *et al.*, 2016a, 2017). Then, farmers were and are still the most impacted

152 by conservation plans for the European hamster. However, the top-down policy-making process did  
153 not facilitate the relations between the different local actors since the animal as its protection was  
154 mostly felt as being imposed by others' decisions (politics and scientists) instead of being fully  
155 appropriated by farmers (Losinger et al., 2006; Méchin, 2013). Of course, the appearance of such  
156 group-conflicts and reactance processes are well-known to challenge the success of conservation plans  
157 (Lüchtrath and Schraml, 2015). On a larger scale, with larger mammals such as the European otter or  
158 the Eurasian lynx in France, the limiting factor appears to be only anthropic (Laurent, 2014). In these  
159 examples, fishers and hunters respectively do not accept the presence of those whom they regard as  
160 their direct competitors. Stakeholders as well. This led to a major ethical issue: shall we favour humans  
161 or animals? Why is it so difficult to favour both? And more importantly, how do we even get to the  
162 question of our legitimacy to choose between both?

163         When considering the protection of a species and more generally biodiversity, two approaches  
164 are possible. The first consists in the establishment of protected areas in which human activities are  
165 strongly regulated or prohibited, leading to land-use conflicts. There is no doubt that in any case, it will  
166 require permanent protection of animals and their habitat. A second approach involves integrating the  
167 protection of biodiversity and ecosystems into human socio-economic activities. Both strategies have  
168 been applied in the case of the European hamster.

169         Studies and surveys of hamsters' populations have been carried out in several European  
170 countries including Germany, Poland, Czech Republic, Netherlands, Belgium, Austria and France. The  
171 decreasing of most of the populations led to the setting of protected areas. For example, in 2002,  
172 protected areas have been created in the Netherlands to reintroduce a hamster population in a  
173 favourable habitat (Müskens et al., 2005; La Haye et al., 2010). Such conservation plans (habitat  
174 protection and restocking measures) have also been carried out in Belgium (Verbist 2007; Verbeylen  
175 *et al.*, 2007), in Poland where wild animals from Czech Republic have been released as genetic support  
176 for the Polish population of Jaworzno (NAP 2019-2028), as well as in Germany (please see Weinhold,  
177 2008 for an inventory of measures for each Federal states). In Alsace, population reinforcements of  
178 European hamsters are carried out since 2000 in three priority restocking areas with animals coming  
179 from breeding facilities. Releases performed in these areas lead to good results and hamster's  
180 population grew the first years, but after this time hamster's population decreased again and remain  
181 still low. The reasons for this partial failure seem to be an attraction of predators since hamsters were  
182 concentrated in a small area but were absent elsewhere (Villemey *et al.*, 2013). Thus, these areas  
183 appeared for some as sanctuaries allowing protection managers to conduct their actions but also  
184 allowing the out-of-areas farmers to be not concerned by the hamsters' protection following the Not-  
185 In-My-BackYard (NIMBY) principle (Méchin, 2011).

186         A second and more hand-in-hand - or at least holistic strategy - has been developed in France  
187 in 2013 with the beginning of the European granted LIFE+ Alister project. Until its end in 2019,  
188 different actors such as farmers, scientists, NGOs, policymakers operated together to conduct  
189 discussions with hamster opponents, to breed and release individuals, to study the ecological needs and  
190 biology of the species, but also to investigate the social dimension of the ongoing hamster conservation  
191 plan and improve the popularity of the species. A similar strategy was established in Germany with the



192 Feldhamsterland program led by the NGO Deutsche Wildtier Stiftung which aims at targeting the  
193 best measures to protect the German hamsters' populations in collaboration with farmers and citizens.

194 In Alsace, at the beginning of the LIFE+ Alister project, an important step was to identify  
195 negative and positive trends considering the public opinion concerning *Cricetus cricetus* and its  
196 protection plan. Indeed, even if the term 'pest' has been banned from the French legal vocabulary - and  
197 been replaced by the classification 'susceptible to cause significant damages (...) ' - it is still a common  
198 word used by citizens to qualify the European hamster. In 1993, Micoud already asked the question  
199 'How to get rid of so-called pests?'. A first process proposed by the author is the animal's rehabilitation  
200 meaning that its social representation must change positively. This step was and is still not easy  
201 considering the European hamster history in Alsace.

202 A first study focused on the image of the European hamster in articles of regional newspapers  
203 and websites (ACTeon, 2013). When concerning the European hamster, 52% of the articles showed  
204 positive arguments considering its protection whereas 37% appeared more negative about the rodent  
205 and 11% were neutral considering land and territory use mostly. People entailed in the protection of  
206 the European hamster also did not demonstrate the same level of perception. While the agents of its  
207 conservation kept the distance and stayed neutral, the European hamster was considered as a disaster  
208 for politics, and as a victim for the NGOs representatives (ACTeon, 2013). Still today, the European  
209 hamster is the figurehead of actions carried out by environmental NGOs or the totem of the eco-friendly  
210 'tribe' as Méchin (2011) pointed it out. In 2014, a second study using questionnaires and interviews  
211 focused more on Alsations' perception and knowledge about the European hamster (ACTeon, 2015).  
212 Results showed that a large majority of population questioned (90%, 700 persons) knew about the  
213 European hamster's critical situation but only 1 person on 5 was aware of the different protective action  
214 plans. More interestingly and in details, elder people knew the European hamster (96% of the more  
215 than 60 yo) but not its critical situation, conversely to youngest people who knew less the animal (66%  
216 of 18-30 yo) but its situation better (ACTeon, 2015). Benefiting from this knowledge, LIFE+ Alister  
217 project' partners conducted actions of communication towards civilians living close to the European  
218 hamster, notably targeting young public such as children. Regrettably, at the end of the program, the  
219 social image of the European hamster did not evolve so much but one may protest that 3 or 4 years are  
220 too short to measure the impact of the conducted actions at such big scale (ACTeon, 2019).

221

## 222 **2 Population reinforcement**

223 When the conservation status of a species becomes very bad somewhere or if populations are  
224 quickly decreasing, it can be necessary to reinforce them to avoid local extinction of the species. The  
225 reinforcement can occur in the residual area where individuals still survive, to increase their probability  
226 to subsist across time. It can also be done in the area between two sub-populations to maintain the  
227 connectivity between them and to increase the area of the presence of the species.

228 When talking about species conservation and especially with population reinforcements,  
229 genetic considerations have to be taken into account. Genetic diversity in populations has to be  
230 preserved to keep at a high level the fitness of the endangered species. For instance, it has been  
231 demonstrated that the habitat fragmentation of a small rodent-like the European hamsters can lead to  
232 low diversity in the population and threaten the species locally (Reiners *et al.*, 2011). If genetic

233 diversity decreases too much, it can be necessary to introduce animals from other phylogeographic  
234 groups to improve the survival chances of the population (Melosik *et al.*, 2017). But to be successful,  
235 there are other several prerequisites for population reinforcements to fulfil. We will examine these  
236 prerequisites in the next section and expose what has been done for the European hamster and the  
237 results that were obtained.

238

### 239 **2.1 Pre-releasing requisites**

240 The main goal of all wildlife release programs is to put back into their natural habitat animals  
241 that will be able to survive in suitable conditions with long-term resources and a minimum of  
242 disturbances. To achieve this goal, two pre-requisites appear of major importance: animals 'ready' to  
243 be released and suitable habitats. But before even thinking of releasing animals, we should give regard  
244 to the ethical question: are captive animals really able to return to the wild and thrive? Of course, we  
245 are not talking here about animals that spend their all lives in captivity in zoos or circus, but about  
246 animals that are specially bred to be freed, not or little used by humans. Even bred during a short period,  
247 animals can become more or less habituated to humans despite the efforts taken to avoid such a  
248 situation. Then, it might be important to consider (1) to only release individuals that are not habituated  
249 -or at least less habituated- or (2) to disaccustom individuals before the release. The first strategy seems  
250 adequate when considering young individuals shortly after weaning, mimicking a natural dispersion  
251 from their native burrow. For its part, the second strategy involves multiple stages. The animals can be  
252 released into temporary enclosures with vegetation to hide and with some additional food or preys to  
253 hunt. Another advantage, the fences protect them against natural predators or disturbance. Ideally, these  
254 enclosures should be installed in natural reserves or at least in protected and controlled areas. Thus, the  
255 animals will have time to gradually get used to their new life. Some may even breed in the enclosures  
256 and produce wild offspring never handled by humans that can be released on other plots afterwards.  
257 Depending on the species this step will take more or less time. In larger mammals, especially social  
258 animals, this step is essential to create groups. Solitary animals can spend a shorter time in the pre-  
259 release enclosure. In the case of the European hamster, releases were done in fields with unharvested  
260 wheat and surrounded by electrical fences, to provide food and limit predation during the first weeks  
261 of their free life. Unfortunately, sometimes these enclosures can become deadly traps if predators find  
262 their way in (Villemey *et al.*, 2013).

263 Furthermore, all species cannot be released the same way. If we talk about mammals, it might  
264 seem easier to free thousands of rodents with high reproduction rates than a few large mammals whose  
265 reproduction rates are lower. At the individual level, most rodents will certainly not survive very long  
266 but the species as a whole will probably make it out whereas the large mammals will be more successful  
267 in the short term but with an uncertain future, mainly due to human pressure (notably illegal hunting).  
268 In the case of the French European hamster, it is clear that one may ask why such a rather prolific  
269 species (1 to 3 gestations a year of 3 to 12 young) remains endangered after twenty years of  
270 conservation measures and more than three thousands of individuals released.

271 The answer to this question leads us to the second pre-requisite: the suitability of the habitat.  
272 Finding a natural environment suitable for released animals appears to be a real challenge nowadays  
273 in a continuously human-disturbed world. Living in crops, European hamsters' survival is clearly  
274 linked to agricultural management, notably the presence of vegetation cover to protect them against  
275 predators and provide food resources. This is only possible if farmers modify their agricultural  
276 practices (see the specific section below).

## 277 2.2 Reinforcement or habitat improvement: where is the priority?

278 The mortality of released European hamsters is still too high to allow a sustainable increase in  
 279 the population. We can then question ourselves on the merits of such action knowing that freed animals  
 280 will die massively because habitats are not suitable. Should we not first improve all habitats sustainably  
 281 before releasing hundreds of individuals? On the other hand, habitat improvement is a long process.  
 282 Can we do nothing to save the species in the meantime? Certainly not. Even if not easy, it seems  
 283 preferable to strike the balance between both issues, animal and environmental ethics. Keeping the  
 284 species under passive dependence preventing it from disappearing while working on environmental  
 285 improvements is precisely what is done by the French hamster programs (LIFE+ Alister and NAP).  
 286 Moreover, reinforcing populations while gradually improving habitat has many advantages and seems  
 287 more suited to current societal constraints (see Table 1).

288 When populations have totally disappeared, the strategy may be different. Let us consider for  
 289 example a well-studied species, the European otter (*Lutra lutra*). The French otter population  
 290 underwent a continuous decline during the second part of the last century due to illegal hunting, habitat  
 291 loss and water pollution (Kuhn and Jacques, 2011). The reintroduction of animals from remote  
 292 geographical origins is not recommended, because of a risk of outbreeding depression and potential  
 293 reduction of the fitness and long-term survival of the population (Randi *et al.*, 2003). Thus, in this case,  
 294 it appears more suitable to restore habitats and increase connectivity among residual animals via natural  
 295 corridors. In the case of European otters, efforts to protect and rehabilitate such habitats have paid off  
 296 and otters recolonized areas throughout France over the past twenty years with regional variations  
 297 (Lemarchand *et al.*, 2016). But could this strategy of recolonization be applied to hamsters? Although  
 298 the French hamster population is isolated from other residual European populations living in very  
 299 different habitats, the solution could be similar on a local scale: protecting residual wild population  
 300 nuclei and improving the surrounding habitats little by little to allow a natural recolonization. Again,  
 301 the key issue is to change agricultural practices to find suitable crops for both hamsters (i.e. ecologically  
 302 durable) and farmers (i.e. economically viable). This is what research is focusing on even if such  
 303 strategy can take decades and requires considerable human and financial investments.

304

## 305 2.3 Problems risen by releasing programs

306 Releasing animals is accompanied by many constraints or problems. First, some people are  
 307 strongly opposed to breeding in captivity. They consider that captivity is not acceptable and/or that  
 308 breeding conditions in cages are not optimal. Secondly, the mortality level after release can be  
 309 considered as too high from the animal ethics perspective, as already exposed above. Finally, the high  
 310 number of individuals that reinforce core populations might pollute or dilute the genetic pool present  
 311 in the wild population, and may be seen as a potential threat for its survival. These questions have to  
 312 be kept in mind to minimize as much as possible potential problems, but have not been identified as  
 313 prohibitive for European hamster restocking programs in France.

314 Another problem that can be encountered with releasing programs is the regulation of predators.  
 315 For prey species like the hamster, predation pressure is a key determinant of their survival (Kayser *et al.*  
 316 *et al.*, 2003; La Haye *et al.*, 2010; Villemey *et al.*, 2013). Since many efforts are needed to breed and  
 317 release animals, some people may ask for predator regulation to limit predation on released animals.  
 318 Such a measure can be taken even though predation is a natural process, i.e. part of the food chain, and  
 319 despite its low efficiency. Indeed, predator regulation has generally no significant and durable effect  
 320 on the global predation rate of the prey (La Haye *et al.*, 2008; Treves *et al.*, 2016). The killing of  
 321 predators can, however, be considered in programs like NAP since they result in the participation of

322 many stakeholders, including hunters (Virion and Thouvenot, 2019). It is sometimes a wiser choice to  
323 consider this possibility -while trying to convince to never apply it- than showing strong opposition to  
324 it, leading to group reactance.

325

### 326 **2.4 Results of hamsters' releasing programs**

327 Since the early 2000s hamsters are bred in France to participate in restocking programs. On one  
328 side, given the drop in hamster's population at this time and since the species is now still present in  
329 three distinct areas of the region, we can consider that it is a success. Furthermore, releasing allowed  
330 to maintain the species in the region and conserve genetic diversity (Reiners *et al.*, 2014). On the other  
331 side, populations are still not really increasing because of a high predation rate of released animals on  
332 some plots. An improvement of release protocols is currently under study. One way would be to limit  
333 the impregnation of the animals during captivity or prepare them for wildlife in pre-release enclosures  
334 (Virion and Thouvenot, 2019).

335 We cannot predict the situation we would face without this program, but we know that only one  
336 small part of the presence area in Alsace did not need and benefit from any restocking program, *i.e.* the  
337 area close to the city of Obernai. These last years, the Alsatian population started slightly to increase.  
338 However, this is not a demonstration of a general improvement of the situation since the area of  
339 presence of the species is still not increasing. Population increases only in a few areas where population  
340 reinforcements have been accompanied by habitat improvement during several years. This illustrates  
341 the benefits of a conjugate use of those two conservation measures, and a wider application is now  
342 needed.

343 Another illustration is the restocking programs that occurred in the Netherlands (Müskens *et*  
344 *al.*, 2005; La Haye *et al.*, 2010). There, the species was extinct in the wild in 2002, and restocking  
345 programs started the same year. Some hamsters' releases occurred in farmland reserves, *i.e.* fields  
346 bought by the government and managed by nature conservation organisations. Other ones occurred on  
347 fields where farmers signed a contract to implement measures favourable to hamsters. Both releases  
348 led to a nice increase in hamsters' population already during the first years.

349

## 350 **3 *In situ* animals' monitoring**

351 While studying an endangered species, monitoring individuals in the wild is often a necessity  
352 for several reasons. It can first help to assess the size and characteristic of the residual populations. It  
353 allows also to evaluate the benefits of the measures taken to protect the species. Last but not least, it is  
354 an important tool when studying *in situ* a population to better understand its biology or ecology, which  
355 is helpful to better protect it. The impact and a cost-benefit assessment have however to be evaluated,  
356 including ethical considerations. Kletty *et al.* (2019) summarized and compared the different methods  
357 available to monitor small mammals like the European hamster. Hereafter, we discuss some of them  
358 and their implications.

359

### 360 **3.1 Capturing and tagging animals**

361 The capture of an animal is a way to gather many data or information about it. It can be weighed  
362 and measured, and samples of faeces, hairs or blood can be taken for later analysis. At the same time,  
363 individual identification can be done allowing to recognize it later. Different methods can be used: i)

364 photo-identification, if the species have fur or skin patterns that differ from one animal to another like  
 365 with some felines or amphibians. ii) External tags like rings, bands, ear punches, toe clipping, tattoo.  
 366 iii) Internal systems like passive integrated transponders (PIT) for radiofrequency identification  
 367 (RFID).

368 Almost all these methods can have an impact on animals since they require animals to be  
 369 trapped. This can cause stress, but also prevent the animal to perform its natural activity during the  
 370 time of capture. The issue can be dramatic especially when they have new-borns that need protection,  
 371 thermoregulation or regular feedings. The capture of an animal can also modify or prevent some  
 372 behaviours at key periods like reproduction or disturb social groups (Minteer *et al.*, 2014). Even photo  
 373 identification in some cases needs the capture of animals to take good pictures or specific parts of the  
 374 body (like the belly of some amphibians).

375 The stress generated by handling procedures can be increased if there is additional pain linked  
 376 to the method, and this can also affect other biological parameters like body condition or survival  
 377 (Tamarin and Krebs, 1969; Pavone and Boonstra, 1985). However, knowledge about the biology of  
 378 organisms and pain increase, encouraging scientists to question continuously the existing procedures.

379 In this sense, the use of PIT-tags is an interesting method. It is no more painful than a syringe  
 380 injection, easy to use and works for life. Another advantage of PIT-tags is that it can be combined with  
 381 automated identification recorders to monitor the presence or movements (*e.g.* wildlife underpasses or  
 382 burrows), biological parameters (*i.e.* coupled with a weight-watcher) or behaviour (coupled with  
 383 camera) of animals, without requiring their recapture (Tissier *et al.*, 2018a; Kletty *et al.*, 2019). Dying  
 384 and ringing are other ways to gather information on the presence or behaviour of specific individuals  
 385 since it allows a direct or indirect (*via* cameras) recognition. However, even if these methods are  
 386 painless, they can sometimes bother the survival or fitness of individuals, as it has been shown in  
 387 penguins (Culik *et al.*, 1993; Froget *et al.*, 1998; Saraux *et al.*, 2011).

388 All these methods of individual identification allow performing capture-mark-recapture (CMR)  
 389 studies, which consist of capturing, tagging, releasing, and trying to recapture animals later. CMR is  
 390 interesting to collect longitudinal information on individuals, evaluate survival and population size or  
 391 dynamics (by integrating the rate of unknown individuals and performing statistic corrections or  
 392 modelling) (Pradel, 1996; Bohec *et al.*, 2007).

393 Field studies on hamster populations in France are done with such CMR approach where all  
 394 individuals captured, released or participating to experiments are identified with PIT-tags, with the use  
 395 of RFID automatic antennas in different studies and situations. Earrings have also been used in a  
 396 specific study to recognize individuals on camera traps pictures. At the time of capture, body mass and  
 397 tibia length are measured, and material like faeces or hairs can be collected for genetic analysis. During  
 398 periods where females can be lactating, special attention is given to minimize the time between the  
 399 trapping of the animal and its release.

400

### 401 3.2 Transmitters to follow animals

402 Knowing the localization of specific individuals in the wild can provide valuable information,  
 403 like home range or reproductive success. However, some ethical questions can arise with logger-  
 404 transmitter equipment, especially intra-abdominal implantation of transmitters. The proximal issue  
 405 with implantation is surgery that can cause suffering or even death. After surgery, implants can also  
 406 affect on a long-term behaviour and the survival of animals. These questions have been assessed by  
 407 Koehler *et al.* (1987) in a study carried out on four species of small rodents: they show a mortality risk

408 with surgery (14% in their study but they indicate how to improve it), but a good survival after the  
409 release (more than 94% after 1 month). Nowadays, survival after surgery is now much better and can  
410 reach 100% after implantation of transmitters for hamsters (Capber, 2011). Furthermore, some of the  
411 transmitters in Koehler *et al.* exceeded 10% of the mass of animals while it is now recommended not  
412 to exceed 3 to 5% (Macdonald and Amlaner, 1980; Theuerkauf *et al.*, 2007). In France, European  
413 hamsters are only implanted when their body mass exceeds 150g. The transmitter weighing 6.5g does  
414 therefore not exceed 4.3% of the body mass of the hamster and thus, it does never exceed the  
415 recommended range. It explains partially the good tolerance observed in the field. Furthermore, the  
416 transmitters do not seem to impair gestation (Capber, 2011). Thus, it is possible to implant loggers and  
417 transmitters without marked impact on the survival of individuals or on a population. However, since  
418 it is an invasive protocol - even moderate - it has to be used when expected benefits are high enough  
419 for the monitoring of equipped individuals, and only when necessary.

420 The use of external transmitters is also possible and does not require surgery, but it can have  
421 adverse effects on animals, like handicap (especially collars for hamsters, since they have cheek  
422 pouches), perturbation of its behaviour or survival impairment (Webster and Brooks, 1980; Theuerkauf  
423 *et al.*, 2007; Kletty *et al.*, 2019). Thus, if internal transmitters can be used, it seems to be a more suitable  
424 option.

425 Transmitter implantation and animal tracking may affect and disturb animals. On the other  
426 hand, the information gathered by such monitoring appears crucial to protect endangered populations  
427 and improve conservation measures. Once again, enlightened choices have to be made and the balance  
428 must be found to minimize the effects on individuals and the protection of the population.

429

## 430 **4 Modification of agricultural practices**

431 In Alsace, intensive agriculture from the 1950s onwards led to the degradation of the  
432 agricultural ecosystem and the loss of biodiversity. As an illustration, the decline of the European  
433 hamster can be mainly attributed to the lack of protective and nutritional cover part of the year.  
434 Therefore, it is primordial to restore habitat quality to increase hamster's populations, and this ideally  
435 before the reinforcements (see Table 1).

436

### 437 **4.1 What are hamster's needs?**

438 The European hamster is an omnivorous rodent that can feed on a wide variety of food and that  
439 can adapt to different environments (Nechay *et al.*, 1977; Tissier *et al.*, 2019b). Despite this flexibility,  
440 nutrition requirements are often not met in its habitat to allow good development of the population.  
441 Maize cropping is deficient in essential amino acids and vitamins, whereas wheat monoculture that is  
442 however considered as a favourable crop, does not contain enough proteins to ensure a proper  
443 reproduction of hamsters (Tissier *et al.*, 2016a, 2017, 2018b; Weitten *et al.*, 2018). Protein-rich plants  
444 (legumes) or animals (invertebrates, voles, *etc.*) are interesting food supplies that cover these  
445 deficiencies. A diversity of food resources is, therefore, a key issue to restore hamsters' reproduction  
446 and increase the population.

447 The crop in which they live provides hamsters also a protective cover against predators.  
448 However, this cover can be reduced or removed by the work of farmers, like harvesting, mowing or  
449 ploughing, resulting in increased exposure to predation (La Haye *et al.*, 2010, 2014). It has also been



450 observed that such removing of the cover leads to an increased emigration of hamsters out of the  
451 concerned plots, threatening their survival (Kayser *et al.*, 2003; Kourkgy, 2019).

452 Last, the expansion of anthropogenic infrastructures especially roads, linked to unsuitable  
453 agricultural habitat like ploughed fields, limit the movement of animals and the connexion between  
454 different sub-populations (Tissier *et al.*, 2019a). To improve that, underpasses for wildlife have been  
455 constructed under highways and then improved with anti-predation devices to secure the crossing of  
456 small mammals (Tissier *et al.*, 2016b). To be more efficient in reconnecting residual populations safely,  
457 these underpasses need also to be surrounded by favourable habitats. Thus, agricultural practices have  
458 without doubt a key role in this habitat connectivity.

459

## 460 **4.2 How to implement suitable habitats?**

461 To offer to hamsters the diversity and quality of food they need, a first way could be to use less  
462 or no pesticides in the considered fields. Indeed, these products can have negative effects on hamsters'  
463 survival and reproduction, but also alter their food resources. Pesticides kill adventive plants and also  
464 other organisms, from soil bacteria and fungi to invertebrate macrofauna (Edwards and Thompson,  
465 1973; Joy and Chakravorty, 1991), therefore reducing the diversity of food sources for hamsters and  
466 impairing their reproduction.

467 A second way to improve hamsters' habitat is to foster epigeous and endogenous fauna through  
468 adapted agricultural practices bringing them protection and food. Soil disturbance reduction (like  
469 ploughing or tillage suppression or reduction) can be important to increase soil organisms' biomass  
470 (Norris *et al.*, 2016; Chen *et al.*, 2020). This can be achieved by covering the soil with mulch or living  
471 cover, and the holding or the promotion of a maximum of carbonated matter on the fields (non-exported  
472 straws, manure, increased covercrops...). Promoting the presence of different crops at a reduced  
473 distance is also a solution (Sirami *et al.*, 2019). This is especially true since the home range of female  
474 is only 0.2ha (Ulbrich and Kayser, 2004). The implementation of strips of two (or more) different crops  
475 on the same plot, (allowing mechanization and crop diversification at the same time), or simply creating  
476 long but small plots seeded with different crops, would increase plant diversity at a small scale. It  
477 would be also interesting to consider other innovative practices like relay cropping and crop  
478 associations, which bring diversity on a smaller scale (less than a meter). All of these possibilities  
479 would bring shelter for hamsters by the time of mowing or harvesting.

480 As mentioned above, the persistence of a cover along time is important for hamsters, as much  
481 for the shelter as for the food it brings. This can be achieved by seeding intercrop cultures like the ones  
482 seeded to catch nitrogen residuals. However, such crops usually grow too late to be beneficial for  
483 hamsters. The practice can be improved either with early implantation of the intercrop just after the  
484 harvest or by seeding directly a cover crop in an already growing one (*e.g.* clover under-seeded in  
485 wheat or maize).

486 What kind of agriculture functioning at a large scale could provide the different services and  
487 integrate the methods exposed above? Some of them can be filled with organic agriculture, which is  
488 moreover already well integrated by citizens. However, it still usually (but not always) works with  
489 monospecific crops and bare soils, especially for weed control. Other types of agriculture are rising  
490 and aim to develop healthier soils and more biodiversity in agricultural systems. We can find it under  
491 different names like soil conservation, conservation agriculture, agroecology, biodiversity-based  
492 agriculture, or ecologically intensive agriculture. Even if there are many variations in concrete  
493 applications of these innovative agricultures, they all rely on the same principles of - improving soil  
494 quality, - increasing the diversity of plants and habitats along time and space, and - integrating in a

495 holistic approach the relations between the multiplicities of organisms living in the ecosystem (Duru  
496 *et al.*, 2015; Wezel *et al.*, 2018; Chabert and Sarthou, 2020).

497

### 498 **4.3 Why is it so difficult to modify agricultural practices?**

499 We know a lot of elements and practices that may be beneficial for hamsters, but the aim is not  
500 to implement them only on restricted areas, whereas its habitat is impoverished everywhere else.  
501 Instead, social and economic context should be taken into account to develop at a large scale, practices  
502 that would benefit all parties, including biodiversity and farmers.

503 First, it is necessary to understand that the solutions beneficial for farmland biodiversity are  
504 based on the modification of the actual agricultural practices. As with any change in habits, this is not  
505 easy to achieve. This is especially the case when it comes to change the relation a farmer has with its  
506 soil, when its management and especially ploughing is questioned. It has indeed been shown that this  
507 relation is a key element for farmers since it is one of the last element they still control, while many  
508 other competencies are delegated to external operators (Christen, 2011).

509 Developing innovative practices is also difficult since no turnkey solution exists, and while  
510 farmers are advised by agricultural consultants to perform conventional agriculture and use pesticides.  
511 To leave this system, they have to break away from usual structures, and to adapt what is known to  
512 their specific context and then try to find the best solutions. This implies a good understanding of  
513 ecological processes at work on the agricultural ecosystem. In general, only farmers with advanced  
514 agronomic knowledge develop agroecology-based practices. Anyway, the transition between  
515 conventional and biodiversity-based agriculture takes time, since it relies on long-term processes like  
516 soil biodiversity and carbon stock enhancing, or predator-prey balancing. The first years of transition  
517 can thus be particularly difficult for farmers since they face the disadvantages of the new practices but  
518 still not all the advantages (Fiorini *et al.*, 2020). Therefore, there is risk associated and a cost to think  
519 outside the box.

520 Negative externalities in agriculture (*i.e.* indirect cost associated with agriculture like water  
521 pollution or biodiversity loss) (Catarino *et al.*, 2019) are generally not supported by farmers. Thus,  
522 agricultural practices that limit such externalities generally do not benefit from associated retributions  
523 for the efforts performed. There are exceptions for organic farming since it is well recognized and  
524 receive financial support especially for the conversion period to such agriculture (even if it is not  
525 always considered as sufficient). It would be interesting to extend such programs to farmers involved  
526 in agroecology since the positive externalities can be important, and because the cost paid by farmers  
527 to change the system is high.

528 To implement more biodiversity at a landscape scale and help hamster's population to survive,  
529 farmers have also to work together, which can modify their habits. They have indeed to decide together  
530 upon crop rotation of a defined area to maximise the surface of favourable crops where hamsters subsist  
531 and maintain coherence across space and time. Furthermore, the specific material that can be needed  
532 for conservation agriculture (like specific seed drills) is expensive and requires sometimes farmers to  
533 gather to reduce the associated cost. For those reasons, modification of practices to better integrate  
534 biodiversity can lead to a modification of the relations between farmers, which is not always easy and  
535 can require specific coordination.

536 Finally, the last hurdle we can talk about is associated with social perception. In our societies  
537 with task repartition, we delegate to farmers the production of our food. In that context, we can wonder  
538 if it is the consumers and not the farmers that would have the biggest responsibility in the ecological



539 implications linked to agriculture. In one hand, farmers think usually that their actions are limited since  
540 they have to follow the law of the market, so it should be consumers that have to pay the right price if  
541 they want ecology to be considered. In the other hand, consumers think that farmers are responsible  
542 for diverse pollutions and should take the responsibilities linked to what and how they produce. Thus,  
543 an opposition develops between different groups: consumers and farmers, but also environmentalists,  
544 hunters, scientists, politics, *etc.* This is linked to the social identity theory and psychological reactance,  
545 as illustrated by Lüchtrath and Schraml (2015) in the context of hunter's opposition to large carnivores.  
546 They show that the different groups are in reactance with what can be proposed by others, to protect  
547 their social identity. Thus, it seems particularly important to build positive relationships to avoid such  
548 reactions of different groups of actors.

549 In the context of European hamster preservation in France, many of the difficulties cited above  
550 have been limited by the measures developed. The programs have been conducted with a great  
551 implication of farmers. They are not set aside while other stakeholders decide what has to be done, but  
552 they are involved in the studies, participate in the decisions, try new practices or propose possible  
553 improvements. Group-working needed to perform favourable crop rotation or agricultural trials lead to  
554 good relations, discussions and sharing between farmers and with other stakeholders. Furthermore,  
555 specific demonstrations or formations have been proposed in relation to conservation agriculture,  
556 especially with the help of the Agriculture Chamber of Alsace that is also implicated. Farmers are also  
557 encouraged by financial support especially for favourable crop implementation and specific material  
558 to share. They are also now encouraged to promote hamster's presence rather simply developing the  
559 means in favour of biodiversity, since a bonus is given for each favourable crop containing hamster's  
560 burrows. Thus, the protection of a small rodent helps to initiate or develop a transition toward more  
561 sustainable agriculture and a change in practices and states of mind.

562

#### 563 **4.4 The European Union: a leverage or a barrier for the conservation of the European** 564 **hamster?**

565

566 The European Union offers financing tools for the preservation of biodiversity, such as Life  
567 programs. After the condemnation of France by EUJC in 2011, the common hamster benefitted from  
568 such European funding (LIFE+ Alister program from 2013 to 2019) which, in our case, aimed to  
569 improve the habitat of the species, to find new areas favorable to the reintroduction of the species, and  
570 whose educational component to make the species known and welcomed by Alsatians was very  
571 important.

572 However, there were still obstacles to the implementation of some environmental measures that  
573 emerge from these programs, including the concern of not meeting consumers' demand and economic  
574 targets. Indeed, in their economic study, Eppink and Wätzold (2009) demonstrated that the measures  
575 for the protection of the common hamster in Mannheim area (Germany) implied important hidden costs  
576 notably linked to changes in development plans; the invisible costs being even higher than visible ones  
577 -directly associated with conservation measures. Moreover, the delay taken in the protection of the  
578 common hamster not only had a cost for the survival of the species but also a financial one. Indeed,  
579 proactivity in conservation domain (i.e. to start a programme of conservation before a species is  
580 endangered) allows to save a non-negligible amount of money compared to simple reactivity  
581 (Drechsler et al., 2011). It is therefore not only a question of preserving a living territory in terms of  
582 biodiversity but also in terms of economy. Thus, the LIFE+ Alister has sought to structure the  
583 protection of the common hamster around the ecological, but also economic and social development  
584 of the Alsace area.

585 Biodiversity has long been considered as a source but also as a constraint of economic activities,  
586 notably when considering the EU's Common Agricultural Policy (CAP) (please see the review of  
587 Simoncini *et al.*, 2019). Despite an ambitious EU Biodiversity Strategy to 2020 (European commission,  
588 2011), the elaboration of the 2014-2020 CAP did not enable the incorporation of suitable measures to  
589 fulfill the objectives (Pe'er *et al.*, 2014). 77% of the €86 billion EU budget for biodiversity during this  
590 period came from the CAP, but this was not sufficient to stop the decline of farmland's biodiversity  
591 (European court of auditors, 2020). Biodiversity was until recently not considered to be part of  
592 agricultural areas, but this is slowly changing. The post-2020 CAP integrates more and new agro-  
593 environmental measures: farmers will be encouraged firstly to design eco-schemes at the level of  
594 agricultural landscapes, *i.e.* to implement hedges, rows of trees, field copses, ponds or fallow lands on  
595 min. 10% of agricultural land (1<sup>st</sup> pillar of CAP post-2020) and secondly to implement measures that  
596 preserve the environment, such as reducing the use of fertilizers (2<sup>nd</sup> pillar). However, this still does  
597 not correspond to a real transition toward a sustainable and biodiversity-friendly agricultural model.  
598 We recommend the implementation of policies that specifically promote the development of already  
599 identified agricultural practices and farming models that allow a simultaneous consideration of food  
600 production, biodiversity and human well-being (see for example (Duru *et al.*, 2015; Valenzuela, 2016;  
601 Boeraeve *et al.*, 2020; Chabert and Sarthou, 2020). Concerning the French European hamster, studies  
602 and conservation plans, including the Life+ Alister program and agro-environmental measures, played  
603 a crucial role in the subsistence of viable populations and in the development of a more general context,  
604 such as improving the farmland habitat and enhancing hamster's perception through society awareness.  
605 This gives us an optimistic glimpse into the future.

606

### 607 **4.5 What about a successful increase in the population?**

608 Such successful increase is what happened with the bird symbol of Alsace, the white stork. This  
609 species was protected in the 1970s since the survival of the regional population was severely  
610 questioned. A reinforcement program occurred and was a success, since there are now more than 400  
611 pairs. Despite this success, the white stork is still a subject of conversation, because the now numerous  
612 individuals leaving near humans cause disturbances, like infrastructure damages, noise or dropping  
613 nuisances. If the same success occurs with European hamsters, one can fear to come back to the  
614 previous situation when it caused important damages to crops. However, we have now an improved  
615 knowledge about predator-prey dynamics and ecosystem balancing, leading us to consider that  
616 overpopulation can be avoided with natural regulation by predators. Ecosystem balancing seems thus  
617 especially important in that scope to promote biodiversity while maintaining the production and other  
618 services provided by farmland ecosystems.

619

### 620 **4.6 Other issues, same problems, same solutions**

621 Conservation measures and studies that have been carried out allowed a better knowledge of  
622 the biology of the European hamster and its habitat, its needs and threats. In addition, gathering  
623 information improved knowledge in many other scientific fields like ecology or nutrition that can be  
624 transposed to other species (Monecke, 2014). Even if the French European hamster preservation plan  
625 can sometimes be viewed as a lot of energy and money spent for only a 'small rodent', one may recall  
626 the convergence with problems and solutions encountered in a large variety of domains.

627 The European hamster is not the only species endangered in agricultural areas. Many farmland  
628 bird populations are decreasing since several decades (Donald *et al.*, 2001; Heldbjerg *et al.*, 2018;

629 Stanton et al., 2018; Department for Environment, Food & Rural Affairs, 2019; Gaget et al., 2019).  
630 Invertebrate species are also concerned, with insects suffering a massive drop potentially linked to  
631 unsustainable agricultural practices (Benton *et al.*, 2002; Shortall *et al.*, 2009; Hallmann *et al.*, 2017).  
632 Therefore, conservation measures are widely developed to protect farmland species or taxa, involving  
633 various stakeholders. In France, this can be illustrated by the development of different specific national  
634 action plans (NAP) like the one for the little bustard (*Tetrax tetrax*) (Poirel, 2019), the one for  
635 pollinators (Gadoum and Roux-Fouillet, 2016) or the one for adventive plants (Cambecèdes et al.,  
636 2012). During the last European hamster NAPs, conservation measures for hamsters and associated  
637 innovative practices, have been identified to be highly beneficial not only for hamsters but also for a  
638 lot of other species including the above-cited ones (Wilson *et al.*, 2005; Liu *et al.*, 2015; Norris *et al.*,  
639 2017; Zellweger-Fischer *et al.*, 2018).

640 Furthermore, these measures may also help to reduce soil erosion. This issue is of particular  
641 importance for farmers since the soil is the first support their production. Ground runoffs and mudflows  
642 can happen in sloping areas during rainy periods and also affect people outside the crops (material  
643 damages, water quality, safety) (Bronick and Lal, 2005; Heitz *et al.*, 2009). Soil erosion can be limited  
644 or avoided by improving soil quality and coverage, *i.e.* increasing soil biota, soil organic carbon  
645 content, and protecting it thanks to mulch or cover crops (Bronick and Lal, 2005; Seitz *et al.*, 2018).  
646 All these practices join the ones that are beneficial for the European hamster conservation.

647 Drinking water can be affected by nitrogen concentration and by a multiplicity of pesticide  
648 residuals as well, sometimes at high levels (APRONA, 2020). Surprisingly, water pollution is usually  
649 not the most negatively perceived by citizens, since it is not visible. Pesticides application is much  
650 more feared by people, especially when it occurred at the vicinity of habitations. Thus, agriculture with  
651 moderate or no use of pesticide would not only be beneficial for hamsters' biotope but also for its  
652 human neighbours, from a health and a sociological acceptance perspective.

653 Both citizens and hamsters need the development of an agriculture with more plant diversity,  
654 more cultivated or spontaneous biodiversity on crops, and more cover crops. Indeed, this participates  
655 to the creation of more attractive landscapes, thus increasing people's wellness (Hasund *et al.*, 2011).

656 The proportion of farmers in the population is getting smaller and smaller and the difficulties  
657 they met are going in the opposite direction. It is especially true since they face more and more extreme  
658 climatic conditions due to global climate change (Rosenzweig *et al.*, 2001; Fischer *et al.*, 2002).  
659 Conservation or biodiversity-based agriculture can be beneficial for that too, since it relies on the  
660 operation of many ecosystem services that increase the resilience of the agroecosystem (Armand *et al.*,  
661 2009; Dainese *et al.*, 2019; Montoya *et al.*, 2020).

662 If innovative agricultural practices can help to adapt to climate change, they can also be  
663 beneficial to limit it. As explained previously, soil improvement is a key factor for the agricultural  
664 systems, and it relies on the increase of soil organic carbon. This organic carbon comes from the  
665 photosynthesis of plants, taking carbon dioxide from the air. This mechanism is important enough to  
666 have a significant effect on atmospheric CO<sub>2</sub> concentration. This is for example what is promoted  
667 through the 4 per 1000 initiative since an increase of soil carbon of 0.4% each year in the 30 to 40 first  
668 centimetres of all agricultural soils would allow compensating global annual CO<sub>2</sub> emissions (Rumpel  
669 *et al.*, 2020). This does not mean that we found the solution to solve the atmospheric CO<sub>2</sub> problem or  
670 that we have not to reduce carbon emissions, but it shows that agriculture can significantly contribute  
671 to slow down the global change.

672

## 673 5 Conclusion

674 Conservation measures for endangered species are undoubtedly of great importance. It is crucial  
675 to take into consideration animal ethics as societal need in order to be as beneficial as possible.  
676 Furthermore, they have a much broader impact than only protecting the considered species or habitat.  
677 To be successful, they have to include the multiplicity of stakeholders concerned with the topic  
678 covered. This is well illustrated with the case of European hamster whose rescue deeply depends on  
679 modified and innovative agricultural practices developed by farmers. Moreover, these modifications  
680 consisting in more integration of biodiversity, soil and natural processes are not only a solution for  
681 species' protection but an entire improvement of farmers' socio-economic conditions, as well as  
682 citizens' well-being, and contribute to the planet health for sure. All of this implies to take into account  
683 the externalities (positive or negative) of the practices as their implementations, leading to the most  
684 holistic view possible. We recommend to stakeholders to use, to foster and to develop all the measures  
685 available that can promote agricultural biodiversity, and to assist in the development of a new  
686 agricultural model. These measures must also be taken at the level of several territories or countries.  
687 Concerning the common hamster, exchanges of experiences and ideas take place every year during the  
688 International Hamster Workgroup meeting, between scientists and field operators from countries where  
689 the species is present, which makes it possible to improve conservation actions and develop  
690 collaborations. This year, a first joint conservation program between France and Germany will be  
691 submitted to Europe, in order to implement on a larger scale measures to restore population levels and  
692 improve agricultural habitat.

693

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699

### 700 **Conflict of Interest**

701 The authors declare that this review was conducted in the absence of any commercial or  
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### 703 **Author Contributions**

704 FK and MP equally contributed to this work as the first author.  
705 All authors brought constructive thoughts and participated in the elaboration and the redaction of this  
706 review.  
707 All authors contributed to manuscript revision, read and approved the submitted version.

708

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In review

1015 **Figure legends**

1016 **Figure 1: Hamster conservation in Alsace: from evolution of its presence to conservation plans**  
1017 **between 1970 and 2028.** Bars represent the number of municipalities where the European hamster is  
1018 present in Alsace (France). Lower part of the figure represents timeline of principal events  
1019 concerning conservation measures and decisions for the species

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1022 Tables

1023 Table 1: Pros and cons of the strategies considering different priorities for population  
 1024 reinforcement and habitat improvement

	<b>Population reinforcement while improving habitat</b>	<b>Habitat improvement followed by population reinforcement</b>
<b>PROS</b>	<p>May be seen as a first ‘trigger’ step resulting to:</p> <ul style="list-style-type: none"> <li>- the maintenance of the population (no genetic loss)</li> <li>- a better perception/acceptance compared to a reintroduction if population extinct during this time</li> <li>- the maximization of the partners involvement (political and societal)</li> </ul>	<p>Derived from the necessity to solve the causes of the decline before reinforcing (otherwise it leads to a failure) resulting to:</p> <ul style="list-style-type: none"> <li>- a better perception of the conservation plan (seen as holistic instead of species-focused)</li> <li>- the maximization of the conservation efforts</li> </ul>
<b>CONS</b>	<p>Need to continue until the habitat has been sufficiently improved resulting to :</p> <ul style="list-style-type: none"> <li>- a possible long time before seeing positive or lasting effects of the reinforcements</li> <li>- a possible dispersion of actions and resources</li> </ul>	<p>May lead to the complete extinction of the population/species in the wild resulting to:</p> <ul style="list-style-type: none"> <li>- the ↓ of genetic diversity</li> <li>- the ↓ of politics stakes</li> <li>- the ↑ of administrative obligations</li> <li>- the ↓ of motivation of local actors</li> <li>- the ↓ of habits to live with this species</li> </ul>

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Figure 1.JPEG

